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List of Abbreviations

ADP	Associated Danish Ports
AEI	Agencia Estatal de Investigación
AFIR	Alternative Fuels Infrastructure Regulation
APV	Autoridad Portuaria de Valencia (Port Authority of Valencia)
CBS	Copenhagen Business School
CEF	Connecting Europe Facility
CETP	Clean Energy Transition Partnership
CSR	Corporate Social Responsibility
CTH	Chalmers University of Technology
DTU	Technical University of Denmark
EIB	European Investment Bank
ESG	Environmental, Social and Governance
ESIF	European Structural and Investment Fund
GHG	Greenhouse Gas
JASPERS	Joint Assistance to Support Projects in European Regions



JTF	Just Transition Fund
LNG	Liquefied Natural Gas
OPS	Onshore Power Supply
PoA	Port of Aalborg
PoAar	Port of Aarhus
PoE	Port of Esbjerg
PoR	Port of Rønne
PoV	Port of Valencia
PtX	Power-to-X
SWEA	Swedish Energy Agency
TEN-T	Trans-European Transport Network
TEU	Twenty-Food Equivalent Unit
USEV	University of Seville
WMU	World Maritime University
ZEPA	Zero Emission Port Alliance



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Executive Summary

This report examines how European ports can support the green transition by adapting their governance structures and business models to accommodate evolving fuel technologies, green fuel production and emerging port energy ecosystems. It aims to provide practical guidance by identifying emerging practices from port case studies, particularly in the areas of financing infrastructure, mobilizing human resources, adapting governance structures and business models, and coordinating stakeholders. The focus of this report is on actions and tools within the remit of port authorities.

Selected European ports are used as case studies to highlight the challenges they face and the strategies they deploy to address these challenges in the green transition. The methodology combines semi-structured interviews with representatives of the case study ports, desk research of academic and industry literature, and analysis of publicly available sources. Nine interviews were conducted in March–May 2026 with representatives of seven European ports, a regional port association and the European Investment Bank. Interview findings were complemented and triangulated with publicly available port sustainability strategies, annual reports, special sustainability reports, and data and statistics from public sources. Five ports (Aalborg, Aarhus, Esbjerg, Rønne and Valencia) are presented as detailed case studies in this report.

The case studies indicate that ports recognize their changing role in becoming effective orchestrators of the emerging port-energy ecosystem – connecting infrastructure, utilities, government actors, investors, customers and other partners to support the green transition. The case study ports are still primarily in the planning and feasibility phase of the transition; the report therefore highlights the challenges encountered and solutions adopted during this phase. As ports move from the feasibility stage into the implementation stage, additional challenges are likely to emerge.

Ports are shifting from landlords to ecosystem orchestrators. The cases show a move beyond traditional infrastructure provision toward roles as integrators, facilitators, innovators, investors and system builders. The transition therefore requires coordinated changes in infrastructure, technology, governance, business models and stakeholder relationships.

Investment financing requires multiple sources combining public and private funding. Many green transition projects face uncertain demand and revenue streams, resulting in weak business cases. Ports therefore combine public grants and loans, private financing, customer co-financing and broader cost-sharing to support such projects. Collaborative applications can improve access to EU funding. Several ports also use a “palette approach”, combining



commercially viable projects with green transition investments justified by strategic or regulatory considerations.

Dedicated sustainability teams are often small but strategically important. Dedicated sustainability teams remain limited, particularly in smaller ports. The cases highlight the importance of change agents (from senior executives to managers and sustainability specialists) who accelerate decisions and translate strategy into implementation.

Governance needs the right mix of competencies to support the green transition. The cases point toward governance structures that combine public accountability with commercial, financial, technical and industry expertise. Rather than a single governance model, the emerging practice is to ensure that board capabilities match the port's evolving strategic and investment needs.

Business-model change is generally anchored in core strengths. Ports tend to invest in green transition projects linked to existing business activities and market opportunities. Examples include onshore power (OPS) linked to container and cruise traffic or ecosystem development around offshore wind industry.

Targeted partnerships are more effective than broad stakeholder forums. Successful initiatives involve clearly defined collaboration with customers, utilities, municipalities, energy companies, research institutions and technology providers, often with responsibilities and investment risks explicitly shared. The cases indicate that project-specific partnerships can be more productive than broad stakeholder platforms to support the green transition.

Limited electricity-grid capacity remains a significant barrier, among other external barriers. Limited electricity-grid capacity is a recurring barrier to electrification and onshore power supply. EU regulation provides an important transition driver, while national legal frameworks can constrain ports' ability to pursue new energy activities. Local market conditions, infrastructure and stakeholder acceptance also shape which pathways are feasible.

The practical implications of the findings in this report are therefore to support the green transition by combining public and private funding to finance infrastructure investments; ensuring that governance structures have the competencies required for increasingly complex investment decisions; adapting business models by building on the port's existing competitive strengths; and using project-specific partnerships to share risks and capabilities.

Importantly, the port's wider ecosystem, rather than the port's boundaries, should be considered the relevant unit of transition planning. These emerging practices are not intended to provide a universal blueprint, but the authors hope that they offer useful examples of how some of the pressing challenges can be approached.



1. Introduction

This report summarizes emerging practices in organizing governance structures and adapting business models used by European ports to support the clean energy transition. This is Deliverable 11 (D11) under the project which forms part of Work Package 4: Social, Economic and Policy Development of the Ports as Energy Transition Hubs project (POTENT-X).

Drawing on case studies of selected European ports, the report identifies common challenges, emerging trends and recommended practices related to infrastructure financing, governance structures, business model adaptations, stakeholder coordination and other relevant aspects of the clean energy transition. The main objectives of the report are as follows:

- To conduct **case studies** of selected European ports in order to identify their responses to the key challenges of the green transition. In particular, the case studies examine how ports have adapted their governance structures and business models to effectively support and facilitate the green transition.
- To identify **general trends** in the approaches adopted by European ports to facilitate the development of infrastructure for the production, storage, bunkering and distribution of e-fuels. Attention is given to infrastructure developments that support compliance with the EU regulatory framework, including FuelEU Maritime and the Alternative Fuels Infrastructure Regulation (AFIR), such as onshore power supply (OPS) infrastructure and Power-to-X production facilities.
- To summarize the **recommended practices** identified through the case studies in order to provide guidance to ports seeking to support and facilitate the green transition. These recommended practices synthesize innovative solutions adopted by the case study ports to address the key challenges associated with the green transition.

The report focuses on strategies and actions that are within the remit of port authorities and port management. It does not comprehensively assess or comment on the effectiveness of specific public policy instruments, such as subsidies, taxation, regulatory exemptions or other forms of intervention. Broader policy issues are addressed separately in the associated POTENT-X deliverable Policy Analysis.¹

The report is structured as follows. Section 2 presents the conceptual background, drawing on prior research on the green transition in ports. Section 3 describes the research methodology. Section 4 provides an overview of the selected case study ports, including their profiles, traffic composition, governance structures, business models and key green transition initiatives.

¹ Christopher Dirzka, *POTENT X, Ports as Energy Transition Hubs: D4 - Policy Analysis* (2026).



Section 5 analyses the main trends emerging from the case studies and summarizes the recommended practices adopted by ports to facilitate the green transition.

2. Conceptual background

2.1. Ports as energy transition hubs

Ports are evolving from traditional transport and logistics nodes into energy transition hubs that support the production, transformation, storage, distribution and consumption of renewable energy and green fuels.² Their strategic location, extensive infrastructure and central position within global supply chains enable ports to act simultaneously as energy transport platforms, energy transformation platforms and energy generation platforms. While ports have historically facilitated the movement of fossil fuels, they are increasingly expected to support hydrogen, Power-to-X, offshore wind, carbon capture and alternative fuel value chains. Ports are uniquely positioned to support sustainability transition work due to their intermediary role.³

This transformation extends beyond physical infrastructure and requires changes in governance structures, business models, stakeholder relations and regulatory frameworks. Ports deploy different green transition pathways, ranging from ports acting as passive infrastructure providers to becoming proactive entrepreneurs and system builders that intentionally shape new clean energy ecosystems through innovation, collaboration and strategic investment.

As ports assume their role as energy transition hubs, both their functions and stakeholder networks expand significantly. In addition to cargo handling and logistics, ports increasingly perform functions related to renewable energy integration, energy management, alternative fuel production and bunkering, energy storage, carbon capture and smart energy systems (relying on digitalization). They also facilitate coordination between offshore energy generation and onshore energy distribution while supporting the decarbonization of port operations and maritime transport. Ports can discharge these new responsibilities through their core functions as landlords, regulators, operators, and community managers (Table 1).

² Henrik Sornn-Friese, *Ports as Energy Transition Hubs : An Exploratory Study*, in *Research Portal Denmark* (2024).

³ Kristin Ystmark Bjerkan, Lillian Hansen, and Markus Steen, 'Towards Sustainability in the Port Sector: The Role of Intermediation in Transition Work', *Environmental Innovation and Societal Transitions*, 40/August (2021), 296–314.



