Institute of
Shipping Economics
and Logistics

Seaports' Contribution Towards Sustainable Development

Potentials and challenges

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Contents

Introduction

The importance of seaports has been described in detail in numerous studies. Their economic impact is not limited to the local and regional level, but also encompass regions in the hinterland.[1,2]

The change initiated by the international commitment to a more sustainable economy, which is reflected in the climate goals of the Paris Agreement and the United Nations' global sustainability goals, are also affecting ports.[3,4] Sustainability in the sense of the Sustainable Development Goals (SDG) of the United Nations is not limited to ecological sustainability, but also encompasses social and economic sustainability. A total of 17 sustainability goals have been defined, which have been broken down into 169 specific target indicators to be achieved by 2030 at the latest. The goals include, for example, "Climate Action", "Responsible Consumption and Production", but also "Gender Equality" or "Decent Work and Economic Growth".[5]

With regard to the central role that ports play in global supply chains and thus for the respective national economies, they must not only adapt to this change towards a more sustainable way of doing business, but can and must also play a decisive role in shaping it.

> **Hypothesis I: "Seaports must play an active role in the global transition to sustainable development."**

Seaports are important hubs in maritime transport chains where cargo is transferreed between seagoing vessels and other modes of transport such as road, rail, inland waterway transport or pipelines. Due to their central position within maritime transport chains, seaports contribute to sustainable development in various ways (see Figure 1). At the same time, ports can benefit from the associated potential by actively shaping this role.

> **Hypothesis II: "Seaports can benefit from the transition towards sustainable development to expand existing strengths and to open up new potentials."**

To achieve this, port administrations have various options at their disposal. In addition to implementing regulations and standards, port administrations can influence sustainable development through incentive systems, fees and market-based measures. They can also enter into voluntary or binding agreements with relevant transport stakeholders and share knowledge and information, as well as promote their own sustainability development within the framework of port development.[6]

[1] See EDR Group and Tioga Group: Port of Long Beach: Economic Impact Study. URL: https://globalmaritimehub.com/wp-content/uploads/2019/09/POLB-Economic-Impact-Report_FINAL.pdf

[2] See ISL et al. (2021): Untersuchung der regional- und gesamtwirtschaftlichen Bedeutung des Hamburger Hafens. URL: https://www.hamburg-port-authority.de/fileadmin/user_upload/BeschaeftigungsstudieHafenHamburg2019_Endbericht_final.pdf

[3] See Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (o.J.): Klimaabkommen von Paris. URL: https://www.bmz.de/de/service/lexikon/klimaabkommen-von-paris-14602 (Accessed: 22.11.2023)

[4] See United Nations (o.J.): The 17 Goals. URL: https://sdgs.un.org/goals (Accessed: 22.11.2023)

[5] See United Nations (o.J.): The 17 Goals. URL: https://sdgs.un.org/goals (Accessed: 22.11.2023)

[6] See Anas S. Alamoush et al.: „Port greenhouse gas emission reduction: Port and public authorities' implementation scheme". In: Transportation Business & Management 43 (2022). DOI: 10.1016/j.rtbm.2021.100708

