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D2.1 Report of stakeholders' know-how limitations

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Part one: Role of Ports in Maritime Energy Transition: Trends, Drivers, Barriers, and Solutions
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Part two: Cultural analysis and social inclusion approach: The role of women in the port and port logistics
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Part three: Key tools and certifications for the port energy transition
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* It is worth noting that this deliverable is a compilation of different tasks conducted by different partners. These tasks and subtasks have gone through rigorous reviews by the partners over the past five months. This led to an in-advance fully reviewed Deliverable.

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07/08/2023	0.3	Full Deliverable	Final editing by Magellan Circle

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List of Acronyms

Abbreviation / Acronym	Description
AI	Artificial Intelligience
AIS	Automatic Identification System
ANLEG	Argo-Anleg GmbH
ASEAN	Association of Southeast Asian Nations
ATP	ATPERSON Formación y Empleo SL
BEMS	Building Energy Management Systems
CCS	Carbon Capture & Storage
CR	Corporate Responsibility
CRCL	Circle Group – European Affairs Consultancy
CSI	Clean Shipping Index
CSR	Corporate Social Responsibility
EMAS	EU Eco-Management and Auditing Schemes
EMS	Environment Management System
EnMS	Energy Management System
ESPO	European Seaport Organization
ESI	Environmental Ship Index
ETPs	Energy transition Projects
ETS	Emission Trading Scheme (System)
EU	European Union
EVDI	existing vessel design index
FV	Fundación Valenciaport
G7	Group of 7
GDP	Gross Domestic Product
GDPR	General Data Protection Regulation
GHG	Greenhouse Gas
GM	Green Marine
HVAC	Heating, Ventilation, and Air Conditioning
IAPH	International Association of Ports and Harbours

IEEE	Institute of Electrical and Electronics Engineers
IEMS	Industrial Energy Management Systems
IHE	Institute for Hydraulic and Environmental Engineering
IHE	IHE Delft Institute for Water
ILO	International Labour Organization
IMO	International Maritime Organization
IoT	Internet of Things
ISO	International Standard Organization
ITF	International Transport Forum
JIT	Just In Time
KPI	Key Performance Indicator
LNG	Liquefied Natural Gas
LRQA	Lloyd's Register Quality Assurance
MBM	Market Based Measure
MEC	Maritime Energy Contracting
NDC	National Determined Contributions
NGO	Non-Governmental Organization
OPS	Onshore Power Supply
OPS	Onshore Power Supply
PERS	Port Environmental Review System
PSC	Port State Control
R&D	Research and Development
R&D	Research and Development
RINA-C	RINA Consulting
SDM	Self Diagnosis Method
SEAs	Significant Environmental Aspects
SEANERGY	Sustainability EducationAl programme for greeNEr fuels and enerGY on ports
SMS	Sustainability Management System
SSE	Shore-Side Electricity
SOSEA	Strategic Overview Of Environmental Aspects
STCW	Standards of Training, Certification, and Watchkeeping

STEM	Science, Technology, Engineering and Mathematics
SWe	Single Window environment
TEAP	Tool for the Identification and Assessment of Environmental Aspects in Ports
TEIP	Tool for the Identification and Implementation of Environmental Indicators in Ports
TEU	Twenty Foot Equivalent Units
TGCs	Tradable Green Certificates
ToS	Terminal Operating Systems
UN	United Nations
UN	United Nations
US	United States
WEAI	Women's Empowerment in Agriculture Index
WISTA	Women's International Shipping & Trading Association
WMU	World Maritime University
ZER0-E	Zer-0 Emissions Engineering B.V.

1 Introduction

This deliverable encompasses three main parts (Part 1, Part 2, and Part 3) that address issues regarding the port stakeholders, barriers, inclusion issues, and energy transition.

1.1 Purpose of the deliverable

The purpose of Deliverable 2.1, composed of three parts (1, 2, 3), is to ascertain the knowledge limitations of stakeholders within the European port industry and provide insights into ways to overcome these barriers. By fulfilling these aims, this deliverable contributes to addressing the current information limitations, thereby enabling stakeholders to take immediate action towards achieving EU green transition targets.

Part 1 purpose is to provide an overview of stakeholders' barriers for the integration of energy transition in ports, while at the same time discovering pathways to provide solutions to mitigate such barriers (Subtask 1.1.1 – Analysis of the needs, motivation, drivers and barriers of target SEANERGY' stakeholders). WMU led this task and reviewed the literature, i.e., existing articles and projects that examine needs, motivations, drivers and barriers for the incorporation of relevant clean energy and fuel technologies of international ports, with special emphasis on EU ports. While the review compiled the barriers and solutions, a survey was structured and targeted different port stakeholders (identified in D1.1.) to gain insights about the situation in EU ports and rank the barriers and solutions according to stakeholders' opinions (Subtask 2.1.1 Understanding and classifying know-how limitations). Subtask 1.1.1 was led by WMU, and the participants were CRCL, RINA-C, FV, DAFN, IHE. Subtask was led by WMU, and the participants were FPS, FV, DAFN, and ZER0-E.

Part 2 purpose is to provide a comprehensive view of cultural analysis and social inclusion in EU ports (Subtask 1.1.2 Cultural Analysis and Social Inclusion Approach). This subtask reviewed the sociocultural and behavioural aspects (along with the SSH disciplines stated in the previous sections) that directly impact the successful clean energy and fuel transition. The focus is on economics, politics, sociology, demography and ethnology (all with a gender-based lens to understand why the port industry has been mainly predominated by men). Further stakeholders' validation, through survey is being conducted. Subtask 1.1.2 was led by IHE, and the participants were WMU, CRCL, RINA-C, FV.

Part 3 purpose is to identify key tools and certifications that enable EU ports' energy transition (Subtask 2.1.2 Identifying key tools and certifications). Based on disk research (review) an in-depth investigation was carried out on the tools and certifications necessary to facilitate the transition. Subtask 2.1.2 was led by MAGCRCL, and the participants were ATP, RINA-C, ZER0-E, and ANLEG.

1.2 Structure of the deliverable

The purpose of Deliverable 2.1, which comprises three distinct parts, is to better understand and address the knowledge limitations of port energy transition stakeholders. The remainder of this report is sectioned into these specific parts, each with its individual introduction and methodological approach. Here are the elements each part focuses on:

Part 1: *Role of Ports in Maritime Energy Transition: Trends, Drivers, Barriers, and Solutions* - This part of the deliverable is primarily dedicated to the analysis of the stakeholder questionnaire, focusing on the role of ports in the energy transition in the maritime sector.

Part 2: **Cultural Analysis and Social Inclusion Approach: The Role of Women in the Port and Port Logistics** - In this section, we delve into the cultural analysis and examine the part played by women in the port and port logistics sectors, with a keen emphasis on promoting social inclusion.

Part 3: *Key Tools and Certifications for Port Energy Transition* - The final part of the deliverable discusses the essential tools and certifications necessary for facilitating the energy transition within the ports.

Each part of this deliverable has been designed and executed following the guidelines outlined in the grant agreement project for Deliverable D2.1, aiming to address the know-how limitations of stakeholders and to boost their ability to adapt to new technologies and processes. By focusing on these aspects, we aim to fill the information gaps prevalent among the average European port stakeholders and help them overcome barriers preventing immediate action.

This approach is founded on the surveys from task 1.1.1, and 2.1.1. which have been extended to include additional questions targeting stakeholders from pan-European ports. In this way, we aim to categorize and fully comprehend both the technological and knowledge limitations that may be hindering stakeholders in their roles.

1.2 Relation to other project deliverables

This report is directly connected with various Work Packages. With respect to Work Package one, i.e., Task 1.1 SEANERGY's Stakeholders groups identification and framework set-up, particularly Subtask 1.1.1 – Analysis of the needs, motivation, drivers and barriers of target SEANERGY's stakeholders & Subtask 1.1.2 Cultural Analysis and Social Inclusion Approach. Additionally, this deliverable archives

Work Package two Task 2.1 Capturing target stakeholders’ feedback on know-how limitations, which contains two subtasks (i.e., Subtask 2.1.1 Understanding and classifying know-how limitations & Subtask 2.1.2 Identifying key tools and certifications). Importantly, this report also works as a headmark for the other Work Packages that will conduct workshops so that a wide variety of stakeholders' barriers and solutions to port energy transition can be targeted. Some results can be included in the Port Master Plan in Work Package three.

2 Part one- Role of Ports in Maritime Energy Transition: Trends, Drivers, Barriers, Solutions

Introduction

The contribution of shipping to all transport emissions is 10%, while the share of transport emissions to all global carbon dioxide emissions is estimated at 24% (HFW, 2021). Supply chains are characterized by seaports that act as key nodes between all parties participating in the chain (BASREC, 2014). However, as many of the major global ports are located in or nearby densely populated urban areas, there is increasing pressure on these ports to improve their environmental performance (HFW, 2021). The concept of the port energy transition is multifaceted and multi-objective, with different stakeholders involved, so it is difficult to define its scope. Management of ports worldwide is subject to uncertainty regarding the authority and accountability levels, contributing to the task's complexity. Since ports are situated between maritime transport and terrestrial activities, they can significantly influence climate change governance within the supply chain (Nursey-Bray, 2016). Furthermore, as shown in Figure 1, port utilisation has expanded over the years.

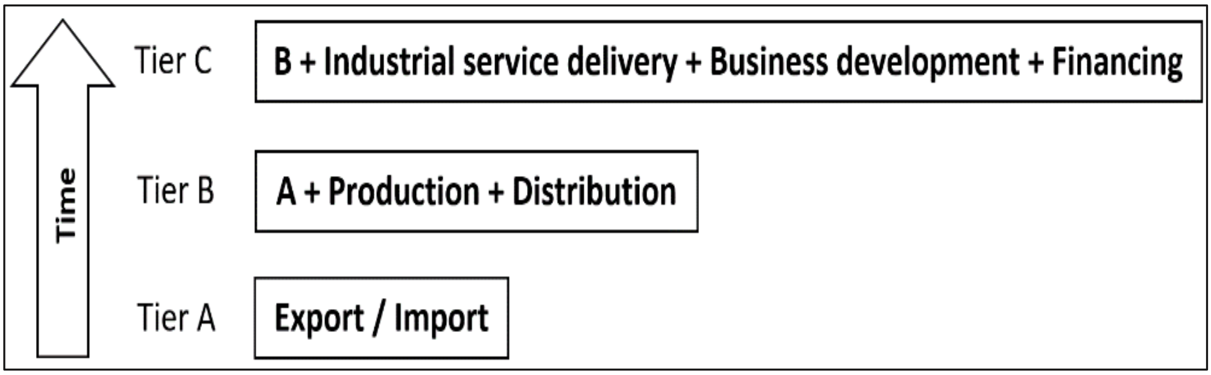

Figure 1: An evolutionary expansion of port utilisation
Source: Adopted from (Sánchez and Mouftier, 2016)

The shipping and logistics industries are under increasing pressure to achieve low or net zero carbon operations, and ports are becoming catalyzers in the efforts to achieve this goal (HFW, 2021). In the context of decarbonisation, ports can play an instrumental role. They can act as energy hubs to create a green network for integrated electricity, hydrogen and other renewable and low-carbon fuel systems (EU COMMISSION, 2021a). In the same vein, IMO has encouraged ports to facilitate the implementation of the GHG strategy through activities such as providing shore-side power from renewable sources, the establishment of infrastructure for low and zero-carbon fuels, optimizing the logistics chain and planning, providing incentives for green ships, and optimisation of port calls (IMO, 2019). The European Commission, in line with the European Green Deal objective (reducing emissions from transport by 90% by 2050), has promoted the growth of short sea shipping and the use of inland waterways to green freight transport (EU COMMISSION, 2021b).

Part 1 aims to investigate the pathways of port energy transition and explore the trends of future ports, drivers, barriers, and practical solutions to overcome these barriers.

Research Scope

The intention of this research is to cover not only the decarbonisation of ports inside the port boundary but also the ship-port interface and port-hinterland interface. As shown in Figure 2, shipping emissions (70%) and hinterland emissions (20%) make up a significant portion of the total port emissions in comparison with emissions resulting from the operation of port machinery (10%). This data is an estimation based on different studies such as Gibbs et al. (2014) and ITF/OECD (2014).

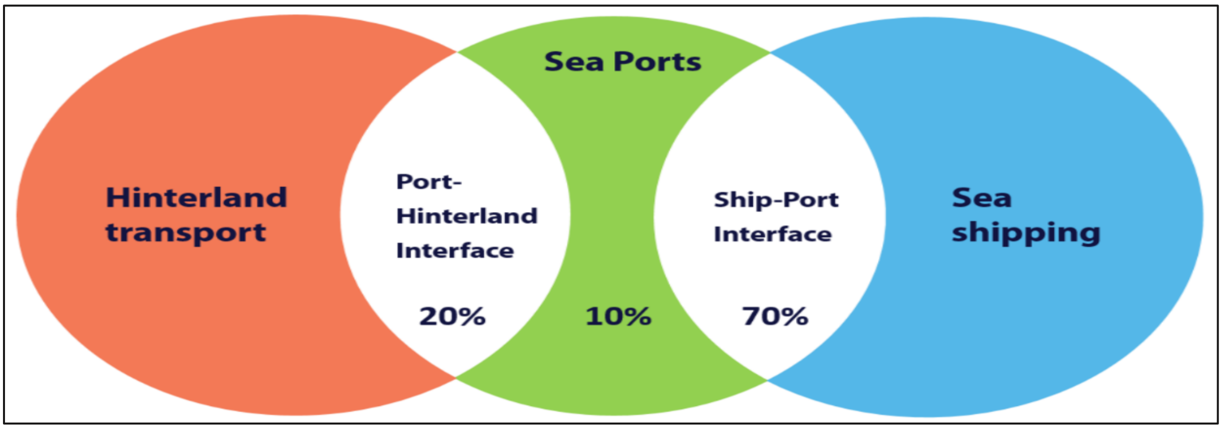

Figure 2: Port emission elements

According to Gibbs et al. (2014), a ship's emissions at port represent 6 to 10% of its total emissions (based on two references cited in this study). Even if the upper limit (10%) is considered, the port emission due to its machinery could be estimated as less than 1.5% of the total emission of a ship. It is in line with Gibbs et al. (2014) estimation for the UK ports, which is less than 2%. It was necessary to highlight these details to emphasize the importance of ports in reducing emissions from ships and transport in the hinterland. From another point of view, emissions from the port business have been categorized into three scopes (HFW, 2021; WPCI, 2010; Gibbs et al., 2014):

Scope 1, Port Direct Sources:

"These sources are directly under the control and operation of the port administration entity and include port-owned fleet vehicles, port administration-owned or leased vehicles, buildings (e.g., boilers, furnaces, etc.), port-owned and operated cargo handling equipment (even though operated by tenants), and any other emissions sources that are owned and operated by the port administrative authority" (WPCI, 2010).

Scope 2, Port Indirect Sources:
"These sources include port-purchased electricity for port administration-owned buildings and operations. Tenant power and energy purchases are not included in this Scope" (WPCI, 2010).

Scope 3, Other Indirect Sources:
"These sources are typically associated with tenant operations and include ships, trucks, cargo handling equipment, rail locomotives, harbour craft, tenant buildings, tenant purchased electricity, and port and tenant employee commuting (train, personal car, public transportation, etc.)" (WPCI, 2010).

This research investigates the role of ports in emission reduction in these three scopes while exploring barriers to and solutions for this process.

Methodology

In this study, we examine barriers that hinder seaports in achieving the energy transition objectives and then investigate best practices and solutions following these barriers. To do so, a systematic literature review is conducted. To gain a general understanding of the barriers' area and category, it is decided to deploy the barrier template constructed by Masodzadeh et al. (2022a). Even though this template has been established for barriers against energy efficiency, considering its comprehensiveness, it has also been used in the energy transition (Masodzadeh et al., 2022a). As shown in Figure 3, this template, with a multi-disciplinary approach, can connect the energy issues to the main pillars of the ESG concept (environment, social, and governance).

Economic barriers	Market barriers (Non-Market failure)	Heterogeneity	
		Risk	
		Hidden cost	
		Access to capital	
		Slim organization	
	Market failure	Information barriers	Imperfect information
			Asymmetric information
		Split incentives	
Non-Economic barriers	Organizational and managerial barriers		
	Behavioral and human element barriers		
	Policy barriers		
	Technical barriers		

Figure 3: Barrier template
Source: (Masodzadeh et al., 2022a)

The process of the literature review is structured in 5 stages, as shown in Figure 4. Data sources used for the analysis in this study include secondary data taken from published peer reviewed articles, on-line reports, industry websites, and government statistics. The main body of the literature discussed in this research includes industry reports explored by the follow up search or snowballing.

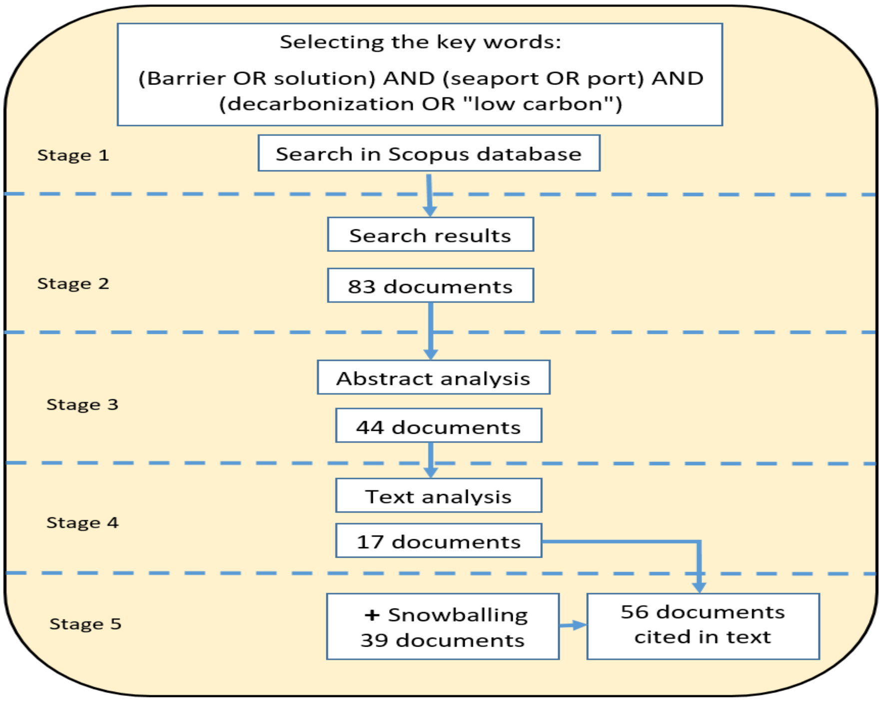

Figure 4: Process of literature review

Trends

The following trends may influence maritime transport and, thus ports.

- **Shift in the economic balance and increased inequalities** resulting in political tensions and *protectionism* (Deloitte, 2020). With a growing trend of protectionism, states try to move their supply points inside their borders close to their consumption market, the so-called "reshoring of industries", resulting in more demand for raw materials and affecting ship sizes and sailing frequencies. Protectionism, therefore, can potentially affect global trade and business models (Deloitte, 2020).
- **Increased use of technologies** throughout the whole supply chain: Technological solutions such as automation and digitalisation are needed to improve productivity. Smart ports will have a competitive advantage in future (Deloitte, 2020).
- **Increase in investment in new technologies and reduction in technology costs** (Deloitte, 2020)
- **Increase in space productivity within seaports** (Deloitte, 2020)
- **Changes in supply and demand points** (Deloitte, 2020) due to: 1. changes in the cost of labour market 2. Increase in local production as a result of technology advancement and less labour-intensive production process. This, in turn, results in different trade routes.
- **Growing opportunities in niche markets** (Deloitte, 2020)**:** Although all predictions indicate that containerisation is on the rise, overcapacity in this shipping segment will continue to exist. Therefore, investment in other sectors like cruise, LNG, and offshore markets could be safer.
- **A shift in strategy from economy-of-scale vessels to green vessels** (Deloitte, 2020) is predictable. Therefore, substantial investment in green infrastructure can create competitive advantages for ports.
- **Emergence and utilisation of the Northern Sea route and transpolar passage (Due to global warming)** (Deloitte, 2020)**.** This shorter route between the Far East and Europe provides access to the Arctic oil and gas resources and can increase world trade due to the less transport cost.
- **Changes in global Geostrategy,** e.g. One belt, One Road initiative, the Trans-Pacific Partnership (TPP), and the expansion of major arteries (the Panama Canal and the Suez Canal) that can lead to changes in shipping routes and demand, and port services (Sánchez and Mouftier, 2016).
- **Advanced technology and sustainability as competitive advantages of the future ports** (Deloitte, 2020; Christodoulou and Cullinane, 2019; Notteboom et al., 2020). Ports can project a green image to society by adopting sustainable procedures, implementing advanced technologies, and establishing green infrastructure.

- **Multi-stakeholder collaborative ecosystem** (Deloitte, 2020; Notteboom et al., 2020): As a result of providing the necessary infrastructure, such as digitalisation and automation, the vertical and horizontal ties between stakeholders in the hinterland, seaports, and shipping companies will become even stronger.

Drivers

The following section provides cluster rivers for ports to reduce their emissions and increase energy efficiency through transitions.

- **Global population growth** with more concentration on urban centers (Deloitte, 2020) is a driver to push port cities towards sustainability. The fact that "almost three-quarters of the world's population live within 50km of the sea" (World Economic Forum, 2022), underlines the importance of this driver.
- **Environmental concerns, namely global warming and climate change** (Deloitte, 2020; Christodoulou and Cullinane; 2019, BASREC, 2014; Notteboom et al., 2020) are persuading ports to take mitigating actions ranging from operational measures like digitalisation and sustainability management systems (ENM and EnMS), to the technical measures like the development of SSE, alternative fuel bunkering facilities, utilisation of renewable sources of energy, etc.
- **In the long term, the depletion of oil resources** is a driver to force the international marine shipping industry to switch to another source of energy (Cannon, 2008).
- **Regulatory pressure** (Acciaro et al., 2014a; Notteboom et al., 2020) on the maritime industry to be aligned, for instance, with the Paris agreement (Deloitte, 2020) or contribution of ports and shipping in countries' NDCs or "national climate change strategies" (Nursey-Bray, 2016). For instance, all EU ports are obliged to install OPS by the end of 2025 according to the European Directive 2014/94/EU and to establish the alternative fuel infrastructure by developing LNG bunkering stations all around the EU (Christodoulou and Cullinane, 2019, Acciaro et al., 2014b).
- **Social pressure** (Acciaro et al., 2014b**;** Notteboom et al., 2020), in particular, by the young generation in requesting fundamental reactions by political leaders and businesses regarding environmental threats. The UN Youth Climate Summit could be the flagship of these activities (Deloitte, 2020). There is often a strong focus on air quality issues in political and societal debates concerning port development plans (BASREC, 2014).
- **Stakeholders' influence** (Christodoulou and Cullinane, 2019; Notteboom et al., 2020) is undeniable. A clear example is the influence of the municipalities on ports in operations and their policies on different aspects of sustainability.

- **Increased efficiency (profitability) or Economic motivations** to reduce operational costs, e.g. energy costs (Christodoulou and Cullinane, 2019; Acciaro et al., 2014a; BASREC, 2014; Notteboom et al., 2020; Lam and Van de Voorde, 2012).
- **Access to financial aid** strongly motivates ports to invest and initiate green activities (Christodoulou and Cullinane, 2019).
- **Insecurity in energy supply** drives seaports to have sustainability goals in their strategic plan. The current energy crisis in Europe due to the Ukraine-Russia conflict could be an example of this.
- **Green technologies and sustainability plans as a competitive advantage**, persuade ports to adopt them as part of the port strategy (Deloitte, 2020; Sánchez and Mouftier, 2016; Christodoulou and Cullinane, 2019; Notteboom et al., 2020; Acciaro, 2015).
- **Customer retention** (Acciaro, 2015; Lam and Van de Voorde, 2012) or **Demand from customers** (Notteboom et al., 2020): Increased customer expectations regarding sustainable commodity transportation place high pressure on supply chain elements such as shippers and shipping lines, which is readily transferred to ports. Wall-Mart Green Label or the IKEA Eco Score Cards are some examples of this (Acciaro, 2015). To keep the continuity of the chain, ports must respond to such demands transparently.
- **Green image or reputation** (Acciaro et al., 2014a; Acciaro et al., 2014b; Notteboom et al., 2020; Acciaro, 2015) is a desired benefit that can be obtained by addressing other key drivers, such as regulatory and social pressures.
- **Ability to attract young employees** is a feature that a port could achieve with a green image and high reputation (Notteboom et al., 2020).

2.1 Results of literature review: Barriers and solutions

The following section presents the barriers that hold back ports' energy transition and emission reduction. In the same vein, solutions for these barriers are presented below each barrier.

