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Identifying Actions to Prepare Electricity Infrastructure in Seaports for Future Power Supplying Cruise Ships with Energy from Land

Joanna Kizielewicz * and Katarzyna Skrzeszewska

Faculty of Management and Quality Science, Gdynia Maritime University, 81-225 Gdynia, Poland; k.skrzeszewska@wznj.umg.edu.pl
* Correspondence: j.kizielewicz@wznj.umg.edu.pl; Tel.: +48-585586603

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Abstract: Cruise ships are unfortunately at the infamous forefront of the means of maritime transport emitting the largest amounts of harmful substances into the atmosphere and aquatic environment. At the initiative of IMO and the European Union, formal restrictions were introduced regarding the level of harmful emissions on the high seas and in ports generated by seagoing vessels. To meet these challenges, shipowners have invested in various technological solutions on their ships to reduce the number of harmful emissions, and by ordering new vessels; they promote the use of pro-ecological solutions related to energy saving and eliminate environmental harm. However, despite the actions taken by shipowners, seaports unfortunately lag behind the challenges and expectations of the market and are still not prepared, for example, to power the ships moored in ports with shore-side energy to reduce the environmental pollution when the ships are at berth. The aim of this paper is to identify actions taken by seaport authorities to prepare electricity infrastructure in seaports to power vessels with energy from the land. Key legal restrictions concerning reduction in pollutions emitted from ships in the ports are also described and analyzed. The results of the study also show the approach of seaports to the issue of Onshore Energy Supply for cruise ships. The research was conducted among the selected ports in the Baltic Sea Region where cruise ships are accepted. The following research questions were formulated: (1) What legal regulations oblige seaports and shipowners to reduce the level of pollutions emitted into the environment? (2) Do the ports use a benchmark to assess the level of harmful emissions when defining the amount of port fees for cruise shipowners? (3) How are cruise ships powered in the port? (4) What investments are planned in the port regarding the infrastructure related to the diversification of shore-side electricity for the ships? The studies were conducted by using a few research methods, i.e., the desk research method, the exploration method, and the CAWI Computer Assisted Web Interview. The results of this research can provide an interesting source of information both for cruise ship owners and cruise seaport authorities, but also potentially for shipyards where new vessels are constructed.

Keywords: sustainable energy transition; harmful emissions; electricity infrastructure

1. Introduction

The significant environmental pollution in coastal regions [1] caused by ships moored in ports [2], including cruise ships, has made port city authorities and seaport authorities look for effective solutions to counteract these phenomena [3]. Regulations introduced by the European Commission [4] and IMO [5] are also enforced. One of the effective solutions involves preparing seaports to render services related to the provision of Onshore Power Supply (OPS) for ships. This solution has been known for a long time, but until now it has not been widespread and appreciated when it comes to the beneficial effects for the environment. Replacing the ships' power supply system with the energy from an onshore facility—rather than from the ship's engine room—exerts a beneficial effect primarily on reducing the level of CO_2 [4,6] and NO_2 [7] pollution, but also on reducing the frequency of vibrations and the noise level in the port. Moreover, the costs of energy from port [8,9] facilities are much lower than from the ship's engine rooms, which is important for ship operators given the constantly rising fuel and energy prices.

The investments in new technological solutions and electric infrastructure providing ships with onshore energy supply systems in ports [10] must take into account different energy parameters, because, for example, cruise ships require access to voltage of a certain value and frequency [11], i.e., 50 Hz or 60 Hz. Unfortunately, the standard power grid in seaports has a different electrical voltage and frequency to most cruise ships. To adapt the port systems to the requirements aboard cruise ships [11], it is necessary to use very expensive converters that adjust the voltage to the level required by the ship's equipment.

Onshore Power Supply (OPS) [12] may provide electricity to any vessel equipped with an AC power supply system [13], either fossil fuel-powered, hybrid [14], or battery-powered [15]. Currently, this solution is mainly used by ferries and cruise ships; although, there are more and more intense discussions about preparing this infrastructure also for cargo ships. Cruise ship owners closely follow the market trends, and, bearing in mind the environmental issues and optimization of ship's operating costs, by ordering new vessels, they install Shore Power Equipment (SPE) aboard their ships to enable connecting to Onshore Power Supply (OPS) [16].

The aim of this paper is is to identify actions taken by seaport authorities to prepare electricity infrastructure in seaports to power vessels with energy from the land. The survey was conducted among the selected ports in the Baltic Sea Region where cruise ships are accepted. The research was conducted among the selected ports in the Baltic Sea Region where cruise ships are accepted. The following research questions were formulated: (1) What legal regulations oblige seaports and shipowners to reduce the level of pollution emitted into the environment? (2) Do the ports use a benchmark to assess the level of harmful emissions when defining the amount of port fees for cruise shipowners? (3) How are cruise ships powered in the port? (4) What investments are planned in the port regarding the infrastructure related to the diversification of shore-side electricity for the ships?

