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Monitoring Energy Efficiency and Environmental Ship Index by Cruise Seaports in Northern Europe

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Abstract: Environmental organizations have alerted that rapid weather phenomena have intensified in recent years, such as floods, hurricanes, whirlwinds, droughts, fires and storms, caused by the deteriorating condition of the natural environment. Carbon emissions, which are the main cause of the deteriorating environment condition and dramatic climate change, are largely caused by the use of heavy fuel by shipping companies and generate large quantities of sulfur oxides, nitrogen oxides and particulate matter. These compounds exert a strong negative impact on the environment and human health. Care for improving the marine environment and coastal areas has become the subject of interest of many international institutions, such as the International Maritime Organization, Organization of United Nations, European Sea Port Organization, European Commission and others, which introduce restrictive regulations and guidelines on the level of permissible harmful emissions into the environment as a result of ship operations in ports and at sea. In addition, they propose to monitor the level of pollution through the use of indicators, such as the Energy Efficient Design Index (EEDI), Ship Energy Efficiency Management Plan (SEEMP) and Environmental Ship Index (ESI), among others. The aim of this paper is to assess the Northern Europe seaports' commitment to monitor the level of pollutants emitted by cruise ships in their ports. This article may constitute a subject of interest for seaport authorities and cruise ship operators.

Keywords: energy efficiency; environmental index; port monitoring

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1. Introduction

Seaports in the world operate under conditions of intense competition. Their main goal is to achieve economic benefits, which sometimes hide other important goals, such as those related to pro-ecological activities. No one needs to be convinced that the seaport activity exerts a major influence on the natural environment of the city and the region where the port is located. It should be noted that seaports are economic entities with their primary goal to generate profits from operating activities, and other goals, i.e., social and environmental ones, were treated as secondary objectives for many years. The situation has changed dramatically in recent years after the introduction of restrictive regulations limiting the level of pollutants emitted into the environment by ships and as a result of port operations. Since the 1980s, the Convention for the Prevention of Pollution from Ships (MARPOL) has been in force. It was established by the International Maritime Organization (IMO) which entered into force on 2 October 1983 (IMO, 1973) [1], but climate change and the pressures of ecological environments and local communities in coastal areas have resulted in stricter regulations. The Directive 2000/59/EC on port reception facilities for ship-generated waste and cargo residues with subsequent additions issued by the European Parliament and of the Council on the 27 November 2000 is also of a great importance. It is also necessary to mention the Annex VI MARPOL Convention which has set strict limits on emissions of SOx, NOx and particulate matter from exhaust gases emitted from ships and a ban on deliberate emissions of ozone-depleting substances, which was issued on the 19 May 2005 [2]. In addition, in 2015, the Organization of United Nations

approved a document called "Transforming our world: the 2030 Agenda for Sustainable Development" [3], which indicated 17 Sustainable Development Goals (SDGS) and on the 11 December 2019, the European Commission issued the program called the European Green Deal [4], which set out the tasks to be achieved by 2030, i.e., a reduction in net greenhouse gas emissions by at least 55% and the second target set by 2050, i.e., net-zero greenhouse gas emissions [5].

All these regulations and guidelines require seaport managers to monitor and control the level of pollutant emissions generated in ports and take actions to support the pro-ecological solutions aimed to reduce energy consumption and increase energy efficiency. In addition, they constitute a reference point as for the acceptable standards for atmospheric and aquatic pollution.

The aim of this paper is an assessment of the Northern Europe seaports' commitment to monitor the level of pollutants emitted by cruise ships in their ports. The following research questions were formulated: (1) How do seaports monitor the level of pollutants emitted by cruise ships calling at these ports? (2) Do the Northern Europe seaports monitor energy efficiency related to cruise ships they handle? (3) Do the authorities in the seaports surveyed apply special tariffs to cruise ship owners in terms of energy efficiency and environmental impact? The content of the paper includes six main sections, including an introduction to the subject related to issues concerning ways of monitoring the level of pollutions emitting by cruise ships in the ports. The second part of the article discusses the use of popular energy efficiency monitoring indicators and environmental impacts and their application by shipowners and port authorities. The next part of the paper presents a description of the materials and research methods applied. Then, the research results and the analysis and discussion are presented. The article ends with a discussion and conclusions as well as a list of reference literature. This article may constitute a subject of interest for seaport authorities and cruise ship operators.

2. Standards and Indicators Used to Monitor and Control the Level of Pollution in Ports and the Energy Efficiency

2.1. Environmental Certification for Seaports

For several years, we can observe a positive trend of seaport authorities who seek to obtain environmental certificates. This is significantly important for marketing and port image reasons. We can observe a noticeable change in the seaport authorities' approach to the issue of environmental protection, which is manifested in numerous investment activities undertaken and the introduction of new technological solutions. Moreover, the port authorities allocate more and more funds to pro-ecological investments and activities promoting eco-behavior among their contractors, i.e., shipowners, port companies and other entities.

Among the most common port certifications sought by port authorities are: EcoPorts; Green Ports; Blue Ports, ISO 14001; ISO 50001; CEN 16258; and also GHG Protocol [6].

The idea of EcoPorts was born in 1997 as a grassroots initiative of the port sector and since 2011 it has been coordinated by the European Sea Ports Organization (ESPO). The main premise of this initiative was "to raise awareness on environmental protection through cooperation and sharing of knowledge between ports and improve environmental management" [7]. Currently, 109 seaports representing 25 countries have joined the initiative, with 35 ports being EcoPorts certified and 60 ISO certified. In port certification, two assessment tools are used, i.e., the Self Diagnosis Method (SDM) including: (1) *SDM* Checklist: identify environmental risks; (2) SDM Comparison: compare your SDM score with the European average; and (3) SDM Review: receive expert's advice and personalized recommendations and also the second indicator Port Environmental Review System (certificate assessed by LRQA Nederland B.V.) [7]. The main assumption is to assess the port in terms of effective environmental and port management [6].

The second popular certificate sought by port authorities is the Certificate of Green Ports, which "shows balancing between environmental protection and economic de-

mand" [6]. Port managers also seek certification with ISO systems. ISO 14001 is a popular environmental certification. The last update of ISO 14001 was introduced in 2015. This is one of the most important standards related to the environmental management systems which enables an organization to implement procedures and manage processes so as to reduce the negative impact of an organization's activities on the environment [8].

