

## Article

# Clean Cruise Shipping: Experience from the BSR

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**Abstract:** The study calculates the costs of the environmental impact of cruise shipping to determine how and to what extent the cruise industry has evolved towards clean shipping in the Baltic Sea Region. While environmental regulations connect directly to emissions reduction, measures to ensure a clean shipping industry are beyond regulatory measures. The sector should be able to fully operate within an environmentally, socially, and financially acceptable structure. A holistic shipping pollution and emissions index, for example, must also include financial or economic quantification of the major environmental impacts. Thus, using empirical data collated from the industry, uncontrolled observations, and experts' interviews, we present the annual CO<sub>2</sub> emissions and the related emissions costs of a typical 7-day cruise that operates within the Baltic Sea region (BSR) as well as a waste management report from the port of Saint Petersburg. The result is a detailed energy demand and cost inventory assessment of cruise trips and their overall impact on the clean shipping campaign of the maritime industry. The focus on a BSR cruise and a port city led to realistic and reliable results since the Baltic Sea represents a well-defined macroregion with clear ports and cruising structures suitable for cross-sectoral activities.

**Keywords:** clean shipping; cruise shipping; green logistics; local sourcing; sustainability; CO<sub>2</sub>; sustainable tourism



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## 1. Introduction

Protecting the environment in principle for the cruise industry is through the management of emissions, waste from the vessels, and human interaction with the sea ecosystem. On the part of emissions, Carić & Mackelworth [1] explained that because fossil fuels remain the major bunkering energy source, the shipping industry is overly compromised. Although emissions have significantly lowered in recent years, one wonders how effective this is vis-à-vis the pressing challenge of global warming. A typical cruise vessel generates a significant amount of waste [2]. Copeland [3] estimated that around 24% of the shipping solid waste generated globally is from cruise ships. A large amount of this waste generated by passengers includes plastic, paper, wood, cardboard, food waste, cans, glass, and a variety of other waste disposed of by passengers. Usually, collectively, they result in about 3.5 kg of solid waste per day per person [4].

There has been a lot of reflection on clean or green tourism owing to the increased discussion on global warming and environmental challenges around the globe. However, as with all subsectors of the shipping industry, there is a need to reduce the conspicuous research gap of ecological and financial quantification of environmental impacts, specifically, the operational impacts and the technical impact (i.e., infrastructure, ship design, etc.) [5]. Most of the research on the cruise industry has mostly focused on either one of the two main streams—ecological issues or marketing/financial aspects. Until now, not much work has been done for impact assessments of the existing tools or instruments for green/clean

shipping. This applies especially to the ecological–economic assessments of passengers’ volume in cruise shipping.

To help bring this to focus, the European Commission issued a detailed “Blue Growth” strategy [6–9] directed at providing long-term sustainability of growth of aquaculture, biotechnology, coastal and maritime tourism, fishery, mineral resources, offshore oil and gas, renewable energy, shipbuilding, and ship repair and transport. Consequently, as more environmental rules are enforced to safeguard the environment, the economic aspect is being compromised in many ways—internally for the companies or externally for prospective customers and maybe for ports and port cities [10].

Accordingly, the research focuses on the economic aspect of sustainability as it interweaves both the ecological and social aspects of clean cruise shipping within the Baltic Sea region (BSR). The attention to the BSR region is because not only are there financial and emissions figures that are reliable and official, but also because thematically, the BSR has a strong cruising standard due to the strong influence from the European Commission.

Mainly, the authors analyzed the environmental and economic impact of green tools used in cruise shipping. Specifically, the study includes a detailed energy demand inventory assessment of the annual CO<sub>2</sub> emissions demand of a typical 7-day cruise along with 24 different transportation combination scenarios. It also conducted an economic impact assessment of waste generation in a classic port city. To achieve the study objectives, the authors examined the research questions of what is the ecological and economic impact of cruise shipping in the BSR and to what extent the distance of cruise supply influences the economic and ecological balance of clean cruising.

The official Baltic Marine Environment Protection Commission (HELCOM) [11] emissions inventory for the BSR port data comprising annual numbers of calls, passengers, and roundtrips was analyzed. In addition, the study explored data from the Cruise Line International Association (CLIA) [12,13] reports on the global organization of the cruising industry to study the impact of cruise shipping activities on the environment.

To show how this manifests in the economic dimension of cruise ships and port cities, the authors used the case of a cruise vessel operating in the BSR—a Sphinx-class cruise ship. This particular cruise ship operates mostly around the BSR. To have a balanced emissions calculation for the whole cruise, the authors considered the cruise supply logistics that includes food (mostly perishables), beverages, and toiletries to the cruise ship. Lastly, experts’ interviews and port documents from Saint Petersburg were examined to determine the impact of cruise shipping on the port and port city paying particular attention to waste generation and management by the port. It is worth noting that, while the port of Saint Petersburg is one of the leading cruise ports in the BSR, the impact of cruise shipping on the quality of the environment in Saint Petersburg as a port city remains largely unexplored. The port of Saint Petersburg hosts ocean liners from the world’s leading cruise and passenger companies. Thus, the motivation to study ship emissions, onshore emissions, and waste caused by cruising operations in the BSR highlights an important issue in clean shipping that represents a vital subsector of sustainable tourism.

The remaining part of the work is presented in the following way. The next section gives a detailed account of the cruise industry, its environmental impact, and the roadmap to sustainable clean activities. The third section details the methodology used in the study; the fourth section highlights the results and their analyses. The fifth section of the article discusses the key theoretical and policy implications around cruise shipping and its sustainability generated from the study, while the last section concludes the study.

## 2. Literature Review

Before World War II, cruising, or rather sea travel was only popular among the elites, but there was a shift after 1945 where more people started preferring air travel, causing a decline in sea travel. It was only after the end of the 20th century that sea travel revived with exponential growth. Ever since, the world has witnessed bigger and cutting-edge ship designs, efficient and more luxurious ships around the world [14].

