



# Greening of European Sea Ports – Final report

STUDY



Written by  
March - 2024



AND

Dr. SOTIRIOS THEOFANIS

**EUROPEAN COMMISSION**

Directorate-General for Mobility and Transport  
Directorate D — Waterborne  
Unit D.3 — Ports and Inland Transport

*E-mail: [MOVE-D3-SECRETARIAT@ec.europa.eu](mailto:MOVE-D3-SECRETARIAT@ec.europa.eu)*

*European Commission  
B-1049 Brussels*

# **Greening of European Sea Ports – Final report**

STUDY

***Europe Direct is a service to help you find answers  
to your questions about the European Union.***

**Freephone number (\*):**

**00 800 6 7 8 9 10 11**

(\* ) The information given is free, as are most calls (though some operators, phone boxes or hotels may charge you).

## **LEGAL NOTICE**

This document has been prepared for the European Commission however it reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

More information on the European Union is available on the Internet (<http://www.europa.eu>).

Luxembourg: Publications Office of the European Union, 2024

ISBN: 978-92-68-20630-0

doi: 10.2832/3479075

© European Union, 2024

Reproduction is authorised provided the source is acknowledged.

## Contents

<b>List of Acronyms .....</b>	<b>7</b>
<b>1. Introduction .....</b>	<b>10</b>
1.1. Background and context of the study .....	10
1.2. Purpose and objectives of the report .....	11
<b>2. Addressing the environmental effects of port operations .....</b>	<b>13</b>
2.1. Environmental aspects and impacts of port operations.....	13
2.2. Environmental laws, regulations and the role of ports.....	17
2.3. Factors affecting the greening capacity of ports .....	19
2.4. Good practices taxonomy.....	21
2.5. Transferability of good practices .....	23
2.6. Importance and use in roadmap development .....	25
<b>3. Roadmap for greening of small and medium size ports .....</b>	<b>26</b>
3.1. Main areas of intervention.....	26
3.2. Elaboration of elements of the roadmap.....	27
3.2.1. Policy and target setting.....	29
3.2.2. Measure assessment and prioritisation .....	30
3.2.3. Monitoring and reporting .....	34
3.3. Summary of roadmap elements .....	35
<b>4. Good practice case analysis .....</b>	<b>38</b>
4.1. Biodiversity protection and restoration .....	39
4.2. Port Electrification and Energy Management.....	49
4.2.1. Shore Side Electricity – Onshore Power Supply .....	51
4.2.2. Port equipment electrification .....	56
4.2.3. Port Electricity Supply & Charging Hubs .....	61
4.2.4. Energy Supply and Consumption Management.....	65
4.3. Alternative fuels .....	70
4.4. Waste management .....	76
4.5. Circular economy .....	84

4.6. Alignment of cases with the steps of the roadmap.....	90
<b>5. Summary and Main Takeaways.....</b>	<b>95</b>
5.1. Overall summary .....	95
5.2. Key messages .....	97
5.3. Recommendations .....	99
<b>6. Annex I – List of EU Legislation .....</b>	<b>101</b>
<b>7. Annex II – Case links with Roadmap steps .....</b>	<b>105</b>

## List of Acronyms

Table 1 – List of acronyms

Acronym	Explanation
3D	Three-dimensional
AES	Alternative Energy Sources
AFIR	Alternative Fuels Infrastructure Regulation
APMT	APM Terminals
BE	Battery – Electric
CCS	Combined Charging System
CDNI	Convention on the collection, deposit and reception of waste produced during navigation on the Rhine and inland waterways
CEF	Connecting Europe Facility
CHE	Container Handling Equipment
CHP	Combined Heat and Power
CMB	Compagnie Maritime Belge
CO2	Carbon dioxide
DC	Direct Current (refers to charging)
DFDS	Det Forenede Dampskibs- Selskab (Ferry Company)
DKK	Danish Krone
DPW	Dubai Ports World
ESG	Environmental, Social and Governance
ESS	Energy Storage Systems
EEC Treaty	European Economic Community Treaty (Treaty of Rome)
ETS	Emission Trading System
EU	European Union
EVs	Electric Vehicles
Ft	Feet (measurement)
GHG	Greenhouse Gas (refers to Greenhouse Gas Emissions)
GTOs	Global Terminal Operators
HEDNO	Hellenic Electricity Distribution Network Operator
HVO	Hydro treated Vegetable Oil
HPA	Hamburg Port Authority
Hz	Hertz
IWT	Inland Waterway Transport
Kg	Kilogram
kV	Kilovolt
kW	Kilowatt
LNG	Liquefied Natural Gas

Acronym	Explanation
MARPOL	International Convention for the Prevention of Pollution from Ships
MCS	Megawatt Charging System
MoU	Memorandum of Understanding
MOW	Flemish Ministry of Mobility and Public Works
MSCTV	MSC Terminal Valencia
MSFD	Marine Strategy Framework Directive
MTBE	Methyl tert-butyl ether
MVA	Megavolt Amperes
NET	New Energy Task force
NGOs	Non-Governmental Organisations
OEM	Original Equipment Manufacturer
OLP	Port of Piraeus
OPEX	Operational Expenses
OPS	Onshore Power Supply
PEM	Proton Exchange Membrane (refers to electrolyser)
PESO	Port Energy Systems Optimisation
PPA	Power Purchase Agreement or Philippines Port Authority
SSE	Shore Side Electricity
RES	Renewable Energy Sources
RDM	Rotterdamsche Droogdok Maatschappij
ROI	Return on Investment
RoPax	Passenger RoRo vessels
Ro-Ro	Roll on/Roll off (refers to passengers)
RTG	Rubber Tyred Gantry
RWG	Rotterdam World Gateway
SANY	Machinery Industry Company
SSP	Shore-to-Ship Power
SC	Straddle Carrier
TCO	Total Cost of Operation
TFEU	Treaty on the Functioning of the EU
TEN-T	Trans-European Transport Network
TT	Tractor – Trailers
UN	United Nations
VLC	Valencia
WPS	Wireless Power Supply
Wh	Watt hour
WWF	World Wide Fund for Nature
WwN	Working with Nature

Acronym	Explanation
WWTP	Wastewater Treatment Plant

Source: Project Consortium Elaboration

## 1. Introduction

### 1.1. Background and context of the study

Sea ports are complex systems, integrated as crucial nodes in supply chains. They accommodate freight and passengers, and they link maritime with land-based transport networks. They often serve as energy hubs and industry clusters, fostering innovation and economic growth on local, regional, and global levels. They are also a critical link in ensuring territorial cohesion particularly with insular areas. However, **port-related activities** may cause several negative **environmental impacts**. These impacts are caused by cargo handling inside the port, by vessel activities, by other (industrial, logistics or other added value) activities taking place within the wider port area, or by intermodal transport networks serving the port hinterland. The rapid increase in trade volumes, the increasing vessel size, and the expansion and development of port infrastructure to meet growing demand create additional environmental pressures and land-use conflicts, including wetland preservation and noise pollution. These developments highlight the **significance of integrating environmental concerns into port management**. Ensuring environmental sustainability could be considered as a necessary “license to operate” and a “license to grow” for ports, emphasising the need to reduce their negative ecological impact, even without a specific business case for each action. Additionally, it signifies that future port expansion and development depend on meeting high environmental standards.

The pivotal role of sea ports in the European economy has been recognised in the European Commission’s Green Deal<sup>(1)</sup>, the Sustainable and Smart Mobility Strategy<sup>(2)</sup> and the new approach for a sustainable blue economy in the EU<sup>(3)</sup> which promote dedicated initiatives for ports and related sectors to **enhance the environmental sustainability and improve the competitiveness of European sea ports**. Aligned with this vision, the European Parliament called to investigate the capacity for greening European sea ports, which led to this study.

The objective of the study was to identify the factors affecting the capacity for greening of European sea ports alongside economic development. The study examined the **environmental effects of port activities**, including seaside operations, terminal operations, and hinterland connection activities. Additionally, it examined the relevant legislation, assessing how current and future policies, strategies and legislation influence the capacity and prospects of ports to effectively manage these environmental effects. It identified **impediments to implementing green initiatives** and presented **good practices** aimed at achieving sustainability objectives. By fostering knowledge-sharing and providing insights into adaptable strategies, the study aimed to provide tools to help ports navigate and address their environmental challenges, with particular **emphasis on smaller ports** that may face constraints or have limited capacity to implement green practices.

---

<sup>(1)</sup> The European Green Deal. COM/2019/640 final

<sup>(2)</sup> Sustainable and Smart Mobility Strategy – putting European transport on track for the future. COM/2020/789 final

<sup>(3)</sup> New approach for a sustainable blue economy in the EU Transforming the EU’s Blue Economy for a Sustainable Future. COM/2021/240 final

Through a holistic approach integrating quantitative and qualitative data from various sources, including desk research, focus groups, expert panels, interviews, an open call, and a survey, the study sought to develop a balanced understanding of the challenges and opportunities associated with the pursuit of sustainable and economically viable practices in European sea ports. This multifaceted approach aimed to address the complex interplay of regulatory frameworks, technological landscapes, and operational constraints faced by ports, ensuring that sustainability efforts are tailored to their specific contexts. The results of the study are presented in this report.

### 1.2. Purpose and objectives of the report

The purpose of this report is to provide guidance and support for stakeholders within the port industry seeking to improve the environmental performance of their ports and achieve sustainability objectives. To fulfil this purpose, the report includes the following components:

- mapping of the adverse environmental impacts associated with port operations
- examination of pertinent legislation and policies governing port activities
- identification and elaboration of key factors and characteristics of ports, which influence their capacity to effectively select, shape, and implement a green strategy
- presentation of diverse good practices implemented by ports across Europe and globally, systematically categorised for clarity and ease of reference, and
- delineation of criteria to be used to assess the transferability of good practices in different port environments.

These components are then used as input to develop key elements of a generic [roadmap](#), which may be used by seaports when integrating new practices into their development and operations. Subsequently, several good practices are detailed to demonstrate the relevance and use of the proposed roadmap.

The report functions as a compendium of knowledge and insights gained from the implementation of selected good practices, enabling the identification of critical elements essential for advancing green objectives. By doing so, it enables ports to customise and adapt their selected strategies, aligning them with their specific circumstances and requirements.

The findings presented in the report include data collected from:

- review of over 100 scientific articles and trade reports on environmental aspects and impacts related to port operations
- seven in-depth interviews with legal experts and a focus group on legislation pertinent to port environmental considerations

- a survey of 96 port stakeholders to identify and analyse impediments and challenges in implementing good practices at ports
- a desk review of 380 cases of good practices
- an open call resulting in detailed information on 31 cases of good practices implementation
- interviews with 12 port stakeholders providing information on 36 cases of good practices implementation and
- a focus group on validating a roadmap for implementing sustainable solutions

The report is organised as follows:

**Introduction** – This section describes the report's scope and outlines its structure.

**Addressing the environmental effects of port operations** – This section provides a summary of the environmental aspects and impacts of port operations, including the direct and indirect relationships among them. It offers an overview of relevant policies and legislation and describes the key factors affecting the capacity of ports to implement green practices. Additionally, it includes a taxonomy of good practices, classified in 22 domain categories, and an approach for assessing transferability of good green practices.

**Roadmap for greening of small and medium size ports** – This part presents a roadmap to guide the greening of small and medium-sized ports. It is structured around three key areas of intervention, namely: policy and target setting; measure assessment and prioritisation; and monitoring and reporting.

**Good practice case analysis** – This part provides a brief description of the main categories of good green practices. It details cases where selected practices have been implemented, examining the drivers and motivations, opportunities, challenges, as well as barriers encountered. It also provides information on their key outcomes along with their scalability and transferability potential. Elements from these good green practices are incorporated into the roadmap, enhancing its relevance and applicability.

**Summary and main takeaway** – This section offers key concluding remarks and summarises the main outcomes of the study in relation to the process that may be followed by ports, especially small and medium-sized ones, for selecting and implementing good green practices.

## 2. Addressing the environmental effects of port operations

### 2.1. Environmental aspects and impacts of port operations

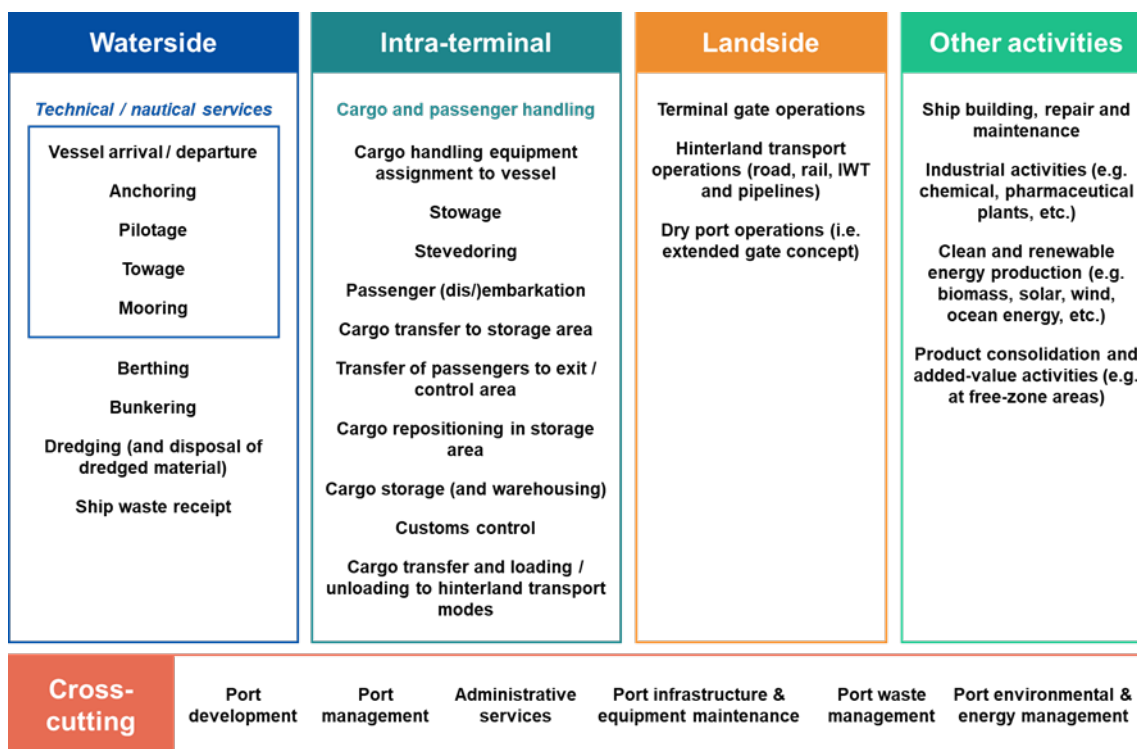
Port-related activities refer to processes taking place at the waterside of the port, within the port area, and on the landside of the port.

The port-related activities, as shown in [Figure 1](#), mainly include vessel handling and operations, passenger and cargo handling and operations, as well as infrastructure and equipment development, management, operation, and maintenance. More specifically, the activities include: service provision, such as technical/nautical services (e.g., pilotage, towage, mooring), cargo handling services (e.g., stevedoring, storage, stowage) for various cargo types (e.g., containers, dry bulk, liquid bulk, vehicles), cruise and ferry passenger services, as well as other supporting services (e.g., bunkering, waste management), port infrastructure development and maintenance (e.g., port construction, dredging and disposal of dredged material) and port superstructure development, maintenance and management.

[Waterside](#) operations, both at anchor and during seaside access, as well as at berth, are mainly related to servicing vessels. The type and size of vessels influence the type of the services provided, although common patterns and functions are encountered. [Intra-terminal](#) operations are complex, multifunctional activities related to the type of services provided at specific terminals for handling different types of cargo and passenger traffic. The exact characteristics of these operations are related to (i) the scale of the different terminals, (ii) the degree of cargo processing inside a terminal/port, (iii) the number and functions of terminals located inside a port, (iv) the existence, extent and scale of added-value activities taking place inside the port territory, and (v) the hinterland transport modes and infrastructure available (i.e., road, rail, inland waterways transport, pipelines) connecting ports with their captive and extended hinterland. Industrial and/or energy generation activities also influence intra-terminal operations.

[Landside operations](#) mainly include intermodal transport operations and logistics activities that interact with ports either directly or indirectly (i.e., activities at satellite terminals, dry ports, depots, etc.).

Furthermore, [additional activities](#) (e.g., industrial activities, clean and renewable energy production, logistics business development and innovation support) have been integrated into several ports, advancing their role and impact in various areas (e.g., economic, social). Any assessment of a port's [environmental footprint](#) should consider the characteristics of the port in terms of type, location, size, and traffic fluctuations.

**Figure 1 – Schematic overview of port operations**

© European Commission, 2024.

Source: Project consortium elaboration.

Schematic overview of port operations.

Typical environmental aspects related to port activities may be broadly classified as: emissions to air, releases to water, leakage or spillage to soil, noise and vibration, waste production, resource consumption, and changes in terrestrial habitats and marine ecosystems. Environmental aspects include:

1. those for which the port authority has a strict legal liability or responsibility
2. those over which (as a landlord) it may reasonably be expected to be able to bring influence to bear (e.g. over tenants/operators), and
3. aspects that are deemed to be of local, national or regional importance.

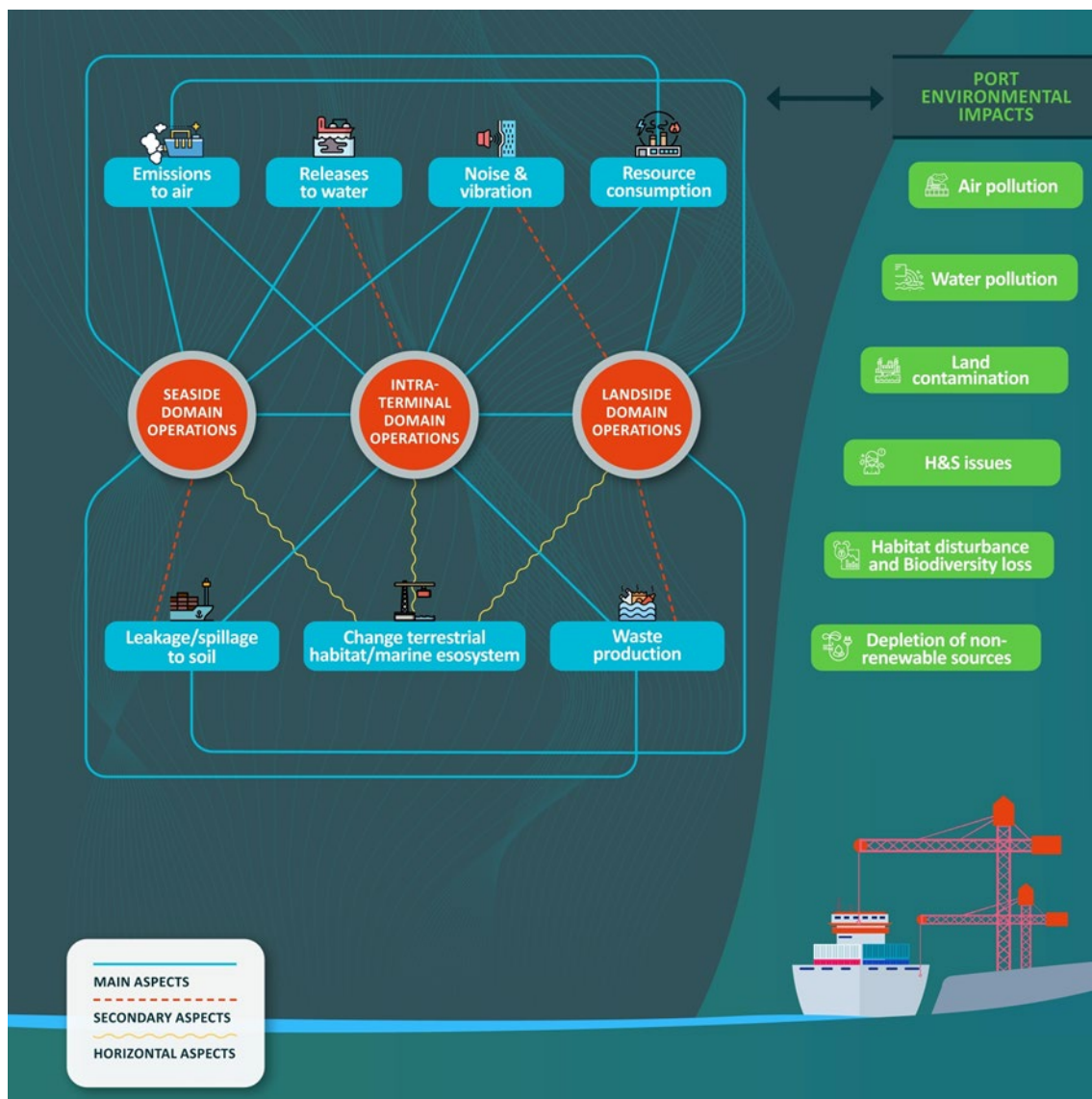
Key resulting environmental impacts include, among others, air and water pollution, land contamination, health and safety issues, habitat disturbance and biodiversity loss, and depletion of non-renewable resources. Although the range of port activities and operations can greatly vary from port to port, a broad categorisation of environmental impacts relating to port activities and operations can be established as follows:

- environmental impacts caused by cargo and passenger handling activities in the port area,
- environmental impacts caused by other activities in the port area (e.g., a wide spectrum of industrial activities),

- environmental impacts caused by the vessels calling at the port, and
- environmental impacts caused by hinterland transport modes that connect the port to different regions in the hinterland.

The cause-and-effect relationship of environmental aspects and impacts related to port operations (waterside, intra-terminal, and landside) is shown in Figure 2.

**Figure 2 – The cause-and-effect relation of environmental aspects and impacts related to the port operations**



© European Commission, 2024.

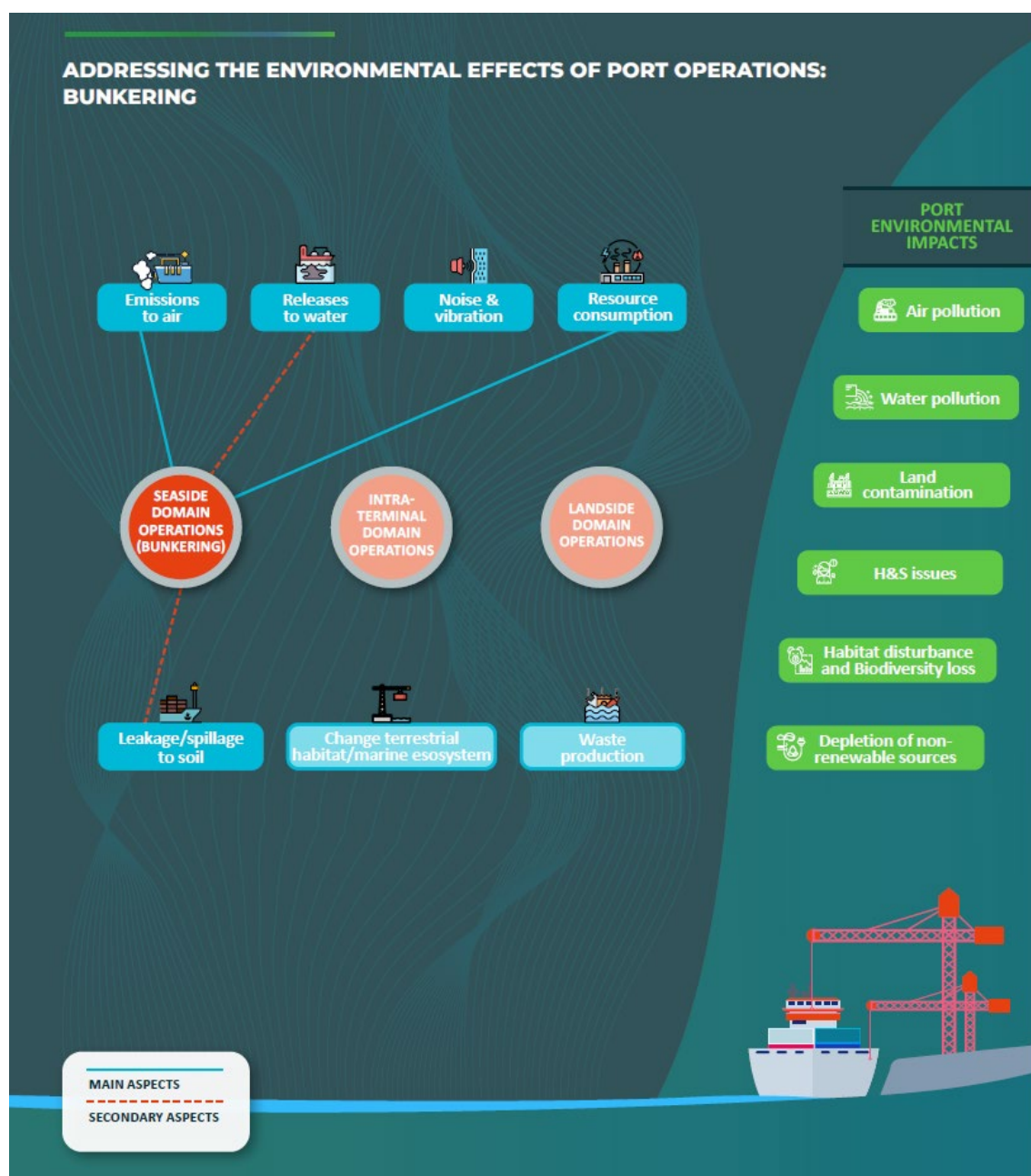
Source: Project consortium elaboration.

The cause-and-effect relation of environmental aspects and impacts related to the port operations.

Environmental aspects are inherent in port activities, and may have direct or indirect negative impacts. Different activities within port operations affect the environment

in varying ways and degrees. This is highlighted in [Figure 3](#) which presents an example of the relation between the environmental aspects and the impacts of bunkering operations. [Bunkering activity](#), taking place at the seaside domain, may cause emissions to air and resource consumption, as direct environmental aspects. In addition, it may result in releases to water and leakage to soil, as indirect environmental aspects. These direct and indirect environmental aspects may result in environmental impacts such as air and water pollution, resource depletion, land contamination, and biodiversity loss.

**Figure 3 – Example of the relation between environmental aspects and impacts of bunkering operations**



© European Commission, 2024.

Source: Project consortium elaboration.

Example of the relation between environmental aspects and impacts of bunkering operations.

## 2.2. Environmental laws, regulations and the role of ports

Environmental protection has a long history within the EU. Already in 1970, the Commission suggested that a programme was needed for the protection and improvement of the environment. In 1986, the Single European Act created a legal

basis for EU environmental law in the EEC (European Economic Community) Treaty. Since then, policies, and legislation aimed at protecting and improving the environment have become increasingly important.

In 2019, the Commission announced the '*European Green Deal*', aiming to make the EU climate-neutral by 2050. In 2021, these ambitions were enshrined in law with the '*EU Climate Law*'<sup>(4)</sup>. As an intermediate step towards climate neutrality, the Climate Law mandates a 55% reduction in net greenhouse gas emissions by 2030. To achieve this target, the Commission presented the '*Fit for 55*' package in 2021, consisting of several legislative proposals. This package builds on the Commission's 2020 '*Sustainable and Smart Mobility Strategy*', which includes flagships such as creating zero-emission ports (flagship 2) and greening freight transport (flagship 4).

The Fit for 55 package includes, among others, the *FuelEU Maritime* Regulation<sup>(5)</sup>, the extension of the EU *Emission Trading System (ETS)* to cover shipping<sup>(6)</sup>, the new *Alternative Fuels Infrastructure Regulation*<sup>(7)</sup> which replaces the existing Alternative Fuels Infrastructure Directive, the new *Renewable Energy Directive*<sup>(8)</sup> and the *Energy Efficiency* Directive all of which are of particular interest for the maritime and port sectors. Additionally, in 2021, the Commission announced its Action Plan '*Towards Zero Pollution for Air, Water and Soil*'<sup>(9)</sup>, which is also relevant to ports.

Transport to and from ports, along with activities within the ports, clearly impact the environment. By promoting more environmentally sustainable practices, the Climate Law, the Fit for 55 package and their associated measures and policies apply to ports and port users. As part of this study, a *legal analysis* of the EU environmental law (as it is relevant to ports) was conducted. The EU's ambition to make ports and transport greener is clear, as are the Commission's efforts to coordinate policies and legislation to support and enable ports and port users. Such efforts include for instance mandating the installation of alternative fuels infrastructure in ports and the use of such infrastructure by ships calling at the ports in a complementary approach. However, *the breadth and depth of relevant EU legislation create – perhaps inevitably – a complex background for ports to operate*. Relevant EU legislation noted in the context of the study is listed in Annex I – List of EU Legislation. The legal analysis did not find major issues preventing ports from pursuing green initiatives, but the legal context does require careful navigation. Ports are well advised to involve their legal departments and advisors from the earliest stages of green initiatives.

---

<sup>(4)</sup> Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law')

<sup>(5)</sup> Regulation (EU) 2023/1805 of the European Parliament and of the Council of 13 September 2023 on the use of renewable and low-carbon fuels in maritime transport, and amending Directive 2009/16/EC

<sup>(6)</sup> Directive (EU) 2023/959 of the European Parliament and of the Council of 10 May 2023 amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union and Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading system

<sup>(7)</sup> Regulation (EU) 2023/1804 of the European Parliament and of the Council of 13 September 2023 on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU

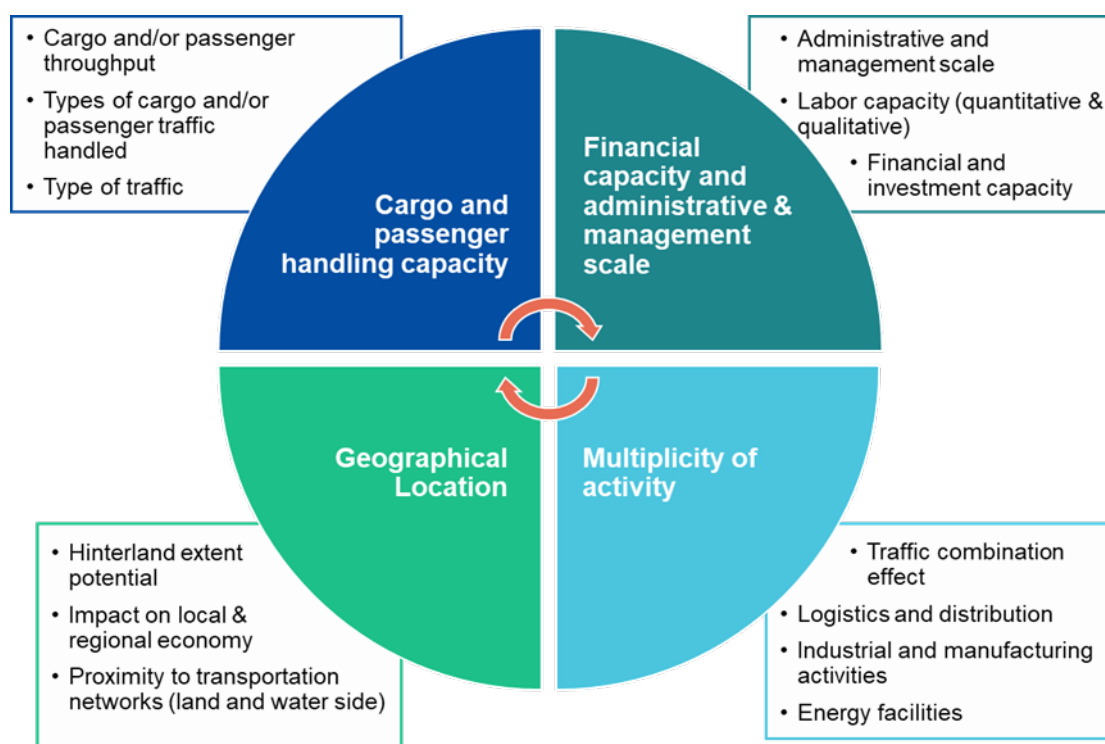
<sup>(8)</sup> Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652

<sup>(9)</sup> Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Pathway to a Healthy Planet for All EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil'

### 2.3. Factors affecting the greening capacity of ports

Factors related to physical characteristics, capacity, as well as operational and managerial aspects of ports must be assessed when evaluating their capacity to adopt environmentally sustainable practices. These considerations cover both quantitative and qualitative aspects and provide a comprehensive view of the role and capabilities of a port in fostering environmental stewardship. In the context of this study, four main categories of factors have been considered as shown in Figure 4.

**Figure 4 – Key factors affecting the greening capacity of ports**



© European Commission, 2024.

Source: Project consortium elaboration.

Key factors affecting the greening capacity of ports.

**Cargo and passenger handling capacity:** This criterion refers to the total volume of cargo and/or passengers handled annually by the port, which varies between ports of different sizes. In addition, the type of cargo (e.g., dry bulk, containerised, liquid bulk, breakbulk) and passenger traffic (i.e., ferry or cruise passengers), as well as the type of traffic movement (i.e., local, transit, transshipment) are considered, as these factors contribute to the unique characteristics of a port.

**Financial capacity, administrative and management scale:** This criterion refers to the examination of the decision-making and administrative processes, and the overall organisational structure of the port authority. Factors such as the number of employees, their skills levels, and their

capacity to deal with complex tasks related to port operations, along with the provision of training programmes are also considered. Another critical element under this criterion is the financial and investment capacity of the port and its commitment to modernisation and overall growth, including in-port and terminal infrastructure and equipment, digital solutions, and the adoption of technological advances. The ownership/management typology (i.e., landlord or comprehensive) also influences this criterion, including the delegation of authorities.

**Geographical location:** The potential for hinterland extension is a key factor in a port's strategy to access a large market share. By accessing larger geographical areas and increasing annual cargo throughput, ports can boost economic activity in those areas. The impact of this economic activity on the local and regional economy is linked to port operations such as warehousing, logistics and manufacturing. Moreover, ports' proximity to land and water transport networks facilitates the availability of intermodal transport options, allowing for seamless transitions between different modes of transport, thus improving overall transport efficiency.

**Multiplicity of activity:** Ports aim to capitalise on the traffic combination effect, which refers to optimising the use of their facilities, minimising downtime, ensuring continuous operations, and efficiently handling different types of cargo. Intermodal connectivity and efficient logistics facilitate the seamless movement of goods with minimal delays. Ports with industrial and manufacturing activities, or those located near industrial clusters can leverage economies of scale as well as resource sharing/synergies and enhance efficiency in the production and transportation of goods. In addition, increased focus on energy production, storage, and distribution facilities as well as components of renewable energy production such as wind and solar infrastructure, both within and near ports, can bolster their economic activities and contribute to their sustainable growth.

Assessment of these factors provides valuable insights into the distinctive operational environment of each port and its ability to address sustainability needs, priorities, and challenges, within the context of a changing maritime trade and transport landscape. While parameters such as land area and annual throughput are important, these identified factors also **prioritise strategic positioning, economic significance, and operational capabilities in assessing a port's capacity to implement green practices**. By evaluating these factors, informed decisions can be made regarding the port's developmental scope, investment strategies, and engagement frameworks with key stakeholders, including shipping companies, investors, and government authorities, to enhance the competitiveness of the port and strengthen its ability to apply sustainability practices.

## 2.4. Good practices taxonomy

Another important element in addressing the environmental effects of port operations is the development of a comprehensive understanding of the range of [practices available](#) for this purpose. To support this effort, several good practices from Europe and the world have been reviewed. These practices were identified through a combination of literature search, an open call for good practices and interviews with various port stakeholders. They encompass a [diverse range of practice types](#) with different business models and cooperation characteristics between port authorities and related stakeholders, various types of technology-related applications, technical specifications for infrastructure development and green designs, green strategies and sustainable policies, business model development, financial and operational incentives, and environmental awareness campaigns. The good green port practices reviewed have been grouped into 22 categories, as shown in [Figure 5](#).