Whereas the Blue Ports concept is an initiative comprising 25 ports in the Atlantic region, aiming to monitor the condition of the natural environment and manage the risk in ports [9].

Another ISO standard also used in the maritime sector is ISO 50001. These are standards within which the organization receives support to improve energy consumption through the use of the development of an Energy Management System (EnMS) [10].

The ISO 14046 system Environmental Management—[11]. relates the water footprint assessment of products, processes and organizations based on life cycle assessment.

Methodology CEN 16258 is also well known and is "the calculation and declaration of energy consumption and greenhouse gas (GHG) emissions related to any transport service" [12].

The above considerations indicate that seaports have a wide range of mandatory and voluntary tools and methods available, which can be used to monitor and control energy consumption and greenhouse gas. On the one hand, the tools and methods used by the port managers in their sustainable development activities depend on the legal requirements and, on the other hand, on the mission and vision regarding the port development.

2.2. Pollution Monitoring Indicators and Energy Efficiency

Until now, many different indicators for measuring and monitoring greenhouse gases and energy efficiency used in the maritime sector have been developed (Table 1). They constituted a response of many maritime sector interest groups to the introduction of mandatory guidelines on limitations regarding harmful emissions into the atmosphere. The most popular and most frequently used include three main indicators, i.e., EEDI, SEEMP and ESI, and they have been discussed in more detail in this article.

Table 1. Indicators used to monitor greenhouse emissions and energy efficiency in the maritime sector.

Short Name of an Indicator	The Full Name of an Indicator	Description
EEDI	Energy Efficiency Design Index	It is a nonprescriptive, performance-based mechanism. As long as the required energy efficiency level is attained, ship designers and builders would be free to use the most cost-efficient solutions to comply.
EEXI	Energy Efficiency Existing Ship Index	It is a measure to reduce the greenhouse gas emissions of ships introduced by the IMO and is related to the technical design of a ship.
SEEMP	Ship Energy Efficiency Management Plan	All ships must have a SEEMP on board before the issuance of the first IEEC.
IEEC	International Energy Efficiency Certificate	It provides shipowners with certification of compliance to new standards. For new ships, the certificate will state both the attained and required EEDI of the vessel.
EEOI	Energy Efficiency Operational Index	It is used in SEEMP and is based on the vessel's actual operational data.
EVDI	Existing Vessel Design Index	It was developed by Right Ship and is the core measure used to calculate the Right Ship GHG Emissions Rating.
ESI	Environmental Ship Index	It is designed to identify and reward ships that perform over and above the IMO's current international legislation.

Source: own elaboration on the base of: [13–17].

The most popular mandatory measures to reduce greenhouse gas emissions (GHGs) from international shipping are introduced by International Maritime Organization on the 62nd session—Marine Environment Protection Committee (MEPC) [18]—which took

place between the 11 to 15 July 2011 [19]. The represented parties to MARPOL Annex VI adopted amendments to the Annex VI Regulations for the prevention of air ollution from ships on the regulation of the energy efficiency of ships and established the mandatory Energy Efficiency Design Index (EEDI), which relates exclusively to new vessels, and the Ship Energy Efficiency Management Plan (SEEMP), which applies to all units (Table 1). These rules introduced a global scheme to reduce greenhouse gas emissions in the maritime sector and became applicable on 1 January 2013. [14]. "The regulation will require most new ships to be 10% more efficient beginning 2015, 20% more efficient by 2020 and 30% more efficient from 2025" [19].

The Energy Efficiency Design Index (EEDI) is rather a simple indicator showing ship CO_2 emissions per ton-mile of goods transported relative to a reference average of similar ships [19].

$$\text{EEDI} = \frac{P * SFC * C_f}{2 * DWT * V_{ref}} \quad (1)$$

"where p means 75% of the rated installed shaft power, SFC is the specific fuel consumption of the engines, C_f is CO_2 emission rate based on fuel type, DWT is the ship deadweight tonnage and V_{ref} is the vessel speed at design load" [19]. EEDI was not applicable to passenger ships, including ferries and cruise ships, and to vessels of less than 400 GT [14], but in 2014 the MEPC adopted amendments to the EEDI regulations to extend the scope of EEDI to LNG carriers and also for passenger ships and cruise passenger ships which have non-conventional propulsion [14].

However, the IMO plans to introduce further indicators that would cover the remaining groups of seagoing vessels without exemptions. The ICCT calculated that the use of EEDI would save between 141 and 263 mmt of CO_2 annually by 2030 [19]. If implementation is delayed by 4 years for all ships, the potential CO_2 reductions drop to between 2 and 6 mmt for 2020 and 80 and 143 mmt for 2030.

An important indicator introduced in January 2013 in Chapter 4 of the MARPOL Annex VI, which in turn refers to all ships or ship operating companies, is the Ship Efficiency Management Plan (SEEMP) [19]. The assumption of this indicator is to monitor the performance of the ship over time. All vessels must have a SEEMP (Table 1) on board before the issuance of the first IEEC [13]. It should be remembered, however, that other regulations are applied to ships with a tonnage above 400 GT, because Part I of the regulation 22A of MARPOL Annex is then used and applies to the ship management plan for energy efficiency, and in the case of ships over 5000 GT, the ship fuel oil consumption data collection plan is developed. "From the 1 January 2019 each ship shall commence in Appendix IX of MEPC 278(70)" [16].

As part of the World Port Climate Initiative, the Environmental Ship Index (ESI) has been developed (Table 1) and was introduced on the 1 January 2011, and currently, as many as 6933 vessels have valid scores. According to the ESI, seagoing vessels are assessed for the fulfilment of standards in reducing air emissions [17]. The ESI evaluates the amount of sulfur oxide (SO_X) and nitrogen oxide (NO_X) emitted by sea-going ships and includes a reporting scheme on the greenhouse gas emissions of the ship [17].

Numerous ports in the world respect the ESI and grant significant discounts, amounting to several dozen percent, in port fees for ships that meet the requirements of ESI. In addition, it is a convenient tool for achieving the Sustainable Development Goals. The ESI is improved in accordance with the needs imposed by restrictive legal regulations.