Table 1 - The Functions of Port Authorities in the Clean Energy Transition⁴

Port function	Use of the function to support the green transition
1. Landlord	Ports can allocate space for clean energy projects (e.g., e-fuel production), invest in green infrastructure (OPS/electrification), and use concessions and lease agreements to incentivize transition.
2. Regulator	In some cases, ports can issue and enforce their own regulations, individually or in coordination with government agencies. Ports can use differentiated fee structures and emissions reduction monitoring to incentivize compliance.
3. Operator	Ports can reduce GHG emissions in their operations and include sustainability criteria when selecting subcontractors. Certification can be used to assess, manage and demonstrate environmental performance.
4. Community manager	Ports can act as coordinators of sustainability initiatives among users and stakeholders in the port ecosystem. Ports can set strategic decarbonization goals for the port cluster and coordinate transition through formal multilateral fora or informal meetings with stakeholders.

These expanded responsibilities require ports to engage with a much broader range of stakeholders than under traditional port governance. Besides shipping companies, terminal operators and logistics providers, ports increasingly collaborate with renewable energy companies, utilities, technology providers, infrastructure investors, research institutions, universities, regulators, municipalities, environmental organizations and local communities.⁵ Consequently, the green transition requires ports to move beyond their traditional customer base and develop relationships with entirely new actors, including hydrogen producers, biofuel companies, renewable energy equipment manufacturers, carbon capture providers and energy storage companies.⁶ Successful transition therefore depends on ports' capabilities as "system builders" to develop extensive collaboration across maritime, energy, industrial and public sector, which together represent a complex sociotechnical system⁷.

2.2. Factors influencing green transition pathways

⁴ Sigrid Damman and Markus Steen, 'A Socio-Technical Perspective on the Scope for Ports to Enable Energy Transition', *Transportation Research Part D: Transport and Environment*, 91/January (2021), 102691.

⁵ Sornn-Friese, *Ports as Energy Transition Hubs : An Exploratory Study*.

⁶ Sornn-Friese, *Ports as Energy Transition Hubs : An Exploratory Study*.

⁷ Johnn Andersson, Hans Hellsmark, and Björn Sandén, 'The Outcomes of Directionality: Towards a Morphology of Sociotechnical Systems', *Environmental Innovation and Societal Transitions*, 40/April (2021), 108–31.



Each port represents a unique transition context due to the complexity of actors and activities undertaken at port.⁸ Green transition pathways depend on multiple interacting factors that shape how ports develop as energy transition hubs.⁹ First, *local context* strongly influences transition pathways. Differences in geography, existing industrial activities, traffic composition, available infrastructure and proximity to renewable energy resources determine which technologies and business opportunities are feasible. Second, *governance*¹⁰¹¹ and *business models* play a decisive role in facilitating the clean energy transition. Rather than adopting a single governance model, ports require context-specific governance arrangements that reflect local stakeholder needs while enabling investment, innovation and collaboration. Third, *technological readiness* affects transition choices. Ports must integrate renewable energy systems, alternative fuels, digital technologies, smart grids, automation and decision-support tools while adapting existing infrastructure to new energy sources. Finally, *collaboration*¹²¹³ across supply chains is identified as a key enabler. Ports face an increasing challenge of integrating maritime, port and hinterland energy systems through collaborative value chains and green shipping corridors, supported by coordinated regulatory frameworks, public-private partnerships and investment mechanisms that reduce technological and commercial risks.

Ports should approach the energy transition as a process of co-evolution with other sectors and systems such as green fuels, the energy sector and the transport sector. Their development as energy transition hubs will depend on parallel changes in renewable electricity generation and grid capacity, green fuel production and distribution, and the uptake of alternative fuels across maritime and landside transport. Ports can actively shape these systems by connecting energy production, transformation, storage, distribution and consumption and by fostering new green-fuel value chains and business ecosystems.¹⁴

⁸ Kristin Ystmark Bjerkan and Marianne Ryghaug, 'Diverging Pathways to Port Sustainability: How Social Processes Shape and Direct Transition Work', *Technological Forecasting and Social Change*, 166/November 2020 (2021), 120595.

⁹ Sornn-Friese, *Ports as Energy Transition Hubs : An Exploratory Study*.

¹⁰ Port governance is defined as a system of rules, policies and processes that determine how a port is managed and operated (Sornn-Friese et al., 2024). Conceptually, port governance is defined along two dimensions: ownership of assets (public vs private) and exercise of strategic and regulatory control (state vs market actors) (Brooks et al., 2007).

¹¹ Mary R. Brooks and Kevin Cullinane, 'Chapter 18 Governance Models Defined', *Research in Transportation Economics*, 17 (2007), 405–35.

¹² Collaboration between partner organizations is a combination of cooperation and coordination. Cooperation refers to the joint pursuit of agreed upon goals in a manner corresponding to a shared understanding about contributions and payoffs. Coordination is the deliberate and orderly alignment or adjustment of partner's actions to achieve jointly determined goals (Gulati et al., 2012).

¹³ Ranjay Gulati, Franz Wohlgezogen, and Pavel Zhelyazkov, 'The Two Facets of Collaboration: Cooperation and Coordination in Strategic Alliances', *Academy of Management Annals*, 6/1 (2012), 531–83.

¹⁴ Sornn-Friese, *Ports as Energy Transition Hubs : An Exploratory Study*.



Strengthening links with local economies is an integral part of the transition process because ports' development as energy transition hubs increasingly connects port activities with local industries, cities and communities. Ports can create local synergies and value chains, for example through shared energy infrastructure and exchanges of energy and resources between co-located firms, while also supplying renewable energy to nearby industrial and urban consumers. Closer integration with the local economy requires ports to balance economic opportunities with social and environmental impacts and to engage local stakeholders so that the benefits of the transition are shared and public acceptance is maintained.¹⁵

3. Methodology

The case studies presented in this report were developed using a combination of methodological approaches for data collection and analysis.

- **Semi-structured interviews** with selected European ports were the primary data collection method. We conducted a total of nine interviews, including interviews with representatives of seven European ports, one regional port association and the European Investment Bank.¹⁶ The interviews were conducted during the period of March, April and May 2026. The individuals interviewed either had direct responsibility for supervising the sustainability transition at the port or played a key role in shaping its direction through their managerial or executive functions. These individuals included dedicated sustainability managers, business development managers, project managers and directors working on energy transition, chief commercial officers, and a former CEO. The open-ended questionnaires were designed for one-hour interviews. The interviews were conducted under the promise of anonymity, all of which were recorded and subsequently transcribed. At the beginning of each interview, the purpose and expected outcomes of the study and the terms of information gathering were explained. We then proceeded to the open-ended questionnaire. We were careful to ask broad and open-ended questions to minimize the potential for biasing or leading the interview subjects. This approach gave us the flexibility to adjust our questions, allowing us to go deeper into newly revealed information and better understand its significance¹⁷.

¹⁵ Sornn-Friese, *Ports as Energy Transition Hubs : An Exploratory Study*.

¹⁶ The case studies presented in section 4 of this report represent five ports that gave us an explicit permission to feature them as case studies.

¹⁷ Dennis A. Gioia, Kevin G. Corley, and Aimee L. Hamilton, 'Seeking Qualitative Rigor in Inductive Research: Notes on the Gioia Methodology', *Organizational Research Methods*, 16/1 (2013), 15–31.



- **Publicly available information**, including ports' websites and press releases, national statistical agencies, news articles and analytical reports were used to validate and complement insights obtained from the semi-structured interviews. For example, data on ports' profiles in terms of traffic composition and main business segments served were obtained from ports' websites, press releases and annual reports. Where publicly available, data on ports' sustainability strategies, decarbonization plans, as well as current and planned green transition initiatives were collected from official port websites and related online sources.
- **Public funding instruments** were analyzed to identify and evaluate the eligibility criteria of EU-level funding programs relevant to ports. As access to investment financing emerged as a key theme in the interviews with ports, particularly the role of public funding, we conducted an interview with the European Investment Bank (EIB) to understand a funder's perspective on how financing decisions are made, the criteria used to support port green transition projects, and the financial barriers that may constrain the green transition. The report summarizes the funding instruments available to port authorities to help them identify suitable sources of financing for green transition projects. Complementing this analysis, the report also summarizes emerging practices for applying for these funding opportunities, drawing on insights obtained from interviews with the case study ports.

Data from the above sources were triangulated to strengthen the validity of the findings and support the analysis ¹⁸.