2.1.1 Market barriers (Non-market failures)

Heterogeneity

Barriers

- The diversity of ports in terms of size, operation (type of vessels), infrastructure, local governance, ownership (type of management), geographical/hydrographical peculiarities, traffic and trade volume, energy sources, number and nature of stakeholders, and other factors, create challenges to develop a unified response to environmental and sustainability demands in port industry (Kuznetsov et al., 2015; BASREC, 2014; Wooldridge et al., 1999).

- The issue of heterogeneity is even more complex for smaller ports where the diversity characterizes these ports with different purposes such as fishery, recreational boats, tourism, providing different port facilities, etc. (Kuznetsov et al., 2015).
- Diversity of ports is a barrier to the systematic assessment of the overall sustainability of a port and its operations (Kuznetsov et al., 2015).

Solutions

- While there is a great deal of diversity in port details, establishing an EMS that is realistic and tailored to each port would be a common initiative (Wooldridge et al., 1999). Environmental monitoring is the first and most essential step for ports to realize their environmental status. Implementing a monitoring system leads port management to the sets of collected data, environmental (energy) baseline, and designing and analyzing the relevant KPIs (Wooldridge et al., 1999). Regardless of the port's differences, these are common steps for all ports.

Risks

Barriers

- **External risk:**

- Global economic trends are under the influence of unexpected features such as pandemics and economic recessions (Masodzadeh et al., 2022a).
- Natural disasters in ports, e.g. sea level rise, storms, tsunamis, floods, soil erosion on coastlines, and droughts that may affect ship draft limits in rivers and inland waterways (Sánchez and Mouftier, 2016; Drewry, 2016; Nursey-Bray, 2016)
- Energy price and energy security (Masodzadeh et al., 2022a), e.g. stability in gas supply through Nord stream pipeline.
- Geopolitical occurrences (Masodzadeh et al., 2022a), e.g. Ukraine-Russia conflict and sanctions on oil export of Iran and Venezuela.
- Uncertainties regarding future policies (Notteboom et al., 2020), e.g. uncertainties in compulsion of On Shore Power supply, banning of fossil fuels, the emergence of new Emission Control Areas, or inclusion of shipping in EU ETS.

- **Business risk:**

- The growing popularity of alternative fuels could trigger an alarm for ports that are currently oil hubs, such as Rotterdam (Acciaro et al., 2014b).

- Reconfiguration of the network and shipping routes led to fewer port calls (blank sailing) due to the large size of ships (economy of scale) that affects the port transactions and revenue (Sánchez and Mouftier, 2016)
- Changes in ports' service demand as a result of shifts in business models, trade patterns, and supply/demand points due to:
  - Changes in the materials transported and in final products (Sánchez and Mouftier, 2016)
  - Emergence of advanced technologies in manufacturing and production process, e.g. 3D printing and unmanned vehicles as well as new patterns in consumption, e.g. e-commerce (Sánchez and Mouftier, 2016; Drewry, 2016)
- A port may undergo major changes or even be closed as a result of a change in use. It is possible for example, that general cargo terminals be converted to container terminals or coal export/import terminals be completely eliminated (Authors idea).

- **Technical risk:**

- Uncertainty about green solutions (Notteboom et al., 2020) or doubt in the technical performance of new technology, and potential of operation disruptions (Acciaro et al., 2014a)
- Social admissibility for some new technologies at ports in the vicinity of cities is in doubt (e.g., LNG bunkering facility (Aneziris et al., 2020)). For instance, it has become more common for LNG liquefaction and regasification plants to be located away from populated areas (Acciaro et al., 2014b). Similarly, there has been opposition to the establishment of Ammonia production and bunkering infrastructure in port cities.

Solutions

- There are many examples of initiatives and best practices in adaptation to natural disasters in ports. For instance, "Climate proofing as part of urban renewal in ports is being trialled by the Port of Genoa, sustainability and climate mitigation and adaptation planning is a feature of the Ports of Amsterdam, San Diego and Port of Seattle, and in Sydney, the ports corporation has invested in climate change risk assessments" (Nursey-Bray, 2016). The following cases are practical examples: raising the port level to 3 meters above sea level to protect yards from storms in the port of Mississippi, and raising quay walls, improvements in the surface drainage, and increasing the maintenance and replacement of port infrastructure in Vietnamese ports (Nursey-Bray, 2016).
- An accurate cost-benefit analysis (CBA) can assist ports' management in selecting the most beneficial projects and reducing investment risks (Lam and Van de Voorde, 2012).
- Shared information and lessons learned from implementing new technologies in other ports is extremely valuable in making informed decisions with the least risk (Nursey-Bray, 2016).

- Port management should place the **preliminary studies** at the early steps of the project preparation cycle. Preliminary studies could include project risk assessment, environmental impact assessment, as well as economic and technical feasibility studies that are essential in raising awareness of the investment risks and shedding light on the mitigation measures (Authors idea).
- Receiving subsidized insurance support at the earliest stage of the integration of green technologies into port infrastructure can reduce the risk of investment (Authors idea).

Hidden cost

Barriers

- Port congestion: High congestion at ports will create long-term effects, such as lower inter-port competitiveness and a decrease in demand (Saeed et al., 2018).
- The effect of *asset specificity* can impact port congestion. "Asset specificity means an investment carried out by a firm, such as by a shipping company that has little or no use outside particular ports" (Saeed et al., 2018). For instance, if a port cannot provide LNG bunkering facilities, it may lose port calls from ships requiring this service.
- Transaction costs
  - "Cost of obtaining information on the energy use of purchased equipment" (Masodzadeh et al., 2022a)
  - Cost of identifying opportunities, analyzing cost-effectiveness, feasibility studies, and tendering (IMO, 2021; Acciaro et al., 2014b)
  - Bounded rationality (non-optimal choice) and asymmetric information (incomplete or distorted information) can lead to high transaction costs (Saeed et al., 2018).
- Contract-associated costs such as consultancy, meetings, writing the contract, etc. (Masodzadeh et al., 2022a)
- Cost related to the establishment of EnMS or EMS and certification (Masodzadeh et al., 2022a)
- "Overhead cost for energy management including employment of energy manager and auditors, data collection and analysis, sub-metering, and fault finding" (Masodzadeh et al., 2022a)
- Cost for training personnel (Masodzadeh et al., 2022a)
- A potential opportunity cost may arise if an occasion is missed to invest in more productive and beneficial initiatives (Masodzadeh et al., 2022a; Saeed et al., 2018).

Solutions

- To mitigate the consequences of non-optimal decisions due to asymmetric information and the opportunistic behaviour of some partners, the adaptation of "safeguard measures, such as contingent claims contracts and monitoring" is recommended (Saeed et al., 2018).

Access to capital

Barriers

- Doubt in profitability and return on investment (ROI) of the green measure (Notteboom et al., 2020; Ashrafi et al., 2019; Radwan et al., 2019)
- High capital cost for the establishment of green infrastructures in ports (Acciaro et al., 2014a; BASREC, 2014; Chen et al., 2019; Radwan et al., 2019); for instance, 1 million USD per berth equipped with OPS (Gibbs et al., 2014) and similar to this high cost in the establishment of LNG bunkering facility (Park N.K. and Park S.K., 2019).
- The cost of converting diesel engines to dual-fuel engines or installation of SSE equipment onboard ships is a considerable burden on ship owners. Such adaptations by ship owners are vital, since establishing the port infrastructure not used by ships will result in stranded assets in
- ports (Acciaro et al., 2014).
- In a port, energy efficiency is not considered a priority business area because of the low share of energy costs in total costs (BASREC, 2014).
- Stranded energy efficiency investment: for instance, investment in LNG bunkering infrastructure at ports with doubt about future alternative fuel could lead to stranded assets at ports (Masodzadeh et al., 2022a).
- Lack of resources to engage specialists to assess the potential impact of the port operation on port sustainability (Kuznetsov et al., 2015).
- Lack of cost-effectiveness of the equipment; for instance the case of OPS:

  Considering the very low potential of OPS in CO_2 reduction, its capital investment is very high (1 million USD per berth equipped with OPS). According to Gibbs et al. (2014), the average of ships' emissions at the port is around one-tenth of their emission at sea. Assuming that all ships and all ports globally are equipped with OPS, only 10 percent of shipping emissions will be eliminated. Discharge operation in oil tankers is performed by cargo oil pump turbines which are very energy-demanding (steam boilers) and connecting to OPS for this segment of shipping has no economic rationalisation. Several factors can influence the rationality of OPS installation, including port congestion, frequency of port visits by specific ships, and the distance of ports from residential areas. For example, it is not possible to imagine OPS installation at oil and gas terminals located far from cities. Furthermore, green electricity to feed OPS is not available in all ports. The consistency of voltage and frequency between the port OPS and the ship busbar is also of high importance. It is also not economically feasible to install OPS on vessels with fewer port calls. In the case of RO-RO ships that visit ports near cities on a regular basis, OPS may be a viable option, however, the downside is that the time spent at berth could be so short that it becomes impractical for them to install OPS. Last but not least, the time required to connect and disconnect OPS (1 hour per call) inhibits the minimisation of turnaround time at ports (Gibbs et al., 2014).

Solutions

- Digitalisation (BASREC, 2014), adopting an energy management system (Port of Dover*)*, conducting an energy audit scheme (Port of Antwerp), and carbon footprint calculation (Port of Valencia) (ESPO, 2012a) can lead to a significant reduction in the port operational costs.
- Continuous financial incentives provided by public authorities (e.g. tax exemptions or subsidies) and green loans by commercial banks are very stimulating in green investment decision-making (Notteboom et al., 2020). Providing subsidies for ships' electricity consumption through OPS installation at ports encourages port management to provide this facility (Gothenburg).
- Economic models:
    - **Investment in and operation of port infrastructures by shippers and shipping companies (**Saeed et al., 2018**):** in this collaborative model, shippers (cargo owners) or/and shipping companies whose vessels are liner in specific routes, invest in port infrastructure that is used by their vessels and further these infrastructures are operated by the representative of these companies at ports. For instance, in the case of OPS connection at the port of Gothenburg, it is the result of collaboration between the Port of Gothenburg, paper and forest products suppliers Stora Enso, and the shipping companies Wagenborg and Cobelfret. Stena line in the port of Gothenburg has been the operator of a new OPS facility since 2011 for its new ferries used on the route to Germany (BASREC, 2014; ESPO, 2012a).
    - **MEC and ESC models:** Maritime Energy Contracting (MEC), in the case of cooperation between technology providers and ship owners in the installation of scrubber and LNG retrofit, has been practised in the shipping industry. However, the Energy Supply Contracting (ESC) model is a new emerging economic model in shipping. In these models, the energy provider (producer and transporter) supplies the energy at the consumption point to the clients with less economic power (or motivation) to invest in such an energy supply chain. Supply of Liquid Biogas (LBG) at seaports could be an example of this model, considering that the final decision-makers are seaports. The success of this model

depends, of course, on subsidies provided to biofuels such as LBG. Philipp (2020) has discussed the LBG MEC model in detail.

- **Joint investment:** In this model, the national and regional governments take the major part of investment in support of the port authority. An example of this is the port of Genoa, in which the project of quay electrification has been financed 50% by the national government, 30% by the regional government, and 20% by the port authority (Acciaro et al., 2014b).

- The research by Notteboom et al. (2020) found that respondents were more supportive of subsidies than tax systems.
- Financial support by the future MBM Fund could be necessary and determinant in developing green infrastructure at ports.
- Commercial operations should be benefited from improvements in red tape and tax procedures. In order to achieve sustainable development in ports, a fiscal policy favoring investment in green and innovative initiatives and simplifying the tax procedures will be imperative (Sánchez and Mouftier, 2016).

Slim organisation

Barriers

- It is rare to find a systematic approach to sustainability management in small ports. It is difficult for many small ports to sustain their profitability in the face of the costs associated with implementing EMS practices, such as ISO 14001 (Kuznetsov et al., 2015; Ashrafi et al., 2019).
- In small ports, sustainable port management could also be hindered by a lack of knowledge and resources (Puente-Rodríguez et al., 2016; Ashrafi et al., 2019).
- A growing trend in the economy of scale in shipbuilding (intention to build larger vessels) has resulted in a loss of revenue for small ports due to blank sailings and fewer port calls (Sánchez and Mouftier, 2016).
- Small ports might not have enough resources to conceptualize the environmental work, such as implementing the differentiated port due policy (Mellin and Rydhed, 2011).

Solution

- “A plausible way forward for small ports is to work collectively with neighboring ports to acquire expert consultation, establish contacts and management systems, benefit from co-representation, and engage proactively with funding initiatives to promote environmental awareness” (Ashrafi et al., 2019) cited from (Dinwoodie et al., 2012).

2.1.2 Market failures

Information barriers

Barriers

- Scarce information
  - Lack of data concerning berth specifications: Shipping companies and charterers need precise specifications of the berths in a port to plan and select the best ship in terms of the draft, length, and beam compatible with berth dimensions or to select an appropriate next port of call. "The terminal and berth identifiers are currently not inputted into AIS". (IMO, 2021)
  - "Reluctance of key stakeholders (port, terminals and shipping) and data owners in the port call process to share information and data" (IMO, 2021).
  - In a port area, information on energy consumption is generally collected from companies that work there; however, no detailed information is available regarding where energy is being consumed or how energy could be more efficiently utilized (BASREC, 2014).
- Inaccurate information
  - "Lack of data quality, timelines and standardisation of data being shared" (IMO, 2021).
  - The lack of operational data can result in inaccurate emission inventories (WPCI, 2010), which can lead to unrealistic life cycle assessment studies.
- Lack of information disclosure and transparency: There are often challenges associated with the exchange of information between different port-related actors (BASREC, 2014; TURUN YLIOPISTON, 2012).
- Asymmetric information: Asymmetry in information occurs when some opportunistic actors disclose incomplete information (leading to adverse selection) or distorted information (moral hazard) (Saeed et al., 2018; Masodzadeh et al., 2022a).

Solutions

- Future Single Window environment (SWe) could unify and standardize the data requirements and reporting formats, and in the same direction, digitalisation can expedite the data exchange process to minimize the ships waiting time to get port clearance. The EU is almost at the final stages of the establishment of the European Maritime Single Window environment (EMSWe) (EU Commission, 2019).
- Develop international standards for electronic data exchange and promote a collaborative approach for all stakeholders to share data (IMO, 2021).

- Port Master Data should be expanded by including terminal databases and access to these data to be granted to relevant stakeholders like charterers (IMO, 2021).
- Dissemination of information with reference to environmental compliance can create more transparency and promote green objectives at ports (Acciaro et al., 2014a).
- Spreading information between ports, for instance, in the form of best practices, is recommended (BASREC, 2014).
- Digitalisation is a way to improve the precision of the available data. For instance, Terminal Operating System (TOS) is a software tool to manage the information flow (BASREC, 2014; Green Crane, 2013). Using an IT system can facilitate the mapping of energy profiles by providing accurate monitoring, data collection, processing, and logging, significantly improving port energy (electrical) management (Green Crane, 2013).
- "Digitalisation of port management can improve the data sharing process, save time, and increase the chance to deploy options like the electronic bill of lading. Policy intervention by the IMO is required in this case" (Masodzadeh et al., 2022a; Poulsen and Sampson, 2020).
- Data dissemination should be integrated into the energy management system as a best practice. For example, the port of Dover in the UK encourages port tenants to participate in implementing EnMS and provide feedback on their performance against targets through a monitoring scheme, regular meetings, and newsletters (ESPO, 2012a).
- In order to develop an accurate port emission inventory, port tenants, shipping lines, and other port users play an essential role by providing accurate information regarding their activities and operations (OECD, 2013).
- Regular publication of informative reports like Technology Readiness Level (TRL), Investment Readiness Level (IRL), and Community Readiness Level (CRL) (Lloyd's Register, 2022), can raise the awareness of technology providers, financial institutes, ports, and ship owners on the latest technology advancement, maturity and penetration level (Author idea).

Split incentive (Misplaced incentives/separation of costs and benefits)

Barriers

- **Governments Vs private port management:** Environmental policies by governments, which are primarily based on emissions and energy targets, can directly affect port management. These targets could impose commitment on ports, for instance, to contribute to the country's NDC, improve the port-hinterland connectivity, etc. (Author idea). As a result, governments may utilize various interventions and economic instruments, such as taxation and subsidies in order to achieve these targets (Notteboom et al., 2020). This is a source of split incentive as the green investment in private ports will benefit governments to achieve their NDC targets, for instance.

- **Port landlord Vs port company/operator (tenant):** When **a** port superstructure like cargo handling equipment is owned by the landlord but rented by the port company, this question is raised who should invest in the energy efficiency of the port superstructure? Who is beneficiary of this investment, and who should pay the energy bill? It is important to note that the duration of the contract may aggravate this misplaced incentive. In a short contract, the tenant has no motivation to invest in energy efficient machinery (Author idea).
- **Port company Vs subcontractors:** Inefficient utilisation of port infrastructure could be an outcome of this kind of split incentive. For instance, in the case of port lighting or heating/cooling systems, the port company is responsible for the lighting of the shared areas of the port, and the tenants (subcontractors) are responsible for the lighting of the areas they rent (BASREC, 2014). In this way, they cannot manage overall energy efficiency, and at the time of maintenance, renovation or retrofit work, they cannot be beneficiaries of the economy of scale in repair and retrofit. As another example of a split incentive, the cargo handling equipment owned by the port company might be rented to the operators, resulting in inefficient operation, a lack of retrofitting, and less maintenance (BASREC, 2014).
- **Port management Vs ship owners/operators Vs technology/energy providers:** This aspect of misplaced incentive happens when a port tries to integrate a new technology like SSE or alternative fuel bunkering station in its infrastructure. Here, the technology or fuel/electricity providers will benefit by selling their technology/energy, and ship owners will benefit by utilizing this technology/energy at ports. The question is, what could be the motivation of ports to invest in these technologies? Does integrating these technologies into the port infrastructure offer them a competitive advantage?
- **Port management Vs ship owners/operators and charterers:**
  - Waiting times and turnaround times in port can be reduced to the benefit of vessel operators and charterers, however, to achieve this, port authorities and terminal operators must implement an accurate pre-booking scheme, since they do not necessarily have the incentive to do that (Masodzadeh et al., 2022a; Gibbs et al., 2014; ITF/OECD, 2018). Poulsen and Sampson (2019) highlight the lack of trust between shipping companies and ports as a barrier to virtual arrival implementation. The implementation of an advanced berth allocation mechanism is costly for ports and further creates a commitment on their part. Moreover, by

reducing turnaround times, ports may lose out on the opportunity to sell other services, such as maintenance and bunkering (Masodzadeh et al., 2022a; Gibbs et al., 2014).

- When the demurrage rate is higher than the freight rate in a depressed market, shipowners follow a "rush-to-wait" behaviour (Jia et al., 2017), which disregards slow steaming in an effort to collect demurrage from ports (Masodzadeh et al., 2022a).

Solutions

- In mitigating the split incentive between governments and private ports, governments need to depict the roadmap and encourage stakeholders to follow it, but not with a strict follow-up process and tight timelines (Notteboom et al., 2020). Therefore, if governments assign emission targets to ports as part of a country's NDC, they should support ports by providing information, action plans, expertise, and economic aid. Meanwhile, ports should have enough time for adaptation of the action plan and there should be guarantees for the continuity and stability of government policies over time (Notteboom et al., 2020).
- Considering environmental factors when selecting port operators (tenants) can provide sufficient clarity in the area of energy conservation between port landlords and tenants. Similarly, operators should consider environmental concerns in the selection and management of subcontractors (Acciaro et al., 2014a). Environmental commitments should be included in terminal concession contracts (HFW, 2021; Notteboom et al., 2020).
- Encourage and facilitate the adoption of green practices by port users (Acciaro et al., 2014a).
- “Reduction of port demurrage could be used as a motivational element for port commitment” (Gibbs et al., 2014). As another option, “reduction of port demurrage (at least less than daily freight rate) can deter the *rush-to-wait* behaviour by ship operators” (Masodzadeh et al., 2022a).
- “Port management by sharing real-time traffic data (Poulsen and Sampson, 2020) among all port actors, and in close communication with other stakeholders like ship operators, receivers, and shippers (e.g. Port CDM (Collaborative Decision-Making) (Lind et al., 2015)), can prepare the ground for implementation of VA and minimizing the port turnaround- time” (Masodzadeh et al., 2022a; Jia et al., 2017).
- One of the most effective approaches is for technology/energy providers who install their technology on board ships to also invest in port infrastructure. In this way, they will ensure that they have loyal customers from shipping companies for their assets at the ports. By offering such services to shipping lines, ports can gain a competitive advantage and a green image as well.
- Investment in and operation of port infrastructures by shippers and shipping companies (BASREC, 2014; ESPO, 2012a; Saeed et al., 2018): in this collaborative model, shippers (cargo owners) or/and

shipping companies whose vessels are liner in specific routes, invest in port infrastructure that is used by their vessels and further these infrastructures are operated by the representative of these companies at ports. An example of this model is discussed previously in section 6.1.4.

- Liner shipping companies can "Finance (typically with significant support from public funds), build, and operate their own container terminal, acting as a 'pure' terminal operator, eventually also handling third-party traffic" (Saeed et al., 2018).
- For port tenants, a lease agreement can provide financial support to replace old equipment, as well as retrofit cargo handling equipment with emissions control measures (Nursey-Bray, 2016).

2.1.3 Organisational and managerial barriers

Barriers

- **Power:**
  - Low priority of energy efficiency (BASREC, 2014)
  - Absence of energy management responsible or coordinator (Acciaro et al., 2014b)
  - The disintegration of energy objectives into operating, maintenance, and purchasing procedures (BASREC, 2014)
- **Culture:**
  - Environmental values are not institutionalized in the organisational culture (Masodzadeh et al., 2022a).
  - Organisational inertia (Resistance to adopting new organisational routines aimed at enhancing energy efficiency): Port authorities may reluctantly adopt energy management because it may be perceived as an extra burden (Acciaro et al., 2014b).
- **Split incentive in the organisation:**
  - Considering that there are many different actors involved in port operations, responsibilities regarding the energy system would be shared among them, resulting in inefficient overall energy management (BASREC, 2014).
  - Internal split incentives (conflicts of interest) between different departments: for instance, the procurement department may just care about the capital cost and ignore the CO_2 footprint. Similarly, the maintenance department may decide to purchase heavy-duty and maintenance-free machinery regardless of its energy rating (BASREC, 2014).

- It is likely that port operators may not seek to implement energy-efficient operations due to their lack of accountability for energy costs and lack of benefits from energy savings (BASREC, 2014).

- **A failure to recognize the interests of other stakeholders**

  Ship-port interface:

  - Facilitating immobilisation of ships at ports to perform essential repairs on the main propulsion engine while ship is under loading/unloading operation (IMO, 2021)
  - Providing the hull cleaning facilities at port despite environmental concerns, on releasing of scrapings in the port water and potential risks for divers cleaning the hull while ship is under loading/unloading operation (IMO, 2021)
  - Providing different services simultaneously to ships under loading/unloading operation (IMO, 2021) e.g. bunkering, store and provision delivery, inspections, etc.
  - Issuance of pre-clearance for ships prior to arrival and departure to minimize the waiting time (IMO, 2021)
  - The necessity to plan for ships calling different berths of a port (IMO, 2021)
  - Expectations from ports to facilitate implementation of just-in-time (JIT) arrival for ships (IMO, 2021; IMO, 2020; Masodzadeh et al., 2022a).
  - Expectations from ports to reduce the waiting and turnaround time of ships at ports (Gibbs et al., 2014; Notteboom et al., 2020; Masodzadeh et al., 2022a)
  - To recognize greener vessels and provide encouraging incentives and required infrastructure for them (e.g. alternative fuel bunkering station) (Notteboom et al., 2020).

  Port-hinterland interface:

  - Reductions in waiting and idle times of inland transport modes (BASREC, 2014; Notteboom et al., 2020)
  - Providing alternative fuel stations (e.g. LNG) for road trucks
  - Review and study the port-hinterland connectivity and plan to improve it

- **Ineffective waste management** in the industrial zone of ports: The concept of "ecologies of scale" may not be planned and implemented in the port industrial zone. In this concept, companies utilize one another's waste materials or by-products, such as heat. If the plants are scattered over a large area, this concept is very difficult to implement (Notteboom et al., 2020).
- **Ineffective resource management** (Acciaro et al., 2014a)
- **Difficulties in implementing environmental (energy) management system due to:**

- High number and diversity of authorities/stakeholders involved (BASREC, 2014)
- Energy management is not a strategic priority. In a study in 2013, none of the ports being interviewed had a specific action plan for energy efficiency (BASREC, 2014). The energy issue has been incorporated into the environmental program in most cases.
- Expenses to establish EnMS (BASREC, 2014)
- Lack of setting energy-related targets/goals (Christodoulou and Cullinane, 2019)
- Lack of strategic plan to reach the targets (Christodoulou and Cullinane, 2019)
- Ineffective monitoring and reporting system, e.g. inadequate sub-metering (failure in the monitoring of energy consumption in subsidiary sections) (Acciaro et al., 2014a; BASREC, 2014)
- Lack of commitment in top management (BASREC, 2014)
- Lack of awareness and knowledge of best practices (BASREC, 2014; Acciaro et al., 2014b)
- Difficulties in identification of responsible authority (split incentive) (BASREC, 2014)
- Lack of information and guideline (BASREC, 2014)
- Lack of energy efficiency incentive or reward system in port organisations for successful departments or employees (BASREC, 2014)
- Lack of energy audit (BASREC, 2014)
- Lack of proper KPI in energy management system (BASREC, 2014)

Solutions

- Identifying stakeholders (Interest Parties- IP) and their interests is a major part of any management system. It could be done through consultation and stakeholder analysis (Lam and Van de Voorde, 2012). Following cases are some examples of port actions in response to these expectations:
  - By considering port potential (e.g. the number of free tugs available), weather conditions, understanding the concerns of relevant stakeholders, and undertaking a comprehensive risk assessment, ports can grant **immobilisation** to ships at ports. On the other hand, the ship master must send the request for immobilisation in advance and receive permission through clear communication. Ship staff must ensure enough crew, expert, and spare part availability and, considering the terminal plan, weather outlook, and crew rest hours, try to schedule the repair work precisely (IMO, 2021).
  - Under strict contemplations, ports can select competent contractors for **hull cleaning at ports**. The competent contractors deploy remotely operated vehicles (ROVs) with the capacity

to collect the scraping material during the cleaning process at port. The facility to dispose of the scraping material must be available at the port (IMO, 2021).