Monitoring the level of pollution constitutes a subject of interest to many researchers around the world. Larrucea (2017) [14] set out to define the legal framework for the application of the Energy Efficiency Design Index (EEDI) and the problems associated with its use. Murphy et al. (2013) [20] made an attempt to compare two indicators, i.e., the Clean Shipping Index (CSI) and Environmental Ship Index (ESI) at the same time, putting forward the thesis that these are not the best tools for assessing environmental performance. Additionally, for example, Gibson et al. (2019) [21] even proposed the authors' method for assigning pollutant weighting factors claiming that "current methods for environmental

assessment of ships are fragmented and a more holistic approach is required (. . .) and they proposed to assess vessel performance based on voyage data rather than design criteria" [21].

According to the European Sea Ports Organization (ESPO), 86% of seaports have set up an environmental monitoring program and what is really important is that 68% of ports annually publish their environmental report [22]. ESPO uses the 10 most important environmental management indicators in the assessment of the involvement of seaports in environmental protection activities: (1) Existence of a certified environmental management system (EMS)—the International Organization for Standardization (ISO), the EU Eco-Management and Audit Scheme (EMAS) or the Port Environmental Review System (PERS); (2) Existence of an environmental policy; (3) Environmental policy makes reference to ESPO's guideline documents; (4) Existence of an inventory of relevant environmental legislation; (5) Existence of an inventory of significant environmental aspects; (6) Definition of objectives and targets for environmental improvement; (7) Existence of an environmental training program for port employees; (8) Existence of an environmental monitoring program; (9) Environmental responsibilities of key personnel are documented; (10) Publication of a publicly available environmental report [7]. In the maritime industry, various measures are used to assess the level of pollution emitted by ships and to assess energy efficiency. For the research reason in the paper, the EEDI and SEEMP indicators were mainly selected, as they are the most widely used indices introduced by the IMO. In addition, the ESI index is also the indicator most commonly used by seaports in determining discounts in fees for ships.

The above analysis proves that there is an increased activity of port authorities related to improving the condition of natural environment, as indicated by their initiatives and implemented projects, as well as regular monitoring system. Unfortunately, the regulations introduced by the IMO fail to provide sanctions for entities that do not comply with the specified limits on pollution, but nevertheless, seaports respect them.

3. Materials and Methodology of Research

For the purpose of this article, a thorough query of available literature was performed and empirical research was conducted among the seaports in Northern Europe. The research was a type of qualitative research. Two research methods were used to adjust the research technique to the respondents' needs, i.e., CASI (Computer-Assisted Self Interviewing) and EMS (Electronic Mail Survey). The CASI method is a computer survey filled in by respondents themselves, whereas the EMS method involves sending a survey to the respondent by e-mail with a message and an attachment to the e-mail address including an invitation to participate in the survey. The research methods and techniques applied are convenient, fast and inexpensive, and make it possible to reach a wide range of respondents in different countries. The research results are collected in an Ms Excel sheet, which facilitates monitoring and improves the verification, coding and analysis of research results.

The questionnaire was developed under the Forms application in MsOffice. In total, surveys were sent to 32 ports in Northern Europe and addressed to CEO and cruise mangers. All cruise home ports and most ports of call that play a key role in cruise shipping in Northern Europe were selected for the study. Unfortunately, not all ports responded to the invitation. The port database was taken from port guides provided by Cruise Europe and Cruise Baltic. The selection of the sample of ports was not random and the results are not representative.

The pilot study was conducted between July and October 2021, and then between November 2021 and March 2022, the relevant research was conducted. As a result, 9 seaports accepted the invitation to participate in the survey, which accounted for 27.3% of the survey response rate, including the response from four ports from Germany (Port of Rostock, Port of Kiel, Port of Bremen and Bremerhaven a Port of Mukran), from Finland (Port of Turku), from Sweden (Port of Stockholm), from Poland (Port of Gdynia) and two ports from Denmark (Port of Roenne and Port of Aarhus).

The research included a survey consisting of 21 questions, including 15 closed questions and 6 so-called open-ended questions. However, the analyses provided in this article included only the questions related to indicators monitored by ports, i.e., Energy Efficiency Design Index, Ship Energy Efficiency Management Plan and Environmental Ship Index. The questionnaire had a broader context and concerned not only the analysis of indicators monitoring energy efficiency and the level of pollution in ports, but also questions about investments carried out in ports and planned in onshore electricity grids adapted to various kinds of electricity networks onboard ships, investments related to the diversification of ship to shore energy supply sources, planned budget of these investments, entities involved in the development of electricity infrastructure for cruise ships, port infrastructure prepared to handle giant cruise ships, etc., but only questions 1–4 and 7–8 are used for the purposes of this article.

This paper also referred to a number of legal acts and reports of international institutions such as IMO, UN, OECD and others. To analyze the research results, the critical and comparative analysis was applied, as well as inductive and deductive reasoning.

4. Results of Research Carried Out in Seaports in Northern Europe

4.1. ESPO Research Results in the Field of Pollution Monitoring and Energy Efficiency in Seaports

A report prepared by ESPO [22] shows that over the last two decades the priorities for assessing the environmental impact of port activities have changed. In the 1990s, port authorities paid more attention to the monitoring of indicators regarding port development (water), dredging disposal, dust, contaminated land, habitat loss/degradation, traffic volume and also industrial effluent. Ports authorities currently indicate important priorities in terms of environmental impact, i.e.: energy efficiency, air quality, garbage/port waste, ship waste, dredging operations, noise and port development (land related), the relationship with the local community and climate change (Figure 1).