The content of the paper includes five main sections, including an introduction to the subject related to issues concerning pollutions emitting by cruise ships and solutions in seaports such as Onshore Power Supply. The second part of the article discusses the pollution generated by cruise ships during a stop in ports. Then, legal provisions regulating the issue of reducing pollutant emissions generated by ships is presented. The next part of the paper presents available solutions delivered by the market for powering ships with Onshore Energy Power Supply, and a brief description of selected seaports is presented. The paper also contains a description of the method of research implementation as well as their analysis and conclusions.

2. Ships as a Source of Air Pollution in Ports and Coastal Areas

Coastal areas, especially ports, due to their functions, are particularly exposed to increased levels of harmful substances emitted both by industry and by means of transport whose routes converse in ports. Studies in coastal regions and ports have shown a number of harmful substitutions in the atmosphere. In the ports, their source are activities connected with ships operations: manoeuvring, loading and unloading, operations in terminals, hoteling (e.g., lighting, heating, and refrigeration), waste disposal, bulk handling, spill, and with usual port activities and its expansion: dredging, land traffic, goods movement, infrastructure construction and maintenance, and industrial activities [17,18]. The pollution resulting from the use of fossil fuels to propel the ships and the servicing of ships in the ports includes: greenhouse gases (carbon monoxide (CO) and carbon dioxide (CO_2)) [4,6] as well as polycyclic aromatic hydrocarbons (PAHs) [2]; volatile organic compounds (VOCs) [1,6]; ozone depleting substances (ODS) [6]; nitrogen oxides (NO_X); sulphur oxides (SO_X) [7], which, during their combustion, result in generating other substances polluting the atmosphere particulate matter (PM) [3,19,20], ultrafine particles (UFP) [21], metals [20], and carbon (organic and elemental) [6,22], etc. (Figure 1).

The emission of gases (and other substances) leads to changes in average temperatures, rising sea and ocean levels, melting of glaciers, etc. This, in turn, translates into human and animal health, the condition of ecosystems, energy production and consumption, farming and forest management, and can be observed in social changes; it affects the social wealth and costs incurred by the society [23–25].

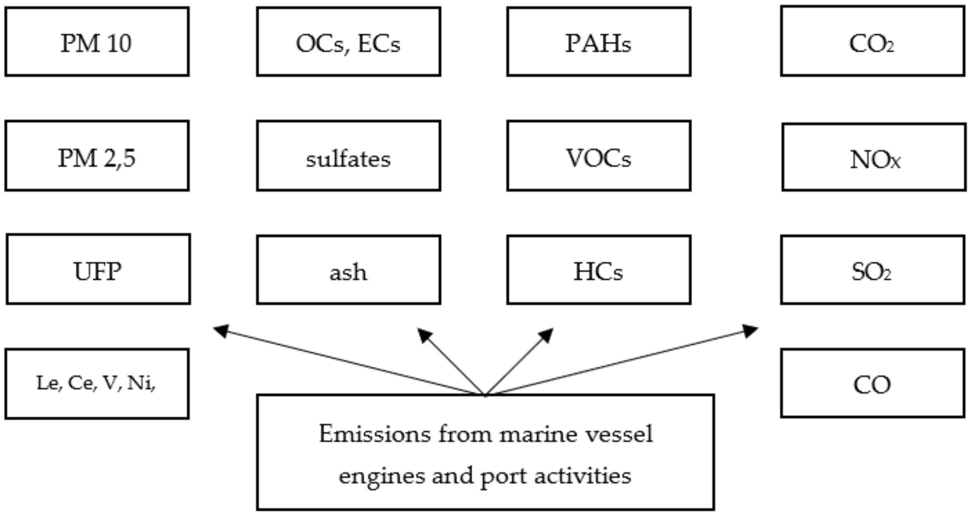

Figure 1. Compounds of emissions from marine vessel engines Sources: [26].

3. Legal Regulations on the Hazardous Substance and Greenhouse Gas Emissions in the Baltic Sea Region

The emission of gases (and other substances) leads to changes in average temperatures, rising sea and ocean levels, melting of glaciers, etc. This, in turn, translates into changes in human and animal health, the condition of ecosystems, energy production and consumption, farming and forest management, and can also be observed in social changes; it affects the social wealth and costs incurred by the society [24–27].

Regulations on the reduction in harmful emissions resulting from fleet operations were developed by institutions and organizations with different impact—from global (UN) and regional (the European Union) to local (governments and port authorities) (Figure 2). The largest scope of activities is provided in document entitled, "Transforming our world: The 2030 Agenda for Sustainable Development" adopted by the UN member states in 2015 [27]. The document defines 17 Sustainable Development Goals (SDGS). The fourteenth goal aims to "Conserve and sustainably use the oceans, seas, and marine resources for sustainable development".