- Port authority, by having an overview of activities within the port, coordinating between different stakeholders, and having access to necessary data on time, can plan ships precisely between different berths within a port. An established means for electronic data exchange could be very useful in this way (IMO, 2021).
- Establishing an advance berth allocation mechanism by ports could be a way to implement the **JIT** arrival for ships (Masodzadeh et al., 2022a). Presenting a proof-of-concept and providing examples of ports that have implemented JIT Arrivals, could be very useful for the promotion of this concept (IMO, 2021). Furthermore, JIT arrival could be a clause included in the charter parties (IMO, 2021; Masodzadeh et al., 2022a; BIMCO, 2021)

- Establishing a sustainability management system (SMS) in particular at smaller ports can save time and cost in the sustainability assessment process (Kuznetsov et al., 2015). Furthermore, SMS enables port managers to develop customized improvement plans for a specific area on an urgent basis (Kuznetsov et al., 2015). SMS is a significant tool for developing sustainability indicators. Implementation of SMS can empower port managers to facilitate the stakeholders' partnership (Kuznetsov et al., 2015). In a systematic way, the EMS (Acciaro et al., 2014a) or EnMS (Christodoulou and Cullinane, 2019) allow port managers to identify and fix the root causes of potential problems in the energy system and to improve energy performance and minimize CO_2 emissions.
- Establishment of EnMS or EMS in ports could provide a framework to designate environmental (energy) managers and monitor environmental (energy) performance through the systematic use of predesigned indicators (BASREC, 2014).
- Emissions inventory at ports: Developing an EnMS in ports requires establishing an energy baseline, which can be achieved by conducting a comprehensive inventory of port CO_2 emissions. Emissions inventories should be integrated into comprehensive sustainability reports to underline the environmental impacts and provoke mitigation initiatives. Therefore, it is vital to establish a set of common indicators applicable to different ports. The baseline depicted by CO_2 emission inventory can reveal the current status and further be a benchmark to measure the subsequent progress and performance. Identifying the sources of CO2 emissions is the first step. Emission sources can be mobile (e.g. ocean-going vessel, harbour craft, cranes, trains) or stationary (e.g. energy production facilities) (OECD, 2013; SISI, 2020; WPCI, 2010).

- By separating the business into different components, ports can provide customers more value, be proactive with sustainability, and integrate sustainable practices into their operations (Kuznetsov et al., 2015).
- Market consultation can be used to overcome difficulties in decision-making. International market consultation by receiving proposals from experts can assist port authorities at the planning stage, for example, to expand ports or develop port infrastructure (Acciaro et al., 2014a). For instance, in order to gather ideas on possible uses of the area and alternative configurations, the port of Hamburg launched an international market consultation in 2009 (Acciaro et al., 2014a).
- The energy audit process, by depicting the energy baseline and identifying the significant energy users in ports, can propose a set of energy efficiency measures along with feasibility analysis for those measures. Considering that the audit reports identify areas and potentials for energy savings and the fact that the audit team has demonstrated the feasibility of these proposals, the private sector could be strongly encouraged to invest in these measures. The port of Antwerp is the best example in this regard (ESPO, 2012a).
- A common set of CO_2 reduction objectives must be defined for different departments in the port organisation to avoid split incentives between them. The Port of Rotterdam, for instance, has incorporated the reduction of CO2 emissions into its sustainable procurement criteria for investment projects such as maintenance dredging, the construction of quay walls and other port development work (ESPO, 2012a). Similarly, in Copenhagen-Malmö port, environmental personnel are involved in the purchasing decisions (BASREC, 2014).
- Environmental spatial planning of the site, in particular at the early stages, can be helpful in accomplishing ecologies of scale in the port industrial zones (Notteboom et al., 2020).
- In order to optimize waste management, seaports with a high potential to serve as recycling hubs should promote industrial ecology and the circular economy among all stakeholders. Several ports can receive recycling flows, process them into new products, and re-export them around the world (Notteboom et al., 2020).

2.1.4 Behavioral and human element barriers

Barriers

- **Inertia:**

- Resistance to change in port employees: In some cases, a less efficient older machinery may be utilized instead of a newer one with the perception that the modern machinery is challenging and less convenient to operate (BASREC, 2014).
- Momentum of past behaviour: An environmental (energy) decision made by the port normally follows a hierarchy of different geographical levels, including city, region, and country; this may create inconsistencies and barriers caused by some outdated procedures and routines. This is particularly evident in ports that are undergoing a transformation into green ports from traditional ones (Acciaro et al., 2014b).
- Resistance to change among other stakeholders and port users prevents them from adopting the energy management measures that the port has implemented (Author idea).

- **Values:**
  - Lack of commitment to CSR (Corporate Social Responsibility) and environmental norms (Notteboom et al., 2020)
  - Lack of staff awareness: The lack of awareness and understanding of sustainable practices in ports can be attributed primarily to the absence of sustainability management systems (Kuznetsov et al., 2015).
- **Bounded rationality:** It results in satisfying decisions rather than optimum decisions, mainly due to the limits on cognitive capabilities (Saeed et al., 2018) which is rooted in the lack of information, time, and expertise (Masodzadeh et al., 2022a). For instance, when the port of Genoa tried to disseminate their experiences to other ports, they observed that due to a lack of awareness, expertise, and information, local actors just considered a simple action, installation of solar panels on roofs, and they did not attempt further steps towards efficiency performance assessment (Acciaro et al., 2014b).
- **Lack of communication:** In many cases, miscommunication and misunderstandings between ports and their communities undermine the ability of port authorities to safeguard their harbours and threaten the future of their communities (Kuznetsov et al., 2015).
- **No intention to change by the vested interests groups** (Masodzadeh et al., 2022a). Depending on the circumstances, some stakeholders may benefit from the current status and have no intention of changing it.
- **Lack of manpower** in port management and operation, e.g. lack of available crew to support simultaneous ship operations at ports (IMO, 2021)
- **Lack of experts** capable of conducting energy analyses at ports (Acciaro et al., 2014b)
- **Decision-making difficulties** due to:

- Resistance by managers/decision-makers (Masodzadeh et al., 2022a)
- Lack of information, guidelines, and best practices, and inability to use information (Masodzadeh et al., 2022a)
- Misplaced incentives and long/complex decision chain (Masodzadeh et al., 2022a)
- No decision criteria or imperfect evaluation criteria (Masodzadeh et al., 2022a)
- Non-involvement of employees in the process of decision-making (Acciaro et al., 2014b)
- High number of stakeholders (BASREC, 2014)

- **Lack of education and training** (Masodzadeh et al., 2022a)
- **Lack of technical skills** to work with energy efficiency measures (Masodzadeh et al., 2022a)

Solutions

- By integrating CSR into their sustainability program, port authorities and companies can improve their social and environmental impacts. This allows port management to promote environmental and social norms among a broad range of stakeholders. Commitment to CSR could be demonstrated in the following ways: publishing port sustainability reports, developing and disseminating local initiatives and best practices, and cooperation with universities, R&D centers, and consultancy firms (Notteboom et al., 2020).
- An effective stakeholder relations management can strengthen management capabilities, raise awareness of sustainability issues, and contribute to corporate sustainability integration into the ports' organisational structure (Ashrafi et al., 2019).
- Corporate Responsibility (CR) could contribute to logistic value creation (Acciaro, 2015). A port strategy could incorporate CR practices in the following ways (Acciaro, 2015):
    - **Coercive effect:** A growing trend in regulatory and social pressure has led port authorities to attempt the CR concept more than ever before.
    - **Mimetic effect:** In light of the lack of information, best practices, and guidelines as well as the uncertain investment environment, ports are looking at each other for ways to move forward. The number of ports considering CR as a part of their strategy increases as a result, as the number of ports already committed to CR increases.
    - **CR in the form of standard:** Throughout its evolution, CR practices have taken the form of a code or standard, which is more readily accepted by ports.
    - **Competitive effect:** A port may integrate the CR into its sustainability program under competitive pressure, not only to increase its legitimacy and reputation, but to improve the operational efficiency and elevate the port's economic gains.

- Ports can demonstrate their commitment to decarbonisation by setting ambitious targets (Ports for people, 2022; Christodoulou and Cullinane, 2019). This commitment, which is the first step in the formation of climate action in ports (Ports for people, 2022), must be communicated truly from top management to all staff (Christodoulou and Cullinane, 2019). For instance, the port of Rotterdam has launched a programme to become carbon-neutral by 2050 (Sánchez and Mouftier, 2016).
- Enough and relevant training must be provided for operators in port (Christodoulou and Cullinane, 2019). Training of eco-driving for port drivers in two ports of Copenhagen-Malmö and Gothenburg are examples of this (BASREC, 2014). Lam and Van de voorde (2012) have shown in case studies on three ports that port authorities have trained employees on waste management and energy conservation.
- The port of Antwerp, based on its people-centric policy and to improve internal communication, appointed an internal communication officer in 2010 (Lam and Van de Voorde, 2012).
- Organisational skills audit (Kuznetsov et al., 2015) can help to recognize a broader range of skills for a particular position in the port organisational structure.
- Environmental awareness among employees must be a priority for port managers (Acciaro et al., 2014a). Implementing SMS at ports can be a valuable tool for raising awareness among port authorities and providing them with guidelines (Kuznetsov et al., 2015; Acciaro et al., 2014b).
- By steering a competition, Port management can encourage employees to bring forward their suggestion to enhance energy efficiency and decarbonisation. This has happened in the port of Hamburg (Acciaro et al., 2014b). Similarly, the port of Hong Kong emphasizes the involvement of employees in the implementation of the green port strategy (Lam and Van de Voorde, 2012).
- It is imperative that the required competencies and KUPs (Knowledge, Understanding, and Proficiency) for handling alternative fuels are considered during the revision of the STCW code (Author idea) inspired from (Together in Safety, 2022).

2.1.5 Policy barriers

Barriers

- The absence of binding international energy regulations for ports: Ports under jurisdiction of national governments and local states, with high diversity in the nature of governance, are challenging to integrate into a global and uniform climate change regime (Christodoulou and Cullinane, 2019; Nursey-Bray, 2016). Heterogeneity in ports in terms of their purpose (type of port), their geographical location, their size and cargo transaction, and type of management (landlord or operative), are even exacerbating the situation to enact international energy regulations for ports. It is interesting to note that ports serve as the means of implementing maritime regulations (through the PSC network), they are able to enact local rules and requirements, and even provide incentives for visiting ships to adhere to the rules; however, they are not subject to any global climate regulation.

- Lack of economic policy such as MBM in the shipping industry: Because there is no MBM in place, the large price gap between conventional and alternative fuels discourages ship owners from investing in green fuels, which in turn prevents ports from investing in such technologies (Masodzadeh et al., 2022a).
- Dilemma in authority and accountability of port management: While port management "may not necessarily be directly and legally responsible for the activities, products and services of certain components of the logistic chain, but its overarching administrative role, ownership of the estate (land and water) and permanency of operational presence, means that the port is the obvious point of contact and the readily identifiable player for any environmental issues concerning the whole port area" (BASREC, 2014).
- Challenges in compliance especially for small ports due to complex legislation and evolving stakeholders' expectations (Kuznetsov et al., 2015).
- Regulatory implications, as a result of interaction between different levels of legislation, such as the European Union, national governments, and regional authorities (Acciaro et al., 2014b).
- Uncertainties in government policies and its continuity, for example, providing or abolishment of subsidies for certain green investments, has a significant impact on green strategies and investments (Notteboom et al., 2020).
- The port state plays a limited role in implementing ship energy regulations. Their role is limited to ensuring the availability and validity of documents onboard (Author idea).
- Lack of codes and standards for new burgeoning technologies like alternative fuels (Together in Safety, 2022; Masodzadeh et al., 2022a)
- Lack of policy review and policy effectiveness assessment; for instance in the case of port incentive programs (Masodzadeh et al., 2022a)

Solutions

- In the absence of international energy regulations applicable for ports, the establishment of standards such as EnMS (Christodoulou and Cullinane, 2019), EMS (Nursey-Bray, 2016; Kuznetsov et al., 2015; Acciaro et al., 2014a; Wooldridge et al., 1999), and sustainability management system (Kuznetsov et al., 2015) in ports must be promoted. The other action could be encouraging ports to publish their environmental performance report with a focus on GHG reduction and its relevant PIs.

- Implementation of an MBM like bunker levy not only can close the price gap between conventional and alternative fuels, but can support ports financially in the establishment of green infrastructures (Masodzadeh et al., 2022a).
- Governments need to depict the roadmap and encourage stakeholders to follow it, but not with a strict follow-up process and tight timelines (Notteboom et al., 2020).
- Ports can contribute to achieving the Green Supply Chain Management (GSCM) objectives in the hinterland by establishment of policies such as pricing mechanisms (taxes and incentives), investing in infrastructure, regulating emission standards, providing information to users, development integrated traffic management systems for rail, barge and truck, and implementing tools such as appointment systems and pick pricing to spread traffic in time and space (Notteboom et al., 2020).
- PSC plays a vital role in enforcing international shipping energy regulations. The importance of PSC could be more obvious by enforcement of the GHG strategy from 1st January 2023. The role of PSC, from merely document validity check, should be promoted to a more operational role. In this vein, Masodzadeh et al. (2022a, 2022b) recommend a voyage-based data collection mechanism by port authorities.
- **Role of governments** (Cannon, 2008):
    - Develop and implement a national port clean-up strategy
    - Create a national funding mechanism to finance comprehensive port clean up
    - Advocate global environmental standards in the international arena
    - Create a clearinghouse of public information about port clean-up efforts
- **Voluntary policies**
    - **Incentive schemes:** Many port authorities are now employing voluntary incentive schemes in addition to compliance with mandatory regulations. These voluntary incentive schemes focus either on ships via programs such as slow steaming, fuel shifts, and cleaner ships program or on hinterland through strategies like truck retirement and modal shifts. Port-driven initiatives, such as using green fees for clean shipping promotion can take place in partnership with shipping companies, though at the cost to the port. Green Award, the CSI

(Clean Shipping Index), and the ESI (Environmental Shipping Index) are some examples of port incentive schemes (Gibbs et al., 2014). There are also some opportunities to provide incentives for rail and road operators in the hinterland side. For instance, the port of Hamburg has developed a tariff system to provide incentives for using cleaner diesel locomotives or particle filters and lower noise brakes. Similarly, the Port of Los Angeles/Long Beach has initiated the clean truck programme (Acciaro et al., 2014b).

- **Collaboration**
  - **Collaboration between ports:** Ports are, in many respects, competitors (BASREC, 2014). However, more opportunities can emerge when competition and cooperation are combined to form "coopetition" (Sánchez and Mouftier, 2016). The scope of action in energy transition at ports is very broad, with a limited capacity of individual ports in this field. Therefore, knowledge partnerships, information dissemination, and incorporation with academia can enhance the efficiency and productivity of ports (Sánchez and Mouftier, 2016). For example, a five-year cooperation agreement between the port of Los Angeles and Copenhagen-Malmö port was signed in 2019 to develop sustainable energy sources and promote green terminal technologies. Additionally, 10 ports in the Nordic region have agreed to collaborate to meet the UN's Sustainable Development Goals (SISI, 2020).
  - **Collaboration between ports and outside companies:** Ports with a few people engaged in energy management (BASREC, 2014), and with a very limited R&D capacity, need the technical and managerial advisory support from companies specialized in this field. As an example, a collaboration agreement has been signed between the Port of Antwerp and eight companies in the field of chemical energy in order to research and develop CCS applications (SISI, 2020).
  - **Cooperation between different actors at the port:** It is common practice for companies and actors working in the ports to attend common meetings regarding the operation and development of the ports. Taking advantage of this opportunity, the port actors can examine how they cooperate together and benefit from each other's strengths (BASREC, 2014).
  - Ports may benefit from stronger representation and professional networking by forming an association (e.g. the British Ports Association) (Kuznetsov et al., 2015). Such associations represent the interests of port authorities and private companies in the

process of policymaking at national, regional, and international levels (Kuznetsov et al., 2015).

- Collaboration between ports, technology providers, and classification societies or ISO institutes, can facilitate the type of approval of new technologies in ports (Author idea)
- Collaborative research projects, by disseminating the knowledge and project achievements to the participating stakeholders, have a significant role in raising awareness and training (BASREC, 2014) (e.g. Green EFFORTS, "Green and Effective Operations at Terminals and in Ports" co-funded by the European Commission (Green EFFORTS, 2022)).
- **Cooperation between ports and incentive providers:** Nowadays, incentive programs such as the Green Award, CSI, and ESI are becoming more popular within the maritime industry. However, implementation of these incentive schemes requires close cooperation of ports with the centric role of providing incentive packages like discounts in port and fairway dues.
- **Cooperation in the form of information sharing:** The port of Dover by dedicating an environmental section to its website has initiated supreme transparency in data disclosure by publishing general information, environmental reports, and policies. Such action opens the door to all engaged stakeholders to raise their environmental concerns during the Port Consultative Committee (ESPO, 2012a). In the same vein, different platforms like the European Sea Port Organisation (ESPO), the Baltic Ports Organisation (BPO), Cruise Europe, and the Cruise Baltic organisations must be encouraged to disseminate information on energy efficiency issues (BASREC, 2014).
- **Networking for sustainable development of the area around the port:** The port of Aalborg is an example of gathering companies in the vicinity of the port to establish a corporation to promote sustainability and contribute to the development of infrastructure, services, employment and social life within the area (BASREC, 2014; ESPO, 2012a).

- **Innovation**

Innovative actions follow a very diverse pattern in different ports. In a port, innovation can be in different forms technical, organisational (e.g. managerial and decision-making), policy (e.g. incentive and reinforcement), and stakeholders relation (Acciaro et al., 2014a). “Innovation is needed in the city-port nexus to achieve harmonious integration of aligned and coordinated objectives” (Sánchez and Mouftier, 2016). Prior to initiating any innovative action, a holistic and systematic approach is needed to identify deficiencies and barriers, as well as potential for improvement. Government intervention is required to facilitate the innovative processes becoming materialized (Acciaro et al., 2014a; Notteboom et al., 2020).

2.1.6 Technical barriers

Barriers

- Immatureness of technologies:
  - Technical risk: In some cases, new ship technology may require infrastructural changes to be implemented and may be resisted by port authorities if they are viewed as hazardous (e.g., nuclear power, hydrogen fuel cells) (Gibbs et al., 2014).
  - Possible poor performance of equipment (Acciaro et al., 2014a), or reduction in service quality and flexibility (Notteboom et al., 2020).
  - Uncertainty in future operational costs; for instance, in the case of SSE, the electricity cost is very dependent on the local electricity policy (Radwan et al., 2019).
- Process of technical and economic feasibility study before implementation of some new technologies could be very long and costly. For instance, in the case of wind mill installation, it is necessary to monitor the wind conditions on the chosen site for a full year (Acciaro et al., 2014b). In the case of LNG bunkering facilities, there are very rare published studies or guidelines to demonstrate a methodology for estimation of the requirements of LNG bunkering stations in terms of storage capacity (Park N.K. and Park S.K., 2019).
- Inconsistency between port and ships equipment: for instance, physical interference between port cargo handling equipment and ship's wind sail (Rehmatulla et al., 2017), or in another case, inconsistency between OPS and ship's busbar in voltage and frequency (Gibbs et al., 2014; Chen et al., 2019; Radwan et al., 2019).
- Limitations in energy supply include a lack of capacity to feed the SSE by green electricity (Gibbs et al., 2014) or poor access to the LNG supply chain (Green Crane, 2013).
- Recently a technical paradox has emerged. Economies of scale argue that larger vessels are best suited to improving energy efficiency; however, available technologies such as hydrogen, batteries, and fuel cells are driving ship builders to build smaller ships for short-sea shipping, so that the ship's energy storage capacity can support the entire voyage (Deloitte, 2020). In turn, this can create a great deal of confusion for port management when making investment decisions for the future (Author idea).
- **Lack of physical space:** With the increasing complexity of port operations, the use of land is increasingly being diversified and intensified (Deloitte, 2020). Expanding the port area is necessary

in order to increase the port capacity for goods transactions, as well as establishing new industrial zones, exhibition centers, and similar activities. As a consequence of the scarcity of space, ports are normally required to relocate their activities from their original sites to locations outside the city. On the other hand, with the emergence of new technologies in sea transport like containerisation, traditional ports (normally in the vicinity of or surrounded by resident areas) are losing their value in the supply chain (Deloitte, 2020).

- Low priority of Asset Management and Maintenance (AMM): the traditional mentality of some port governance models based on cost minimisation is a barrier to proactive maintenance of port infrastructure (Kuznetsov et al., 2015).
- In contrast to LNG and Methanol, hydrogen and ammonia do not have international regulations and guidelines regarding their use as fuel in the marine environment (Together in Safety, 2022).

Solutions

- **Investment in R&D** is an essential step in the decarbonisation roadmap. For instance, in the case of propulsion electrification, the state-of-the-art equipment onboard and infrastructure in ports are very dependent on the **technical progress** to improve the operational parameters and decline the costs of individual components such as battery modules, chargers, energy management systems, electro motors or automatic mooring systems (Tarkowski, 2021). Electromobility policy could be very promising for short routes with a high frequency of journeys (e.g. ferries) due to a reduction in investment cost (less battery modules) and a higher rate of ROI due to price difference between electrified and diesel propulsion systems (Tarkowski, 2021).
- Part of the future GHG Fund could be spent to provide R&D Fund for technology providers (Author idea).
- Park N.K. and Park S.K., (2019) have demonstrated a methodology to estimate the requirements of an LNG bunkering facility in terms of size and number of LNG storage tanks. They consider large vessels at peak times to determine the peak ratio of LNG fuel required. Furthermore, they consider the following factors in their estimation:
    - Analysis of vessels entering the port
    - Analysis of transit time, charging time and bunkering time
    - Estimation of sailing distance by area and by ship type
- As part of preliminary studies, risk assessment has a vital role in identifying LNG bunkering hazards. Some quantitative risk assessment methods have already been performed (Aneziris et al., 2020). For instance, Apostolopoulou et al. (2018) have recommended the establishment of safety

exclusion zones in LNG bunkering stations. Their proposal is based on risk assessment and relevant calculations for a certain port in Greek.

- Technological developments are likely to be increasingly utilized to address the challenges of space scarcity in ports. The waterfront redevelopment could be a way to compensate for the space scarcity in ports. Waterfront redevelopment, especially in port cities can create added value and employment, which is advantageous for both urban areas and ports (Deloitte, 2020). Furthermore, digitized port operations can partially solve the space scarcity in ports (BASREC, 2014).
- **Digitalisation** should be a key part of port strategy, enabling better allocation of resources and improving efficiencies. The use of digital technology can lead to data exchange systems that are more efficient and less prone to errors. A digitized data collection system can improve monitoring and calculating emissions across the supply chain, and provide better visibility of cargo movements (HFW, 2021). Through digitalisation, by standardisation of the common best practices, all stakeholders can minimize the administrative burden and volume of paperwork, whether they are port authorities, ship and shore staff in shipping companies, charterers, shippers or any other party in the supply chain (Sánchez and Mouftier, 2016). The best example of this is the *Single Window* environment proposed to harmonize the high volume of legal reporting requirements during port calls. The European Commission is in the process of finalizing the European version of this window, known as the European Maritime Single Window environment (EMSWe) (EU Commission, 2019). Even though digitalisation can be viewed as a concept that encompasses the entire supply chain, it can also be viewed as three distinct components as follows:
    - Digitalisation in management of the ship-port interface: It is a base for running an advance berth allocation system and scheduling "just in time" berthing, which can reduce waiting and idling times for vessels and improve voyage planning by ship operators (HFW, 2021; Masodzadeh et al., 2022a; BASREC, 2014; Notteboom et al., 2020)
    - Digitalisation in management of the port-hinterland interface: It can facilitate the information flow between port and hinterland actors to minimize the waiting and idling times of trucks at the terminal gates (HFW, 2021; BASREC, 2014; Notteboom et al., 2020).
    - Digitalisation in management of port activities (inside port boundaries): A digitalized planning and control system for all cargo movements within the terminal increases operational efficiency by optimizing the use of yard machinery and equipment (BASREC, 2014). For instance, the concept of Port Collaborative Decision Making (PortCDM) not

only can manage the flow of information but "can create a common situational awareness, supporting the involved actors to make more efficient collective decisions" (Lind et al., 2015).