Figure 5 – Good green practices taxonomy

Green Policy & Planning (40*)	Cooperation / Agreements (27)	Pollution prevention & response (11)	Environmental quality monitoring (8)	Carbon mgmt (8)	Circular economy (20)	Waste mgmt (13)	Shore-Side Electricity – Onshore Power Supply (SSE-OPS) (61)	Terminal equipment (19)	Supporting vessels & vehicles (15)	Environmental training & education (1)
Modal split	Shipping companies & port authorities	Water pollution prevention	Air emissions	Capture	Recycling	Reduction	Implementation	Use of alternative power sources	Use of alternative power sources	Course development
Carbon neutrality	Port authorities & terminal operators	Vessel emission capture	Odour nuisances	Storage	Efficient (re)use of resources	Reception	Commercialisation	Engine efficiency		Educational placements
Zero emission operations	Authorities of adjacent ports		Water quality	Transport		Recovery & use	Management & treatment			
Climate change adaptation	Port authorities and energy power providers		Acoustic characterisations	Monitoring		Mgmt & treatment				
				Utilisation						
				Reporting						

Social cohesion (1)	Alternative fuels (70)	Renewable energy (31)	Energy efficiency (26)	Operational efficiency (41)	Certification schemes (3)	Award schemes (1)	Incentive schemes (11)	Campaigns (6)	Innovation support (7)	Biodiversity protection & restoration (12)
Public parks	Production	Production	Infrastructure	Automation	Environmental management	Environmental awareness	Discounts / Compensation	Environmental	Investments on green start-ups	Port (re)development planning
RES Provision to deprived communities	Bunkering / charging (vessels, trucks)	Provision	Equipment	5G, AI & IoT	Energy management		Priority handling		Green fund set-up	Port land uses
	Transport network – corridor – supply chain planning	Conversion (to gas, synthetic methane)	Energy systems	Port traffic mgmt	Buildings		Sustainable mobility of port personnel		Open innovation events	Protection infrastructure
	Training of port personnel	Use		Port enviro cond forecast	Integrated management		Asset renewal			Marine species management
				Port call optimization						Planting
				Eco-driving						Sediment management

© European Commission, 2024.

Source: Project consortium elaboration.

Good green practices taxonomy (\* number of cases reviewed)

The figure presents the broad categories of green practices, including subcategories of specific activities. The number of notable cases examined within each category is indicated in parentheses. This taxonomy was designed to serve as a concise reference instrument, aiming to **raise awareness** on the types and variety of initiatives that have been effectively implemented in ports. Several compilations of good practices, gathered and catalogued on an ongoing and systematic basis, are available <sup>(10),(11),(12)</sup>. These compilations provide comprehensive descriptions of successful practices, as documented by their respective implementers.

The categories highlighted in orange within **Figure 5** represent groups of good practices that were selected for further elaboration. Their selection is not exhaustive and was based on the attention they received in existing literature or on the importance attributed to them through the online survey and the interviews with port stakeholders. For the selected cases, detailed descriptions of their attributes, experiences gained from their implementation, and the outcomes achieved, have been developed, based on various sources of information. These elaborated descriptions can be found in **section 4**.

## 2.5. Transferability of good practices

To assess the potential for successful adoption of a good practice, an assessment of its transferability is essential. “Transferability” in the context of this study refers to the ability to **transfer or adapt practices from larger and more resourceful port entities to smaller ports**, as well as ports with potentially limited capacity. The concept of transferability includes several components which are outlined in **Figure 6**.

The first component relates to the **scale and complexity of green initiatives**, which may pose significant challenges for implementation in smaller ports. Scale and complexity refer to the size and scope of the solutions, as well as the intricacy of the tasks involved and the level of expertise required for their implementation. This is a crucial aspect for the successful adaptation of an initiative to the specific characteristics of the targeted port, which may require tailored solutions, capacity building programmes and support mechanisms. The adaptation process ensures that the green practice will remain feasible and effective for the scaled-down operations of smaller ports.

A second component relates to the transfer of environmentally friendly technologies from larger to smaller ports, particularly when the technology is relevant to the smaller-scale ports (i.e., in terms of compatibility, resource availability and institutional capacity). **Technology transfer** should consider the compatibility of solutions with the technical capabilities and operational needs of smaller ports, to ensure successful adoption.

**Capacity building** programmes are another important component of transferability. As smaller ports may lack the necessary knowledge and expertise to implement green practices effectively, developing and providing such programmes is essential to enhance the understanding, knowledge, and skills of personnel for the successful adoption of environmentally friendly practices. Training programmes, knowledge

---

<sup>(10)</sup> <https://www.espo.be/practices>

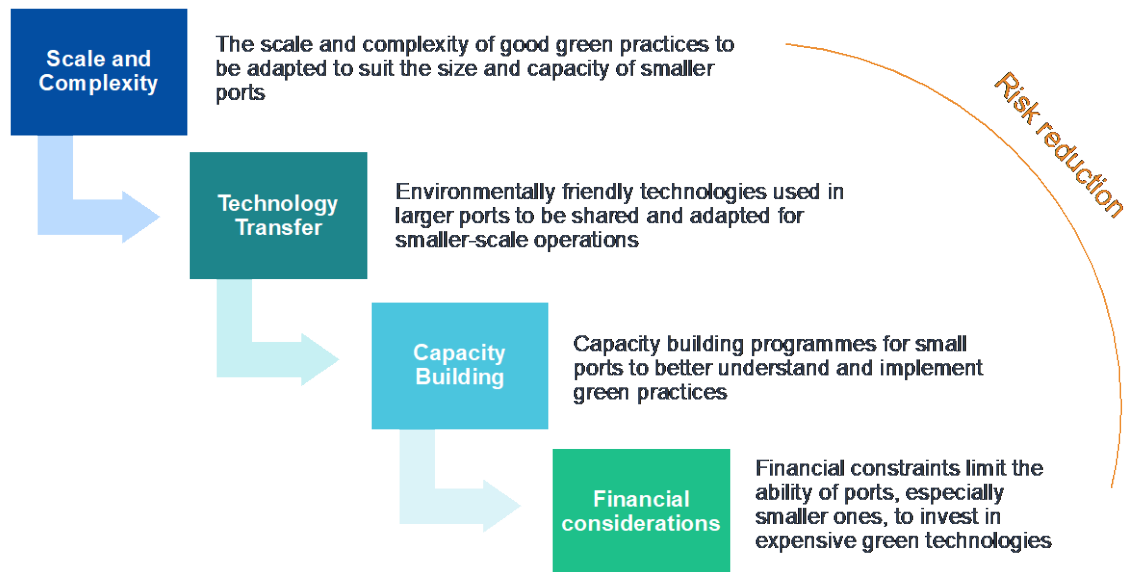
<sup>(11)</sup> <https://www.pianc.org>


<sup>(12)</sup> <https://www.iaphworldports.org/iaph-wpsp/>

sharing initiatives, and partnerships with industry experts can enhance the skills and capabilities necessary for implementing and maintaining sustainable initiatives. Capacity building efforts address technical expertise, regulatory compliance, and operational management.

**Figure 6 – The transferability concept of good green practices related to sea ports**

**Certain aspects should be considered for successful transferability of good green practices to smaller ports.**



 ***A port's ability to prioritise sustainability and implement green initiatives is not necessarily limited by its size.***

© European Commission, 2024.

Source: Project consortium elaboration.

The transferability concept of good green practices related to sea ports

**Financial considerations** define the potential and level of the adoption of good practices in ports of all sizes. Analysis shows that financial considerations are one of the key factors affecting the capacity of ports to implement green initiatives. In the context of the transferability approach, addressing this aspect includes exploring alternative funding mechanisms and financial assistance programmes, such as government grants, public-private partnerships, environmental funds, green bonds, concessions and technical assistance programmes. These mechanisms aim to alleviate financial barriers and support smaller ports in adopting sustainable practices.

The assessment of the transferability of green port practices should encompass all four components presented above. The aim is to ensure the successful implementation of green initiatives in smaller ports, based on their capacity to do so, taking into consideration the factors outlined in Section 2. Emphasising sustainability principles and effectively implementing green initiatives are equally important for smaller ports as they are for larger ones. **Drawing lessons from experienced**

implementers and ensuring that the necessary conditions are in place can help mitigate risks and expedite the green transition of small and medium-sized ports.

Larger ports have a better possibility to assume risk. For smaller ports, risk reduction is a crucial factor, enabling them to implement good green practices, especially given the various challenges they face related to scale, complexity, technology transfer, capacity building and financial constraints, as mentioned above. Strategies for risk reduction include thorough planning, stakeholder engagement, pilot projects, and monitoring mechanisms to address uncertainties and challenges throughout the implementation process. Risk reduction boosts confidence, facilitates decision-making, attracts investment, and improves stakeholder engagement.

## 2.6. Importance and use in roadmap development

An analysis of environmental impacts of port operations and relevant regulatory landscapes, an assessment of the characteristics and unique contexts of different ports, as well as an analysis of factors that affect the capacity of ports to implement good practices and the transferability potential of good practices, have been elaborated in the previous sections. A thorough assessment of these elements is important in the development and elaboration of a roadmap. This assessment will ensure that the roadmap will be targeted and effective in identifying and addressing critical environmental issues; legally sound and aligned with broader environmental goals; adjustable to the unique contexts of different ports; inclusive of proven solutions that can be tailored to different port contexts; practical and adaptable, facilitating the smooth adoption of green practices across different ports.

The insights gained from the preceding comprehensive analysis are instrumental in the development of a roadmap for greening of ports, with emphasis on small and medium size ones. More specifically, based on the above, the roadmap will:

- **Identify priorities:** by understanding the specific environmental impacts and regulatory requirements, and, therefore, actions that offer the greatest benefits may be prioritised.
- **Tailor strategies:** considering the unique factors affecting each port, the roadmap will propose tailored strategies that address their specific challenges and leverage their strengths.
- **Ensure feasibility:** by accounting for financial capacity and administrative scale, the roadmap will outline feasible steps that ports can realistically implement.
- **Promote effective practices:** drawing from the taxonomy of good practices, the roadmap will recommend proven strategies and technologies that can be adapted to local conditions.
- **Facilitate transferability:** by addressing the complexities of technology transfer and capacity building, the roadmap will provide guidance on how to effectively implement green practices across diverse port settings.

The specific elements of the roadmap are presented next, detailing the steps and the strategies that ports can implement to achieve their greening objectives.

### 3. Roadmap for greening of small and medium size ports

This section presents a [roadmap](#), to guide ports through the process of adopting good green practices, ensuring that they can achieve sustainable operations, while meeting regulatory requirements and contributing to broader environmental goals.

This roadmap is designed to be a [practical tool for small ports](#) interested in implementing sustainable solutions to green their operations. While it provides a [comprehensive strategy](#) that can be applied to all aspects of port activity, it is essential to approach it as a [flexible guide](#) rather than a rigid blueprint. The roadmap is structured to accommodate the varying scales and scopes of projects typically undertaken by smaller ports, in a generic yet comprehensive manner.

For smaller ports, the roadmap should be viewed as a framework that can be adapted to both minor and major initiatives. Each port, however, can [tailor the individual steps to the specific needs and capacities of their projects](#). For example, a port might use the roadmap to guide a small-scale initiative like upgrading to energy-efficient lighting, where the steps might include assessing current energy usage, exploring funding options, and selecting appropriate technology. On the other hand, for a larger project like implementing a comprehensive waste management programme, the steps could involve conducting a detailed waste audit, engaging stakeholders, and developing a phased implementation plan. In any case, a port will often need to combine information from existing cases and experience with innovative approaches that would fit its particular situation and challenges.

Not all steps in the roadmap need to be undertaken for every project, or to be undertaken in sequence in the order in which they are presented. Smaller ports can use the [roadmap as a checklist](#) to ensure that essential elements are not missed, even in the context of smaller projects. For instance, when installing a small solar panel system, it might not be necessary to conduct an extensive stakeholder engagement process, but ensuring compliance with environmental and energy regulations and conducting a feasibility study would still be critical.

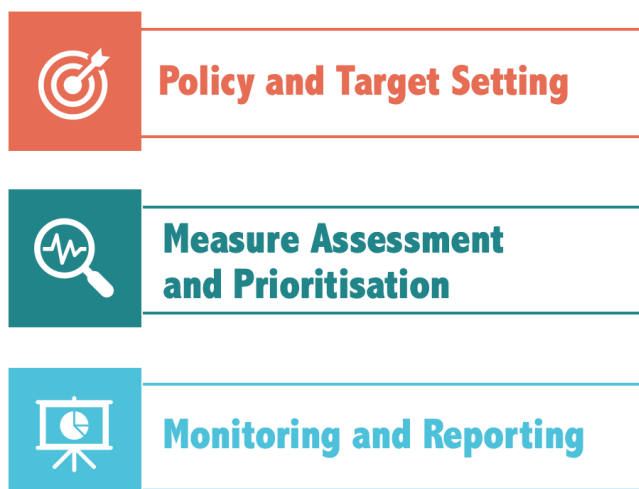
By using the roadmap in this flexible manner, smaller ports can make significant strides toward sustainability without being overwhelmed by the process. The roadmap offers a structured yet adaptable approach, empowering ports to undertake projects of varying scales while maintaining a focus on essential green practices.

The main areas of intervention and the elements of the roadmap are detailed next.

#### 3.1. Main areas of intervention

[Figure 7](#) shows the three areas of intervention around which the roadmap has been developed. These elements include: (a) Policy and Target Setting; (b) Measure Assessment and Prioritisation; and (c) Monitoring and Reporting.

**Figure 7 - Main intervention areas of a roadmap for greening of small and medium-sized EU sea ports**



© European Commission, 2024.

Source: Project consortium elaboration.

Main intervention areas of a roadmap for greening of small and medium-sized EU sea ports

**Policy and Target Setting** include considerations of the relevant institutional framework and the legal and regulatory environment related to the EU sea ports, influencing, directly or indirectly, their greening activities. It also includes an assessment of the motivation and drivers guiding the greening initiatives.

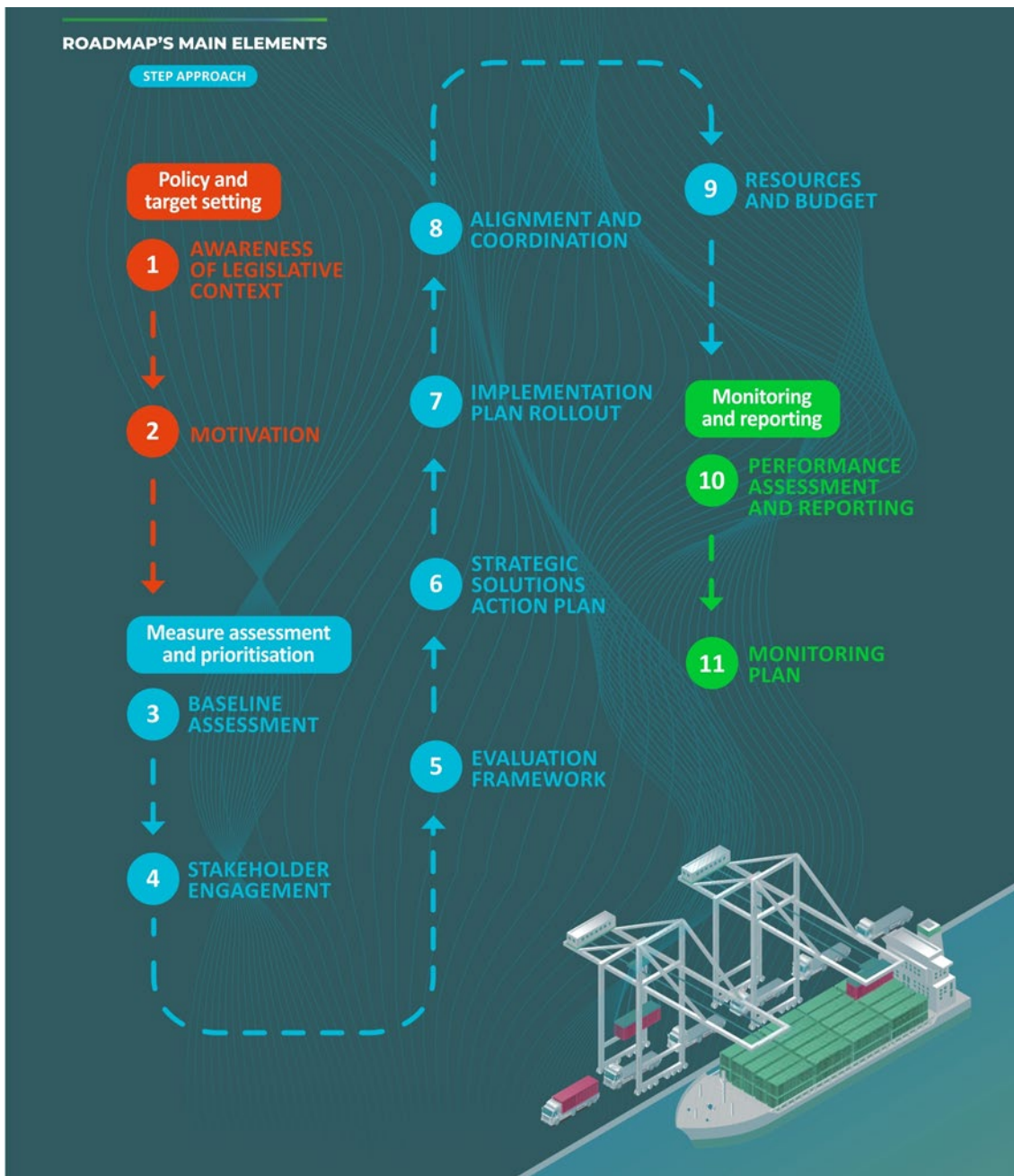
**Measure Assessment and Prioritisation** encompasses operational components and guides port stakeholders through an iterative approach of identifying operations to be improved, targets to be achieved and relevant actions to be implemented for achieving these targets, within the context of a collaborative environment and considering financial constraints and regulatory limitations.

**Monitoring and Reporting** concerns the process in place to ensure proper implementation and increase the likelihood of success and long-term sustainability of the initiative.

### 3.2. Elaboration of elements of the roadmap

The main elements are further elaborated, introducing the key steps of the roadmap. These steps are highlighted in [Figure 8](#) and are described next.

**Figure 8 – Main elements of the roadmap for selecting and implementing good green practices**



© European Commission, 2024.

Source: Project consortium elaboration.

Main elements of the roadmap for selecting and implementing good green practices

Each step is strongly linked to the others, while some of them represent recurring components that may be ongoing or iterating throughout the process. The following sections describe these steps focusing on their definition, goal, methods of implementation and main expected outputs from their realisation.

### 3.2.1. Policy and target setting

The 'Policy and target setting' element consists of two steps, the 'Awareness of legislative context' and the 'Motivation', which are elaborated in the following two subsections.

#### 3.2.1.1. Step 1. Awareness of legislative context

Understanding the legislative context involves identifying and comprehending the legal and institutional frameworks that influence port operations. This includes EU Directives and Regulations, national legislation and local regulations that impact port activities and greening initiatives. This step [ensures compliance and prepares for future regulations](#), encompassing mandatory and voluntary frameworks addressing economic, operational, environmental, technological and governance aspects.

In implementing this step, ports may conduct an in-depth analysis of existing and anticipated regulations, by engaging early on in the process their legal department or by seeking external legal counsel, to ensure compliance and mitigate risks. For smaller-scale projects, the implementation of this step may focus on key regulations and their impacts, highlighting major requirements and compliance steps. Internal meetings may be organised with legal advisors and relevant stakeholders to identify legal requirements and potential challenges.

For comprehensive projects, a detailed legal compliance checklist may be developed, including all relevant regulations, required permits, and compliance steps. For smaller projects, a summary of key legal requirements, highlighting the most critical regulations and steps for compliance may be adequate.

An example illustrating how legislation may be cumbersome and resource-demanding pertains to dredging activities. A port that has identified a need to perform dredging will need to determine whether the water body and/or the sea or riverbed at the dredging location is protected. If it is, an impact analysis and/or licenses might be required, along with compensatory measures. Furthermore, the spoils that result from the dredging operation will need to be removed to another location. From a legal perspective, the spoils might constitute 'waste', particularly if they are contaminated, which would make their removal a shipment of waste. If the spoils are then dumped at a marine location, the international conventions on dumping at sea would come into play. If the spoils are brought ashore, the reception or treatment facility may need licenses for its operation and will need to ensure that the emissions caused by its processes stay within the acceptable limits. Even though this is primarily the responsibility of the treatment facility, a port that deals with this facility may itself have a responsibility to check and verify compliance. This example shows how the legal framework affects almost every aspect of a dredging project. Properly and timely addressing the legal framework and legal requirements is necessary to ensure the successful completion of a greening project.

#### 3.2.1.2. Step 2. Motivation

Cultivating motivation among port stakeholders is crucial for the successful implementation of greening initiatives. This step involves establishing a clear and

relevant port vision with specific goals, objectives, and targets, to demonstrate the port's [commitment to environmental quality beyond regulatory compliance](#). The vision should inspire stakeholders and create a collective sense of purpose.

In implementing this step and effectively motivating stakeholders, ports should start with a preliminary [assessment of environmental impacts](#) related to their operations, or the operations relevant for the project they are considering. This understanding helps in communicating the importance of green practices and their benefits. Creating a concise and realistic vision statement with specific environmental goals, easily communicated to all stakeholders, will assist in fostering shared understanding and commitment. Initial stakeholder meetings should be organised to discuss the port vision and gather input. Employees, customers, suppliers, local communities, and regulatory authorities could be invited. Workshops can further promote collaboration, ensuring diverse perspectives are considered and innovative solutions identified. Stakeholders ideally should be actively involved in decision-making by developing a stakeholder engagement plan outlining involvement timelines and methods. Regular updates on the progress of greening initiatives will assist in maintaining engagement and gathering feedback. To inspire stakeholders and demonstrate the port's contribution to sustainable development, greening efforts should be aligned with broader economic, social and environmental objectives.

Key outputs of this step may include a report detailing environmental impacts, a port vision statement outlining goals, a stakeholder engagement plan, workshop reports summarising outcomes and regular progress updates. For large scale projects, detailed environmental assessments and vision workshops with a broad range of stakeholders and establishment of formal committees for structured engagement may be needed. For smaller-scale projects, a focus on key environmental impacts with regular stakeholder meetings or even informal stakeholder discussions, and progress reports or brief updates and community meetings may be adequate.

Installing solar panels on port buildings is an example of a small-scale project. To cultivate motivation in a small port environment the following actions may be undertaken: conduct an assessment of current energy use and carbon footprint; communicate the benefits, such as reduced cost and emissions; develop a vision statement, for example: "reduce energy consumption by 30% within five years using solar energy"; organise meetings and workshops with stakeholders to discuss the project and gather input; produce an engagement plan to involve stakeholders in selecting providers and planning installation; provide regular progress updates; align the project with local and national sustainability goals to demonstrate wider benefits and inspire stakeholders.

### 3.2.2. [Measure assessment and prioritisation](#)

The 'Measure assessment and prioritisation' element consists of seven steps, namely the 'Baseline assessment,' the 'Stakeholder engagement,' the 'Alignment and coordination,' the 'Implementation plan rollout,' the 'Strategic solutions and action plan,' the 'Evaluation framework,' and the 'Resources and budget.' Each of these steps is elaborated in the following seven subsections.

### 3.2.2.1. Step 3. Baseline assessment

A baseline assessment provides a detailed understanding of the current environmental status and identifies areas for improvement. This step involves evaluating factors such as air and water quality, energy use, waste generation, and noise levels. By systematically analysing these factors, ports can gain [insights into their environmental performance and identify areas of concern](#) that warrant attention.

To implement this step, thorough data collection, monitoring and analysis using tools and technologies suited to the port's size and resources should be performed. Factors that extend beyond the port boundaries and which may impact port conditions, including, but not limited to economic and geopolitical ones, should be considered.

Key outputs of this step include a comprehensive baseline assessment report for large-scale projects. For smaller-scale initiatives a focused simplified report may be adequate. This will serve as a starting point for identifying key areas for environmental improvement.

A small port, for example, could measure current energy consumption patterns to identify inefficiencies and opportunities for energy-saving updates.

### 3.2.2.2. Step 4. Stakeholder engagement

Stakeholder engagement is about involving relevant parties to gain insights, prioritise the issues, and create a collaborative framework for implementing green practices. This step ensures that all voices are heard and that initiatives gain broad support. In this context, it should be noted that the Port Services Regulation<sup>(13)</sup> requires port authorities to consult port users and other relevant stakeholders on essential matters within its competence regarding *inter alia* environmental matters.

In implementing this step, stakeholders from various sectors, including industry, technology providers, environmental agencies, and local communities should be identified and become involved. It is important to focus on the most relevant stakeholders for a specific case. Both formal meetings and informal discussions may be used to engage stakeholders, gather input and build consensus. Methods of engagement may include focus groups, surveys, and workshops.

It is important to [involve stakeholders proactively](#) and even from the policy and target setting steps. This way potential conflicts and challenges can be identified at an early stage and commonly acceptable solutions can be sought. Stakeholders can also provide ideas as well as point to areas where actions will be needed.

A key output of this step is a stakeholder engagement plan, to define why, who, when and how relevant engagement processes should be carried out. Other outputs include summaries of stakeholder feedback, and enhanced support and buy-in for greening initiatives. Overall, stakeholder consultation should not be seen as an "advertisement" or "damage control" activity but an [important resource for](#)

---

<sup>(13)</sup> Regulation (EU) 2017/352 of the European Parliament and of the Council of 15 February 2017 establishing a framework for the provision of port services and common rules on the financial transparency of ports, Art. 15.2 (d).

information and central component in ensuring the success of projects. This is particularly important when the stakeholders concerned are the port-cities or local communities and citizens, and especially in projects that combine port development with nature protection and restoration for the benefit of the port as well as of these communities and citizens<sup>(14)</sup>.

A small port, for example, may hold community meetings to discuss plans for a new waste recycling programme, gathering feedback and addressing concerns. An inclusive approach to stakeholder engagement from the early stages and throughout the project can ensure that the waste recycling programme is not only environmentally beneficial, but also supported and embraced by the local community and other stakeholders. Collaborative efforts and transparent communication can lead to more effective and sustainable outcomes, such as shared infrastructure and technology, and building a sense of shared responsibility and partnership.

### 3.2.2.3. Step 5. Evaluation framework

The evaluation framework serves as a structured approach to [assess environmental impacts and prioritise greening efforts](#). This step involves selecting appropriate solutions and assessing their feasibility and effectiveness.

In implementing this step, a framework using insights from previous steps such as the baseline assessment and stakeholder engagement should be developed. This can be a comprehensive framework, or a simplified one, focusing on key impact areas and feasible solutions for smaller projects. Pre-feasibility studies, including cost-benefit analyses and stakeholder consultations should be conducted, to select promising solutions.

Key outputs include an evaluation framework document, which can be detailed or simplified for smaller projects, and pre-feasibility study reports for selected green practices.

A small port for example, considering an electric vehicle fleet, may assess the costs, benefits, and necessary infrastructure changes (e.g., charging hubs and maintenance infrastructure).

### 3.2.2.4. Step 6. Strategic solutions action plan

The strategic solutions action plan outlines prioritised solutions that offer environmental benefits, while ensuring economic viability and operational efficiency. It involves development of an action plan for the implementation of the selected good practices.

In implementing this step, a comprehensive action plan describing the selected good green practice or a combination of them, their specific requirements for implementation, expected outcomes and impacts on the port operations and relevant stakeholders should be developed. Specific activities, including timelines, resources

---

<sup>(14)</sup> ESPO Award 2023 “Nature restoration projects in ports benefitting the local community”

and responsibilities should be detailed. For smaller-scale projects, a simplified action plan focusing on key activities and timelines may be adequate.

Given the complex environment ports operate in, ports should also be encouraged to [explore unconventional and innovative solutions that go beyond traditional practices](#). Furthermore, ports should explore new financing models or partnerships. This could involve collaborating with tech startups to develop custom solutions for port operations or seeking public-private partnerships to fund large-scale green initiatives. By embracing innovative approaches, seeking “out of the box” solutions, and stepping “out of their comfort zones” ports may develop more effective and sustainable action plans that not only improve environmental performance but also enhance economic and operational efficiency.

Key outputs include a detailed or a simplified action plan, for larger or smaller-scale projects, respectively, including clear timelines and resource allocation.

A small port, for example, could develop an action plan for installing energy-efficient LED lighting, including steps for procurement, installation, and expected energy savings. As another example, and in terms of seeking financing/funding options or introducing operational solutions, a port with the potential of excess electrical capacity at certain periods could think creatively about using this surplus. Instead of simply storing the energy, the port could develop a peer-to-peer energy trading platform, allowing it to sell excess electricity to other port stakeholders. This innovative solution not only addresses energy wastage, but also creates a new revenue stream.

#### 3.2.2.5. Step 7. Implementation plan rollout

The implementation plan rollout translates the action plan into actionable steps. It involves ensuring the [effective execution of the plan](#).

In implementing this step, managerial and technical experts should be involved in overseeing the effective execution of the plan. Detailed implementation steps and progress monitoring should be developed. For smaller-scale projects, a simplified approach focusing on key actions and quick wins may be sufficient.

Key outputs include a comprehensive implementation plan for larger initiatives, or a simplified document describing the implementation steps for smaller projects, aiming to support the successful execution of green practices.

A small port implementing a recycling programme, for example, would outline steps for establishing a comprehensive waste management system, educating users, and managing collected materials. This initiative could become part of a more comprehensive recycling and waste-to-energy program, aligned with broader local or regional energy production initiatives.

#### 3.2.2.6. Step 8. Alignment and coordination

Alignment and coordination ensure that the port’s action plan is consistent with other relevant plans and strategies. This step [identifies potential synergies and avoids conflicts](#).

In implementing this step, corresponding plans should be identified, and stakeholders should be engaged to ensure alignment. Regular review and update is required to reflect new developments.

The main anticipated output of this step is an aligned planning framework with coordinated actions, mainly at a local and regional level.

A small port, for example, may coordinate its energy efficiency initiatives with regional sustainability programmes to leverage additional resources and support.

### 3.2.2.7. Step 9. Resources and budget

Securing necessary resources and budget is critical for implementing green practices. This step involves [assessing resource needs and establishing financial schemes](#).

In implementing this step, human, financial, and other resource requirements should be assessed. A cost-effective financial plan, including potential funding sources should be developed. In terms of financial resources, a proper scheme may be based on own resources, equity, debt financing in the form of bank loans or bonds, EU grants, or other forms of financing and combinations of them. The use of specific clauses in port concession contracts or collaboration with third party providers should also be considered. Adequate resources need to be secured to effectively conduct the planned activities.

The key output includes a detailed resource and budget plan, outlining all costs, roles and timelines, along with secured funding sources.

A small port, for example, installing solar panels to reduce reliance on traditional energy sources, should assess resource needs, including a project manager, engineers, and technicians. It should also secure funding, which may include own resources, a grant and a low-interest loan, to cover the total estimated cost.

### 3.2.3. Monitoring and reporting

The 'Monitoring and reporting' element consists of two steps, namely the 'Performance assessment and reporting' and the 'Monitoring plan.' Each of the two steps is elaborated in the following two subsections.

#### 3.2.3.1. Step 10. Performance assessment and reporting

Performance assessment and reporting evaluate the effectiveness of implemented initiatives. This step involves setting key performance indicators (KPIs) and gathering data to [assess performance of implemented initiatives](#). Such data may include quantitative data such as energy consumption, waste reduction, air emissions and cost savings, as well as qualitative data, gathered by exploiting stakeholder engagement processes (i.e., feedback questionnaire surveys, workshops, etc.). Relevant criteria that can be applied include economic, social, environmental, technological, operational, and other aspects related to the greening of ports (i.e., Environmental, Social and Governance (ESG) criteria, etc.).

Implementing this step involves the establishment of KPIs and collection of quantitative and qualitative data. It also requires conducting regular performance reviews and compiling assessment reports.

The main expected output is an assessment report, which includes a detailed description of the performance metrics and KPIs associated with each step and target outlined in the strategy and action plan, along with the data requirements, sources, and collection methods.

A small port, for example, could track the reduction in energy consumption and report the savings achieved through energy-efficient lighting.

#### 3.2.3.2. Monitoring plan

A monitoring plan ensures continuous tracking of performance and progress. This step involves regular reviews and adjustments based on data. The aim is to **ensure that the initiatives remain responsive to changing circumstances and priorities.**

In implementing this step, a monitoring system with performance dashboards and periodic reviews should be developed. Stakeholders should be engaged in feedback sessions and in adjusting plans as needed.

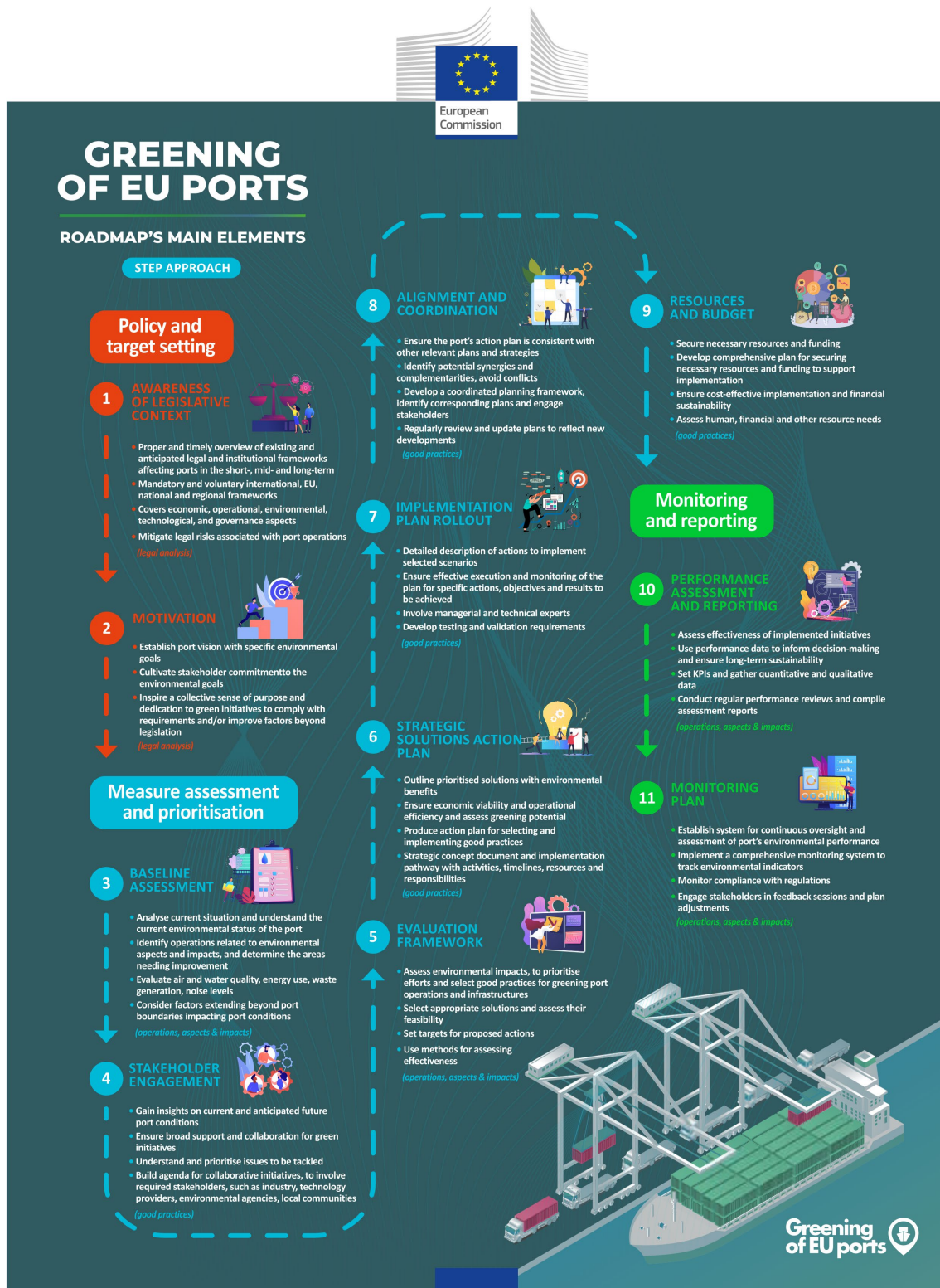
The main expected output of the monitoring plan is a comprehensive monitoring and evaluation plan accompanied by a dedicated monitoring system. This system supports the delivery of relevant monitoring reports, enabling stakeholders to track progress, evaluate performance, and make data-driven decisions throughout the implementation process. Furthermore, it may serve as a reference for other ports interested in implementing similar solutions.