The sample of ports interviewed for this report includes seven ports: five in Denmark and two in southern Europe. We also contacted ports in other European countries but were unable to secure interviews with all of them. The resulting sample provides both depth and regional representation, enabling us to identify common and emerging practices within a relatively consistent institutional context while also incorporating perspectives from two southern European ports. As a research institution based in Denmark, CBS has strong access to ports and relevant industry stakeholders in the country, allowing us to explore their approaches to the green transition in greater depth. Focusing primarily on Denmark also provides greater contextual consistency, as regulatory frameworks and policy incentives vary across European countries and can influence the pathways ports pursue in the green transition. Examining five ports within the same national regulatory and institutional environment therefore allows us to better distinguish emerging practices from country-specific factors and identify similarities and differences in how ports approach the transition. At the same time, the inclusion of two

¹⁸ Sarah J. Tracy, 'Qualitative Quality: Eight a"big-Tent" Criteria for Excellent Qualitative Research', *Qualitative Inquiry*, 16/10 (2010), 837–51.



southern European ports provides a broader European perspective and allows us to consider whether practices observed in Denmark are also present in other contexts. The sample thus combines in-depth analysis of the Danish context with insights from other parts of Europe, supporting the report's objective of identifying emerging business and governance models for the green transition.

Several limitations of this study must be acknowledged. First, the ports and the regional port association interviewed are primarily located in Northern Europe, with only two ports from Southern Europe. As a result, the findings may be somewhat skewed towards ports operating in regions with relatively advanced green transition agendas, stronger institutional capacity and greater experience in developing and implementing decarbonization initiatives. Consequently, the findings may not fully reflect the challenges faced by ports operating in other parts of Europe, and practices deployed to address these challenges. Second, the case study ports are still predominantly in the early stages of the green transition, currently undertaking feasibility studies to assess the technical and commercial viability of green technologies. Consequently, the challenges and emerging practices presented in this report primarily reflect the planning phase. Additional challenges and practices are likely to emerge as ports progress to implementation and operation of green infrastructure.

4. Case studies

4.1. Port of Aalborg

The Port of Aalborg (PoA) is a modern industrial inland port located in the north of Denmark. In 2024, the port handled 901 ship calls and about 2.5 million tonnes of cargo¹⁹. The port serves as a multimodal hub connecting North Jutland with international markets, handling a diverse mix of cargo including dry bulk (grains, feed, construction materials), liquid bulk (notably petrol and diesel fuels) and general cargo. Container traffic is a relatively smaller segment with annual throughput of 10,000 TEUs²⁰, down from about 70,000 TEUs in 2021 after a major shipping company moved to another Danish terminal, but it has been slowly recovering in recent years. The port does not handle passenger traffic. PoA is experiencing increasing exports of general cargo linked to the green transition, against declining imports of petrol and diesel²¹.

¹⁹ Port of Aalborg, *Port of Aalborg Annual Report for 2024 (2025)*.

²⁰ Danmarks Statistik, 'Throughput of Containers and Ro-Ro Units in Major Danish Ports', 2024.

²¹ Port of Aalborg, *Port of Aalborg Annual Report for 2024*.



The port is home to a business park, offering leasing of office, warehouse and production premises to industry companies. In 2024, the business park experienced an increase in interest from companies in the green transition²². In addition to being active in national and international networks, the port is a member of several professional regional associations including *Aalborg Renewables*, a local network of stakeholders in renewable energy which aims to promote growth and innovation through collaboration between companies and academic/research institutions. The port has entered into a strategic development collaboration with Aalborg Utility and Aalborg Municipality, promoting the green transition by linking energy, infrastructure, and business development, including CO₂ infrastructure and green technology initiatives. Moreover, PoA is facilitating the Aalborg Maritime og Logistics network focusing on these thematic areas and for target companies in Northern Jutland. PoA has a climate and environmental strategy²³, which relies on four pillars aiming at: (1) CO₂ neutrality through energy savings, renewable energy and decarbonization, (2) minimal waste and increased resource efficiency, (3) focus on ecosystems and biodiversity, and (4) sustainability infrastructure, services and products²⁴. The port's strategy is aligned with the municipal target of reducing GHG emissions by 70% by 2030 (compared to 1990 levels). Initially, the port targeted full decarbonization by 2030, however, the target was adjusted to bring it in line with the municipal environmental strategy.

Governance. PoA is operated by a limited company, the Port of Aalborg Group, 100% owned by the municipality of Aalborg. The port is governed by a board of directors comprising 12 members. The board has a political majority with six representatives from the city council, four from the port authority, and two external members. It is chaired by a city councilor, with an external advisor serving as vice chair, reflecting a governance structure that combines public oversight with external expertise. In 2024, the port established a sustainability forum to engage port customers in understanding and advancing sustainability and decarbonization objectives. However, the forum was discontinued because large differences in company size and maturity made it difficult to find common ground, resulting in insufficient engagement to sustain the initiative (interview with PoA).

Business model. The port operates as an infrastructure provider and landlord, developing and maintaining facilities that enable its tenants to conduct industrial activities and support the green transition. Its role is to prepare and supply ready-to-use sites (e.g. for the offshore wind sector). The port currently has no onshore power supply (OPS) in place, a reflection of its low container traffic and the absence of passenger vessels which reduces immediate demand. However, the on-going construction of a new quay includes OPS as well as upgrading other

²² Port of Aalborg, *Port of Aalborg Annual Report for 2024*.

²³ The strategy is currently under revision.

²⁴ Port of Aalborg, *Climate and Environmental Strategy for Port of Aalborg (2024)*.



quay areas with fixed grid, combined with mobile battery-based solutions to provide flexible shore power across existing quay areas (interview with PoA). The Energy Community Project aims to develop power generation from solar panels for the port's operations, which will later be extended to possibly include companies in the port when the regulatory framework so allows. In partnership with Aalborg University, the port has established a test and demonstration site focused on research and development to support the green transition, initially focusing on e-methanol²⁵. The long-term goal is to create a pilot site where the university can test various technologies in real-world conditions, but the facility was not operational at the time of writing this report. No adjustments to the port's traditional business model have been made, as its green transition initiatives are still in the feasibility assessment stage. However, partly influenced by the EU Port Strategy, PoA is looking seriously into how to become an Energy Hub adding to the present business model.

In summary, the port embraces an ecosystem-based strategy to support the green transition, which relies on decarbonization of its own operations, development of testing facilities for green fuels, and business park development with focus on growth in green and innovation clusters. The port describes itself as a “local integrator” and places a strong emphasis on participation in professional networks and partnership development, including partnerships with knowledge institutions, municipalities, utility companies and private companies.²⁶

4.2. Port of Aarhus

The Port of Aarhus (PoAar) is the largest commercial port in Denmark, which handles over 660,000 TEUs annually or 70% of the country's container traffic ²⁷. In 2024, the port handled about 7,000 ship calls and 10 million tonnes of cargo ²⁸. While containers are the core business area (over 50% of its total cargo volume), the port also handles ro-ro, dry bulk and liquid bulk traffic. The port handles about 200,000 cruise passengers and 3.2 million ferry passengers annually ²⁹. The port serves as a key gateway to the country for trade. It is a central logistics and industrial hub housing logistics companies and production facilities that operate within the port area. The port's planned expansion was put on hold by a political majority at Aarhus City Council.³⁰

²⁶ Port of Aalborg, *Strategy Report 2020* (2020).

²⁷ Statistik, ‘Throughput of Containers and Ro-Ro Units in Major Danish Ports’. In 2025, the port of Aarhus handled 843,665 TEUs in container traffic, which represents an increase of 28% compared to 2024. The port handled about 3.2 million in ferry passenger traffic and called on by 61 cruise ships.

²⁸ Port of Aarhus, *Annual Report 2024* (2025).

²⁹ Port of Aarhus, *Annual Report 2024*.

³⁰ Port of Aarhus, *Annual Report 2024*.



PoAar integrates sustainability as part of its core business strategy, with the overall goal to become CO2 neutral by 2030. The core elements of this strategy include electrification of the port's vehicles and machines, OPS for ships using green electricity, and CO2-neutral fuels for the port's boats. The port places emphasis on developing OPS for cruise and container ships, as these two are its core business segments. In 2023, the OPS system for cruise ships was put in place, with 68% of cruise ships connecting to green electricity in 2024 ³¹. The green tax is used to incentivize cruise ships to use the OPS system. The port is set to use 100% Danish-produced green electricity under a 10-year power purchase agreement with the NRGi Group. Electrical charging is available to ferries, financed by Molslinjen.

The port is also in the process of installing OPS for container ships, funded through a joint grant of EUR 18.8 million from the EU CEF fund. PoAar bid for the grant as part of a consortium with other ports (Gothenburg, Bremerhaven and Stockholm). The PoAar's share of the funding of EUR 5.29 million will cover 50% of the total cost ³². The port is a member of the Zero Emission Port Alliance (ZEPA), a partnership between 12 container ports, terminal operators and equipment providers established to accelerate the development of battery-powered container handling equipment as part of the green transition.

Governance. The port is 100% owned by the municipality of Aarhus and has traditionally operated a municipal self-governing port. On 1 April 2025, the port was converted into a municipal joint stock company. This marks a significant governance reform aimed at supporting commercial growth and creating new business opportunities. The port is governed by a board of directors which consists of 11 members representing both public and private interests. It is led by a private-sector chair and the Mayor of Aarhus as vice chair, with an additional two members from the city council, four members from the port authority, two external private-sector representatives and one member who brings experience from the Danish Maritime Authority.