- Ship contingency manual (plan) and shipping company SMS (Safety Management System) must be updated by covering all emergency scenarios that could happen when a ship is operated on alternative fuels (Author idea) inspired by (Together in Safety, 2022).
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2.1.7 Classification of solutions to barriers

All the solutions explored in the last section have been categorized in Table 1. As we can see, the classification includes Preliminary studies, Technical, Management, Economic models, Policy, Information, and Social solutions.

Table 1: Clusters of the solutions for port energy transition

Solution category	Solution praxis and objectives
Preliminary studies	Cost-benefit analysis, economic and technical feasibility studies, risk assessment, environmental impact assessment (to mitigate technical risks, investment risks, and environmental risks)
Technical	**Wharf (quay)** • Securing port infrastructures against natural disasters (to mitigate risks due to natural disasters) • Waterfront redevelopment (to create more space in port) **Digitalisation** • To connect ship-port & port-hinterland & inside port actors (to enhance data quality and data flow) **R&D** • Investment in R&D by port management • Providing R&D Funds for technology providers • Joint research projects with research institutes and universities **Renewable sources of energy** (e.g. wind and solar) **Establishment of green fuels infrastructure** **Shore-Side Electricity (SSE)**
Management	**Establishment of SMS, EMS, or EnMS** • Identifying stakeholders and their interests (to improve stakeholders' management) • Establishment of an energy department with designated responsible • Emission inventory (to depict the energy baseline) • Market consultation (to make optimal decisions) • Energy audit (to identify the sources of inefficiency) • Common energy objectives for all departments (to institutionalize decarbonisation objectives in port) • Environmental spatial planning (to materialize the ecologies of scale) • Design of SMART KPIs (to improve monitoring)
Economic models	• Lease agreement for tenants to renovate port superstructure • Investment of technology providers at ports and on ships simultaneously • Economic collaboration of shipowners-shippers-ports-technology providers to invest and run the infrastructures at port • MEC and ESC models • Joint investment • Financial support by future GHG Fund
Policy	**Regulatory** • Cooperation of ports in the implementation of the future MBM in shipping

	• Compliance with local, national, regional, and international rules • Green concession contracts (e.g. with terminal operators) • PSC to play a more operational role in the enforcement of shipping energy regulations • Establishment of codes and standards for new technologies and green fuels
	Voluntary • Incentive schemes for ships and rail/road operators • Collaboration • Innovation
	Role of governments • Depicting roadmap and gathering and encouraging stakeholders • Simplifying tax procedures • Providing financial incentives or subsidies • Collaboration with insurance companies to provide coverage for ports
Information	**Information share** • Port CDM (to improve efficiency, run an advanced berth allocation mechanism, and reduction of waiting time) • Single Window environment (to mitigate the administrative burden) • Standardisation of data exchange (to facilitate the data exchange) • Improved Port Master Data (updated berth details can help to find the best match between ships and berths)
	Information dissemination • Publication of best practices and guidelines • Meetings, forums, and working groups • Publication of port annual environmental reports • Regular publication of TRL (Technology Readiness Level) reports
Social	• Promotion of CSR • Stakeholder relations management • Commitment by setting ambitious targets • Training at both operation and management levels • Organisation skill audit

2.2 Discussion of the survey results on barriers and solutions

A survey questionnaire was launched by the World Maritime University (WMU) at the beginning of May until the end of June 2023. The construction of the survey went through rigorous reviews by the project partners. Additionally, a stakeholder identification was held up in WMU, which helped gather data on more than 600 stakeholders spread around the EU. The survey sought to investigate the barriers that ports' stakeholders have with respect to the port energy transition. While the barriers were investigated, the significance of stakeholders to the port energy transition in addition to finding some solutions to identified barriers were also highlighted. The survey reached 1420 stakeholders, 260 responded, and only 104 completed it until the last question. The analysis will reflect the numbers that answered each question considering that 170 stakeholders answered some questions. Figure 5 below shows the proportion of the stakeholders that answered the survey. Please find the full list and details of survey questions in Appendix 1, at the end of this deliverable document.

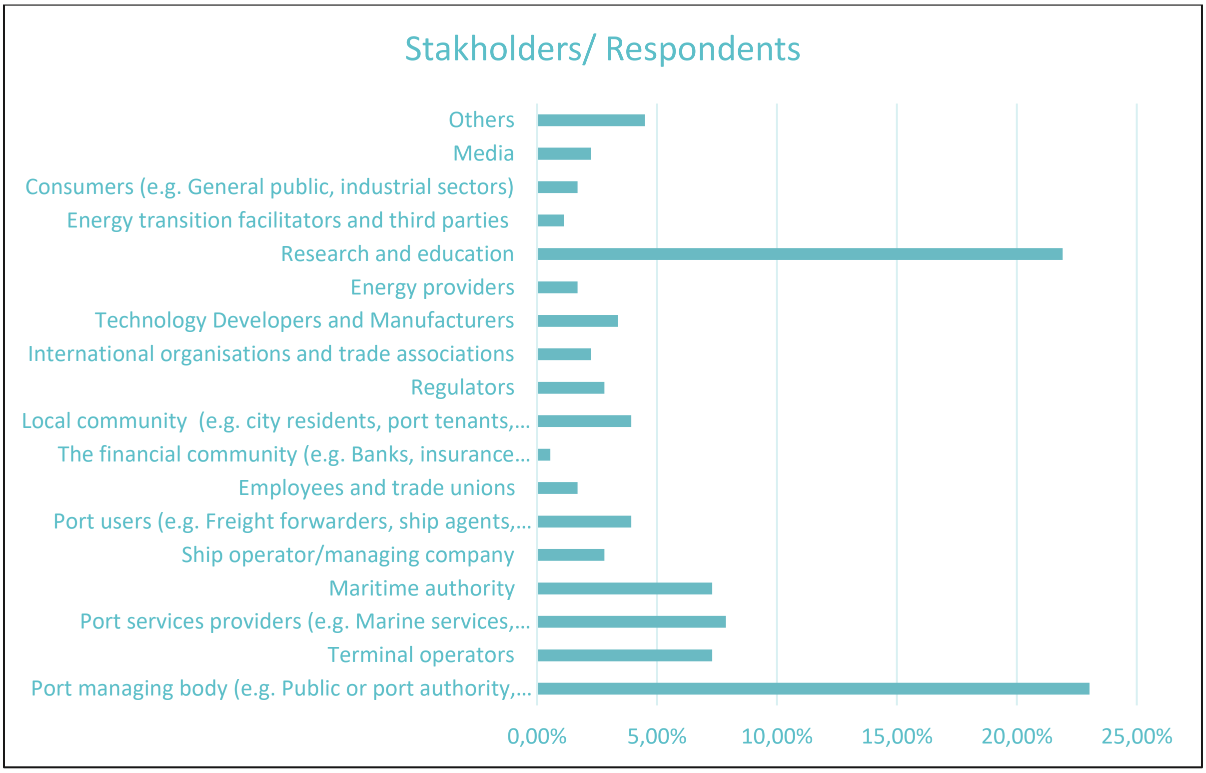

Figure 5: The proportion of the stakeholders that answered the survey

Responses were collected from 19 EU countries. The port managing bodies, academia, port users, service providers, terminal operators, and local communities highly answered the questionnaire than other stakeholders.

2.2.1 Importance of stakeholders to the port energy transition

The survey dedicated one question that asked the respondents about the importance of different stakeholders in the port transition to renewable energy and clean fuels. The respondents were asked to rate the level of significance in such transition using (1-lowest to 5-highest). The result shows that the port managing body (I.e., Public or port authority, port operating companies) is on top as it was rated the highest. On average, 87% of the responding stakeholders believed that the managing body is the most important (4.34) player in the port energy transition, followed by energy providers, ship operators, terminal operators, regulators and the maritime authority. This confirms the role of the port itself as a catalyst in the transition, while also highlighting the energy provider's role. Without cleaner fuels, ports cannot supply their equipment, ships and land transport. The regulators' role is also important as the domestication of climate change mitigation is essential for port authorities to begin the transition and also drive the shipping and port operators to comply. Most of the rating is between medium and intermediate for the rest of the stakeholders. This also confirms that stakeholders have power and interests in the port energy transition, and they should not be left behind.

Table 2: Results of ranking of the significance of stakeholders to port energy transition

Rating order	Stakeholders' category	Rating mean	Percentage of responses
1	Port managing body (e.g., Public or port authority, port operating companies)	4.34	87%
2	Energy providers	4.12	82.4%
3	Ship operator/managing company	4.10	81.9%
4	Terminal operators	4.05	81%
5	Regulators	4.00	81%
6	Maritime authority	3.99	85%
7	Technology Developers and Manufacturers	3.87	81%
8	Energy transition facilitators and third parties (Designers, Architects, Contractors, Construction workers, port project managers, consultants, and other service providers)	3.63	80.4%
9	The financial community (e.g., Banks, insurance companies, stock exchange, credit institutions, investors, ministry of finance, public funds)	3.59	77.2%
10	Research and education	3.57	77.5%
11	Port services providers (e.g., Marine services, customs, coastguards)	3.53	87%
12	Port users (e.g., Freight forwarders, ship agents, brokers, road hauliers, railway companies, and logistics providers)	3.50	70%
13	Consumers (e.g., General public, industrial sectors)	3.46	81.5%
14	Local community and societal groups of interest (e.g., city residents, port tenants, None Governmental Organisations (NGOs))	3.33	66.5%
15	International organisations and trade associations	3.20	66.5%
16	Employees and trade unions	3.15	62.9%
17	Media	3.15	62.3%

As a takeaway, mapping and understanding the stakeholder and being sensitive and responsive to them minimizes the use of their abusive powers, strengthens cooperation, and facilitates successful energy transition (planning, execution and construction, and operation). As recommended in D1.1., mapping of stakeholders engaged in the ports energy transition is required, and thus needs to be a transparent and dynamic process that verifies and builds understanding of stakeholders. The D1.1., in fact, discussed the applicability of the stakeholder circle method from the port perspective, i.e., the five steps (identify, prioritize, visualize, engage, and monitor). This cycle provides a holistic understanding of the stakeholders' needs, expectations, interests, power, legitimacy, proximity, and how to build a collaborative platform through the communication plans.

2.2.2 Ranking of barriers and solutions

Barriers' ranking

In the survey, respondents were requested to rate the significance of the barriers to energy transition in ports on a scale of 1 to 6, based on the strength of each barrier. Based on the perspective of different stakeholders, Figure 6 shows the overall ranking of barriers to energy transition in ports.

The next step is to investigate and compare the perspective of stakeholders about the strength of barriers. For this reason, stakeholders with the highest participation in the survey are considered, including port managing bodies, research and education professionals, port service providers, maritime authorities, and terminal operators. Table 3 demonstrates a comparison of the strength and priority of barriers in the view of different stakeholders.

Table 3 illustrates how different stakeholders' opinions differ on the ranking of barriers and how they differ from the overall results. As we can see, the viewpoint of port managing bodies is very similar to the overall results with some disorders of the barriers. Although this could be attributed to the high number of respondents from this group, however, the centric role of port managers and their mastery and awareness on general issues related to energy in ports should be acknowledged. As a result of continuous engagement with internal port actors and outside port stakeholders, port managers possess a real perspective of the current and potential barriers to port energy transition.

As expected, research and education professionals have a comprehensive perspective from the outside. While they see the policy and regulatory issues as the main barriers, they do not overlook the port economy and social issues. By emphasizing inertia, training of the workforce, and social admissibility of new technologies, they expressed their concerns about social affairs. However, in the list of the eight highest ranking barriers, they do not highlight technical barriers such as maturity of technologies and availability of technical codes and standards.

By contrast, the main concern of the port service providers is the immaturity of new technologies, followed by information issues and hidden costs. This shows that port service providers are more interested to see disseminated information about new technology performance and readiness. Valid and open sources of information will reduce the hidden cost for all stakeholders.

The priority of the concerns of the maritime authorities is different. They think more about the relationship between stakeholders as their main concern is the lack of communication and split incentives in various forms. However, they do not ignore the technical issues, including the immaturity of new technologies. Interestingly, they do not believe in uncertainties regarding future policies and regulatory implications as main barriers, probably due to their engagement in such issues.

Terminal operators are directly engaged with daily port operations. Therefore, their concerns in dealing with port landlord, regional and national authorities, port workforce, and neighbouring society are realizable. In the next step, they think about technical barriers.

Figure 6: Overall perspective of stakeholders on the ranking of barriers to energy transition in ports

Table 3: Comparison of stakeholders' perspectives on barriers to the energy transition in ports *

Ranking of the barriers each stakeholder						
Overall ranking	**The barriers**	**Port managing body**	**Research and education**	**Port service providers**	**Maritime authorities**	**Terminal operators**
1	Uncertainties regarding future policies	1	1	4	N/A	5
2	Immatureness of technologies	3		1	2	8
3	Limited access to capital by ports' authority	4	2	N/A	N/A	N/A
4	Lack of codes and standards for new technologies	2	N/A	N/A	7	6
5	Regulatory implications	7	4	8	N/A	2

6	Inertia (resistance to change)	8	3	5	N/A	N/A
7	Hidden costs	5	5	3	4	1
8	Inconsistency between port and ships equipment	6	6	6	6	7
Other concerns with higher priorities			7- lack of trained workforce	2- information issues	1- lack of communication	3- social admissibility of some new technologies
			8- social admissibility of some new technologies	7- social admissibility of some new technologies	3- split incentives between port landlord and tenants	4- lack of trained workforce
					5- split incentives between ports, shipowners, and tech. Providers	
					8- lack of space	

* The number in the table indicates the raking of the barrier among other barriers (from 1, the first top barrier, to 8, the lowest barrier level)

Solutions’ ranking

In the survey, respondents were requested to rate the significance of the solutions for the energy transition in ports on a scale of 1 to 6, based on the strength and priority of each solution. Based on the perspective of different stakeholders, Figure 7 shows the overall ranking of solutions for the energy transition in ports. Similar to barriers, an investigation and comparison of the stakeholders' viewpoint about the priority of solutions is carried out. Table 4 demonstrates a comparison of the priority of solutions in the view of different stakeholders.

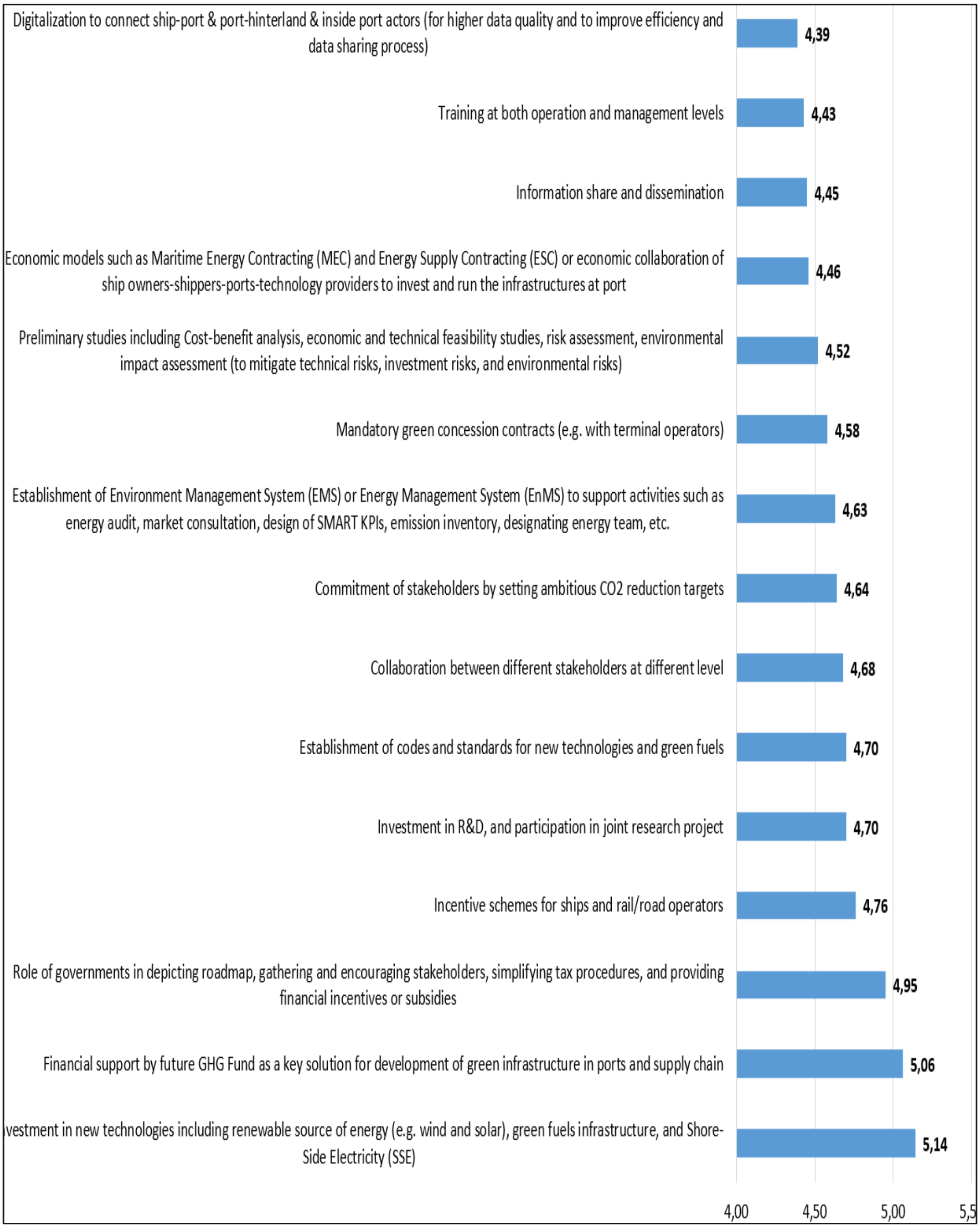

Figure 7: overall ranking of solutions for the energy transition in ports

*Table 4: A comparison of the solutions priority recommended by stakeholders regarding the energy transition in ports**

Ranking of the solutions to each stakeholder						
Overall ranking	**The solutions**	**Port managing bodies**	**Research and education**	**Port service providers**	**Maritime authorities**	**Terminal operators**
1	Investment in new technologies	3	1	1	1	1
2	Financial support by future GHG Fund	1	3	4	2	2
3	Role of governments	2	2	8	7	8
4	Incentive schemes for ships and rail/road operators	6	6			5
5	Investment in R&D, and participation in joint research project	N/A	5	3	4	3
6	Establishment of codes and standards for new technologies and green fuels	8	N/A	5	N/A	N/A
7	Collaboration between different stakeholders at different level	N/A	4	N/A	N/A	7
8	Commitment of stakeholders by setting ambitious CO_2 reduction targets	N/A	N/A	N/A	N/A	4
Other solutions with higher priority		4- Mandatory green concession contracts	7- Training	2- Preliminary studies	3- Preliminary studies	6- Mandatory green concession contracts
		5- Economic models	8- Information share and dissemination	6- Digitalisation	5- Establishment of EMS or EnMS	
		7- Digitalisation		7- Mandatory green concession contracts	6- Mandatory green concession contracts	
					8- Digitalisation	

* The number in the table indicates the raking of the barrier among other barriers (from 1, the first top barrier, to 8, the lowest barrier level)

Table 4 shows that almost all stakeholders believe in investment in new technologies as a priority. Similarly, receiving financial support from the future GHG Fund is the desire of most stakeholders. While future MBM can close the price gap between conventional fuels and alternative fuels, at the same time its revenue can facilitate the energy transition by supporting ports in the establishment of bunkering infrastructure and green corridors. Following that, all stakeholders indicate the significant role of governments in facilitating the energy transition in ports through economic instruments, initiating negotiations between stakeholders, and depicting a roadmap.

Based on the results in Table 4, port management is more interested in short- and mid-term practical solutions with tangible results such as mandatory green concession contracts, economic models, and digitalisation. They may suppose that already there are enough commitment and collaboration between stakeholders. By contrast, research and education professionals have a more long-term view by considering collaboration between stakeholders, investment in R&D, and upskilling the workforce in ports.

Port service providers believe that if the investment in new technologies is the first step, it should be immediately followed by preliminary studies, investment in R&D, and the establishment of codes and standards for the adoption of these new technologies. In this direction, they see financial support from GHG Fund and mandatory green concession contracts as drivers of this movement.

Maritime authorities are the only group with less consistency between their desired solutions and their indicated barriers. While their main concerns were about the lack of communication and split incentives between stakeholders, it was expected to see some solutions like collaboration between stakeholders or economic models in response to split incentives. However, their preferences are more based on operational strategies such as the establishment of EMS or EnMS, mandatory green concession contracts, and digitalisation.

The preferences of terminal operators are solutions that improve the relationship between stakeholders, such as port incentive programs for ships and rail/road operators, green contracts, collaboration between stakeholders, and the leading role of governments. It may be due to their central role in port operations, which requires them to interact with a variety of stakeholders.

2.3 Conclusions and recommendations for part one

This part addresses the growing environmental concerns and the pressing need to combat climate change in ports. Specifically, the barriers and solutions to ports' energy transition have emerged as a pivotal area of research and policy implementation. The transition to cleaner and sustainable energy sources in the maritime industry is no longer an option but a necessity to ensure a greener future. Therefore, it is important to understand the impediments that hinder progress in this domain and identify the potential solutions that can drive positive change.

All the stakeholders involved in the maritime sector benefit from the results in this part. Firstly, understanding the barriers to ports' energy transition enables governments, policymakers, and industry leaders to design more effective and targeted strategies to overcome these obstacles. By addressing these challenges head-on, they can create an environment that fosters the adoption of renewable energy solutions, promoting a significant reduction in greenhouse gas emissions and air pollution associated with traditional port operations. Furthermore, the results shed light on the economic benefits of embracing energy transition in ports. Investing in sustainable technologies and renewable energy sources can lead to long-term cost savings, increased operational efficiency, and enhanced competitiveness for ports. It opens up new avenues for economic growth and job creation, particularly in the renewable energy sector. Additionally, the adoption of cleaner technologies in ports can improve the overall public perception of the maritime industry, attracting more environmentally-conscious customers and investors.

By identifying and addressing these challenges and solutions, ports can unlock immense benefits for the environment, economy, and society at large. Through concerted efforts and strategic planning, ports can become energy hubs that is a pioneer in the adoption of clean energy practices, playing a pivotal role in the global fight against climate change and setting an inspiring example for other industries to follow suit.

Recommendations for Ports:

Based on the insights gained from this part, several recommendations are proposed for ports to facilitate a smoother energy transition:

- Set Ambitious Renewable Energy Targets: Ports should establish ambitious yet achievable renewable energy targets to guide their transition plans. These targets should be aligned with national and international climate goals, fostering a collective commitment to sustainability.
- Foster Public-Private Partnerships: Collaboration between port authorities, private companies, and research institutions is crucial to overcoming the financial and technical barriers to energy transition. Public-private partnerships can accelerate the deployment of renewable energy projects and facilitate knowledge sharing.
- Develop Incentives and Subsidies: Governments and relevant authorities (port authorities) should introduce incentives and subsidies to encourage ports to adopt green technologies and invest in renewable energy infrastructure. Financial support can offset the initial costs and motivate ports to embrace sustainable practices.
- Embrace Technological Innovation: Ports should embrace innovative technologies, such as smart grid systems, energy storage solutions, and shore power facilities, to optimize energy consumption and facilitate the integration of renewable energy sources.
- Engage with stakeholders: Collaboration with stakeholders and local communities is essential to building trust, fostering support, and addressing potential concerns related to ports' energy transition. Transparent communication and community engagement are vital for successful implementation.

3 Part two- Cultural analysis and social inclusion approach: The role of women in the port and port logistics

3.1 Introduction to the Port Industry

The role of women in the port and port logistics industry is an important topic that has received limited attention in the literature. However, some studies have been conducted to evaluate the gender equality criteria related to social sustainability in ports (Sanrı, 2022). These studies have shown that the logistics and transport industry is male-dominated, and the degree of female participation is low. Female employees are said to constitute only 31% of the total workforce in the industry, and female employees occupying technical roles in logistics and transport companies are less than 15% on average (Amushila, 2022). Despite the low representation of women in the industry, there are efforts to increase the women's workforce share in the port industry (Sanrı, 2022).