As an example, a small port could use a dashboard to monitor emissions reductions from a new green energy project, adjusting strategies based on real-time data.

### 3.3. Summary of roadmap elements

The roadmap elements detailed above are summarised in the following figure. Under each step of the roadmap, key points related to its scope and implementation are presented.

Figure 9 – The Roadmap for greening the EU sea ports



© European Commission, 2024.

Source: Project consortium elaboration.

The roadmap for greening the EU sea ports

By following this roadmap and adapting each required step to the scale of the project, small ports can effectively implement good green practices, ensuring that the process is manageable and relevant to their specific context and capacities.

The next section presents examples of good practices, elaborating on the details of their implementation. Links to the relevant steps of the roadmap are pointed out in these descriptions.

## 4. Good practice case analysis

To gain a thorough understanding of the challenges and unique environments of each sea port, a comprehensive research approach has been employed. This includes desk research, complemented by an open call for good practices and a series of interviews with port stakeholders, to gather detailed information on successful sustainability initiatives. Several initiatives are elaborated next, covering a broad range of sustainability cases. These include practices that are easily scalable and transferable, as well as those that are site-specific in their technical details but address issues facing the whole port industry, practices that present a long-term investment, practices requiring strong collaborations among stakeholders and others in which the port authority is solely responsible for their implementation. Examples are drawn from various categories of good green practices, with emphasis on those highlighted in the literature and by interviewed stakeholders, as noted in [Section 2](#).

The analysis uses specific and detailed information from [successful practice implementations](#), highlighting key steps of the generic roadmap. While no single good practice is directly and unconditionally transferable to different ports, concrete examples and real-world experiences make the abstract concepts of the roadmap more relevant and comprehensible.

The elaborated cases show how ports:

1. target specific operations and identify related environmental aspects and impacts
2. assess key elements determining their scale and capacity to implement sustainable solutions and enhance their ability to identify and remedy relevant issues
3. use the good practice taxonomy to identify relevant solutions for specific challenges
4. identify and assess key elements of transferability when selecting good practices
5. address challenges in implementing good practices
6. consider legal and regulatory frameworks when implementing selected good practices

The sections that follow detail 24 cases across five main categories of good practices, namely biodiversity protection and restoration (4 cases), port electrification and energy management with emphasis on shore side electricity (SSE) – onshore power supply (3 cases), port equipment electrification (2 cases), port electricity supply and charging hubs (3 cases), energy supply and consumption management (3 cases), alternative fuels (3 cases), waste management (3 cases) and circular economy (3 cases). Each section includes a description of the context for the good practice category, a schematic representation of key environmental aspects and impacts, the relevant legal framework, and detailed descriptions of selected good practices. This is followed by a table with links to additional good practices and a summary of key messages from the analysis.

The depth of analysis for each case varies based on available literature, information from interviewees, and the maturity of the case implementation. Some cases present

well-established practices, while others are new initiatives with promising but yet to be demonstrated outcomes. Some initiatives are driven by Port Authorities, while others are led by terminal operators. These cases underscore the applicability and relevance of different elements outlined in the roadmap for various sustainability enhancement endeavours. A summary of elements of the various cases in relation to each of the steps of the roadmap is presented in Annex II – Case links with Roadmap steps.

#### 4.1. Biodiversity protection and restoration

Ports are often situated near environmentally sensitive areas, such as coastlines, estuaries, and wetlands. The development and expansion of port infrastructure often entail dredging operations and the disposal of dredged materials, leading to alterations in natural shoreline habitats and seabed environments. While dredging activities are crucial for increasing the resilience of port and coastline infrastructure against the impacts of climate change (such as sea level rise and flooding), they can also disrupt sediment composition, modify hydrological processes, and reshape habitat structures, thereby impacting the distribution and abundance of species dependent on these habitats. This case demonstrates how the [implementation of environmentally sustainable solutions can serve as a “license to operate or grow”](#).

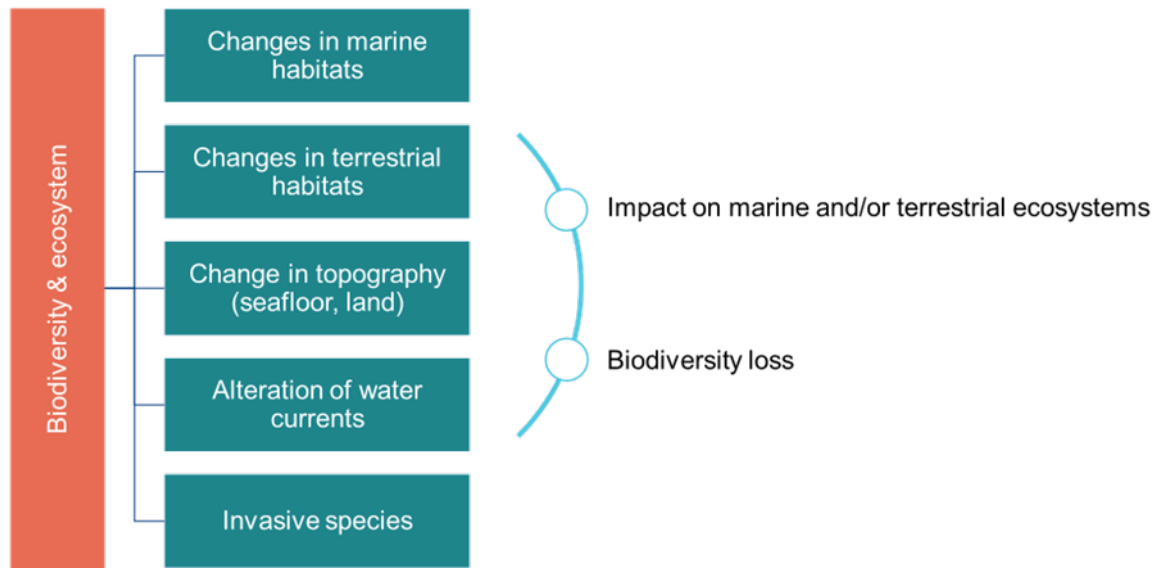
Furthermore, ports serve as pathways for the potential introduction of invasive species through ballast water discharge and hull cleaning practices, as well as the release of various pollutants into the surrounding environment, which may directly impact ecosystems nearby or even further away. Operations at ports, including vessel traffic, cargo handling, and construction activities, generate noise and vibrations that can disturb both marine and terrestrial wildlife.

The alteration of topography, both underwater and on land, resulting from port-related activities, and changes in water currents due to port and shipping operations constitute additional environmental considerations. The cumulative effects of port operations on biodiversity are substantial, encompassing habitat loss, pollution, the introduction of invasive species, disturbance from noise and vibration, and habitat modification.

Biodiversity loss, characterised by reductions in species abundance, genetic diversity, and ecosystem variety, is a significant consequence of these impacts. Moreover, the repercussions extend to marine and terrestrial ecosystems, encompassing aspects such as water and air quality, soil health, landscape/sea/riverbeds integrity, and the diversity of flora and fauna within adjacent ecosystems.

The environmental aspects and impacts concerning biodiversity and the protection and restoration of ecosystems are outlined in [Figure 10](#).

**Figure 10 – Environmental aspects (left side) and impacts (right side) related to the biodiversity and ecosystem**



© European Commission, 2024.

Source: Project consortium elaboration.

Environmental aspects (left side) and impacts (right side) related to the biodiversity and ecosystem

The [preservation of ecosystems](#) surrounding a port is imperative due to their role as critical habitats for diverse flora, fauna, and marine life forms. The implementation of strategies aimed at safeguarding biodiversity within the port area is paramount for the continued existence of these ecosystems and the species reliant upon them for sustenance and long-term viability.

Biodiversity conservation initiatives entail [proactive measures](#) undertaken by port authorities to enhance the protection, recovery and restoration of adjacent ecosystems, aligning with the overarching goal of promoting sustainability in port operations. These endeavours are pivotal not only for mitigating environmental impacts but also for ensuring regulatory compliance and demonstrating the port's dedication to corporate social responsibility, thereby minimising its ecological footprint.

Moreover, from a broader perspective, [biodiversity preservation](#) efforts play a vital role in bolstering the resilience of port ecosystems against the adverse effects of climate change, such as rising sea levels, intensified storms, and ocean acidification. Furthermore, they yield socio-economic benefits by maintaining various ecosystem services, such as fisheries, tourism, and coastal protection, thereby contributing to a comprehensive approach to sustainability.

## Legal Framework

The key legal framework for biodiversity protection in European seaports consists of the Water Framework Directive (WFD)<sup>(15)</sup> and the Marine Strategy Framework Directive (MSFD)<sup>(16)</sup>, which both aim to achieve 'good environmental status' of the marine environment. This involves the implementation of measures, such as the establishment of marine protected areas, to conserve biodiversity. Compliance with the Water Framework Directive and Marine Strategy Framework Directive, together with the Habitats<sup>(17)</sup> and Birds<sup>(18)</sup> Directives, is essential for the operation and expansion of ports and underlines the need to integrate environmental considerations into port management and development in line with international efforts to conserve biodiversity. The Ambient Air Quality Directive<sup>(19)</sup> and the National Emission reduction Commitments (NEC) Directive<sup>(20)</sup> set targets for air quality and thus also contribute (at least indirectly) to the protection of biodiversity.

This section, examines four good green practices pertaining to biodiversity preservation, offering valuable insights into aspects of their implementation. Spanning across these practices, the interventions undertaken encompass a diverse array of actions strategically formulated to advance the ports' sustainability agendas. The findings for the good practice related to biodiversity have been obtained through desk research, open consultation, and targeted interviews with port-related stakeholders.

*The port of Huelva* has adopted an integrated approach that combines ecosystem restoration with the conservation of protected areas. It leverages innovative bio-tools and the beneficial use of dredged material to create nesting and breeding habitats, and it enhances its coastal area with leisure infrastructures for the public, intervening on the port's landside and seaside area. *The port of Malaga* has undertaken efforts to enhance its environmental footprint by increasing green spaces within the port vicinity. Initiatives include planting of trees along the port-city interface and investing in the landside environmental upgrading of the port. The Kreet sand tidal zone project at *the port of Hamburg*, combines the improvement of access in the port through the Elbe River with nature-based principles, creating a conducive environment for local fauna. These interventions primarily focus on the seaside area of the port. *The port of Rotterdam* installs artificial reefs produced through three-dimensional (3D) printing using recycled materials, to restore damaged reef systems and protect vulnerable coastlines.

---

<sup>(15)</sup> Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.

<sup>(16)</sup> Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy.

<sup>(17)</sup> Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.

<sup>(18)</sup> Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds.

<sup>(19)</sup> Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe.

<sup>(20)</sup> Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC.

## Case 1 – Port of Huelva: Recovery of habitats and seabirds through the beneficial use of dredging and bio-tools <sup>(21),(22)</sup>

*The port of Huelva* is among Spain's most important industrial sites, and it is in an estuary of great ecological importance, protected at regional, European and international level. The area of the Port of Huelva is formed by the confluence of the rivers Tinto and Odiel, which run in a north-south direction through the province of Huelva, creating an area that is rich in minerals. On an annual basis the two rivers carry thousands of tons of heavy metals into the estuary of the port. Consequently, when acidic river water mixes with seawater, the pH of the rivers rises, leading to significant metal deposition in the seaport's area. This pollution becomes embedded in the sediments that are dredged, necessitating the implementation of proper environmental management practices. At the same time, from an ecological point of view, the estuary of the port is subject to significant tidal dynamics, leading to a constant replenishment and cycling of nutrients resulting to a high level of biodiversity and biological productivity. (*This is linked to Roadmap Step 2: Motivation, please see page 106*).

Within this environment, infrastructure development aligned with social welfare imperatives and the preservation of over 245 000 hectares of protected areas in the port vicinity constituted the main sustainability challenge and the driving force behind the development of an ecological recovery project. The port's ecological restoration project promoted this integrated "working with nature" approach with the aim of restoring the degraded left bank of the Odiel estuary and preserving habitats and their ecological integrity for over a decade (2008 – 2018). Contaminated dredging material was used to generate ecological value through the creation of nesting and breeding habitats for several populations of seabirds protected under the European Birds Directive. (*This is linked to Roadmap Step 1: Awareness of legislative context, please see page 105*).

Apart from nature restoration through the beneficial use of dredging and bio-tools, leisure benefits have been provided for the population of Huelva: a degraded area has been restored, new nesting and breeding habitats for protected seabirds have been created and social use has been promoted through the creation of a pedestrian path and river walk, alongside environmental education and outreach initiatives.

This integrated approach, embedded in the management of the port, is seen as fundamental to transforming elements threatening the port into opportunities for sustainable development. The total investment for the project over the ten-year period was EUR 27 million. (*This is linked to Roadmap Step 9: Resources and budget, please see page 123*).

In brief, the project objectives include the following:

---

(21) WPSP. (2016). <https://sustainableworldports.org/project/port-of-huelva-ecological-recovery-project/#:~:text=Through%20concentrated%20efforts%20for%20over,habitats%20and%20their%20environmental%20values.>

(22) PIANC. (2023). [https://www.pianc.org/wp-content/uploads/2024/02/Port-Huelva-Habitats-DM-and-bio-tools-Questionnaire-WwN-database\\_2023-01-23.pdf](https://www.pianc.org/wp-content/uploads/2024/02/Port-Huelva-Habitats-DM-and-bio-tools-Questionnaire-WwN-database_2023-01-23.pdf)

- considering biodiversity conservation and ecosystem recovery actions into dredging operations, integrating “working with nature” criteria and using bio-tools
- enhancing ecological connectivity in the estuary and in habitats of Community Interest under the European Habitats Directive
- creating a carbon storage area to capture over 300 tons of carbon per year
- reinforcing wetlands that have been eroded due to changes in sea level
- protecting threatened species and removing invasive species

The Port Authority of Huelva initiated and oversaw the project. However, its successful implementation necessitated the collaboration of a multidisciplinary team comprised of engineers, environmentalists, and various external stakeholders specialising in dredging, marine biology, and other related fields. (*This is linked to Roadmap Step 9: Resources and budget, please see page 123*). It was also necessary to cooperate with the environmental administration as well as Non-Governmental Organisations (NGOs), research groups and other actors linked to the conservation of biodiversity. In addition, society has been involved, through questionnaire surveys, info days to raise awareness and environmental volunteer days. (*This is linked to Roadmap Step 4: Stakeholder engagement, please see page 111*).

Throughout the decade-long implementation process, it became evident that the “Working with Nature” principles needed to be communicated frequently to contractors, even though the terms of the contract were clear from the early stages about the requirements and limitations of using bio-tools and respecting the natural processes of restoration. From a financial perspective, the Port Authority emphasised the substantial investment required by the stringent environmental considerations of the Working with Nature approach. With a total cost of EUR 27 million, this investment underscores the port’s commitment to sustainability principles. While the investment may not yield direct financial returns, it aligns with the port’s sustainability objectives, emphasising the long-term ecological benefits and the port’s dedication to responsible environmental stewardship.

Currently, the results of the restoration project monitoring, indicate the successful conservation of biodiversity. A total of 57 bird species has been documented within the restored marshlands, with a parallel reduction in the invasive species population. The restored marshes exhibit the capacity to capture carbon at a rate of 300 tons per year. Based on population surveys, coastal marshes are regarded favourably by 75 per cent of respondents, underlining their perceived ecological benefits. Moreover, over 60 per cent of the population visit the marshes at least once a year, primarily for recreational activities such as walking, cycling, fishing, photography, and leisure. (*This is linked to Roadmap Steps 10 as well as 11: Performance assessment and reporting as well as Monitoring plan, please see pages 125 and 127*).

## **Case 2 – Port of Malaga: Ecosystem restoration through tree planting<sup>(23),(24)</sup>**

The *port of Malaga* is one of the oldest ports in the world and currently one of the most important cruise terminals in Spain. Although the port is near the city centre,

<sup>(23)</sup> Port of Malaga. (2024a). [https://www.puertomalaga.com/es/proyectos\\_iniciativa/iniciativa-puerto-verde-ajardinamiento-viario-fase-1/](https://www.puertomalaga.com/es/proyectos_iniciativa/iniciativa-puerto-verde-ajardinamiento-viario-fase-1/)

<sup>(24)</sup> Port of Malaga. (2024b). [https://www.puertomalaga.com/es/proyectos\\_iniciativa/iniciativa-puerto-verde-ajardinamiento-viario-fase-2-proyecto-financiado-mediante-el-mecanismo-de-recuperacion-y-resiliencia/](https://www.puertomalaga.com/es/proyectos_iniciativa/iniciativa-puerto-verde-ajardinamiento-viario-fase-2-proyecto-financiado-mediante-el-mecanismo-de-recuperacion-y-resiliencia/)

it had been off limits to the public due to its past industrial use. Since the 1990's, efforts have been underway to integrate the port into the urban fabric, turning part of it into new civic space. The port has been working on an expansion plan, which has increased its capacity for cruise vessels, while in parallel, through a city-port plan, it has been developing the port area for recreational and commercial use. (*This is linked to Roadmap Step 8: Alignment and coordination, please see page 121*). A wide range of actions aiming at improving the air quality in the port area, reducing greenhouse gas (GHG) emissions in the port by improving energy efficiency and increasing the use of renewable energy are being undertaken as well. (*This is linked to Roadmap Step 2: Motivation, please see page 106*).

The greening initiative places emphasis on restoration and ecosystem reclamation through afforestation in the port area and between the port and the city to enhance the green space and contribute to carbon dioxide (CO<sub>2</sub>) sequestration by creating CO<sub>2</sub> sinks. At the same time activities related to raising awareness against climate change and enhancing collaborations through community-building exercises are being undertaken. (*This is linked to Roadmap Steps 2 and 4: Motivation, and Stakeholder engagement, please see pages 106 and 111*).

The initiative unfolds in three phases. As part of the roll-out phase of the implementation plan, since 2019, a total green area of 5 248 m<sup>2</sup> has been added to the port in phase I with an investment of approximately EUR 395 000 and almost 3 024 m<sup>2</sup> of green area in phase II with an investment of approximately EUR 231 000. Phase III is currently under development. It is estimated that trees planted as part of the overall initiative could offset around 585 tons of CO<sub>2</sub>, marking a significant stride in climate mitigation efforts. (*This is linked to Roadmap Steps 7 and 9: Implementation plan rollout, and Resources and budget, please see pages 118 and 123*).

In its decision to implement this initiative, the Board of Directors of the port of Malaga took into consideration the objectives set by the United Nations in its agenda to combat climate change, along with national legislation and regulations, including the Spanish "Sustainable Mobility Strategy" of 2009, which is complemented by the national "Sustainable Transport Strategy in Ports". Within this framework, efforts were concentrated on the aspects that influence the greening of the port, which led to the approval of the 2019-2023 Investment Plan and subsequent approval of the initiative and the corresponding action plans. (*This is linked to Roadmap Steps 1, 6 and 9: Awareness of legislative context; Strategic solutions action plan, and Resources and budget, please see pages 105, 115, and 123*).

### **Case 3 – Port of Hamburg (Kreetsand Tidal Zone): Environmental protection, habitat restoration and sustainable development** <sup>(25),(26),(27)</sup>

The *Hamburg Port Authority's* (HPA) Kreetsand Tidal Zone Project aimed to achieve several objectives related to environmental protection, habitat restoration and sustainable development in the port area. The primary objective of the project was to secure the seaward access to the port by reducing the tidal energy, resulting in

---

<sup>(25)</sup> WPSP. (2023). Hamburg Port Authority – Kreetsand tidal zone. <https://sustainableworldports.org/project/hamburg-port-authority-kreetsand-tidal-zone/>

<sup>(26)</sup> IBA Hamburg. (2024). <https://www.internationale-bauausstellung-hamburg.de/en/projects/elbe-islands-dyke-park/pilot-project-kreetsand/projekt/pilot-project-kreetsand.html#:~:text=T>

<sup>(27)</sup> WPSP. (2023). Hamburg Port Authority – Kreetsand tidal zone. <https://sustainableworldports.org/project/hamburg-port-authority-kreetsand-tidal-zone/>

less upstream sediment transport, and thus reducing the need for dredging in the port of Hamburg. The constant change between the high and low tide creates the “tidal pumping” effect and leads to an accumulation of sediment that requires frequent dredging in the port of Hamburg.

In this regard, the HPA and the Federal Waterways and Shipping Administration have been developing an innovative concept for sustainable development of the tidal Elbe since 2006, which includes an integrated strategy with various measures along the river for both tidal moderation and nature conservation. (*This is linked to Roadmap Steps 4 and 8: Stakeholder engagement; and Alignment and coordination, please see pages 111 and 121*). Initially, as part of the pilot project, a particular section of the Kreetzand area, which did not belong to the intertidal zone was reshaped and restructured to create an area of shallow water. The action took place between 2012 and 2022. A major excavation of 2 million cubic metres of soil has been carried out to allow natural tidal flooding and a new tidal area of 30 hectares has been developed. The total investment of the project amounts to EUR 80 million. The Hamburg Port Authority sees this specific green practice as a not easily transferable and scalable initiative, mainly due to the specific spatial conditions required for the successful implementation, and the targeted technical studies. However, although the specificities of the project and the elements detailed in the technical studies are unique, reflecting the characteristics of the Kreetzand Tidal Zone, the project presents an approach that can be broadly used in different ports with varied contexts. (*This is linked to Roadmap Steps 5, 7 and 9: Evaluation framework; Implementation plan roll-out; and Resources and budget, please see pages 114, 118, and 123*).

More specifically, for the Kreetzand Tidal Zone development, thorough studies and planning processes were essential, (*This is linked to Roadmap Step 3: Baseline assessment, please see page 109*) encompassing various elements such as:

- Hydraulics: Comprehensive understanding of flow conditions within the project area using 3D modelling techniques and assessment of the flow dynamics to evaluate the patterns of water movement and the potential hydraulic challenges.
- Nature conservation: Exploring the baseline conditions and biodiversity by compiling and assessing the existing ecological inventory. Defining the requirements to mitigate the potential impacts on natural habitats and species and conducting impact assessments for potential ecological effects of proposed developments.
- Earthworks: Examining the soil stability through geotechnical analysis and applying targeted construction methodologies.
- Technical planning: Translating the conceptual designs of the previous stages into detailed engineering plans by comparing the alternative options through a concrete evaluation process, emphasising on the environmental impact, cost, and feasibility of the proposed solution.

By creating valuable estuarine habitat, the project goes beyond legal requirements, is consistent with the Natura 2000 management plan for the Elbe estuary and forms part of a larger protected area (*This is linked to Roadmap Step 1: Awareness of legislative context, please see page 105*). It is expected that the new tidal area will be particularly beneficial also for fish species and endemic “*Oenanthe coniooides*”. One of the key elements has been the involvement of local stakeholders from the early stages of the project. Citizens, NGOs and relevant authorities have been regularly

approached to contribute with their opinion to the development of the project. The Port of Hamburg already collaborates with other organisations (International Association of Ports and Harbours, European Sea Ports Organisation, World Ports Climate Action Program, chainPort partnership) to share its best practices and jointly work on environmental initiatives. *(This is linked to Roadmap Step 4: Stakeholder engagement, please see page 111).*

#### Case 4 – Port of Rotterdam: Artificial Reefs through 3D Printing

The *Port of Rotterdam* supports an initiative promoted by a company<sup>(28)</sup> that produces Artificial Reefs through 3D printing<sup>(29)</sup>. The company designs, produces and installs artificial reefs to help restoration of damaged reef systems and protect vulnerable coastlines. They report building geometrically complex organic shapes, while delivering savings on material use. They use shapes that are found in nature (biomimicry), and which are optimised to local conditions. According to the company, the printing process does not require support material for these complex shapes, since the unbound powder surrounds the printed shape. *(This is linked to Roadmap Steps 2 and 7: Motivation; and Implementation plan rollout, please see pages 106 and 118).*

The company uses the outer wall of RDM (Rotterdamsche Droogdok Maatschappij), the regenerated area of an old shipbuilding and ship repair facility, which is currently a centre for innovative manufacturing industry, education, and events. This outer wall, located in the water of the Maas, serves as a test bed for prototype reefs. *(This is linked to Roadmap Step 8: Alignment and coordination, please see page 121).* They also report using various materials, such as local sand and water, as well as recycled materials, like concrete, silt or shells. The printers do not require chemical additives or high temperatures to print, and the residual material, such as concrete, is recycled.

This initiative, in addition to its biodiversity protection component, is a good example of circular economy activity related to coastal areas and ports, which can be easily replicated in areas where man-made activities can damage or destroy natural reefs.

Other green initiatives related to the biodiversity protection in ports were retrieved from the desk research and an indicative list can be found in [Table 2](#).

**Table 2 – Other green practices related to the biodiversity protection in ports**

Name of port	Country	Short description	Reference
Port of Rotterdam	Netherlands	Specific biodiversity related Strategy, called “Nature Vision” in the Port Vision 30, incorporating nature and biodiversity in their plans and projects	<a href="https://www.portofrotterdam.com/en/to-do-port/nature-in-the-port">https://www.portofrotterdam.com/en/to-do-port/nature-in-the-port</a>

<sup>(28)</sup> <https://www.coastruction.com/>

<sup>(29)</sup> <https://maritime-professionals.com/restoring-nature-with-3d-prints/>

Name of port	Country	Short description	Reference
Port Authority of New York and New Jersey	United States	Open space for conservation and ecological development / Restoration of several Jamaica Bay marsh islands, using the clean dredge material	<a href="https://www.inboundlogistics.com/articles/10-greenest-ports-in-america/">https://www.inboundlogistics.com/articles/10-greenest-ports-in-america/</a>
Port of Algeciras	Spain	Recuperate the local Patella Ferruginea population	<a href="https://www.espo.be/practices/life-remopaf-project">https://www.espo.be/practices/life-remopaf-project</a>
Port of Algeciras	Spain	Early detection of invasive algae at the Port of Algeciras	<a href="https://www.espo.be/practices/early-detection-of-potentially-invasive-algae-at-t">https://www.espo.be/practices/early-detection-of-potentially-invasive-algae-at-t</a>
Port of Cava	Spain	Repopulation of protected species	<a href="https://www.espo.be/practices/elba-island-repopulation-of-protected-species">https://www.espo.be/practices/elba-island-repopulation-of-protected-species</a>
Port of Gothenburg	Sweden	Large scale planting of eelgrass meadows	<a href="https://sustainableworldports.org/project/port-of-göteborg-large-scale-planting-of-eelgrass-meadows/">https://sustainableworldports.org/project/port-of-göteborg-large-scale-planting-of-eelgrass-meadows/</a>
Port of Hamad	Qatar	Reef restoration and mangrove enrichment	<a href="https://www.hellenicshippingnews.com/qatar-hamad-port-is-one-of-worlds-largest-green-projects/#:~:text='Hamad%20Port%20is%20the%20largest,on%20its%20Twitter%20handle%20yesterday">https://www.hellenicshippingnews.com/qatar-hamad-port-is-one-of-worlds-largest-green-projects/#:~:text='Hamad%20Port%20is%20the%20largest,on%20its%20Twitter%20handle%20yesterday</a>
Port of Tarifa	Spain	Breakwater restoration	<a href="https://www.espo.be/practices/pilot-project-for-the-repositioning-of-rocky-block">https://www.espo.be/practices/pilot-project-for-the-repositioning-of-rocky-block</a>
Port of Le Havre	France	Nest boxes for birds and bats	<a href="https://www.espo.be/practices/nest-boxes-for-birds-and-bats">https://www.espo.be/practices/nest-boxes-for-birds-and-bats</a>
Port of Vigo	Spain	Sunset dock project	<a href="https://sustainableworldports.org/project/port-of-vigo-sunset-dock-project/">https://sustainableworldports.org/project/port-of-vigo-sunset-dock-project/</a>

Source: Project consortium elaboration.

## Summary and key lessons learned

The good practices detailed above, present examples of nature-based solutions as well as so-called grey infrastructure projects. In the first case, “*working with nature*” solutions are implemented, including restoring mangroves, planting trees, or introducing flood parks and tidal zones. In the second case, human-constructed infrastructure (such as artificial reefs) is built, which, however, may use specialised materials and techniques that improve habitats. Despite the specificities of each case, the types of solutions and the philosophy of the projects are highly relevant to smaller ports, particularly when considering enhancing their resilience against climate change-induced phenomena, such as sea level rise inundating low-lying lands, and coastal flooding.

The first case represents a paradigm where an integrated “biodiversity strategy” needs to be adopted by the initiator (Port authority or other initiating body), suited to the specificities of the particular port and local conditions, along with a full implementation roadmap including the relevant eleven steps presented elsewhere in the report. The second case represents the adoption of a technology that can be adapted to the local conditions in a more flexible, yet “localised” manner.

The examination of biodiversity protection and restoration practices in ports highlights innovative and impactful strategies for balancing ecological sustainability with port development. The following key lessons can be drawn from the four cases presented:

**Integrated ecological restoration:** Industrial development in ports can successfully integrate ecological restoration projects, as demonstrated in the case of the port of Huelva. By using contaminated dredging materials to create nesting habitats and leveraging bio-tools, the port of Huelva managed to protect over 245,000 hectares while enhancing social welfare through recreational infrastructures. This model underscores the potential for ports to align industrial activities with significant environmental gains, serving as a benchmark for similar industrial contexts.

**Collaborative and multidisciplinary approaches:** The importance of collaboration among engineers, researchers, environmentalists and other stakeholders is highlighted in the port of Huelva and the port of Hamburg cases. Such multidisciplinary teams are crucial for leveraging a wide range of expertise and resources, ensuring that projects meet both technical and environmental objectives. This collaborative approach is essential for ports seeking to implement comprehensive and sustainable biodiversity projects.

**Sustainability principles justify financial investment:** Adhering to sustainability principles often necessitates significant financial investment, as seen in the high costs associated with the projects in Huelva and Hamburg. In any case, financial viability of an integrated biodiversity action plan should be assessed in terms of the overall economic viability, taking into account social costs and benefits. Moreover, in the long run, such a plan may be financially sound in terms of long-term positive effects, e.g., protecting infrastructure from climate-related vulnerabilities, and regulatory compliance. Besides these considerations, development of a localised port biodiversity plan may be a prerequisite for the appropriate licensing process for a particular port, e.g. through the environmental licensing. Ports must view these expenditures as essential for maintaining their “licence to operate” and ensuring responsible environmental stewardship.

**Incremental and scalable initiatives:** The step-by-step implementation of green spaces through phased investments at the port of Malaga demonstrates how ports can gradually enhance their environmental footprint. This scalable approach allows ports to align improvements with available resources and future opportunities, making it a practical model for ports of varying sizes and capacities. Scaling down is straightforward and the practice can be tailored to the specific scale of ports and relevant port activities, though, ideally, this initiative must be incorporated into the port master plan. Under certain circumstances, this initiative can be incorporated as a “greening clause” in newly awarded or extended port concessions. Inclusion in the port concessions or sub-concessions may take various forms from the requirements of the tendering process to the clauses of the concessions contracts, and post - transaction concessions monitoring.

**Tailored solutions for unique environmental conditions:** The success of the Kreeftand tidal Zone project is heavily reliant on specific tidal and spatial conditions of the Elbe estuary. The case of the port of Hamburg highlights the need for tailored approaches to habitat restoration, emphasising that while the principles can be broadly applicable, the execution must consider local environmental conditions. Ports with different characteristics can draw from this experience to implement similar initiatives adapted to their unique contexts.

**Innovative technologies and circular economy:** The use of 3D-printed artificial reefs from recycled materials at the port of Rotterdam showcases how innovative technologies can contribute to biodiversity protection, while promoting circular economy principles. This initiative is replicable across various ports, provided that environmental assessments are thoroughly conducted to ensure compatibility with local ecosystems. Such technologies represent an innovative approach to habitat restoration and coastal protection.

## 4.2. Port Electrification and Energy Management

Port Electrification is a key element within the spectrum of port-related green practices. It spans across several good practice categories, including Shore Side Electricity – Onshore Power Supply, terminal equipment, supporting vessels and vehicles, energy efficiency, and renewable energy. These practices seem to have significant potential for reducing pollutants in port environments. As an illustration, using onshore power supply (OPS) can reduce CO<sub>2</sub> and NO<sub>x</sub> emissions by over 50%, while for a typical container ship during a 24-hour stay at port, this technology has been reported to eliminate emissions of 45 kg NO<sub>x</sub>, 32 kg SO<sub>x</sub> and 7 kg of other pollutants<sup>30</sup>. The extensive literature review conducted in the context of the greening of EU seaports study, however, indicates that while the potential for emissions reduction is clear, the reported numerical data are based on various assumptions and methodologies that can differ widely.

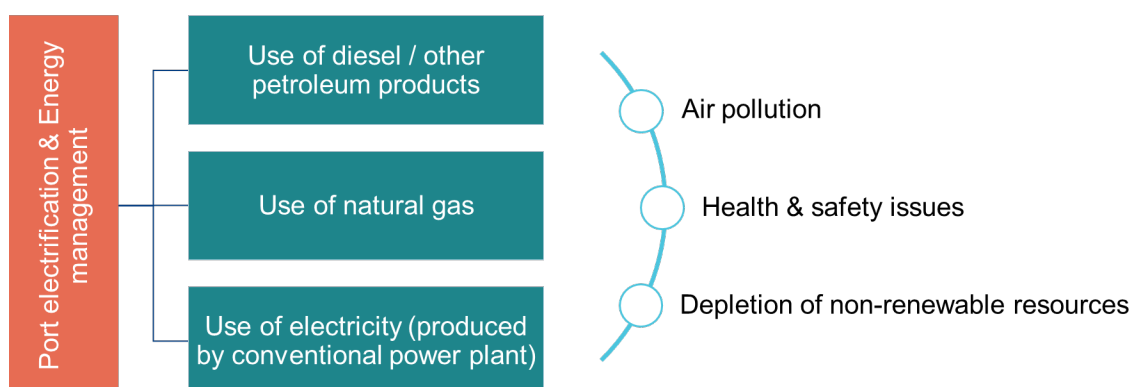
Some of the good practices have been developed and applied as standalone practices, while others have been combined in the form of a “chaining” sequence. An important element of this spectrum of green practices is the optimisation of energy consumption through various operational measures.

The environmental aspects and impacts associated with port electrification and energy management, which have been emphasised in the cases reviewed in this report, are presented in [Figure 11](#).

---

<sup>30</sup> Onshore power is one option to reduce air emissions in ports: <https://link.springer.com/article/10.1007/s00550-020-00497-y>

**Figure 11 – Environmental aspects (left side) and impacts (right side) related to port electrification and energy management**



© European Commission, 2024.

Source: Project consortium elaboration.

Environmental aspects (left side) and impacts (right side) related to port electrification and energy management

### Legal Framework

The regulatory framework for Onshore Power Supply (OPS) in EU ports is governed by the Alternative Fuels Infrastructure Regulation (AFIR)<sup>(31)</sup> and Regulation 2023/1805 on fuel use in maritime transport<sup>(32)</sup>. Member States must ensure the installation and use of OPS infrastructure, with exceptions, and report on progress every two years. The proposed revision of the Energy Taxation Directive<sup>(33)</sup> would allow tax exemptions for electricity supplied to ships. OPS includes the generation, transmission and supply of electricity, which is regulated by Directive 2019/944<sup>(34)</sup>, with an emphasis on unbundling activities. Furthermore the Port Services Regulation<sup>(35)</sup> establishes a framework for the provision of port services, which includes OPS among others. These provide a comprehensive legal framework for the provision and use of electricity by vessels at berth.

This section explores various facets of port electrification and energy management, focusing on key categories of green practices. These include shore side electricity – onshore power supply, for the provision of electricity to vessels while at berth; port equipment electrification, for intra-port/intra-terminal cargo handling and transport equipment, including retrofitting of existing equipment to use electricity; port electricity supply and charging hubs, including providing charging hubs to intra-port transport means as well as electrified external trucks; and energy supply and consumption management, including producing and using clean electricity. The following sub-sections present examples of these practices, elaborating on their scope, initiating entities, stakeholder engagement, and financial considerations among others.