The document outlines a framework for actions aimed to improve human well-being through the restoration of marine ecosystems, which in turn requires actions to protect sea basins against the negative effects of anthropopressure. The document contains no clear recommendations—it aims to help develop policies and take actions resulting in sustainable development. In 2017, the intention to work together for the sustainable management of marine resources was confirmed by the adoption of another declaration, "Our ocean, our future: call for action" [28].

Specific actions to protect the marine environment are taken by the International Maritime Organization (IMO)—the UN specialized agency [26,29–31]. Under the auspices of IMO, several conventions were developed covering a full range of issues related to the safe (regarding environmental protection) exploitation of the seas. The most important from the point of view of achieving the goal of the undertaken research was: the MARPOL Convention (International Convention for the Prevention of Pollution from Ships) and its six Annexes (I–VI), the AFS Convention (2001) on the control of harmful anti-fouling systems on ships, the Ballast Water Management Convention (2004), and the Ship Recycling Convention-Hong Kong Convention (2009) [5]. The MARPOL Convention was adopted in

1973, but it only became applicable in 1983. In 1997, during the Air Pollution Conference, Annex VI "Regulations for the Prevention of Air Pollution from Ships" was added; it became applicable in May 2005 [32]. In the context of research, the results of which are presented in this article, the most important provisions of the Convention include: establishing special areas and Section 3: Requirements for control of emissions, and Section 4: Energy efficiency regulations for ships.

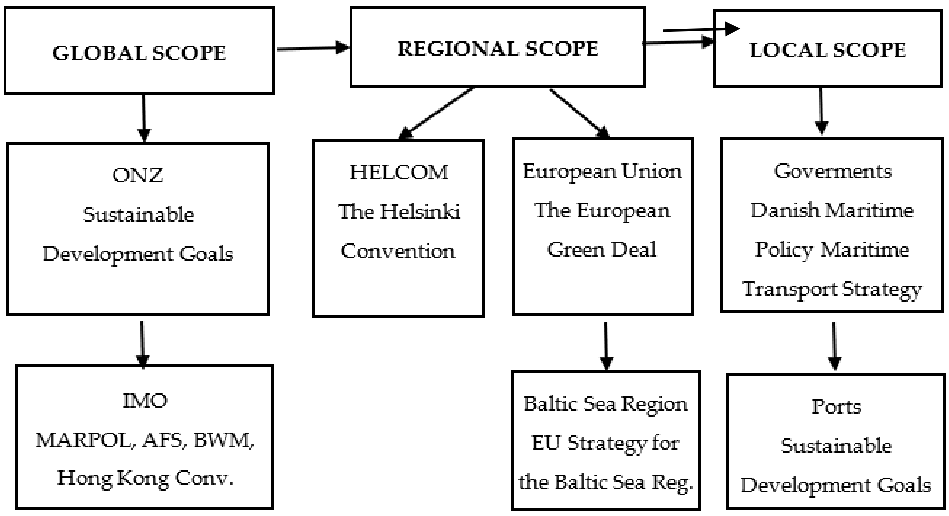

Figure 2. Selected legal solutions for the protection of marine environment. Source: own elaboration.

The Baltic Sea as a specific body of water (due to its insufficient connection with other bodies of water it is characterised by low salinity, and it is closely surrounded by land—industrialized and urbanized) requires special care regarding the quality of natural environment. This is reflected in initiatives dedicated to improving the marine environment and coastal area. The most compelling evidence of the special treatment towards the Baltic Sea is the special care of the Baltic Sea by IMO through granting the status of a special area [33] since the beginning of the MARPOL Convention.

At the intergovernmental level, actions to protect the marine environment of the Baltic Sea were undertaken by the countries in the Baltic Sea Region. The form of cooperation established to take action to protect the environment involved an intergovernmental organization the Baltic Marine Environment Protection Commission (HELCOM—Helsinki Commission). The activities by HELCOM are determined by the so-called Helsinki Convention (Convention on the Protection of the Marine Environment of the Baltic Sea Area) [34]. The Convention was signed in 1974, and was updated due to geopolitical changes in the region, new environmental challenges (1992), and when it was required due to the changing provisions of international environmental law or maritime law (the last amendment entered into force in 2014). The convention, signed by all the Baltic States, aims to protect the Baltic Sea against any pollution: from the land, air, and facilities operating at sea. It aims to protect the Baltic Sea biodiversity and ensure the sustainable exploitation of resources.

Among the pro-ecological solutions promoted by the European Union [35–37], the most important initiative, announced in December 2019 by the European Commission, is the European Green Deal—a document that outlines the directions for the EU economic transformation [38]. The changes aim, for example, to ensure a resource-efficient and competitive economy with net-zero greenhouse gas emissions by 2050. This is a part of strategy implementing the UN 2030 Agenda for Sustainable Development.