This part will study the sociocultural and behavioural aspects (along with the SSH disciplines stated in the previous sections) that directly impact the successful clean energy and fuel transition. This will be approached in two segments. First, desk research has been conducted by searching and summarising how the port industry has progressed in the following issues according to previous public and private reports: economics, politics, sociology, demography and ethnology (all with a gender-based lens to understand why men have traditionally predominated the port industry)[1]. As a result, an overall human-dimension picture will be obtained, from which further strategies for technology integration can be drawn as recommendations for stakeholders to allow for an easier and smoother transformation of activities and inclusion of women and underrepresented communities. IHE Delft has developed the content of the survey/questionnaire, using the GDPR-compliant software “Netigate”, in collaboration with the other task participants and the survey questionnaire will be sent out to potential respondents in the last week of July 2023[2].

3.1.1 Progression of the Port Industry: Economics, Politics, Sociology, Ethnology

The port industry has been an essential component of global trade and commerce for centuries, serving as a crucial link between producers and consumers across the world. The industry has undergone significant development and progression over time, evolving from simple docks for ships to modern, sophisticated facilities adapting to changing market dynamics, technological

[1] Then, through online surveys, will be sent to stakeholders to get a grasp of the community's perception of the same concepts

[2] Results of the survey will be analysed at later stage

advancements, and geopolitical shifts. Today, ports around the world handle large volumes of cargo, and continue to play a pivotal role in facilitating international trade and economic growth. The port industry has played a critical role in global trade and commerce for centuries (Wang et al., 2018). During the early stages of development, ports operated in areas with ample and secure space, allowing for safe and cost-effective operations (Liu et al., 2020). However, as society evolved and the global economy expanded, ports had to adapt and progress alongside them (Xu et al., 2019). In the last few decades, the port industry has seen a substantial transformation as it responded to increasing demands from international trade and technological advancements (Tu, 2022). Today, the port industry continues to evolve, driven by technological advancements and changing global trade patterns. Many ports have expanded their infrastructure to accommodate larger ships, with some capable of handling vessels of over 20,000 TEUs (Twenty-foot equivalent units). The development of automated and semi-automated container terminals has also led to more efficient cargo handling, reducing turnaround times and improving productivity.

One of the most significant developments in the port industry has been containerisation, which gained rapid popularity over several decades. Containerisation revolutionised the industry by facilitating a more efficient and cost-effective transport method. The use of standardised containers meant that goods could be loaded and unloaded faster, enabling ships to spend less time docked at port (Akbayirli et al., 2016). Over the past 40 years, world seaborne trade has increased by almost 40%, with containerised cargo showing the most dynamic growth. Containerisation has become a crucial element of maritime activity, world trade and global industrial structure, reflecting changes in manufacturing and production. Container lines have gone through various organisational phases in their pursuit of profitability, with most container ship advancements being focused on increasing vessel size to cater to trade expansion and provide economies of scale (Peters, 2001). Terminal productivity and port efficiency drove market development. Automation and other port technology solutions increased terminal productivity. Such solutions were able to boost outputs but adoption was hindered by high fixed costs, managerial obstacles, and differing laws. Few studies examined how handling technologies and external factors such as port location affected terminal efficiency (Ghiara and Tei, 2021). Furthermore, the adoption of automated cargo handling systems and technology has allowed ports to increase their efficiency while reducing costs significantly (Markkula, 2021). Numerous innovations have been introduced in the maritime port industry over the past few decades, demonstrating that innovation is essential in this intensely competitive and evolving industry. These initiatives, including container terminal optimisation (Gharehgozli et al. 2016) and port-centric logistics (Kramberger et al. 2018) have been fundamental transformations in port labour. This included changes in the types of tasks required, skills needed, professional profiles, employment relationships, work organisation, training methods, and the overall number of jobs available. As a result of these advancements, port infrastructures have undergone significant changes as shown in Figure 8, with modern ports featuring larger and deeper berths to accommodate the increasing size of vessels. Moreover, with the emergence of global supply chains and hub-and-spoke networks, ports have become a crucial link between producers and consumers across different regions (Šekularac-Ivošević et al., 2013), Port development has been a continuous process, and modern ports now offer far more than just cargo handling services. They also provide logistics and warehousing services, administrative management, insurance, consolidation, and delivery (Chen, 2022; Xu et al., 2019).

One of the most significant trends in the port industry today is the emphasis on sustainability and reducing the carbon footprint. Many ports have implemented eco-friendly initiatives, such as the use of renewable energy sources and reducing emissions from ships and cargo handling equipment. Some ports have also developed green initiatives, such as the use of electric vehicles and the installation of solar panels.

Another trend in the port industry is the growing importance of digitalisation and data analytics. Many ports have implemented advanced technology systems, such as Internet of Things (IoT) devices, artificial intelligence (AI), and blockchain, to optimise operations, enhance security, and improve supply chain visibility. These technologies have enabled ports to track cargo movements, predict demand, and optimise resources, improving efficiency and reducing costs.

The COVID-19 pandemic has also significantly impacted the port industry, with disruptions to global trade and supply chain operations. The pandemic highlighted the importance of resilient and adaptable port systems that respond quickly to changing market conditions and disruptions.

The port industry has seen significant progression over the years, from developing natural harbours to implementing containerisation, digitalisation, and sustainability initiatives. The industry continues to evolve, driven by technological advancements, changing trade patterns, and global economic trends. As the world becomes increasingly interconnected, the role of ports in facilitating global trade and commerce is set to become even more critical in the years ahead.

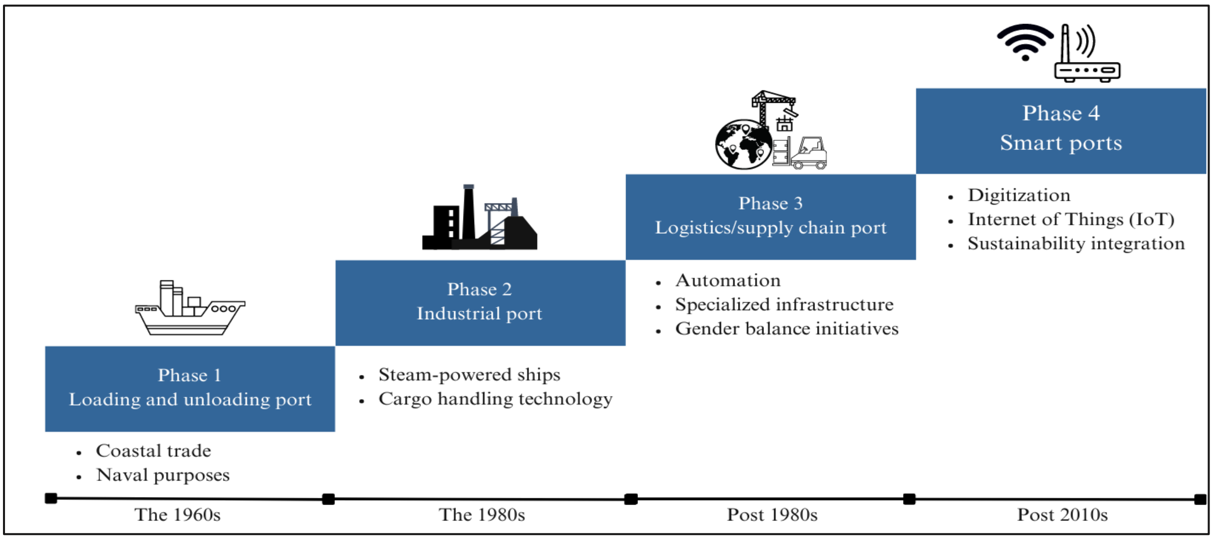

Figure 8: Evolution of the port system

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Economics

The port industry plays a crucial role in the global economy by facilitating the movement of goods and people. Over the years, the industry has undergone significant changes in response to evolving trade patterns, technological advancements, and environmental concerns. As a result, the economic development and progression of the port industry have been shaped by a complex interplay of factors that vary across regions and countries. The port industry is an integral part of the global economy, serving as a hub for the movement of goods and connecting businesses to markets worldwide (Ma et al., 2021). The industry has played a significant role in the economic development of nations, particularly those with coastal regions. In this article, we will discuss the economic development of the port industry in the world, its growth, and the challenges it faces.

Historically, ports have been the gateways for trade, connecting different regions and facilitating the exchange of goods. The development of port infrastructure and technology has played a vital role in the growth of the global economy (Hua et al., 2020). The industrial revolution in the 18th and 19th centuries led to an increase in demand for goods, and ports became crucial in the movement of goods across the world. The growth of the shipping industry and advancements in technology, such as containerisation, have further contributed to the development of the port industry (Haralambides, 2021). Today, the port industry is a major contributor to the global economy, with ports serving as critical nodes in global supply chains. The World Bank estimates that around 80% of global trade by volume and 70% by value is transported by sea, and ports play a crucial role in this movement. The port industry has grown significantly over the years, with ports becoming larger and more complex, and handling greater volumes of cargo (Munim and Schramm, 2018). The port industry's economic development has significantly impacted national and regional economies. Ports are major employers, with thousands of people working in various roles such as stevedores, terminal operators, truck drivers, and customs officials. The development of ports has also led to the growth of ancillary industries, such as logistics and transportation, and has attracted foreign investment (Wu and Fu, 2020). Countries with well-developed port infrastructure have a competitive advantage in global trade, and ports have played a significant role in the growth of many economies. For example, the Port of Singapore, one of the world's busiest ports, has been a key factor in the economic growth of Singapore, contributing to the country's status as a global financial and trading hub. Similarly, the development of the Port of Rotterdam in the Netherlands has played a significant role in the country's economic growth, with the port handling around 450 million tons of cargo annually and serving as a major gateway for trade with Europe (Trujillo and Tovar, 2007). As part of a city's transportation infrastructure, a port contributes to the city's economic growth from various angles. Due to its geographical advantages, shipping has become the primary mode of transportation in many European regions, and port logistics services have been found to play a crucial role in the economy of the hinterland, as evidenced by numerous studies (Notteboom, 2009; Essoh, 2013). The interaction between the port and city development impacts GDP and other key factors such as population, area, and intellectual properties (Bottasso et al., 2014). Furthermore, ports have been found to impact world trade, as the shipping industry is fundamental to global import and export trade, as exemplified by the causal relationship between world trade and port throughput in Rotterdam (Heijman et al., 2017). Port throughput, as the most critical indicator of port service production, is frequently used to analyse the interaction mechanism between the port and the city's economy, and how it affects the port city, ports located in Rouen, for example contribute more than 21% of regional Gross Domestic Products (GDP) in 2007 (Cong et al., 2020). Ports can be viewed as facilitators of economic growth since they encourage development in particular economic sectors and locations near ports or corridors. The economic advantages of ports are typically divided into direct, indirect, and induced categories, shown in Figure 9. Indirect and induced benefits are challenging to identify explicitly, as it is difficult to prove that the economic activity and usage of related resources would have occurred only due to the port investment.

When an investment in a port leads to increased economic activity, the benefit is assessed by determining the net value of the additional output. The direct benefits for the port are financial and would be factored into any financial appraisal and economic appraisals. However, the financial benefits would be evaluated somewhat differently, with economic appraisals utilising a social discount rate and, for certain inputs, potentially valuing them at shadow prices (Notteboom et al., 2022).

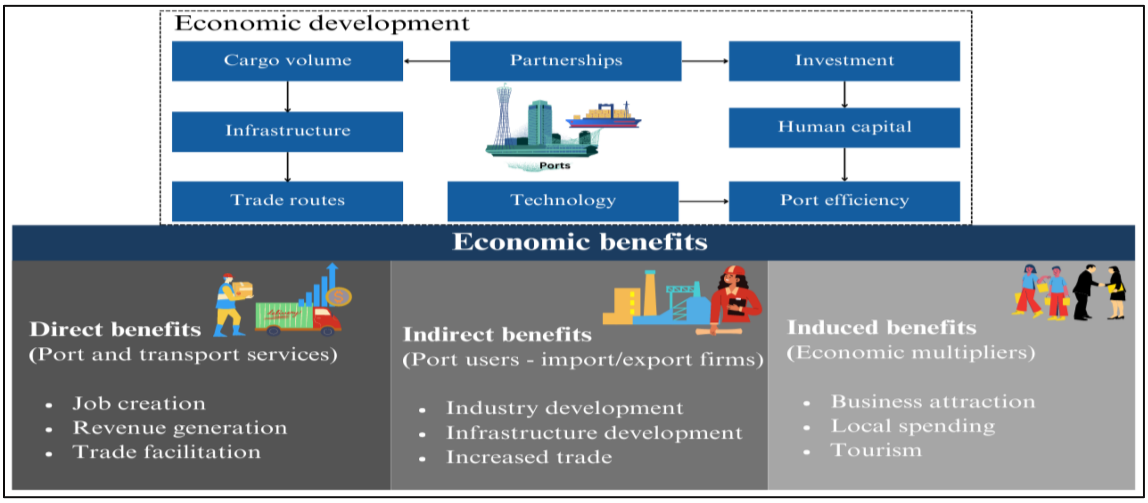

Figure 9: The economic development of ports

As shown in Figure 9, the economic development of ports is driven by several key aspects. Cargo volume plays a crucial role in port growth as ports strive to increase their capacity to handle larger volumes of cargo, both in terms of import and export. This requires continuous infrastructure development, such as expanding container terminals and improving storage facilities. Higher cargo volumes lead to increased revenue, job creation, and overall economic growth in the port's surrounding areas. Partnerships and investments are vital for the economic development of ports. Collaboration between port authorities, private sector stakeholders, and governments can lead to significant investments in port infrastructure and services.

Politics

The port industry is an essential part of global trade and commerce, with ports serving as the gateway for the movement of goods and services between countries. As a result, the port industry is highly regulated, and political developments significantly impact its operations. In recent years, there have been several political developments in the port industry that have shaped its operations and governance. Various factors have influenced these developments, including globalisation, technological advancements, and changing geopolitical landscapes. The global port industry has thus experienced significant political developments throughout its history. From the early days of port activities to modern times, there have been numerous instances where political decisions have significantly impacted the growth and nature of port industry operations (Pintossi et al., 2021).

As global trade expanded over time, the development of port infrastructure became increasingly significant, and many governments started investing heavily in building modern seaports to support international trade (Vasilyeva et al., 2018). One of the most significant political developments in the port industry has been the increasing privatisation of ports. In the past, many ports were state-owned and operated, but in recent years, many governments have turned to private sector involvement in the port industry. This shift has been driven by the belief that private operators can bring greater efficiency and innovation to port operations, leading to increased competitiveness and economic growth.

Another significant political development in the history of the port industry was the shift towards privatisation in the late 20th century (Hein and van de Laar, 2020). Governments across the world began to recognise that privately operated ports can be more efficient, cost-effective and adaptable compared to government-owned facilities. This shift towards privatisation was often driven by political pressures, such as reducing public spending or attracting private investment into the country's infrastructure (Juhel, 2001). Additionally, there have been several instances where geopolitical conflicts and tensions impacted port industry operations. For example, the ongoing trade tensions between the U.S. and China have resulted in significant disruptions to global shipping patterns and changes to port infrastructure investment priorities, as countries look to redirect their trade flows

(Munim and Schramm, 2018). In recent years, the political development of the port industry has also been influenced by environmental concerns. Environmental concerns have emerged as a significant political issue in the port industry. Ports are major air and water pollution sources, with ships and cargo-handling equipment emitting significant amounts of greenhouse gases, particulate matter, and other pollutants. Thus, various governments are increasingly recognising the need to reduce the environmental impact of port operations, limiting carbon emissions and increasing sustainability. These political developments in the port industry reflect changing global priorities and objectives over time, from expanding trade power to reducing public spending to addressing environmental concerns (Christodoulou and Cullinane, 2019). Furthermore, political decisions have also impacted the legal and regulatory frameworks of port industry operations. For example, changes in trade policies and regulations at the national or international level can have significant effects on port operations, including tariffs and quotas affecting the import and export of goods, as well as changes to labour laws that impact the workforce (Bucher et al., 2021).

Sociology

The development of the port industry has been an important aspect of sociological study due to its impact on global trade and economic growth (Vukić et al., 2018). From a sociological perspective, the development of the port industry reflects society's changing attitudes towards commerce and globalisation (Janardhan, 2019). Historically, ports were centres of power for coastal cities and nations. As societies became more interconnected through trade and transportation, ports became gateways to the global economy (Kim et al., 2016).

The sociological development of the port industry has also been shaped by technological advances, such as containerisation and automated systems, which have led to increased efficiency and productivity (Durán et al., 2021). Furthermore, the concept of port cities as cultural melting pots has facilitated the development of a globalised society by fostering cross-cultural interaction and exchange (Scholars Strategy Network, 2018). This has also significantly impacted port cities' and surrounding communities' social and economic development. The sociological impacts of port development can be seen in the social and economic changes within port communities. As ports have grown in size and importance, they have often attracted migrants seeking employment, creating diverse communities with unique social dynamics (Natteboom, 2009). The port industry is undergoing significant sociological developments that reflect the changing nature of global trade and economic development. While these changes present opportunities for innovation and growth, they also pose challenges in terms of labour relations, urban planning, and social and environmental sustainability.

Demography

The demographic developments in the port industry reflect the changing trends in global trade and the dynamics of the workforce. The demographic developments in the port industry have played a significant role in shaping the history of global trade and economic growth. The port industry has seen significant demographic changes in recent years due to several factors, including globalisation, technological advancements and changing consumer behaviours (Wu et al., 2022). The port industry has experienced significant growth in trade and shipping activities, particularly in emerging economies (Lam and Yap, 2019), due to changes in (i) **gender diversity** is an important demographic development in the port industry. Historically, the port industry has been male-dominated, but this is slowly changing as more women enter the industry. Many ports are actively promoting gender diversity, with initiatives such as training programs, mentoring, and leadership development opportunities for women, (ii) the **globalisation of the port industry** has led to increased cultural diversity in the workforce. Ports are now home to workers from diverse backgrounds with different languages, customs, and traditions. This diversity has created new challenges for port operators, such as ensuring effective communication and creating a culture of inclusion and respect, and (iii) **increasing labour force diversity**, including changes in workforce demographics such as age, gender and skill level, has led to a need for more flexible and inclusive management practices.

Ethnology

The port industry has played a crucial role in the development of trade and commerce worldwide. Throughout history, ports have served as key entry and exit points for goods, people, and cultures. In contrast to historical ports, which were often integrated with the surrounding communities and served as cultural melting pots, modern mega ports have been conceived as gated industrial complexes designed to facilitate the efficient movement of goods. However, the development of ports is not solely a technological or economic process; it is also grounded in cultural and social factors (De Martino, 2020). For example, the ethnological development of ports in different parts of the world has been impacted by factors such as regional cultural practices and beliefs about work and commerce and national and international policies shaping port development (Chang and Chang, 2012). Understanding the cultural and social factors that have influenced the development of ports is critical for policymakers and port managers seeking to foster sustainable development in their communities (Boza et al., 2017).

Workforce diversity is also an important ethnological development in the port industry. Historically, the port industry has been male-dominated, with few opportunities for women and minorities. However, there has been a concerted effort to promote diversity and inclusivity in the industry in recent years. They have implemented various programmes and initiatives aimed at encouraging women and minorities to pursue careers in the port sector. These efforts include training programs, mentorship opportunities, and scholarships to support individuals from underrepresented groups. By providing access to education, skills development, and mentorship, ports aim to create a more inclusive and diverse workforce. Promoting workforce diversity in the port industry brings numerous benefits. Firstly, it expands the talent pool and increases the potential for innovation and creativity. Diverse perspectives and experiences foster new ideas and approaches, leading to improved problem-solving and decision-making within port operations. Additionally, diverse workforces enhance cultural sensitivity and understanding, allowing ports to better serve their diverse clientele and international partners.

Moreover, fostering diversity in the port industry contributes to economic growth and social development. By breaking down barriers and creating equal opportunities, ports can tap into a broader pool of talent, resulting in increased productivity and competitiveness. Additionally, providing women and minorities with meaningful employment in the port industry helps to reduce socio-economic disparities and promotes social inclusion.

3.1.2 Gender-based lens in understanding male predominance in the port industry

The port industry is predominantly male-dominated, with men occupying most of the positions in the industry, including top management roles, dockworkers, and sailors. Understanding this phenomenon through a gender-based lens provides a useful framework for understanding the underlying factors that contribute to male predominance in the port industry. The gender-based lens recognises that gender roles and stereotypes play a significant role in shaping the dynamics of different industries and workplaces. In the case of the port industry, gender stereotypes may have contributed to the marginalisation of women in this field.

Given the historically male-dominated nature of labour-intensive industries, including the port industry, gender norms and expectations may play a role in perpetuating this imbalance (MacNeil and Ghosh, 2017). Feminist economists have identified several factors that contribute to the gender wage gap and occupational segregation in male-dominated industries. One key factor is the universal tendency towards gendered job segregation, as noted by (Anker et al., 2003). This tendency towards gendered job segregation is further reinforced by the societal norms and expectations regarding men's and women's roles in the workplace (Michel, 2020). One major factor contributing to the gender imbalance in the port industry is gender stereotypes and societal expectations. Gender stereotypes are deeply ingrained in many societies and often dictate what is considered appropriate behaviour and roles for men and women. In the case of the port industry, the perception that physical strength and toughness are essential traits for the job has led to the exclusion of women from the industry. The stereotype that women were physically weaker than men was used to justify the idea that women were not fit for physically demanding jobs like those in the port industry (MacNeil and Ghosh, 2017).

Gender bias in recruitment and promotion practices can also contribute to male predominance in the port industry. Hiring managers and recruiters may unconsciously favour male candidates over female candidates due to gender bias, leading to fewer women being hired for jobs in the industry. Similarly, promotion practices in the industry may favour male employees over female employees, leading to fewer women in management positions. This also contributes to the lack of diversity in the industry's recruitment and retention policies. Many port employers tend to rely on word-of-mouth recruitment or hire based on personal connections, which can lead to a lack of diversity in the workforce (Pastra and Swoboda, 2021).

Moreover, the port industry has historically been male-dominated, which means that the existing culture and norms may not be welcoming or inclusive of women. This can create a hostile or unwelcoming work environment that discourages women from pursuing careers in the industry. Additionally, the lack of female role models and mentors in leadership positions can make it difficult for women to envision themselves in leadership roles within the industry (Sanrı, 2022).

The gender-based lens provides a valuable perspective for understanding the male predominance in the port industry. By recognising the role of gender stereotypes and discrimination, and implementing policies and programmes that promote diversity and inclusivity, it is possible to create a more equitable and inclusive workplace that benefits everyone.

3.2 Perception of the community in topics related to port industry progression

The perception of the community plays a crucial role in the port industry's progression. The industry's impact on the local economy, environment, safety, and community relations can shape the community's perception of its progress. Therefore, the industry's efforts to prioritise sustainability, safety, and community engagement can help build trust and support among the community and promote positive perceptions of its progression.

Communities are critical stakeholders in the port industry. They are directly affected by the industry's activities, and their perception of the industry can influence government policies, regulations, and investment decisions. In recent years, there has been increasing attention to the role of communities in shaping the future of the port industry. Several factors influence communities' perceptions regarding the industry's progression, including environmental impacts, economic benefits, employment opportunities, and social impacts (Felício et al., 2022).

One of the key factors influencing the community's perception of the port industry's progression is its impact on the local economy. Ports are major economic drivers, providing jobs and supporting local businesses. The community's perception of the industry's progress is often linked to its perception of the local economy's health. If the community perceives the port industry as thriving and contributing to the local economy's growth, it is likely to view the industry positively. The port industry provides direct and indirect employment opportunities for communities. Direct employment opportunities are in cargo handling, shipping, logistics, and maintenance, while indirect employment opportunities are in transportation, retail, and hospitality. The perception of communities regarding the industry's employment opportunities can be positive or negative, depending on the level of skill required, job security, and the impact on the local labour market. The industry has responded by investing in training and education programmes to develop a skilled workforce, creating stable job opportunities, and collaborating with local communities to support workforce development.

One of the most significant concerns of communities related to the port industry is the potential environmental impacts of the industry's activities. The industry's operations, such as cargo handling, dredging, and ship emissions, can negatively affect air and water quality, noise pollution, and the natural environment. Communities are increasingly concerned about the impact of the industry on their health, safety, and quality of life (Mthembu and Chasomeris, 2022). The perception of communities regarding the industry's environmental impact can be positive or negative, depending on the measures taken to mitigate these impacts (Stan, 2022).

The study of communities in maritime traffic, particularly in the context of port industry progression, has drawn increasing attention from researchers in recent years (Lloyd's Register, n.d.). One topic of interest in this area is communities' perception of the changes brought about by the port industry progression. This area of research seeks to understand how communities perceive the benefits and drawbacks of port industry progression, such as increased traffic volume, pollution regulations, and technological advancements. The port industry's safety record is another crucial factor that can shape the community's perception of its progression. Safety incidents such as spills, fires, and accidents can significantly impact the industry's reputation and public perception. Therefore, the industry's efforts to prioritise safety and implement best practices can help build trust and support in the community. The port industry's relationship with the local community is also vital in shaping perception. Community engagement, open communication, and transparency can help build trust and promote positive perceptions of the industry's progression. Additionally, the industry's efforts to address community concerns and prioritise social responsibility can help enhance its reputation and public perception.