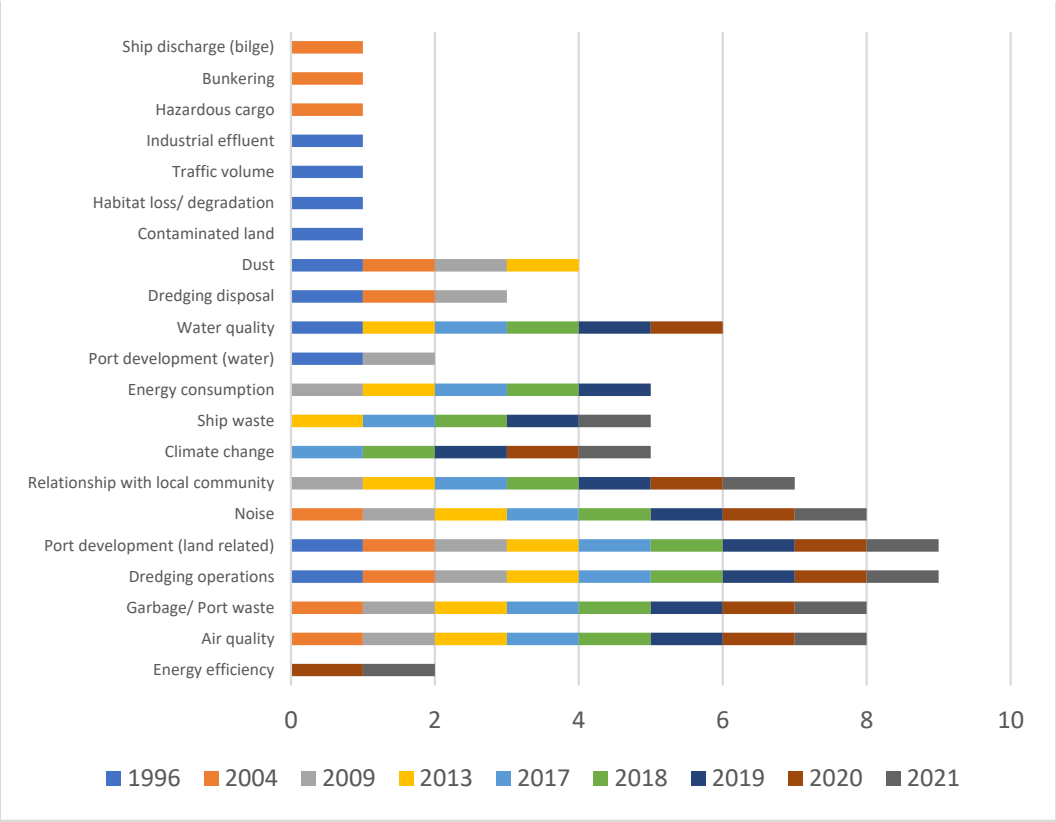

Figure 1. Environmental priorities monitored by seaports in the period form 1996–2021 Source: own elaboration on the base of: [22–39].

In the field of environmental monitoring indicators, seaports analyze various indicators, including those relating to air quality, port waste, noise, water quality and water consumption, sediment quality, as well as energy efficiency and carbon footprint, among others (Figure 1). Just a few years ago, ports monitored "energy consumption" and now they attach more importance to "energy efficiency". To reduce greenhouse gas emissions, noise and air pollution ports are taking various measures to introduce new technologies including the use of onshore power supply (OPS).

According to the ESPO report, 46% of the surveyed ports declare the launch of OPS on their quays in the coming years, and 31% of seaports claim that liquefied natural gas (lng) bunkering is available and 26% seaports plan to develop LNG bunkering facilities.

It should be noted that ports also apply a number of incentives for shipowners by applying special discounts and exemptions from fees for ships that use the ecological fuel and are "greener ships". The ESPO report proves that 53% of the ports surveyed apply such solutions and 30% plan to introduce them [22].

4.2. Research Results on Pollution Monitoring and Energy Efficiency in the Surveyed Ports in Northern Europe

The survey conducted in 32 ports in Northern Europe, responded by 23% of them, showed that only 44.4% of the surveyed ports apply the monitoring system using the Energy Efficient Design Index EEDI. On the other hand, verification of application of Ship Energy Efficiency Management Plan SEEMP by cruise ships is only run in the Port of Turku. The situation is slightly better regarding the Environmental Ship Index ESI monitoring, because as research shows, 50% of the surveyed ports confirm using this indicator, and two 22% indicated that they do not use it yet, but intend to do so (Figure 2).

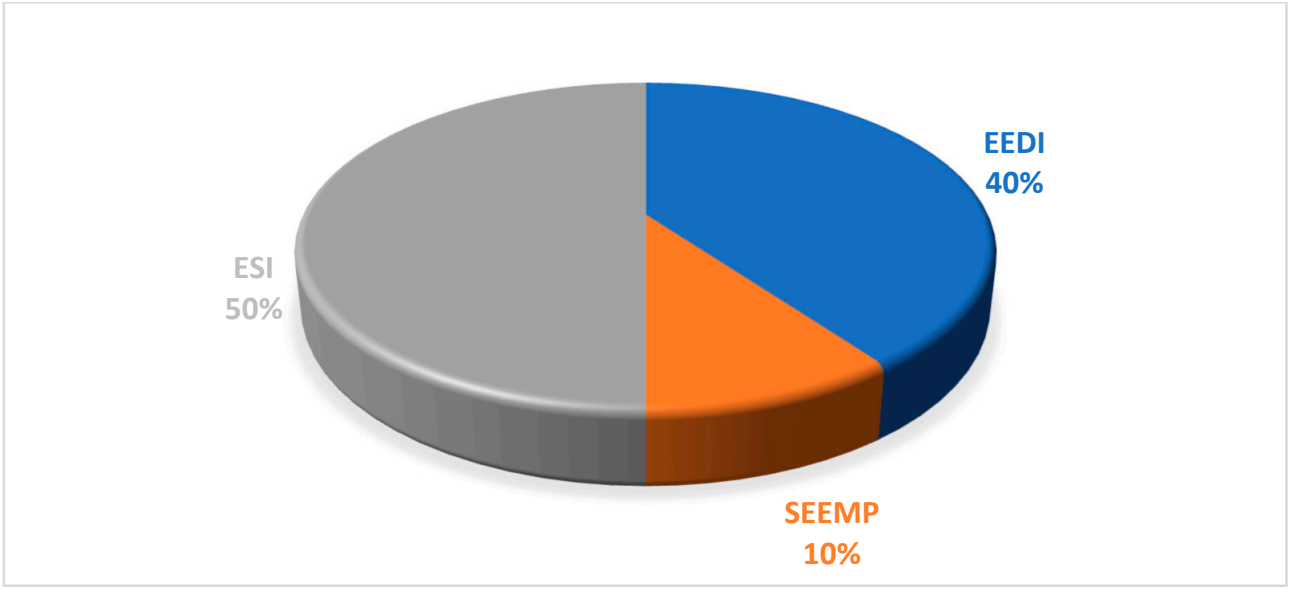

Figure 2. Application of port waste and energy efficiency monitoring indicators in the surveyed ports in Northern Europe. Source: own study.