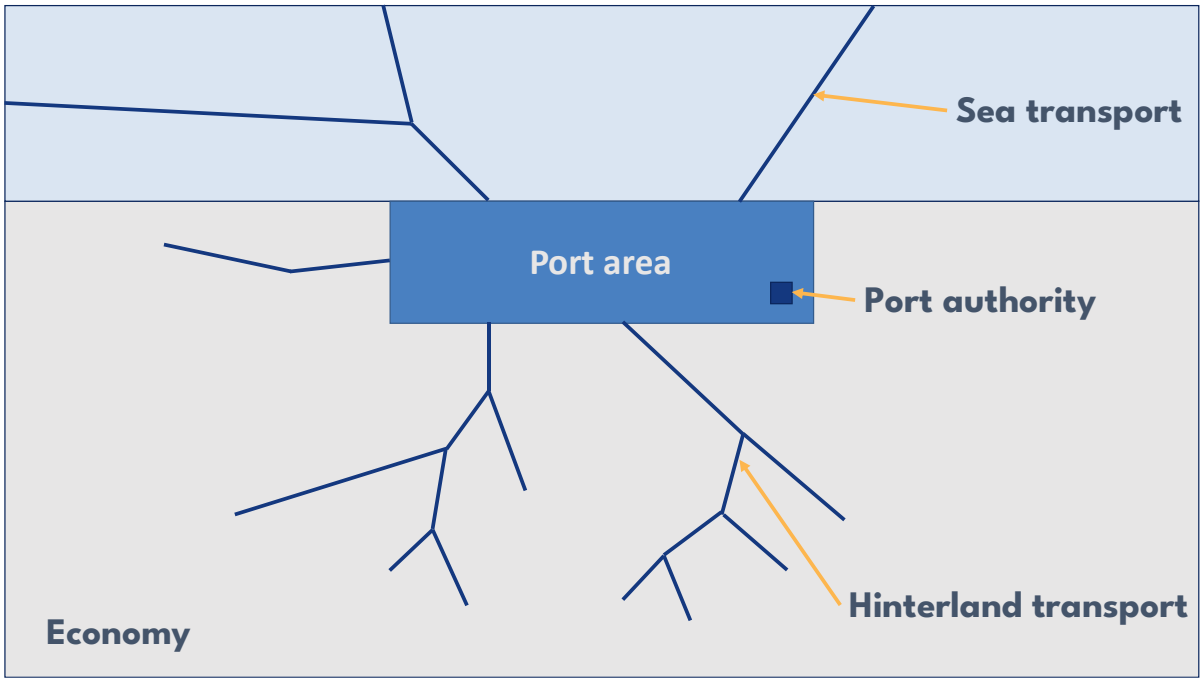

Figure 1: 4 levels at which seaports can promote sustainable development

Level 1: Activities of the Port Administrations

In large European and American seaports, the landlord model prevails today, in which the port administrations are only responsible for the construction and maintenance of the infrastructure and lease the areas to terminal operators. The port administrations themselves are therefore not directly involved in the transport chains.

The greenhouse gas emissions directly attributable to port administrations are for example low compared to those of shipping companies and hinterland transport companies. Port administrations generate emissions in different ways. Socalled direct emissions are commonly referred to as Scope 1 emissions and are caused by the combustion of energy sources such as diesel, heating oil or natural gas within the company itself. Scope 1 emissions in the port are primarily caused by heating the buildings or operating the company's vehicle fleet. In addition to direct emissions, port administrations also emit indirect emissions, e.g. through electricity consumption. These socalled Scope 2 emissions are calculated for the proportion of electricity consumed in the port that does not come from renewable sources. In addition, there are other indirect emissions known as Scope 3, which arise from activities upstream and downstream of the actual business, such as business trips or employee commuting.[7]

The first step towards reducing greenhouse gas emissions at all three Scope levels is to systematically record them. Measures to reduce emissions can be introduced on the basis of such recording. In Scope 1, for example, emissions can be reduced by using more modern and efficient technologies such as heat pumps and solar thermal energy for heat supply and by using electric vehicles within the company's own vehicle fleet. The emissions from Scope 2 can be

[7] See bremenports GmbH & Co. KG (n.D.): Energie & Klimaschutz in der Hafeninfrastruktur. URL: https://www.bremenports.de/nachhaltigkeit (Accessed: 18.09.2023)

reduced by purchasing electricity from renewable energies either via the electricity provider or by operating corresponding generation plants, such as photovoltaic or wind energy plants in the port area.[8,9] In the ports of Bremen, for example, the share of renewable energies in the electricity used is regularly around 90 %, while the remaining emissions from this scope are offset via climate certificates.[10,11] Scope 3 emissions of a port administration can be reduced, for example, by incentivizing low-emission means of transportation such as rail or bicycle. It is also possible to enable employees to work from home in order to reduce the total commuting distances.[12]

Even the consumption of resources for the core activities of a port administration can be reduced, e.g. through the digitalization of business processes and the avoidance of paper as much as possible.

However, there is a much greater potential for port administrations to reduce greenhouse gas emissions and resource consumption along the supply chain. When assigning construction contracts, which are generally particularly resource intensive, sustainability criteria such as greenhouse gas emissions or recycling rates can be included as evaluation criteria, for example. This forces bidders to include such criteria early in the planning stage and, if necessary, to revise their concepts in favor of more environmentally friendly construction methods.