5. Women's roles in energy transition and innovation

The global energy environment is experiencing fundamental change, with the need to transition to sustainable and renewable energy sources becoming more pressing than ever. As the globe moves towards cleaner energy solutions, women are increasingly taking the lead in pushing innovation and adopting sustainable practices in the port sector, with a rising acknowledgement of the contributions that women can make.

Women can play a broad range of roles in port innovation and energy transition, including coordinating and facilitating the adoption of novel technologies. By establishing an innovation network in which women are essential players and decision-makers, port authorities may play a critical role in the development of a regional innovation system.

Governments and public policy, according to a study on speeding a clean energy transition in Southeast Asia (Aleluia et al., 2022), play a critical role in the transition to renewable energy. This shows that women in administration and policy roles may have an impact on port energy transitions.

Furthermore, in a study on green transition and gender prejudice, Arias et al. (2023) examined the participation of women in renewable energy generation firms in Latin America and the Caribbean. According to the study, renewable energy enterprises with the largest female participation had the highest relative efficiency in the labour-capital ratio.

Another study looked at the role of women in guaranteeing justice during the energy transition in ASEAN and G7 countries (Sumarno et al., 2023). According to the study, women's engagement in just energy transition is critical, yet they are underrepresented in the energy industry. The study encourages women's participation in a just energy transition and seeks to reconcile justice and inclusivity in the energy transition from upstream and downstream ASEAN beneficiaries with G7 examples. Women may play important roles in energy transition and port innovation, including leadership and management, training and education, and technology and engineering.

Leadership and management: Women's leadership in energy transition and innovation in ports is crucial for driving positive change, fostering sustainability, and creating a more inclusive and forward-thinking industry.

Breaking stereotypes and entering technical professions: The port industry's technical sector is fast evolving as more women break stereotypes and enter historically male-dominated professions such as engineering, environmental sciences, and renewable energy technologies. Their presence contributes a variety of viewpoints, inventiveness, and problem-solving talents, which eventually benefits the development of sustainable practices within ports.

STEM education promotion and mentorship: It is critical to inspire and empower the next generation of women to continue the momentum of their participation in the energy transition and port innovation. Women in the sector are actively committed to encouraging young girls to seek professions in energy and port-related fields by supporting STEM (Science, Technology, Engineering, and Mathematics) education. Guenaga et al. (2022) examined the effects of a group mentorship programme directed by a female STEM role model on the young people who took part in the programme, as well as whether or not these effects varied depending on the participants' gender. The authors demonstrated how the mentorship sessions changed their perspectives on technology, self-efficacy in mathematics, gender stereotypes, allusions to science and technology, and professional choices. According to a report by the International Labour Organisation (ILO) titled Women in STEM Workforce Readiness and Development Programme in Indonesia (ILO, 2021), a programme has been implemented to increase productivity and prevent women from losing their employment as a result of automation in various sectors. This programme aims to strengthen ties between private-sector businesses, social partner institutions, and vocational training facilities to increase women's access to STEM-related jobs and their retention and advancement. Furthermore, mentorship programmes headed by women provide important assistance and direction to ambitious professionals, establishing a nurturing environment in which talent can blossom.

Engineering and Design: Women can work as engineers and designers to develop and optimise energy-efficient port infrastructure and processes. This includes creating eco-friendly port facilities, green buildings, and sustainable transportation systems within the port.

Research and Development (R&D): Women can make important contributions to R&D efforts in developing sustainable and renewable energy solutions for port operations. They may be involved in designing and implementing technologies such as solar, wind, or wave energy systems and investigating new energy storage methods.

Policy and Advocacy: Women can help shape energy policy and advocate for environmentally friendly practices in the port and maritime industries. They can get involved in organisations and activities that promote cleaner energy and lower pollution.

3.3 Inclusion of women and underrepresented communities

3.3.1 Challenges and Opportunities

In recent years, there has been a growing recognition of the importance of diversity and inclusion in the workplace, and the port industry is no exception, given that historically, the industry has been male-dominated, with a limited representation of women and underrepresented communities. One of the main challenges in the inclusion of women and underrepresented communities in the port industry is the perception that it is a male-dominated industry. This perception can discourage women and underrepresented communities from pursuing careers in the industry. The industry's lack of role models and mentors can also be a barrier to entry for these groups. Additionally, the physical demands of some jobs in the industry, such as loading and unloading cargo, can be a deterrent for women.

This lack of diversity and inclusion can have a negative impact on the industry's growth, innovation, and overall success. As such, there has been a growing push towards the inclusion of women and underrepresented communities in the port industry, recognising the valuable contributions they can make and the benefits of a diverse workforce (Barreiro-Gen et al., 2021). Women's participation in the maritime industry has been reported to be fairly limited in many parts of the world and both horizontal and vertical segregations can still be observed even today (Kitada, 2009; Kitada and Bhirugnath-Bhookhun, 2019).

This topic encompasses various issues, such as increasing the number of women and minorities in port-related jobs, providing equal opportunities and fair treatment, promoting diversity and inclusivity in leadership roles, and addressing the unique challenges faced by these groups in the industry. In this context, it is important to understand the current state of the industry and the various initiatives aimed at promoting inclusion and diversity, as well as the challenges that still need to be addressed.

The inclusion of women and underrepresented communities in the port industry has become a critical issue. Women constitute a significant portion of the global population, and their contributions to the workforce cannot be ignored. Similarly, underrepresented communities bring unique perspectives and experiences to the table, which can help businesses to grow and thrive (Hoobler et al., 2018).

The benefits of diversity in the port industry are numerous. First and foremost, a diverse workforce can bring a range of perspectives and experiences to the table, which can help businesses to understand their customers better and adapt to changing market conditions. Additionally, diversity can lead to increased creativity and innovation, as individuals with different backgrounds and experiences are more likely to approach problems from unique angles (Turnbull, 2013).

Various governmental initiatives, including laws promoting gender equality, have been implemented to initiate the process of reducing gender segregation and enhancing the existing work environments. However, there is a need for more comprehensive measures to break down access barriers to jobs and facilitate the retention of underrepresented genders. It is crucial to integrate such efforts since ad hoc initiatives are usually not effective in decreasing gender segregation (Dragomir, 2018). Despite the benefits of diversity, however, women and underrepresented communities continue to face barriers to entry into the port industry. One of the main challenges is the lack of female role models in leadership positions. Without visible female leaders, women may struggle to see a path forward in the industry and may be less likely to pursue careers in port-related fields (Kim et al., 2019).

This research shows that European ports have engaged in measures aimed at reducing gender segregation, and the research found that men and women tend to do different jobs in ports due to traditions and culture (Barreiro-Gen et al., 2021). This was in good agreement with other reports published in the literature (Struthers and Strachan, 2019).

Gender segregation, compliance, gender equity, and gender equality play significant roles in the sustainability of ports, Figure 3. Historically, the port industry has been characterised by gender segregation, with certain roles predominantly filled by men and others by women. This segregation limits opportunities for women to access higher-level positions and contributes to gender disparities in the industry. Addressing gender segregation is crucial for promoting sustainability in ports. Breaking down these barriers allows for the utilisation of the full potential of the workforce, leading to increased productivity and innovation.

Compliance with gender equality regulations and international frameworks is essential for fostering sustainability in ports. Governments and port authorities need to implement and enforce legislation and policies that promote gender equality and prohibit discrimination. This includes addressing issues such as pay gaps, workplace harassment, and unequal opportunities for career advancement. Compliance with gender equality standards ensures that ports create a fair and inclusive environment that supports the well-being and professional growth of all employees.

Gender equity involves providing fair and impartial opportunities, resources, and support to individuals regardless of their gender. Promoting gender equity in the port industry entails addressing the underlying factors that contribute to gender disparities, such as bias and stereotypes. This can be achieved through targeted initiatives, including mentorship programs, training opportunities, and career development support for women in traditionally male-dominated roles. By striving for gender equity, ports create a sustainable, inclusive work environment that attracts and retains diverse talent.

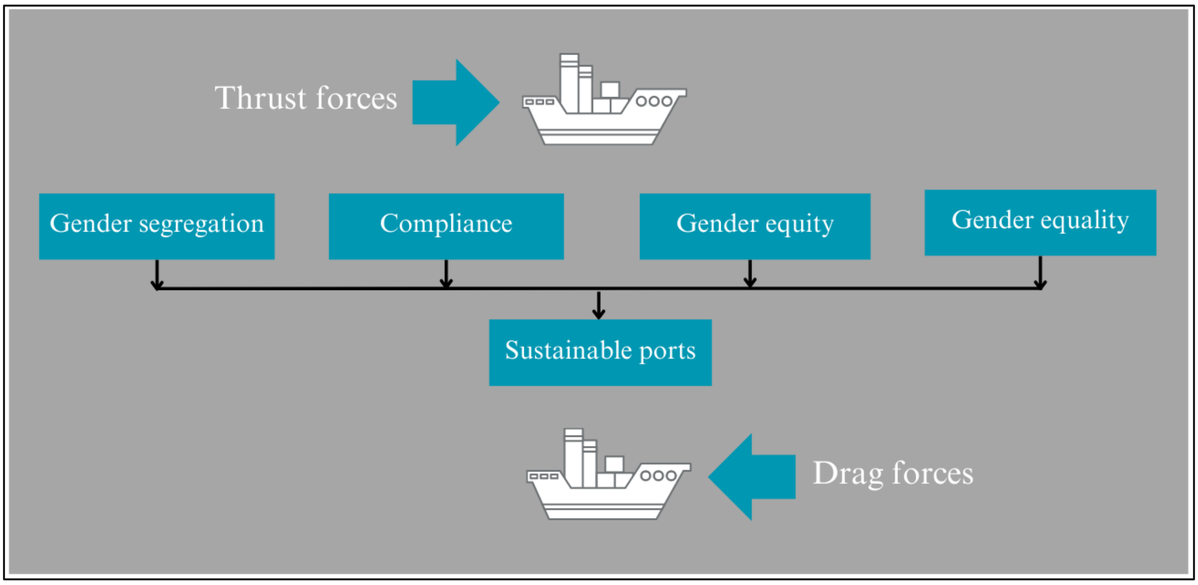

Figure 10: Gender equality for sustainability in ports
Adapted from (Barreiro-Gen et al., 2021)

Gender equality goes beyond gender equity and aims for equal rights, opportunities, and treatment for individuals of all genders. Achieving gender equality in the port industry is fundamental to its sustainability. This involves eliminating discriminatory practices, ensuring equal pay for equal work, and providing equal opportunities for career advancement. Ports can work towards gender equality by fostering a culture of inclusivity, actively challenging gender biases, and promoting diversity at all levels of the organisation.

By addressing gender segregation, ensuring compliance with gender equality regulations, promoting gender equity, and striving for gender equality, ports can create a more sustainable and thriving industry. Gender diversity and inclusivity foster innovation, enhance decision-making processes, and improve organisational performance. Furthermore, promoting sustainability in ports through a gender lens contributes to the broader goals of social responsibility and economic development within the industry and the communities they serve.

Despite the overall progress reported in customary gender equality indicators, women's empowerment and contribution to economic growth are still limited in reality (Kitada and Bhirugnath-Bhookhun, 2019).

In this vein, how can we operationalise women's contribution to economic growth? In the maritime sector, which is known as a traditionally male-dominated industry, research on women's empowerment to support the maritime economy is scarce. Bhirugnath-Bhookhun and Kitada (2017) recognise women managers' important role in boosting the maritime economy in Southern and Eastern Africa.

Advancement of technology through innovation is expected to increase the mobility of people, assets and information across traditional borders and boundaries. Consequently, the contribution of these technological advancements in breaching the reported gender disparity or unreported gender parity can only be underscored. As such, future maritime clusters, which integrate gender-based components, will potentially grow further and add value to this age-old concept in its contribution to economic growth. However, its ultimate growth will depend on the capacity of maritime industries to accept diversity and innovative ideas, particularly in embracing the potential of women professionals and going beyond business as usual (Kitada and Bhirugnath-Bhookhun, 2019).

The maritime industry requires a workforce with advanced technical skills. To encourage more women to pursue careers in this field, the industry and regulatory bodies must take a comprehensive and proactive approach to address gender role bias issues and create physical working conditions that are suitable for both genders. This includes providing women with the necessary skills for the future and fostering their self-efficacy and interest in pursuing maritime careers (Kim et al., 2019).

Despite these challenges, there are also opportunities for the inclusion of women and underrepresented communities in the port industry. The industry is facing a labor shortage, and there is a growing need for skilled workers. This presents an opportunity for the industry to tap into a broader pool of talent by recruiting and retaining women and underrepresented communities. By doing so, the industry can benefit from a wider range of skills and perspectives, which can lead to greater innovation and success.

Furthermore, there is increasing recognition of the benefits of diversity and inclusion in the workplace. Companies that prioritise diversity and inclusion are more likely to attract and retain top talent, have higher employee engagement, and be more innovative and successful. Inclusion can also lead to better decision-making by bringing together diverse perspectives and experiences.

To promote the inclusion of women and underrepresented communities in the port industry, there are several strategies that can be employed. Firstly, companies can prioritise diversity and inclusion in their recruitment and hiring practices. This can include reaching out to underrepresented groups and providing training and development programmes to support their career advancement. Secondly, companies can implement policies and practices that support work-life balance, such as flexible working arrangements and parental leave. Thirdly, companies can establish mentorship and networking programmes that provide women and underrepresented communities with the support and guidance they need to succeed in the industry. Finally, companies can prioritise diversity and inclusion in their leadership development programs, ensuring that women and underrepresented communities are given equal opportunities to advance into leadership positions.

The inclusion of women and underrepresented communities in the port industry is essential for the industry's success and growth. While there are challenges to achieving this goal, there are also significant opportunities for the industry to benefit from a more diverse and inclusive workforce. Companies can promote inclusion by prioritising diversity in their recruitment and hiring practices, implementing policies that support work-life balance, establishing mentorship and networking programs, and prioritising diversity and inclusion in their leadership development programs. By doing so, the industry can tap into a broader pool of talent and improve its competitiveness in the global economy.

3.3.2 Women in the port of the global supply chain

Over the years, the roles of women in the global supply chain have evolved significantly. The port industry, which is a crucial component of the global supply chain, has seen an increase in the number of women employed in various roles. Traditionally, the port industry has been dominated by men, and women's participation was limited to administrative and clerical roles. However, in recent years, women have increasingly taken up roles in operational and technical areas, such as crane operators, stevedores, port engineers, and logistics coordinators.

The global supply chain is a complex system of networks, processes, and people that ensure that goods are produced, transported, and delivered to consumers worldwide. It involves numerous industries, including shipping, logistics, manufacturing, and retail. Women have always been integral to this system, working in various roles across different industries (Koberg and Longoni, 2019). However, women's participation in the global supply chain is still relatively low, particularly in the maritime industry. According to the International Maritime Organisation, women represent only 1.2% of the maritime seafarer workforce worldwide. This lack of female representation is particularly striking given the sector's increasing demand for skilled labour.

The importance of diversity and the roles of women in maritime shipping is huge. Despina Panayiotou Theodosiou, President of WISTA International, commented: “The recognition of the vital roles women play in the maritime world has been thrown into even greater perspective by the global pandemic. The importance of the contribution everyone plays in the shipping world, the ports sector and the wider maritime industry cannot be undervalued – and women are an integral part of the solutions that the global economy needs as the slow recovery continues" (https://grrip.eu/the-importance-of-women-in-maritime/).

Women are also making significant contributions in the management and leadership roles in the port industry. They are breaking down barriers and challenging gender stereotypes, leading to increased diversity in decision-making positions. In addition to the benefits of diversity and inclusivity, having more women in the port industry has economic advantages. A study by the International Transport Forum found that increasing women's employment in the transport sector could lead to a $30 trillion increase in global GDP by 2025.

Women play a crucial role in the port of the global supply chain, but they face various challenges that limit their employment and career advancement opportunities. These challenges include discrimination, harassment, and lack of representation. To overcome these challenges, it is important to provide women with access to training and educational opportunities and to create a supportive and inclusive work environment. By doing so, we can create a more diverse and inclusive workforce in the port of the global supply chain. UNCTAD (2021) (United Nations Conference on Trade and Development) studied the business case for diversity in the Indian maritime industry. It was reported that, while companies often viewed diversity as a moral obligation, they tended to overlook its potential positive impact on business outcomes. Besides, after interviews with HR heads, CEOs, and experts, the study found that companies generally lacked data connecting diversity to financial performance.

Gender equality is an important aspect of the global supply chain, which refers to the network of companies, organisations, and individuals involved in the production and distribution of goods and services around the world. Despite progress in recent years, gender inequality remains a significant challenge in many parts of the supply chain, particularly in manufacturing, agriculture, textiles, and the port industry. A gender perspective is vital to fully understanding and conceptualising global value chains, their power structures, division of labour, welfare effects and empowerment (Schumacher, 2014). Gender equality is a fundamental human right that is critical for the growth and development of every society. Despite the progress made over the years, there are still significant gender gaps in various industries, including the global supply chain (Gonzalez et al., 2015). The supply chain is an interconnected network of companies involved in producing, transporting, and distributing goods and services. This complex system spans multiple industries and geographies, with numerous players involved in each stage of the process (Barrientos et al., 2019). Global networks are socially located and involve men and women embedded in their social networks with individual opportunities and restrictions or exclusions from particular fields of productive activities (Schumacher, 2014). The dimension of gender equality in the global supply chain is a complex issue requiring a multifaceted approach. Historically, women's participation in the supply chain workforce has been limited to low-paying and low-skilled jobs (Vijeyarasa, 2020). However, recent years have shifted towards more significant female representation in higher-skilled roles such as engineering, management, and technology (Prieto-Carrón, 2008).

One of the key dimensions of gender equality in the global supply chain is access to employment opportunities. Women are often excluded from certain jobs or industries due to cultural, social, or economic factors, which can limit their ability to earn a living wage and contribute to the overall economic growth of their communities. Moreover, women with access to employment opportunities in the supply chain may face discrimination in hiring, promotion, or pay, further exacerbating gender disparities.

Figure 11 highlights the significant disparity between men and women in the maritime industry, as reported by (Sandvick, 2019), specifically in supporting line positions and operative line positions. The data reveals that women are underrepresented in these roles compared to men. In supporting line positions, where roles involve functions such as administrative support, logistics coordination, and customer service, women represent only 13% of the workforce, while men make up 49%.

This gender disparity may stem from various factors, including social norms, cultural biases, and historical gender stereotypes that have associated certain roles within the industry as more suitable for men. Addressing this disparity requires concerted efforts to challenge these stereotypes and promote equal opportunities for women to pursue and succeed in supporting line positions. Similarly, in operative line positions, which encompass tasks related to cargo handling, vessel operations, and maintenance, women comprise a mere 5% of the workforce, while men account for 39%. The low representation of women in these roles can be attributed to physical demands, perceived occupational hazards, and the prevalence of male-dominated work environments. Achieving gender balance in operative line positions necessitates creating an inclusive and supportive atmosphere that encourages women's participation, addresses safety concerns, and provides equal access to training and career advancement opportunities.

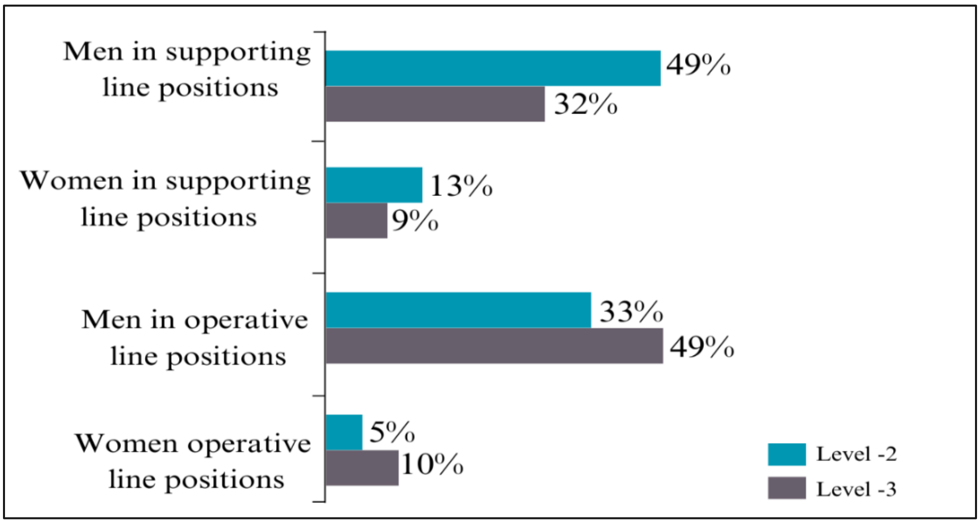

Figure 11: Management employees in the maritime industry
Source: (Sandvik, 2019)

To bridge these gender gaps, various strategies can be employed. Increasing awareness about the diversity of roles and career paths available within the maritime industry can help challenge stereotypes and attract more women to these traditionally male-dominated positions. Implementing proactive recruitment and mentorship programmes can provide support and guidance to women seeking careers in supporting and operative line positions. Additionally, promoting workplace policies and initiatives that foster gender equality, such as flexible work arrangements, equal pay, and zero-tolerance policies against gender-based discrimination and harassment, are essential for creating an inclusive work environment that values and respects the contributions of all employees.

Another critical challenge facing women in the supply chain is the gender pay gap. Women in the supply chain typically earn less than their male counterparts, even when performing the same job (Islam, 2008). This pay gap is particularly prevalent in developing countries where there are limited regulations to enforce gender pay equity. The gender pay gap has a cascading effect on women's economic empowerment, as it limits their ability to achieve financial independence and economic mobility (Szymczak et al., 2022).

Another critical dimension of gender equality in the global supply chain is access to education and training. A lack of education and training opportunities often limits women's participation in the supply chain (Grønning et al., 2020). In many countries, girls have limited access to education, which limits their ability to acquire the skills needed to participate in higher-skilled supply chain roles. Additionally, women often face cultural barriers that discourage them from pursuing non-traditional roles in male-dominated industries (Rubin and Manfre, 2014).

Addressing gender inequality in the supply chain requires a multi-stakeholder approach (van Zyl and Mans-Kemp, 2022). Governments, NGOs, and the private sector all have a role to play in promoting gender equality in the supply chain. Governments can implement policies and regulations that promote gender equity, such as laws mandating gender pay equity and quotas for female representation on boards (Grosser, 2009). NGOs can work with local communities to provide education and training opportunities for women (Kumi and Elbers, 2022), while the private sector can implement policies and practices that promote gender equity in the workplace (Finley et al., 2022).

One way that the private sector can promote gender equality in the supply chain is by implementing supplier diversity programmes (Miguel and Tonelli, 2023). These programmes aim to increase the number of women-owned businesses in the supply chain by setting procurement targets and providing support and training to women entrepreneurs. Supplier diversity programmes not only promote gender equality but also help to create a more diverse and inclusive supply chain, which is beneficial for business performance (Worthington et al., 2008).

Gender equality is a critical dimension of the global supply chain that requires a multifaceted approach to address. Addressing gender inequality in the supply chain requires the involvement of all stakeholders, including governments, NGOs, and the private sector. Promoting gender equality in the supply chain benefits women and creates a more diverse and inclusive supply chain, which is beneficial for business performance. By working together, we can create a more equitable and sustainable supply chain for all.

Women's rights and the policies supporting empowerment

In recent decades, the global community has made significant strides towards achieving gender equality and promoting women's empowerment. However, despite these efforts, women still face systemic barriers in many areas of life, including access to education, healthcare, employment, and political representation. Realising women's rights and empowerment requires comprehensive policy interventions that address the root causes of gender inequality and provide women with the tools and opportunities they need to thrive. Women's rights and empowerment have been at the forefront of global discussions for decades, and with good reason. Women make up a significant portion of the global workforce, particularly in the manufacturing and supply chain industries. Women often face discrimination and inequality in the workplace, which can limit their economic opportunities and impede their ability to reach their full potential (Prieto-Carolino et al., 2021).

Women's rights and gender equality are crucial issues that need to be addressed in the global supply chain industry. Recently, there has been an increased focus on policies and initiatives supporting women's rights and empowerment in the global supply chain. These policies address the systemic issues hindering women's progress and create a more equitable and inclusive workplace (George et al., 2017).

The United Nations Sustainable Development Goals (UN SDGs) are a set of 17 global goals that aim to address the world's most pressing challenges, including poverty, inequality, and climate change, by 2030. One of these goals, Goal 5, specifically focuses on achieving gender equality and empowering all women and girls. It recognizes gender equality as a fundamental human right but alsoa fundamental human right and a fundamental human right and a foundation for a peaceful, prosperous, and sustainable world. It aims to end all forms of discrimination, violence, and harmful practices against women and girls and ensure their full participation and equal opportunities in all areas of life. One such policy is the UN Women's Empowerment Principles, which provide a framework for businesses to promote gender equality and empower women in the workplace (de Souza Mauro et al., 2019). These principles include measures such as promoting women's leadership and development, ensuring equal pay for equal work, and implementing policies to prevent discrimination and harassment.