The conducted research reveals that ports in Northern Europe consider the introduction of various indicators into the monitoring system regarding port waste and energy efficiency. However, the Port of Roenne applies neither EEDI, nor SEEMP and ESI yet, the Port of Turku fails to apply EEDI and ESI yet, while the survey results on the Port of Kiel indicate that the port applies none of the above-mentioned indicators (Figure 3).

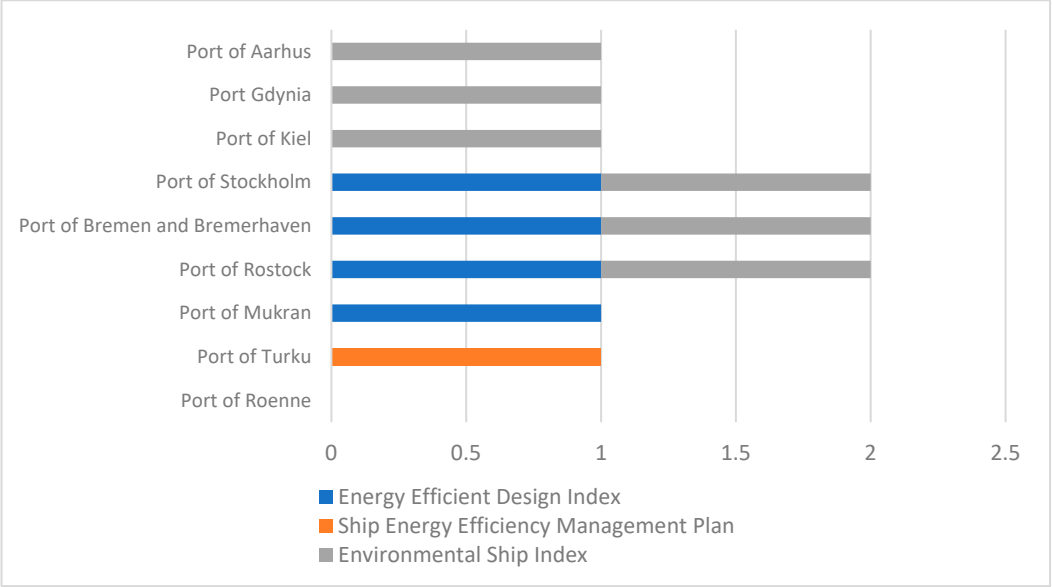

Figure 3. Monitoring of energy efficiency measures and other indicators in the surveyed maritime ports of Northern Europe. Source: own study.

Port authorities have also been asked whether they apply any additional internal regulations or documents regarding the use of energy by cruise ships and the related tariffs with discounts and exemptions. The survey results showed that 22% of the surveyed ports have introduced such solutions. Whereas a thorough analysis of port tariffs available on the surveyed seaports official websites indicates that such solutions are also used in other seaports. (Table 2). For example, in Kiel Port and Quay Tariffs, we can read that ships "certified according to the Environmental Ship Index (ESI), have paid the port charges in accordance with the tariff and achieve more than 30 ESI points, receive a discount on the tariff port charges in the amount of 5 % upon presentation of a currently valid certificate" [40] (Table 2).

Table 2. Environmental Ship Index point requirements for reduced duty fees at selected ports in Northern Europe.

Port	Minimum ESI Point Requirements	Discount
Port of Rostock	≥40	5%
	≥50	7.50%
	≥60	10%
Port of Bremen and Bremerhaven	≥20	5%
Port of Stockholm	≥50 to ≤62.9	from −0.01 SEK/GT to−0.04 SEK/GT
	≥63 to ≤72.9	from −0.05 SEK/GT to−0.07 SEK/GT
	≥73 to ≤82.9	from −0.08 SEK/GT to−0.10 SEK/GT
	≥83 to ≤92.9	from −0.14 SEK/GT to−0.16 SEK/GT
	≥93 to ≤100	from −0.17 SEK/GT to−0.19 SEK/GT
Port of Kiel	≥30	5%
Port of Gdynia	≥40	10%
	≥60	30%
	≥80	50%

Source: own elaboration on the base of: [40–44].

The analysis of charges applied in the surveyed ports in Northern Europe showed that more than 50% of them apply discounts for ships that meet the standards of the Environmental Ship Index ESI. They offer discounts from 5% when the ship scores between 20 and 40 ESI points, up to even 50% discount when the ship scores more than 80 (Table 2).

Looking more deeply at the activities of ports for sustainable development, it must be recognized that the Ports of Bremen/Bremerhaven are very active in this area. The port is certified with EcoPorts PERS. They implemented an energy management system in place that was initially certified in accordance with DIN EN ISO 50001 and developed "Guidelines for energy-efficient and sustainable procurement", in which they encourage all their contractors to use ecological solutions, including the use of new green technologies, renewable energy sources. The Ports of Bremen/Bremerhaven use the Environmental Ship Index (ESI), and grant discounts to ships that meet the requirements of the ESI. In addition, in order to reduce emissions of harmful substances and increase energy efficiency, the Ports of Bremen/Bremerhaven are implementing numerous investment projects, such as using solar thermal systems and the gas heating systems, waterside outdoor lighting changed to retrofit LED lamps, outdoor lighting changed to LED lamps and other initiatives. (Figure 4) In addition, they introduced electric bicycles in the port area instead of cars and electric cargo bikes at the building yard (Figure 4). All these initiatives have an impact on the level of pollutant emissions and energy savings [23].