In addition to the environmental sustainability criteria, ports can also actively shape social sustainability. This can be done by the introduction of a gender equality plan for their own personnel, measures to improve work-life balance and occupational health and safety measures. Here too, the port administrations' influence can be extended beyond their own employees by including social criteria in the evaluation when awarding contracts.

Progress towards the sustainability goals should be monitored on an ongoing basis and the achievement or failure to achieve the goals should be recorded, e.g. in the form of sustainability reports.[13] The sustainability strategy can be permanently adapted on this basis.

Level 2: Promoting Sustainability in the Port Area

Port administrations can indirectly influence the sustainability of the activities of terminal operators and other companies in the port area through their role as lessors of port areas. One low-threshold option is to include sustainability goals in the bidding process when leasing port areas.[14] In corresponding tenders, seaports can impose the condition that applicants must

[8] See bremenports GmbH & Co. KG (n.D.): Energie & Klimaschutz in der Hafeninfrastruktur. URL: https://www.bremenports.de/nachhaltigkeit (Accessed: 18.09.2023)

[9] See EUROGATE GmbH & Co. KGaA, KG (21.02.2015): Windenergieanlage in Bremerhaven in Betrieb genommen. URL: https://www1.eurogate.de/Ueber-uns/Presse/Pressemeldungen/Windenergieanlage-in-Bremerhaven-in-Betrieb-genommen (Accessed: 19.09.2023)

[10] See bremenports GmbH & Co. KG (n.D,): Kennzahlen Klimaschutz. URL: https://bremen-ports.de/greenports/wp-content/uploads/sites/3/2022/06/Kennzahlen-gesamt-2022.pdf (Accessed: 18.09.2023)

[11] See bremenports GmbH & Co. KG (n.D.): Energie & Klimaschutz in der Hafeninfrastruktur. URL: https://www.bremenports.de/nachhaltigkeit (Accessed: 18.09.2023)

[12] See bremenports GmbH & Co. KG (n.D.): Energie & Klimaschutz in der Hafeninfrastruktur. URL: https://www.bremenports.de/nachhaltigkeit (Accessed: 18.09.2023)

[13] See Port of Los Angeles: Sustainability Report 2011. URL: https://kentico.portoflosangeles.org/getmedia/af21244f-0aa8-4a05-bab7-1d171dc0defd/REPORT_Port_Sustainability_Report_2011 (Accessed: 25.09.2023) und nachfolgende Berichte.

[14] See United Nations (n.D.): The 17 Goals. URL: https://sdgs.un.org/goals (Accessed: 11.09.2023)

state in the bidding process which of the sustainability goals can be met by leasing to this bidder and to what extent.

In order to promote environmental sustainability within the port area, it is important to identify various emitters of air pollutants, greenhouse gases and noise and to determine the effect of implemented measures. Emission inventories can be used to calculate and visualize the emission quantities of various emittents in the port area. Emission inventories are used as an instrument to quantify the effectiveness of measures to reduce emissions. The U.S. ports of Los Angeles and Long Beach, for example, carry out such regular emissions inventories on a yearly basis in order to quantify the effectiveness of measures, identify the environmental impact of the port activities and to transparently present the correlations between port activities, handling volumes and emissions. These analyses are also used to forecast the impact of measures to be implemented.[15,16] Other ports, such as Rotterdam, also include industrial activities in the port area in these emission analyses.[17]

One source of large quantities of greenhouse gases, air pollutants and noise emissions are ships in port that operate auxiliary diesel generators to supply important systems on board with energy. The provision of shore power connections, if necessary in combination with incentive systems for their use, can minimize the emissions caused in port by auxiliary diesel generators onboard vessel. The U.S. state of California is going one step further with regard to shore power. The "Ocean-Going Vessels At Berth Regulation", which was adopted in 2007 and revised in 2020, is applied in several Californian ports and obliges ships or the operators of fleets and terminals to use shore power or take precautions that are at least as effective as those in reducing emissions. The regulation aims to reduce air pollution in the region.[18]

