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GREENHOUSE GAS EMISSIONS IN SEAPORTS EXEMPLIFIED BY THE PORT IN GDYNIA

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Purpose: Faced with climate change, reducing greenhouse gas emissions is one of the most difficult and urgent global challenges. Seaports are large GHG emitters, and they have been assessing their carbon footprint and adopting decarbonization strategies. However, calculating the carbon footprint of ports is a serious challenge due to the specificity of the service-based activities they conduct. This article addresses the topic of GHG emissions in seaports, using the example of the port in Gdynia (one of the four largest Polish ports), where the port authority started estimating the carbon footprint as part of preparations for ESG reporting. The aim of this article is to identify challenges related to assessing and reporting carbon footprint in a seaport.
Design/methodology/approach: The study used secondary and primary data sources. A review of the literature on the subject was conducted, as well as the analysis of the summaries of reports published by the Gdynia port management for the years 2003 and 2020-2023 (in which the identified sources of GHG emissions were described and the amount of emissions was estimated), and data from non-standardized interviews conducted in January 2025 with employees of Polish ports were used, which allowed us to establish that the Port of Gdynia Authority SA was the first of all Polish ports to attempt to estimate the amount of GHG emissions in the port and prepare a report on the size of its carbon footprint.
Findings: It was established that the specificity of port activities results in various problems and challenges, which concern, among others, collecting the required and reliable data, using analytical tools dedicated to ports, methods of estimating the carbon footprint, taking into account the incomplete scope of emissions and making numerous "exclusions" (which may lead to doubts as to the reliability of the report), proposals for directions of actions to reduce GHG emissions in the port.
Research limitations/implications: The credibility of reports and the effectiveness of seaport carbon footprint reduction strategies depend on the reliability and discipline of the GHG emission estimation process.
Practical implications: The study of GHG emissions and the preparation of a reduction strategy in seaports is one of the primary challenges port authorities and port service companies face in light of the need for decarbonization. This article indicates problems and challenges that the authors of carbon footprint reports and reduction strategies in seaports must confront.
Originality/value: In the Polish literature on this subject, there is a lack of studies on the specifics of GHG emissions in seaports, reporting of port carbon footprint and related problems. This article identifies challenges and provides some recommendations.

Keywords: seaport, greenhouse gases, GHG emissions, carbon footprint of seaports, carbon footprint reporting.
Category of the paper: Research paper.

1. Introduction

Contemporary seaports, as important members of logistics supply chains, host various economic activities mainly related to the handling of passengers, cargo and means of transport. They are (especially large universal ports) multi-entity economic organisms within the boundaries of which many service and industrial enterprises operate. Their activities are accompanied by various emissions from greenhouse gases, noise, water and soil contamination. This article addresses the issue of greenhouse gas emissions in ports and the need to monitor and reduce them. The first step in this direction seems to be the study and reporting of the carbon footprint (CF), which may be the basis for taking action to reduce it, but it may also be a serious problem due to the specificity of seaport operations. The aim of this article is to identify the challenges related to estimating and reporting the CF in a seaport. The described example of a port that attempted to study and report its GHG is the seaport in Gdynia, one of the four largest Polish ports (in 2024, it handled 26.9 million tons of cargo), which was the first to publish data on GHG emissions (ZMPG-a SA, 2003, 2020, 2021, 2022, 2023). The study used secondary and primary data sources. A review of the subject literature was conducted along with an analysis of the summaries of reports published by the Port of Gdynia Authority for the years 2003 and 2020-2023 (which described the identified sources of GHG emissions in the Port of Gdynia and estimated the amount of emissions), and data from non-standardized interviews conducted in January 2025 with employees of Polish ports was also used, which allowed us to establish that the Port of Gdynia Authority SA was the first of all Polish ports to attempt to estimate the amount of GHG emissions in the port and prepare a report on the size of its carbon footprint. In the Polish literature on this subject, there is a lack of studies on the specifics of GHG emissions in seaports, reporting of port carbon footprint and related problems. This article identifies challenges and provides some recommendations.