Cruising is a leisure floating trip specifically tailored towards relaxation and sightseeing on the sea, which can be short or long depending on the destination [15]. A popular subsector of the global tourism industry [16] and an important player in the global economy, the cruise ship industry contributes about 10.4% of the gross world product, making it directly responsible for one out of every ten jobs globally [17]. Many cruise activities use multiple ports and visit different countries in a single voyage so their contributions to global economic growth are very important [18].

Cruise tourism has been in a winning competition with traditional tourism because of human desire and longing for the intrinsic benefit and psychological outcomes of cruise experiences embedded in relaxation, learning, self-reflection, and family leisure [19]. In short, the essence of cruise tourism is the creation of an opportunity to escape the regular familiarity for an “exotic” or “luxurious” perspicacity [20].

The Mediterranean and the Baltic Sea region (BSR) are choice destinations for many cruise tourists; vessels with 500 to 1500 passengers capacity make up about 63% of the total number of these exotic destinations [21]. Passengers spend considerable time on-board during cruise trips, which explains why cruise lines give considerable thought to the infrastructures they provide on-board. In addition, for many passengers, their expectations are not so much of the destinations but rather their experience while on the ship. Many times, destinations serve as a break for each cruise voyage; although most would argue that the services or experiences offered on-board are structured to fill the monotonous long hours spent aboard, this, arguably, may not always be the case.

In North America and Europe, the Caribbean and the Mediterranean cruises are considered lucrative, although it seems that the North American markets are becoming slightly saturated. For example, Weeden, Lester, and Thyne [22] reported a decline in the growth rate for leisure adventure in the North American market, which used to be recognized as one of the biggest destinations in the world, although this may be attributed to the quest of finding new routes to delight clients. On the other hand, the European market has steadily increased its market share from 21% to 30% within a short period, while the United States cruise market experienced a decrease and dropped from 70% to 56% in the market share. Against all odds, the European cruise industry grew in a span of 10 years (2007–2017) from 4.05 million to 6.96 million euros [12], far exceeding all existing forecasts. Besides this, the prediction of 25 million passengers by 2019/2020 was also surpassed, and the current figures show that as of 2017, the number of passengers was already over 25.4 million. Furthermore, as experienced in Europe, other parts of the world, especially the Asian cruise market, also experienced growth [10]. It seems the whole world is on an exploratory and exciting journey through cruising *savoir-faire*.

In 2018, cruise shipping alone was estimated to have generated approximately over a million jobs across the globe; 2019 ushered in a year where about 18 megaships were built for cruising, estimated to increase at 3.3% every year until 2030 [23]. Although its growth has been temporarily slowed down by the COVID-19 pandemic, judging by the pre-COVID-19 yearly growth, the situation promises to change as soon as the pandemic is overcome and passengers can access exquisite packages that allow them to cruise all over the world.

Surprisingly, the BSR, despite being one of the flagships of sulfur emissions restrictions, had a significant increase in cruise tourism. In 2019, the leading tourist ports in the BSR per passenger numbers were the ports of Stockholm (656,400 passengers), Tallinn (656,100 passengers), Saint Petersburg (643,100 passengers), and Helsinki (603,500 passengers) [24]. The growth cruise lines enjoy is somewhat attributed to its contribution to improved demand configuration for many destinations [25].

Cruising, from a marketing point of view, easily sways and lures prospective customers with the idea of green. The guests are made to see their adventures from the point of nature, the vast sea, endless sun, and wind as a breath of fresh air [20]. However, when examined closely, it becomes noticeable how far this could be from the truth. This discrepancy in

customers' expectations throws in a complexity to the industry tied to the demand and supply sides of the sector [22]

Because cruise ships move from one place to another, they provide hotel-like amenities that are highly energy-intensive [26,27], making cruising the most energy-demanding form of tourism [28]. At a closer look, the energy need for each voyage is rather high when calculated per person [15]. This is undoubtedly a negative outcome of this boisterous sector. While land-based transportation generates quite an amount of energy, as with other shipping activities, there is a distinctive challenge when we consider the astronomical amount of energy demand per passenger plus the crew for cruise ships [2]. Moreover, the ecological effect of cruise tourism further affects plants, animals, land use, water [15]. Thus, whilst providing luxurious comfort for passengers, repeated cruising shipping activities are detrimental to the biodiversity in seawaters through ship discharges, ship hull coatings, and the anti-fouling systems applied to prevent rusting and attachment [29]. Even with the argument of environmentally friendly products used as protective treatment, we cannot rule out the possible harmful effect they would have in a long run [30].

International cruise traffic especially contributes considerably to the energy challenge at the most densely trafficked shipping lanes, especially prominent hotspot tourist destinations. Jalkanen, Johansson, and Kukkonen [31] compared 16 flag state fleets based on their emissions, and their results show that the highest emissions from cruise ships were from European fleets (at 55%). As expected, the highest concentrations of emissions are around the busiest coastal countries (i.e., the Netherlands, Belgium, and in the English Channel (e.g., Antwerp, Rotterdam, and Amsterdam), in the straits of Gibraltar, Sicily, and Bosphorus, and the Danish Straits, Gibraltar, Saint Petersburg, and some ports in the UK, Germany, Italy, and Spain. Lately, more ships are built with environmental and green considerations [14], usually tying their market value and competitiveness to environmental sustainability efforts [32].

Along these lines, waste management is another pertinent issue to consider. Advancement in technology is noticeable not only in emissions reduction, but also in waste management. Most cruise ships already adhere to international guidelines on waste management systems, especially in reducing the amount of waste generated on-board [33]. Furthermore, a sewage treatment system can treat up to 7 gallons of sewage and 90 gallons of greywater per passenger/crewmember daily [2]. Sadly, a typical 3000 passengers capacity ship generates up to about 50 tons of solid waste every week and an average of 50 tons of sewage (blackwater) per day [34]. A ship twice that size will generate no less than twice the amount of waste. Although many cruises incinerate their generated wastes, they, unfortunately, let them back into the water during each voyage [25,35].