In landlord ports, infrastructure operators can influence operational sustainability in lack of own terminal equipment, primarily through incentive systems or specifications imposed on terminal operators. In addition to ships, large quantities of air pollutants and CO_2 are emitted by diesel-powered cargo handling equipment in particular. The port administration or regulatory authorities can impose more restrictive regulations on terminal operators regarding the emission limits to be complied with for the means of reducing emissions from cargo handling equipment. Regulations prescribing the mandatory use of modern engines in cargo handling equipment, for example, were issued by the California Air Resources Board in 2005 - also in the U.S. state of California - and came into force in 2007.[19] They achieved an absolute reduction of air pollutant emissions in 2022 by 71 % to 80 % compared to 2005 levels in the corresponding segment by successively converting the engines of cargo handling equipment to low-emission diesel engines and in some cases also to electric drivetrains.[20] Since investments such as the engine conversions of an operating fleets of cargo handling equipment can only be carried out over a long time horizon due to the high investment volume, it is necessary that the corresponding regulations of port administrations and regulatory authorities take

[15] See Starcrest Consulting Group, LLC (Sep 2007): Port of Los Angeles. Inventory of Air Emissions 2005.
[16] See Starcrest Consulting Group, LLC (Aug 2023): Port of Los Angeles. Inventory of Air Emissions 2022.
[17] See Port of Rotterdam: CO_2 emissions port of Rotterdam fell by over 4%. URL: https://www.portofrotterdam.com/en/news-and-press-releases/co2-emissions-port-of-rotterdam-fell-by-over-4-in-2022 (Accessed: 26.09.2023)
[18] See California Air Resources Board (30.03.2023): Ocean-Going Vessel At Berth Regulation. Enforcement Notice.
[19] See California Air Resources Board (08.12.2005): Regulation for Mobile Cargo Handling Equipment at Ports and Intermodal Rail Yards
[20] See Port of Los Angeles (n.D.): Air Quality Report Card 2022

this into account. Such consideration can be given, for example, via a regularly adjusted reference line.

In addition to greenhouse gases and air pollutants, port operation also emit noise, which can affect the quality of life negatively. Both seaport administrations and terminal operators can utilize various levers to reduce emissions in this group of emissions. Incentive systems on port charges, such as those implemented in the ports of Vancouver (CA), Hamburg (DE) or Rotterdam (NL), are a low-threshold way of influencing noise emissions. If a ship has an ESI Noise Score (Environmental Ship Index (ESI)), uses noise-reducing technologies or has corresponding classification notations, discounts are granted on port charges.[21,22] However, it is not only ships that emit noise in the port area, but also trucks that frequently pass through residential areas on their way to or from the port area. For example, a training program for truck drivers was set up in the port of Auckland (NZ) to reduce noise emissions from air brakes, especially at night.[23]

Level 3: Enabling Sustainable Maritime Transport Chains

Seaports have several tools they can employ to optimize the environmental sustainability of maritime transport chains. A maritime transport chain is an interorganizational logistics system in which a flow of goods takes place on at least one transport leg by seagoing vessel. Seaports are central nodes for the consolidation and distribution of goods flows.

The majority of seagoing vessels are currently powered by conventional fuels such as heavy fuel oil or marine diesel oil. Ships with propulsion systems for alternative fuels such as methanol or ammonia only make up a very small proportion of the fleet and are also only slowly gaining visibility in the order book.[24] It is unclear which sustainable fuels will prevail in shipping in the long term and shipping companies are faced with the challenge that alternative fuels can only be bunkered in selected ports and are only available in limited quantities, at least at present and in the foreseeable future. By offering alternative, sustainable fuels and a diversified bunker supply, bunker service providers can break this hen-and-egg problem on the way to more sustainable maritime transport chains, whereby port administrations can participate in a coordinating role. An important step in this direction is the involvement in so-called "green corridors", in which seaports in at least two different countries enter into a partnership with the aim of decarbonizing a selected maritime trade route with the involvement of relevant stakeholders. The development of such corridors requires the cooperation of various parties in the port. The political will to establish such corridors was expressed at the UN

[21] See Port of Vancouver (n.D.): EcoActionProgramme

[22] See Port of Hamburg (09.10.2019): Keine Preisanpassung bei Hafenentgelten – HPA sendet starkes Signal an die Schifffahrt. URL: https://www.hafen-hamburg.de/de/presse/news/keine-preisanpassung-bei-hafenentgelten-hpa-sendet-starkes-signal-an-die-schifffahrt--36501/ (Accessed: 13.09.2023)