Another policy that has gained momentum in recent years is the Women's Empowerment in Agriculture Index (WEAI), which measures the empowerment of women in the agricultural sector (Malapit et al., 2019). The WEAI assesses factors such as access to resources, decision-making power, and control over income and assets. The index has been used to inform policies and programmes that support women's empowerment in agriculture, such as improving access to credit and training. In addition to these policies, there are also numerous initiatives and programmes that support women's empowerment in the global supply chain. For example, the International Finance Corporation (IFC) has launched a programme called "SheWorks" (Datta and Kotikula, 2017) which supports businesses in creating more opportunities for women in their workforce. The programme provides tools and resources for businesses to promote gender equality and support women's career development. In addition to these initiatives, many companies in the global supply chain industry have implemented their initiatives to support women's empowerment. For example, some companies have established women's leadership programmes to help women advance into leadership roles. Others have implemented flexible work arrangements to support working mothers and allow them to balance their work and family responsibilities. Some companies have also implemented initiatives to address the specific challenges faced by women in the industry, such as the gender pay gap and sexual harassment.

For example, some companies have conducted gender pay audits to identify and address any pay disparities between men and women. Others have implemented anti-harassment policies and training programmes to prevent and address sexual harassment in the workplace. Despite the progress that has been made in recent years, much work still needs to be done to ensure women's rights and empowerment in the global supply chain. Some of the key challenges that remain include the lack of access to education and training for women, as well as the persistence of discriminatory attitudes and practices in the workplace (Cornwall, 2016). To address these challenges, it is essential to prioritise policies and initiatives supporting women's empowerment in the supply chain. This includes investing in education and training programmes that provide women with the skills and knowledge they need to succeed in the workforce. It also means addressing the cultural and societal factors that contribute to gender inequality and discrimination, such as unconscious bias and stereotypes (Shackleton et al., 2011). Women's rights and gender equality are crucial issues that need to be addressed in the global supply chain industry. While various policies and initiatives have been implemented to support women's empowerment, there is still much work to be done to achieve gender equality in the industry. It is essential to continue to promote policies and initiatives that address the root causes of gender inequality and provide women with the resources they need to succeed.

3.4 Conclusions to part two

In conclusion, this part (SEANERGY PROJECT Subtask 1.1.2) aimed to comprehensively understand the sociocultural and behavioural aspects influencing the port industry's clean energy and fuel transition. The deliverable shed light on the male predominance in the port industry by examining the industry's progression in economics, politics, sociology, demography, and ethnology through a gender-based lens. The analysis[3] has revealed that the port industry has traditionally been male-dominated, and several factors contribute to this predominance. These factors include gender biases, cultural norms, and a lack of representation in leadership positions. In order to ensure an inclusive, successful transition towards clean energy and fuels, stakeholders must address these issues and promote diversity and inclusivity in the workforce.

Based on the desk research, the following recommendations have been proposed for stakeholders' strategies on technology integration and inclusion:

- Develop and implement gender-responsive policies and practices in the port industry to ensure equal opportunities for all individuals, regardless of their gender.

[3] The forthcoming online surveys will definitely provide valuable insights into the community's perception of the port industry's progression

- Enhance diversity in decision-making processes by ensuring women and underrepresented communities have a seat at the table.
- Invest in education and training programmes that promote skill development and capacity building for women and underrepresented communities, fostering a more diverse talent pool.
- Encourage mentorship and networking opportunities to support women and underrepresented individuals in advancing their careers in the port industry.
- Address any existing gender pay gaps by regularly reviewing compensation and benefits packages to ensure fairness and equity.
- Foster a supportive and inclusive work environment by promoting awareness and addressing unconscious biases and discrimination.

By adopting these recommendations, stakeholders can drive meaningful change towards a more inclusive port industry that effectively integrates clean energy and fuels. This, in turn, will contribute to a more sustainable and socially responsible future for the port and port logistics sectors.

4 Part three- Key tools and certifications for the port energy transition

4.1 Introduction and Methodology

This part addresses essential steps in the port energy transition. It is in line with subtask 2.1.2 in the SEANERGY project. These key tools and certifications are highly required to facilitate the green transition in European ports.

With respect to the structure of this part, it comprehensively explores the key tools and certifications necessary for the green transition in European ports. Beginning with an introductory section, it sets the context, outlines the research's objectives, and summarises the methodology used. The methodology section details the identification process of crucial tools and certifications, mentioning the investigation's participants and its timeline. It underscores the value of a thorough literature review and desktop analysis of relevant sources for a robust, easily replicable methodology. Subsequent sections 3 and 4 delve into the tools and certifications, defining them, underlining their significance, and providing examples. These parts draw from the investigation findings to present the most crucial tools and certifications to expedite the green transition in European ports. The part then moves on to section 5, which encapsulates the research's results and provides project recommendations based on these findings. This section weaves together the previous sections' information, offering a complete overview of the key elements required for facilitating a green transition in European ports.

Methodology

This section describes the approach to identifying the key tools and certifications necessary to facilitate the green transition in European ports. The methodology is based on an extensive literature review and desktop analysis carried out by the project team.

An extensive literature review and desktop analysis were carried out to identify the key tools and certifications. The literature review involved searching for articles, reports, and other relevant documents on green transition in European ports. The desktop analysis involved examining the websites of relevant organisations, such as certification bodies, energy management system providers, and renewable energy providers. The research team also conducted an internal review and validation by experts inside the SEANERGY Consurtium in order to gain insights into the tools and certifications currently being used in European ports. The experts consulted included representatives from certification bodies, port authorities, and energy management system providers.

The investigation involved the participation of various stakeholders, including the project team members and external experts. The project team members involved in the investigation included CRCL, WMU, ATP, RINA-C, ZER0-E, and ANLEG. External experts were also consulted to provide insights and recommendations on the key tools and certifications necessary for the green transition in European ports. The research was carried out parallel to the implementation of the surveys in WP1 and lasted for a period of three months (M5-M8). The investigation timeline was designed to align with the overall project timeline and ensure that the findings could be incorporated into the project's Master Plan content. The research was conducted promptly and efficiently to ensure that the results could be shared with the project team members and external stakeholders as soon as possible.

4.2 Key Tools for the Green Transition

This section provides a comprehensive overview of the key tools necessary to facilitate the green transition in European ports. The information provided in this section is based on an extensive literature review and desktop analysis carried out by the project team.

4.2.1 Definition of key tools and their importance

The key tools for the green transition are those that can help European ports to reduce their carbon footprint, increase energy efficiency, and promote the use of renewable energy sources. These tools are essential to achieving the EU's green transition targets and creating a sustainable future for European ports. There are several programmes for ship certifications in the context of decarbonisation or environmentally friendly profiles rather than direct certification for ports. Therefore, all these programmes used for the certifications of ships or shipping companies are considered tools for the ports for green transition to greener fuels and energy.

More in detail, key tools for the green transition refer to the various management instruments, technologies, systems, and practices that can help ports reduce their environmental impact and transition to more sustainable operations. These tools can include energy management systems, energy efficiency measures, renewable energy sources, and tools for calculating carbon footprints and assessing environmental impacts for ports. The importance of these key tools lies in their ability to help ports reduce their greenhouse gas emissions, improve air and water quality, and reduce their overall environmental footprint. By implementing these key tools, ports can become more sustainable and contribute to the global effort to combat climate change.

4.2.2 Examples and typologies of key Tools

Some examples of key tools for the green transition in ports include energy management systems, energy efficiency measures, renewable energy sources, and tools for calculating carbon footprints and assessing environmental impacts. These tools can help ports reduce their greenhouse gas emissions, improve air and water quality, and reduce their overall environmental footprint. The following are examples of key tools identified in the investigation:

Energy Management Systems and Tools for Energy Efficiency Improvement

Energy Management Systems (EMS) are pivotal for optimising energy consumption and boosting energy efficiency in European ports (Mikulandric et al., 2016). They allow organisations to streamline energy use, identifying and correcting wasteful practices (Radovanović et al., 2017). EMS include Building Energy Management Systems (BEMS), which automate and control building systems for energy-efficient operation (Pérez-Lombard et al., 2008), and Industrial Energy Management Systems (IEMS), which focus on industrial facilities (Sorrell, 2007). Implementing EMS in ports can lead to substantial energy savings and a smaller carbon footprint. For example, the Port of Barcelona achieved a 20% reduction in energy consumption within two years through EMS, while the Port of Antwerp saved approximately €2 million annually in energy costs (Port of Barcelona, 2018; Port of Antwerp, 2019).

Energy efficiency measures are crucial for reducing energy consumption and waste, contributing to environmental sustainability (Sorrell et al., 2004). These measures in ports include upgrading lighting systems, enhancing insulation, optimising heating, ventilation, and air conditioning (HVAC) systems, and implementing more efficient manufacturing processes. Upgrading to LED lighting can save energy and reduce maintenance costs (Alstone et al., 2015). Improved insulation can dramatically lower heating and cooling costs, providing a more stable indoor climate. Optimising HVAC systems can also enhance energy efficiency and reduce costs (Pérez-Lombard et al., 2008). Lastly, adopting energy-efficient technologies in port-related industries can minimise energy consumption, operational costs, and environmental impacts (Worrell et al., 2001).

Renewable Energy as a Tool towards greener fuels and Energy in Ports

Renewable energy sources such as wind, solar, and wave power offer a sustainable alternative to traditional fossil fuels, providing a valuable tool for European ports seeking to reduce their carbon footprint and become more environmentally sustainable (Jacobson & Delucchi, 2011). Unlike fossil fuels, these renewable energy sources are naturally replenished and do not deplete over time. Solar, wind, hydroelectric, and geothermal power are prime examples of renewable energy sources. Utilising these sources can help ports lessen their dependency on fossil fuels, reducing their carbon emissions and significantly contributing to environmental sustainability. These key renewable energy tools are crucial for driving the green transition in European ports and aligning with the EU's ambitious sustainability targets (European Commission, 2020).

Tool for the Identification and Implementation of Environmental Indicators in Ports (TEIP)

The Tool for Identifying and Implementing Environmental Indicators in Ports (TEIP) is a methodology developed by the Polytechnic University of Catalonia to help port authorities identify and implement environmental indicators (Figure 12). Created within the PORTOPIA research project, TEIP is a 20-minute, five-step process involving port contact details, identification of Significant Environmental Aspects (SEAs), questions on SEAs, environmental management and port development, and Environmental Performance Indicators. Users receive a final list of recommended indicators for monitoring, specific implementation guidelines, and recommendations for effective environmental management. All data provided is treated confidentially.

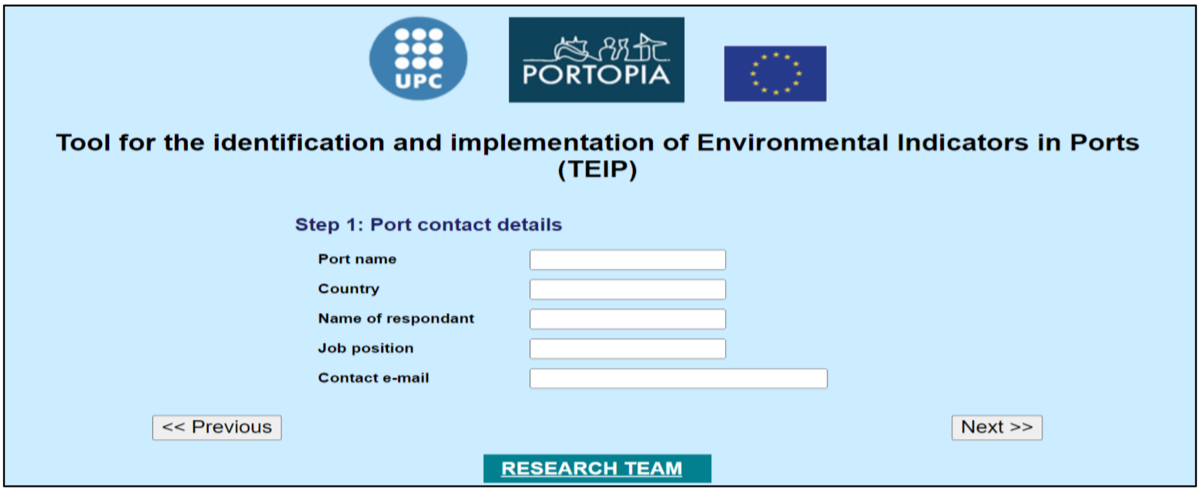

Figure 12: Tool for the identification and implementation of Environmental Indicators in Ports (TEIP)
Source: https://eports.cat/teip/

Tool for the Identification and Assessment of Environmental Aspects in Ports (TEAP)

Developed under the European MSP Platform to assist port authorities in identifying environmental issues and in assessing their significance. The Tool for identifying and assessing Environmental Aspects in Ports (TEAP) was developed under the European MSP Platform as part of the PERSEUS project (Figure 13). It assists port authorities in identifying and assessing Significant Environmental Aspects

(SEA) while unifying approaches across South European Seas to meet environmental management system standards like ISO 14001, PERS, and EMAS. TEAP aims to help port authorities meet legislative and regulatory obligations, improve the environmental quality in port areas, and consolidate methods for achieving environmental management standards. This confidential, user-friendly online platform consists of a 5-step procedure that can be completed in approximately 30 minutes.

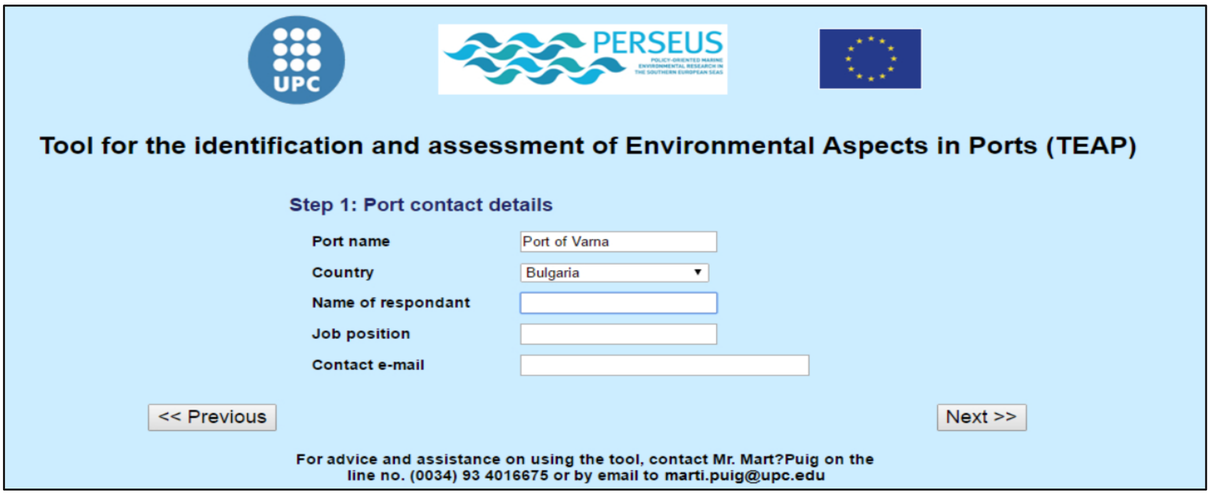

Figure 13 Tool for the identification and assessment of Environmental Aspects in Ports (TEAP)

Source:https://maritime-spatial-planning.ec.europa.eu/practices/tool-identification-and-assessment-environmental-aspects-ports-teap

IAPH World Ports Sustainability Membership Programme

In its third year, the IAPH World Ports Sustainability Program was established in order to assist ports in applying the UN's 17 Sustainable Development Goals in practice. The programme aims to enhance and coordinate future sustainability efforts of ports worldwide and foster international cooperation with partners in the supply chain. The programme has reached the milestone of over 200 projects that IAPH members have registered and their partners from the global port community in resilient infrastructure, climate and energy, safety and security, community outreach and governance (Ng and Song, 2021). In 2021, IAPH received a record 64 projects submitted by 37 member ports from 21 countries as entries for the 2021 World Ports Sustainability Awards.

Carbon Foot Print Calculator for Portsn(IAPH)

The Carbon Footprint Calculator for Ports is an online tool developed by the International Association of Ports and Harbors (IAPH) to help port authorities and terminal operators calculate and report their greenhouse gas (GHG) emissions. The tool calculates the emissions associated with a port's activities, including energy consumption, transportation, and waste management, and provides a report that can be used to track progress in reducing emissions and complying with environmental regulations. The calculator also provides benchmarking data to compare a port's emissions with other ports around the world. The tool is designed to be user-friendly and accessible to port stakeholders of all levels of technical expertise.

EcoPorts Membership and Tools

EcoPorts is a membership organisation and initiative within the European port sector, and is a membership network of European ports that voluntarily take part in the initiative. EcoPorts aims to foster environmental sustainability in the port sector through cooperation and sharing of knowledge between ports (Notteboom, 2016).

(1) Self-Diagnosis Method (SDM): This is a tool provided to EcoPorts members. It is used to identify environmental risks and to compare a port's environmental management measures to the average across Europe. It is also used to obtain expert advice and personalised recommendations for improving environmental performance.
(2) Port Environmental Review System (PERS): This is a certification provided by EcoPorts, assessed by Lloyd's Register Quality Assurance (LRQA) in the Netherlands. PERS is the only port sector-specific environmental management standard. It is a certification that shows a port has met certain standards in managing its environmental impact.

So, to summarise, ports can become members of EcoPorts and use its tools to improve their environmental sustainability. They can also seek PERS certification to demonstrate their commitment to environmental sustainability. For more detailed and specific information, please refer to the official EcoPorts and ESPO (European Sea Ports Organisation) websites.

Clean Shipping Index (CSI) Tool

Clean Shipping Index (CSI) is indeed a tool that ports, shipping companies, and terminals can use to assess and improve the environmental performance of their ships. It's not a certification but a database and rating system. The CSI is an evaluation system that rates ships based on their environmental impact. This is done through a questionnaire that covers various aspects of a ship's operations, such as emissions, waste management, and chemical usage (Johnson and Styhre, 2015). Here's how it works:

i. Ship owners or operators fill out the CSI questionnaire for their ships, providing detailed information about the ship's environmental performance in areas such as air emissions, waste handling, and chemical usage.
ii. This information is then stored in the CSI database.
iii. Members (ports, terminals, shipping companies, etc.) can access this database to evaluate the environmental performance of ships.

iv. Ships are then ranked based on their environmental performance, with high-performing ships potentially receiving economic benefits, such as reduced port fees.

The goal of the CSI is to encourage ship owners to improve the environmental performance of their ships by providing them with tangible benefits for doing so. It's a significant tool in the maritime industry's effort to reduce its environmental footprint and transition to more sustainable practices. For more information, you can visit the official Clean Shipping Index website.

Green Award Programme

In 2011 Green Award launched a certification program for inland shipping. The Green Award Foundation, a neutral, independent, non-profit body based in Rotterdam, the Netherlands, is in charge of the Green Award programme. Established in 1994, the foundation aims to promote safer and cleaner shipping in various types of maritime transport, including sea-going and inland navigation ships. The Green Award is more of a certification for ships and shipping companies rather than ports. It demonstrates high environmental and safety standards, exceeding the industry's legal requirements. Once a ship is awarded, it receives a Green Award certificate, which numerous ports, maritime service providers, and suppliers recognise. These entities often provide incentives to Green Award certificate holders, such as discounts on port fees and other services. The certification program for inland navigation barges has turned out to be a success. Due to this success and demand for the Green Award certification, the program was developed further and a 3-tier certification was introduced, namely, Brons, Silver and Gold certification levels and a Platinum label to stimulate innovations. Ports and other maritime service providers and suppliers provide incentives to Green Award-certified inland barges. These incentives are meant to motivate ship owners to invest in cleaner technologies and safer operations. Green Award believes that its certification program contributes to a sustainable environment.

EU Eco-Management and Auditing Schemes (EMAS)

The EU Eco-Management and Audit Scheme (EMAS) is a voluntary environmental management tool developed by the European Commission for companies and other organisations to evaluate, report, and improve their environmental performance. Ports can apply and use EMAS to assess and improve their environmental performance. Organisations that participate in EMAS implement an Environmental Management System (EMS) to assess and improve their environmental performance. The EMS includes procedures for evaluating the organisation's environmental impacts, setting environmental objectives, and implementing measures to improve environmental performance. Organisations that follow the guidelines of the EMAS regulation can be EMAS-registered. EMAS registration provides several benefits to ports. It can help ports to reduce their environmental impacts, strengthen legal compliance and employee involvement, and save resources and money. By participating in EMAS, ports can demonstrate their commitment to environmental protection and sustainable development. For more information, you may refer to the link: https://green-business.ec.europa.eu/eco-management-and-audit-scheme-emas_en

Strategic Overview of Environmental Aspects (SOSEA)

The Strategic Overview of Significant Environmental Aspects (SOSEA) is a methodology designed to help port managers identify their Significant Environmental Aspects (SEAs) and reinforce their awareness about them in order to prioritise work in environmental management. SOSEA assists ports in getting proper knowledge of the management carried out as to the environmental aspects that actually represent a concern for them (Hossain et al., 2020). SOSEA is based on ISO 14001 vocabulary and requirements and can be considered the basis for implementing any Environmental Management System for port communities. By using SOSEA, port managers can identify and rank the significant environmental aspects in their port, allowing them to focus their time, efforts, and resources on those issues with major potential for environmental impact.

Environmental Ship Index (ESI)

The World Port Climate Initiative (WPCI) and the International Organisation of Ports and Harbors (IAPH) initiated the ESI. Ports can register themselves as incentive providers to ships that have been certified by registering their fuel consumption and air emissions. The index, thus, has a score ranging from 0 to 100. Based on the score, ports give incentives as percentage reductions in port dues, though the percentage calculations differ from port to port. Examples of ports that use the ESI as a basis for ships' incentives are Ports of New York and New Jersey, Los Angeles, Rotterdam, Antwerp, Hamburg, Gothenburg, Le Havre, Busan, Tokyo and Dubai, among others (Alamoush, Olcer, & Ballini, 2022).

GHG Emissions Rating (GHG ER)

The GHG ER is an initiative launched by the Carbon War Room, which is a non-profit organisation based in the US, in cooperation with the RightShip (GHG ER, 2020). RightShip is an independent vetting company that provides online information on ship design and energy efficiency and classifies oceangoing vessels in terms of GHG emissions rating (Becqué et al., 2017). The rating ranges from A as the best to G as the least efficient, based on the existing vessel design index (EVDI). The registration of ships is automatically captured, provided that owners register ships' specifications in the IHS Fairplay ship registry. Incentive providers, such as ports, are allowed to retrieve data at no cost. Two Canadian ports use this rating to provide ships with incentives, i.e. Vancouver and Prince Rupert, along with other indices and criteria. The recent IMO EEXI criterion and the RightShip EVDI are similar, but the application is different. The EEXI will become a mandatory statutory requirement, requiring equal to or less than a fixed value of the Required EEXI, while the EVDI is a voluntary industry indicator that ranks ships against their peers and is thus continuously changing. EVDI scores are relative to other ships' scores and change once new ships enter the registry system, even if the rated ship changes nothing in its energy efficiency (Becqué et al., 2017).

Green Marine (GM) Environmental Programme

GM is an environmental certification programme for the North American marine industry (USA and Canada). This eco-labelling scheme certifies ships, ports, terminals and shipyards that achieve better environmental performance each year in relation to air emissions reduction (air pollutants and GHG), water pollution, noise and garbage indicators (GM, 2021). The shipping GHG reductions can be rated based on five-level criteria. The highest criterion, criterion five, is achieved when the annual average reduction of GHG intensity reaches 2% reduction compared to 2008. The Green Marine Europe environmental program is now available to European shipowners following a partnership with Surfrider Foundation Europe. The Ports of Vancouver and Prince Rupert in Canada incentivise ships certified by GM and other indices. **5** shows examples of the ports that have applied key tools for the green transition collected through the literature review.