2. Seaport as a specific economic object

Contemporary ports are complex economic centers that service international trade (currently, around 80% of the world's global trade cargo, i.e. around 12.3 billion tons, is transported by sea) (UNCTAD, 2024). They are equipped with appropriate infrastructure and equipment for moving cargo between the operated means of transport (sea and land), but seaports are also convenient places for locating various economic activities, especially transport, logistics, industrial and commercial (Szymanowska, Dąbrowski, Klimek, 2024; Klimek, 2010). In addition to the port authority, which, among other things, oversees the port area and the infrastructure (sometimes also superstructure) and establishes developmental strategies for the entire port, the port is home to companies from the operating sphere that conduct service activities (Grzelakowski, Matczak, 2012; Klimek, 2010). The port users are cargo managers, shipowners, ship agents, brokers, land carriers, logistics operators and passengers (Szymanowska, Dąbrowski, Klimek, 2024).

In order to provide port services, infrastructure facilities and equipment, as well as superstructure, i.e. handling, storage and auxiliary equipment and facilities, are necessary. Their use generates various emissions into the natural environment, especially those related to the combustion of fuels to power equipment or the use of electric and heat energy and technical gases. The specificity of the provision of port services results in additional emissions related to the dusting of some cargo, accidental spills into port waters, and combustion of fuels to power ship engines and land transport vehicles. Ports are, therefore, places of high economic activity that cause air pollution, especially greenhouse gases. The authorities of some ports are implementing plans to reduce gas emissions from various sources. The basis for taking these actions is the estimation of the CF.

3. Greenhouse gases and their emission reporting

Greenhouse Gas (GHG), both natural and anthropogenic, contributes to the greenhouse effect. Regulation of the European Parliament and the Council (EU) 2018/1999 (in Annex V) identifies seven key types of GHG (which must be reported): carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), nitrogen trifluoride (NF_3), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs). Since GHGs have different greenhouse effect potential, their impact is converted to CO_2 equivalent (CO_2e) to make comparisons meaningful. The amount of GHG emissions generated at a given time by a person, organization, event or product is the carbon footprint (a commonly accepted indicator) expressed in CO_2 equivalents (Puig et al., 2014).

In 2023, global GHG emissions amounted to about 53.0 billion tons of CO_2e. This was the highest level on record, and emissions continue to rise despite agreements between countries to mitigate climate change (EDGAR, 2024; IPCC, 2021). EU countries emitted a total of 3.22 billion tons of CO_2e (Crippa et al., 2024), with transport accounting for almost a quarter of total emissions (EEA Report, 2024). The share of maritime shipping in global emissions amounted to about 3% (IMO, 2023). The international community is undertaking various initiatives aimed at reducing emissions (Agenda 2030, 2015; IMO, 2023; Fit for 55, 2021), and shipowners are looking for alternative fuels for ships, examining the possibilities of using hydrogen, methanol or ammonia (DNV, 2022; Szymanowska, Daczuk, Klimek, 2022). GHG are also emitted by seaports and their value chains. The largest emitters in Europe in 2023 were the ports of Rotterdam (20.3 million tons of CO_2e) (Port Rotterdam, 2023) and Antwerp (17.0 million tons of CO_2e) (T&E, 2023). Constructive action by shipowners and ports to reduce GHG emissions requires estimating their amount (in accordance with the CSRD many companies in the EU have been required to calculate and report GHG emissions since 1 January 2025, and this will include others in the following years) (CSRD, 2022). However, on 26 February 2025, the European Commission has adopted a new package of proposals to simplify EU rules (the so-called Omnibus I), boost competitiveness, and unlock additional investment capacity. The reporting obligation for most companies will be postponed by 2 years (OMNIBUS I, 2025). In the second project, the EC envisages limiting the number of entities subject to ESG reporting, limiting the information reported in the value chain and reducing the costs of attesting ESG reporting (OMNIBUS II, 2025).

Companies use the standards and guidelines provided by the GHG Protocol (GHG Protocol, 2025a; WRI) to reliably and transparently account for and report their GHG emissions. Those that can measure their carbon footprint can also manage their GHG emissions by modifying their activities and processes. Emissions have been categorized depending on their source into the following scopes: 1. (direct, from fuel combustion, process and fugitive), 2. (indirect, energy) and 3. (indirect, generated in the value chain of the reporting company, included in 15 categories), but only the most important data are taken into account (GHG Protocol, 2025c).