[23] See Marta Gonzalez-Aregall (2019): Chapter 10 - Port-Driven Measures for Incentivizing Sustainable Hinterland Transport. In: Green Ports. Elsevier: Amsterdam. DOI: 10.1016/B978-0-12-814054-3.00010-4

[24] See Hansa Online (07.09.2023): DNV warnt vor Mangel an alternativen Kraftstoffen. URL: https://hansa-online.de/2023/09/schiffstechnik/219627/dnv-forecast/ (Accessed: 20.09.2023)

Climate Change Conference in Glasgow 2021 with the signing of the Clyde Bank Declaration by 24 countries.[25]

The operation of ships not only generates emissions, but also waste of various kinds. The discharge of this waste into the sea is regulated by the International Convention for the Prevention of Pollution from Ships. While its Annex V stipulates that, for example, food, cargo residues or cleaning agents may be discharged into the sea under precisely defined conditions, the majority of waste must be disposed of on land, where it can be returned to the circular economy if possible. Even if the disposal of waste at sea is permitted, disposal in port reception facilities is preferable wherever possible.[26] The involvement of appropriate service providers in the seaport enables a sustainable return to the circular economy by setting up suitable port reception facilities for waste.

Seaports can implement incentive systems as a tool to encourage parties involved in maritime transport chains to use sustainable technologies in their means of transport. Such incentive systems can have an impact on ships and shipping companies, but also on other means of transport or companies that are active in the port area as part of a landlord port system. Dynamically adjusted port charges encourage users to take measures that go beyond existing regulations and framework agreements. Measures can be of a technological or operational nature and reduce emissions of greenhouse gases, air pollutants or noise, reduce waste or provide other environmental benefits. Seaports can use existing indices or programs to assess whether and to what extent means of transport are equipped with sustainable technologies and use these to apply a bonus or penalty to port charges.[27] Certification systems such as the "Environmental Ship Index" already exist for this purpose, for which the intensity of NO_x, SO_x and CO_2 emissions and the equipment of a shore power connection on seagoing vessels are assessed individually. Shipping companies have the option of improving the calculated value by using alternative fuels or technologies such as a scrubber or catalytic converter.[28] Another index is the "Clean Shipping Index". This assesses the environmental performance of individual ships in the six areas of SO_x, NO_x, CO_2, chemicals, wastewater & waste and particulate emissions and is calculated on the basis of a questionnaire. The "Greenhouse Gas Emissions Rating" assesses the greenhouse gas intensity of ships on a scale of A-G and thus follows a similar approach to the IMO's "Carbon Intensity Indicator", which assesses the carbon dioxide intensity of ships over 5,000 GT on a scale of A-E, with the threshold values being adjusted at regular intervals between the individual steps.[29,30] All four indices can be used by seaports as a basis for incentive systems. In addition to these indices, the "Green Award", which is awarded to both seagoing and inland waterway vessels that demonstrate exceptional quality

[25] See UK Department of Transport (13.04.2022): COP 26: Clydebank Declaration for green shipping corridors. URL: https://www.gov.uk/government/publications/cop-26-clydebank-declaration-for-green-shipping-corridors/cop-26-clydebank-declaration-for-green-shipping-corridors (Accessed: 13.09.2023)

[26] See Marine Environment Protection Committee (07.07.2017): 2017 Guidelines für the Implementation of MARPOL Annex V. MEPC.295(71)

[27] See Anas S. Alamoush et al.: „Ports' role in shipping decarbonisation. A common port incentive scheme for shipping greenhouse gas emissions reduction". In: Cleaner Logistics and Supply Chain 3 (2022). DOI: 10.1016/j.clscn.2021.100021

[28] See International Association of Ports and Harbors (n.D.): General Information ESI. URL: https://www.environmentalshipindex.org/info (Accessed: 28.08.2023)

[29] See Rocky Mountain Institute (n.D.): GHG Emissions Rating – RMI. URL: https://rmi.org/our-work/shipping-efficiency/ghg-emissions-rating/ (Accessed: 29.08.2023)