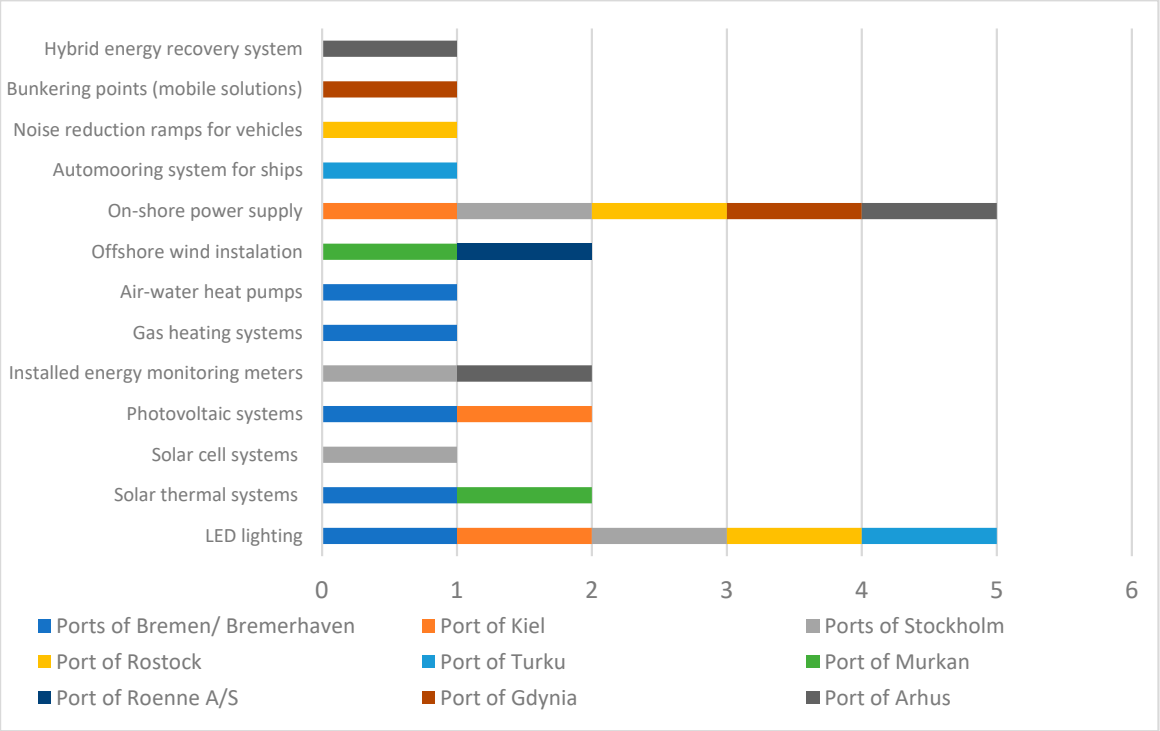

Figure 4. Pro-ecological solutions applied in the surveyed seaports in Northern Europe. Source: own elaboration on the base of: [23–27,29–39,45].

In turn, the Port of Stockholm, which is one of the main base ports for cruise ships in the Baltic Sea Region, regularly monitors emission indicators of pollutants to air, waste, energy use and energy efficiency. The environmental standards ISO 9001 and ISO 14001 are respected in the port. The port authorities have defined a long-term strategy to reduce the emission of greenhouse gases and air pollutants from shipping by 2040, including 2030, they plan to reduce emissions by 30%, up to 75% by 2035 and finally in 2040 they plan to reduce the emission of harmful substances completely [24]. The Port of Stockholm Authority has introduced "Prices and terms 2022" rebates and discounts for ships that meet the criteria set for the Clean Shipping Index (CSI) and Environmental Ship Index (ESI) (Table 2) [25]. In ports of Stockholm, there is access to onshore power supply (Table 3) at several quays, which, of course, has an impact on reducing vibrations, noise and exhaust gas levels. In order to optimize energy consumption, they also use solutions such as LED

lighting and energy saving installations and solar cell systems (Figure 4) in the port areas as alternative energy sources [25].

Table 3. Power supply services for cruise ships at berth in the surveyed ports in Northern Europe.

Port Name	How Are Cruise Ships Mooring in the Port Powered by Electricity?
Port of Roenne	Standard
Port of Turku	System "shore to ship" (main transformer station and local stations on quay)
Port of Mukran	System "shore to ship" (main transformer station and local stations on quay)
Port of Rostock	System "shore to ship" (main transformer station and local stations on quay)
Port of Bremen and Bremerhaven	System "shorebox"
Port of Stockholm	System "shorebox"; Compact modular cable guidance system so-called e-chain dispenser
Port of Kiel	System "shore to ship" (main transformer station and local stations on quay)
Port Gdynia	System "shorebox"
Port of Aarhus	System "shore to ship"

Source: own study.

An equally important base port in the Baltic Sea Region is Rostock Port GmbH. It is a home port for AIDA Cruises ships. In 2014, Rostock Port GmbH was certified with Environmental Management System DIN EN ISO 9001:2015. "A recertification was carried out in 2020 and is valid until 2023" [26]. Various pro-ecological initiatives are undertaken in the port. In 2020, the largest installation providing shore-side energy consumption for cruise ships was put into operation, delivering up to 20 MVA of electrical energy and allowing simultaneous pick-up by two ships at berths P7 and P8 [27]. Renewable energy solutions are also used at the port, for example, in 2020, 360 ultra-light DAS Energy PV modules on the roof of a building in the Port of Rostock were installed [28]. Port authorities also reward ships submitting a valid ESI certificate with a discount on the port dues from 40 ESI points [43].

Another surveyed port in Germany, Port of Kiel, applies the Blue Port concept, which involves the port authorities taking all measures to reduce the level of pollutants emitted into the atmosphere, reduce the noise generated by ships at berth and increase the energy efficiency. Shipowners can count on a 5% discount on charges if they meet standards above $\geq$30 ESI points. (Table 2). In the port, the level of air pollution is monitored by using measurement procedure in cooperation with State Agency for Agriculture, Environment and Rural Areas Schleswig-Holstein (LLUR) and the Environmental Protection Authority of the State Capital City of Kiel. In addition, in the Port of Kiel, on-shore power supply installations are available at all terminals (Norwegenkai, Schwedenkai and Ostseekai), (Table 3) which allows cruise ships to access zero-emission power to meet the electricity needs on board the ships while its berthing in the port. The port authorities declare that "44 percent for the energy demand of the vessels berthing in the Port of Kiel are covered in an emission-free and climate-neutral way. With the integration of the cruise vessels, it is going to be no less than 60 to 70 percent" [29]. In addition, further investments in this area are already planned. It is worth noting that the Port of Kiel is a leader in the maritime cruise shipping market in terms of solutions in this area, because so far, on-shore power supply is only available in a few ports in Northern Europe.