The maritime industry's institutional response to shipping pollution has been policy-based. For example, the EU successfully restricted a considerable amount of emissions from shipping in general with a positive health impact within the sulfur emissions areas [33,36]. The current focus of the International Maritime Organization (IMO), given the global climate change, is to reduce the greenhouse gas (GHG) emissions from ships by at least 50% by 2025 [37]. However, policy changes are expensive and lead to increased costs for all actors across the industry [31].

In the quest for compliance solutions to regulatory changes, the choice between the use of a cleaner fuel like marine gas oil (MGO), nonfossil fuels, and abatement technologies has always been a major tug of war among shipowners who must make suitable and profitable strategic choices [38]. Currently, nonfossil fuels are a new rage; abatement solutions or gas oils are, however, better solutions for older vessels to avoid the costly demands of engine modifications [37]. This is why old vessels will still be operating some years down the line. The good news is that because of rules like the SECA, ship traffic is better accounted for through the mandatory automatic identification system (AIS) that generates automatic emissions reports on activities of all the registered ships, including their geographical spread and patterns [31,39].

Factoring in the UN Brundtland Report [40] on best practices and sustainability helps to justify the expensive regulatory demand because the report focuses on mitigating the negative impacts of these activities on the economy, society, and the environment. These practices in principle would embed everyday operational, social, and environmental activities of the cruise ships, their passengers, the ports, the host communities, as well as the sea [41]. The understanding of each factor as it relates to every other factor is the strategic route to addressing sustainable goals.

Looking at the concept of the industrial ecology theory which centers on the management of resources for human development, their adaptation, and sustainable environment, it is clear that the unification of interactions between humans, industries, and the environment is based on how science and technology are applied to everyday events and the environment. Thus, the physical, biological, as well as social laws should guide the dependency of the cruise industry (which by itself is an ecosystem) on the other ecosystems [10]. There should be coherent connectivity between the social, economic, and ecological targets, which should be alongside active participation and responsibility of different stakeholders [21]. Passengers must also begin to place strong environmental demands on cruise companies [14]. This way, we can achieve a wholesome equilibrium between cruise shipping ecosystems and the related ecosystems, taking into consideration the interdependencies between the principles of protecting the environment, improving economic activity, and ensuring social equity [42].

Additionally, considering their huge influence on controlling the international shipping traffic, ports need to take a huge responsibility for emissions reduction for metropolises or hinterlands that are the major destinations for cruises. Many works (e.g., [25,37,38,43]) have placed emphasis on impactful port development entrenched in infrastructural investments in green technologies and tools that provide nonfossil fuels and electricity to generate the onshore power supply (OPS) when ships berth. They insist that this is the only way ports can control and tackle incoming and outgoing emissions generation—at least around their coastal regions [44]. While these works have supported the disbursement of these green tools (i.e., cleaner fuels, OPS, e-buses), their long-term ecological and economic impacts are still grossly missing in the literature. The same applies to the impact of cruise shipping logistics on the total shipping emissions.

The demand and supply of essentials on cruising ships are customarily forecast to prevent unnecessary deficit, obsolescence, and expiration of products. Seasonality of some products as well as products that require special transportation such as freezers often makes the supply chain requirement for cruise shipping complex and time-constrained [45]. Thus, the integration of ports and supply chains should be greatly explored by any forward-thinking cruise line [46] bearing in mind product consistency, food safety, and quality control [24]. Improving corridors by integrating port systems with green multimodal transport systems is a rewarding effort that will improve the effect of short cruises [47].

So far, regarding cruising and shipping, there are many instruments for green shipping introduced and used. There are ongoing debates regarding the ecological and economic impact of these instruments, but there has been no holistic analysis of the use of these instruments under different scenarios on the passenger level. There is no clear direction on what is most important. The impact performance versus the price ratio is yet to be thoroughly examined. The lingering question in most works has been, which indicator is right for the industry?

A responsible “best practice” ensures that the world keeps evolving. The pace of growth needs to be strategically nurtured to include all shipping operations or the after-effects and must be spread to reach the host community, the port, and, especially, the guests or passengers [2,48,49]. As long as cruise lines focus on the required aspects of economic, environmental, and cultural integrity preservation, sustainable tourism can be achieved [10]. The integration of cruise activities within a set period together with the related carbon footprint to analyze costs of the environmental impact of cruise shipping will

provide a plausible and indicative economical index to quantify emissions data that will guide the formation of precautionary measures and strategies for directional policymaking.

### 3. Methodology

#### 3.1. Instrument and Materials

For this study, a special attention regarding clean shipping for a 7-day cruise was given to two major points of emissions: the sea (emissions from ships) and the ports and port cities (emissions from ships, excursion buses, and supply logistics).

One important cornerstone for the emissions inventory for maritime traffic in the BSR was the HELCOM study [11] that monitored the AIS data of ship emissions comprising specific data of cruise ships. The study used the 2015/2016 report, which is the latest report on BSR emissions. Together with statistical information from the Cruise Baltic Market Review 2000–2021, Delft reports as well as study results from the CLIA [12,13] laid the ground for detailed updated data and further enables the designation of an empirically validated CO<sub>2</sub> footprint for cruise tourism in the BSR. The financial figures, especially from the CLIA, represent the business organization of the cruising industry from all over the world. These figures comprise direct information from cruise lines aggregated to financial data, taking into account the average values over all cruise lines. Expert interviews and case studies from different parts of the BSR empirically validate all estimations.

A case study of a cruise ship built in 2009 at Meyer Werft, Germany, was used to calculate the average CO<sub>2</sub> emissions using different operational scenarios. To triangulate and benchmark all the results, the authors carried out interviews with maritime and port experts in five major ports, namely ports of Rostock, Hamburg, Tallinn, Turku, and St Petersburg. These are major ports with some of the highest cruise passenger flows around the BSR. Based on their impact, i.e., how closely they are related to the cruise sector, the authors chose shipping companies and ports as the target points of interviews. Stakeholders within the executive levels of management were interviewed because they are a core part of the everyday decision process in most organizations. In total, ten expert interviews were carried out between August and December 2020. All the calculations were made in US dollars.