[30] See Marine Environment Protection Committee (10.06.2022): 2022 Guidelines on the Operational Carbon Intensity Rating of Ships (CII Rating Guidelines, G4). MEPC.354(78)

and safety standards as part of an inspection and use technologies to optimize environmental sustainability, can be used as an indicator to grant discounts on port charges.[31,32]

Another way in which seaports might have an impact on the environmental sustainability of maritime transport chains is by optimizing ship calls. Currently, ships spend up to 9 % of their operating time at anchor or drifting outside ports until permission is granted to enter the port. Even when the main engine is switched off, auxiliary diesel generators and boilers run to power vital systems and generate emissions of greenhouse gases, air pollutants and noise. By using modern technologies, ports can optimize the approach control of seagoing vessels so that they arrive just-in-time and waiting times outside the ports are minimized.[33,34] Thus, ships can approach a port at a lower speed, which reduces overall fuel consumption at a higher rate than the reduction in speed and cuts emissions along the maritime transport chain.[35]

Sea and hinterland transportation converge in seaports. Transportation in the hinterland usually takes place by road, rail and inland waterway; for liquid bulk goods, hinterland transport is also partly by pipeline. The share of the various modes of transport in hinterland transportation is referred to as the modal split. Compared to rail and inland waterways, road transport has a significantly greater average ecological footprint per tonne-kilometre and should therefore be kept to a minimum, especially in long-distance transport. Port operators can influence the modal split through various measures.[36] In 2018, for example, the port of Antwerp agreed on various measures with terminal operators and shipping companies to improve the handling of inland waterway transport, reduce waiting times and thus make inland waterway transport more attractive. Part of the measures included setting up special berths for handling inland vessels at the large container terminals in the port.[37] When announcing the areas for future container terminal operators on Maasvlakte II, the Port of Rotterdam stipulated that at least 65 % of the modal split should be used for rail and inland waterway transport.[38] As large shippers in particular are increasingly pushing for the use of more climate-friendly hinterland transport and rising CO_2 prices are increasing the pressure to use more climate-friendly transport chains, a targeted intermodal strategy by the ports can also pay off in the form of higher market share compared to other ports.

[31] See Green Award Foundation (n.D.): About Green Award - Inland Shipping. URL: https://www.greenaward.org/inland-shipping/about-green-award/ (Accessed: 29.08.2023)

[32] See Green Award Foundation (n.D.): Certificate holders & ships - Sea Shipping. URL: https://www.greenaward.org/sea-shipping/certificate-holders-ships/ (Accessed: 29.08.2023)

[33] See GEF-UNDP-IMO GloMEEP Project (2020): Just In Time Arrival Guide – Barriers and Potential Solutions. London: International Maritime Organization

[34] See Port of Rotterdam (n.D.): Optimierung der Schiffsanläufe. URL: https://www.portofrotterdam.com/de/seeschifffahrt/optimierung-der-schiffsanlaeufe (Accessed: 07.09.2023)

[35] See Jasper Faber et al. (18.10.2017). Regulating speed. A short-term measure to reduce maritime GHG emissions. Delft: CE Delft

[36] See M. Langenus et al.: Modal shift ambitions of large North European ports: A contract-theory perspective on the role of port managing bodies. In: Maritime Transport Research 3 (2022): S. 1 & 10. DOI: 10.1016/j.martra.2021.100049

[37] See J. Louppova: Antwerp joins forces to deal with barge congestions. In: port.today, online verfügbar unter: https://port.today/antwerp-joins-forces-counter-barge-congestion/amp/ (Accessed 26.09.2023)

[38] See R. Van den Berg and P. W. De Langen: An exploratory analysis of the effects of modal split obligations in terminal concession contracts. In: International Journal of Shipping and Transport Logistics 6(6), S. 571-592. DOI: 10.1504/IJSTL.2014.064903

Level 4: Seaports for the Sustainable Transformation of the Economy

Seaports have enabled the growth of global trade flows through the expansion of port infrastructure. There have also been structural changes in the past, such as the containerization of previously conventionally shipped goods, which required massive investments on the part of ports and terminal operators.