<sup>(31)</sup> Regulation (EU) 2023/1804 of the European Parliament and of the Council of 13 September 2023 on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU.

<sup>(32)</sup> Regulation (EU) 2023/1805 of the European Parliament and of the Council of 13 September 2023 on the use of renewable and low-carbon fuels in maritime transport, and amending Directive 2009/16/EC.

<sup>(33)</sup> Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity (ETD).

In 2021, the Commission proposed a revision of this Directive (COM/2021/563 final).

<sup>(34)</sup> Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast).

<sup>(35)</sup> Regulation (EU) 2017/352 of the European Parliament and of the Council of 15 February 2017 establishing a framework for the provision of port services and common rules on the financial transparency of ports.

#### 4.2.1. Shore Side Electricity – Onshore Power Supply

OPS is a green practice that has been widely considered and/or applied. In the past, however, uncertainties about its use by ships calling at ports hindered OPS initiatives. The 2023 Alternative Fuels Infrastructure Regulation (AFIR)<sup>(36)</sup> and FuelEU Maritime Regulation<sup>(37)</sup> were introduced to address this issue. These regulations mandate the use of OPS by ships starting from January 1st, 2030, ensuring that the OPS infrastructure ports are required to install will indeed be used.

The aim of this analysis is not to present an extensive array of examples of OPS applications. Instead, this section highlights three examples of OPS implementation in medium-sized ports: the Port of Kiel, Germany; the Port of Aarhus, Denmark; and the Port of Gävle, Sweden. The goal is to draw insights from these implementations.

Financial support to cover partially the cost of OPS installation can be instrumental. EU level financial instruments such as the Connecting Europe Facility (CEF) and the Alternative Fuels Infrastructure Facility (AFIF)<sup>(38)</sup>, along with national financial sources can be explored. So far OPS was installed and operated primarily by the port authorities, however, the change in the legal environment means that other options can be considered (for example provided as a service under a concession with a third party, or through collaboration with shipping companies). Therefore, the OPS provision model may vary between ports.

A very valuable source of information about OPS and other forms of Shore Side Electricity is the EMSA Guidance on Shore-Side Electricity<sup>(39)</sup>, incorporating extensive up to date information on technical, institutional and capacity aspects. Further valuable information can be sourced from the European Onshore Power Supply Association (EOPSA)<sup>(40)</sup>.

#### Case 5 – Port of Kiel: Variable OPS use charging scheme <sup>(41),(42)</sup>

The *Port of Kiel*, situated within an urban area, handles significant RoPax, Ro-Ro and cruise traffic. Operated by a private company wholly owned by the municipality, the port has invested EUR 17 million in developing OPS facilities across its four piers, allowing seven ships to connect simultaneously during peak berthing times. This investment in shore power facilities, which enable multiple ships to connect to the local electricity grid simultaneously, significantly reduces emissions and noise during berthing. (*This is linked to Roadmap Step 6: Strategic solutions action plan, please see page 115*). This exemplifies the Port of Kiel’s proactive approach to sustainability and environmental responsibility, representing a major step towards its goal of carbon neutrality in line with its Blue Port strategy. (*This is linked to Roadmap Step 2: Motivation, please see page 106*).

---

<sup>(36)</sup> Regulation (EU) 2023/1804 of the European Parliament and of the Council of 13 September 2023 on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU.

<sup>(37)</sup> Regulation (EU) 2023/1805 of the European Parliament and of the Council of 13 September 2023 on the use of renewable and low-carbon fuels in maritime transport, and amending Directive 2009/16/EC.

<sup>(38)</sup> [https://cinea.ec.europa.eu/funding-opportunities/calls-proposals/cef-transport-alternative-fuels-infrastructure-facility-afif-call-proposal\\_en](https://cinea.ec.europa.eu/funding-opportunities/calls-proposals/cef-transport-alternative-fuels-infrastructure-facility-afif-call-proposal_en)

<sup>(39)</sup> <https://emsa.europa.eu/csn-menu/items.html?cid=14&id=4799>

<sup>(40)</sup> <https://www.eopsa.eu/>

<sup>(41)</sup> Port of Kiel. (2023a). <https://www.portofkiel.com/blue-port-en/shore-power-facilities.html>

<sup>(42)</sup> Port of Kiel. (2023b). <https://www.portofkiel.com/news-reader-en/contract-for-new-shore-power-facilities-goes-to-siemens-ag.html>

The OPS infrastructure includes both 50/60 Hz systems for cruise ships and ferries and a 50 Hz system for ferries only. These systems are designed to meet the different technical standards and power requirements of international shipping. The first type of unit has a capacity of 16 MVA and can serve both ferries and cruise ships. It connects four berths to shore power simultaneously, providing either 50 or 60 Hz frequency and 6.6 kilovolts (kV) or 11 kV voltages. This flexibility supports the port's objective of accommodating a wide range of vessels with different electrical requirements. The second type of unit, designed to serve Ro-Ro vessels, operates on a 50 Hz grid frequency and can supply two berths with a maximum power of 5 MVA, at voltages of 6.6 kV or 11 kV. (*This is linked to Roadmap Step 7: Implementation plan rollout, please see page 118*).

The electricity provided through the central urban distribution grid is reported to be 60% green. An interesting element of this case is that the port charges its customers for energy usage based on fluctuating electricity prices. It charges the price at which electricity is bought in the spot market, with a marginal surcharge of 2 to 4 cents per Wh for operational expenses. The port is essentially offering energy at cost, without considering this service as a profit centre, fostering excellent cooperation with shipping lines.

Funding for the EUR 17 million development came from a combination of national, regional and EU sources (80%) supplemented by the port's own financing (20%). According to the port, operational expenses (OPEX) are covered through general port fees. (*This is linked to Roadmap Step 9: Resources and budget, please see page 123*).

In terms of cooperation with shipping companies, an annual letter of intent with approximate usage per year is submitted by the shipping lines. Advance notification for every vessel call is required to inform the energy provider. For regular shipping services, this is a straightforward process. (*This is linked to Roadmap Step 4: Stakeholder engagement, please see page 111*).

Several challenges were encountered, and they were addressed by the port. The first one was related to regulatory issues, regarding the port company as the energy seller. In order for a port to be able to sell energy to its customers for the use of shore power, a change in legislation was necessary, so that the operator of a shore power station is not classed as an energy company that has to adhere to strict rules and regulations. The law regulating the operations of charging infrastructure in Germany was amended to include an exemption for operators of shore power stations for ships, similar to the existing exemption for car charging infrastructure operators according to which the operator of such an infrastructure is not seen as an energy company. This amendment allowed ports to operate shore power stations without having to become licenced energy companies, thus avoiding the regulatory restrictions associated to being an energy company. In order to achieve this, several German ports entered into a discussion with national politicians to explain the operational problem and achieve a solution together.

Another challenge was related to grid capacity issues, especially during peak demand. Kiel addressed this issue by connecting to the national grid at a high voltage level, ensuring sufficient energy supply to cover peak demand. This solution cost approximately an additional EUR 1.5 million and required building a port substation. In ports where there is no such option, however, the local energy provider can expand the grid, although this process may prove to be time consuming. Alternatively, mobile

solutions such as power-producing barges, tested as a pilot project in the Port of Hamburg<sup>(43)</sup>, can be used instead of fixed shore power stations.

Finally, issues related to justifying the business case for OPS service and addressing initial concerns about fluctuating energy prices had to be resolved. On this aspect, there were some tax exemptions achieved to reduce the price for shore power for the shipping companies that improved the business case. In addition, purchasing power on the stock market further reduced the costs, according to the port officials, making them comparable to the price of bunkering fuel. However, significant investment costs had to be funded to a large extent, as otherwise there would not be a viable business case for the use of shore power.

Despite these challenges, the port's innovative approach sets a precedence for sustainable port operations. (*This is linked to Roadmap Step 3: Baseline assessment, please see page 109*).

### **Case 6 – Port of Aarhus: Port dues promoting use of OPS** <sup>4445</sup>

Denmark's first shore power facility for cruise ships, established at the *Port of Aarhus*, marks a significant milestone in the country's sustainability efforts. The facility enables cruise ships to connect to green electricity sourced directly from Danish wind turbines, allowing them to switch off their diesel engines. (*This is linked to Roadmap Step 6: Strategic solutions action plan, please see page 115*). To incentivise the use of shore power, the port has introduced a novel fee model: cruise ships that do not connect to the facility are charged with higher port dues<sup>46</sup>. Specifically, the new fee model imposes an additional charge of Danish Krone (DKK) 0.75 per gross ton on cruise ships that do not utilise shore power, resulting in an additional fee ranging from DKK 50 000 (EUR 6 700) to DKK 75 000 (EUR 10 000) per cruise ship call, depending on the vessel's size<sup>47</sup>. This fee is supplementary to the normal port dues. This measure aims to promote the use of OPS and support the port's environmental objectives. (*This is linked to Roadmap Steps 7 and 9: Implementation plan rollout, Resources and budget, please see pages 118 and 123*).

The first OPS facility at the port became operational in July 2023, and the new fee model was announced in November 2023. While it is still too early to assess the measure's effectiveness, initial responses from cruise lines have been promising, indicating a positive shift towards embracing OPS. Even though not all cruise ships are currently equipped to use shore power, there is a growing trend for those that call at the port to convert, and shipping lines increasingly appear capable to connect to shore power. This initiative underscores the port's commitment to attracting more shipping companies that have adapted their ships to use shore power, highlighting its ambition to remain competitive and environmentally conscious.

Key stakeholders involved in developing OPS at the port of Aarhus include the port authority, collaborating cruise lines, and government and state entities focused on

---

<sup>(43)</sup> [https://www.becker-marine-systems.com/files/content/pdf/product\\_pdf/Becker\\_HPE\\_LNG\\_Power\\_Barge.pdf](https://www.becker-marine-systems.com/files/content/pdf/product_pdf/Becker_HPE_LNG_Power_Barge.pdf)

<sup>(44)</sup> Ship technology. (2023). <https://www.ship-technology.com/news/port-of-aarhus-opens-denmarks-first-shore-power-facility-for-cruise-ships/>

<sup>(45)</sup> Port of Aarhus. (2023). <https://www.portofaarhus.dk/en/news-and-press-releases/port-of-aarhus-investing-in-shore-power-for-cruise-ships/>

<sup>(46)</sup> <https://www.portofaarhus.dk/media/qe2l11db/terms-and-conditions-for-use-of-onshore-power-supply-in-the-port-of-aarhus-wcag.pdf>

<sup>(47)</sup> <https://www.bunkerspot.com/europe/60545-europe-port-of-aarhus-introducing-increased-charges-for-cruise-ships-that-don-t-hook-up-to-shore-power>

reducing pollution and GHG emissions in and around the port. (*This is linked to Roadmap Step 4: Stakeholder engagement, please see page 111*).

It should be noted that several initiatives have been considered by ports to incentivize the decarbonization of the shipping sector. For example, ports may offer preferential fees to the best-performing ships in terms of sustainability and energy efficiency, e.g., through considering the operational carbon intensity index<sup>(48)</sup> (CII). A 2017 study<sup>(49)</sup> examined differentiated port infrastructure charges as a means to promote environmentally friendly maritime transport and sustainable transportation, providing relevant recommendations. However, a review of pertinent literature conducted in the context of the study for greening of EU seaports, shows that the progress made in implementing such initiatives and achieving concrete outcomes has not been substantial in the meantime.

### **Case 7 – Port of Gävle: Diversified use of OPS**

In an interesting development at the *Port Gävle* in November 2023, a tanker conducted an unloading operation while connected to shore power<sup>(50)</sup>. This endeavour is part of the Green Cable project led by the Port of Gothenburg<sup>(51)</sup> which aims to develop a new global standard for the electrical connection of tankers at the dock in hazardous environments. A key challenge lies in the risk of explosions when tankers are berthed at energy terminals. This risk stems from the presence of combustible gases during loading and discharge operations, combined with the potential for sparks during power connection. To mitigate this risk, unique safety measures had to be developed. Besides addressing safety-related challenges, the initiative addresses challenges associated with logistical efficiency and environmental impact, while also resulting in significant cost savings. Its development is driven by collaboration of the port with other stakeholders, including classification societies, local oil companies, shipping companies, and regulatory agencies. (*This is linked to Roadmap Steps 2, 4 and 8: Motivation; Stakeholder engagement; Alignment and coordination, please see pages 106, 111, and 121*).

This effort is a positive example of regional cooperation to address challenges associated with the deployment and use of OPS.

Additional cases of good green practices related to the implementation of SSE OPS are listed in [Table 3](#).

---

<sup>(48)</sup> <https://www.imo.org/en/MediaCentre/PressBriefings/pages/CII-and-EEXI-entry-into-force.aspx>

<sup>(49)</sup> [https://transport.ec.europa.eu/document/download/b706e2f0-b01d-4e4d-86e4-eb67816ef400\\_en?filename=2017-06-differentiated-port-infrastructure-charges-report.pdf](https://transport.ec.europa.eu/document/download/b706e2f0-b01d-4e4d-86e4-eb67816ef400_en?filename=2017-06-differentiated-port-infrastructure-charges-report.pdf)

<sup>(50)</sup> <https://www.offshore-energy.biz/port-of-gavle-tanker-switches-to-shore-power-during-unloading-operation-for-the-first-time/>

<sup>(51)</sup> <https://www.portofgothenburg.com/about/projects-at-the-port/onshore-power-supply-for-tankers/>

**Table 3 – Other green practices related to the implementation of SSE-OPS**

Name of port	Country	Short description	Reference
Port of Leith	Scotland	Port of Leith pioneers shore power for Scottish commercial vessels.	<a href="https://maritime-executive.com/article/port-of-leith-becomes-first-scottish-mainland-port-with-shore-power#:~:text=The%20Port%20of%20Leith%20has,deep%2Dwater%20port%20in%20Scotland.">https://maritime-executive.com/article/port-of-leith-becomes-first-scottish-mainland-port-with-shore-power#:~:text=The%20Port%20of%20Leith%20has,deep%2Dwater%20port%20in%20Scotland.</a>
Port of Genoa	Italy	Port installs multipurpose medium-voltage network to supply power to cruise ships	<a href="https://sustainableworldports.org/project/port-of-geoa-onshore-power-supply-to-vessels/">https://sustainableworldports.org/project/port-of-geoa-onshore-power-supply-to-vessels/</a>
Port of Copenhagen	Denmark	Port of Copenhagen goes green by co-operating with DFDS (Det Forenede Dampskibs-Selskab) Onshore Power Facility	<a href="https://www.espo.be/practices/onshore-power-supply-ops-facility-at-the-dfds-ferr">https://www.espo.be/practices/onshore-power-supply-ops-facility-at-the-dfds-ferr</a>
Port of Gdynia	Poland	Gdynia Port's modern public ferry terminal achieves a major milestone with OPS capability for incoming ferries.	<a href="https://www.espo.be/practices/first-onshore-power-supply-ops-charging-station-in">https://www.espo.be/practices/first-onshore-power-supply-ops-charging-station-in</a>
Port of Marseille	France	Port of Marseille Fos improves sustainability and efficiency by investing €20 million in OPS for maritime passenger transport	<a href="https://www.espo.be/practices/comprehensive-electrification-of-the-port">https://www.espo.be/practices/comprehensive-electrification-of-the-port</a>
Port of Rotterdam	Netherlands	Construction of a new onshore power plant in Vlaardingen	<a href="https://www.offshore-energy.biz/actemium-shore-power-facility-in-vlaardingen-ready-for-use/">https://www.offshore-energy.biz/actemium-shore-power-facility-in-vlaardingen-ready-for-use/</a>

Source: Project consortium elaboration

### Summary and key lessons learned

OPS faced adoption hurdles due to uncertainties about ship usage in ports. The 2023 AFIR and FuelEU Maritime Regulation now mandate OPS use by 2030, ensuring ports' OPS infrastructure will be utilised, acting on a "back to back" approach. Examples from Kiel, Aarhus and Gävle highlight key strategies: Kiel's flexible systems and variable pricing foster cooperation; Aarhus' fee model incentivises OPS use; and Gävle's safety trials for tankers demonstrate the impact of regional collaboration. In the case of Kiel, provision of OPS at many berths may lead to a flexible berthing slots strategy that will result in easing the peak grid capacity requirements, a common challenge facing many ports. Key lessons include the importance of regulatory support, flexible infrastructure, stakeholder engagement, innovative pricing models, and substantial funding, all of which drive environmental and economic benefits. More specifically:

**Regulatory support:** Regulatory support, such as AFIR and FuelEU Maritime Regulation is crucial in providing a regulatory framework that ensures the utilisation of OPS infrastructure, addressing previous uncertainties.

**Flexibility in infrastructure:** Flexible OPS systems, like those in Kiel, cater to various technical standards and power requirements, ensuring broader applicability and future-proofing investments, as well as the possibility to coordinate berthing patterns to ease peak electricity requirements.

**Innovative pricing models:** Variable energy pricing models, as implemented in Kiel, foster cooperation and transparency with shipping lines, making OPS economically attractive.

**Incentives and disincentives:** Financial incentives and disincentives, such as port of Aarhus' fee model, may effectively assist in strengthening cooperation with shipping companies towards OPS adoption.

**Stakeholder engagement:** Successful OPS implementation requires collaboration with multiple stakeholders, including government bodies, shipping companies, and local industries.

**Safety and technical challenges:** Addressing technical and safety challenges in hazardous environments, as seen in Gävle, requires innovative solutions and regional cooperation.

**Funding and financial support:** Financial support from EU financial instruments (e.g., CEF, AFIF) as well as national or regional financial sources are instrumental for the capital investment needed to develop OPS facilities. While there are several sources of finance, it is clear that public funding will not be able to cover all investment needs. As such it is important that each port seeks the right instrument based on its situation. Certain relevant projects may also be eligible for financing by the European Investment Bank (EIB). Furthermore, in addition to payment for the use of OPS, contribution of the general port fees may cover, at least to a certain extent, the cost of developing and operating OPS systems. Finally, a port could consider outsourcing the provision of OPS to a third party under a concession.

**Environmental and economic benefits:** OPS adoption not only reduces emissions and noise pollution but also supports long-term environmental goals and economic competitiveness of ports.

#### 4.2.2. Port equipment electrification

The widespread adoption of port equipment electrification, whether through the acquisition of new machinery or retrofitting of existing equipment may be attributed to the early implementation of electrification by port cargo handling equipment providers, and the keen interest of terminal operators in integrating this technology into their operations.

The scope of the Equipment Electrification best practices involves replacing mobile (untethered) port equipment with electric (battery) alternatives, and/or retrofitting existing diesel-powered dense container stacking equipment such as Rubber Tyred Gantry (RTG). This practice can be applied within individual port terminals, across a network of terminals managed by a Global Port Operator, or throughout an entire

port, depending on the management typology and structure in place. The initiation of this practice can stem from either a Terminal Operator acting alone, or in partnership with Original Equipment Manufacturer(s) (OEMs), depending on the scale and the individual characteristics of the project.

Stakeholders, directly or indirectly involved, encompass Port Operators, OEMs, other Retrofitting Companies, Port Authorities, Grid Operators, the Energy Providers, and Transport Companies serving the port / terminal, particularly if charging hubs are also provided to external trucks. The elements of the investment consist of acquiring new Battery-Electric (BE) untethered equipment; retrofitting existing equipment (usually high-density stacking equipment); establishing charging hubs; potentially engaging in clean energy production (by the initiator or a partner, depending on the local circumstances); and establishing a maintenance and support base. The challenges include concerns regarding the production cost of electric equipment; total cost of operation; equipment manufacturers' production capacity; lack of standardisation among equipment manufacturers, particularly in relation to battery sizes and charging solutions; potential constraints in accessing sufficient power supply in certain areas; and the requirement for a skilled maintenance workforce. Scalability is promising, particularly for untethered cargo handling equipment, provided that certain applicability challenges are addressed.

Project financing options include using the initiator's own financial resources backed by a substantiated business case; seeking co-sponsorship from a Public Agency, especially for demonstration projects; or securing co-financing from the OEM, either through project partnership or through leasing arrangements. Port equipment electrification is also eligible for support under the Alternative Fuels Infrastructure Facility (AFIF).

Finally, application of the Equipment Electrification best practices can be incentivised through relevant provisions of the Terminal Concessions' arrangements, either during the initial Bidding Process or through the process of the Concession Contract extension. Incorporating this obligation into the Terminal concession may cover the Tender requirements, relevant concession clauses and post-award concession monitoring.

Several cases of electrification of Container Handling Equipment (CHE) are presented in the following sections. These cases provide different perspectives of the port equipment electrification, presenting important information on the scope, the initiating entity for the green practice, the spectrum of the application, the stakeholders involved, the investment elements, financing, and potential concession "green" clauses.

### **Case 8 – APMT and Dubai Ports World (DPW): Initiative to electrify Container Handling Equipment (CHE) <sup>(52),(53)</sup>**

A collaborative effort between two Global Terminal Operators (GTOs), *APMT and DPW*, is the basis of a strategic initiative aimed at electrifying port operations within a 2-to-8-year timeline, supported by industry partners including Eurogate, Port of Kalundborg, and Smart Freight Centre. (*This is linked to Roadmap Step 4: Stakeholder engagement, please see page 111*) Advocating for a transition to

---

<sup>(52)</sup> DP World. (2023). <https://www.dpworld.com/insights/whitepapers/reaching-a-tipping-point>

<sup>(53)</sup> Port Technology. (2023). <https://www.porttechnology.org/news/apmt-dp-world-team-up-to-accelerate-decarbonisation-in-port-operations/>

Battery-Electric (BE) container handling equipment (BE-CHE), this initiative identifies a pivotal “tipping point” where the total cost of operation (TCO) for BE-CHE becomes lower than that of diesel-fuelled equipment, and outlines four elements to close the existing gap, namely scale, standardisation and modularisation, reducing charging downtime, and incentives from the public sector and customers.

Furthermore, it emphasises the mobilisation of the entire stakeholder ecosystem, including operators, OEMs, port authorities, policy makers and customers, to collectively address these challenges.

At the operational level, three options of reducing equipment downtime during charging are proposed: (a) through commercially available ultra-fast chargers with an output of 600 kilowatt (kW), positioned in optimal locations; b) via battery swapping stations capable of changing batteries competitively with diesel refuelling; and c) through the deployment of Wireless Power Supply (WPS), potentially eliminating downtime by utilising asset idle time for equipment battery recharging. Although still in initial stages of implementation, WPS demonstrates promise and can be tailored for use with Tractor-Trailers (TT) through suitable operational protocols within an equipment pool assignment system. *(This is linked to Roadmap Step 6 – Strategic solutions action plan, please see page 115).*

A noteworthy aspect of this initiative is its integrative nature, building upon previous individual efforts of the two GTOs to electrify specific equipment in selected Terminals. For instance, DP World Antwerp, in collaboration with the Port Authority of Antwerp, and in accordance with the port’s green objectives and concession agreement, has been systematically replacing its straddle carrier (SC) fleet with hybrid (electric powered) equipment since 2018, with electricity demand met entirely by locally produced green energy sources (i.e. wind turbines biogas plant, and locally purchased green power - upstream energy supply chaining effect). *(This is linked to Roadmap Step 4 – Stakeholder engagement, please see page 111).*

Similarly, DP World Rotterdam World Gateway (RWG) is in the process of electrifying most of its untethered cargo handling equipment, with an average implementation timeframe ranging from 2 to 5 years and an investment cost between EUR 20 million and EUR 50 million. The Return on Investment (ROI) period is approximately 10 years. Despite challenges encountered in scaling up the practice across the entire terminal facility, such as limitations to automated mobile equipment running on predefined tracks, DP World indicates that the practice can be easily transferred to other terminals of the group or to other ports, including the possibility of applying retrofit packages available in the market.

The environmental impacts addressed by this practice include air emissions, particulate matter, sulphur dioxide, nitrogen oxides, and greenhouse gases. DP World evaluates the effectiveness and impact of this green practice as high. *(This is linked to Roadmap Step 10 – Performance assessment and reporting, please page 125).* The scalability of the practice is noted for both smaller and larger ports, with key factors for transferability being the electrification potential of all Rubber-Tired Gantry terminals, along with the supply of green electricity to ensure a green practice “chaining effect.” Moreover, recently, DP World launched Britain’s first all-electric terminal tractor which is now in service at London Gateway port.

APMT has initiated a pilot project for the electrification of Container Terminal Equipment in the Port of Barcelona (APMT Barcelona), co-funded by the Spanish

Government and realised in partnership with suppliers. Funding became available through a Programme for Efficient and Sustainable Mobility, developed as part of the Spanish Government's Recovery, Transformation, and Resilience Plan, funded by the European Union NextGenerationEU. The project consists of the purchase of five zero-emission electric straddle carriers; four charging stations; associated civil and electrical works; an IT network; and the development of processes to apply the technology necessary for equipment operations and recharging. (*This is linked to Roadmap Steps 4 and 7 – Stakeholder engagement, and Implementation plan rollout, please see pages 111 and 118*).

The project aims to assess the technical and economic feasibility of deploying all electric CHE, improve operational procedures, and examine scalability to other terminals handling cargo with similar systems and technology. The electricity supplied to the terminal for the pilot electric equipment deployment is exclusively from renewable sources.

Key challenges identified by APMT include the production of reasonably priced heavy-duty equipment (i.e., reach stackers, terminal tractors, empty container handling equipment and straddle carriers) and the need for further R&D, highlighting the importance of collaboration with OEMs. In support of pilot projects with electric handling equipment, APM Terminals has recently signed agreements with two OEMs (Konecranes and SANY) for long-term collaboration on further developing this port equipment.

### **Case 9 – Port of Valencia: Equipment retrofit partnership<sup>(54),(55)</sup>**

In Spain, MSC Terminal VLC (MSCTV) has partnered with KONECRANES to undertake a significant initiative aimed at enhancing the sustainability, safety, and efficiency of port operations. This initiative builds on the successful implementation of the country's first busbar retrofit of RTG cranes at the *Port of Valencia*. MSCTV has procured new, fully busbar-ready, Konecranes RTGs and converted its existing RTGs to fully electric operation through a busbar retrofit.

This effort underscores MSCTV's commitment to reducing environmental impact by adopting clean equipment, which improves operational efficiency, productivity, and reliability, while reducing carbon emissions and noise pollution. (*This is linked to Roadmap Step 2 – Motivation, please see page 107*).

The terminal has also established a service agreement with Konecranes, to facilitate regular maintenance and servicing of all cranes. Dedicated technicians work closely with the terminal's maintenance department, ensuring optimal performance and longevity of the equipment. (*This is linked to Roadmap Step 7 – Implementation plan rollout, please see page 119*).

The project presents a good example of collaboration between a Terminal Operator and an OEM to evaluate a promising retrofitting technology for high density container storage equipment. Furthermore, the project involves the integration of new units of the same technology into the terminal's equipment inventory. (*This is linked to Roadmap Step 4 – Stakeholder engagement, please see page 112*).

---

<sup>(54)</sup> Konecranes. (2019). [https://www.konecranes.com/sites/default/files/2019-07/Konecranes%20Case%20Study%20MSC%20Terminal%20Valencia\\_6418\\_v2.pdf](https://www.konecranes.com/sites/default/files/2019-07/Konecranes%20Case%20Study%20MSC%20Terminal%20Valencia_6418_v2.pdf)

<sup>(55)</sup> <https://container-mag.com/2019/05/15/port-valencia-converts-existing-konecranes-rtgs-fully-electric-operation/>

**Table 4 – Other green practices related to the implementation of terminal equipment electrification**

Name of port	Country	Short description	Reference
Port of Tauranga	New Zealand	The Port of Tauranga in New Zealand has placed an order for the purchase of four new hybrid straddle carriers to assist in the achievement of its carbon neutral targets.	<a href="https://www.portstrategy.com/environment-and-sustainability/tauranga-takes-the-hybrid-approach-to-getting-greener/1484507.article?utm_medium=email&amp;utm_campaign=Weekly%20Greenport%20%20Weekly%20Newsletter&amp;utm_content=Weekly%20Greenport%20%20Weekly%20Newsletter+CID_0bef54b0a13249efdf4b65fc158d1074&amp;utm_source=Email%20marketing%20software&amp;utm_term=Tauranga%20takes%20the%20hybrid%20approach%20to%20getting%20greener">https://www.portstrategy.com/environment-and-sustainability/tauranga-takes-the-hybrid-approach-to-getting-greener/1484507.article?utm_medium=email&amp;utm_campaign=Weekly%20Greenport%20%20Weekly%20Newsletter&amp;utm_content=Weekly%20Greenport%20%20Weekly%20Newsletter+CID_0bef54b0a13249efdf4b65fc158d1074&amp;utm_source=Email%20marketing%20software&amp;utm_term=Tauranga%20takes%20the%20hybrid%20approach%20to%20getting%20greener</a>
Port of Ipswich	UK	Electric-Powered Hydraulic Cranes for the Port of Ipswich	<a href="https://maritimeeducation.com/252-2/">https://maritimeeducation.com/252-2/</a>
Port of Vancouver	Canada	Terminal tractors running on electricity, a crane powered by hydrogen, and the terminal locomotive using 100% renewable diesel are employed.	<a href="https://www.portstrategy.com/greenport/zero-emission-testing/1479157.article?utm_medium=email&amp;utm_campaign=Weekly%20Greenport%20%20Weekly%20Newsletter&amp;utm_content=Weekly%20Greenport%20%20Weekly%20Newsletter+CID_e8b5952973c51f6fd9ffb0ed08ee6834&amp;utm_source=Email%20marketing%20software&amp;utm_term=Zero-emission%20testing">https://www.portstrategy.com/greenport/zero-emission-testing/1479157.article?utm_medium=email&amp;utm_campaign=Weekly%20Greenport%20%20Weekly%20Newsletter&amp;utm_content=Weekly%20Greenport%20%20Weekly%20Newsletter+CID_e8b5952973c51f6fd9ffb0ed08ee6834&amp;utm_source=Email%20marketing%20software&amp;utm_term=Zero-emission%20testing</a>

Source: Project consortium elaboration.

### Summary and key lessons learned

Port equipment electrification, driven by early adoption from equipment providers and interest from terminal operators, involves replacing diesel-powered equipment with electric alternatives and retrofitting existing machinery. This practice can be implemented at individual terminals, across terminal networks, or through entire ports. Good practices, like APMT and DPW’s efforts and the Port of Valencia’s partnership with an equipment manufacturer, demonstrate significant potential for reductions in emissions and improvements in operational efficiency.

Key lessons derived from the analysis of good green practices related to the terminal equipment electrification, can be summarised as follows:

**Collaborative efforts:** Partnerships between terminal operators and OEMs are vital for addressing technical challenges and ensuring equipment performance. Port equipment electrification encompasses a strategic shift towards sustainable port operations, driven by collaborative initiatives and individual endeavours within the industry.

**Investment and financing:** Significant investments are required for electrification, but a mix of public and private financing, including co-sponsorship from public agencies and OEM partnerships, can support these initiatives. The exploitation of co-financing eligibility for port equipment electrification provided by the Alternative Fuels Infrastructure Facility (AFIF) is also noteworthy.

**Standardisation and scalability:** Lack of standardisation among equipment manufacturers, particularly in battery sizes and charging solutions, poses challenges. However, standardisation efforts can enhance scalability and transferability across different terminals and ports. Initiatives led by container terminal operators exemplify the adoption of battery-electric container handling equipment and retrofitting technologies, with a focus on minimising environmental impact and optimising operational efficiency.

**Environmental and operational benefits:** Electrification leads to substantial environmental benefits, including reduced emissions and noise pollution, while also improving operational efficiency and productivity.

**Stakeholder engagement:** Engaging a wide range of stakeholders, including port operators, OEMs, retrofitting companies, port authorities, grid operators, energy providers, and transport companies, is essential for successful implementation.

**Overcoming challenges:** Key challenges include a high production cost of electric equipment, total cost of operation, production capacity, power supply constraints, and the need for a skilled maintenance workforce. Addressing these challenges through stakeholder collaboration and strategic planning is critical.

**Regulatory and incentive frameworks:** Incorporating electrification goals into terminal concession contract clauses and providing incentives for adoption can drive the transition towards greener port operations.

**Technological innovations:** Innovations such as ultra-fast chargers, battery swapping stations, and wireless power supply systems can significantly reduce equipment downtime during charging and enhance operational efficiency.

### 4.2.3. Port Electricity Supply & Charging Hubs

Provision of Charging Hubs for electric vehicles (EVs), including electric trucks visiting the port to deliver or dispatch cargo, as well as for electrified port equipment as presented above, are crucial for the electrification of port activities. It can be provided either by the Port Authority (in case of a landlord port) or by the Port Operator, which may be responsible for implementing an overall equipment electrification plan. A fundamental element of this green best practice is the upstream supply of clean electricity, meaning that it is important to ensure that electricity is produced using renewable sources.

This section examines three major North European landlord ports, i.e. Port of Antwerp-Bruges, Port of Rotterdam and Port of Hamburg, showcasing their initiatives in developing charging infrastructure and facilitating the transition towards sustainable transportation. Developments take place at a Port Authority level for the two first cases, while in the third a fuel supplier provides the facility.

## Case 10 – Port of Antwerp – Bruges: Port Authority charging hub for external electric trucks

The *Port of Antwerp-Bruges* is developing two charging hubs at the Truck Parkings Goordijk and Ketenis (on the right and left bank of the river Scheldt, respectively)<sup>(56)</sup>, free parking facilities for trucks visiting the Antwerp port with a capacity of 210 and 280 slots, respectively. (*This is linked to Roadmap Step 4 – Stakeholder engagement, please see page 112*).

The Antwerp Port hubs, which are planned to be operational during 2024, will initially consist of two plots with a total of 30 charging bays. During the second phase of development, the number of charging bays will be expanded. Each charging hub will reportedly be equipped with 15 high-performance Combined Charging System (CCS) chargers offering up to 400 kW of charging power. It is also reported that the technology provider intends to make the switch to the Megawatt Charging System (MCS) technology as soon as it is ready. (*This is linked to Roadmap Step 6 – Strategic solution action plan, please see page 115*).

According to the Port of Antwerp, the partner is developing its network with a focus on creating green corridors for road transport connecting key logistics hubs, major ports and airports, building a reliable charging network for electric heavy-duty trucks. The collaboration aims at removing one of the major barriers for transport companies working with the port of Antwerp to make the switch to electric trucks.

The Flemish Ministry of Mobility and Public Works (MOW) granted a project subsidy for this project, co-financed through the Connecting Europe Facility (CEF). A licensee will operate the parking facilities<sup>(57)</sup>.

## Case 11 – Port of Rotterdam: Port Authority charging hub for external electric trucks

The *Port of Rotterdam* recently opened the first truck charging hub with several specialist partners. It is reported that up to eight electric trucks can recharge with up to 360 kW charging power at the port<sup>(58)</sup>. A partner specialised in truck parking, handled the installation for the Port of Rotterdam Authority and built the new charging stations at the Bodaanweg truck park in the Waalhaven area. Another five technology providers are responsible for operating specialist partners of Port Authority charging points. (*This is linked to Roadmap Step 7: Implementation plan rollout, please see page 119*).

A Swiss technology company delivered five high-power chargers. Three columns are capable of DC (Direct Current) charging two trucks simultaneously, while two other fast chargers offer one charge point each so that up to eight lorries can charge at the same time. Electric trucks are exempt from parking fees and can use all the truck park facilities. There is 24/7 surveillance of parking and charging bays, and smart scheduling capabilities are provided. Carriers can schedule smart combinations, for instance, by charging their trucks while drivers stay in the truck park for mandatory rest, thus avoiding spending productive time. Anticipating a significant increase in

<sup>(56)</sup> <https://www.porttechnology.org/news/port-of-antwerp-bruges-pioneers-electric-vehicle-charging-hubs/>

<sup>(57)</sup> <https://newsroom.portofantwerpbruges.com/new-truck-parking-in-port-also-impetus-for-green-corridor-antwerp-zeebrugge>

<sup>(58)</sup> <https://www.portofrotterdam.com/en/port-future/energy-transition/making-logistics-chains-more-sustainable/charging-stationfor#:~:text=There%20are%20%20charging%20bays,180%20kW%20charging%20capacity>

electric truck traffic by 2030, the Port Authority is considering expanding charging infrastructure and implementing truck charging service scheduling system to meet growing demand. (*This is linked to Roadmap Step 10: Performance assessment and reporting, please see page 125*).