#### 3.2. Data Measurement and Analysis

According to the HELCOM [11] report on the emissions and fuel consumption inventory for the BSR, the total annual CO<sub>2</sub> emissions from cruise ships in the BSR are as shown in Table 1.

**Table 1.** Emissions data for cruise shipping.

Parameter	Figure
Total CO <sub>2</sub> emissions from cruising	463,000 tons of CO <sub>2</sub>
Fuel consumption	a. Main engine fuel: 121,000 tons b. Auxiliary engine fuel: 24,000 tons
Traveled distance	1,278,000 km
Number of cruise ships	93
Number of roundtrip cruises	403
Number of cruise port calls	2157
Average passengers per call	1986
Total cruise passengers	4,282,807
Total annual cruise guests	800,172
Average Baltic cruise duration	7-day cruise

The current study defines a “call” of a ship as the number of the ship entering a port, i.e., the number of calls in a port is the number of ships visiting that port. A call is called a turnaround if the passengers leave the ship at the port and new passengers board the ship. The cruise industry further differentiates between cruise passengers and cruise guests. A cruise guest is a person buying a cruise trip. However, since a cruise includes visits to

several cities and ports, the guest is counted as a passenger for each visit to a port or a port city (one passenger visit). In other words, if a cruise guest stays on the ship for 7 nights and visits five cities/ports, he or she is counted as one guest, but as a passenger—five times with seven bed-days (on-board the ship).

Considering these clarifications together with the available statistical data from HEL-COM [11], the authors calculated the number of annual cruise guests to about 800,172 cruise guests since the emissions inventory reveals that BSR cruising represents only a half-year business because the main period of cruise ship operations is limited to the time between April and October.

In addition to the emissions inventory and the data on ship operations and guests, it is also important to consider financial data related to cruise emissions. A solid base is the financial assessment of the CLIA [12,13] that reveals a financial breakdown of revenue and expenses for an average guest on a 7-day trip. This data covers a typical universally operating cruiser across all ocean cruise lines in the following structure (Table 2):

**Table 2.** Financial breakdown per guest on a 7-day trip of an average operating cruiser.

		Revenue in US\$	
Tickets		1217.00	
Onboard spending		497.00	
—Casinos and bars		273.00	
—Shore excursions (cruise line portion)		99.00	
—Spa		50.00	
—All other onboard spending		75.00	
Total spending		1714.00	
		Expenses in US\$	Percentage of spending
Other operating costs		249.00	14.5%
Agent commissions		23.00	13.0%
Ship fuel costs		185.00	10.8%
Corporate operating costs		199.00	11.6%
Payroll		189.00	11.0%
Depreciation/amortization		165.00	9.6%
Victualing (food)		103.00	6.0%
Onboard and other costs		75.00	4.4%
Other costs and transportation		57.00	3.3%
Interest expenses		53.00	3.1%
Total expenses		1564.00	
Profit before taxes		218.00	12.7%

Equipped with the above itemization, it becomes possible to evaluate financial figures together with their underlying operational activities linked to CO<sub>2</sub> emissions. The approach to the calculation of the total CO<sub>2</sub> emissions from cruising in the BSR is realized through the CO<sub>2</sub> emissions in the direct ship's emissions (from the main engine and the auxiliary engine), excursions, and supply logistics. It is also worth noting that CO<sub>2</sub> emissions per passenger and a 7-day trip are considered for the operational carbon footprint for a cruise trip comprising all cruise operations, including also ship construction.

Through the decision matrix approach, the authors used the case of a cruise ship activity to create 24 cruise scenarios of CO<sub>2</sub> emissions and calculate the average CO<sub>2</sub> emissions from different source combinations to evaluate both ecological and economic impact of clean cruise tools and instruments. The decision matrix rules are best used for the decisions taken under objective uncertainties [50].

The case vessel operates in the BSR and carries about 2000 cruise guests. The technical data reveal a length of about 250 m, a width of about 32 m, and a draught of about 7.5 m. These dimensions are typical of BSR cruise vessels because it this optimal size is suitable for the geographical location of the BSR's narrow and shallow waters [51]. Usually,

during summer, half-year cruise trips are offered within the BSR, while outside the season, companies operate in other cruise areas. All cruise calculations are based on a full 2000 cruise guests on-board capacity for a 7-day cruise voyage.

For additional environmental impact, the authors considered port waste and its management using the port of Saint Petersburg, a popular cruise destination in the BSR.

## 4. Results

### 4.1. CO<sub>2</sub> Analysis: Excursions and Logistics

The costs of excursions and supply logistics are based on the CLIA data on the average spending for cruise excursions that leads to an average value of US\$100 where 20% of this cost is allocated to the bus transfers from the port to excursion targets. According to Table 1, the total number of cruise passengers is 4,282,807 persons. This number represents the sum of all cruise passengers registered in Baltic ports. Interviews with experts from different BSR cruise ports revealed that about 80% of these cruise passengers participate in organized excursions using bus trips. On average, one bus trip consists of a 2 h ride, i.e., 1 h from the port and 1 h back to the port, so that the additional total CO<sub>2</sub> emissions stemming from excursions sum up to 6 852 tons of CO<sub>2</sub> of bus trips executed by diesel buses as calculated in Table 3.

**Table 3.** CO<sub>2</sub> emissions from port city excursions.

Number of calls	2157	
Passenger port calls	1986	
Total passengers	4,282,807	
80% excursions	3,426,246	Representing 80% of passengers for excursions
1 kg CO <sub>2</sub> /1 h bus	6852	CO <sub>2</sub> tons for 2 × 1 h bus excursions of passengers

To calculate the green impact of local or remote/long-distance sourcing, the authors based the emissions analyses of the supply logistics on the STREAMS study of Otten et al. [52] together with the experts' interviews that revealed that per guest of a 7-day cruise trip, 50 kg of supply are delivered. Individual supply is usually transported with trucks once directly to the berth at the starting port of the 7-day leg of the cruise.