With regard to the changes necessary for maritime transport, the Commission announced the end to subsidies for fossil fuels, revision of the current tax exemptions, including those concerning marine fuel, and "(. . .) is going to propose extending the European Emissions Trading Scheme to the maritime sector (. . .)". These actions are scheduled to be coordinated with the activities undertaken by IMO. Moreover, access to the EU ports will be regulated for ships generating and emitting pollution on a large scale, and the ships moored will be obliged to take the electric energy from onshore facilities [38].

The EU Member States within the Baltic Sea Region implement the European Union Strategy for the Baltic Sea Region (EUSBSR), the first macro-regional strategy adopted in 2009, and prepared for eight EU Member States with the possibility to offer cooperation and take actions with four neighbouring countries (Russia, Belarus, Norway, and Iceland) [39,40].The strategy was developed to achieve three objectives: Save the Sea, Connect the Region, and Increase Prosperity, supplemented by sub-objectives. Among the current nine sub-objectives, as many as four refer to the protection of marine environment: clear water in the sea; rich and healthy wildlife; clean and safe shipping; climate change adaptation; and risk prevention and management [SWD (2021) 24 final]. The EUSBSR provisions are implemented within separate policy areas (PAs). The issue of regulations regarding ships operating in the Baltic Sea Region is raised as part of PA Ship; the related activities under this policy are coordinated by Denmark (Danish Maritime Authority). Activities under PA Ship are based on the assumptions and activities undertaken within the European Green Deal; they comply with the objectives of SDGs and follow the provisions of, e.g., the Helsinki Convention, the EU integrated maritime policy, and aim to fulfil the obligations defined in the IMO Conventions (including MARPOL Convention and IMO's Initial Strategy on Reduction of GHG Emissions). The PA Ship achievements include projects accelerating the completion of investments related to "development of infrastructure and value chain of LNG in the Baltic Sea region, with the objective to reduce air pollutant emissions from ships", projects "working on policy impact and concrete solutions for sewage and waste in the ports", and initiatives focused on "emissions from shipping in the Baltic Sea region and on economic incentives to reduce emissions" [40,41].

International solutions should be reflected in the strategic documents of countries participating in the agreements, unions that are parties to the agreements. In the case of ports analysed, both Denmark and Finland provide policies for the development of maritime economy. They include Danish Maritime Policy and Maritime Transport Policy for Finland. In Denmark, the government declares investments [17]. The Finnish policy focuses on green development and Finland achieving the status of "a frontrunner in (. . .) environmental technologies for shipping and an exporter of leading expertise in these technologies" [42].

In view of numerous issues addressed in the high-level strategic documents, the Danish and Finnish maritime strategies make little reference to measures aimed at reducing pollution caused by the exploitation of the seas.

4. Solutions Applied in Seaports within Onshore Power Supply for Cruise Ships

4.1. Presentation of Selected Solutions in Seaports

An important factor taken into account by seaport authorities while taking decisions to invest in Onshore Power Supply for cruise ships involves the fact that currently only about 10% of the world's cruise ships have Shore Power Equipment on board to take onshore energy, and a vast majority of these vessels sail mainly on the US West Coast and Canada (Table 1).

Today, more and more companies offer various solutions on the construction of shore-side energy facilities for ships. For example [43] Danish engineering company PowerCon offered the LoCOPS System which converts the frequency and voltage to the levels adjusted to the ship's capabilities and meets the requirements of international standards IEC/ISO/IEEE 80005-1 44 [43]. Such solutions are also offered by Danfoss Drive whose installations meet the standards of IEC/ISO/IEEE 80005-1 High voltage shore connection (HVSC) systems—General requirements and IEC/PAS 80005-3 Low Voltage Shore Connection (LVSC) Systems—General requirements. They also provide an offer that meets the standards for shore-side power supply for cruise ships. Moreover, they offer support to cruise ship owners in adapting and modernising the ships' supply systems to onshore power supply [18]. Currently, typical cruise ships consume, on average, from 7 to 11 MW, which poses a significant challenge for onshore facilities [44].

Table 1. Shore Power Equipment on cruise ships of leading cruise shipping organizations.

Name of a Cruise Corporation	Number of Cruise Ships with SPE
Royal Caribbean	19
Carnival Group (Carnival, P&O and Cunard)	0
Princess Cruises	2
MSC	16
Holland America Line	2
Norwegian Cruise Line	1

Source: [44].

The installation costs of Shore Power Equipment aboard the ships range from 0.5 million to 10 million Euros [44] depending on the type of installation, its range and parameters.