A change in the cargo handling structure and therefore also of the required port infrastructure, which is directly linked to the development towards a more sustainable economy, is the expected decline in the turnover of fossil fuels. The amount of fossil fuels handled in European seaports has stagnated at around 1 billion tons since 2000, while other handling segments - in particular container shipments - have grown significantly. Accordingly, the share of fossil fuels (coal, crude oil and petroleum products) fell from around 45 % in 2000 to around 35-40 % in the early 2020s (see Figure 2).

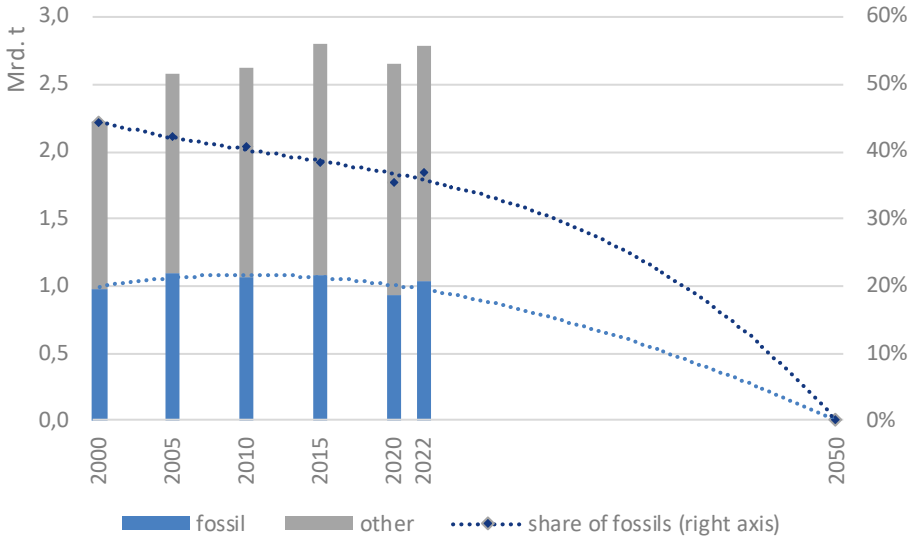

Figure 2: Development of the trade pf fossil fuels and their share in total cargo in European seaports 2000-2022 and target for 2050.
Includes seaports of all countries that were EU member states from 2000 to 2022. Source: ISL based on Eurostat

On the way to complete climate neutrality, this segment will slow down significantly and come to an almost complete stop by 2050, meaning that handling capacities for around one billion tons of dry and liquid bulk goods in European ports will no longer be needed for these types of goods. At the same time, it is foreseeable that energy sources will continue to be imported by sea. However the specific products and the necessary handling facilities are currently unknown. Currently, liquid, hydrogen-based energy sources are being discussed in particular, so that a modified use of existing facilities for the handling of mineral oil products with corresponding adjustments to the infrastructure seems possible. However, there is no foreseeable replacement for the handling of coal with other solid energy sources on a comparable scale.

However, the importance of ports for achieving sustainability goals goes far beyond decarbonization. The blockade of and attacks on Ukrainian grain ports by the Russian military in

the course of the war in Ukraine has brought their importance for the global grain market to the public's attention and showed that ports also contribute to the United Nations' goal of guaranteeing global food security by 2030. The European Commission is attempting to facilitate the export of Ukrainian grain via EU ports and the so-called "Solidarity Lanes".[39] Given that, according to the IPCC, climate change is one of the key risks to African food production, demand for grain on the global markets is expected to increase further in the long term, meaning that additional capacity for grain handling in ports will also be required.

Ports will also play an important role in a global circular economy, which is a prerequisite for resource-conserving economic activity, as well as in the expansion of offshore wind energy. As a result, the shift towards a more sustainable economy will also create new cargo potentials that ports must keep in mind in their strategic development and land use planning.