Thus, a ship with about 2000 passengers requires approximately 50 kg of food per passenger (usually received once per cruise trip) for a 7-day voyage which translates into about 6–8 truckloads of food supply. All transported goods are sourced from local destinations or farther hinterland depending on the supply chain strategy of the cruise line. Since this supply consists mainly of food, the authors assume on the basis of cruise lines documentation an average supply distance of 60 km from the berth. Cruise guests generate about 1200 t CO<sub>2</sub> emissions from supply logistics. The same calculation was made for the supply distances of 20 km and 100 km from berth to cover situations where supplies are made from closer places or farther hinterlands executed by diesel trucks itemized in Table 4. The distances are derived from the average speed of supply and their impact on the costs and ecological balance of clean cruising. Cycles around the harbor and their distances were calculated. For example, 60 km equal 1 h of delivery time, 100 km represents 2 h, and 20 km makes 30 min of delivery time.



**Table 4.** CO<sub>2</sub> emissions from supply logistics.

Roundtrips	403	
Average number of guests per call	1986	
Cruise guests	800,172	
Kg supply/guest	50	
Total supply (tons)	40,009	—Guests × supply/1000
0.5 kg CO <sub>2</sub> /tkm	0.5	—Kg CO <sub>2</sub> /tkm for truck logistics
Tons of CO <sub>2</sub> (logistics)/km	20	—CO <sub>2</sub> per km for hinterland supply
60 km CO <sub>2</sub> logistics	1200	
20 km CO <sub>2</sub> logistics	400	
100 km CO <sub>2</sub> logistics	2000	

#### 4.2. Ship CO<sub>2</sub> Analysis: Cruising Carbon Footprint

Summing up the total cruise shipping CO<sub>2</sub> emissions will result in around 470,000 tons of CO<sub>2</sub> considering the emissions on the guest level (i.e., 590 kg CO<sub>2</sub> per 7-day trip), or about 84 kg per day and guest during a cruise trip. The CO<sub>2</sub> emissions of 590 kg per guest and 7-day trip, i.e., direct ship's emissions from the main engine and the auxiliary engine (including the ship's construction), excursions, and supply logistics are considered as the operational carbon footprint for a cruise ride comprising all cruise operations. The underlying data for the calculation of the operational carbon footprint are depicted in Table 5.

**Table 5.** Total CO<sub>2</sub> emissions from a 7-day cruise.

Sum tCO <sub>2</sub>	472,423	
Cruise guests	800,172	
Tons of CO <sub>2</sub> per guest	0.590	—Per 7-day trip
Kg CO <sub>2</sub> per guest	590	—Per 7-day trip
Kg CO <sub>2</sub> per guest	84.34	—Daily footprint

The result of 590 kg of CO<sub>2</sub> emissions per guest during a 7-day trip from the HELCOM emissions inventory together with the official cruise guest statistics of the BSR is further compared to earlier values that could be found in the scientific literature. Walnum [53] came in his calculations in the Vestforsk report from 2011 to the daily CO<sub>2</sub> emissions per passenger on a cruise ship of 169 kg CO<sub>2</sub>, which is about twice as high as the current study figures. Reasons for the different carbon footprint values can be due to more energy-efficient technologies, different ship types, and a lower average number of cruise guests.

The next step in the study is dedicated to the financial evaluation of CO<sub>2</sub> emissions to find relationships between emissions and energy costs to be able to assess the efficiency of emissions reduction measures. As itemized in Table 6, to monetize the carbon footprint outcome, the authors based their calculations on the overall average financial breakdown for a 7-day cruise, part of which is the fuel cost that accounts for US\$185 per cruise guest. By multiplying this figure by the total number of cruise guests from the data (i.e., 800,172), the total fuel costs related to BSR cruising is about US\$148 million for a 7-day cruise, whereby the fuel cost for the auxiliary engine amounts to US\$24 million, and the remaining fuel cost for the main engine is approximately US\$124 million.

**Table 6.** Fuel costs per week.

Fuel cost per guest	\$185.00
Annual cruise guests	\$800,172
Total fuel costs	\$148,031,839
Auxiliary auxiliary costs	\$24,214,524
Main engine costs	\$123,817,315

#### 4.3. Economic Evaluation of the Environmental Impact of Cruise Shipping

To calculate the environmental impact of CO<sub>2</sub> emissions, the authors constructed 24 cruise scenarios for different ships' propelling and energy supply. The remaining transportation options are related to excursion diesel buses or e-buses as well as supply logistics with a truck in a range distance of 20 km, 60 km, and 100 km. All supply transports are assumed to take place at once from the starting port of the 7-day trip. This supply consists of 50 kg alimentation per passenger for each week. The scenarios were evaluated using their CO<sub>2</sub> emissions and their corresponding costs. Elaborating and assessing all the considered options is Table 7 that expresses the all possible transportation combinations related to CO<sub>2</sub> emissions:

**Table 7.** Scenarios of restricted CO<sub>2</sub> emissions.

Scenarios	Ship	Excursion	Logistics (km)	Scenario Combinations
1	MGO	bus	60	n-n-n-nL
2	LNG	bus	60	n-OL-n-nL
3	MGO/OPS	bus	60	LNG-n-n-nL
4	LNG/OPS	bus	60	LNG-OL-n-nL
5	MGO	e-bus	60	n-n-eB-nL
6	LNG	e-bus	60	n-OL-eB-nL
7	MGO/OPS	e-bus	60	LNG-n-eB-nL
8	LNG/OPS	e-bus	60	LNG-OL-eB-nL
9	MGO	bus	20	n-n-n-sL
10	LNG	bus	20	n-OL-n-sL
11	MGO/OPS	bus	20	LNG-n-n-sL
12	LNG/OPS	bus	20	LNG-OL-n-sL
13	MGO	e-bus	20	n-n-eB-sL
14	LNG	e-bus	20	n-OL-eB-sL
15	MGO/OPS	e-bus	20	LNG-n-eB-sL
16	LNG/OPS	e-bus	20	LNG-OL-eB-sL
17	MGO	bus	100	n-n-n-IL
18	LNG	bus	100	n-OL-n-IL
19	MGO/OPS	bus	100	LNG-n-n-IL
20	LNG/OPS	bus	100	LNG-OL-n-IL
21	MGO	e-bus	100	n-n-eB-IL
22	LNG	e-bus	100	n-OL-eB-IL
23	MGO/OPS	e-bus	100	LNG-n-eB-IL
24	LNG/OPS	e-bus	100	LNG-OL-eB-IL

Notes: n: normal bunkering/marine gas oil; LNG: liquefied natural gas; eB: electric bus; OL: on-shore power supply; nL: 60 km; sL: 20 km; IL: 100 km.