Currently, ports provide various solutions for the shore-side energy supply:

- Mobile power generator units with combustion engines consuming ca. 800 litres of fuel per day; however, their efficiency is quite low since the generators often run at low loads;
- VACON® NXC air-cooled frequency converters to convert the 50 Hz onshore voltage to 60 Hz voltage, sine filter to create a near-sine waveform, and an isolation transformer to eliminate common disturbances and develop the IT power supply required on ships (port of Odense in Denmark);
- Compact modular cabling system the so-called HVSC dispenser;
- Main transformer station and local stations at the quay;
- The "shorebox" system.

On the market, there are various types of cable systems to power ships from land, i.e., [44]:

- A fixed cable crane with a working radius of ca. 10 m along the quay;
- A cable truck with a working radius of ca. 50 m along the quay;
- An underground cable system combined with a cable truck.

Onshore Power Supply for cruise ships has already become an obligation on the US West Coast, for example, such installations are located in the ports in San Diego, Los Angeles, San Francisco, Seattle, Vancouver, and Juneau (Alaska) [16]. It is worth emphasizing that the investments in OPS in these ports were co-financed from public funds.

In Europe, such actions can also be observed in some seaports [17]. However, it is necessary to remember that this task is neither easy nor low-priced. Upon developing the quay facilities, it is necessary to remember that the equipment used to convert power must be able to deal with any limitations regarding the amount of available power and different voltages and frequencies to ensure reliable and safe energy supply to ships moored in the port [18].

The solutions related to shore-side energy supply for ships are supported by the European Commission, which considers this solution less harmful to the environment. For example, in accordance with Article 19 of Directive 2003/96/WE, Denmark was authorised under the Council Implementing Decision to apply a reduced tax rate for electric energy supplied directly to ships moored in the port. It refers to the reduction in energy tax applicable to shore-side electricity from the standard level of 89.2 øre/kWh (rate from 2020) to 0.4 øre/kWh [45]. The European Commission also issued a similar decision authorising Germany to apply a reduced tax rate for electric energy supplied directly to ships moored in the port [46]. Such actions constitute an incentive for port authorities looking for solutions to increase their competitiveness on the market.

4.2. Presentation of Selected Seaports in the Baltic Sea Region

The Port of Turku (Lat: 60°26′5″ N Lon: 22°13′2″ E), situated on the southwestern coast, at the mouth of the river Aura, is the leading port on the shipping route between Finland and Scandinavia. The port has four quays for cruise ships from 150 to 230 m in length and a draught between 7.5 and 11 m (Table 2) [46]. The quays are prepared to handle cruise ships; although, these ships are not treated in the port as a priority. Cruisers must adjust their arrival and departure to the timetable of regular ferry connections between Kuuva and the Port of Turku [47]. The recent available data on cruise ship calls to Turku indicate a low frequency of cruiser calls: in 2018 there were 5 of them compared to ca. 1972 total number of ships, in 2019—only 2 compared to 1886 ships [47,48].

Table 2. Basic data on quays dedicated to cruise ships in selected ports in the Baltic Sea.

Name of a Port	Port of Turku				Port of Roenne			
Berths	River Aura Pier 12	Pier 41	Pier 38–40	Pier 35–36	Krydstogtkajen Pier 31/32	Tværmolen-Pier 22/23	Kulkajen pier 13	Multipier-Pier 34
LOA max	150 m	203 m	230 m	231 m	250 m	130 m	160 m	350 m
Depth max:	7.5 m	10.6 m	11.0 m	8.5 m	9.0 m	7.0 m	7.0 m	11.0 m
Type of berth	Cruise	Container/ Cruise	Container/ Cruise	Container/ Cruise/ Projects	Passenger (multi)	Passenger/ cargo	Bulk/ Passenger	Passenger, offshore etc.
Proper tender facilities if available and needed by cruise lines	Available	Available	Available	Available	+	+	+	+
Bilge and Sludge disposal facilities	Available	Available	Available	Available	Available (truck)	Available (truck)	Available (truck)	Available (truck)

Source: [48–50].

The Port of Roenne (Lat: 55°5′48″ N Lon: 14°41′30″ E) is the largest commercial port at Bornholm, with ca. 3000 ships calling at the port annually. For cruise ships there are four quays of 160 to 350 m in length and a depth between 7 and 11 m (Table 2.) [50]. Currently, cruise ships account for less than 2% of all port calls: 42 ships in 2018, and 46 in 2019. Because of its attractive location (on route and from the Baltic Sea), initiatives are taken in the port to increase the port accessibility for cruise ships (better manoeuvring opportunities, larger quays, and water depths) [47,50].

Both ports analysed provide infrastructure prepared to receive cruise ships and to collect waste from the combustion in ships' engines.