Business model. The port's business model remains largely unchanged as part of the green energy transition. It operates as a landlord port, generating revenue from ship traffic, lease agreements and port services. The green transition is driven by regulatory compliance, with a focus on infrastructure investments in electrification and OPS. There are no significant new revenue streams or business model changes linked to the transition. The port largely responds to customer requests when developing green activities. While there is increased interaction with energy providers and some tenant/customer led initiatives, the overall business model does not show major adjustments. As a publicly owned company, the port is subject to legal constraints. For example, it cannot freely produce and use its own electricity, as it would be

³¹ Port of Aarhus, *Annual Report 2024*.

³² Port of Aarhus, *Annual Report 2024*.



obligated to provide it to the market. Hence, the port will meet its needs for green electricity through a long-term partnership with the NRGi Group.

In summary, the port incorporates sustainability into its core business strategy. Sustainability objectives are focused on full decarbonization compliance (scope 1 and 2 by 2030). Due to increasing political focus on the port as critical infrastructure, the port has experienced a shift in priorities toward security and operational continuity, where sustainability is becoming less central. However, the port remains committed to complying with EU regulatory requirements, supported by early investments in electrification and OPS.³³

4.3. Port of Esbjerg

The Port of Esbjerg (PoE) in Denmark is one of the world's largest originating ports for offshore wind power. As such, a significant share of activity at the port is linked to wind turbine and components cargo and the port acts as a base for warehousing, assembly and shipping of wind power equipment. In 2024, the port handled 5,712 ship calls and 3.9 million tonnes of cargo ³⁴. The PoE's traffic is dominated by Ro-Ro (40%) and bulk cargo (33%), followed by wind components (12%), containers (7%), liquid bulk (5%), with only small shares from project cargo (2%) and coal (1%) ³⁵. The port handles about 1.9 million passengers annually.³⁶ Historically the port has provided passenger ferry services on routes to/from the UK. The port is one of the largest ports in Denmark (4.5 million square meters) and is home to more than 200 businesses.

Within a broader Getting-to-Zero framework, PoE focuses on initiatives aimed at reducing emissions through electrification (OPS, electrification of cranes and mobile equipment, charging infrastructure for trucks and port operations). The port's sustainability strategy emphasizes partnership building as a key element in the green transition. The port actively participates in cross-border networks and partnerships with like-minded ports, including the North Sea Wind Ports Partnership (2022), Wadden Seaports (2018), Nordic Ports for a Sustainable Future (2019), Getting to Zero Coalition (2019), Offshore Wind Ports Platform (2016), often assuming a leadership role ³⁷. Rather than following a comprehensively defined sustainability strategy, the port takes a market-driven pragmatic approach with focus on initiatives that can be scaled up gradually on demand. Due to a lack of market demand, the port currently does not pursue green fuel infrastructure projects. It takes a wait-and-ready

³³ Interview with the port of Aarhus, conducted by Kate Markhvida and Christopher Dirzka.

³⁴ Port Esbjerg, *Annual Report 2024* (2025).

³⁵ Port Esbjerg, *Annual Report 2024*.

³⁶ Port Esbjerg, *Annual Report 2024*.

³⁷ Henrik Sornn-Friese, Petar Sofev, and Kirils Kondratenko, 'The Port Authority as System Builder in Cross-Border Regionalization: An Exploratory Study of Port Esbjerg in the Development of North Sea Wind', *Maritime Transport Research*, 4 (2023).



approach by participating in technical studies and training programs (e.g., EU's Hydrogen Valleys).

Governance. PoE is a municipal self-governing port, 100% owned by the Municipality of Esbjerg. The port is governed by a 9-member board of directors that reflects both public and private interests. Chair of the board is the Speaker of the Danish Parliament and Vice Chair is the Mayor of Esbjerg, indicating strong political oversight. The board also includes one additional city council representative, four members from the private sector appointed by the city council and two employee representatives, creating a mixed governance structure that combines political leadership, industry expertise and internal representation.

Business model. PoE supports the green transition by becoming a platform and orchestrator of a wider energy ecosystem – particularly in the offshore wind power segment – through a combination of infrastructure provision, ecosystem coordination and strategic investment. In addition to leasing land, the port acts as “a system builder”, coordinating actors and assuming a proactive role in developing the North Sea offshore wind energy system³⁸. Strategic investment into electrification initiatives is undertaken by the port with costs spread across the entire port system over time. The port therefore uses a pricing model where costs associated with renewable energy projects are internalized collectively as they are passed on to port users.

In summary, the port identified a strategic niche market – offshore wind power – as a core element in its sustainability strategy and has assumed a role as orchestrator in this broader ecosystem. The port faces key challenges such as a lack of stable demand for green energy fuels (e.g., shore power, hydrogen), weak business cases and high upfront investment costs. Uncertainty about future technologies and market uptake further complicates decision-making. It has approached these challenges by focusing investment in certain areas and flexible and shared cost models.

4.4. Port of Rønne

The Port of Rønne (PoR) is the main port for freight and passenger traffic on the island of Bornholm in Denmark. As such it is the main bridge between Bornholm and the rest of the world, a strategically important island for Denmark's energy and industrial policy. PoR has traditionally focused on ferry and bulk traffic as its core business areas, with cruise added since the early 1990s.³⁹ Since 2020, the port has been involved in offshore wind power installation, a market segment experiencing growth. In 2024, the port handled over 3,000 ship calls and over 1.4 million tonnes of cargo ⁴⁰. The port handles about 69,000 cruise passengers

³⁸ Sornn-Friese, Sofev, and Kondratenko, 'The Port Authority as System Builder in Cross-Border Regionalization: An Exploratory Study of Port Esbjerg in the Development of North Sea Wind', p. 10.

³⁹ Port of Rønne, *Annual Report for 2024* (2025).

⁴⁰ Danmarks Statistik, 'Call of Vessels, Passengers and Throughput of Goods in Danish Ports', 2024.



annually, with a total of 55 cruise ship calls in 2024 ⁴¹. The port also handles around 2 million ferry passengers annually, a stable business segment expected to continue in the coming years.⁴²

PoR's sustainability strategy identifies CO2 neutrality by 2030 as its overarching target. The port's sustainability work combines CSR, ESG and UN Sustainable Development Goals, and prioritizes areas such as emissions reduction, renewable energy, sustainable industry and resource efficiency ⁴³. The port embraces a pragmatic approach to sustainability initiatives, closely integrated with its business and commercial development ⁴⁴. Key initiatives include development of OPS despite weak business cases, participation in R&D and feasibility projects on e-fuels (e.g. methanol, hydrogen, ammonia), and the ambition to become a green bunker hub. Under the Bornholm Bunker Hub collaboration, the port works with Ørsted, Topsoe, Rambøll, Bunker Holding, Wärtsilä, Bureau Veritas and Molslinjen to set up a green refuelling station for some of the 60,000 ships that pass by the port annually. The port actively collaborates with partners and engages in early-stage risk reduction to enable future clean energy projects, reflecting its role as an active facilitator and enabler rather than a direct producer of green energy.

Governance. PoR is operated by a limited company, which is 99% owned by the Bornholm regional municipality and the residual shares owned by a trade union (F.O. Bornholm) and the Danish Industry Association Bornholm. The port is governed by a 9-member board of directors. The board is presided by Chair from the private sector and Vice Chair from the maritime sector. The board also includes three political appointees, three independent professional members and one employee representative, reflecting a balanced governance structure that combines industry knowledge, public accountability and internal representation.

Business model. In the context of the green transition, the port has shifted from a passive landlord role to a more proactive “enabler” role, actively supporting the development of new green energy businesses. This includes early-stage feasibility studies on green fuels (ammonia, hydrogen, methanol) and risk-reduction activities (e.g., technical studies on fuel storage, safety and infrastructure requirements) to make future projects viable and to attract private investors. Financing of green energy initiatives is supported with a mix of public and private funding, rather than direct large-scale capital investment by the port. Public funding is complemented with internal resources. The port also actively engages with private-sector stakeholders with the expectation that private actors will invest in large-scale infrastructure once commercial viability is clearer. The port may also use pricing mechanisms (e.g., reduced

⁴¹ Port of Rønne, *Annual Report for 2024*.

⁴² MOLSLINJEN, 2025: *Endnu En Færgerekord*, (2025).

⁴³ Port of Roenne, *Sustainability Report 2023* (2024).

⁴⁴ Port of Roenne, *Sustainability Report 2023*.



tariffs or shared cost structures) to support early adoption and improve project feasibility. The port proactively seeks clean energy opportunities (e.g., Bornholm Bunker Hub) and projects linked to Baltic Energy Island and Energy Island Bornholm, coordinates with stakeholders, reduces early project risks and prepares infrastructure with the goal of enabling the green transition.