### Case 12 – Port of Hamburg: Private provider charging hub for external electric trucks

In the *Port of Hamburg*, the initiative for the development of charging hubs has been taken by a fuel supplier<sup>(59)</sup>. The charging hubs, located at Georgswerder Bogen, have a capacity of 360 kW and will enable electric trucks to be charged with 100% renewable energy. Complementing existing depot charging facilities, this initiative kickstarts the development of a nationwide charging network for trucks, endorsed by the Hamburg Port Authority. With plans to set up additional charging stations at central port locations, Hamburg demonstrates a commitment to supporting sustainable heavy-duty traffic and advancing green port initiatives. (*This is linked to Roadmap Steps 7 and 8: Implementation plan rollout; and Alignment and coordination, please see pages 119 and 121*).

Additional good practices related to the implementation of port charging hubs are summarised in Table 5.

**Table 5 – Other green practices related to the implementation of port charging hubs**

Name of port	Country	Short description	Reference
Bremen/Bremerhaven	Germany	Maersk is looking into setting up charging infrastructure with green electricity for its own e-truck fleet	<a href="https://www.porttechnology.org/news/maersk-obtains-e-trucks-for-green-transport-in-germany/">https://www.porttechnology.org/news/maersk-obtains-e-trucks-for-green-transport-in-germany/</a>
Port of Felixstowe	UK	At the Port of Felixstowe, large fleet of electric autonomous commercial vehicles are being developed, as well as battery swapping infrastructure and services to support the fleet's operations.	<a href="https://www.porttechnology.org/news/westwell-hutchison-ports-introduce-over-100-q-trucks-at-the-port-of-felixstowe/">https://www.porttechnology.org/news/westwell-hutchison-ports-introduce-over-100-q-trucks-at-the-port-of-felixstowe/</a>
Port of Seattle and Tacoma	US	Federal grant allocates \$12 million for shared charging stations for drayage trucks between Seattle and Tacoma ports.	<a href="https://www.porttechnology.org/news/nwsa-secures-12-million-for-truck-charging-stations/">https://www.porttechnology.org/news/nwsa-secures-12-million-for-truck-charging-stations/</a>

Source: Project consortium elaboration.

<sup>(59)</sup> <https://www.freightcarbonzero.com/infrastructure/shell-connects-high-performance-charging-stations-for-trucks-at-port-of-hamburg/1018.article>

## Summary and key lessons learned

The electrification of port activities hinges on the development of charging hubs for electric vehicles (EVs), including electric trucks and port equipment. These hubs can be established by Port Authorities or Operators and are crucial for supporting the shift towards sustainable transport. Ensuring the supply of clean, renewable electricity is essential. Notable examples from North European ports include the port of Antwerp-Bruges, port of Rotterdam, and port of Hamburg, each demonstrating initiatives to build charging infrastructure and facilitate green transport.

Key lessons derived from the analysis of good green practices related to the port charging hubs, can be summarised as follows:

**Stakeholder collaboration:** Effective electrification requires collaboration between port authorities, technology providers, fuel suppliers, and government bodies. Initiatives led by ports such as Antwerp-Bruges, Rotterdam, and Hamburg, underscore collaborative efforts between port authorities, government agencies, and industry partners to develop robust charging infrastructure.

**Investment in infrastructure:** Significant investment is needed to develop a dense network of high-power charging hubs capable of supporting heavy-duty EVs. A crucial element of these initiatives relates to using electricity from renewable sources to maximise environmental benefits.

**Strategic location and planning:** Charging hubs should be strategically located to serve key logistics areas and integrate smart scheduling to optimise usage and reduce downtime. Charging hubs for electric vehicles, particularly electric trucks, are integral to promoting the electrification of port activities and fostering sustainable transport solutions.

**Scalability and expansion:** Initial projects should be designed with scalability in mind, allowing for future expansion to meet increasing demand. Anticipating a growing demand for electric truck charging services, ports are poised to expand infrastructure and implement smart scheduling systems to optimise charging efficiency and meet future traffic demands. Provision of charging hubs for both intraport/intraterminal electrified equipment, as well as electric trucks visiting ports is a green practice that can be relatively easily applied to medium size ports, provided that grid capacity issues are addressed.

**Government support and subsidies:** High-performance charging technologies, supported by public co-financing facilities and strategic partnerships, pave the way for the widespread adoption of electric trucks and the creation of green corridors for road transport.

**Performance monitoring:** Ongoing performance assessment and reporting are essential to ensure that the infrastructure meets the growing needs of electric transport and maintains high efficiency.

**Incentivising adoption:** Offering incentives such as fee exemptions and enhanced facilities encourages transport companies to transition to electric vehicles.

#### 4.2.4. Energy Supply and Consumption Management

Energy Supply and Consumption Management green practices in ports encompass a broad spectrum of activities aimed at optimising energy usage, enhancing efficiency, and promoting sustainability. Such practices include intra-terminal energy optimisation and energy recovery from port equipment; management of port supply grid congestion; deployment of smart grids; and holistic collaborative port wide energy conservation partnerships. These initiatives are related to the wider spectrum of port electrification initiatives. Energy Supply and Consumption Management appears to be a very promising area of implementing green practices. In certain cases, these practices are relatively easy to transfer. Three cases of good practice examples are presented next. The first one is the case of a grid congestion management strategy implemented at the port of Rotterdam. Many interviewees highlighted managing grid congestion as an issue that needs to be addressed to facilitate implementation of other green initiatives. The second and third cases are described broadly and not necessarily in detail in the context of any specific port. They refer to energy recovery and energy management systems, which were noted in several articles, reports, and by several interviewees as practices that support or complement other initiatives. As such, it was considered valuable to include descriptions of these, as generic and broadly applicable cases, under Energy Supply and Consumption Management.

##### **Case 13 – Port of Rotterdam: Grid Congestion Management<sup>(60),(61)</sup>**

The need to manage peak electricity demand and coordinate with grid operators was highlighted by various ports interviewed during the course of the study. Many interviewees have stressed issues relating to grid capacity and the need to coordinate peak electricity demand, through employing usage flexibility practices, with grid operators, along with increasing grid capacity where necessary. The *port of Rotterdam* is tackling grid congestion issues caused by increased electricity demand from both intra-terminal operations and broader intra-port activities. This is crucial for implementing green practices.

To address these challenges, the port of Rotterdam has launched a New Energy Taskforce (NET) in partnership with grid operators TenneT and Stedin. The NET aims to resolve grid congestion by expanding grid capacity, improving electricity demand forecasting, and promoting flexible energy consumption. These strategies are crucial as industries shift from conventional fuels to electricity to reduce their environmental impact. (*This is linked to Roadmap Steps 4, 6, and 8: Stakeholder engagement, Strategic solutions action plan, and Alignment and coordination, please see pages 112, 115, and 122*).

With the rise of electrification in industrial processes, green hydrogen production, and electric transport, the port of Rotterdam has seen a significant increase in electricity demand. This is compounded by limited space for new infrastructure, essential for grid expansion. (*This is linked to Roadmap Step 3: Baseline assessment, please see page 109*). To optimise space use and ensure maximum efficiency of new facilities, the port has integrated high-voltage substations and power lines, strategically planned in line with long-term demand and geographical considerations.

---

<sup>(60)</sup> <https://news.europawire.eu/net-initiative-port-of-rotterdam-takes-steps-to-solve-grid-congestion/eu-press-release/2024/01/31/10/54/39/129091/>

<sup>(61)</sup> <https://www.heavyliftnews.com/new-energy-taskforce-set-up-to-tackle-grid-congestion-in-the-port-of-rotterdam/>

*(This is linked to Roadmap Step 7: Implementation plan rollout, please see page 119).* This proactive approach allows the port to meet current needs while preparing for future growth.

The project is part of a larger programme established in late 2023 to address grid congestion in the port and neighbouring regions. The Taskforce partners want to assist electricity consuming companies to avoid grid congestion limitations<sup>(62)</sup> and the Taskforce aims at establishing and facilitating measures for flexible power usage and encouraging flexibility in power offtake through separate flex tenders. It supports companies in developing solutions to enhance flexibility in power use, thereby contributing to efficient grid management.

The grid operators TenneT and Stedin have announced that there will continue to be shortages on the electricity grid in future and there is already a waiting list for new connections in Europoort, Botlek and Pernis, while there is still capacity for new connections on the Maasvlakte and in the Waal-Eemhaven. In addition to increasing demand, due to more intense electricity use, the fluctuating supply of electricity due to the increase in wind and solar energy contribution affects the grid capacity<sup>(63)</sup>.

Within its scope, NET has promoted the development of energy hubs at the cluster level. These hubs enable multiple companies to coordinate energy generation, storage, conversion, and consumption, leading to a more integrated and efficient energy management approach. Companies can share resources and infrastructure, reducing costs and increasing efficiency, overcoming the challenges of operating independently. *(This is linked to Roadmap Step 8: Alignment and coordination, please see page 122).*

Part of a larger programme initiated in late 2023 to address grid congestion in the port and surrounding regions, the Taskforce links to the broader strategic planning and implementation efforts necessary for sustainable port operations.

Grid congestion in wider port areas is an issue stemming from industrial activities within ports or adjacent to ports, as well as from increase of use of electricity by port entities, including OPS and electrification of equipment.

The Task Force is planned to act as a kind of “one stop shop” in coordinating electricity demand and grid congestion issues. Grid operators will launch separate flex tenders and the Taskforce plans to support companies in developing broader solutions that can contribute to flexibility in power use with the aim of encouraging more flexible power offtake<sup>(64)</sup>. According to the same source, a team with expert knowledge of the energy sector and congestion problems, including experts from PoR, Stedin and TenneT was formed for the Taskforce and the plan is to approach companies in the port area to identify bottlenecks and opportunities for tackling grid congestion and work on possible solutions for each bottleneck.

Though coordination with electricity consumers to avoid magnification of peak demand and, therefore, grid congestion is a rather “soft” action, it is considered to

---

<sup>(62)</sup> <https://www.industryandenergy.eu/energy/port-of-rotterdam-tennet-and-stedin-explore-solutions-to-electricity-grid-crunch/>

<sup>(63)</sup> <https://www.industryandenergy.eu/energy/port-of-rotterdam-tennet-and-stedin-explore-solutions-to-electricity-grid-crunch/>

<sup>(64)</sup> <https://www.portofrotterdam.com/en/news-and-press-releases/new-energy-taskforce-to-support-with-tackling-grid-congestion-in-the-port>

be instrumental in avoiding grid congestion and easing the peak demand issues. This grid flexibility and electricity coordination approach may be also instrumental in avoiding peak electricity demand associated with peak OPS operation. Berth planning slot arrangements may be used to avoid design peak demand to operate OPS in all berths where shore side electricity is provided. Though this approach is highly case dependent, it can lead to easing the peak capacity demand for shore side electricity and, therefore, reduce congestion on the electricity grid supplying the port area, while reducing the need for investments to upgrade the grid. Additionally, port bound microgrids that use renewable energy to generate electricity can assist in meeting the power demand of critical loads in emergency situations and can be used along the grid flexibility approach presented above<sup>(65)</sup>.

This coordination practice can be easily adopted in ports of different sizes to include port authorities, port operators, other port related electricity consumers and grid operators. Grid flexibility, in general, is considered to be a crucial element of electricity supply and demand coordination in future.

### Case 14 – Energy Recovery

Energy recovery systems, particularly those capturing energy generated during container hoisting operations, present promising methods for reducing fuel consumption and emissions in ports. This sustainable practice has been tested in several terminals, where energy generated is recovered and stored using various Energy Savings Systems (ESS). ESS systems have been used in the past for diesel fuelled equipment (e.g., RTGs), but currently energy savings using these systems are considered also for electricity powered equipment (Ship to Shore Gantry Cranes and Stacking Cranes). These ESS can be distinguished in four categories, i.e. supercapacitors<sup>(66),(67)</sup>, flywheels<sup>(68)</sup>, batteries and hybrid systems.

Although many of these efforts are still at a pilot stage and initiated mainly by Port Operators in collaboration with OEMs, early results have shown promising outcomes.

As environmental standards become more restrictive and fuel costs rise, operators of Rubber Tyred Gantry (RTG) cranes are switching from diesel to electric power systems. However, challenges such as wasted regenerative power, harmonic pollution and low power efficiency are often encountered with these systems. (*This is linked to Roadmap Step 3: Baseline assessment, please see page 109*). To address these challenges, an innovative solution involves the integration of an active front-end system. This technology significantly improves energy efficiency, captures and reuses regenerated power, and stabilises the power supply against grid fluctuations. This solution is ideal for RTG crane systems seeking greater sustainability and operational efficiency as it achieves up to 95% power regeneration efficiency, reduces total harmonic distortion to less than 5% and improves power factor to 0.99. This not only promotes energy efficiency, but also reduces environmental impact by minimising the need for traditional braking systems<sup>(69)</sup>. (*This is linked to Roadmap Steps 10 and 11: Performance assessment and reporting; and Monitoring plan, please see pages 125 and 127*).

---

<sup>(65)</sup> <https://www.oaepublish.com/articles/ces.2022.46>

<sup>(66)</sup> [https://www.pema.org/wp-content/uploads/2023/01/PEMA\\_Ultracapacitors\\_Digital\\_AW.pdf](https://www.pema.org/wp-content/uploads/2023/01/PEMA_Ultracapacitors_Digital_AW.pdf)

<sup>(67)</sup> <https://www.skeletontech.com/skeleton-blog/ultracapacitors-cut-energy-consumption-of-port-cranes-by-30>

<sup>(68)</sup> <https://www.s4-energy.com/projects/rotterdam-flywheel>

<sup>(69)</sup> <https://www.deltaww.com/en-US/solutions/Heavy-Industry/205>

Another effective example of energy recovery in ports is the use of hybrid electric Ship-to-Shore (STS) cranes equipped with energy storage systems such as batteries or supercapacitors. These systems capture the kinetic energy generated as containers are lowered, store this energy and reuse it to power crane operations such as lifting. Typically, a hybrid system that captures kinetic energy during operations, such as lowering loads, combines efficient diesel generators with robust lithium-ion batteries. This energy is then stored and reused, significantly reducing the crane's overall energy requirements and dependence on diesel fuel. In addition to reducing fuel consumption by up to 60%, this method also reduces emissions, paving the way for fully electric or zero-emission crane operations. Such systems are essential for ports seeking to increase operational efficiency while reducing environmental impact, in line with global sustainability goals<sup>(70)</sup>. *(This is linked to Roadmap Steps 7 and 8: Implementation plan rollout; and Alignment and coordination, please see pages 119 and 122)*

### Case 15 – Energy Management

Many ports across the EU, regardless of their management structure, whether landlord or comprehensive, have implemented energy management programmes. These initiatives aim to optimise energy consumption and shift towards clean energy sources, both at the port authority and port operator levels. Strategies vary in scale and approach, often combining energy optimisation with the adoption of clean electricity and fuels for port equipment. Additionally, many port authorities and port operators seek “chaining strategies” in upstream energy sourcing or downstream green practices.

These good practices include simple lighting energy savings, energy savings through intra-terminal equipment operations optimisation, avoiding and eliminating unproductive movements, intelligent reefer energy management and asset use optimisation. Operational improvements alone can lead to an average energy consumption reduction of 10 to 15 percent.

An indicative example of energy savings utilising an intelligent lighting system has been implemented at the port of Emden<sup>(71)</sup>. Niedersachsen Ports, the operator of the port of Emden, has implemented an advanced lighting system at a railway reloading point. The system spans a 900-meter railway site with six tracks. It covers approximately 10 hectares and utilises the latest LED technology for innovative and sustainable lighting solutions, such as targeted illumination. Customisable scenarios ensure precise lighting for various activities, compliant with European safety standards. Each lamp is individually controllable and programmable, with automated activation through sensors. This technology may achieve benefits of reduced costs, reduced CO2 emissions by 80%, increased on-site safety and decreased light pollution. The project received co-funding in the framework of an EU funded project.

Most of these Energy Management practices are generally scalable. While they follow similar approaches, they are specific in terms of scale and application pathway. Several additional good practices related to energy supply and consumption management are summarised in [Table 6](#).

---

<sup>(70)</sup> <https://www.kuenz.com/energy-storage-systems-on-cranes-enable-sustainable-solutions-for-intermodal-terminals/>

<sup>(71)</sup> <https://sustainableworldports.org/project/niedersachsen-ports-innovative-intelligent-lighting-system/>

**Table 6 – Other green practices related to the energy supply and consumption management**

Name of port	Country	Short description	Reference
Port of Valencia	Spain	A project that pioneers a smart energy grid system that integrates energy supplied by the Spanish network technologies to boost energy efficiency	<a href="https://www.espo.be/practices/h2ports">https://www.espo.be/practices/h2ports</a>
Port of Portsmouth	UK	The Port Energy Systems Optimisation (PESO) project at Portsmouth International Port showcases the application of smart grid technology in port decarbonisation.	<a href="https://www.portstrategy.com/environment-and-sustainability/using-smart-grid-technology-to-decarbonise/1481586.article">https://www.portstrategy.com/environment-and-sustainability/using-smart-grid-technology-to-decarbonise/1481586.article</a>
Port of Vigo	Spain	An electrical efficiency management smart grid system has been deployed, along with the installation of a photovoltaic renewable energy system for clean energy provision. The building's new design incorporates an energy storage system for nighttime consumption and integrates marine geothermal energy for diversified clean energy supply	<a href="https://www.espo.be/practices/fish-market-40">https://www.espo.be/practices/fish-market-40</a>

Source: Project consortium elaboration.

### Summary and key lessons learned

Energy supply and consumption management in ports encompasses diverse strategies aimed at optimising energy usage, enhancing efficiency, and promoting sustainability. These include managing grid congestion, energy recovery systems and comprehensive energy management programmes.

Key lessons derived from the analysis of good green practices related to energy supply and consumption management, can be summarised as follows:

**Collaborative partnerships:** The collaboration between ports and grid operators, as seen in the port of Rotterdam’s New Energy Taskforce, illustrates the importance of working together to address complex challenges like grid congestion due to increased electricity demand.

**Innovative technologies:** The case studies underscore the critical role of innovative technologies, such as active front-end systems for energy consumption management, energy recovery and hybrid energy storage systems for cranes, in achieving energy efficiency and sustainability targets. Energy recovery systems hold promise in reducing fuel consumption and emissions during port operations, although further research and development is needed to assess their scalability and effectiveness.

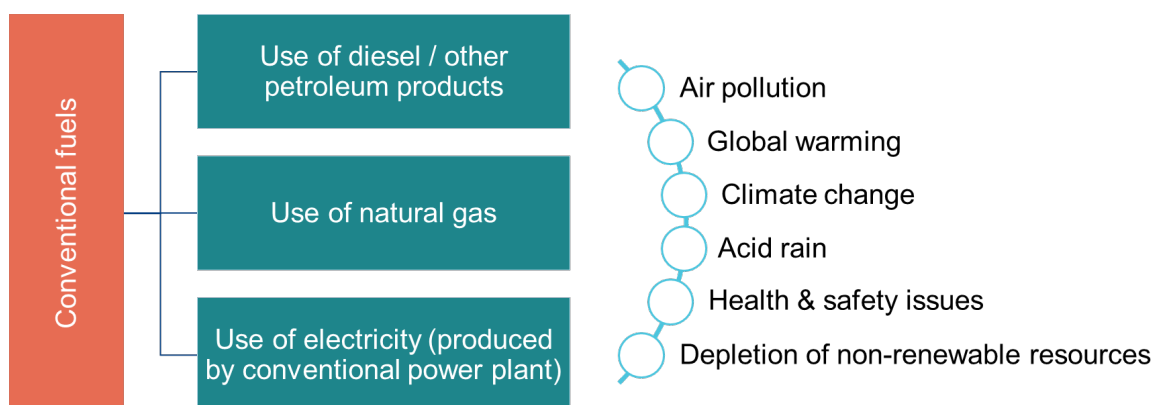
**Energy management:** Energy management programmes across EU ports aim to optimise energy consumption and transition to clean energy sources, with operational measures offering significant potential for energy savings. Strategies range from simple lighting upgrades to operational improvements and clean energy adoption on diverse scale settings.

**Scalability and adaptability:** Ports vary in size, infrastructure, and operational requirements, necessitating scalable and adaptable approaches to energy management. Scalability and adaptability of energy management systems provide ample opportunities for application in medium and small size ports, owing to the port specific circumstances.

### 4.3. Alternative fuels

The use of conventional fuels in port operations has significant environmental impacts and implications, mainly due to the combustion of fossil fuels and the release of air pollutants. Ports traditionally rely on heavy-duty fuel consuming crafts and machinery, such as tugboats and port equipment, the majority of which are powered by fossil fuels. The combustion of these fuels emits air pollutants, and these emissions contribute to air pollution, posing several risks for human health, local biodiversity and surrounding areas, further contributing to global warming and climate change as shown in Figure 12.

**Figure 12 – Environmental aspects (left side) and impacts (right side) of using conventional fuels in port operations**



© European Commission, 2024.

Source: Project consortium elaboration.

Environmental aspects (left side) and impacts (right side) of using conventional fuels in port operations

Green practices relating to alternative fuels considered for the purpose of this section are those of production, transport, storage and use of renewable hydrogen<sup>(72)</sup>, the product of water electrolysis with electricity produced through Alternative Energy Sources (AES) and bio methanol, while reference to green methanol and ammonia prospects are present.

Port Authorities in these cases can act either as landlord, or as partnership builders and enablers or as producers/investors or, finally, as end users. They can also act combining some of these roles. As landlords they can provide space to third parties

<sup>(72)</sup> [Renewable hydrogen production: new rules formally adopted \(europa.eu\)](https://european-council.europa.eu/media/en/press-summaries/doc/default-source/press-summaries/2022/22-11-10-renewable-hydrogen-production-new-rules-formally-adopted-europa.eu.pdf)

to develop production and storage of renewable hydrogen or other alternative fuels. As partnership builders and enablers, they can actively participate in building and enabling partnerships and facilitating activities relating to production, storage, transport (including loading and unloading) and use (including fuelling infrastructure). As producers and investors, they can bear fully or partially the cost of investment and they can partner with specialised companies to undertake alternative fuels production activities. As end users, they can use alternative fuels for either landside port equipment or marine services crafts (e.g., fuelling of tugboats).

### Legal Framework

The Alternative Fuels Infrastructure Directive (AFID) of 2014 has been replaced by the Alternative Fuels Infrastructure Regulation (AFIR)<sup>(73)</sup>, which requires TEN-T maritime ports to provide shore-side electricity for 90% of container and passenger ship calls by 31 December 2029 and sets requirements for liquefied methane refuelling points by 31 December 2024. The National Policy Frameworks that the Member States need to submit to the Commission by the end of 2024 should also include measures to prepare for the deployment of alternative fuels not (yet) mandated under AFIR, such as hydrogen, ammonia or methanol. In addition, EU legislation promotes renewable energy in transport<sup>(74)</sup> and restricts state aid for fossil fuel refuelling infrastructure.

Efforts related to alternative fuels in ports have been selected through interviews and desk research and analysed based on the potential roles of Port Authorities and Port Operators. Three specific cases are highlighted: the port of Klaipėda, which is establishing Lithuania's first hydrogen production facility for bunkering ships and the port authority's marine services fleet; the port of Antwerp, which uses hydrogen as fuel for service vessels; and the port of Rotterdam, which has initiated bunkering operations with green methanol for container vessels. Although these cases are in the planning phase or early stages of development and implementation, and thus do not yet offer concrete lessons learned from outcomes, they are significant due to their focus on sustainable alternative fuels in shipping. These cases provide valuable experiences and initial lessons from early adopters.

### Case 16 – Port of Klaipėda: Hydrogen production and Fuel Use

By 2026, the *Port of Klaipėda* will establish Lithuania's first hydrogen production facility with public hydrogen fuelling station, as part of the Economy Recovery and Resilience Plan "Next Generation Lithuania," co-funded by the European Union's NextGenerationEU. The Klaipėda State Seaport Authority has received about EUR 5 million in funding to develop this renewable hydrogen production project, with a total project cost of about EUR 7 million, which will be used to install a 2.0 MW Proton Exchange Membrane (PEM) Electrolyser with the necessary ancillary equipment for hydrogen production<sup>(75)</sup>. (*This is linked to Roadmap Steps 7 and 9: Implementation plan rollout; and Resources and budget, please see pages 119 and 123*).

<sup>(73)</sup> Regulation (EU) 2023/1804 of the European Parliament and of the Council of 13 September 2023 on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU.

<sup>(74)</sup> Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources.

<sup>(75)</sup> <https://portofklaipeda.lt/en/port-authority/projects/green-port-hydrogen-production-and-refuelling-stations/>

It is envisaged that part of the renewable hydrogen produced at Klaipėda port will be used for public transport by “Klaipėdos autobusų parkas – UAB.” The hydrogen produced will also be used for bunkering ships calling at the port and port authority’s marine services fleet. A waste collection craft running on hydrogen is already being designed and built and it is estimated to consume approximately 44 tonnes of hydrogen per year. (*This is linked to Roadmap Step 6: Strategic solutions action plan, please see page 116*).

The pilot production unit, anticipated to be operational by 2026, is expected to produce 300 tonnes of renewable hydrogen annually. (*This is linked to Roadmap Step 10: Performance assessment and reporting, please see page 125*).

A standard 40 ft marine container will house the hydrogen production unit, and the Klaipėda Port Hydrogen Plant is designed to consume 3 MW of electricity. The precise location of the installation will be selected between the former Klaipėda Port Vessel Traffic Service site (Nemuno g. 8A, Klaipėda) and the fleet base of the Port Authority (Nemuno g. 40, Klaipėda). As the number of ships using hydrogen as fuel is expected to increase steadily, hydrogen is anticipated to be used for refuelling ships arriving at the port. Although challenges exist, such as ensuring sufficient renewable hydrogen for all vessels exist, the motivation for introducing renewable hydrogen in the port of Klaipėda is driven by a combination of regulatory, competitiveness and environmental factors. This initiative is influenced by emerging regulations like the Alternative Fuels Infrastructure Regulation (AFIR) and the port’s commitment to environmental protection, initiated with the Green Port Concept in 2019. Providing sufficient renewable hydrogen for all vessels in need of alternative fuels will be a challenge for ports, both small and big ones. (*This is linked to Roadmap Step 2: Motivation, please see page 107*).

This concept is not a stand-alone initiative, but part of a comprehensive environmental strategy that aims to achieve ambitious sustainability goals, including significant reductions in greenhouse gas emissions, improvements in water quality and the introduction of hydrogen as a clean alternative fuel. (*This is linked to Roadmap Steps 8 and 2: Alignment and coordination, and Motivation, please see page 107 and 122*). However, issues concerning long-term financial feasibility, safety near residential areas, equipment compatibility, and commercial risks for hydrogen-fuelled buses remain pertinent. To address these issues, the port of Klaipėda can take several steps, including the following.

To address the long-term financial feasibility issue the port may secure appropriate Power Purchase Agreement (PPA) with renewable energy providers, such as offshore wind or solar farms, to ensure a steady and cost-effective energy supply of electricity for hydrogen production. Concerns regarding safety near residential areas will be addressed by implementing stringent safety protocols and adhere to safety standards for hydrogen production, storage and distribution. Furthermore, community engagement is expected to increase awareness about safety measures to build trust and address concerns, increasing acceptance of hydrogen technology. Equipment compatibility with the hydrogen fuel requires working closely with equipment manufacturers and terminal operators, and adopting industry standards and specifications. Commercial risks for hydrogen-fuelled buses may be addressed by providing financial incentives to public transport operators, demonstrating the long-term economic benefits, and ensuring the development of adequate refuelling infrastructure to support the operation of hydrogen buses.

## Case 17 – Port of Antwerp – Bruges: Use of hydrogen as service vessel fuel

The *Port of Antwerp – Bruges* has announced<sup>(76)</sup> that a hydrogen fuelled tugboat has been developed in partnership with Compagnie Maritime Belge (CMB), a leading innovator in hydrogen propulsion for maritime applications. Termed the “Hydrotug,” this tugboat prototype is propelled by combustion engines that burn a blend of hydrogen and diesel fuel. These engines adhere to the strict EU Stage V emissions standard, positioning them among the most environmentally friendly options available. The Port of Antwerp-Bruges acting as a significant testbed for this technology on a large scale, will undergo extensive trials of the Hydrotug. Currently undergoing final testing procedures, followed by certification by Lloyd’s Register, the Hydrotug is anticipated to commence full-scale operations at the port during the course of 2024. (*This is linked to Roadmap Steps 6 and 7: Strategic solutions action plan; and Implementation plan rollout, please see pages 116 and 119*). As such, no concrete outcomes are derived.

This project, however, will showcase the potential of hydrogen as a viable marine fuel. The Hydrotug employs combustion engines instead of hydrogen fuel cells, thereby pioneering the utilisation of BeHydro V12 dual-fuel medium speed engines. Measuring 30 meters in length, this tug is equipped with two MW V12 engines and boasts a bollard pull capacity of 65 tons. A defining feature of the Hydrotug is its storage capacity of 415 kg of compressed hydrogen in six stillages installed on deck. This storage capacity enables the vessel to operate continuously for up to 24 hours of operation. Also, this configuration represents a significant advance in environmentally friendly marine technology, with an overall 65% reduction in fuel consumption and associated emissions<sup>(77)</sup>. (*This is linked to Roadmap Step 10: Performance assessment and reporting, please see page 126*).

Although the project is still at the testing phase, it offers some insights into the development, implementation and operationalisation of hydrogen-powered marine technologies and the importance of their integration into long-term sustainability plans.

## Case 18 – Port of Rotterdam: Green Methanol Bunkering

On the front of using methanol as alternative fuel the *Port of Rotterdam* has initiated bunkering operations with the first green methanol-powered container vessel<sup>(78),(79)</sup> owned by Maersk, with OCI HyFuels green methanol for the final leg of its maiden voyage. The producer is reported to be pioneering the production of green methanol, including the production of biomethanol and bio-MTBE (Methyl tert-butyl ether).

The mother company of the green methanol producer (OCI Global) operates the Port of Rotterdam’s only ammonia import terminal, which announced to triple its capacity, in anticipation of growing demand for ammonia as cleaner fuel. OCI Global also announced<sup>(80)</sup> a partnership with Unibarge to develop the world’s first dual-fuelled bunker barge powered by green methanol, which will be deployed at the Port of

---

<sup>(76)</sup> <https://newsroom.portofantwerpbruges.com/hydrogen-powered-tug-is-world-first-for-port-of-antwerp>

<sup>(77)</sup> <https://gcaptain.com/worlds-first-hydrogen-powered-tug-launched-in-antwerp/>

<sup>(78)</sup> <https://oci-global.com/news-stories/stories/oci-global-completes-first-european-green-methanol-bunkering-in-port-of-rotterdam-the-netherlands/>

<sup>(79)</sup> <https://www.portofrotterdam.com/en/news-and-press-releases/x-press-feeders-will-start-bunkering-green-methanol-at-oci-global-in>

<sup>(80)</sup> <https://oci-global.com/news-stories/stories/oci-global-completes-first-european-green-methanol-bunkering-in-port-of-rotterdam-the-netherlands/>

Rotterdam next year in the context of the partnership developed by the Port of Rotterdam with OGI Global. *(This is linked to Roadmap Step 8: Alignment and coordination, please see page 122).*

Biomethanol is produced by using biomethane instead of natural gas or from biogenic fraction of gasification of municipal solid and biomass waste, e.g. feedstock. The gasification of biomass is potentially boosted by additional hydrogen. Electro (E) - Green methanol is produced by combining renewable hydrogen from electrolysis using renewable electricity and biogenic or recycled carbon dioxide. The quantity of substrate (biomass waste) to produce biomethanol is a limiting factor for mass production, while the production of green methanol has as intermediate product the production of renewable hydrogen, referring to the points mentioned above about the renewable hydrogen. In any case, the limiting factors for producing green methanol or biomethanol and for scalability are the following: high price of the produced alternative fuel; currently, low level of commercial maturity; need for ample renewable electricity; cost of carbon dioxide for E-Methanol (direct air capture); difficulties in feedstock sourcing (Biomethanol), along with the limitations described earlier for production and use as fuel of renewable (green) hydrogen. Such challenges may be addressed by scaling up production to benefit from economies of scale; investing in research and development, running pilot projects and forming strategic partnerships with industry leaders to accelerate innovation and market readiness; invest in or partner with renewable energy projects to secure long-term availability of renewable energy; diversify feedstock sources and partner with local agricultural and waste management entities to ensure sustainable feedstock supply. Such solutions, however, will need to be reviewed individually, in the context of each port. *(This is linked to Roadmap Step 3: Baseline assessment, please see page 109).*

This case highlights the port of Rotterdam’s leadership in adopting and promoting alternative, environmentally friendly fuels. The port achieves this by forging strategic partnerships with industry leaders and collaborating with companies at the forefront of green fuel production, to leverage expertise and enhance its own capabilities and infrastructure. Smaller ports may adopt similar practices, even if they do not engage in cutting-edge, large-scale projects, to improve their operations and sustainability efforts, by positioning themselves as forward-thinking and environmentally responsible entities.

**Table 7 – Indicative list of other green practices related to alternative fuels in ports**

Name of port	Country	Short description	Reference
Port of Shoreham	UK	Shoreham Port Green Energy Hub produces green hydrogen	<a href="https://www.portstrategy.com/greenport/financing-green-growth/1479438.article">https://www.portstrategy.com/greenport/financing-green-growth/1479438.article</a>
Port of Gothenburg	Sweeden	bunkering hub for renewable methanol in Northern Europe	<a href="https://www.portstrategy.com/greenport/methanol-bunkering-hub-plan/1470736.article">https://www.portstrategy.com/greenport/methanol-bunkering-hub-plan/1470736.article</a>

Name of port	Country	Short description	Reference
HAROPA Port	France	HAROPA Port partnership with VERSO ENERGY (a company specialized in renewable energy) to establish an industrial unit to produce low-carbon hydrogen and synthetic fuels in the HAROPA Port area in Grand-Quevilly to be commissioned in 2029.	<a href="https://www.haropaport.com/en/news/low-carbon-hydrogen-new-production-unit-seine-axis">https://www.haropaport.com/en/news/low-carbon-hydrogen-new-production-unit-seine-axis</a>
Port Wallhamn	Sweeden	Recycling waste which is then used to produce electricity and green methanol	<a href="https://www.portstrategy.com/environment-and-sustainability/recycling-waste-into-green-methanol-for-port-use/1485374.article">https://www.portstrategy.com/environment-and-sustainability/recycling-waste-into-green-methanol-for-port-use/1485374.article</a>
Port of Yokohama	Japan	Hydrogen supply chain planning	<a href="https://sustainableworldports.org/project/port-of-yokohama-hydrogen-supply-chain-joint-study/">https://sustainableworldports.org/project/port-of-yokohama-hydrogen-supply-chain-joint-study/</a>
Port of Wilhelmshaven	Germany	Hydrogen production	<a href="https://www.espo.be/practices/hydrogen-production-at-wilhelmshaven">https://www.espo.be/practices/hydrogen-production-at-wilhelmshaven</a>
Port of Valencia, Port of Hamburg	Europe	Cooperation agreement on hydrogen projects	<a href="https://www.espo.be/practices/new-agreement-around-hydrogen-between-the-port-of-">https://www.espo.be/practices/new-agreement-around-hydrogen-between-the-port-of-</a>

Source: Project consortium elaboration.

## Summary and key lessons learned

The transition to alternative fuels in port operations addresses the significant environmental impacts of conventional fossil fuels, which are typically used in vessels and port equipment. Ports are exploring renewable hydrogen and biomethanol, as well as ammonia. Ports can act as landlords, partnership builders, producers/investors, or end-users to support the adoption of these alternative fuels. Efforts at the ports of Klaipėda, Antwerp and Rotterdam illustrate various approaches, span of activities, and challenges in implementing these green practices. Several lessons can be drawn:

**Strategic partnerships:** Forming strategic partnerships with industry leaders is crucial for the successful adoption and implementation of alternative fuels. The collaboration can enhance expertise, infrastructure development and financial resources.