Port of Turku Ltd. also applies special tariffs for shipping companies that meet the standards of the Clean Shipping Index classification [30]. Currently, discounts are offered on charges for ships using modern technologies to reduce pollution, i.e., nitrogen oxide emissions of the vessels [31] (Table 2), but the port authorities consider extending the discounts for shipowners using new environmentally friendly solutions on ships. The Environmental Report 2019 published [31] shows that the port authorities make efforts to protect marine waters, reduction in emissions into the air and also improvement of energy efficiency and regularly monitor the related indicators. The port authorities emphasize that from 2011 to 2018, they managed to reduce pollution levels by more than 16% and

improve energy consumption indicators by 24% [42]. Plans for the coming years included in the Environmental Program for 2019–2025 assume further actions to improve these indicators [31]. The Port of Turku has three main objectives in the near future: (1) healthy maritime environment; (2) restrain climate change as part of carbon neutral Turku urban areas; and (3) enhance energy consumption and save energy. As for priority 2, they assume a "decrease of greenhouse gas emissions of port operations by 40% from 2018 to 2025" [31]. Noise generated by port operations is measured in the port and the port authorities have taken actions to develop good solutions within international projects aimed to facilitate noise reduction and the related environmental nuisance for the port vicinity. As part of reducing energy consumption and increasing energy efficiency, the port authority has installed LED lighting in the biggest warehouse and in the inner harbor area (Figure 4). In addition, the operation of passenger units has been improved by introducing "auto-mooring system that speed up mooring and unmooring system of ships as well as to cut down their fuel consumption and reduce the emissions during port calls" [31].

The Port of Murkan is also taking measures to increase energy efficiency. At present, they implement a project aimed to build a wind farm planned to be commissioned in 2023. It is assumed that offshore installation should generate electricity to power the equivalent of up to 290,000 households [32]. There are no special rates for port charges regarding green solutions aboard the ships.

Since 2002, the Port of Roenne A/S has also got ISO 14001 certification in environmental management which means that significant importance is attached to the protection of natural environment and requirements regarding the handling and disposal of waste [33]. The port authorities are very proud of the implementation of a large-scale project regarding an offshore wind farm (Figure 4), which will be launched on the island. The energy produced there is also designed to power ships, including ferries and cruise ships [34].

The Port of Gdynia performs regular noise measurements as a result of legal regulations introduced in 2011, which impose an obligation to perform such measurements by the port operator [46]. The Port Authority is also obliged to regularly measure the level of pore water pollution, performed twice a year [46]. In addition, LNG bunkering points with the help of mobile solutions have been arranged in the port (Figure 4) as well as an installation for onshore power supply for vessels with the following parameters: 3 MW, 11 kV and 50 Hz/60 Hz from an onshore electric grid of 15 kV 50 Hz [35]. Expert opinions indicate that connecting a large cruise ship to this installation for 10 h can reduce CO_2 emissions by 22 tons, nitrogen oxides by 1.4 tons and sulfur oxides by 1.2 tons [45]. The Port of Gdynia is considering the Green Ports concept and consequently implements a project entitled "The port area monitoring and observation system with the use of floating unmanned mobile research platforms" co-financed by the Norwegian Financial Mechanism and the Polish state budget. The project aims to achieve zero emissions, smart technology, process automation and environmental protection [36]. The port authorities have also introduced discounts for ships meeting ESI standards, offering discounts from 10% on charges for $\geq$40 points to 50% discounts on charges at $\geq$80 points [44] (Table 2).

The Port of Arhus also presents strong commitment to sustainable development. They took an active part in the initiative called "Getting to Zero Coalition", which provided a platform for international cooperation for 150 entities directly or indirectly related to the maritime economy and energy industry. As part of its efforts for sustainable development, the Port of Arhus set four goals: (1) sustainable energy (SDG 7); (2) industry, innovation and infrastructure (SDG 9); (3) sustainable cities and communities (SDG 11); and (4) life at sea (SDG 14) [37]. The "Sustainability Report 2021" shows that the port authorities are carrying out large-scale activities to improve the environment and responsible waste management. An investment in a shore power facility (Figure 4) for cruise ships is also planned which is expected to be ready for the 2023 season [38]. The Port of Aarhus has also joined the EcoPort initiative and the port policies were adapted to the "Port Environmental Review System" (PERS) [39].

The above analysis proves that port managers in Northern Europe are indeed taking the issue of environment improvement seriously, including above all the quality of air and water in port waters through various investments and operational activities. Surely, we can always say that they are doing it too slowly and doing too little, but unfortunately investments in this area are highly expensive and sometimes go beyond the port budget possibilities. It is a good thing that, in many cases, they are supported by public funds within the EU projects.

5. Discussion

The conducted research shows that in all the surveyed ports in Northern Europe, actions are taken to improve the condition of natural environment, reduce greenhouse gases and reduce the number of harmful substances emitted into the atmosphere. All the surveyed ports confirm that they regularly monitor the level of pollution, which is imposed by restrictive international regulations, but also national and local ones. Ports also constitutes a response to the reported needs of local communities and pro-ecological organizations who are alarmed at the deteriorating condition of the natural environment and its impact on the health of the public.

The guidelines introduced by the European Commission—the European Green Deal [4], and the program of the Organization of United Nations called "Transforming our world: the 2030 Agenda for Sustainable Development" had a big impact on the activation of port operations in Northern Europe. Theseboth initiatives are signposts for port activities aimed at achieving net-zero greenhouse gas emissions in 2050. Port development strategies and reports on the implementation of sustainable development policies, regularly published by port managers, always refer to these documents. They defined the goals and framework for developing investment projects and constitute some kid of incentive to act. It can even be stated that seaports have begun to compete with each other for the title of the greenest port and are outdoing each other in achieving better and better indicators in terms of CO_X, SO_X, NO_X and PM emissions.

More and more seaports also seek certification within the EcoPorts, Green Ports or Blue Ports concept. Furthermore, many of them boast about environmental certificates, such as the management system standards ISO 14001 and energy management standards ISO 50001. This, of course, has a marketing and image-related meaning. Each of these concepts refer to a number of obligations and restrictions for seaports regarding the monitoring of the level of pollution, introducing pro-ecological solutions in the field of water purification, reducing energy consumption and increasing energy efficiency through the use of renewable energy sources. However, few ports in Northern Europe have prepared onshore power supply systems that solve the problems of nuisances related to noise, vibration and pollution generated by cruise ships at berth in ports. Cruise ships require access to voltage of a value and frequency, i.e., 50 Hz or 60 Hz [47]. Unfortunately, the economic efficiency analyses conducted, for example by the Port of Copenhagen [48], show that regrettably these investments are not economically profitable for port authorities, but necessary for environmental reasons. However, in recent years, many port authorities have taken the effort to install such systems (Rostock, Stockholm, Kiel and Gdynia), and others are planning to implement them (e.g., Arhus). Connecting the ship to onshore power supply when the ship is at berth in the port provides significant savings for shipowners because fuel to power the ship power plants is much more expensive.