Table 5: Examples of ports with key tools for the green transition

Tool	Example 1	Example 2
Energy Management Systems	Port of Gothenburg, Sweden	Port of Los Angeles, USA
Energy Efficiency Measures	Port of Hamburg, Germany	Port of Barcelona, Spain
Renewable Energy Sources	Port of Amsterdam, Netherlands	Port of Vancouver, Canada
Standardised tool to calculate Carbon Footprint in Ports	Port of Valencia, Spain	Port of Seattle, USA
3.2.6 Tool for the identification and implementation of Environmental Indicators in Ports (TEIP)	Port of Genoa, Italy	Port of Copenhagen, Denmark
Tool for the identification and assessment of Environmental Aspects in Ports (TEAP)	Port of Bremen, Germany	Port of Venice, Italy
IAPH World Ports Sustainability Program	Port of Felixstowe, UK	Port of Long Beach, USA
Carbon Foot Print Calculator for Ports (IAPH)	Port of Singapore	Port of Gdansk, Poland
EcoPorts	Port of Le Havre, France	Port of Piraeus, Greece
Clean Shipping Index (CSI)	Port of Helsinki, Finland	Port of Huelva, Spain
Green Award	Port of Antwerp, Belgium	Port of Dublin, Ireland
EU Eco-Management and Auditing Schemes (EMAS)	Port of London, UK	Port of Livorno, Italy
Self-Diagnosis Method (SDM)	Port of Trieste, Italy	Port of Malmö, Sweden
Strategic Overview Of Environmental Aspects (SOSEA)	Port of Tallinn, Estonia	Port of Dunkerque, France
World Port Sustainability Program(WPSP) Focused on UN Sustainable Development Goals	Port of Auckland, New Zealand	Port of Santander, Spain
Environmental Ship Index (ESI)	Port of Bremerhaven, Germany	Port of Los Angeles, USA

GHG Emissions Rating (GHG ER)	Port of Ghent, Belgium	Port of Marseilles, France
Green Marine (GM) environmental program	Port of Montreal, Canada	Port of Tacoma, USA

4.3 Certifications for the Green Transition

This section defines certifications and their importance in facilitating the green transition in European ports. The definitions and examples presented in this section are based on an extensive literature review and desktop analysis carried out by the project team.

4.3.1 Definition of certifications and their importance

Certifications are voluntary programs that enable organisations to demonstrate their compliance with certain standards or best practices. Certifications can play a crucial role in facilitating the green transition in European ports by providing a framework for measuring and improving environmental performance. They can also help to build trust among stakeholders and provide a competitive advantage in the marketplace.

4.3.2 Examples and Typologies of Certifications

There are some certifications for the green transition in ports, and these certifications can help ports demonstrate their commitment to sustainability and provide a framework for implementing best practices. The following are examples of certifications that are relevant to the green transition in European ports:

ISO 50001 Energy Management

This certification provides a framework for implementing and maintaining an energy management system that helps organisations to improve energy efficiency, reduce greenhouse gas emissions, and lower energy costs (ISO, 2021). ISO 50001 is a standard developed by the International Organisation for Standardisation (ISO) that provides a framework for organisations to establish, implement, maintain, and improve an energy management system (EnMS). The standard aims to help organisations improve their energy efficiency, reduce greenhouse gas emissions and other environmental impacts, and lower energy costs. ISO 50001 certification involves an independent third-party audit of an organisation's EnMS to determine its conformity with the requirements of the standard. The certification process typically involves a gap analysis, implementation of improvements, internal audits, and a final audit by a certification body (ISO, 2021). ISO 50001 certification can provide various benefits to organisations, including improved energy performance, reduced energy costs, enhanced reputation, and increased stakeholder confidence. It can also help organisations comply with energy-related regulations and demonstrate their commitment to sustainable energy management practices. ISO 50001 can be applied and used by ports and terminals to improve their energy efficiency, reduce greenhouse gas emissions, and lower energy costs. By implementing an energy management system based on the ISO 50001 standard, ports and terminals can establish a systematic approach to managing energy use and improving performance (Port Technology, 2020). The standard provides a framework for implementing and maintaining an energy management system that is applicable to all organisations, regardless of size, type, or nature (ISO, 2021). This means that ports and terminals of any size or type can use the standard to improve their energy management systematically. By obtaining ISO 50001 certification, ports and terminals can demonstrate to their stakeholders that they are committed to responsibly managing their energy use.

ISO 14001 Environmental Management

The ISO 14000 family of standards, developed by the ISO Technical Committee ISO/TC 207 and its subcommittees, provides practical tools for organisations to manage their environmental responsibilities. ISO 14001, a part of this family, sets out criteria for an environmental management system, offering a framework that any organisation, regardless of its size, type, or sector, can follow to improve its environmental performance, fulfill compliance obligations, and achieve environmental objectives (ISO, 2015). Ports and terminals can apply ISO 14001 Environmental Management to manage their environmental impacts and comply with regulations. Implementing an environmental management system based on ISO 14001 allows ports and terminals to identify and control their environmental aspects, enhancing performance and achieving objectives. By obtaining ISO 14001 certification, ports and maritime terminals demonstrate their commitment to responsible environmental management to stakeholders.

ISO 14064 Carbon Footprint – GHG Certification of Operations

ISO 14064 is a set of standards for measuring, quantifying, and reporting greenhouse gas (GHG) emissions and removals, providing organisations with a framework to manage and reduce their carbon footprint and demonstrate their commitment to addressing climate change. The standard comprises ISO 14064-1 for organisational-level GHG inventories, ISO 14064-2 for project-level emissions and removals, and ISO 14064-3 for the certification of GHG emissions reports. Ports and terminals can apply ISO 14064 Carbon Foot Print – GHG Certification of Operations to measure, quantify, and report their GHG emissions and removals. Implementing a GHG management system based on ISO 14064 helps ports and terminals manage and reduce their carbon footprint, demonstrating their commitment to climate change mitigation. By obtaining ISO 14064 certification, ports and terminals can assure stakeholders that their GHG emissions reports are accurate and reliable (Puig et al., 2014).

Tradable Green Certificates (TGCs) for Renewable Electricity and Energy Savings

Tradable Green Certificates (TGCs) are certificates that represent proof that a certain amount of electricity has been generated from renewable energy sources or that a certain amount of energy savings has been achieved through energy efficiency measures. Tradable Green Certificates (TGCs) serve as evidence of electricity generated from renewable sources or energy savings through efficiency measures. They facilitate trading between parties and support renewable energy and energy efficiency projects. Ports and terminals can purchase TGCs to offset emissions, even if they cannot generate renewable energy or achieve energy savings. TGC certification ensures authenticity and traceability, giving ports and terminals confidence in their contributions to renewable energy and energy efficiency projects. Participation in TGC markets demonstrates a commitment to reducing environmental impact and supporting a sustainable energy transition (European Commission, 2022).

Sustainable Port Certification

This certification provides a framework for measuring and improving the sustainability performance of ports. It covers a range of environmental, social, and economic indicators, including greenhouse gas emissions, energy consumption, waste management, and stakeholder engagement. Sustainable Port Certification provides a framework for measuring and improving the sustainability performance of ports. One example of such a certification is the EcoPorts certification, the main environmental initiative of the European port sector. It was initiated by some proactive ports in 1997 and has been fully integrated into the European Sea Ports Organisation (ESPO) since 2011. The overarching principle of EcoPorts is to raise environmental protection awareness through cooperation and sharing of knowledge between ports and improve environmental management 1. Ports can apply for the Port Environmental Review System (PERS), which is the only recognised port-sector-specific standard. By obtaining this certification, ports can demonstrate their commitment to sustainability and provide a framework for implementing best practices (ESPO, 2021).

PortCDM

PortCDM (Port Collaborative Decision Making) is a digital platform that facilitates communication and collaboration among different stakeholders involved in port operations. The platform allows for real-time sharing of information related to vessel traffic, cargo operations, and other critical aspects of port operations. This information is shared among the port authority, shipping companies, terminal operators, and other stakeholders. PortCDM aims to optimise vessel traffic and reduce waiting times and emissions by improving the flow of information and coordination among stakeholders. By providing real-time information, the platform enables stakeholders to make more informed decisions and take actions that improve efficiency and reduce environmental impacts. PortCDM is based on open standards and can be integrated with other systems used in the port ecosystem(Bergmann et al., 2018). The platform is currently being used in several ports around the world, including the Port of Gothenburg in Sweden and the Port of Rotterdam in the Netherlands.

IEEE Certification in Artificial Intelligence and Machine Learning

The IEEE Certification in Artificial Intelligence and Machine Learning is designed for professionals developing, implementing, and deploying AI and machine learning solutions, specifically focusing on the optimisation of energy systems. However, this certification does not apply to the port itself but to professionals working within the ports and terminals industry. The program covers various topics, including AI and machine learning fundamentals, techniques, optimisation, prediction, and ethical considerations. Obtaining this certification demonstrates expertise in AI and machine learning, making it valuable for professional development and enhancing job market prospects. AI and machine learning can significantly improve the efficiency and sustainability of energy systems in ports and terminals. Applications include optimising energy consumption, predicting energy demand, and enhancing renewable energy system performance. By acquiring the IEEE Certification in Artificial Intelligence and Machine Learning, professionals in the ports and terminals industry can strengthen their ability to develop and implement solutions that boost the efficiency and sustainability of energy systems(IEEE, 2021). Table 6 shows examples of the ports with certifications for green transition collected through a literature review.

Table 6: Examples of ports with certifications for the green transition

Certificates	Example 1	Example 2
ISO 50001	Port of Bilbao, Spain	Port of Houston, USA
ISO 14001 Environmental Management	Port of Koper, Slovenia	Port of Yokohama, Japan
ISO 14064 Carbon Foot Print – GHG Certification of Operations	Port of Tarragona, Spain	Port of Melbourne, Australia
Tradable Green Certificates (CTs) for Renewable Electricity and Energy Savings	Port of Rotterdam, Netherlands	Port of Antwerp, Belgium
Green Marine Certification	Port of Quebec, Canada	Port of Seattle, USA
Sustainable Port Certification	Port of Durban, South Africa	Port of Odesa, Ukraine
PortCDM (in Digitalisation and Artificial Intelligence knowledge and training)	Port of Valencia, Spain	Port of Baltimore, USA
Institute of Electrical and Electronics Engineers (IEEE) Certification in Artificial Intelligence and Machine Learning	Port of Marseille, France	Port of New York, USA
Institute of Electrical and Electronics Engineers (IEEE) Certification in Artificial Intelligence and Machine Learning refers to the application of AI and machine learning in port operations and not the certification of the port itself. Therefore, it would		

not be appropriate to provide examples of ports with this specific certification. However, there are examples of ports that have implemented AI and machine learning technologies in their operations:
- Port of Rotterdam, Netherlands: The port has implemented AI and machine learning technologies in various aspects of its operations, including predictive maintenance, vessel traffic management, and smart infrastructure management.
- Port of Hamburg, Germany: The port utilises AI and machine learning to optimise its logistics processes, improve traffic management, and enhance container terminal operations.

4.4 Conclusion to part three

This subtask of the SEANERGY project focused on pinpointing the essential tools and certifications driving the maritime and port industry's green transition. This was accomplished through comprehensive analysis, stakeholder consultations, expert discussions, and a validating workshop. The findings present a wide array of critical tools and certifications that foster sustainability and lower the maritime sector's environmental footprint. Among these are Tradable Green Certificates, Energy Management Systems, Renewable Energy Sources, and port-specific tools like the Carbon Footprint Calculator for Ports and the Tool for the Identification and Implementation of Environmental Indicators in Ports (TEIP). We also identified significant certifications defining industry benchmarks and environmental performance standards. These include ISO 50001 for Energy Management, ISO 14001 for Environmental Management, ISO 14064 for Carbon Footprint - GHG Certification of Operations, as well as sport-specific ones like Green Marine Certification and Sustainable Port Certification.

Shared the subtask info/document with several experts in port, maritime, and energy industries; the review by two energy and port certified experts within the consortium sought to verify the accuracy of information about the identified tools and certifications discussed in previous chapters of this document. Engaging experts in the field provided valuable insights, helped identify any gaps or inaccuracies, and confirmed the relevance of the chosen tools and certifications. This collaborative approach has contributed to a more robust and reliable outcome for the project deliverables. These tools and certifications catalyse the green shift within the maritime and port sectors. By leveraging these resources and acquiring appropriate certifications, stakeholders can effectively manage their environmental impact and adhere to international regulations and industry standards, thereby enhancing sustainability. The insights derived from this research will be utilised to generate practical recommendations for the SEANERGY project in D2.1.

The investigation conducted in Subtask 2.1.2 of the SEANERGY project has successfully identified key critical tools and certifications for facilitating the green transition in the maritime and port sectors. The extensive research and consultation with industry stakeholders have yielded valuable insights into the importance of these tools and certifications in promoting sustainable practices and minimising environmental impact. Based on the results of the research and investigation, the following recommendations can be made:

1. Encourage and support the adoption of key tools and certifications by port authorities, shipping companies, and other stakeholders within the maritime industry to ensure compliance with international regulations and industry best practices.
2. Facilitate sharing of knowledge and best practices among stakeholders through workshops, conferences, and online platforms to increase awareness and understanding of the benefits of utilising key tools and certifications.
3. Provide financial and technical assistance to stakeholders, particularly small and medium-sized ports, in implementing key tools and obtaining relevant certifications to accelerate the green transition.
4. Continuously monitor and evaluate the effectiveness of the identified tools and certifications to ensure they remain up-to-date and relevant in addressing the evolving challenges faced by the maritime and port sectors.
5. Advocate for developing and harmonising international standards and regulations related to the green transition to create a level playing field and promote healthy competition within the industry.

The implications of this investigation for the SEANERGY project are significant. By integrating the findings of this research into D2.1, the project will be better equipped to provide actionable insights and recommendations to help the maritime and port sectors transition towards more sustainable operations.

5 Final Conclusion of this Deliverable D2.1

As we conclude this comprehensive analysis, it is clear that the path towards sustainable and inclusive port operations is multi-faceted. This project has intricately delved into the three crucial aspects that will contribute to this transition: addressing the barriers to and solutions for ports' energy transition, understanding the sociocultural and behavioural aspects affecting the port industry's progression, and identifying key tools and certifications to guide this transition. By interlinking the conclusions and recommendations of each part, the overarching vision of this research begins to take shape.

The first part of this deliverable underscored the pressing need for ports to transition towards cleaner and sustainable energy sources, making it a non-negotiable aspect of the maritime industry's future. Addressing the barriers to this transition, such as market failures, hidden costs, access to capital, and more, is crucial for implementing effective strategies. However, the solution does not solely lie in overcoming these barriers. Ports need to set ambitious renewable energy targets, foster public-private partnerships, develop incentives and subsidies, embrace technological innovation, and engage with stakeholders. Moreover, these practices will ensure environmental benefits and unlock long-term economic advantages and societal gains.

The second part seeks into the sociocultural and behavioural aspects influencing the port industry's clean energy and fuel transition. Despite male predominance being a longstanding issue in the port industry, promoting diversity and inclusivity in the workforce has now become an integral part of the path towards clean energy and fuels. From the gender-based analysis of the industry's progression, it is recommended to develop gender-responsive policies, enhance diversity in decision-making processes, and address pay gaps. The port industry will be better equipped to drive a sustainable and socially responsible future by adopting these recommendations.

The third and final part underlines the crucial role of key tools and certifications in facilitating the green transition. These tools and certifications help to ensure compliance with international regulations and industry best practices. Stakeholders are encouraged to adopt these tools and certifications and share knowledge and best practices. It is also recommended to provide financial and technical assistance to stakeholders, especially small and medium-sized ports, and advocate for the development of international standards and regulations.

In conclusion, it is evident that the transition to a sustainable port and maritime industry is not solely an environmental imperative but also a social and economic necessity. The energy transition in ports, including diverse workforces, and adopting key tools and certifications are all essential components of this transition. By integrating the conclusions and recommendations from this deliverable, the port industry is anticipated to be better equipped to move towards more sustainable operations, fostering a greener, more inclusive, and economically prosperous future.

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Appendixes

Appendix 1 Survey questions conducted by WMU for Part One of this deliverable

Title: Port energy transition: Investigation of ports stakeholders' barriers and solutions

Introduction

Dear Sir/Madam,

This questionnaire is developed by the World Maritime University (WMU) in Malmö, Sweden. As you may be aware, WMU was established in 1983 by the International Maritime Organization (IMO) - a specialized agency of the United Nations - as a premier centre of excellence for maritime postgraduate education, research, and capacity building.

This questionnaire is part of the Sustainability Educational Programme for Greener Fuels and Energy on Ports (SEANERGY) project. WMU is a partner in the SEANERGY team along with 12 European partners from 9 countries. SEANERGY has received funding from the European Union's Horizon 2020 Research and Innovation Program under Grant Agreement 101075710. The SEANERGY project sets out to support the transition of ports towards zero-emission, green energy hubs that use hydrogen, integrated electricity systems, and other low-carbon fuels. For further information on SEANERGY, you can kindly refer to the project website: Seanergy Project – Greener Fuels and Energy on Ports. This questionnaire seeks to investigate the barriers that port's stakeholders have with respect to port energy transition. While we aim to understand the barriers. we also intend to highlight the significance of stakeholders and finding some solutions to identified barriers. The questionnaire consists of 4 questions in 3 sections. Section 1 contains two background questions and another question about rating the significance of port's stakeholders to the energy transition, Section 2 contains a question regarding stakeholder's barriers with the scope of port energy transition, and Section 3 contains a question about expected solution for the stakeholder's barriers. We sincerely invite you to support this research project and participate in completing the questionnaire which should take about 10-13 minutes. There is no right or wrong answer. Kindly answer all questions from your organizational experience. Should you have any questions or require any additional clarification, please feel free to contact Anas Alamoush atasa@wmu.se. The accompanying consent form specifies the confidentiality clauses relating to the answers provided by you. Thanking you.

Yours sincerely
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Consent Form

Dear Participant,

The information provided by you in this questionnaire will be used for research purposes and the results will form part of a deliverable and a journal paper, which will be published online and made available to the public. Your personal information will not be published. You may withdraw from the research at any time, and your personal data will be immediately deleted. Anonymised research data will be archived on a secure virtual drive linked to a World Maritime University email address. All the data will be deleted as the project is complete. Your participation in the questionnaire is highly appreciated. The World Maritime University I consent to my personal data as outlined above, being used for this research. I understand that all personal data will be held and processed in the strict confidence and deleted at the end of this research.

1. Yes, I want to continue
2. No, I want to quit

Section 1: Stakeholders

Please select your country

Please select the port's stakeholder category that you belong to:

1. Port managing body (e.g. Public or port authority, port operating companies)
2. Terminal operators
3. Port services providers (e.g. Marine services, customs, coastguards)
4. Maritime authority
5. Ship operator/managing company
6. Port users (e.g. Freight forwarders, ship agents, brokers, road hauliers, railway companies, and logistics providers)
7. Employees and trade unions
8. The financial community (e.g. Banks, insurance companies, stock exchange, credit institution, and investors, ministry of finance, public funds)
9. Local community and societal groups of interest (e.g. city residents, port tenants, None Governmental Organisations (NGOs))
10. Regulators
11. International organisations and trade associations
12. Technology Developers and Manufacturers
13. Energy providers
14. Research and education
15. Energy transition facilitators and third parties (Designers, Architects, Contractors, Construction workers, port project managers, consultants, other service providers)
16. Consumers (e.g. General public, industrial sectors)
17. Media
18. Other, please specify ___________

Question 1: Considering that the following stakeholders play a role in port transition to renewable energy and clean fuels, please rate their level of significance in such transition using (1- lowest to 5-highest)

	1	2	3	4	5
Port managing body (e.g. Public or port authority, port operating companies)	❑	❑	❑	❑	❑
Terminal operators	❑	❑	❑	❑	❑
Port services providers (e.g. Marine services, customs, coastguards)	❑	❑	❑	❑	❑
Maritime authority	❑	❑	❑	❑	❑
Ship operator/managing company	❑	❑	❑	❑	❑
Port users (e.g. Freight forwarders, ship agents, brokers, road hauliers, railway companies, and logistics providers)	❑	❑	❑	❑	❑
Employees and trade unions	❑	❑	❑	❑	❑
The financial community (e.g. Banks, insurance companies, stock exchange, credit institution, and investors, ministry of finance, public funds)	❑	❑	❑	❑	❑
Local community and societal groups of interest (e.g. city residents, port tenants, None Governmental Organisations (NGOs))	❑	❑	❑	❑	❑
Regulators	❑	❑	❑	❑	❑
International organisations and trade associations	❑	❑	❑	❑	❑
Technology Developers and Manufacturers	❑	❑	❑	❑	❑
Energy providers	❑	❑	❑	❑	❑
Research and education	❑	❑	❑	❑	❑
Energy transition facilitators and third parties (Designers, Architects, Contractors, Construction workers, port project managers, consultants, other service providers)	❑	❑	❑	❑	❑
Consumers (e.g. General public, industrial sectors)	❑	❑	❑	❑	❑
Media	❑	❑	❑	❑	❑

Section 2: Stakeholders' barriers

Question 2: Please rate (from 1-lowest to 6-highest) the significance of following stakeholder's barriers that hinder ports' energy transition. Please not that: 1- Not at all a barrier, 2- A very low strength barrier, 3- A low strength barrier, 4- A high strength barrier, 5- A very high strength barrier, 6- An extremely high strength barrier, 7- I don't know:

	1	2	3	4	5	6	I don't know
Hidden costs (e.g. transaction costs, contract associated costs, overhead cost for energy management, cost for training personnel, opportunity cost, etc.)	❑	❑	❑	❑	❑	❑	❑
Limited access to capital by ports' authority (or in other word, high capital cost for establishment of green infrastructures)	❑	❑	❑	❑	❑	❑	❑
Information issues including scarce information, inaccurate information, lack of information disclosure and transparency	❑	❑	❑	❑	❑	❑	❑
Misplaced (split) incentives between Port landlord versus port operator (tenant) and subcontractors	❑	❑	❑	❑	❑	❑	❑
Misplaced (split) incentives between Port management versus ship owners versus technology/energy providers	❑	❑	❑	❑	❑	❑	❑
Difficulties in implementing energy (environmental) management system	❑	❑	❑	❑	❑	❑	❑
Inertia (resistance to change) in port management and other stakeholders	❑	❑	❑	❑	❑	❑	❑
Social admissibility for some new technologies at ports in the vicinity of cities is in doubt (e.g. production of Ammonia at ports)	❑	❑	❑	❑	❑	❑	❑
Lack of trained and competent operators at ports	❑	❑	❑	❑	❑	❑	❑
The lack of communication that may result in a failure to identify stakeholders (Interested parties) and their interests	❑	❑	❑	❑	❑	❑	❑
Uncertainties regarding future policies	❑	❑	❑	❑	❑	❑	❑
Regulatory implications, as a result of interaction between different levels of legislation (local, national, regional, and international)	❑	❑	❑	❑	❑	❑	❑
Lack of codes and standards for new burgeoning technologies like	❑	❑	❑	❑	❑	❑	❑

alternative fuels							
Immatureness of technologies (in terms of safety, operation disruption, and doubt in performance)	❑	❑	❑	❑	❑	❑	❑
Inconsistency between port and ships equipment	❑	❑	❑	❑	❑	❑	❑
Lack of physical space in ports	❑	❑	❑	❑	❑	❑	❑

Section 3: Stakeholders' Solutions

Question 3: Up to what extent the following solutions can be helpful for ports and relevant stakeholders to overcome the barriers mentioned in the last question? 1- Not at all an effective solution, 2- A very low effect solution, 3- A low effect solution, 4- A high effect solution, 5- A very high effect solution, 6- An extremely effective solution, 7- I Don't know:

	1	2	3	4	5	6	I don't know
Digitalization to connect ship-port & port-hinterland & inside port actors (for higher data quality and to improve efficiency and data sharing process)	❑	❑	❑	❑	❑	❑	❑
Preliminary studies including Cost-benefit analysis, economic and technical feasibility studies, risk assessment, environmental impact assessment (to mitigate technical risks, investment risks, and environmental risks)	❑	❑	❑	❑	❑	❑	❑
Investment in R&D, and participation in joint research project	❑	❑	❑	❑	❑	❑	❑
Investment in new technologies including renewable source of energy (e.g. wind and solar), green fuels infrastructure, and Shore-Side Electricity (SSE)	❑	❑	❑	❑	❑	❑	❑
Establishment of Environment Management System (EMS) or Energy Management System (EnMS) to support activities such as energy audit, market consultation, design of SMART KPIs, emission inventory, designating energy team, etc.	❑	❑	❑	❑	❑	❑	❑
Financial support by future GHG Fund	❑	❑	❑	❑	❑	❑	❑

as a key solution for development of green infrastructure in ports and supply chain							
Economic models such as Maritime Energy Contracting (MEC) and Energy Supply Contracting (ESC) or economic collaboration of ship owners-shippers-ports-technology providers to invest and run the infrastructures at port	❑	❑	❑	❑	❑	❑	❑
Mandatory green concession contracts (e.g. with terminal operators)	❑	❑	❑	❑	❑	❑	❑
Establishment of codes and standards for new technologies and green fuels	❑	❑	❑	❑	❑	❑	❑
Incentive schemes for ships and rail/road operators	❑	❑	❑	❑	❑	❑	❑
Collaboration between different stakeholders at different level	❑	❑	❑	❑	❑	❑	❑
Role of governments in depicting roadmap, gathering and encouraging stakeholders, simplifying tax procedures, and providing financial incentives or subsidies	❑	❑	❑	❑	❑	❑	❑
Information share and dissemination	❑	❑	❑	❑	❑	❑	❑
Training at both operation and management levels	❑	❑	❑	❑	❑	❑	❑
Commitment of stakeholders by setting ambitious CO2 reduction targets	❑	❑	❑	❑	❑	❑	❑