**Role diversification:** Port authorities can play multiple roles, such as landlords providing space, enablers building partnerships, investors funding projects, and end-users adopting new technologies. Combining these roles, under given circumstances, can maximise the impact of green initiatives.

**Early adoption challenges:** The initial phases of adopting alternative fuels face challenges such as high costs, low commercial maturity, and the need for substantial renewable energy. Addressing these requires a mix of scaling production, investing in research and development, securing renewable energy sources and diversifying feedstock supplies. Ensuring that the high quantity of renewable energy required in steady supply is available, is an issue to be addressed in every case when addressing the feasibility of a project and the relevant business case.

**Financial and safety considerations:** Ensuring long-term financial feasibility through power purchase agreements and community engagement to address safety concerns seems essential. Financial incentives for infrastructure support can mitigate commercial risks associated with new technologies.

**Regulatory and environmental drivers:** Regulatory frameworks like the Alternative Fuel Infrastructure Regulation, though the alternative fuels considered in this study are not covered by this Regulation, and commitments to environmental protection are key motivations for ports to transition to sustainable practices. Aligning with these regulations can drive the adoption of green fuels.

**Performance and market assessment:** Continuous performance assessment and reporting are necessary to evaluate the success and scalability of green fuel projects. Pilot projects and trials provide valuable data and insights for further development. Furthermore, the economic feasibility of such projects and the dynamics of demand for alternative fuels refuelling services remain uncertain, highlighting the importance of conducting thorough market assessments and stakeholder consultations to inform decision-making.

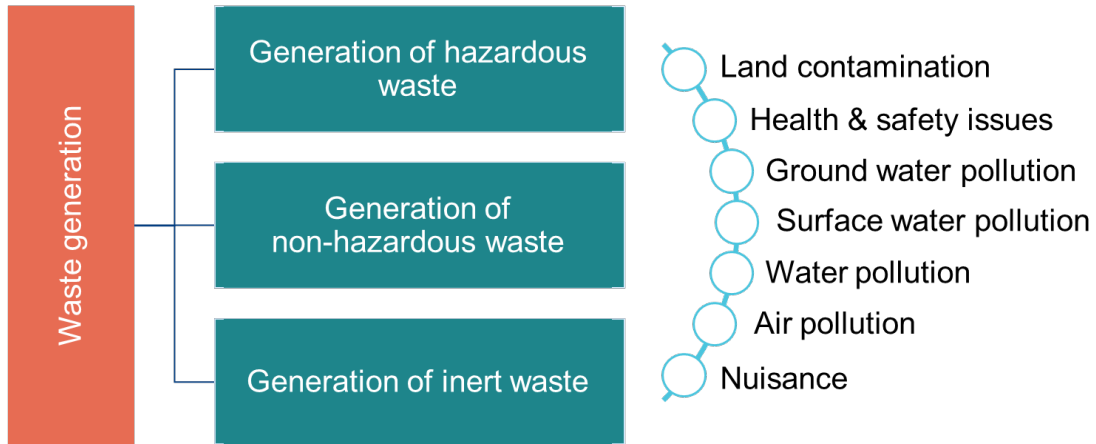
**Transferability and scalability:** The issue of providing ample space for a production site and storage is an issue, particularly relating to safety aspects. This raises questions as to whether the concept, based on the current status of technology, can be applied to small ports, particularly if these ports are adjacent to residential areas. It should be noted for example, which based on the Seveso Directive (Seveso III Guidelines), a hydrogen storage exceeding 5 000 kg of hydrogen falls within the provisions of the Directive, an element that needs to be reconsidered in terms of legal provision and actual risk evaluation. It is reported that this element poses severe constraints in deploying hydrogen fuelled port equipment, due to the space constraints in locating refuelling stations and hydrogen storage.

#### 4.4. Waste management

Waste generation in ports include several key environmental aspects. Firstly, the generation of hazardous waste poses significant concerns, as it includes materials harmful to human and the environment. Hazardous waste that often include asbestos, waste oil, chemicals, and effluent water, must be segregated and stored separately in designated containers to prevent environmental contamination. Ships also contribute to hazardous waste generation through sewage, bilge water and oil sludges. At the same time, the generation of non-hazardous waste, including recyclables (e.g. plastics, paper and metals) requires appropriate segregation to minimise environmental impact. Finally, the materials generated from the development and maintenance activities necessitate appropriate disposal methods to prevent the environmental harm. The environmental impacts associated with the three categories include land contamination, health and safety issues, ground water

pollution, surface water pollution, water pollution, and air pollution. Figure 13, shows the environmental aspects and impacts related to the waste generation in ports.

**Figure 13 – Environmental aspects (left side) and impacts (right side) related to the waste management**



© European Commission, 2024.

Source: Project consortium elaboration.

Environmental aspects (left side) and impacts (right side) related to the waste management

Waste management is of critical importance for port authorities to protect the environment, comply with regulations, ensure public health and safety, preserve infrastructure, achieve cost savings and maintaining positive relationships with the surrounding communities. Implementing effective waste management strategies can reduce environmental risk, improve operational efficiency, and further contribute to the port's sustainable development. In this regard, efficient waste management practices in ports prevent water pollution, soil contamination and harm to marine life. Often located close to sensitive ecosystems such as coastal and marine protected areas, port authorities have the responsibility to minimise their environmental footprint and ensure that waste generated within port premises is effectively managed to prevent ecological damage.

## Legal Framework

The key regulatory framework for waste management in European seaports includes international conventions such as MARPOL (International Convention for the Prevention of Pollution from Ships) and CDNI (Convention on the collection, deposit and reception of waste produced during navigation on the Rhine and inland waterways), as well as EU legislation such as the Waste Reception Facilities Directive<sup>(81)</sup>. Both MARPOL and CDNI require waste reception facilities in ports and prohibit the discharge of waste from vessels. The Waste Reception Facilities Directive emphasises safety and environmental protection in waste reception, with ports required to ensure adequate facilities and compliance monitoring. The Waste Framework Directive<sup>(82)</sup> sets out principles and responsibilities for waste management and waste handling, while Regulation (EC) No 1013/2006<sup>(83)</sup> regulates the shipment of waste. Directive (EU) 2019/904<sup>(84)</sup> aims to reduce plastic pollution and imposes obligations on Member States and port users. Compliance ensures effective waste management and environmental protection in port operations.

Insights and findings on good green practice of waste management have been gathered through desk research and the open call for good practices. Three cases are detailed. The cases represent good practices that go beyond the “traditional” practices of collecting and processing materials included in the MARPOL Convention annexes. The Philippines Ports Authority partnered with WWF-Philippines to reduce plastic waste at key ports, achieving substantial reductions through waste segregation, recycling initiatives, and stakeholder engagement. The port of Antwerp has implemented drone technology to manage floating debris, significantly enhancing operational efficiency and environmental protection. The port of Gävle uses waste materials to create new port land, demonstrating a sustainable approach to port expansion and waste management.

### Case 19 – Philippines Ports Authority: Clean Port, Clean Oceans: Improving Port Waste Management <sup>(85)(86)</sup>

In 2021, the *Philippines Ports Authority*, responsible for managing public ports across the country, signed a Memorandum of Understanding (MoU) with World Wide Fund for Nature (WWF)-Philippines to achieve a 50% reduction in plastic waste discharge at the ports of Batangas, Manila and Cagayan de Oro. This initiative was driven by studies showing a national increase in the use of plastics, with inadequate waste management and recycling<sup>(87)</sup>. This was the driving force behind the project. (*This is linked to Roadmap Step 2: Motivation, please see page 107*).

The project, part of WWF-Philippines’ No Plastics in Nature initiative, ran for three years until 2023, using these three ports as pilot sites.

<sup>(81)</sup> Directive (EU) 2019/883 of the European Parliament and of the Council of 17 April 2019 on port reception facilities for the delivery of waste from ships, amending Directive 2010/65/EU and repealing Directive 2000/59/EC.

<sup>(82)</sup> Directive 2008/98/EC of 19 November 2008 on waste and repealing certain Directives.

<sup>(83)</sup> Regulation (EC) 2006/1013 of the European Parliament and of the Council of 14 June 2006 on shipments of waste.

<sup>(84)</sup> Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment.

<sup>(85)</sup> WWF. (2023). <https://wwf.org.ph/resource-center/story-archives-2023/three-major-philippine-ports-achieve-50-reduction-of-plastic-waste-leakage/>

<sup>(86)</sup> Deloitte. (2021). [https://nor.deloitte.com/rs/712-CNF-326/images/Pollution-in-ports-in-the-Philippines.pdf?\\_ga=2.173734502.475360013.1637087333-249522371.1637087333](https://nor.deloitte.com/rs/712-CNF-326/images/Pollution-in-ports-in-the-Philippines.pdf?_ga=2.173734502.475360013.1637087333-249522371.1637087333)

<sup>(87)</sup> WWF. (2020). [https://wwf.org.ph/wp-content/uploads/2020/12/WWF\\_REPORT\\_EPR\\_Philippines\\_2020.pdf](https://wwf.org.ph/wp-content/uploads/2020/12/WWF_REPORT_EPR_Philippines_2020.pdf)

The legal framework for the project included the Republic Act 9003 (Ecological Solid Waste Management Act of 2000), the Republic Act 6969 (Toxic Substances and Hazardous and Nuclear Wastes Control Act) and the Single-Use Plastic Products Regulation Bill. *(This is linked to Roadmap Step 1: Awareness of legislative context, please see page 105)*. Funded by the Grieg Group Foundation and implemented by WWF and the Grieg Group, the first step in 2022 involved WWF Philippines conducting baseline studies to assess the plastic waste generated by the ports and its potential leakage into the environment. Results showed significant waste generation: Batangas port produced 43 000 kg of plastic waste per year with a 12% potential leakage into the environment, Manila North Port 12 000 kg with a potential leakage up to 13%, and Cagayan De Oro Port 22 000 kg with a 3% potential leakage into the environment. *(This is linked to Roadmap Step 3: Baseline assessment, please see page 110)*.

Implemented solutions included improving waste segregation with 100% recycled plastic bins, holding plastic waste collection events, awarding environmental points for waste diversion, constructing a new materials recovery facility, supporting waste collection workers with new cleaning equipment, raising passenger awareness through informational videos, and requesting a ban on single-use plastics. *(This is linked to Roadmap Step 6: Strategic solutions action plan, please see page 116)*. Stakeholders involved in the project included the local social enterprise Plastic Flamingo, Basic Environmental Systems and Technologies, Inc., the social enterprise Plastic Bank and the national Biodiversity Management Bureau. *(This is linked to Roadmap Step 4: Stakeholder engagement, please see page 112)*.

The Philippines Ports Authority, participating in the Open Call for good green practices related to ports, highlighted that port waste management requires no more than two years to implement at a low cost of less than EUR 20 000. They found that this green practice can be easily transferred or adapted to other ports and terminals without significant challenges. From the financial perspective, the return on investment was evaluated over three years, indicating scalability for ports of various sizes worldwide. *(This is linked to Roadmap Step 5: Evaluation framework, please page 114)*.

## **Case 20 – port of Antwerp - managing floating debris with drones<sup>(88),(89),(90)</sup>**

The *Port of Antwerp* has implemented an innovative approach to managing floating debris in its waters by utilising drones. For one of Europe's largest and busiest ports, this initiative represents a significant advancement in environmental protection and operational efficiency. Each year, approximately 50 tonnes of debris - comprising plastic, wood, cardboard, organic material and mooring lines - is collected from the port's docks. *(This is linked to Roadmap Step 3: Baseline assessment, please see page 110)*. This debris poses significant risks, including water pollution, damage to biodiversity and potential harm to ships. Given the size of the port, which covers more than 120 square kilometres, manual monitoring alone is insufficient. Drones offer a crucial solution by providing comprehensive aerial images that enable rapid detection and response. The Port of Antwerp has developed a 'machine vision' application that uses drone images to automatically generate maps highlighting areas of floating debris. These drones, used several times a day, enable debris to be

---

<sup>(88)</sup> <https://www.porttechnology.org/news/port-of-antwerp-cleans-up-floating-debris-with-help-of-drones/>

<sup>(89)</sup> <https://safety4sea.com/watch-port-of-antwerp-uses-drones-to-detect-floating-debris/>

<sup>(90)</sup> <https://newsroom.portofantwerpbruges.com/port-of-antwerp-deploys-drones-to-detect-floating-debris>

identified and removed more quickly and efficiently, significantly reducing the environmental impact and improving the overall cleanliness of the port. ([This is linked to Roadmap Step 6: Strategic solutions action plan, please see page 116](#)).

The use of drones to collect debris is part of a wider strategy to improve the sustainability and environmental performance of the port and demonstrates how modern technology can be integrated into traditional port operations to address environmental challenges. ([This is linked to Roadmap Step 8: Alignment and coordination, please see page 122](#)). To detect and monitor floating debris in real time, drones equipped with advanced sensors and cameras are used. These drones can pinpoint the location of debris by providing a high-resolution view of the port's extensive waterways. Once the debris is identified, the drones communicate this information to a central control system, which co-ordinates the deployment of vessels to remove the debris. ([This is linked to Roadmap Step 7: Implementation plan rollout, please see page 120](#)). Compared to traditional manual inspection methods, which are time consuming and often less accurate, this method is much more efficient and effective.

The use of drones in this context offers several advantages. Firstly, it significantly reduces the response time to floating debris. This is crucial in preventing the debris from spreading or causing further environmental damage. Secondly, the drones can quickly cover large areas and access hard-to-reach locations that would be difficult for human operators or conventional vessels to navigate. This comprehensive coverage ensures that even the most remote parts of the port can be monitored and maintained. Furthermore, by integrating drones into debris management, the port is not only improving its operational efficiency, but also reducing its environmental footprint through the use of cutting-edge technology. ([This is linked to Roadmap Step 10: Performance assessment and reporting, please see page 126](#)). The drones are powered by renewable energy sources, minimising their carbon emissions and supporting the port's overall goal of reducing its environmental impact. ([This is linked to Roadmap Step 2: Motivation, please see page 107](#)).

The data collected by the drones can be also used for wider environmental monitoring and research, in addition to improving debris collection. ([This is linked to Roadmap Step 11: Monitoring plan, please see page 127](#)). The high-resolution images and footage collected by the drones provide valuable insights into the types and sources of debris, which can inform future preventive measures and policy decisions. ([This is linked to Roadmap Step 8: Alignment and coordination, please see page 122](#)).

This data-driven approach enables the port to adopt more proactive strategies to manage and mitigate environmental risks.

Antwerp's successful drone-assisted litter collection system is a model for other ports, of any size, worldwide. It demonstrates how innovative technology can be used to address long-standing environmental issues in maritime operations. The positive results of this initiative highlight the potential for wider adoption of similar practices in other ports and coastal areas, contributing to global efforts in marine conservation and pollution control.

## Case 21 – port of Gävle – Utilising waste to create new port land<sup>(91)</sup>

The use of waste materials to create new port areas is an innovative and sustainable practice that has been successfully implemented by the *Port of Gävle*. In addition to addressing waste management issues, this approach supports green port expansion. The use of dredged material, industrial by-products and construction waste to create new land areas within the port is at the core of this practice. (*This is linked to Roadmap Step 6: Strategic solutions action plan, please see page 116*). These materials are carefully selected and processed to ensure they are safe and suitable for land reclamation.

In the case of the Port of Gävle, the process begins with dredging sediments from the harbour basin. These sediments, together with other waste materials such as slag from steel production and fly ash from power plants, are then mixed and treated to stabilise them and improve their bearing capacity. The materials are transported to designated reclamation sites within the port area once they have been prepared. Here the materials are systematically layered and compacted to form a stable foundation for new land. (*This is linked to Roadmap Step 7: Implementation plan rollout, please page 120*). In addition to providing a practical use for the waste, this method reduces the environmental impact associated with traditional methods of disposing of waste, such as landfilling. In addition, the newly created land can be used for various port operations, including the construction of new terminals, storage areas and other infrastructure developments. (*This is linked to Roadmap Step 8: Alignment and coordination, please see page 122*). Over 390,000 square metres of new space was created as a result of this innovative approach. A significant proportion of this, more than 154,000 square metres, was achieved using a process stabilisation technique, making it one of the largest projects of its kind to use binders other than concrete. The use of a mixed method for stabilisation, rather than the traditional mass stabilisation with excavators, underlines the innovative nature of this method. After the site had been created, it was left to settle for two years to allow them to support heavy equipment. The expansion of the port's infrastructure has been aided by this new land. (*This is linked to Roadmap Step 6: Strategic Solutions Action Plan, please see page 116*).

A total of about EUR 114 million has been invested in various port development activities between 2010 and 2015. The cost breakdown for the main components of this investment includes about EUR 40 million for dredging and EUR 15 million for stabilisation of material used to create land. This significant expenditure on dredging and stabilisation underlines their importance in the overall expansion strategy. In addition, further contributing to the port's diversified capabilities and infrastructure improvements, about EUR 23 million was allocated for the creation of a new energy pier. To ensure better accessibility and operational efficiency, the project also included the construction of stone walls and improvements to road links. (*This is linked to Roadmap Step 9: Resources and budget, please see page 124*). In the more recent development phase between 2018 and 2019, an additional amount of over EUR 76 million has been earmarked for further port improvements. This continued

---

<sup>(91)</sup> [https://www.porttechnology.org/wp-content/uploads/2019/05/PORT\\_OF\\_GAVLE.pdf](https://www.porttechnology.org/wp-content/uploads/2019/05/PORT_OF_GAVLE.pdf)

investment underlines the ongoing commitment to maintaining and expanding the port's capacity and functionality.

The use of waste to create new port land is a forward-thinking and sustainable approach that can significantly benefit both large and small ports. The operational aspects of this practice, including careful selection and processing of materials, strategic planning and efficient management, ensure its viability and effectiveness..

Table 8 provides a list of examples of other cases of implementation of green practices worldwide, related to the successful management of various types of waste. A considerable number of the following cases concern the reduction of single-use plastic in ports and systems of reception and treatment of other types of waste.

**Table 8 – Other green practices related to waste management in ports**

Name of port	Country	Short description	Reference
Port of Liverpool	UK	Eco-friendly cruise facilities	<a href="https://www.portstrategy.com/greenport/planning-for-green-cruise-growth/1479430.article">https://www.portstrategy.com/greenport/planning-for-green-cruise-growth/1479430.article</a>
Port of Busan	Korea	Plastic waste recycling	<a href="https://sustainableworldports.org/project/busan-port-recycling-of-plastic-waste/">https://sustainableworldports.org/project/busan-port-recycling-of-plastic-waste/</a>
Port of Rotterdam	Netherlands	Plastic waste recycling through pyrolysis	<a href="https://www.portofrotterdam.com/en/news-and-press-releases/plastic-waste-raw-material-circular-port">https://www.portofrotterdam.com/en/news-and-press-releases/plastic-waste-raw-material-circular-port</a>
Port of Vlissingen	Netherlands	Industrial plant for chemical recycling of plastic waste	<a href="https://www.espo.be/practices/chemical-recycling-of-plastic-waste-at-north-sea-p">https://www.espo.be/practices/chemical-recycling-of-plastic-waste-at-north-sea-p</a>
Port of Valencia	Spain	Pilot project supplying water to port terminal employees (for avoiding plastic bottles)	<a href="https://www.espo.be/practices/port-of-valencia-gets-rid-of-plastic-bottles">https://www.espo.be/practices/port-of-valencia-gets-rid-of-plastic-bottles</a>
Port of Kiel	Germany	Ship waste-water reception facility	<a href="https://www.espo.be/practices/waste-heat">https://www.espo.be/practices/waste-heat</a>
Port of Antwerp	Belgium	Recover waste heat from a waste incineration facility	<a href="https://www.espo.be/practices/waste-heat">https://www.espo.be/practices/waste-heat</a>
Port of Algeciras	Spain	Actions to reduce the use of plastics (installation of water jets in offices, glass jugs in meeting rooms, etc.)	<a href="https://www.espo.be/practices/plastics-reduction-campaign">https://www.espo.be/practices/plastics-reduction-campaign</a>
Port of Barcelona	Spain	System of water sources with water treatment located in common spaces and offices for reducing use of plastic	<a href="https://www.espo.be/practices/elimination-of-plastic-bottles">https://www.espo.be/practices/elimination-of-plastic-bottles</a>
Port of Vigo	Spain	Waste management system from fishing ports	<a href="https://www.espo.be/practices/ml-style">https://www.espo.be/practices/ml-style</a>
Port of Marseille	France	Waste water segregation system	<a href="https://www.espo.be/practices/water-treatment-system">https://www.espo.be/practices/water-treatment-system</a>

Name of port	Country	Short description	Reference
Mediterranean ports	Europe	Waste reception facilities in cruise ports	<a href="https://spoudai.unipi.gr/index.php/spoudai/article/view/2572">https://spoudai.unipi.gr/index.php/spoudai/article/view/2572</a>
European ports	Europe	Reception of waste and cargo residues from ships,	Deja, A. (2013). Scientific Journals Zeszyty Naukowe Maritime University of Szczecin Akademia Morska w Szczecinie. Scientific Journals, 33(105), 16–21.
Port of Napoli	Italy	Management Control Systems in port waste management	di Vaio, A., Varriale, L., & Trujillo, L. (2019). Management Control Systems in port waste management: Evidence from Italy. Utilities Policy, 56, 127–135. <a href="https://doi.org/10.1016/j.jup.2018.12.001">https://doi.org/10.1016/j.jup.2018.12.001</a>
Port of Rotterdam	Netherlands	Controlled degassing barge (remaining vapours and gases are sucked from cargo tanks and treated) – Floating degassing	<a href="https://www.portofrotterdam.com/en/news-and-press-releases/first-trial-using-mobile-degassing-installation-successful">https://www.portofrotterdam.com/en/news-and-press-releases/first-trial-using-mobile-degassing-installation-successful</a>

Source: Project consortium elaboration.

## Summary and key lessons learned

Waste management in ports encompasses several critical environmental aspects, including the generation of hazardous and non-hazardous waste. Effective waste management practices are essential for protecting the environment, complying with regulations, ensuring public health and safety, preserving infrastructure, achieving cost savings, and maintaining positive community relations.

Ports often situated near sensitive ecosystems have a significant responsibility to minimise their environmental footprint. Three cases have been presented, highlighting innovative waste management practices. The following key lessons can be drawn from these cases:

**Integrated waste management:** Effective waste management in ports requires integrating strategies for both hazardous and non-hazardous waste. This includes proper segregation, storage, and disposal to prevent environmental contamination and health risks.

**Technological innovation:** Utilising modern technology, such as drones in the port of Antwerp, can greatly enhance the efficiency and effectiveness of waste management. Drones provide rapid detection and response capabilities, reducing the environmental impact and improving operational efficiency. Application of technological innovation in recycling (e.g., advanced recycling of plastics in port of Rotterdam) is also of great importance.

**Sustainable practices:** The port of Gävle's use of waste materials for land reclamation illustrates how sustainable practices can address waste management challenges while supporting port expansion. This approach reduces reliance on traditional disposal methods like landfilling.

**Stakeholder engagement:** Successful waste management initiatives, like those in the Philippines, rely on engaging various stakeholders, including local communities, social enterprises, and environmental organisations. The collaborative approach between various stakeholders exemplifies a robust partnership model, which can be adapted in other cases and provides a blueprint for leveraging expertise. A similar example of stakeholders collaboration is that of the port of Rotterdam and the plastics recycling, where the value chain players; (petro)chemical manufacturers; brand owners; plastic recycling solution providers; waste management companies; packaging producers; key industry non-governmental players and governmental institutions work alongside each other to address the plastic waste challenge, while the Port of Rotterdam Authority aims to host these technological high-quality and innovative industries in the Rotterdam port and industrial complex<sup>(92)</sup>.

**Legislative compliance and support:** Aligning waste management practices with national and international regulations is crucial. The Philippines' initiative underscores the importance of legal frameworks in guiding and supporting waste management efforts. The project is heavily embedded in national legislative framework, institutionalising the project's objectives and making scalability across different jurisdictions with similar legal regimes more feasible.

**Data-driven decision making:** Collecting and analysing data, such as high-resolution images from drones in the port of Antwerp, provides valuable insights into waste types and sources. These data support informed decision-making and proactive environmental management strategies.

**Awareness raising:** The use of educational campaigns such as videos to prevent plastics discharge at sea, highlights the role of awareness and behaviour change in achieving environmental goals. This strategy is universally applicable and can enhance the effectiveness of waste management efforts in other ports.

**Scalability and transferability:** Waste management practices developed in one port can often be adapted and scaled to other ports. The Philippines' ports experience shows that green practices can be implemented with minimal challenges and at a relatively low cost, making them accessible to smaller ports worldwide.

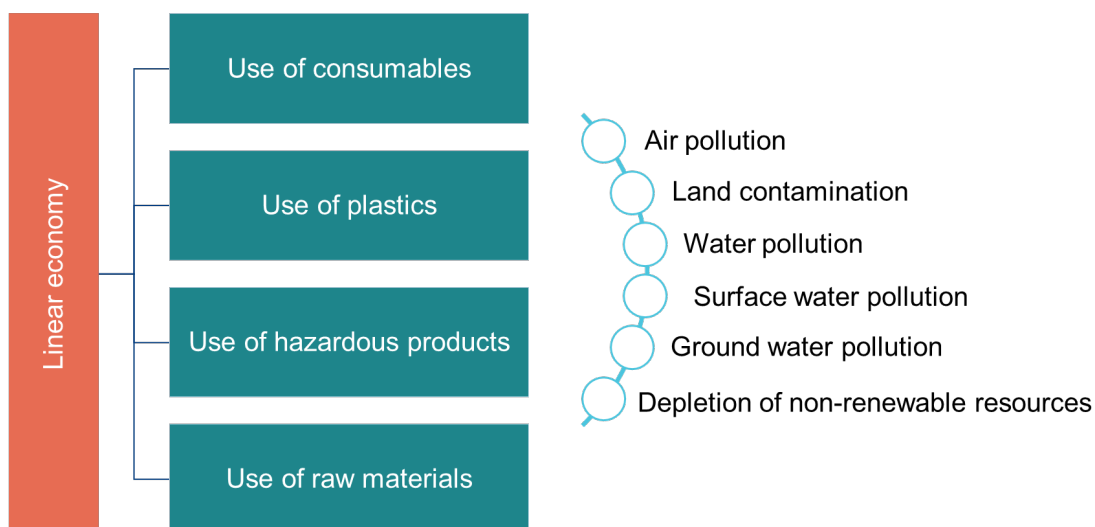
## 4.5. Circular economy

The traditional linear economy model that dominates the way ports operate contributes significantly to environmental degradation. Resource consumption, including large volumes of energy and water consumption, leads to significant carbon footprint and contributes to the depletion of non-renewable resources. [Figure 14](#) shows the environmental aspects and impacts related to the linear economy in ports.

---

<sup>(92)</sup> <https://www.portofrotterdam.com/en/news-and-press-releases/plastic-waste-raw-material-circular-port>

**Figure 14 – Environmental aspects (left side) and environmental impacts of linear economy principles in ports**



© European Commission, 2024.

Source: Project consortium elaboration.

Environmental aspects (left side) and environmental impacts of linear economy principles in ports

The adoption of circular economy principles is being recognised as increasingly important for a number of reasons. Circular economy principles focus on reducing waste, reusing resources and recycling materials to create a more sustainable and efficient economic system. In this context, the integration of circular economy principles into the port operations is important not only for environmental sustainability but also for economic resilience, regulatory compliance and strategic positioning in a rapidly evolving global market. The circular economy is enabling new pathways for innovation and business models in port operations such as material recycling, renewable energy projects and development of circular supply chains between ports, further enhancing the role of seaports in the global economy. Also, ports that demonstrate commitment to circular practices can improve their reputation in port industry and further strengthen the engagement with stakeholders and possibly attract more business investments.

Some of the good practices presented above under the biodiversity category (Case 1 and Case 4) and under the waste management category (e.g., Case 21) include elements of circular economy.

## Legal Framework

The regulatory framework for circular economy practices in EU ports is guided by directives of the Waste Framework Directive<sup>(93)</sup>, the Waste Shipments Regulation<sup>(94)</sup> and Directive 2019/904<sup>(95)</sup> on the reduction of plastics. The primary responsibility lies with port users, with extended producer responsibility being enforced. Environmental legislation such as the Ramsar Convention may apply, and the classification of dredged material under the Waste Framework Directive determines its disposal. Compliance with the Basel Convention and the Waste Shipments Regulation is required for transboundary disposal. The environmental impacts of dredging require careful management and coordination of national and international legislation for effective regulation and sustainable port development.

Insights and findings on good green practices of circular economy in ports have been gathered through desk research and the open call for good practices. In addition to the cases noted above, three other cases have been detailed. The port of Antwerp implements a project to harness waste heat for residential heating. The North Sea Port's biodiesel plant converts waste oils and fats into renewable biodiesel. The port of Barcelona is implementing a project to recover residual refrigeration gases and supply it to local industrial and commercial sites.

## Case 22 – Port of Antwerp: Harnessing industrial residual heat for district heating

The *Port of Antwerp* has initiated a project<sup>(96)</sup> to harness waste heat from a waste incineration facility for district heating. This project is reported to be the largest hot water network in Flanders, resulting in a reduction of 20,000 tons of CO<sub>2</sub> annually. Project financing, amounting to EUR 15.7 million, has been provided by the Flemish government through the Flemish Energy and Climate Agency, with additional support from partners including the City of Antwerp, Indaver and Fluvius. (*This is linked to Roadmap Step 9 – Resources and budget, please see page 124*). While waste heat is already used for industrial processes and energy generation, the remaining heat is suitable for district heating, aligning with circular economy principles and addressing regional heating needs. The project, recently operational (end of February 2024) and expanding<sup>(97),(98)</sup> utilises residual heat from the rotary kilns of Indaver<sup>(99)</sup> (a waste management company where industrial waste is thermally processed), supplying it to Boortmalt<sup>(100)</sup> (the world's largest malting production site), for malt production, and further to a residential heat network for social housing of Woonhaven Antwerp. (*This is linked to Roadmap Steps 4 and 6 – Stakeholder engagement and Strategic solutions action plan, please see pages 112 and 116*). The heat is transported from Indaver to Boortmalt at a temperature of approximately 105°C, about 10 km away in the harbour and the cooled water (65°C) flows back to Indaver through a second pipeline to be reused. This 'open access' heat network, the first of its kind in Belgium, allows heat producers and consumers in the Port of Antwerp-Bruges cluster to

<sup>(93)</sup> Directive 2008/98/EC of 19 November 2008 on waste and repealing certain Directives.

<sup>(94)</sup> Regulation (EC) 2006/1013 of the European Parliament and of the Council of 14 June 2006 on shipments of waste.

<sup>(95)</sup> Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment.

<sup>(96)</sup> <https://www.espo.be/index.php/practices/waste-heat>

<sup>(97)</sup> <https://jshippingandtrade.springeropen.com/articles/10.1186/s41072-023-00153-w>

<sup>(98)</sup> <https://newsroom.portofantwerpbruges.com/antwerp-north-heat-network-kicks-off-with-first-carbon-free-heat-delivery-to-boortmalt>

<sup>(99)</sup> <https://indaver.com/>

<sup>(100)</sup> <https://www.boortmalt.com/>

connect and exchange residual heat. The pipeline network runs along the sites of the cluster, the so called 'Next Gen District'.

Following the completion of the first phase, i.e., the industrial heat network, the second phase will be devoted to the construction of the residential network over the next few years. (*This is linked to Roadmap Step 7 – Implementation plan rollout, please see page 120*). The residential network will allow sustainable heat supply to schools, public buildings and 3,200 households in two high-rise districts in north of Antwerp.

An interesting element of the project is the collaboration between public and private stakeholders. Indaver and the [Port of Antwerp-Bruges](#) jointly built the first part of the network that currently supplies heat to Boortmalt. From this industrial heat network, Fluvius will build the second part, a residential network on behalf of and in cooperation with the City of Antwerp. To this end, agreements were concluded with social housing company Woonhaven Antwerp, among others. The Flemish government is also an important partner, providing financial support to the project, with the aim to boost the reuse of industrial waste heat and the deployment of heat networks. (*This is linked to Roadmap Step 2 – Motivation, please see page 107*). This case represents a multistage, multi partner, multidisciplinary reuse of waste heat project in a rather innovative and expandable setting. Though this project cannot be directly reproduced, it provides interesting insights on how different public and private stakeholders can partner to accomplish an ambitious circular economy project.

### **Case 23 – North Sea Port: Waste-based biodiesel production<sup>(101),(102)</sup>**

The use of waste in ports as a valuable energy resource is becoming increasingly evident, moving beyond the perception of waste as merely a disposable commodity. This market is expanding rapidly as turning waste into green energy addresses challenges related to waste storage and compliance with stricter regulations, particularly in Europe and the United States.

Although still at its early stages, waste-to-energy applications are gaining traction in European ports. As the global priority shifts towards energy transition, regulatory frameworks have become more stringent, making waste-to-energy a compelling approach. Financial incentives in several countries have encouraged local authorities to invest in these initiatives, promoting sustainable practices and reducing dependence on traditional energy sources.

A significant development in sustainable energy production from waste is the opening of a biodiesel plant at [North Sea Port](#) in 2022, established by a leading food and agricultural company. (*This is linked to Roadmap Step 4 – Stakeholder Engagement, please page 112*). This plant, which converts waste oils and fats into renewable biodiesel, represents an important step in the port's circular economy strategy. (*This is linked to Roadmap Step 2 – Motivation, please see page 107*).

The biodiesel facility uses advanced waste treatment technology to transform various waste products into high-quality biodiesel. The process begins with the collection and pre-treatment of the waste oils and fats to remove any contaminants. These pre-processed materials are then subjected to a chemical reaction that transforms the

---

<sup>(101)</sup> <https://www.offshore-energy.biz/cargill-opens-waste-based-biodiesel-plant-in-north-sea-port/>

<sup>(102)</sup> <https://www.pc-nsp.com/en/news/377-cargill-expands-biodiesel-production-in-north-sea-port>

fats into biodiesel. The resulting biodiesel meets stringent quality standards, making it suitable for use in marine and heavy-duty applications, sectors traditionally challenging for low-carbon fuel alternatives (*This is linked to Roadmap element 6 – Strategic solution action plan, please see page 116*).

The plant produces up to 115 000 tons of biodiesel annually and it is considered as one of the largest in Europe. The fuel produced is equivalent to the annual fuel consumption of approximately 10 000 trucks or 150 000 cars. (*This is linked to Roadmap Step 10 – Performance assessment and reporting, please see page 126*). The facility, which costs about EUR 150 million, highlights the port's commitment to alternative fuel production and the circular economy. In addition to advancing renewable energy production, the investment generates economic opportunities by creating 20 direct and 60 indirect jobs. (*This is linked to Roadmap Step 9 – Resources and budget, please see page 124*).

The investment includes the construction of the plant, the implementation of advanced processing technologies, and the integration of the facility into the existing infrastructure at the North Sea Port.

#### **Case 24 – Port of Barcelona: Recovery of residual cold of LNG terminal<sup>(103)</sup>**

At the *Enagás LNG terminal in the port of Barcelona*, a pioneering solution for the recovery of residual refrigeration gases has been initiated. This concept is expected to generate 131 GWh per year of local, affordable, and environmentally friendly energy. The solution is expected to be fully operational in the second quarter of 2024, marking a significant step towards sustainable energy use in the region. The project will contribute to significant CO<sub>2</sub> emission savings, estimated at 32 205 tonnes per year, in addition to reducing dependence on imported gas, with the potential to be replicated at other LNG regasification plants across the country. (*This is linked to Roadmap Steps 2 and 6: Motivation; and Strategic Solutions Action Plan, please see pages 108 and 117*).