5. Materials and Methods

The research conducted was a type of qualitative research. The studies were conducted by using a few research methods, i.e., desk research method and exploration method and surveys using the method CAWI Computer Assisted Web Interview. The CAWI method is a kind of interview with respondents using an electronic survey. This is a very convenient, fast, and cheap method of reaching respondents in different countries. Test results are generated directly in MS Excel sheets, which facilitates verification and speeds up the analysis of test results. The questionnaire was prepared thanks to the Forms application in MS Office. It should also be emphasized that it is necessary to increase the credibility and reliability of conducting this type of research to ensure direct contact with respondents by electronic means. The authors of the study sent questionnaires along with an e-mail letter directly to the CEO or Cruise Mangers at seaports in the Baltic Sea Region. Access to respondents was possible thanks to the port guide prepared by the organizations Cruise Europe and Cruise Baltic. The questionnaire consisted of 21 questions, including 15 closed questions and 6 so-called open questions, where the respondents could provide their individual opinions and comments.

The questions in the questionnaire focused on ports' respect for standards of MARPOL VI concerning Energy Efficient Design Index and Ship Energy Efficiency Management Plan, as well as an indicator of Environmental Ship Index. Questions also concerned elements of the power grid in the port and whether the onshore electricity grid has been adapted to various kinds of electricity networks onboard ships and allows the supply of electricity of a different voltage frequency. Issues related to investment plans in ports in the field of power infrastructure were also asked. Ports were also asked if they monitor the sources of energy from ships and if they have knowledge of how ships are powered by energy. In addition, we also wanted to obtain information on port infrastructure and state of its preparation for the reception of large cruise ships with a length of over 360 m and a tonnage of over 220,000 GT.

The survey was conducted between August 2021 and October 2021 and a total of six seaports were invited to participate in the study in the Baltic Sea Region but, unfortunately, only two ports agreed to take part in the study, i.e., Port of Roenne (Bornholm, Denmark) and Port of Turku (Finland). Nevertheless, the authors tried to find information about the other ports in various materials including reports of various institutions. In the analysis we have also applied critical and comparative analysis, and induction and deduction reasoning.

6. Results of Surveys Conducted in Seaports in the Baltic Sea Region

Port city authorities and seaport authorities within the Baltic Sea Region recognise the issues regarding the increasing environmental pollution and nuisance to local communities resulting from cruise ship traffic. The solutions related to reducing the pollution emitted by the ships while at berth, include, for example, investments in Onshore Power Supply. Unfortunately, not all the ports in the Baltic Sea Region are interested in investing in such solutions dedicated to cruise ships despite the economic effectiveness of such projects [51,52]. For example, the ports of Stockholm and Helsinki do not intend to invest in this type of facility for cruise ships, rather offering onshore energy supply for ferries, but it should be noted that the technical requirements for ferries are much more modest [44].

The first Onshore Power Supply facility in Europe was launched in 2015 in the Cruise Terminal Altona in Hamburg [53]. This investment was completed thanks to the participation of many entities, including awarding authority the Hamburg Port Authority (HPA), general contractor "Siemens", local authorities, energy network operator Stromnetz Hamburg GmbH, the owner of infrastructure, cruise ship companies, and residents [10]. The main benefits for the environment resulting from this facility include preventing the emissions in amount of 3354 tons of CO_2 per year [10].

Whereas in the Baltic Sea Region, actions aimed to launch the shore-side energy supply for cruise ships began in 2015 in Denmark where City & Port Development, CMP and the City of Copenhagen prepared a report called "Options for Establishing Shore Power For Cruise Ships In Port of Copenhagen Nordhavn", which provided several scenarios regarding investments in Onshore Power Supply, estimating the potential benefits for the environment over the next 30 years from 2016 to 2045 (Table 3) and the financial projection for these investments.

Table 3. Environmental effects of an Onshore Power Supply in the port of Copenhagen (2016–2045).

Reduction in Emissions (Tonnes)	Scenario 1 (Baseline)	Scenario 2 (High)	Scenario 3 (Low)
CO_2	59,048	117,174	45,362
NOX	1182	2346	912
Particles	19	38	15
SO_2	12	24	9

Source: [44].

However, the authors of the above-mentioned report pointed out that such investments are very capital-intensive and that positive economic effects are possible only if the investments are co-funded from public funds [44].

Bearing in mind the prospects for the development of maritime cruise shipping market in the Baltic Sea Region [54], in which an average annual growth is about 7%, seaport authorities must seek solutions to reduce the level of pollution generated by ships moored in ports.

The results of the survey conducted among ports in the Baltic Sea Region revealed (Table 4) that port authorities neither offer any special privileges for shipowners nor apply the Environmental Ship Index (ESI) when determining port fees for ships that are ecologically safe and assure lower emission rates of nitrogen oxides, sulphur oxides, and carbon dioxide. From the ports analysed, only the port of Turku declares that it respects the standards called Ship Energy Efficiency Management Plan (MARPOL VI 2012) and have introduced guidelines regarding the use of energy by cruise ships berthed in the seaport called "Clean shipping index CSI". Unfortunately, it is surprising that none of the ports analysed respect the standards of the Energy Efficient Design Index (MAPROL VI 2012). This raises the question about the reasons for such a situation? Is it caused by the lack of availability of proper investment funds or is this an error of omission?