In summary, PoR's key challenges in the clean energy transition include uncertain and weak business cases due to market immaturity for green fuels, lack of sufficient grid capacity for electrification, limited access to funding and high complexity of coordinating multiple actors across long supply chains. Political and institutional risks can slow down decision-making. The port actively engages in early-stage feasibility work and risk reduction, alignment with customer and stakeholder needs and proactive internal initiatives that integrate sustainability into operations. The port's ability to act as an enabler combined with a willingness to invest despite negative business cases puts it at the forefront of the green transition.

4.5. Port of Valencia

The Port of Valencia (PoV) is a major Mediterranean port, handling a wide range of cargo types, including containerized cargo, liquid and dry bulk cargo, general cargo, ro-ro traffic and passenger traffic. In 2024, the port handled 6,210 ship calls and over 73 million tonnes of cargo⁴⁵. It also handled 776,900 ferry passengers and 781,280 cruise passengers the same year⁴⁶. Containerized cargo represents about 80% of the overall volume of cargo handled by the port. The port is a major gateway for container traffic, handling approximately 5.4 million TEUs in 2024; about 57% of fully loaded containers are transhipped⁴⁷.

The port authority of Valencia (APV) sustainability policies are included in the Net Zero Emissions Plan, which aims to achieve carbon neutrality at Valencia port's facilities by 2035. The port authority will lead the decarbonization process for the entire port community. The plan includes measures to provide OPS for ships at various terminals and the roll out of a smart energy management system using digital twins throughout 2027⁴⁸.

The clean energy transition approach relies on several measures, including electrification, renewable electricity generation, alternative fuel experimentation, hydrogen and methanol pilot projects, and terminal decarbonization. To support the deployment of OPS infrastructure, the port is upgrading its internal electricity grid, expanding renewable electricity generation, installing new charging stations and preparing berths for OPS. Renewable electricity generation relies on the installation of PV plants, which will be integrated into the upgraded

⁴⁵ Port of Valencia, *Statistical Report Port Authority of Valencia*, no. December (2024).

⁴⁶ Port of Valencia, *Statistical Report Port Authority of Valencia*.

⁴⁷ Port of Valencia, *Statistical Report Port Authority of Valencia*.

⁴⁸ Valenciaport, *Valenciaport Launches a Strategy to Adapt Its Ports to Climate Change*, 2026.



internal electricity grid. Under the H2Ports project, the port is testing deployment of hydrogen-powered equipment (reach stackers, yard tractors and a mobile hydrogen refuelling station) for port terminal operations. The port is currently conducting studies to explore alternative sustainable fuels including LNG and bio-LNG for ferries, hydrogen, pyrolytic fuels, long-chain alcohol fuels and fuels from waste biomass. Through the Poseidon project, the port is evaluating the potential for methanol production and carbon capture from methanol production, which will be purposed to decarbonize tugboat operations at the port. The port participates in several networks to share knowledge and best practices on the clean energy transition, including the World Ports Climate Action Program, the Global Ports Hydrogen Coalition and EU innovation projects and partnerships.

Governance. PoV is managed by the port authority of Valencia, which manages two other ports: the Port of Sagunto and the Port of Gandia. The Board of Directors of APV consists of 15 voting members and 2 non-voting members. The board is strongly dominated by political appointees, with 9 members representing government interests at the central, regional and municipal levels. The remaining members represent the executive leadership of APV, business organizations, the port sector and labor unions. Overall, the composition reflects a governance structure in which political and public-sector interests exert substantial influence over the strategic direction of the port.

Business model. PoV is adapting its traditional landlord-port business model toward a broader role as an energy infrastructure provider, innovation platform, and ecosystem coordinator in support of the green transition. Beyond its conventional focus on container and passenger traffic, the port is increasingly involved in electrification, renewable energy integration, and alternative fuel development. Key initiatives include the deployment of OPS, grid upgrades, new substations, and photovoltaic installations to support vessel electrification. The port is also participating in innovation projects related to hydrogen and alternative fuels, including the H2Ports project testing hydrogen-powered terminal machinery, and the Poseidon and SEAFARER projects exploring methanol production and fuels derived from biomass residues. These developments are creating potential new revenue streams linked to OPS provision, energy infrastructure leasing, charging services and alternative fuel systems, which will be available to private sector actors with PoV taking on a facilitating role. Also, new actors are being introduced into the port ecosystem, such as renewable fuel producers, technology providers and electric mobility companies.

The main challenges facing PoV in the clean energy transition are the high cost of electrification and OPS infrastructure, uncertainty regarding future revenue streams and technology pathways, and the need to coordinate a growing number of actors across the port ecosystem. While the port has secured significant EU funding and agreements for future electricity supply, large investments in grid upgrades, renewable energy integration and alternative fuel



infrastructure are still needed. The transition is further complicated by uncertainty over which fuels and technologies (hydrogen, methanol, biofuels or electrification) will become dominant, as well as the need to maintain port competitiveness through affordable electricity pricing.

5. Emerging practices in addressing key challenges

This section identifies key challenges faced by European ports in the green transition. Based on case studies of selected European ports, it also discusses emerging practices and experiences in addressing these challenges.

5.1. Identification of trends, challenges and tradeoffs

Ports are increasingly recognizing their changing roles in the green transition, marking a shift from traditional providers of infrastructure (landlords) to strategic actors who embrace proactive roles (system builders, integrators, innovators, investors, platforms). As such, developing ports into energy transition hubs presents a system transformation challenge where ports must adapt not only their infrastructure and technologies but also their business models, governance structures, partnerships and stakeholder relationships. A successful energy transition requires interlinked changes across technology, markets, policy, society and environmental practices.⁴⁹

- **Capital investment financing constraints.** Ports evolving into energy hubs require substantial investments in infrastructure for green fuels, energy production, distribution, storage and related industrial activities. The ability of ports to attract capital investment for infrastructure development and upgrades has become a central issue for many ports. In some cases, the problem of raising capital is compounded by the fact that clean energy projects require significant upfront costs and involve uncertainty regarding future revenue and demand conditions.⁵⁰ Many such projects are not economically viable in the short term, which makes it difficult to attract investors or convince management to invest in this area.⁵¹ At some ports existing assets still have useful economic lives and therefore replacing them with cleaner alternatives takes

⁴⁹ Frank W. Geels, Florian Kern, and William C. Clark, 'System Transitions Research and Sustainable Development: Challenges, Progress, and Prospects', *Proceedings of the National Academy of Sciences of the United States of America*, 120/47 (2023), 1–6.

⁵⁰ Interviews with the port of Aalborg, the port of Aarhus, the port of Esbjerg and the port of Rønne, conducted by Kate Markhvida and Christopher Dirzka.

⁵¹ Interviews with the port of Aalborg, the port of Esbjerg and the port of Rønne, conducted by Kate Markhvida and Christopher Dirzka.



time. Public funding in the form of grants or loans is often necessary to complement private funding to make green transition projects feasible.

- **Human resources and the role of change agents.** Prior research suggests that ports support the green transition primarily by building interdisciplinary expertise and collaborative networks with external partners, rather than creating standalone sustainability departments⁵². Consistent with these prior findings, the case studies show that standalone functional departments or teams within ports overseeing sustainability initiatives are still rare. Most ports do not have dedicated departments to oversee the green transition; rather, sustainability is often embedded across different port functions in operational, technical, commercial, business development or management teams. Dedicated sustainability teams are relatively new. Where dedicated port staff are allocated to oversee and support the green transition, the teams tend to be small (1-3 people). Among the small to medium-sized ports interviewed, only one port formed a dedicated sustainability team consisting of 3 full-time employees⁵³, while also actively seeking broader participation from staff throughout the organization during the development of its sustainability strategy.
- Intriguingly, sustainability agendas can be strongly influenced by dedicated individuals within a port itself, who may or may not be part of the dedicated sustainability team. We will call them “change agents” and define them as internal and external individuals who exert strong influence over the direction of a port’s sustainability strategy and initiatives in the green transition. Internal change agents may operate at different levels of the port, each playing a distinct role in shaping, legitimizing and implementing sustainability initiatives. Through the case studies, five categories of change agents involved in the green transition of ports were identified: strategic (CEOs and senior executives), legitimacy (boards of directors), entrepreneurial (business development managers), implementation (sustainability coordinators and ESG specialists), and external (consultants, research institutions and strategic partners).
- **Governance and coordination.** To effectively support the green transition, ports must adapt their governance structures, decision-making processes and stakeholder engagement practices. Thus, governance is one of the central enablers of the green transition at ports⁵⁴. Beyond their traditional roles, ports are increasingly expected to

⁵² Sornn-Friese, *Ports as Energy Transition Hubs : An Exploratory Study*.

⁵³ Interview with the port of Aalborg, conducted by Kate Markhvida and Christopher Dirzka.

⁵⁴ Sornn-Friese, *Ports as Energy Transition Hubs : An Exploratory Study*.



coordinate complex business ecosystems emerging around clean energy that involve central and local governments, utility companies, energy producers, logistics providers, investors and local communities. Ports that effectively manage the energy transition are those that actively orchestrate and build relationships with organizations in their ecosystems.