Thus, all calculation conditions are set to real-life situations and are crosschecked by document reviews, observations of schedules of different cruise lines together with expert interviews as elucidated in the methodology section.

The CO<sub>2</sub> emissions and costs baseline scenario (i.e., scenario 1) reflects the situation in the HELCOM report that is defined by MGO-fueled ship engines, diesel buses for excursions, and supply logistics delivered by diesel trucks within a distance of 60 km between the suppliers and the berthed vessel.

Emissions costs are a sum of the price of tickets purchased by all cruise guests for fuel and other fuel-related costs from excursions and supply logistics. By taking into account the given data, the annual baseline values came to 472,423 tons of CO<sub>2</sub> emissions and a total cost of US\$228,919,410. The authors calculated the values of the remaining 23 scenarios under the following frame conditions:

- LNG as a marine fuel has 20% less CO<sub>2</sub> emissions than MGO;
- OPS is available only in ports and during sea days. Full green electricity production with zero CO<sub>2</sub> emission for OPS use;
- A typical 7-day cruise consists of five port days and two sea days;

- Like in the case of OPS use, it is assumed that the use of e-buses is CO<sub>2</sub> emissions-free. Thus, the electricity for the two technologies (OPS and e-buses) is generated from nonfossil energy (which is only true for a few ports in the world since the majority of electricity plants use coal or oil for energy production);
- CO<sub>2</sub> emissions for the supply logistics are evaluated by the distance of the supply trucks deliveries starting from a standard 60 km (city/usual logistics) to distances of 20 km (closer supply) and 100 km (hinterland supply). The corresponding CO<sub>2</sub> emissions are taken from the STREAMS study [51];
- The costs LNG and OPS use are assumed to be double the costs of MGO, which is in line with the investment cost (CAPEX) and the operating costs (OPEX) for both energy types. In addition, both LNG and OPS technology require additional technology and installation on-board that would reduce passengers' space and cargo space and thus yielding opportunity costs;
- E-buses are also assumed to generate double costs compared to diesel buses by taking into account the investment cost (CAPEX) as well as the operating costs (OPEX) found in the 2018 studies of transport and environment [54];
- The financial evaluation of supply logistics depends on the distance to the berth and takes into account different levels of food prices depending on the considered logistics source, e.g., in a city, the price of food is higher than in the hinterland because logistics costs usually include sophisticated stocking, packaging, and handling.

By elaborating and assessing all 24 scenarios of CO<sub>2</sub> emissions and their costs, the authors came to the following scenario table expressing the annual CO<sub>2</sub> emissions and their costs for various transportation combinations in the BSR.

The first view of Table 8 reveals that the classical situation described in scenario 1 has the highest CO<sub>2</sub> emissions, but also represents the scenario with the lowest costs. Other quick observation shows that the use of OPS in ports has a significant influence on CO<sub>2</sub> emissions and reduces port emissions by about 25%. While LNG/OPS combinations achieve the lowest CO<sub>2</sub> emission values, these combinations also produce the highest ticket costs for cruise passengers. Another close look at the table shows that scenarios 8 and 16 with the lowest CO<sub>2</sub> emissions involve LNG-propelled cruise ships that use the service of onshore power supply, execute their excursions with an electric bus, and source the supply locally. However, the précis of this outcome is that the low emissions scenarios yield the highest costs that are nearly double the classical situation of MGO and diesel buses.

The authors further used the scenarios to execute a regression analysis between the daily CO<sub>2</sub> emissions and the related daily costs per passenger to evaluate the costs for CO<sub>2</sub> emissions. The regression analysis between the costs and emissions reductions delivers a relationship of a decrease of 573 kg of CO<sub>2</sub> for each US\$1000 invested into reduction measures. The goodness of fit  $R^2 = 0.58$  and the  $p$ -value of the regression is less than 0.1 permille, i.e., 0.1‰. By taking into account these results, it becomes possible to assess the impact of "green" price increases on CO<sub>2</sub> emissions. Here, the consideration is that the full price increase would be used for emissions reductions investments. Under this condition, the calculations yield an increase of 5%, or about US\$60, of the ticket price for an average 7-day cruise resulting in a CO<sub>2</sub> reduction of about 30% in the current circumstances. However, the open question is how much clients are willing to pay extra for greener cruise shipping. It is known that those companies which were considered green in the client perception were able to generate a 5–10% additional turnover due to their green company image with an average value of an additional 7.7% for the logistics and travel sector [55].