Table 4. Seaport regulations on harmful emissions from ships.

Variables	Name of a Cruise Seaport	
	Port of Roenne	**Port of Turku**
Do you respect the standards called Energy Efficient Design Index (MAPROL VI 2012) in cruise seaports?	Not yet	Not yet
Have the port authorities worked out a Ship Energy Efficiency Management Plan (MARPOL VI 2012)?	Not yet	Yes
Have the port authorities applied the Environmental Ship Index (ESI) to assess emissions of nitrogen oxides, sulphur oxides, and carbon dioxide when setting port charges for cruise shipowners?	Not yet	No
Have the port authorities introduced any other guidelines regarding the use of energy by cruise ships berthed in the cruise seaport?	No	Yes

Source: own study.

The port authorities were also asked about the condition of electricity infrastructure available onshore to supply power to ships. It is important to know that currently on the market, there are various technical solutions to enable ships to collect energy onshore. This solution may significantly reduce harmful emissions into the environment because the ships do not need to use the energy generated by ship's engines, and thus reduce the exhaust emissions, which significantly reduce the level of noise emissions from the ship's engine room. In modern seaports, we can find various elements of the port power grid that facilitate the supply of energy from shore to ships, including cruise ships:

- Power transformers.
- Frequency converters.
- Medium voltage switchgear.
- Monitoring and power grid control equipment.
- Power grid security equipment.
- HVSC dispensers and other.

However, studies have shown that seaports in the Baltic Sea Region still have a lot to do in this area.

In the Port of Roenne, as far as components of the berth to ship electricity grid are concerned, they have only power transformers and shore-power just only dedicated to ferries, but in the Port of Turku, they offer medium voltage switchgear, safety equipment, and also an electricity grid 50Hz for one cruise vessel (Table 5). The cruise ships mooring in the Port of Turku are powered by electricity System "shore to ship" i.e., main transformer station and local stations on quay.

Table 5. Seaport readiness to provide Onshore Power Supply for cruise ships.

Variables	Name of a Cruise Seaport	
	Port of Roenne	Port of Turku
What are the components of the berth to ship electricity grid?	Power transformers	Medium voltage switchgear, safety equipment
What other elements of the electricity grid are located in the port?	No, we do not have that infrastructure	Electricity grid 50 Hz
How many cruise ships can be connected to the existing onshore electricity grid in the port at the same time?	Only shorepower–to ferries	Only one
How are cruise ships mooring in the port powered by electricity?	Standard	System "shore to ship" (main transformer station and local stations on quay);

Source: own study.

Nevertheless, the authorities in the seaports surveyed declare that they are aware of the challenges they face and plan to undertake investments to adapt the port electricity infrastructure to new market requirements (Table 6).

Table 6. Investments planned in seaports to provide Onshore Power Supply for cruise ships.

Variables	Name of a Cruise Seaport	
	Port of Roenne	Port of Turku
Do you plan any investments related to the diversification of cruise ship to shore energy supply sources?	No *	Yes
What investment activities are planned in this area?	N/A **	Reservation for Shorepower
What is the duration of these investments?	N/A	2024
What is budget planned for these investments?	N/A	N/A
What types of entities are involved in the development of electricity infrastructure for cruise ships?	State authorities, Port Authorities	Port Authorities, Private equity

* No—means that port authorities said "No"; ** N/A—means that port authorities did not answer. Source: own study.

The authorities of the Port of Turku intend to start new investments in 2024 to prepare the investment entitled "Reservation for Shorepower". The investment will be conducted in cooperation with port authorities and private equity. Unfortunately, not all ports can afford to invest in new electricity infrastructure, as such investments are highly capital-intensive, and still not all mooring ships have proper equipment to use these solutions, which also provide difficulties in estimating the return on investment.

Interesting are also the results of studies showing that seaport authorities do not monitor the sources of energy supply on ships entering the ports (Table 7).

Table 7. Seaport analysis as for the sources of Onshore Power Supply for cruise ships.

Variables	Name of a Cruise Seaport	
	Port of Roenne	Port of Turku
Is there any monitoring of the cruise seaport concerning the source of energy generation by cruise ships moorings in the port?	No	No
Are the vast majority of cruise ships berthed in the port equipped with "Onboard" devices on ships, i.e., plugs for connecting the power supply from the mainland?	No	Yes

Source: own study.