Scope 3. emissions are particularly important because they come from a wide variety of entities that are not controlled by the reporting entity. The process of collecting data from multiple sources is a significant challenge for most organizations, including seaports. It is tedious and time-consuming. The data needed to estimate CF is scattered because port value chains are very complex. Large universal ports are visited by thousands of ships, trucks and trains each year. Data is very difficult to obtain, especially in the case of ports that do not have extensive electronic data exchange platforms connecting participants in port-maritime trade (port community systems PCS). A port authority preparing a report on emissions for the entire port (sometimes consisting of hundreds of companies) must obtain data from its suppliers, operating companies, shipowners, land carriers, cargo operators and participants in their value chains, as well as passengers. The importance of GHG emissions in scope 3. cannot be overestimated (e.g. they accounted for 96% of the carbon footprint of the Port of New York) (PortXchange, 2025b), but most ports currently do not monitor them in full. The scope and quality of their reports vary significantly. Some measure only selected emission categories. This was pointed out by Cammin et al. (2022). Often, these data are not published and certainly do not reflect the actual amount of emissions; preparing a report on CF that is based on the analysis of only selected data distorts the image of actual emissions and results in formulating an incomplete strategy for their reduction, even though CF is calculated to manage and reduce emissions.

Cammin et al. (2020) identified the main challenges related to estimating GHG emissions in ports, e.g. difficulties in collecting data, lack of resources and fear of disclosing sensitive data. Some ports publish only aggregated data that cannot be linked to emission source categories. This may be related to building their positive image in the eyes of an increasingly critical public opinion (Stein, Acciaro, 2020). Munin and Saha (2021) emphasize that correct emission reporting is important for raising the environmental awareness of port workers and their stakeholders. In this sense, Santos et al. (2016) underscore that the involvement of a given entity in informing about its activities for the benefit of sustainable development may cause an imitation effect.

It seems that the solution to the problem of collecting and analyzing data necessary to determine the CF may be the use of analytical capabilities of artificial intelligence (AI), as evidenced by the example of the solution used by the authorities of the largest port in Europe, which is also one of the largest in the world. In 2019 in Rotterdam, a start-up PortXchange Products BV was called upon to develop a digital platform for optimizing port processes, enabling efficient data exchange between participants of port-maritime trade and facilitating their analysis and real-time sharing. It is the EmissionsInsider electronic platform and its improved version, EmissionInsider Carbon Insight Suite, which enables ports to accurately, quickly and inexpensively report GHG emissions. It is an innovative analytical tool dedicated to ports, based on BigMile technology (BigMile, 2025), used to measure, track and analyze emissions, enabling not only reporting but also more effective decision-making (Szymanowska, Dąbrowski, Klimek, 2024; PortXchange, 2025a). The launch of EmissionInsider was a key step towards creating a unified global standard for reporting GHG emissions in ports, available to all interested parties (PortXchange, 2025a).

4. Greenhouse gas emissions in the Port of Gdynia

The Port of Gdynia is one of the four largest seaports in Poland and an important international transport hub (in the TEN-T core network) in the Baltic Sea region. It is a universal port, i.e. it can handle various types of bulk and general cargo. In addition to the Port of Gdynia Authority SA (ZMPG-a SA), the port services supply center, operating under the Port Gdynia brand, consists of 11 port terminals and numerous other companies participating in handling port-maritime trade (Dąbrowski, Klimek, Rolbiecki, 2023; Port Gdynia, 2025).

Information on GHG emissions in the port in 2003 and 2020-2023 was published by ZMPG-a SA in the form of five report summaries on the port's website. The GHG emissions were estimated as part of preparations for fulfilling the ESG reporting obligation (resulting from the CSRD), which will apply to the company in relation to the year 2025.

In order to determine the size of the port's emissions, it was necessary to obtain data on the emissions of all entities operating in the port as well as entities in their value chains. In practice, it turned out to be very difficult or even impossible (data was obtained from approx. 160 different entities). Estimating emissions from means of transport required adopting assumptions and simplifications (ZMPG-a SA, 2023), which significantly affected the calculation results. The most important problems were related to collecting data from stakeholders. The research excluded port areas located outside the city, shipyards, the naval port and roadsteads. Process and fugitive emissions (scope 1.) were also not included, as well as, critically, emissions from port activity waste, business trips of employees and their commuting to work (scope 3.), which, due to the specificity of port activities and the size of employment in port enterprises, affected the size of the port's CF.

The CF study included emissions from commercial ships calling at the Port of Gdynia, other vessels floating in the port waters, land transport, transshipment equipment, terminal vehicles and other vehicles, as well as energy for electricity and heat used by various entities operating in the Port of Gdynia. The emission results were presented in two cross-sections, i.e. taking into account emission sources and scopes defined by the GHG Protocol, but without taking into account emissions from some of the sources mentioned above, which was justified by the decision of the managing board of ZMPG-a SA (ZMPG-a SA, 2023). The structure of GHG emissions calculated in this way, taking into account the scopes and sources, is presented in Table 1.