**Table 8.** Scenario table of CO<sub>2</sub> emissions costs.

Scenarios	Combinations	t CO <sub>2</sub>	Costs
1	n-n-n-nL	472,423	\$228,919,410
2	n-OL-n-nL	396,463	\$253,133,933
3	LNG-n-n-nL	394,741	\$352,736,724
4	LNG-OL-n-nL	318,781	\$376,951,248
5	n-n-eB-nL	465,570	\$297,444,322
6	n-OL-eB-nL	389,610	\$321,658,846
7	LNG-n-eB-nL	387,888	\$421,261,636
8	LNG-OL-eB-nL	311,928	\$445,476,160
9	n-n-n-sL	471,623	\$241,282,069
10	n-OL-n-sL	395,663	\$265,496,592
11	LNG-n-n-sL	393,941	\$365,099,383
12	LNG-OL-n-sL	317,981	\$389,313,907
13	n-n-eB-sL	464,770	\$309,806,981
14	n-OL-eB-sL	388,810	\$334,021,504
15	LNG-n-eB-sL	387,088	\$433,624,295
16	LNG-OL-eB-sL	311,128	\$457,838,819
17	n-n-n-IL	473,223	\$222,738,080
18	n-OL-n-IL	397,263	\$246,952,604
19	LNG-n-n-IL	395,541	\$346,555,395
20	LNG-OL-n-IL	319,581	\$370,769,919
21	n-n-eB-IL	466,370	\$291,262,992
22	n-OL-eB-IL	390,410	\$315,477,516
23	LNG-n-eB-IL	388,688	\$415,080,307
24	LNG-OL-eB-IL	312,728	\$439,294,831

#### 4.4. The Carbon Footprint from Cruise Ship Construction

Using a case of a lightweight cruise ship of about 26,000 tons and by assuming 1850 kg CO<sub>2</sub> emissions for each ton of the ship, the calculation comes to a total sum of CO<sub>2</sub> footprints for all the 93 cruise ships in the BSR to around 4,473,300 tons of CO<sub>2</sub>. The normal lifetime of a ship is about 20 years, and by taking into account the half-year operation within the BSR, it comes to an annual 112,000 tons of CO<sub>2</sub> emissions in the ship construction. Thus, the bound CO<sub>2</sub> amount per guest for a 7-day trip is about 140 kg. Accordingly, the gained results per BSR cruise guest and a 7-day trip are as follows:

- Operations CO<sub>2</sub> per guest: 590 kg CO<sub>2</sub>
  - Construction-bound CO<sub>2</sub> per guest: 140 kg CO<sub>2</sub>
- Total CO<sub>2</sub> emissions per cruise guest: 730 kg CO<sub>2</sub>

These data can be considered as a holistic CO<sub>2</sub> footprint for BSR cruise guests for a 7-day trip or, equivalently, a daily total carbon footprint per cruise guest of 104 kg of CO<sub>2</sub> emissions. These figures are benchmarked with earlier studies of Hoffmann, Van Hoey, and Zeumer [56] as well as with CO<sub>2</sub> footprints from other parts of the cruise world.

#### 4.5. Environmental Impact of Tourism on Port Cities: The Case of the Port of Saint Petersburg

On the basis of experts' interviews and official document reviews of the Saint Petersburg State Treasury's Agency on External Transport, the authors gathered that at the Marine Terminal, 68 ship calls were made with 165,790 passengers from March to September 2019. However, in 2019, the passenger port of Saint Petersburg received 265 cruise liners, on board of which over 600,000 passengers arrived in Saint Petersburg. The number of days of maximum loading where 5–7 ships simultaneously docked at the port was 29. The number of vessel days was 510. Passenger turnover accounted for 1,104,479 passengers. In the same year, the number of passenger operations was 2,194,993. There are no official figures for 2020/2021 yet.

In previous years, the ports predicted an increase in traffic flow and made deliberate preparations. As of 2009, the capacity of the sewage reception facilities at the port of Saint Petersburg was about 1000 m<sup>3</sup> per day. In 2010, due to the port's infrastructure

expansion, the capacity of sewage collection increased to 2700 m<sup>3</sup> per day. By 2011, after the completion of terminal construction and putting into operation of two new quays, the capacity of sewage collection further increased to 4745 m<sup>3</sup> per day. This has been serving the port until now.

Experts' interviews also reveal that in the port of Saint Petersburg, an astronomical 40,947 m<sup>3</sup> of sewage was generated by cruise ships in 2017. This figure is 50.5% higher than the 27,207 m<sup>3</sup> sewage generated in 2016, implying that an increase in waste generation is equally proportionate to an increase in cruise tourism. By 2019, reception of wastewater and special ship waste from passenger ships consisted of 49,683 m<sup>3</sup> of domestic wastewater and 3059 m<sup>3</sup> of special ship waste. In 2018, the Baltic Marine Environment Protection Commission [57] acknowledged that the port of Saint Petersburg has adequate sewage reception facilities.

The triangulation of the results from the cruise ship, logistics, and tourist services provided at the port of Saint Petersburg shows a comparable outcome. Tourists arriving on cruise ships use mainly diesel buses to commute to sightseeing spots and choice places for food consumption. The average length of a bus trip to one destination is 40–60 min. During the average stay of 32–48 h, tourists use bus transportation for approximately 170 min.

## 5. Discussion

The most expensive scenario from the result has the best CO<sub>2</sub> emissions reduction, but the cost is nearly two-thirds more expensive than the original price when added to the cost of the cruise. While the study considers the reduction of cruise shipping CO<sub>2</sub> emissions, passengers might have to dig deeper into their pockets to make this happen, although, according to the figures of this study, the energy needed for each passenger is rather "low," which is advantageous in an ecological sense. In addition, on the emissions level, the emissions generated by a cruise ship are considered lower when compared to other ships like containers, dry and liquid bulk ships. Still, according to Polat [21], emissions and energy demand from cruise ships could be up to 50% of local emissions, partly because cruising is heavily invested in on-board hoteling, which uses a staggering amount of energy. Moreover, we might want to consider the regular energy implication of thousands of passengers and the consequences of emissions for residents in the destination communities.

In their studies, Ruiz-Guerra et al. [10] admit there is a knowledge gap between the societal expectation and the maritime industry reality. As the scholars put it, one of the ways to reduce this expectation/reality gap is to make sure precise knowledge of the CO<sub>2</sub> footprints generated pre- and post-voyage is clear. One of the factors that draw attention to the cruise business is that it is a resource-dependent sector; to achieve a significant equilibrium between ship technology and emissions, the renewal of cruise fleet worldwide will become critical for ecological balance. One of our expert interviews reveals that already during the COVID-19 pandemic (2020/2021), over 23 ships were scrapped, suggesting that the world is moving towards having ships with improved propelling and energy-saving technology so that CO<sub>2</sub> emissions should be reduced significantly very soon. By taking into account the new IMO standards for energy efficiency (EEDI), Olaniyi and Prause [37] and Rutherford et al. [58] already explained that the industry should expect better energy efficiency technology and new energy saving of up to 30% fuel consumption saved with newly built vessels compared to the scrapped old cruise ships that were at least 20 years old.