- The *structure and composition of a port's board of directors* is a key governance mechanism providing legitimacy through formal approval and strategic oversight of green-transition initiatives. Green transition strategies often depend on the composition and diversity of expertise represented on the board. Rather than a single governance model, the emerging practice is to ensure that board capabilities match the port's evolving strategic and investment needs. Ports with mixed boards combining political representatives, industry representatives, independent professionals and external experts are generally viewed as well suited for navigating the complexity of the green transition.
- *Collaborative governance* is required to support the green transition which cannot be achieved by ports acting independently. Collaborative governance arrangements are required to balance the interests of multiple parties involved in the transition process (regulators, investors, universities, utility providers, energy companies, environmental groups and local communities). Ports increasingly face the challenge of acting as ecosystem builders and network coordinators⁵⁵ whose effective governance to support the green transition relies on transparency, stakeholder inclusion, community engagement and social acceptance of issues surrounding energy infrastructure projects. The case studies collectively suggest that the clean energy transition is fundamentally a network-governance challenge rather than purely an organizational challenge.⁵⁶
- **Insufficient electricity grid capacity.** A stable and reliable local electricity grid is essential to ensure a constant power supply for port electrification and onshore power supply (OPS). Grid capacity restrictions have a significant impact on the roll-out of a shore-based power network⁵⁷. The case studies reveal that limited availability and reliability of electricity supply, resulting from constraints in grid infrastructure, constitute a significant barrier to ports' ability to comply with regulatory requirements

⁵⁵ Sornn-Friese, *Ports as Energy Transition Hubs : An Exploratory Study*.

⁵⁶ Interviews with the port of Aalborg, the port of Aarhus, the port of Esbjerg, the port of Rønne and the port of Valencia, conducted by Kate Markhvida and Christopher Dirzka.

⁵⁷ Interreg North Sea, *Shore Power in European Shipping, SPIES (2025)*.



for OPS. Several ports explicitly stated that sufficient electricity capacity is not available for planned OPS investment.⁵⁸ OPS requires high-voltage power supply, especially for larger vessels. Where capacity is insufficient, additional connections to charging stations cannot be realized without expanding the electricity grid. Delays with implementation of OPS projects can occur due to delays in expanding capacity by grid operators in areas where grid congestion exists.

- **Regulatory and legislative constraints.** Comprehensive EU regulations (e.g., AFIR, FuelEU Maritime) are the dominant external drivers for the green transition at European ports.
 - The *Alternative Fuels Infrastructure Regulation* (AFIR, Regulation (EU) 2023/1804), applicable from 13 April 2024, establishes binding requirements for alternative fuel infrastructure across the TEN-T network of ports. It requires Member States to develop national deployment strategies and sets mandatory national target for the deployment of alternative fuels infrastructure in the EU. The regulation requires onshore power supply (OPS) for container and passenger vessels in maritime ports and for inland waterway vessels. Further, the regulation requires infrastructure to ensure an appropriate number of liquefied methane refuelling points in maritime TEN-T ports.
 - The *FuelEU Maritime Regulation* (Regulation (EU) 2023/1805), applicable from 1 January 2025, introduces the world's first well-to-wake greenhouse gas (GHG) intensity standard for energy used on board vessels. The regulation applies to commercial cargo and passenger vessels of 5,000 GT and above and progressively reduces the permitted GHG intensity of energy used on board relative to a 2020 baseline. The regulation requires that vessels moored in a port subject to the regulation use OPS for all their electrical power demand at berth from 1 January 2030.⁵⁹ By targeting both conventional and alternative fuels, FuelEU Maritime aims to accelerate the uptake of renewable and low-carbon fuels while supporting the decarbonization of maritime transport.

⁵⁸ Interviews with ADP and the port of Roenne, conducted by Kate Markhvida and Christopher Dirzka. ADP operates the Port of Fredericia, Nyborg and Hanstholm in Denmark.

⁵⁹ Publications Office of the European Union, *FuelMaritime - REGULATION (EU) 2023/1805*, 2019/July (2023), 48–100, Article 6.



For a comprehensive assessment of AFIR, FuelEU Maritime and other applicable EU regulations, see the report titled *Policy Analysis*, prepared under the POTENT X project.⁶⁰

- On one hand, the EU regulations create both demand- and supply-side incentives for the transition to clean energy in the maritime sector. On the other hand, national legal and regulatory frameworks can act as a constraint on the ability of ports to fully realize clean energy opportunities. For example, the Danish Act on Ports (*Havneloven*) places certain limitations on the ability of ports to operate renewable energy business under the auspices of the port authority, which are typically wholly owned by municipalities or municipal self-governing ports. Such entities must be separated into independent taxable limited-liability companies operating on market terms⁶¹. The law therefore does not prohibit ports from generating or selling renewable energy (e.g., electricity), but it requires that these energy-market activities be carried out through a separate taxable company operating on commercial terms, rather than directly within the public port authority. The practical implication of this legal requirement is that some ports have chosen to delay or not pursue such projects due to the regulatory hurdles.

5.2. Emerging practices in addressing key challenges

This section outlines emerging practices that ports are adopting to address key challenges associated with the green transition. These practices are derived from the experiences of the case study ports and insights gathered through interviews with port representatives. They reflect practical approaches that ports have developed or are currently implementing in response to common technical, financial, organizational and regulatory challenges. The practices presented are not intended to constitute an exhaustive set of solutions, but rather to highlight relevant approaches observed across the case studies that may provide useful insights for other ports navigating similar challenges in their green transition.

5.2.1. Financing capital investment

Ports tend to finance green transition initiatives through a combination of multiple funding sources including private and public funding. Many green transition initiatives are not economically viable due to uncertain demand and insufficient financial returns. Public funding through loans or grants remains an important vehicle or supporting ports in undertaking investment in sustainable operations.

⁶⁰ Dirzka, *POTENT X, Ports as Energy Transition Hubs: D4 - Policy Analysis*.

⁶¹ Transportministeriet, *Bekendtgørelse Af Lov Om Havne*, 2024, paras 9(11) and 10(9).



Although EU funding (see Table 2) is an important source of capital for some ports, smaller ports often struggle to secure it due to intense competition from other ports (or modes of transport) or the requirement to show project maturity to qualify for funding through some EU programs. To address this challenge, ports can benefit from collaborative applications for European funding. Rather than applying individually, several ports can form a consortium to strengthen their competitiveness in applying for EU funding programs, such as Connecting Europe Facility (CEF) funding.

- For example, the ports of Aarhus, Gothenburg, Bremerhaven and Stockholm partnered to seek EU CEF funding through a joint application for OPS infrastructure for container vessels. The EU.OPS.Network project has a total budget of €37.61 million, of which 50% (€18.8 million) is co-financed through the EU CEF.⁶²

Ports can obtain private funding for capital investments from a variety of sources, including commercial bank loans, co-financing arrangements with customers and revenues generated from port operations.

- *Co-financing* with or by port customers, particularly for investments in OPS, is a common practice used by ports. For example, ferry operator Molslinjen in Denmark finances its own shore power infrastructure for electric ferries, while ports can support such investment by coordinating electricity grid access and cooperation with energy providers.⁶³
- *Cost spreading* across the broader customer base in another practice used by ports, particularly where individual green investment projects are not commercially viable. Ports can recover investment costs through general port revenues, including vessel tariffs, cargo tariffs, passenger fees or shared infrastructure charges applied to a broad base of customers.⁶⁴
- *Prioritization* of green transition initiatives that are closely aligned with their core business activities and strategic objectives is commonly used by ports to determine which initiatives are implemented ahead of others. This approach helps manage investment risk by focusing resources on projects with the greatest strategic relevance while addressing uncertainties surrounding future demand and commercial viability.⁶⁵

Public funding provided through EU programs and the European Investment Bank (EIB) represents an important source of capital for large-scale infrastructure investments. Ports can leverage these funding mechanisms to finance or co-finance investments in green energy

⁶² Port of Stockholm, 'Northern European Ports in Collaboration Receive EU Funding for Onshore Power for Container Ships', Press Release (2024).

⁶³ Interview with the port of Rønne, conducted by Kate Markhvida and Christopher Dirzka.

⁶⁴ Interview with the port of Esbjerg, conducted by Kate Markhvida and Christopher Dirzka.

⁶⁵ Interview with the port of Aarhus, conducted by Kate Markhvida and Christopher Dirzka.



infrastructure and related projects. Our interviews indicate that some ports actively make use of certain EU funding instruments, such as the Connecting Europe Facility (CEF). However, we also found that awareness of other available resources remains limited, particularly regarding funding opportunities and advisory assistance provided by the EIB. To support ports in identifying relevant financial resources and selecting appropriate funding options, a summary of the main EU-level funding instruments available for infrastructure and green energy investments was developed. Table 2 provides an overview of these instruments and their potential relevance to port infrastructure investment.