The project sets a precedent for using local energy solutions to drive decarbonisation and improve competitiveness in port areas and beyond, by turning wasted cold energy into a valuable resource for the urban grid. Specifically, it takes the energy released during the regasification process at the LNG terminal, which is normally discharged into the sea, and converts it into usable energy for the urban grid. (*This is linked to Roadmap Step 7: Implementation plan rollout, please page 120*). This pioneering project was made in collaboration between Veolia and Enagas company, with the support of Barcelona City Council. In addition, the EcoEnergies Barcelona district cooling network, which serves around 150 000 people over an area of 1 500 hectares, will use this green cold for air conditioning. The initiative is planned to improve the competitiveness of industrial and commercial sites in the port area, including public infrastructures such as the Palacio de Congresos and the Mercabarna food market, by recovering residual cold energy and reintroducing it into the city's grid. (*This is linked to Roadmap Step 4 – Stakeholder Engagement, please see page 113*).

---

<sup>(103)</sup> Veolia. (2023). <https://www.veolia.com/en/our-media/press-releases/veolia-implements-pioneering-cold-energy-recovery-solution-port-barcelona>

Its replicable and scalable potential offers significant opportunity for other ports and port cities around the world, particularly those with urban and industrial densities with similar characteristics.

**Table 9 – Indicative list of other green practices related to circular economy in ports**

Name of port	Country	Short description	Reference
Port of Marseille	France	Recycling and reuse of vessels' wastewater	<a href="https://sustainableworldports.org/project/port-of-marseille-energy-recovery-from-cruise-ships-wastewater/">https://sustainableworldports.org/project/port-of-marseille-energy-recovery-from-cruise-ships-wastewater/</a>
Port of Antwerp	Belgium	District nearby the port of Antwerp exploring / employing circular carbon solutions and renewable energy technologies	<a href="https://www.espo.be/practices/circular-economy-hotspot-nextgen-district-at-the-p">https://www.espo.be/practices/circular-economy-hotspot-nextgen-district-at-the-p</a>
Port of Valencia	Spain	Set-up of Circular Economy Network	<a href="https://www.espo.be/practices/loop-ports">https://www.espo.be/practices/loop-ports</a>
Port of Sevilla	Spain	Regeneration of Donana's beaches using dredged material	<a href="https://www.espo.be/practices/regeneration-of-the-donana-coastline-at-the-port-o">https://www.espo.be/practices/regeneration-of-the-donana-coastline-at-the-port-o</a>
Port of Nakskov	Denmark	Red beacon grinding and repainting for being reused	<a href="https://www.espo.be/practices/port-of-nakskov-applying-circular-economy-principi">https://www.espo.be/practices/port-of-nakskov-applying-circular-economy-principi</a>
Port Authority of New York and New Jersey	United States	New property for preserving open space for conservation and ecological development	<a href="https://www.inboundlogistics.com/articles/10-greenest-ports-in-america/">https://www.inboundlogistics.com/articles/10-greenest-ports-in-america/</a>

Source: Project consortium elaboration.

## Summary and key lessons learned

Waste-to-energy initiatives in ports are emerging as a key solution for converting general waste into usable energy. These initiatives are proving to be highly effective in addressing environmental concerns, despite requiring significant initial investment. While these initiatives exhibit considerable success within the implementing organisation, transferability to other ports may be challenging due to infrastructure limitations and the fact that successful implementation should consider the reliance on significant volumes of waste from local communities.

Ports should invest in infrastructure development to accommodate waste-to-energy facilities, including storage facilities, equipment, and processing plants. Nevertheless, these initiatives demonstrate scalability and can be adapted to both smaller and larger port facilities. The potential transferability of these initiatives to other ports depends on the viability and overcoming of the challenges associated with developing energy recovery infrastructure, addressing convincingly community objections and the need for significant volumes of waste to ensure viability. In this context, ports

should develop comprehensive waste management strategies to ensure reliability and sufficient supply of waste for energy conversion. Partnerships with local communities, waste management companies and relevant stakeholders interested in using the produced energy may be included in the strategy.

The cases mentioned above illustrate the growing importance of integrating circular economy principles into port operations to address environmental concerns, enhance economic resilience, and foster innovation. Some key lessons learned include the following:

**Environmental and economic benefits:** implementing circular economy practices, such as harnessing waste heat for district heating, converting waste oil into biodiesel, and recovering residual energy from LNG terminals, can lead to significant reductions in emissions and reliance on traditional energy sources. Additionally, these initiatives generate economic opportunities by creating jobs and improving the competitiveness of port areas.

**Public-private collaboration:** successful circular economy projects often involve collaboration between public and private stakeholders, as seen in the partnership between the Port of Antwerp, Indaver, Fluvious and the Flemish government. Such collaborations facilitate the mobilisation of resources and expertise necessary for project implementation and ensure alignment with regulatory frameworks and strategic objectives.




**Innovation and scalability:** circular economy initiatives in ports drive innovation in waste management, energy production, and resource utilisation, paving the way for scalable solutions that can be replicated in other ports. For example, the biodiesel plant at North Sea Port and the energy recovery project at the Port of Barcelona demonstrate the potential for replicable and scalable solutions that address local energy needs while reducing environmental impact. Nevertheless, assessing scalability is a strongly case specific issue that needs to be addressed carefully, depending on a number of parameters that need to be considered (volume and supply of material to be processed, space required etc.).




**Stakeholder engagement:** engaging stakeholders, including local communities, industry partners, and government agencies, is crucial for the success of circular economy projects in ports. By involving stakeholders from the planning stages onwards, ports can ensure that projects meet the needs and priorities of all involved parties, enhance social acceptance and build trust and support for future initiatives.




#### 4.6. Alignment of cases with the steps of the roadmap



This section presents a summary of the elements of the various cases related to each step of the roadmap. [Table 10](#) provides a list of the roadmap steps along with a brief description of the key elements of each step. In addition, the table includes a list of the cases that pertain to each specific step of the roadmap. Detailed information on these elements in relation to the respective roadmap steps is provided in Annex II – Case links with Roadmap steps.

**Table 10 – Overview of cases per roadmap step**

Roadmap Steps	Roadmap’s main elements	Cases
 <p><b>1</b> AWARENESS OF LEGISLATIVE CONTEXT</p>	<p>Proper and timely overview of existing and anticipated legal and institutional frameworks affecting ports in the short-, mid-, and long-term</p> <p>Mandatory and voluntary international, EU, national and regional frameworks</p> <p>Covers economic, operational, environmental, technological and governance aspects</p> <p>Mitigate legal risks associated with port operations</p>	<p>Case 1 – Port of Huelva; Case 2 – Port of Malaga; Case 3 – Port of Hamburg; Case 19 – Port of Philippines;</p>
 <p><b>2</b> MOTIVATION</p>	<p>Establish port vision with specific environmental goals</p> <p>Cultivate stakeholder commitment to the environmental goals</p> <p>Inspire a collective sense of purpose and dedication to green initiatives to comply with requirements and/or improve factors beyond legislation</p>	<p>Case 1 – Port of Huelva; Case 2 – Port of Malaga; Case 4 – Port of Rotterdam; Case 5 – Port of Kiel Case 7 – Port of Gävle; Case 9 – Port of Valencia; Case 16 – Port of Klaipėda; Case 19 – Port of Philippines; Case 20 – port of Antwerp; ; Case 22 – Port of Antwerp; Case 23 – Port of North Sea Port; Case 24 – Port of Barcelona</p>
 <p><b>3</b> BASELINE ASSESSMENT</p>	<p>Analyse current situation and understand the current environmental status of the port</p> <p>Identify operations related to environmental aspects and impacts, and determine the areas that need improvement</p> <p>Evaluate air and water quality, energy use, waste generation, noise levels</p> <p>Consider factors extending beyond port boundaries impacting port conditions</p>	<p>Case 3 – Port of Hamburg; Case 5 – Port of Kiel Case 13 – Port of Rotterdam; Case 14 – Energy Recovery; Case 18 – Port of Rotterdam; Case 19 – Port of Philippines; Case 20 – port of Antwerp</p>

Roadmap Steps	Roadmap's main elements	Cases
<p data-bbox="248 488 533 577">  <b>4</b> STAKEHOLDER ENGAGEMENT </p>	<p data-bbox="564 300 1053 353">Gain insights on current and anticipated future port conditions</p> <p data-bbox="564 407 1053 461">Ensure broad support and collaboration for green initiatives</p> <p data-bbox="564 515 1053 568">Understand and prioritise issues to be tackled</p> <p data-bbox="564 622 1053 766">Build agenda for collaborative initiatives, to involve required stakeholders, such as industry, technology providers, environmental agencies, local communities</p>	<p data-bbox="1072 273 1351 788">Case 1 – Port of Huelva; Case 2 – Port of Malaga; Case 3 – Port of Hamburg; Case 5 – Port of Kiel; Case 6 – Port of Aarhus; Case 7 – Port of Gävle; Case 8 – APMT and Dubai Ports World; Case 9 – Port of Valencia; Case 10 – Port of Antwerp; Case 13 – Port of Rotterdam; Case 19 – Port of Philippines; Case 22 – Port of Antwerp; Case 23 – North Sea Port; Case 24 – Port of Barcelona</p>
<p data-bbox="248 936 533 1025">  <b>5</b> EVALUATION FRAMEWORK </p>	<p data-bbox="564 815 1053 922">Assess environmental impacts, to prioritise efforts and select good practices for greening port operations and infrastructures</p> <p data-bbox="564 976 1053 1030">Select appropriate solutions and assess their feasibility</p> <p data-bbox="564 1048 1053 1075">Set targets for proposed actions</p> <p data-bbox="564 1120 1053 1146">Use methods for assessing effectiveness</p>	<p data-bbox="1072 936 1351 1021">Case 3 – Port of Hamburg; Case 19 – Port of Philippines</p>
<p data-bbox="248 1420 533 1509">  <b>6</b> STRATEGIC SOLUTIONS ACTION PLAN </p>	<p data-bbox="564 1232 1053 1285">Outline prioritised solutions with environmental benefits.</p> <p data-bbox="564 1339 1053 1429">Ensure economic viability and operational efficiency and assess greening potential.</p> <p data-bbox="564 1482 1053 1536">Produce action plan for selecting and implementing good practices.</p> <p data-bbox="564 1590 1053 1675">Strategic concept document and implementation pathway with activities, timelines, resources and responsibilities</p>	<p data-bbox="1072 1164 1351 1733">Case 2 – Port of Malaga; Case 5 – Port of Kiel Case 6 – Port of Aarhus Case 8 – APMT and Dubai Ports World; Case 10 – Port of Antwerp; Case 13 – Port of Rotterdam; Case 16 – Port of Klaipėda; Case 17 – Port of Antwerp-Bruges; Case 19 – Philippines Ports Authority; Case 20 – port of Antwerp; Case 21 – port of Gävle; Case 22 – Port of Antwerp; Case 23 – North Sea Port; Case 24 – Port of Barcelona</p>

Roadmap Steps	Roadmap's main elements	Cases
 <p>7 IMPLEMENTATION PLAN ROLLOUT</p>	<p>Detailed description of actions to implement selected scenarios.</p> <p>Ensure effective execution and monitoring of the plan for specific actions, objectives and results to be achieved.</p> <p>Involve managerial and technical experts.</p> <p>Develop testing and validation requirements</p>	<p>Case 2 – Port of Malaga; Case 3 – Port of Hamburg; Case 4 – Port of Rotterdam; Case 5 – Port of Kiel; Case 6 – Port of Aarhus; Case 8 – APMT and Dubai Ports World (DPW); Case 9 – Port of Valencia; Case 11 – Port of Rotterdam; Case 12 – Port of Hamburg; Case 13 – Port of Rotterdam; Case 14 – Energy Recovery; Case 16 – Port of Klaipėda; Case 17 – Port of Antwerp-Bruges; Case 20 – port of Antwerp; Case 21 – port of Gävle; Case 22 – Port of Antwerp; Case 24 – Port of Barcelona</p>
 <p>8 ALIGNMENT AND COORDINATION</p>	<p>Ensure the port's action plan is consistent with other relevant plans and strategies.</p> <p>Identify potential synergies and complementarities, avoid conflicts.</p> <p>Develop a coordinated planning framework, identify corresponding plans and engage stakeholders.</p> <p>Regularly review and update plans to reflect new developments.</p>	<p>Case 2 – Port of Malaga; Case 3 – Port of Hamburg; Case 4 – Port of Rotterdam; Case 7 – Port of Gävle; Case 12 – Port of Hamburg; Case 13 – Port of Rotterdam; Case 14 – Energy Recovery; Case 16 – Port of Klaipėda; Case 18 – Port of Rotterdam; Case 20 – port of Antwerp; Case 21 – port of Gävle;</p>
 <p>9 RESOURCES AND BUDGET</p>	<p>Secure necessary resources and funding.</p> <p>Develop comprehensive plan for securing necessary resources and funding to support implementation.</p> <p>Ensure cost-effective implementation and financial sustainability.</p> <p>Assess human, financial and other resource needs.</p>	<p>Case 1 – Port of Huelva; Case 2 – Port of Malaga; Case 3 – Port of Hamburg; Case 5 – Port of Kiel; Case 6 – Port of Aarhus; Case 16 – Port of Klaipėda; Case 21 – port of Gävle; Case 22 – Port of Antwerp; Case 23 – North Sea Port</p>

Roadmap Steps	Roadmap's main elements	Cases
 <p>10 PERFORMANCE ASSESSMENT AND REPORTING</p>	<p>Assess effectiveness of implemented initiatives.</p> <p>Use performance data to inform decision-making and ensure long-term sustainability.</p> <p>Set KPIs and gather quantitative and qualitative data.</p> <p>Conduct regular performance reviews and compile assessment reports.</p>	<p>Case 1 – Port of Huelva; Case 8 – APMT and Dubai Ports World (DPW); Case 11 – Port of Rotterdam; Case 16 – Port of Klaipėda; Case 14 – Energy Recovery; Case 17 – Port of Antwerp – Bruges; Case 20 – port of Antwerp; Case 23 – North Sea Port</p>
 <p>11 MONITORING PLAN</p>	<p>Establish system for continuous oversight and assessment of port's environmental performance.</p> <p>Implement a comprehensive monitoring system to track environmental performance indicators.</p> <p>Monitor compliance with regulations.</p> <p>Engage stakeholders in feedback sessions and plan adjustments.</p>	<p>Case 1 – Port of Huelva; Case 14 – Energy Recovery; Case 20 – port of Antwerp</p>

## 5. Summary and Main Takeaways

The report addresses the environmental challenges faced by European sea ports and aims to provide guidance to smaller ports for improving their environmental performance while achieving sustainability goals, through experiences gained by implementing noteworthy green initiatives in practice.

Larger ports possess significant advantages in terms of financial resources, risk tolerance and organisational capacity. They often have the means to invest in innovative solutions and actively participate in research and development projects, leading to co-funded pilot implementation of green initiatives. They typically have more skilled personnel, stronger influence, and stakeholder leverage, which position them better to lead the way in sustainability efforts. Finally, larger ports often form robust collaborations to drive collective action towards sustainable goals.

Smaller ports face unique challenges stemming from, typically, limited resources and risk aversion. They often prioritise mature solutions, relying on tested practices to mitigate potential risks. They may lack internal expertise, requiring guidance and capacity-building programmes to navigate the selection and implementation of green practices. Also, they require financial and technical support, particularly as they may underutilise available funding mechanisms and have limited participation in R&D programmes. They may benefit from partnerships with other ports and stakeholders to create synergies and gain experience from their lessons learned, to boost their capacity to implement green practices.

### 5.1. Overall summary

Considering these, and to better support and enhance the capacity of smaller ports to adopt sustainable initiatives, this study identified factors affecting the capacity for greening of European sea ports, with emphasis on small and medium-sized ports, paired with economic development. It examined environmental effects, legislation, impediments and good practices, emphasising on the importance of integrating environmental concerns into port strategy and management. Based on these elements the study produced a generic roadmap, which was subsequently illustrated with detailed case studies to demonstrate its relevance and use.

Data collection methods included literature review, interviews, survey, and focus groups, resulting in insights organised into different sections of the report. These sections cover addressing environmental effects, providing a roadmap for greening small and medium-sized ports and analysing a wide spectrum of good practices, placing them in the context of the roadmap.

Overall, the report serves as a comprehensive yet dense resource for port stakeholders, offering insights, strategies, and examples to guide their efforts in enhancing environmental sustainability and economic viability.

The second chapter of the report, titled "Addressing the environmental effects of port operations", categorises port-related activities into waterside, intra-terminal and landside operations, emphasising their complexity and multifunctionality. Environmental aspects and impacts related to these activities are outlined, highlighting emissions, resource consumption, pollution, and habitat disturbance as

key concerns. It further discusses the legal framework governing environmental protection in the EU, with a focus on recent initiatives. It underscores the EU's commitment to making ports and transport greener, albeit with a complex regulatory landscape that requires careful navigation. Factors affecting the greening capacity of ports are explored next, encompassing cargo and passenger handling capacity, financial and administrative scale, geographical location, and multiplicity of activity. These factors provide insights into a port's ability to adopt environmentally sustainable practices and inform decision-making processes. A taxonomy of good practices is presented, showcasing various initiatives implemented by ports globally. These practices are grouped into 22 categories, highlighting their diversity and applicability across different contexts. Transferability of these practices is also discussed, emphasising the importance of assessing their scalability, technological compatibility, capacity building needs and financial considerations. Finally, the chapter underscores the importance of these insights in the development of a roadmap for greening of ports.

The third chapter presents the roadmap, with key elements tailored to small and medium-sized ports. The roadmap is designed to assist ports, especially small and medium-sized ones, in adopting sustainable practices while complying with regulations and contributing to environmental goals. It offers a flexible framework for ports to tailor to their specific needs and capacities. It aims to identify priorities, elaborate strategies, ensure feasibility, promote effective practices, and facilitate transferability, thereby guiding ports towards their greening objectives in a targeted and practical manner.

The roadmap is divided into three main areas of intervention – Policy and Target Setting, Measure Assessment and Prioritisation, and Monitoring and Reporting. Eleven key steps are elaborated in the context of the roadmap, emphasising on the importance of ports building an understanding of the legislative context and cultivating motivation among stakeholders, evaluating their current environmental status, prioritise issues, identify feasible and potentially effective solutions, prioritise them and create clear action plans for their implementation, align them with other relevant strategies and initiatives, and secure necessary resources and funding, while also setting performance indicators and process for continuously tracking progress. Overall, the roadmap offers a structured yet adaptable approach to assist smaller ports to implement green practices effectively.

The fourth chapter presents a structured compilation of experiences gained in the adoption and implementation of good practices in various ports. Information on successful sustainability initiatives has been gathered through desk research, an open call for good practices, and interviews with port stakeholders. A broad range of cases, including both scalable and transferable practices as well as practices that are site-specific in their technical details, but address issues of broad interest are presented. The analysis includes twenty-four detailed cases across five main categories of good practices, including four cases on biodiversity protection and restoration, eleven cases on various elements of port electrification and energy management, three cases on alternative fuels, three cases on waste management and three cases on circular economy aspects.

## 5.2. Key messages

Based on the analysis of various elements influencing the capacity of ports to implement green practices, the elaborated steps of the roadmap and the analysis of good practices, several key points are derived, as presented below.

### Strategic Insights

- **Stakeholder Engagement and Partnerships:** The establishment of local stakeholder partnerships and the broader agreement on port green practices appears to boost the course of their adoption and implementation. It should also be pointed out that consultations by the port authorities with port users and other stakeholders are encouraged or even mandated under the Port Services Regulation<sup>104</sup>. Proactive outreach on the earlier planning stages should be encouraged as it can anticipate future challenges, improve support and reach commonly acceptable solutions. Collaborative platforms that bring together ports, stakeholders, and industry partners, may drive collective action and build shared capacity towards shared sustainability goals.
- **Regional Cooperation:** Regional cooperation appears to be instrumental in realising green practices. It is envisaged that regional cooperation can help in addressing issues of scalability and transferability for certain green practices for medium and small size ports. Furthermore, regional cooperation may facilitate deployment of innovative solutions, overcoming technical and safety challenges, besides building trust between initiative players. Any cooperation should in any case be in line with competition rules and seek to establish and exploit synergies in shaping and applying best practices.
- **Financial Strategies and Economic Viability:** Financial viability of sustainability initiatives should be assessed taking into consideration social costs and benefits, regulatory compliance and climate-related risk mitigation. Investing in sustainability principles, despite high costs, may be economically viable in the long run, though the short term business case may look marginal or even negative. This perspective should be considered as essential element for ports maintaining their “license to operate”. Financial support from public financial instruments and other private sources and financial incentives are important in mitigating risks and supporting capital investments. In this, ports should make use of those instruments best suited for their individual situation. The use of specific clauses on sustainability initiatives, including electrification of port equipment and deployment of OPS and alternative fuels infrastructure, in port concession contracts or collaboration with third party providers, such as electricity companies, should also be considered.
- **Innovation and Out-of-the-Box Thinking:** To drive sustainability and efficiency, ports should think - “outside the box” by adopting innovative technologies, exploring new funding models and forming unique

---

<sup>104</sup> Regulation (EU) 2017/352 of the European Parliament and of the Council of 15 February 2017 establishing a framework for the provision of port services and common rules on the financial transparency of ports, Art. 15.

partnerships. By embracing creative solutions ports may overcome traditional challenges, optimise operations and achieve significant environmental and economic benefits.

- **Chaining Approaches:** Efforts to combine green practices in a “chaining approach” are important in ensuring synergies, besides integrated positive sustainability results, particularly in large ports with diversifying activities. An example is the massive production of alternative fuels, which is mainly introduced or planned in ports with significant industrial activities inside the port area or adjacent to the port. Such a “Chaining approach” can take the form of “vertical” chaining, i.e., combining a green practice with upstream (e.g., clean energy sourcing) and downstream (e.g., supporting practice users that follow green initiatives) green practices or “horizontal” chaining, i.e., combining assets and initiatives of stakeholders to produce a concerted green practice.
- **Adoption of New Technologies:** Certain practices based on new technologies, such as producing artificial reefs through 3D printing to restore damaged reef systems, utilising intelligent lighting, and energy recovery systems, can be easily adopted by small and medium sized-ports.
- **Scaling Sustainability Initiatives:** Scaling down for several sustainability initiatives, among those mentioned above, is rather straightforward and the practice can be shaped to the specific scale of ports and relevant port activities. Ideally, however, such initiatives should be incorporated in the port master plan, or, under certain circumstances, they can be incorporated as a “greening” clauses in the port concession contracts, newly awarded or extended. Concessions, incorporating “green” clauses look to have a strong potential in the medium and long run.

### Specific Implementation Strategies

- **Transition to Alternative Fuels:** Transitioning to alternative fuels requires substantial investment, regulatory support, and innovative but mature for commercial application technologies. Whether small ports can deploy alternative fuels production and/or bunkering activities depends on the potential to specialise or focus on specific elements of these processes. Attention should be given to developing strategies that enable small ports to effectively participate in alternative fuels production and bunkering, preferably through a “horizontal” chaining, as indicated above, through developing synergies and participating in concerted initiatives with appropriate technology and industry partners, having adequate prior experience in implementing similar initiatives.
- **Electrification of Port Equipment:** Electrification of port equipment is already widespread and could be adopted by medium and small size ports. However, standardisation and support issues need to be addressed in partnership with the OEMs. Furthermore, ongoing assessment and reporting are essential to ensure that infrastructure meets the growing needs of electric transport. Incentives for adoption and addressing grid capacity issues are vital for successful implementation.
- **Onshore Power Supply (OPS):** It appears that OPS will be widely adopted in the near future, based on the provisions of the recent relevant EU

Regulations (2023/1804 and 2023/1805), working “back-to-back” for EU ports and vessels calling at them, despite certain concerns for the business case viability and the issues relating to technical challenges (e.g., distribution grid capacities at peak demand, business case substantiation etc). OPS for ferries seems to be well advanced and OPS for cruise vessels is also well in progress in most ports that provided input to this study, while the application for container vessels to meet the regulatory requirements is generally still at an earlier stage.

- **Effective Waste Management:** Effective waste management integrates strategies for hazardous and non-hazardous waste, utilising modern technology for enhanced efficiency. Engaging various stakeholders and aligning practices with regulations are key for successful implementation. Waste management green practices, in many cases, relate to circular economy initiatives and production of biofuels, representing an interesting class of “chaining” green practice paradigms.
- **Circular Economy Initiatives:** Circular economy initiatives, such as converting waste into usable resources, can reduce emissions and reliance on traditional energy sources, though these practices represent a much wider spectrum of activities. Public-private collaborations may drive innovation and scalability of relevant initiatives, creating economic opportunities. Issues of continuous sourcing of waste in adequate quantities to sustain operations should be considered, in assessing the long term viability and scaling such solutions to smaller ports.

### 5.3. Recommendations

To further support small and medium-sized ports in implementing sustainability initiatives, some generic key recommendations include the following:

- Study specifically the scale application limitations of applying green initiatives and provide targeted assistance and capacity-building programmes to help smaller ports overcome barriers to green practices implementation.
- Build upon the existing initiatives that are compiling catalogues of good practices on a systematic basis. Enhancing catalogues of good practices by demonstrating their transferability and scalability potential can make them more relevant to smaller ports.
- Enhance access to funding mechanisms and support structures specifically designed for small and medium-sized ports.
- Provide a framework that supports and even enables ports stepping out of their comfort zones to develop strategies and implement innovative solutions to enhance sustainability.
- Facilitate knowledge-sharing initiatives and partnerships between larger and smaller ports to leverage best practices and lessons learned.
- Foster collaborative platforms that bring together ports, stakeholders, and industry partners to drive collaborative action towards shared sustainability goals.

- Advocate for policies that incentivise and support sustainability initiatives across the maritime sector, with a focus on equitable distribution of resources and support.

By implementing the above, smaller ports may be better empowered to embrace green practices.

## 6. Annex I – List of EU Legislation

Short name	Directive/Regulation
AFIR (Alternative Fuels Infrastructure Regulation)	Regulation (EU) 2023/1804 of the European Parliament and of the Council of 13 September 2023 on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU
Ambient Air Quality Directive	Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe.
Birds Directive	Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds.
EED (Energy Efficiency Directive)	Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC
EIA Directive (Environmental Impact Assessment Directive)	Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment
ETD (Energy Taxation Directive)	Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity
ETS (EU Emission Trading System)	Directive (EU) 2023/959 of the European Parliament and of the Council of 10 May 2023 amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union and Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading system
EU Climate Law	Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law')
FuelEU Regulation	Regulation (EU) 2023/1805 of the European Parliament and of the Council of 13 September 2023 on the use of renewable and low-carbon fuels in maritime transport, and amending Directive 2009/16/EC.

Short name	Directive/Regulation
Habitats Directive	Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.
IED (Industrial Emissions Directive)	Directive 2010/75/EU of the European Parliament and the Council on industrial emissions
MSFD (Marine Strategy Framework Directive)	Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy.
NEC Directive (National Emission reduction Commitments Directive)	Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC
Port Services Regulation	Regulation (EU) 2017/352 of the European Parliament and of the Council of 15 February 2017 establishing a framework for the provision of port services and common rules on the financial transparency of ports.
SEA Directive	Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment
SSP Directive (Ship-source Pollution Directive)	Directive 2005/35/EC of 7 September 2005 on ship-source pollution and on the introduction of penalties, including criminal penalties, for pollution offences
VOC Directive (Control of volatile organic compound emissions)	Directive 94/63/EC of 20 December 1994 on the control of volatile organic compound (VOC) emissions resulting from the storage of petrol and its distribution from terminals to service stations.
WFD (Waste Framework Directive)	Directive 2008/98/EC of 19 November 2008 on waste and repealing certain Directives
WFD (Water Framework Directive)	Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.
Waste Regulation Shipments	Regulation (EC) 2006/1013 of the European Parliament and of the Council of 14 June 2006 on shipments of waste.
Assessment and management of environmental noise Directive	Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise.

Short name	Directive/Regulation
Public access to environmental information Directive	Directive 2003/4/EC of the European Parliament and of the Council of 28 January 2003 on public access to environmental information.
Plans and programmes relating to the environment Directive	Directive 2003/35/EC of the European Parliament and of the Council of 26 May 2003 providing for public participation in respect of the drawing up of certain plans and programmes relating to the environment.
Prohibition of organotin compounds on ships Regulation	Regulation (EC) 2003/782 of the European Parliament and of the Council of 14 April 2003 on the prohibition of organotin compounds on ships.
Environmental liability with regard to the prevention and remedying of environmental damage Directive	Directive 2004/35/CE of the European Parliament and of the Council of 21 April 2004 on environmental liability with regard to the prevention and remedying of environmental damage.
Arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air Directive	Directive 2004/107/EC of the European Parliament and of the Council of 15 December 2004 relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air.
Prohibition of organotin compounds on ships and amending Regulation No 782/2003	Commission Regulation (EC) 2008/536 of 13 June 2008 giving effect to Article 6(3) and Article 7 of Regulation (EC) No 782/2003 of the European Parliament and of the Council on the prohibition of organotin compounds on ships and amending that Regulation.
Ship recycling Regulation and amending Regulation (EC) No 1013/2006 and Directive 2009/16/EC	Regulation (EU) 2013/1257 of the European Parliament and of the Council of 20 November 2013 on ship recycling and amending Regulation (EC) No 1013/2006 and Directive 2009/16/EC.
Monitoring, reporting and verification of carbon dioxide emissions from maritime transport Regulation, and amending Directive 2009/16/EC	Regulation (EU) 2015/757 of the European Parliament and of the Council of 29 April 2015 on the monitoring, reporting and verification of carbon dioxide emissions from maritime transport, and amending Directive 2009/16/EC.
Limitation of emissions of certain pollutants into the air from medium combustion plants Directive	Directive (EU) 2015/2193 of 25 November 2015 on the limitation of emissions of certain pollutants into the air from medium combustion plants.
Reduction in the sulphur content of certain liquid fuels Directive	Directive (EU) 2016/802 of the European Parliament and of the Council of 11 May 2016 relating to a reduction in the sulphur content of certain liquid fuels.

Short name	Directive/Regulation
Requirements relating to gaseous and particulate pollutant emission limits and type-approval for internal combustion engines for non-road mobile machinery Regulation	Regulation (EU) 2016/1628 of 14 September 2016 on requirements relating to gaseous and particulate pollutant emission limits and type-approval for internal combustion engines for non-road mobile machinery, amending Regulations (EU) No 1024/2012 and (EU) No 167/2013, and amending and repealing Directive 97/68/EC.
Promotion of the use of energy from renewable sources Directive	Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources.
Port reception facilities for the delivery of waste from ships Directive	Directive (EU) 2019/883 of the European Parliament and of the Council of 17 April 2019 on port reception facilities for the delivery of waste from ships, amending Directive 2010/65/EU and repealing Directive 2000/59/EC.
Reduction of the impact of certain plastic products on the environment Directive	Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment.
Common rules for the internal market for electricity Directive	Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast).
CO2 emission performance standards for new heavy-duty vehicles Regulation	Regulation (EU) 2019/1242 of 20 June 2019 setting CO2 emission performance standards for new heavy-duty vehicles and amending Regulations (EC) No 595/2009 and (EU) 2018/956 of the European Parliament and of the Council and Council Directive 96/53/EC.

## 7. Annex II – Case links with Roadmap steps

## Awareness of legislative context

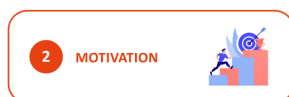


### Case links with Roadmap Step 1: Awareness of legislative context

<b>Case 1 – Port of Huelva</b>	<p>The Port of Huelva's green practices are driven by an awareness of the legal context of balancing infrastructure development, social welfare and environmental protection. This balance is crucial within the 245 000 hectares of legally protected land surrounding the port. This led to the initiation of an ecological restoration project to ensure sustainable development, protecting the environment and benefit local communities.</p>
<b>Case 2 – Port of Malaga</b>	<p>The UN climate change targets and specific Spanish national legislation provide the legal framework for the Port of Malaga's initiative. Key legislative elements, which are an integral part of the Port's 2019-2023 Investment Plan, include the Sustainable Mobility Strategy and the Sustainable Transport Strategy in Ports. These laws and strategies guide the port's efforts in the reduction of carbon emissions and the promotion of sustainable development practices, in line with international and national environmental objectives.</p>
<b>Case 3 – Port of Hamburg</b>	<p>The Hamburg Kreesand project shows how the Port of Hamburg goes beyond legal obligations to create valuable estuarine habitats. The project is in line with the Natura 2000 management plan for the Elbe estuary and will make a significant contribution to the expansion and protection of this important ecological area. The initiative underlines the port's commitment to environmental protection and the enhancement of biodiversity within a wider network of protected areas.</p>
<b>Case 19 – Port of Philippines</b>	<p>The Port of Philippines project's legal framework includes several key environmental laws. These include Republic Act 9003 (Ecological Solid Waste Management Act of 2000), Republic Act 6969 (Toxic Substances and Hazardous and Nuclear Waste Control Act) and the Single-Use Plastic Products Regulation Bill. In line with national environmental protection goals, these laws collectively support the port's efforts to effectively manage waste, control hazardous substances and reduce plastic pollution.</p>

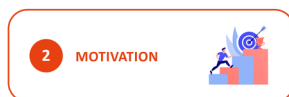
Source: Project consortium elaboration.

## Motivation



### Case links with Roadmap Step 2: Motivation

<p><b>Case 1 – Port of Huelva</b></p>	<p>Balancing its role as a major industrial hub with the preservation of the ecologically important estuary surrounding the port requires an innovative and effective solution. This is demonstrated by the restoration of habitats and seabirds through the beneficial use of dredging and bio-tools. The regulatory framework imposes an obligation to mitigate the impact of pollution while maintaining operations that support economic development, motivating port stakeholders to engage in this practice.</p>
<p><b>Case 2 – Port of Malaga</b></p>	<p>A wide range of measures are being taken to improve air quality, reduce greenhouse gas (GHG) emissions, improve energy efficiency and increase the use of renewable energy. These efforts are crucial to the port's environmental strategy and are in line with wider sustainability objectives.</p>
<p><b>Case 4 – Port of Rotterdam</b></p>	<p>The Port of Rotterdam is supporting an initiative by a company that produces artificial reefs using 3D printing. This project is motivated by the need to restore damaged reef systems and protect vulnerable coastlines. The company designs and installs geometrically complex organic shapes inspired by nature (biomimicry) and optimised for local conditions. The innovative printing process, which does not require a supporting material, provides material savings and demonstrates the port's commitment to environmental sustainability.</p>
<p><b>Case 5 – Port of Kiel</b></p>	<p>Motivated by the goal of achieving carbon neutrality in line with its Blue Port strategy, the Port of Kiel exemplifies a proactive approach to sustainability and environmental responsibility. This initiative demonstrates the port's commitment to reducing its environmental impact and promoting sustainable practices.</p>
<p><b>Case 7 – Port of Gävle</b></p>	<p>In November 2023, a significant development took place in the port of Gävle when a tanker carried out an unloading operation while it was connected to the shore power supply. This effort is part of the Port of Gothenburg's Green Cable project, the aim of which is to develop a global standard for the electrical connection of tankers at docks in hazardous environments. The project is motivated by the need to improve safety and reduce emissions during tanker operations.</p>



## Case links with Roadmap Step 2: Motivation

<p><b>Case 9 – Port of Valencia</b></p>	<p>The Port of Valencia demonstrates strong motivation and stakeholder engagement in going green by electrifying terminal equipment. A collaboration between a terminal operator and an original equipment manufacturer has resulted in the retrofitting of high-density container stacking equipment. This has led to a 20% reduction in carbon dioxide emissions, lower noise levels and reduced maintenance requirements.</p>
<p><b>Case 16 – Port of Klaipėda</b></p>	<p>Port of Klaipėda stakeholders are motivated by a holistic view of hydrogen production and refuelling best practices, driven by a commitment to long-term sustainability and community engagement. This approach reflects the port's comprehensive sustainability strategy, which includes legislative proactivity, environmental responsibility and economic aspirations.</p>
<p><b>Case 19 – Port of Philippines</b></p>	<p>Driven primarily by the urgent need to address the significant increase in plastic waste and its inadequate management and recycling, the "Clean Port, Clean Ocean: Improving Port Waste Management in the Philippines" initiative aims to significantly reduce the amount of plastic waste discharged from ports in the Philippines. Recognising the role of port operations in plastic pollution, the initiative aims to significantly reduce the discharge of plastic waste from the ports of Batangas, Manila and Cagayan de Oro, underlining the environmental motivation behind the project.</p>
<p><b>Case 20 – port of Antwerp</b></p>	<p>The Port of Antwerp is using drones powered by renewable energy sources to minimise carbon emissions and support the port's overall goal of reducing its environmental impact. This innovative approach is part of the port's commitment to the integration of technology and sustainability.</p>
<p><b>Case 22 – Port of Antwerp</b></p>	<p>A remarkable aspect of this project is the cooperation between public and private stakeholders. Indaver and the port of Antwerp-Bruges are jointly responsible for the construction of the first part of the heat supply network for Boortmalt. Fluvius will build the second part, a residential network, in cooperation with the city of Antwerp. This initiative was supported by the Flemish government and the social housing company Woonhaven Antwerp, with the aim of reusing industrial waste heat and developing heat networks.</p>
<p><b>Case 23 – Port of North Sea port</b></p>	<p>The plant at North Sea Port, which converts waste oils and fats into renewable biodiesel, represents an important step in the port's circular economy strategy.</p>



2 MOTIVATION

## Case links with Roadmap Step 2: Motivation

### Case 24 – Port of Barcelona

At the Enagás LNG terminal in Barcelona, stakeholders are working on the recovery of residual refrigeration from the LNG terminal and its conversion into 131 GWh of local energy per year. The motivation for this initiative is the reduction of CO2 emissions by 32,205 tonnes per year and the reduction of the country's dependence on imported gas. The scalable solution increases the competitiveness of industrial and commercial sites in the port area by using waste refrigeration energy for urban supply.