Summary

Various studies have examined the economic importance of seaports and their impact on the surrounding areas. Seaports can therefore make a significant contribution to sustainable development in view of the United Nations' global sustainability development goals and climate protection. A total of 17 sustainability developent goals are to be met by 2030. As important hubs of global supply chains, seaports have the opportunity to actively participate in this change by using regulation, incentive systems, charging schemes and agreements to promote sustainable development on four levels:

1. Port Administration
2. Port Area
3. Transport Chain
4. Economy.

The landlord model, in which **port administrations** provide the infrastructure and lease it to terminal operators, is well established in large seaports. Although this means that port administrations are less directly involved in transport chains than shipping companies and transport companies, the business activities of port administrations also generate greenhouse gas emissions, e.g. heating buildings and operating their own vehicles ("Scope 1"), indirect emissions from electricity consumption ("Scope 2") and indirect emissions, for example from business trips and commuting ("Scope 3"). Port administrations can introduce technologies such as renewable energy and electric vehicles to reduce Scope 1 emissions. In Scope 2, electricity from renewable energy sources can be used. Scope 3 emissions can be reduced through home office options and the use of low-emission transportation. Unavoidable emissions can be offset by climate certificates. However, there is greater potential for reducing emissions in the supply chain. To promote greener practices, sustainability criteria can be integrated into construction contracts. Port administrations can also contribute to social sustainability by introducing gender equality plans and work-life balance measures. Sustainability reports should be monitored and the strategy adapted accordingly.

[39] See European Commission: EU-Ukraine Solidarity Lanes. URL: https://eu-solidarity-ukraine.ec.europa.eu/eu-assistance-ukraine/eu-ukraine-solidarity-lanes_en (Accessed 26.09.2023).

By including sustainability criteria in the bidding process for **port areas**, port authorities can influence sustainability in the port area. Emissions inventories help to identify air pollutants, greenhouse gases and noise sources and develop strategies to reduce emissions. To reduce emissions, ports can incentivize ships to use shore power in port instead of auxiliary diesel generators, as is done in some U.S. ports, for example. To reduce emissions, port administrations can also issue regulations for cargo handling equipment. Incentive systems or training programs for truck drivers can also help to reduce noise emissions from port operations.

There are also numerous approaches that can be used by seaports to make maritime **supply chains** as a whole (and not just in the port area) more environmentally sustainable. This includes, for example, promoting sustainable marine fuels, establishing partnerships to decarbonize maritime trade routes, supporting the circular economy by disposing of waste on land and setting up waste collection facilities in port. Some indices, including the Environmental Ship Index and the Clean Shipping Index, are already being used in some ports to promote environmentally friendly technologies through discounts on port charges. Ports can also optimize ship calls to reduce waiting times for ships outside the ports and thereby reduce emissions. Port operators can also set modal split targets to reduce hinterland transportation by road. These targets can be achieved, for example, by improving the attractiveness of the port for inland vessels and by setting quotas for rail and inland waterways in tenders for port areas.

In the past, seaports have enabled the growth of global trade flows, including structural changes such as containerization, by expanding their infrastructure. Ports are also currently facing structural change. Due to the sustainability goals, a major decarbonization of national **economies** must be achieved. By 2050, the handling of fossil fuels in Europe will almost completely disappear, meaning that the corresponding handling capacities in the ports will no longer be needed. At the same time, decarbonization will require the import of new energy sources, although the products and the necessary handling facilities are not currently known. However, the changes that ports are facing go beyond decarbonization. Ports will also play an increasingly important role in food security, the global circular economy and the expansion of offshore wind energy. Ports should take these new potentials into account in their strategic development and land use planning, thus enabling the associated structural change in national economies.

The maritime industry is currently facing a major challenge. The switch to more climate-friendly, non-fossil fuel requires high levels of investment in the maritime industry, both on the part of the vessel owners and within the ports. The role that seaports and their administrations can play in this context depends heavily on the transport structures and financial possibilities of the ports and the companies active in the port. Investments in sustainable technologies are associated with high investment costs for seaports and the terminal operations located there, which represent a high barrier to entry. This hurdle appears particularly high if measures are not implemented equally in all relevant ports of a market, which may result in competitive disadvantages. Here, publicly funded support programs can help to create incentives through targeted financial support to accelerate the transition to sustainable technologies in seaports.

As the upcoming investment decisions of shipping companies and ports are of a long-term nature, intensive coordination between the stakeholders is necessary to avoid malinvestments and ensure that regulations do not exceed the financial capacities of market participants.

As hubs in international trade, seaports are significantly involved in global supply chains and therefore have a direct influence on the success of the global transformation to a sustainable economy - a role that they must actively shape. In doing so, seaports can set a targeted course and use sustainable development to expand existing strengths and to open up new potentials.

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