Table 2 - Sources of Public Funding and Assistance for Port Clean Energy Infrastructure

Program	Eligibility Criteria	Notes
Connecting Europe Facility (CEF)	available to TEN-T ports	an EU public funding program providing grants and procurement to support the green transition and decarbonization available to all ports of the TEN-T network funding aimed at decarbonizing maritime transport, supporting the use of digital technologies in shipping, better connecting ports with the hinterland and incentivise renewable energy generation in the ports
European Investment Bank (EIB) loans and equity instruments	available to TEN-T ports transport infrastructure investments must meet the eligibility criteria under the Climate Bank Roadmap and be Paris-aligned	available to all ports of the TEN-T network in the EU and EU Neighborhood, which are given priority ⁶⁶ EIB's standard financing instruments include investment loans, intermediated lending and equity-type instruments, including investments in infrastructure funds ⁶⁷ priority is given to economically viable investment programmes and projects that are at an advanced stage of planning ⁶⁸
European Investment Bank (EIB) framework loans	available to sovereign states, national ministries / departments / agencies / institutions, regional or local authorities, public utilities ⁶⁹	an EIB finance instrument typically used to finance investment programmes starting from EUR 100 million which consists of smaller projects ⁷⁰ EIB covers up to 50% of the programme's costs ⁷¹

⁶⁶ European Investment Bank, *Transport Lending Policy 2022* (2022).

⁶⁷ European Investment Bank, *Transport Lending Policy 2022*, p. 3.

⁶⁸ European Investment Bank, *Transport Lending Policy 2022*, p.20.

⁶⁹ European Investment Bank, *Financing a City's or Region's Long-Term Capital Investment Programme: EIB Framework Loans* (2016).

⁷⁰ European Investment Bank, *Financing a City's or Region's Long-Term Capital Investment Programme: EIB Framework Loans*.

⁷¹ European Investment Bank, *Financing a City's or Region's Long-Term Capital Investment Programme: EIB Framework Loans*.



		ports can potentially benefit from on-lended framework loans, subject to general eligibility criteria (generate economic benefits, be financially sustainable, meet environmental and social requirements, meet appraisal thresholds, satisfy financing limits, and be less than 50% physically complete at appraisal) ⁷²
European Investment Bank (EIB) JASPERS ⁷³	available to beneficiaries of Connecting Europe Facility (CEF) funds available to beneficiaries of European Structural and Investment Funds (ESIF) and Just Transition Fund (JTF)	an advisory program, co-funded by the European Commission available to <i>small and medium-sized</i> ports of the TEN-T network advisory services to prepare investment projects, in line with EU policy objectives

5.2.2. Mobilizing human resources

Dedicated sustainability departments at ports remain rare, particularly in medium- and small-sized ports. Many ports continue to rely on small teams or individual coordinators responsible for environmental initiatives to support the green transition.

- The port of Aalborg recently established a dedicated sustainability and ESG group consisting of three dedicated employees. The port of Aarhus currently has one sustainability coordinator responsible for supporting the implementation of its sustainability strategy.

To support ports' sustainability teams, some ports rely on *external expertise* during strategy development and implementation.

- For example, the port of Aalborg organized sustainability workshops with internal staff to support the development of its strategy which were facilitated by Aalborg University, illustrating the use of academic partners to complement and strengthen internal capabilities and broader organizational engagement. The port of Esbjerg uses external expertise as a strategic resource to improve decision-making and develop new capabilities. The port collaborates with research institutions, consultants and industry partners through professional international networks to develop expertise in offshore wind industry and support its role as a facilitator of the green transition.⁷⁴

⁷² European Investment Bank, *Financing a City's or Region's Long-Term Capital Investment Programme: EIB Framework Loans*.

⁷³ Joint Assistance to Support Projects in European Regions

⁷⁴ Sornn-Friese, Sofev, and Kondratenko, 'The Port Authority as System Builder in Cross-Border Regionalization: An Exploratory Study of Port Esbjerg in the Development of North Sea Wind'.



Across ports, individual change agents often play a decisive role in the development of sustainability strategy and the choice of green transition projects. The case studies reveal that executive leadership plays a pivotal role in accelerating decision-making and overcoming organizational inertia during the green transition. However, the case studies also demonstrate that influential individuals at the middle-management level or in dedicated sustainability positions can act as important change agents, shaping the direction and implementation of a port's sustainability strategy.

The influence of individual change agents appears to be particularly pronounced in ports because port authorities are organizations where sustainability functions are still often weakly institutionalized. The implementation of green transition initiatives depends heavily on managerial judgement under the conditions of uncertainty and the degree to which managers maintain a personal interest in pursuing the green transition. Consequently, committed individuals – whether senior executives, middle managers or sustainability coordinators – can exert a disproportionate influence on the direction and pace of the port's green transition.

This finding has important implications for port authorities, as accelerating the green transition becomes a question of not only securing funding or developing technology, but also developing organizational capacity and empowering individual change agents.

- *Invest in dedicated sustainability roles.* Rather than treating sustainability as an additional function within existing departments, ports should establish dedicated sustainability teams with responsibility for the green transition. Even small sustainability teams can exert a significant impact on implementation.
- *Identify and empower individual change agents.* Port authorities can accelerate the green transition by identifying the right individuals and providing them with a clear mandate and visibility within the organization to accelerate implementation.
- *Encourage distributed leadership.* Sustainability leadership should not be confined to the executive team. Innovation can be encouraged through giving managers at different levels opportunities to propose, lead and coordinate green transition initiatives.

5.2.3. Governance structures

Effective governance provides the institutional foundation for implementing green transition initiatives at ports. The case studies point toward governance structures that combine public accountability with commercial, financial, technical and industry expertise as an effective vehicle to support the green transition. Rather than a single governance model, the emerging practice is to ensure that board capabilities match the port's evolving strategic priorities and investment needs.



The case studies suggest that hybrid boards combining professional and commercial expertise with public accountability are well positioned to support sustainability innovation and investment. As green investments often involve significant uncertainty and technological complexity, politically dominated boards that lack the technical or commercial expertise tend to exhibit greater risk aversion, potentially delaying strategic investments.

- For example, the port of Rønne introduced a significant change in its board leadership by moving away from the established practice of appointing a political representative as chair and instead selecting a state-authorised public accountant with a professional business and financial background. Previously, the chairmanship had typically been allocated to a member of the Bornholm municipal council. The change reflected an intention to strengthen the commercial and financial expertise of the port's governance as the organisation entered a new phase of development. The change was intended to bring greater financial and commercial expertise to the board, with a particular focus on improving the profitability of ongoing operations and ensuring that previous investments, including those supporting the offshore wind sector, generate sustainable revenues.⁷⁵

Several ports in the case studies sought to adjust their ownership models or bring additional expertise to their governance structures to better support strategy implementation.

- For example, the port of Aarhus restructured its ownership by becoming a municipally owned joint-stock company. The new corporate structure provides greater commercial flexibility. At the same time, the chair position of the board was transferred from the Mayor of Aarhus to an independent professional board member, strengthening the board's commercial orientation. The Mayor of Aarhus remains on the board.

Some ports bring onboard external expertise by selling equity to private investors and allowing external experts to be represented on their board of directors. ADP owns and operates the ports of Fredericia, Nyborg and Hanstholm in Denmark. While not featured as a separate case study in this report, ADP provided important insights for our study in relation to private capital funding and the use of external expertise.

- For example, ADP's board of directors includes municipal appointees, professional members, employee representatives and a private investor representative following a sale of a minority stake to Brookfield⁷⁶. The rationale for Brookfield's involvement was to

⁷⁵ Kasper Fomsgaard Nielsen, *Operations and Revenue Are the Priorities for the Port of Rønne's New Chairman*, (2026).

⁷⁶ Brookfield is a global alternative asset manager with more than \$750 billion of assets under management across its renewable energy, infrastructure, real estate, private equity and credit and insurance businesses.



attract private capital and industry knowledge and expertise in managing port infrastructure investments.⁷⁷

At the same time, political representation on the board can provide a platform for effective communication between the port's executive leadership and the municipality or other government actors. Strong relationships with government stakeholders, including those facilitated through the board, can help the port identify and pursue new opportunities to support the green transition.

- For example, the port of Esbjerg has worked effectively with industry and government stakeholders to incorporate green-fuel requirements for vessels into offshore-wind tenders, indicating that management is attempting to create the demand conditions necessary for green investment rather than merely responding to existing demand.⁷⁸

Table 3 summarizes the ownership structure and board composition for the case study ports.

⁷⁷ Interview with ADP, conducted by Kate Markhvida and Christopher Dirzka.

⁷⁸ Interview with the port of Esbjerg, conducted by Kate Markhvida and Christopher Dirzka.