Source: Project consortium elaboration.

## Baseline assessment



## Case links with Roadmap Step 3: Baseline assessment

<b>Case 3 – Port of Hamburg</b>	Several studies and planning processes were carried out during the preliminary phase of the Kreeksand Tidal Zone project. These included a thorough baseline and biodiversity study, an assessment of the existing ecological inventory, and extensive studies of the hydraulics within the project area, earthworks and technical planning. These baseline assessments were essential for understanding the starting point and planning effective restoration activities.
<b>Case 5 – Port of Kiel</b>	Grid capacity issues, particularly during peak demand, are managed through advance notifications from customers, allowing the port to coordinate with the energy provider to ensure availability. Justifying the business case for OPS service was achieved through environmental considerations and stakeholder commitment. The port contributed 20% of the installation costs, with 80% covered by national, regional and EU sources, and a minimal charge applied to electricity sales to cover operating costs.
<b>Case 13 – Port of Rotterdam</b>	With the rise of electrification in industrial processes, green hydrogen production, and electric transport, the port of Rotterdam has seen a significant increase in electricity demand. This is compounded by limited space for new infrastructure, essential for grid expansion.
<b>Case 14 – Energy Recovery</b>	As environmental standards become more restrictive and fuel costs rise, operators of Rubber Tyred Gantry (RTG) cranes are switching from diesel to electric power systems. However, challenges such as wasted regenerative power, harmonic pollution and low power efficiency are often encountered with these systems. Baseline assessments included analysing the current performance and issues of existing power systems to identify areas for improvement.
<b>Case 18 – Port of Rotterdam</b>	Leveraging economies of scale, investing in research and development, conducting pilot projects and forming strategic partnerships with industry leaders to accelerate innovation and market readiness can help overcome the challenges of scaling up renewable energy projects. The long-term availability of renewable energy is secured by investing in or partnering with renewable energy projects. Diversifying feedstock sources and partnering with local agricultural and waste management entities ensures a sustainable supply of feedstock. Baseline assessments include evaluation of current production capabilities and potential partnerships.



### Case links with Roadmap Step 3: Baseline assessment

#### Case 19 – Port of Philippines

The World Wide Fund for Nature (WWF)-Philippines conducted baseline studies at the Philippine Ports Authority (PPA) as part of the Clean Port, Clean Oceans project. These studies quantified the current amount of waste generated by the ports of Batangas, Manila North and Cagayan De Oro, which amounted to 43,000 kg, 12,000 kg and 22,000 kg respectively. The baseline studies also assessed the potential environmental leakage of this plastic waste, which was found to be 12%, 13% and 3% per port, respectively. This provided an essential understanding of the scale of the plastic waste challenge facing ports.

#### Case 20 – port of Antwerp

The Port of Antwerp has adopted an innovative approach to managing floating debris in its waters by using drones. For one of Europe's largest and busiest ports, this initiative represents a significant step forward in environmental protection and operational efficiency. Each year, around 50 tonnes of debris - including plastic, wood, cardboard, organic material and mooring lines - is collected from the port's docks. Baseline assessments have quantified the types and quantities of debris present in the port's waters in order to develop effective management strategies.


Source: Project consortium elaboration.

## Stakeholder engagement



### Case links with Roadmap Step 4: Stakeholder engagement

<p><b>Case 1 – Port of Huelva</b></p>	<p>The successful implementation of the Huelva Port Project relied on the management of the Port Authority and the collaboration of a diverse team of engineers, environmentalists, marine biologists and dredging specialists. Collaboration with environmental authorities, NGOs, research groups and public participation through surveys and awareness raising events were crucial to stakeholder engagement.</p>
<p><b>Case 2 – Port of Malaga</b></p>	<p>the Port of Malaga's engagement strategy brought together stakeholders from the Port Authority, urban planners, environmental experts, and community representatives to develop the port for both commercial and recreational use, while prioritising air quality and emissions reduction through energy efficiency and renewable energy initiatives.</p>
<p><b>Case 3 – Port of Hamburg</b></p>	<p>Stakeholder engagement in the project of “Clean Port, Clean Oceans” includes working with various entities such as the local social enterprise Plastic Flamingo, Basic Environmental Systems and Technologies, Inc., the social enterprise Plastic Bank, and the National Biodiversity Management Bureau, all of which contribute to the environmental goals of the project</p>
<p><b>Case 5 – Port of Kiel</b></p>	<p>Cooperation with shipping companies is facilitated by an annual letter of intent submitted by the shipping companies, indicating their approximate annual consumption. Advance notice is required for each ship call to inform the energy supplier, making the process straightforward for regular shipping services.</p>
<p><b>Case 6 – Port of Aarhus</b></p>	<p>Key stakeholders involved in the development of Onshore Power Supply (OPS) at the Port of Aarhus include the Port Authority, cooperating cruise lines, and government and state agencies focused on reducing pollution and greenhouse gas emissions in and around the port.</p>
<p><b>Case 7 – Port of Gävle</b></p>	<p>The port's development is driven by collaboration with various stakeholders, including classification societies, local oil companies, shipping companies and regulators. This collaborative effort aims to improve port operations and environmental sustainability.</p>
<p><b>Case 8 – APMT and Dubai Ports World</b></p>	<p>A collaboration between two Global Terminal Operators (GTOs), APMT and DPW, underpins a strategic initiative to electrify port operations within a 2 to 8 year timeline. Supported by industry partners such as Eurogate, Port of Kalundborg and Smart Freight Centre, this initiative advocates the transition to battery electric container handling equipment (BE-CHE).</p>

	<b>Case links with Roadmap Step 4: Stakeholder engagement</b>
<b>Case 9 – Port of Valencia</b>	<p>The Port of Valencia project is a collaboration between a terminal operator and an OEM to evaluate a promising retrofit technology for high-density container storage equipment. The project also includes the integration of new units with the same technology into the terminal's equipment inventory, improving operational efficiency and sustainability.</p>
<b>Case 10 – Port of Antwerp</b>	<p>The Port of Antwerp-Bruges is developing two charging hubs at the Truck Parking Goordijk and Ketenis, which will provide free parking for trucks visiting the Port of Antwerp, with a capacity of 210 and 280 parking spaces respectively. This initiative supports the port's commitment to reducing emissions and increasing logistical efficiency.</p>
<b>Case 13 – Port of Rotterdam</b>	<p>To address grid congestion, the Port of Rotterdam, together with grid operators TenneT and Stedin, has set up a New Energy Taskforce (NET). The NET aims to expand grid capacity, improve electricity demand forecasting and promote flexible energy consumption. These strategies are crucial as industries switch from conventional fuels to electricity to reduce their environmental impact.</p>
<b>Case 19 – Port of Philippines</b>	<p>Stakeholders involved in the Clean Port, Clean Oceans project included the local social enterprise Plastic Flamingo, Basic Environmental Systems and Technologies, Inc, the social enterprise Plastic Bank and the National Biodiversity Management Bureau. This diverse stakeholder engagement is key to addressing the challenge of plastic waste in ports.</p>
<b>Case 22 – Port of Antwerp</b>	<p>While waste heat is already used for industrial processes and energy production, the residual heat is suitable for district heating, in line with the principles of the circular economy and to meet regional heating needs. The project, which has been operational since February 2024, uses residual heat from Indaver's rotary kilns and supplies it to Boortmalt for malt production and to a district heating network for social housing in Woonhaven Antwerp. This initiative involves cooperation with several stakeholders, including the Flemish government.</p>
<b>Case 23 – North Sea Port</b>	<p>A significant development in sustainable energy production from waste is the opening of a biodiesel plant at North Sea Port in 2022, established by a leading food and agricultural company. This initiative underlines the port's commitment to sustainable practices and stakeholder engagement in renewable energy projects.</p>



## Case links with Roadmap Step 4: Stakeholder engagement

### Case 24 – Port of Barcelona

The waste refrigeration recovery solution at the Enagás LNG terminal demonstrates the strong commitment of key stakeholders. The collaboration between Veolia and Enagás, with the support of Barcelona City Council, aims to boost the competitiveness of the local industrial and commercial sector. This initiative will benefit public infrastructure such as the Palacio de Congresos and the Mercabarna food market by generating and distributing green cold energy.

*Source:* Project consortium elaboration.

## Evaluation framework



### Case links with Roadmap Step 5: Evaluation framework

#### Case 3 – Port of Hamburg

Quantitative methods used for the Kreesand Tidal Zone project included hydrodynamic modelling techniques, ecological inventories and quantitative impact assessment methods to evaluate potential impacts on biodiversity and formulate mitigation strategies. In addition, geotechnical analysis was carried out to assess soil stability and to inform targeted construction approaches. The assessment processes quantitatively compared alternative scenarios to ensure the most effective and sustainable solutions were implemented.

#### Case 19 – Port of Philippines

The Philippines Ports Authority, which participated in the Open Call for Good Green Practices related to ports, highlighted that effective port waste management takes no more than two years to implement at a low cost of less than €20,000. This green practice was found to be easily transferable or adaptable to other ports and terminals without significant challenges. From a financial perspective, the return on investment was assessed over three years, indicating the scalability and feasibility of the practice for ports of different sizes worldwide.

Source: Project consortium elaboration.

## Strategic solutions action plan



## Case links with Roadmap Step 6: Strategic solutions action plan

<b>Case 2 – Port of Malaga</b>	Within this framework, efforts have been focused on the aspects affecting the greening of the port, leading to the approval of the 2019-2023 Investment Plan. This plan included specific action plans focused on improving air quality, reducing greenhouse gas emissions and increasing energy efficiency and the use of renewable energy.
<b>Case 5 – Port of Kiel</b>	The Shore Side Electricity project in the Port of Kiel includes a strategic action plan to implement a €17 million shore side power system. This system will supply up to six vessels with green electricity in line with the port's Blue Port sustainability strategy. The action plan outlines the phased installation and operational strategies to ensure successful implementation.
<b>Case 6 – Port of Aarhus</b>	Denmark's first shore power facility for cruise ships, located in the Port of Aarhus, marks a significant milestone in the country's sustainability efforts. The facility enables cruise ships to connect to green electricity generated directly from Danish wind turbines, allowing them to switch off their diesel engines. The strategic action plan includes steps to expand the facility and increase its use.
<b>Case 8 – APMT and Dubai Ports World</b>	The APM Terminals (APMT) and DPW joint initiative's strategic action plan outlines a coordinated 2 to 8 year effort to electrify port operations. Supported by industry partners, the plan emphasises scalability, standardisation, reduced charging times and public sector incentives. Key operational features include ultra-fast charging, battery swapping and wireless power transfer.
<b>Case 10 – Port of Antwerp</b>	Scheduled to be operational in May 2024, the Antwerp Port Hub will initially consist of two plots with a total of 30 charging stations. In the second phase of development, the number of charging points will be increased. Each hub will be equipped with 15 high-performance Combined Charging System (CCS) chargers with a capacity of up to 400 kW, with plans to switch to Megawatt Charging System (MCS) technology when available.
<b>Case 13 – Port of Rotterdam</b>	To address grid congestion, the Port of Rotterdam, in partnership with grid operators TenneT and Stedin, has set up a New Energy Taskforce (NET). The NET aims to expand grid capacity, improve electricity demand forecasting and promote flexible energy consumption. These strategies are part of the strategic action plan to support the shift from conventional fuels to electricity and reduce environmental impact.



## Case links with Roadmap Step 6: Strategic solutions action plan

<p><b>Case 16 – Port of Klaipėda</b></p>	<p>The Strategic Action Plan for the Port of Klaipėda includes the production of renewable hydrogen for public transport by "Klaipėdos autobusų parkas - UAB" and for bunkering ships and the Port Authority's marine services fleet. A hydrogen-powered waste collection vehicle is being designed and built, which is expected to consume about 44 tonnes of hydrogen per year.</p>
<p><b>Case 17 – Port of Antwerp-Bruges</b></p>	<p>The Hydrotug prototype, powered by internal combustion engines burning a mixture of hydrogen and diesel fuel, meets the stringent EU Stage V emissions standard. The strategic action plan includes steps to further develop and deploy these environmentally friendly tugs.</p>
<p><b>Case 19 – Philippines Ports Authority</b></p>	<p>Solutions implemented include improving waste segregation with 100% recycled plastic bins, holding plastic waste collection events, awarding environmental points for waste diversion, building a new materials recovery facility, supporting waste collection staff with new cleaning equipment, raising passenger awareness with educational videos and requesting a ban on single-use plastics.</p>
<p><b>Case 20 – port of Antwerp</b></p>	<p>To tackle water pollution and debris, the Port of Antwerp has developed an application that uses drone images to automatically generate maps highlighting areas of floating debris. This strategic action plan ensures rapid detection and removal of debris, significantly reducing environmental impact and improving port cleanliness.</p>
<p><b>Case 21 – port of Gävle</b></p>	<p>The use of waste materials to create new port areas is an innovative and sustainable practice successfully implemented by the Port of Gävle. The strategic action plan includes the use of dredged material, industrial by-products and construction waste to create new land areas within the port, address waste management issues and support green port expansion.</p>
<p><b>Case 22 – Port of Antwerp</b></p>	<p>The project, which has been operational since February 2024, uses residual heat from Indaver's rotary kilns to supply heat to Boortmalt for malt production and to a heat network for social housing in Woonhaven Antwerp. The strategic action plan includes extending the use of this residual heat to other industrial and residential areas.</p>
<p><b>Case 23 – North Sea Port</b></p>	<p>The biodiesel plant at North Sea Port uses advanced waste treatment technology to convert various waste products into high-quality biodiesel. The strategic action plan involves the collection and pre-treatment of waste oils and fats, followed by a chemical reaction to produce biodiesel. The resulting biodiesel meets stringent quality standards, making it suitable for use in marine and heavy-duty applications.</p>



## Case links with Roadmap Step 6: Strategic solutions action plan

### Case 24 – Port of Barcelona

At the Enagás LNG terminal in Barcelona, a pioneering solution for the recovery of residual refrigeration gases has been initiated. It is expected to generate 131 GWh per year of local, affordable and environmentally friendly energy, and the strategic action plan includes steps to reach full operational capacity by the second quarter of 2024. This project is a significant step towards sustainable energy use in the region.

*Source:* Project consortium elaboration.

## Implementation plan rollout



### Case links with Roadmap Step 7: Implementation plan rollout

<p><b>Case 2 – Port of Malaga</b></p>	<p>The initiative will be implemented in three phases. As part of the roll-out phase of the implementation plan since 2019, a total of 5,248 m<sup>2</sup> of green space has been added to the port in Phase I, with an investment of around €395,000, and almost 3,024 m<sup>2</sup> of green space in Phase II, with an investment of around €231,000. Phase III is currently being developed. It is estimated that the trees planted as part of the overall initiative could offset around 585 tonnes of CO<sub>2</sub>, marking a significant step forward in climate change mitigation efforts.</p>
<p><b>Case 3 – Port of Hamburg</b></p>	<p>The work took place between 2012 and 2022 and involved the excavation of 2 million cubic metres of soil to allow for natural tidal flooding. A new tidal area of 30 hectares has been developed as part of this extensive implementation plan, restoring natural habitats and improving biodiversity.</p>
<p><b>Case 4 – Port of Rotterdam</b></p>	<p>The company designs, manufactures and installs artificial reefs to help restore damaged reef systems and protect vulnerable coastlines. They report that they build geometrically complex organic shapes while saving on the use of materials and are implementing this innovative solution as part of their strategic action plan.</p>
<p><b>Case 5 – Port of Kiel</b></p>	<p>The Onshore Power Supply (OPS) infrastructure includes both 50/60 Hertz (Hz) systems for cruise ships and ferries, and a 50 Hz system for ferries only. These systems meet the different technical standards and power requirements of international shipping. The first type of unit, with a capacity of 16 MVA, can serve both ferries and cruise ships, providing shore power to four berths simultaneously. The second type of unit, designed for ro-ro vessels, operates on a 50 Hz grid frequency and can supply two berths with a maximum power of 5 MVA. This flexibility supports the port's goal of sustainable maritime logistics operations.</p>
<p><b>Case 6 – Port of Aarhus</b></p>	<p>To encourage the use of shore power, the port has introduced a novel charging model. Cruise ships that do not connect to the facility are charged higher port fees, encouraging the adoption of more sustainable practices.</p>
<p><b>Case 8 – APMT and Dubai Ports World (DPW)</b></p>	<p>APMT has launched a pilot project for the electrification of container terminal equipment at the Port of Barcelona (APMT Barcelona), co-funded by the Spanish government and implemented in partnership with suppliers. This project includes the purchase of five zero-emission electric straddle carriers, four charging stations, associated civil and electrical works, an IT network and the development of processes to apply the necessary technology to operate and recharge the equipment.</p>



## Case links with Roadmap Step 7: Implementation plan rollout

<b>Case 9 – Port of Valencia</b>	<p>The terminal has signed a service agreement with Konecranes to facilitate regular maintenance and servicing of all cranes. Dedicated technicians work closely with the terminal's maintenance department to ensure optimum performance and longevity of the equipment.</p>
<b>Case 11 – Port of Rotterdam</b>	<p>The Port of Rotterdam recently opened the first truck charging hub with several specialist partners. Up to eight electric trucks can be charged at the port with up to 360 kW of charging power. A partner specialising in truck parking handled the installation for the Port of Rotterdam Authority and built the new charging stations at the Bodaanweg truck park in the Waalhaven area. Five technology providers are responsible for the operation of the charging points.</p>
<b>Case 12 – Port of Hamburg</b>	<p>In the port of Hamburg, the initiative to develop charging hubs was taken by a fuel supplier. The charging hubs, located at Georgswerder Bogen, have a capacity of 360 kW and will enable electric trucks to be charged with 100% renewable energy.</p>
<b>Case 13 – Port of Rotterdam</b>	<p>To optimise use of space and ensure maximum efficiency of new facilities, the port has integrated high-voltage substations and power lines, strategically planned according to long-term needs and geographical considerations. This approach is part of the port's comprehensive implementation plan to support increased electrification.</p>
<b>Case 14 – Energy Recovery</b>	<p>The energy recovery in ports is the use of hybrid electric Ship-to-Shore (STS) cranes equipped with energy storage systems such as batteries or supercapacitors is an effective example. These systems capture the kinetic energy generated when containers are lowered, store this energy and reuse it to power the crane, significantly reducing the crane's overall energy requirements and dependence on diesel fuel.</p>
<b>Case 16 – Port of Klaipėda</b>	<p>By 2026, the Port of Klaipėda will establish Lithuania's first hydrogen production facility with a public hydrogen filling station as part of the "Next Generation Lithuania" economic recovery and resilience plan, co-funded by the European Union's NextGenerationEU programme.</p>
<b>Case 17 – Port of Antwerp-Bruges</b>	<p>The Port of Antwerp-Bruges is acting as an important test bed for the Hydrotug technology on a large scale. The Hydrotug, which is currently undergoing final testing and certification by Lloyd's Register, is expected to be fully operational in the port during 2024.</p>



## Case links with Roadmap Step 7: Implementation plan rollout

<p><b>Case 20 – port of Antwerp</b></p>	<p>Drones equipped with advanced sensors and cameras are used to detect and monitor floating debris in real time. These drones provide high-resolution views of the port's extensive waterways, enabling rapid detection and response. The Port of Antwerp has developed a 'machine vision' application that uses drone images to automatically generate maps highlighting areas of floating debris.</p>
<p><b>Case 21 – port of Gävle</b></p>	<p>At the Port of Gävle, the process starts with dredging sediment from the port basin. These sediments, together with other waste materials such as slag from steel production and fly ash from power plants, are mixed and treated to stabilise them and improve their bearing capacity. The materials are then transported to designated reclamation sites within the port area, where they are systematically layered and compacted to form a stable foundation for new land.</p>
<p><b>Case 22 – Port of Antwerp</b></p>	<p>Once the first stage, the industrial heat grid, has been completed in the port of Antwerp, the second stage will focus on building the residential grid in the coming years.</p>
<p><b>Case 24 – Port of Barcelona</b></p>	<p>The project in the port of Barcelona sets a precedent for using local energy solutions to drive decarbonisation and improve competitiveness in port areas and beyond, by turning wasted cold energy into a valuable resource for the urban grid. Specifically, it takes the energy released during the regasification process at the LNG terminal, which is normally discharged into the sea, and converts it into usable energy for the urban grid.</p>

Source: Project consortium elaboration.

## Alignment and coordination



### Case links with Roadmap Step 8: Alignment and coordination

<p><b>Case 2 – Port of Malaga</b></p>	<p>The Port of Malaga, one of the oldest and most important cruise terminals in Spain, has been integrating the port into the urban fabric since the 1990s. This alignment with urban planning has involved developing part of the port area for leisure and commercial use, while expanding its capacity for cruise ships. Coordination with urban planners and local authorities has been crucial in transforming the port into a new civic space open to the public.</p>
<p><b>Case 3 – Port of Hamburg</b></p>	<p>The Hamburg Port Authority's (HPA) Kreesand Tidal Zone Project aimed to achieve several objectives related to environmental protection, habitat restoration and sustainable development. The primary objective was to secure seaward access to the port by reducing tidal energy, thereby reducing upstream sediment transport and the need for dredging. This project is an example of effective alignment and coordination between environmental objectives and port operations.</p>
<p><b>Case 4 – Port of Rotterdam</b></p>	<p>The company uses the outer wall of RDM (Rotterdamsche Droogdok Maatschappij), a regenerated area of an old shipbuilding yard, as a test bed for prototype reefs. This area is now a centre for innovative manufacturing, education and events. The project is in line with Rotterdam's wider strategy of using historic industrial spaces for modern sustainable practices and demonstrates effective coordination between innovation and environmental goals.</p>
<p><b>Case 7 – Port of Gävle</b></p>	<p>In November 2023, the Port of Gävle saw a significant development when a tanker carried out an unloading operation while connected to shore power. This endeavour is part of the Green Cable project, led by the Port of Gothenburg, which aims to develop a global standard for the electrical connection of tankers at docks in hazardous environments. This initiative highlights the alignment and coordination between different ports and stakeholders to improve sustainability.</p>
<p><b>Case 12 – Port of Hamburg</b></p>	<p>Complementing the existing depot charging facilities, this initiative kicks off the development of a nationwide truck charging network supported by the Hamburg Port Authority. With plans to install additional charging stations at central port locations, Hamburg is demonstrating its commitment to supporting sustainable heavy-duty transport and advancing green port initiatives by coordinating efforts with various stakeholders.</p>





## Case links with Roadmap Step 8: Alignment and coordination

<p><b>Case 13 – Port of Rotterdam</b></p>	<p>To address grid congestion, the Port of Rotterdam, in partnership with grid operators TenneT and Stedin, has set up a New Energy Taskforce (NET). The NET aims to expand grid capacity, improve electricity demand forecasting and promote flexible energy consumption. These strategies are crucial as industry shifts from conventional fuels to electricity, requiring coordinated efforts to reduce environmental impact.</p>
<p><b>Case 14 – Energy Recovery</b></p>	<p>Hybrid Electric Ship-to-Shore (STS) Cranes with Energy Storage Systems not only reduce fuel consumption by up to 60%, but they also reduce emissions. These systems are essential for ports seeking to increase operational efficiency while reducing environmental impact, in line with global sustainability goals.</p>
<p><b>Case 16 – Port of Klaipėda</b></p>	<p>The Port of Klaipėda Hydrogen Production and Filling Initiative is part of a comprehensive environmental strategy aimed at significantly reducing greenhouse gas emissions, improving water quality and introducing hydrogen as a clean alternative fuel.</p>
<p><b>Case 18 – Port of Rotterdam</b></p>	<p>OCI Global, the parent company of the green methanol producer, operates the only ammonia import terminal in the Port of Rotterdam. It plans to triple its capacity in anticipation of growing demand for ammonia as a cleaner fuel. In addition, OCI Global announced a partnership with Unibarge to develop the world's first dual-fuel green methanol bunker barge to operate in the Port of Rotterdam. This project highlights the alignment and coordination between the port and industry partners to innovate and advance sustainable fuel solutions.</p>
<p><b>Case 20 – port of Antwerp</b></p>	<p>The use of drones to collect debris is part of a wider strategy to improve the sustainability and environmental performance of the port. This initiative demonstrates how modern technology can be integrated into traditional port operations to address environmental challenges, requiring coordinated efforts between technology providers and port authorities.</p>
<p><b>Case 21 – port of Gävle</b></p>	<p>Using waste materials to create new port areas reduces the environmental impact associated with traditional waste disposal methods. The newly created land can be used for various port operations, including new terminals and storage areas.</p>

Source: Project consortium elaboration.

## Resources and budget

	<b>Case links with Roadmap Step 9: Resources and budget</b>
<b>Case 1 – Port of Huelva</b>	<p>The Resources and Budget step highlights the Huelva Port Authority's commitment to environmental benefits and responsible environmental governance, with a EUR 27 million investment focused on environmental sustainability, as indicated, with no immediate financial return.</p>
<b>Case 2 – Port of Malaga</b>	<p>The initiative unfolds in three phases. As part of the roll-out phase of the implementation plan since 2019 a total green area of 5 248 m<sup>2</sup> has been added to the port in phase I with an investment of approximately EUR 395 000 and almost 3 024 m<sup>2</sup> of green area in phase II with an investment of approximately EUR 231 000. Phase III is currently under development. It is estimated that trees planted as part of the overall initiative could offset around 585 tons of CO<sub>2</sub>, marking a significant stride in climate mitigation efforts</p>
<b>Case 3 – Port of Hamburg</b>	<p>A major excavation of 2 million cubic metres of soil has been carried out to allow natural tidal flooding and a new tidal area of 30 hectares has been developed. The total investment for the project is EUR 80 million , reflecting the significant financial commitment required to achieve environmental restoration and sustainable development objectives.</p>
<b>Case 5 – Port of Kiel</b>	<p>Funding for the EUR17 million development came from a combination of national, regional and EU sources (80%), supplemented by the port's own funding (20%). Operational expenditure (OPEX) is subsidised by general port dues, demonstrating the port's strategic allocation of resources to support the Onshore Power Supply (OPS) project.</p>
<b>Case 6 – Port of Aarhus</b>	<p>The new fee model introduced in the port of Aarhus, imposes an additional charge of Danish Krone (DKK) 0.75 per gross ton on cruise ships that do not utilise shore power, resulting in an additional fee ranging from DKK 50 000 (EUR 6 700) to DKK 75 000 (EUR 10 000) per cruise ship call, depending on the vessel's size. This fee is supplementary to the normal port dues. This measure aims to promote the use of OPS and support the port's environmental objectives.</p>
<b>Case 16 – Port of Klaipėda</b>	<p>The Klaipėda State Seaport Authority has received approximately EUR 5 million in funding for the development of this renewable hydrogen production project. The total cost of the project, excluding VAT, is approximately EUR 7 million. This investment will be used to install a 2.0 MW Proton Exchange Membrane (PEM) electrolyser with the necessary auxiliary equipment for hydrogen production, highlighting the port's allocation of resources to innovative energy solutions.</p>

	<b>Case links with Roadmap Step 9: Resources and budget</b>
<b>Case 21 – port of Gävle</b>	<p>A total of about EUR 114 million has been invested in various port development activities between 2010 and 2015. The cost breakdown for the main components of this investment includes about EUR 40 million for dredging and EUR 15 million for stabilisation of material used to create land. This significant expenditure on dredging and stabilisation underlines their importance in the overall expansion strategy. In addition, further contributing to the port's diversified capabilities and infrastructure improvements, about EUR 23 million was allocated for the creation of a new energy pier. To ensure better accessibility and operational efficiency, the project also included the construction of stone walls and improvements to road links.</p>
<b>Case 22 – Port of Antwerp</b>	<p>The Port of Antwerp has initiated a project to use waste heat from a waste incineration plant for district heating. This project, reported to be the largest hot water network in Flanders, aims to reduce 20,000 tonnes of CO2 per year. Project funding of EUR 15 million was provided by the Flemish government through the Flemish Energy and Climate Agency, with additional support from partners including the City of Antwerp, Indaver and Fluvius. This collaboration underlines the coordinated allocation of resources to achieve environmental goals.</p>
<b>Case 23 – North Sea Port</b>	<p>The EUR 150 million facility underscores the port's commitment to alternative fuel production and the circular economy. In addition to advancing renewable energy production, the investment creates economic opportunities by creating 20 direct and 60 indirect jobs, reflecting the port's strategic allocation of resources to support both environmental and economic goals.</p>

Source: Project consortium elaboration.

## Performance assessment and reporting



### Case links with Roadmap Step 10: Performance assessment and reporting

<p><b>Case 1 – Port of Huelva</b></p>	<p>The performance assessment and reporting step for the restoration project in the port of Huelva shows positive results: successful protection of "Spartina maritima", 57 bird species recorded and a carbon sequestration rate of 300 tonnes/year. Surveys show 75% of public support and over 60% visitation for recreation, confirming ecological and community benefits.</p>
<p><b>Case 8 – APMT and Dubai Ports World (DPW)</b></p>	<p>The environmental impacts addressed by this practice include air emissions, particulate matter, sulphur dioxide, nitrogen oxides, and greenhouse gases. DP World evaluates the effectiveness and impact of this green practice as high, showcasing significant improvements in environmental performance.</p>
<p><b>Case 11 – Port of Rotterdam</b></p>	<p>Electric trucks are exempt from parking fees and can use all the truck park facilities. There is 24/7 surveillance of parking and charging bays, and smart scheduling capabilities are provided. Carriers can schedule smart combinations, for instance, by charging their trucks while drivers stay in the truck park for mandatory rest, thus avoiding spending productive time. Anticipating a significant increase in electric truck traffic by 2030, the Port Authority is considering expanding charging infrastructure and implementing truck charging service scheduling system to meet growing demand.</p>
<p><b>Case 14 – Energy Recovery</b></p>	<p>An innovative solution to improve the energy efficiency of RTG crane systems is the integration of an active front-end system. This technology captures and reuses regenerated power, stabilises the power supply against grid fluctuations and achieves up to 95% power regeneration efficiency. It reduces total harmonic distortion to less than 5% and improves power factor to 0.99, promoting energy efficiency and reducing environmental impact by minimising the need for traditional braking systems.</p>
<p><b>Case 16 – Port of Klaipėda</b></p>	<p>The pilot plant at the Port of Klaipėda, which is expected to be operational by 2026, will have an annual production capacity of 300 tonnes of renewable hydrogen. This significant capacity underlines the port's commitment to sustainable energy solutions and the potential impact on reducing greenhouse gas emissions.</p>



## Case links with Roadmap Step 10: Performance assessment and reporting

### Case 17 – Port of Antwerp – Bruges

This project showcases the potential of hydrogen as a viable marine fuel. The Hydrotug employs combustion engines instead of hydrogen fuel cells, thereby pioneering the utilisation of BeHydro V12 dual-fuel medium speed engines. Measuring 30 meters in length, this tug is equipped with two MW V12 engines and boasts a bollard pull capacity of 65 tons. This configuration represents a significant advance in environmentally friendly marine technology, with an overall 65% reduction in fuel consumption and associated emissions

### Case 20 – port of Antwerp

The use of drones in this context offers several advantages. Firstly, it significantly reduces the response time to floating debris. This is crucial in preventing the debris from spreading or causing further environmental damage. Secondly, the drones can quickly cover large areas and access hard-to-reach locations that would be difficult for human operators or conventional vessels to navigate. This comprehensive coverage ensures that even the most remote parts of the port can be monitored and maintained. Furthermore, by integrating drones into debris management, the port is not only improving its operational efficiency, but also reducing its environmental footprint through the use of cutting-edge technology

### Case 23 – North Sea Port

The biodiesel plant at North Sea Port produces up to 115 000 tonnes of biodiesel per year, making it one of the largest in Europe. The fuel produced is equivalent to the annual fuel consumption of approximately 10 000 trucks or 150 000 cars, highlighting the significant impact on reducing carbon emissions and supporting sustainable fuel alternatives.

Source: Project consortium elaboration.

## Monitoring plan



### Case links with Roadmap Step 11: Monitoring plan

<p><b>Case 1 – Port of Huelva</b></p>	<p>Monitoring results from the restoration project indicate successful biodiversity conservation. A total of 57 bird species have been recorded in the restored marshlands, and the population of invasive species has been reduced. The restored marshes are sequestering carbon at a rate of 300 tonnes per year. Community surveys show that coastal marshes are viewed favourably by 75% of respondents, highlighting their perceived ecological benefits. In addition, over 60% of the population visit the marshes at least once a year for recreational activities such as walking, cycling, fishing, photography and leisure.</p>
<p><b>Case 14 – Energy Recovery</b></p>	<p>This solution is ideal for RTG crane systems seeking greater sustainability and operational efficiency. It achieves up to 95% energy recovery efficiency, reduces total harmonic distortion to less than 5% and improves power factor to 0.99. This promotes energy efficiency and reduces environmental impact by minimising the need for traditional braking systems. Continuous monitoring ensures that these systems operate optimally and meet sustainability targets.</p>
<p><b>Case 20 – port of Antwerp</b></p>	<p>The data collected by the drones in the port of Antwerp case, can be used for wider environmental monitoring and research, in addition to helping to improve the debris collected. This comprehensive monitoring plan will help track environmental changes, evaluate the effectiveness of debris management strategies, and support ongoing research efforts to improve the port's overall environmental performance.</p>

Source: Project consortium elaboration.

## GETTING IN TOUCH WITH THE EU

### In person

All over the European Union there are hundreds of Europe Direct information centres. You can find the address of the centre nearest you at: [https://europa.eu/european-union/contact\\_en](https://europa.eu/european-union/contact_en)

### On the phone or by email

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

- by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),
- at the following standard number: +32 22999696, or
- by email via: [https://europa.eu/european-union/contact\\_en](https://europa.eu/european-union/contact_en)

## FINDING INFORMATION ABOUT THE EU

### Online

Information about the European Union in all the official languages of the EU is available on the Europa website at: [https://europa.eu/european-union/index\\_en](https://europa.eu/european-union/index_en)

### EU publications

You can download or order free and priced EU publications from: <https://publications.europa.eu/en/publications>. Multiple copies of free publications may be obtained by contacting Europe Direct or your local information centre (see [https://europa.eu/european-union/contact\\_en](https://europa.eu/european-union/contact_en) ).

### EU law and related documents

For access to legal information from the EU, including all EU law since 1952 in all the official language versions, go to EUR-Lex at: <http://eur-lex.europa.eu>

### Open data from the EU

The EU Open Data Portal ( <http://data.europa.eu/euodp/en> ) provides access to datasets from the EU. Data can be downloaded and reused for free, for both commercial and non-commercial purposes.

European  
Commission