The surveyed seaport authorities in Northern Europe are also actively involved in various international and cross-sectoral initiatives and projects within different organizations, such as the ESPO, Cruise Baltic, Cruise Europe and others.

However, it should be remembered that all actions for sustainable development constitute a time-consuming and cost-consuming process. Investments in coastal areas are capital intensive and require financial support from public funds. In this case, the European Union funds and coastal state government funds play a significant role.

It is also gratifying that port authorities appreciate the efforts of cruise shipowners in favor of environmentally friendly solutions introduced on ships and apply special port tariffs for them, offering discounts. As many as 50% of the surveyed ports confirmed applying discounts for vessels that meet standards Environmental Ship Index (ESI) and 40% for the Energy Efficient Design Index (EEDI).

6. Conclusions

In conclusion, it must be stated that legal regulations introducing strict limits on emissions of harmful substances emitted from ships and a ban on targeted emissions of substances that deplete the ozone layer had a significant impact on the activities of port managers in Northern Europe. The conducted analysis of source materials, the review of previous studies and the results of surveys conducted among seaports in Northern Europe proved unambiguously that there is a noticeable increase in activities aimed to monitor the level of COx, SOx, NOx and particulate matter emissions from exhaust gases into the air and marine water.

The collected research material and the primary research performed help to conclude that the assumed objective of the research has been achieved. Port authorities develop short- and long-term strategies and action programs to reduce the level of pollution generated in ports while handling the ships and performing other port operations. These actions indicate the seaports' response to the recommendations and guidelines issued by International Maritime Organization, Organization of United Nations and European Commission. Many seaports in Northern Europe have also voluntarily joined various environmental initiatives such as EcoPorts or Green Ports and have got ISO environmental management certificates imposing additional obligations to monitor and counteract environmental pollution.

The research has shown that the Environmental Ship Index (ESI) is the most common monitoring indicator used in the ports in Northern Europe. The research shows that 50% of the surveyed ports currently use this indicator, offering shipowners discounts from 5% to 50% on port charges. Another 20% of the ports surveyed declare that they intend to use the ESI to determine the amount of port charges for ships. In addition, 40% of the ports surveyed confirm the use of the Energy Efficient Design Index (EEDI). Several ports surveyed also indicated that they also monitor the Environmental Clean Index (ECI) and occasionally SEEMP.

Moreover, the analysis of port strategic documents and annual reports on sustainable development activities shows that various measures are taken in the surveyed ports in Northern Europe to increase energy efficiency and energy savings through the use of modern technologies related to the renewable energy sources. In the ports, the lighting is replaced with LED lighting, photovoltaic and solar thermal systems are installed, offshore wind installation, onshore power supply systems are launched and also installed energy monitoring meters for vessels and buildings, gas heating systems, etc. Additionally, many other innovative pro-ecological projects using the renewable energy sources are currently planned. All these activities indicate that the ecological awareness of seaport managers is high enough to guarantee significant improvement in the environment in coastal regions within the next few decades.

The results of the conducted research and analyses show that the answers were obtained to all research questions presented at the beginning: (1) How do seaports monitor the level of pollutants emitted by cruise ships calling at these ports? (2) Do the Northern Europe seaports monitor energy efficiency on cruise ships they handle? (3) Do the seaports of Northern Europe have any additional policy towards cruise shipowners with regard to energy efficiency and environmental impact?

The authorities of the surveyed seaports in Northern Europe regularly publish annual reports on the progress made in implementing sustainable development measures, including in particular the achieved indicators regarding the reduction in the levels of pollution and improving indicators regarding a reduction in energy consumption through the use of modern technologies and increasing energy efficiency. At the same time, they communicate

the goals they set for the near future and for the image-related reasons, they care to achieve the objectives as per the plan. It should also be emphasized that invaluable support for port managers refers to funds that can be obtained from the European Union funds for various pro-ecological innovative investment projects in coastal areas, because unfortunately, as already mentioned, the investments in port and hydraport infrastructure are highly capital intensive and cost intensive.

Despite the fact that only 27.3% of respondents participated in the survey (i.e., 9 out of 32 ports which received an invitation to participate in the survey), we can say that the research results constitute a reliable picture of activities conducted in seaports in Northern Europe in the field of monitoring the release of harmful emissions into the atmosphere and the aquatic environment, not least because among the surveyed ports there were the largest seaports in the Baltic Sea and the North Sea. Therefore, one can say that in other ports of Northern Europe, the situation may be similar.

7. Recommendations

Significant environmental pollution in coastal regions creates considerable challenges for seaport authorities and local authorities. It is necessary to constantly monitor the level of pollution generated by ships and energy efficiency through the use of modern technological solutions. Moreover, seaport authorities should also introduce confirmation of compliance by shipowners with various standards defined by indicators such as ESI, EEXI, SEEMP, IEEC, EEDI and others. Port authorities should consider the introduction of continuous monitoring of the entire package of indicators showing how shipowners approach the issue of pollutant emissions from ships or energy efficiency. Since their application is not forced by legal provisions, it may be worth considering, as it is already used in some ports, the application of incentives in the form of significant reductions in charges or higher port infrastructure charges for those entities that comply with or violate the standards. The measurable economic benefits of savings associated with port charges can also stimulate positive change. In addition, port authorities should also set a good example and use modern technologies in the field of obtaining renewable energy and increasing energy efficiency during port operations.

8. Limitations

The studies carried out have some limitations because they are not representative studies and the sample was selected deliberately. Ports associated in the Cruse Baltic and Cruise Europe organizations from Northern Europe were invited to the study, so some ports that are not members of these organizations were omitted. In addition, the questions asked in the survey may not have provided an opportunity to assess other aspects that affect the approach of port authorities to issues related to the monitoring of pollution in ports generated by ships and issues related to energy efficiency measures. Future studies could provide in-depth interviews at individual ports, involving those responsible for investment and monitoring in seaports. In addition, it is worth conducting this type of research regularly to observe changes.

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