Table 3 - Composition of the Board of Directors in the Case Study Ports

Port	Ownership	Board of Directors ⁷⁹
Aalborg	100% municipal	12 members in total Political majority + 2 external members Chair = city councillor Vice Chair = external advisor 5 members from city council 4 members from port authority 1 external member (industry-public decision making)
Aarhus	Municipal joint stock company (since 1 April 2025)	11 members in total Chair = private sector Vice Chair = mayor of Aarhus 2 members from city council 2 members external private sector 4 members from port authority 1 member former Danish Maritime Authority
Esbjerg	100% municipal (self-governing)	9 members in total Chair = speaker of Danish parliament Vice Chair = mayor of Esbjerg 1 members from city council 4 members external private sector, appointed by city council 2 members employee representatives
Rønne	99% municipal; trade union + industry assoc. hold residual share	9 members in total Chair = sector rep, captain Vice Chair = sector rep, engineer 3 members political appointees 3 members independent professional 1 member employee representative
Valencia	100% publicly owned and managed by the Port Authority of Valencia (APV), a public entity within the Spanish state port system under Puertos del Estado	15 members in total (+2 non-voting members) President = CEO of APV Ex officio member = Harbourmaster of Valencia 3 members from the Spanish Central Government 3 members are mayors of Valencia, Sagunto and Gandia 3 members are regional government political appointees 2 members represent business community 1 member represents the shipping sector 1 member of a trade union

⁷⁹ Information sourced from ports' websites.



The case studies suggest that the influence of board composition on the effectiveness of port governance depends less on whether members are politically or professionally appointed and more on whether the board provides an appropriate diversity of competencies aligned with the port's evolving strategic needs. This issue is becoming particularly relevant as ports take on more complex commercial and investment decisions associated with the green transition. The interviews indicate an emerging emphasis on complementing political representation and public accountability with commercial, financial, technical and industry expertise.

- For example, the port of Rønne combines political representatives with independent professional and industry representatives, while the competencies required from independent board members are identified in relation to the port's strategy and needs. The importance of industry knowledge and commercial understanding at board level is vital for the port's ability to effectively identify and implement green transition initiatives.⁸⁰
- The port of Aarhus similarly moved from having the mayor as chair to appointing a professional board chair, while retaining the mayor and other political representatives on the board. The change reflected a move towards a more professional and corporate approach to managing the port.⁸¹

The case ports point to competency diversity and strategic alignment, rather than a particular board composition, as the more relevant governance consideration. As ports assume new roles in energy infrastructure and decarbonization, periodically reassessing whether board competencies match emerging commercial, financial, technical and stakeholder-management challenges emerges as an important governance practice.

5.2.4. Business models

The case studies highlight that ports tend to align green investments with their *core business activities*. Prioritizing projects that reinforce and support existing business strengths reduces investment risk while supporting long-term competitiveness.

- For example, the port of Aarhus committed significant resources for OPS infrastructure because its large container operations and cruise vessel traffic mean significant demand for shore power.

All the case study ports see their role in the green transition as extending beyond the port's traditional landlord function of providing infrastructure and leasing port land. The ports have

⁸⁰ Interview with the port of Rønne, conducted by Kate Markhvida and Christopher Dirzka.

⁸¹ Interview with the port of Aarhus, conducted by Kate Markhvida and Christopher Dirzka.



described themselves as “integrators”, “facilitators”, “innovators” or “investors” that actively shape regional green ecosystems. Rather than serving solely as providers of infrastructure, ports increasingly act as orchestrators of green transition ecosystems by coordinating stakeholders, facilitating innovation, mobilizing investment and creating other conditions necessary for the transition.

- The port of Aalborg, for example, sees itself as both a landlord and an integrator. Rather than simply hosting new green industries, it actively coordinates multi-stakeholder partnerships that bring together public and private actors. The port of Esbjerg positions itself as a landlord, innovator, incubator and investor. Management views this expanded role as essential for maintaining the port's competitiveness as customer needs evolve.
- The port of Aarhus likewise emphasizes a more proactive role through strategic investment and stakeholder engagement. Early investments in the electrification of port operations and shore power infrastructure were closely aligned with the port's dominant container and cruise business, while the establishment of a dedicated communications and public relations function reflects growing recognition that stakeholder engagement is an integral component of the port's business model.

A key challenge faced by the case study ports is that many green transition projects are not economically viable when assessed individually, owing to uncertain demand and the slow development of markets for green fuels and technologies. As a result, port management often faces difficulties justifying these investments internally. The absence of robust business cases also makes it more challenging to secure external financing, as both public funding programs and private lenders typically require some evidence of commercial viability or project maturity before committing capital funding.

Due to these challenges, several ports have moved away from evaluating projects individually and instead have adopted a “palette approach”. Under *the palette approach*, projects with weaker business cases are justified on strategic or regulatory compliance grounds and financed alongside commercially viable activities.

- The port of Esbjerg illustrates this approach through investment in OPS infrastructure despite a weak short-term commercial outlook. Investment costs are distributed across the wider customer base, ensuring that users of shore power are not faced with prohibitive prices. This approach enables ports to implement projects that are strategically important for future competitiveness or require regulatory compliance, even in the absence of a strong business case.

Ports increasingly employ *economic incentives* to influence customer behavior. Several ports apply tariff discounts or penalties to encourage vessel operators to use shore power or



transition to alternative fuels. However, these incentives are generally designed to encourage behavioral change rather than generate additional revenue for ports.

Importantly, geographic and regional market conditions strongly influence business model and investment choices. Such conditions can both create new opportunities and act as a constraint on implementing clean energy initiatives.

- At the Port of Rønne, investment in OPS is justified primarily by the strategic importance of tourism and ferry services, despite limited commercial returns. Bornholm's island location creates unique opportunities for the Bornholm Bunker Hub. The port has conducted several feasibility studies to assess the potential for producing and storing green fuels (ammonia, hydrogen and methanol) for maritime transport.
- In contrast, the port of Aarhus faces strong local opposition to green fuel production and bunkering (e.g., ammonia) because of its proximity to residential areas.
- The port of Esbjerg considers hydrogen production commercially unattractive due to insufficient local demand and competition from larger ports in the region.

5.2.5. Partnerships and stakeholder engagement

The green transition depends heavily on effective collaboration between ports and external stakeholders. Ports are increasingly faced with the task of coordinating activities across municipalities, universities and research institutions, industry organizations, utilities and energy companies and customers, among other stakeholders.

Ports need to work to strengthen collaboration with municipal authorities and local stakeholders, as successful green transition projects often extend beyond the port perimeter and require alignment with spatial infrastructure planning and community priorities. One approach is to actively engage involvement among public-sector partners.

- For example, the port of Rønne financed the participation of an employee from the municipal spatial planning department in a feasibility study on e-fuel production on Bornholm. Beyond supporting the specific project, this initiative enhanced the municipality's understanding of emerging green technologies and strengthened its capacity to integrate future e-fuel facilities into local spatial planning and permitting processes.

Stakeholder engagement also extends to **communication and relationship management**. Recognizing that the green transition requires broad stakeholder support, the port of Aarhus recently established a dedicated communications and public relations team to strengthen



engagement with public authorities and the local community. This reflects a growing recognition that communication is not merely a supporting function but an integral component of implementing sustainability strategies.

Partnerships with **universities and research institutions** provide ports with access to technical expertise and knowledge. The Port of Aalborg partnered with Aalborg University to establish a test facility for e-fuel production, including pilot-scale production of e-methanol from wastewater. Although the project was scaled down from its original ambitions, it continues to support experimentation and learning with the aim to assess opportunities for e-fuel production.

Participation in **industry and professional networks** enables ports to exchange knowledge, identify emerging technologies and participate in collaborative projects. The port of Esbjerg actively engages in several national and international networks to share experience and strengthen its position within the offshore wind and maritime decarbonization sectors.⁸²

Utilities and energy companies are important strategic partners in regional decarbonization and the green transition because they provide access to power and possess expertise on electricity and energy systems. Even where ports are willing to invest and able to finance OPS infrastructure, electrification cannot proceed without sufficient electricity generation and transmission capacity.

Close cooperation between ports and their **customers** is emerging as a key enabler of green transition projects, allowing investment costs and risks to be shared among the parties involved.

- For example, Danish ferry operator Molslinjen finances and installs its own OPS infrastructure at the ports it serves, while the respective port authorities coordinate with electricity providers to secure the necessary grid connection and power capacity. This multi-stakeholder arrangement rests on a general model of responsibility sharing: the ferry operator invests in customer-specific charging infrastructure, the port facilitates project implementation and coordination with the utility company, and the utility company ensures that sufficient electricity can be supplied through the electrical grid.

Overall, the case studies suggest that *targeted partnerships* tend to be more effective than broad stakeholder forums. For example, the port of Aalborg established a sustainability forum involving a wide range of customers, but the initiative was eventually discontinued because the diversity of participants made it difficult to identify common priorities. Smaller, purpose- or project-specific collaborations have proved more productive.

⁸² Sornn-Friese, Sofev, and Kondratenko, 'The Port Authority as System Builder in Cross-Border Regionalization: An Exploratory Study of Port Esbjerg in the Development of North Sea Wind'.



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