Table 1.
Structure of GHG emissions of the Port of Gdynia in 2003 and 2020-2023 taking into account the scopes and sources of emissions

Specification/year	**2003**	**2020**	**2021**	**2022**	**2023**
Scope 1. emissions [tCO_2e]	10 601	16 194	17 367	19 224	26 125
Scope 2. emissions [tCO_2e]	12 417	32 272	36 485	33 348	23 568
Scope 3. emissions [tCO_2e]	33 781	57 796	65 278	75 766	80 393
Total GHG emissions [tCO_2e]	**56 799**	**106 262**	**119 129**	**128 338**	**130 086**
GHG emissions per tonne of cargo [kgCO_2e/t cargo]	5,83	4,31	4,46	4,59	4,42
Port internal emissions [tCO_2e]	10 601	16 194	17 367	19 224	26 125
Maritime transport emissions [tCO_2e]	34 989	56 242	63 511	74 606	83 630
Land transport emissions [tCO_2e]	3 034	4 431	4 781	5 384	5 231

Source: own study based on: ZMPG-a SA, 2023, pp. 14-25.

In the reviewed years, there was an increase in total emissions in the port. This fact was justified by the increase in the volume of cargo turnovers and the number or size of ships served.

Reports prepared for the years 2020-2023 included a list of proposed actions to reduce GHG emissions in the port. These comprised powering the port fleet with alternative fuels, offering the possibility of powering ships with on-shore electricity (thanks to the installation of onshore power supply-OPS), offering alternative fuel bunkering for ships, giving priority and/or offering discounts on port fees to ships emitting less GHG, offering the possibility of automatic mooring of ships, implementing port facilities and terminal vehicles powered by green electricity or hydrogen, using green energy sources to power port boiler rooms, generating own electric energy (from solar and/or wind energy), installing LED lighting, automating transshipment processes (ZMPG-a SA, 2023).

5. Summary

The specific nature of port operations results in various problems related to determining the amount of emissions. One of the fundamental challenges is to collect (from all port entities and their clients, not just the main port companies) the required and reliable data. The scale of the undertaking requires the use of analytical tools dedicated to ports and the involvement of appropriately trained employees. Following the example of the port in Rotterdam, a special digital platform could be used to enable the exchange of data between participants in port-maritime trade, its fast analysis and reporting.

Another problem is the selection of the appropriate method for estimating the CF. The freedom in this area to date (EU guidelines could be treated as recommendations) has led to the exclusion of some emissions or their incomplete inclusion. The lack of explanation of the reasons for numerous "exclusions" may lead to doubts as to the reliability of the report (the justification for them by the decision of the managing board of ZMPG-a SA is insufficient). The exclusion of some scope 3. emissions from the research also seems unjustified. Such an approach will make it impossible to compare the port's emissions with those of other ports, and a change in the emission estimation method next year (when it will be mandatory) will make it impossible to compare next year's results with previous ones. The Gdynia reports describe the procedure too vaguely (without providing the sources of the coefficients necessary to convert individual emissions to CO2e, which is crucial for the reliability of the calculations).

The proposed directions of actions to reduce GHG emissions in the Port of Gdynia (repeated in four reports) were formulated very generically (they fit every port), without any connection with the assessment of their application possibilities, customer interest and without taking into account the solutions already implemented in the port (Port of Gdynia, 2025; Tariff). It should be added that ZMPG-a SA has no influence over the GHG emission reduction strategies of port enterprises. However, it is essential that its own strategy is based on reliable research results, which are crucial for planning GHG reduction measures and determining their expected impact.

It is hard to disagree with the statement from Cammin et al. (2022) that a well-prepared GHG emission report is an important instrument for assessing the effectiveness of the emission reduction strategy (which ZMPG-a SA will have to adopt) and the statement contained in the port reports that "achieving GHG emission reduction targets and slowing down climate change requires the involvement of entities from every sector of the economy, especially those with high emissions", and such are seaports, which "can be of great significance in activities aimed at reducing GHG emissions" (ZMPG-a SA, 2023). However, for this to happen, it is necessary to estimate the actual port emissions without excluding sources from which obtaining data is difficult or inconvenient.

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