In accordance with the procedures, the owner of the ship entering the port, or their agent, notifies the port master's office about the demand for energy supply, but if the ship is self-sufficient in this respect, then these services will not be provided in the port. However, the lack of information in ports on the energy sources on ships visiting the ports makes it difficult to plan and forecast the demand for shore-side energy supply.

7. Discussion

In view of the intensifying rapid climate changes resulting from significant environment pollution and destruction of the ozone layer, actions taken to reduce the air and marine environment pollution and to save the energy seem well-grounded. In general, a number of strict regulations imposed by international organizations and institutions leave the seaport authorities no choice. Investments in Onshore Power Supply for vessels are an absolute necessity. The benefits resulting from these solutions are incommensurable. We should also emphasize the care for comfort and quality of life of local communities living near the seaports.

Connecting ships to the OPS system when they are at berth exerts an impact not only on the reduction in pollution generated by combustion engines, but also on the noise and vibrations caused by engines running on ships. The pollution resulting from fuel combustion by the engines of large cruise ships is responsible for the smog observed in many popular coastal tourist destinations, such as Venice, Marseille [55,56], Genoa, Dubrovnik, or Barcelona (Mediterranean region). Bearing in mind the protests of environmental organizations and local communities, local authorities in these cities negotiate with port authorities to reduce the number of cruise ships accepted in the ports, introduce limits on the level of harmful emissions, and provide various incentives regarding fees for shipowners providing ecological solutions on their vessels, but also support port authorities in their investments aimed to develop and modernize the OPS infrastructure. In addition, environmental organisations such as, for example, "The Friends of the Earth Organisation" monitor the level of pollution emitted by ships into the environment and regularly publish Cruise Ship Report rankings indicating which cruise lines care about the natural environment. Unfortunately, the results of their analyses are not satisfactory" [57].

8. Conclusions

Summing up, the seaport authorities in the Baltic Sea Region still face many investment-related challenges related to adapting the infrastructure to new market trends, which involve providing power supply for ships entering the ports. Sooner or later, they will be forced to provide this power either by strict regulations on limiting harmful emissions into the natural environment, or they will be forced by market laws. In the future, by reducing the ship's operating costs, cruise ship owners will expect that the ports, during the ship's several-hour stay (up to 10–12 h), will provide facilities to connect to the Onshore Power Supply System. Cruise seaports such as Copenhagen, Tallinn, and Rostock, which receive several hundred cruise ships a year, will have to face these challenges. Studies have shown that some of them have already taken actions in this respect. Seaports rendering only seasonal services to cruise ships do not see any economic justification for such investments and are not willing to invest in such infrastructure.

The results of the CAWI survey and analysis carried out led us to the following conclusions:

- Investments in Onshore Power Supply Systems are very capital-intensive and, thus, few seaports in the Baltic Sea Region have decided to invest in these solutions.
- Pre-investment analyses conducted on behalf of port authorities regarding Onshore Power Supply Systems show that such investments should be based on cooperation between port authorities, coastal city authorities, landowners, and energy supply operators, with the financial support of public institutions.
- Ports within the Baltic Sea Region are still more inclined to invest in Onshore Power Supply Systems dedicated to ferries than to cruise ships, because these investments are much more economically efficient. Such solutions have already been provided in the ports of Oslo, Helsinki, and Stockholm. This results from the fact that ferry services are provided in these ports regularly throughout the year, and not only seasonally as in the case of cruise ships. It is very important for the investment economic calculation.

- On the market, there are various technological solutions regarding Onshore Power Supply Systems, adapted to the quay technical capabilities and the seaport requirements.
- Unfortunately, still a small percentage of cruise ships in the world, only 10% of the fleet (ca. 40 vessels), are equipped with Shore Power Equipment (SPE) able to connect to Onshore Power Supply Systems (OPSS).
- Cruise line operators declare that they are interested in equipping their vessels with systems for taking energy onshore while the ships are at berth in the port for economic and environmental reasons, and on ordering new vessels, they install plug units to connect to the shorebox on land.

The review of the regulations governing the emission of pollutants by sea-going ships indicates that the issue of solving the problem is being considered at all possible decision-making levels: from the global (at the UN forum, within the IMO), through the regional (HELCOM, the European Union, including the Baltic Sea Region), to the local (maritime policies of individual countries, and port development strategies). However, the analysis of the preparation of ports for servicing ships generating lower emissions, so far indicates insufficient progress in this respect. This is due to different approaches to law enforcement. While shipowners comply with new regulations (IMO conventions) within specified deadlines, and the lack of appropriate pro-ecological solutions results in high fines, ports are not subject to such restrictive laws. As a result, ships equipped with Shore Power Equipment (SPE) cannot benefit from shore-generated energy due to the lack or insufficient infrastructure of the Onshore Power Supply (OPS). Therefore, the question arises—how to encourage (enforce) changes in port management, which are subject to ships complying with the strict provisions of the MARPOL Convention.

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