Yet again, a salient observation from the results is that the use of an onshore power supply represents the most important option to reducing about 25% of CO<sub>2</sub> emissions directly from the vessels. However, we need to take into account that OPS can only deploy its full environmental efficiency when using green electricity. This situation is not ensured in all cruise ports around the globe. While OPS is very important for ecological reasons, what is often overlooked is the possibility of a shift of emissions from the ship to the power plant. Power plants use either coal or oil to generate energy. Using oil to power plants to generate electricity for OPS at the port has the same result as not using any OPS because it does not yield any ecological benefit. Yes, coaster areas become safer, but the overall

negative effect on the environment remains the same. Power plants need to be green to create an all-round balanced green. Ultimately, the goal should be to replace fossil fuels with nonfossil ones or use other green alternatives such as windmills or coal to reduce fossil oil usage right from the power plants.

Usually, most green transport chains are broken at disembarkation. So far, very few transport companies are interested in providing interesting and reliable green onshore and inland logistics for cruise ships. Since most cruises are considered short sea transportation, many cruise companies find it challenging to develop better inland transportation modes for their passengers because they cannot make the right networking required to achieve the level of multimodality and operational effectiveness that long sea transportation can enjoy. What is currently obtainable is still diesel buses operating to convey tourists en masse to their various points in the cities they visit. Then, how green are the cruise services beyond shipping?

Regarding carbon footprint from cruise ship construction, half of the ships are linked to steel and metal constructions of about 40,000 tons. However, if we take the average lifetime of a cruise ship of 20–25 years into consideration, it would mean then that each year of operation of the vessel is associated with 3 million kg of CO<sub>2</sub> from the steelwork of the ship. A lightweight dimension to this line of reasoning is not related to steel construction but consists of equipment for the cruise ship comprising cabins, restaurants, kitchens, entertainment, and other parts. The CO<sub>2</sub> emissions for the production of these fittings reveal huge variations between wooden products, plastics, aluminum, and other components. The result also shows only about 1% of CO<sub>2</sub> contribution, so that the overall impact of the CO<sub>2</sub> emissions of the construction of a cruise ship ranges in total around 2% and is thus significantly less than 5%. Hence, the considerations highlight that the CO<sub>2</sub> emissions for running a cruise ship are much more relevant than the bound CO<sub>2</sub> emissions that stem from the construction. Consequently, the use of greener materials, as well as of smarter production processes, will not significantly improve the CO<sub>2</sub> balance of cruise vessels.

The BSR has indeed come a long way in waste management, but it is impossible to recycle everything, and a single technological approach will not solve the problem. In the case of the Saint Petersburg port, the current facilities seem adequate, but the increasing waste generation at the port is becoming alarming. Compared to other Baltic Sea ports, the average time spent in Saint Petersburg is already longer. This is most likely to grow in the coming years, which calls for strong tactical solutions beyond increasing the capacity of sewage collection. A much-lasting solution lies in minimizing the utility of nonrecyclables and using biodegradable materials, recyclable carbon, and eco-friendly materials. The interference and the role of the port in tackling the challenge, especially through their influence in port cities through modal split, i.e., the provision of certain green initiatives like e-biking systems, electric Scooters, electric cars, or electric roller skates for guest tourists to use from the ports will not only improve the green and clean cruising industry, but it will also enhance the economic growth of such cities by generating more income. These initiatives can make the journey more interesting so that tourists can experience better views of the cities they visit. Although, taking into account the climate of Saint Petersburg, this type of alternative transportation will unlikely be employed all year round. Another option could be interconnectivity through trolleybuses.

As the industry continues its steady growth, we need to see more local ports playing active roles as cruise terminals to make up for the surge in the industry. This will require more cooperation between cruise ships and ports that would benefit from this. Thus, following the rule of Merk and Notteboom [47], one of the processes of improving different corridors is by integrating port systems with multiple green multimodal transport systems. Specifically dedicated freight routes can be constructed to achieve this. A collection of actions of all industry stakeholders that include the cruise lines, the host communities, the passengers, the policymakers, and the often-forgotten shipbuilders might provide a more lasting solution towards more sustainable goals.

## 6. Conclusions

The study set out to analyze a catalog of the energy demand of a typical 7-day cruise ship and assess the economic impact of the CO<sub>2</sub> emissions from a cruise. The authors studied twenty-four scenarios of different transportation combinations to determine the cost of emissions and their implications for the cruise industry, the ports, port cities, and the passengers.

Scenarios with the lowest CO<sub>2</sub> emissions i.e., scenarios 8 and 16 with the annual 311,928 and 311,128 of tCO<sub>2</sub> emissions, respectively, use LNG-propelled cruise ships, connect to the port's OPS, execute their excursions with electric buses, and source their supply locally. While the LNG/OPS combinations achieve the lowest CO<sub>2</sub> emission values, these options are the most expensive for both the cruise lines and the passengers. On the brighter side, the use of OPS in ports significantly reduces the CO<sub>2</sub> emissions, by about 25%. This effect is important for coastal areas and smaller destinations with low populations compared to their incoming tourists.

The paper contributes to clean cruise tourism development and IMO's emissions reduction efforts. As humans cannot survive without a safe environment nor persist in a non-resilient economy, the study further contributes to "a resource-wise economy" by linking emissions and the costs implication to the shipping industry, its businesses, and passengers. Interdependency analysis of clean shipping measures and client oriented economic impact, i.e., the exploration of marketing impacts of clean shipping measures. This is new and determines the future viability of business models in cruising industry since the cruise industry has to find its future position in the conflict area of sustainability and economy. Multiple data used for the study limits the work but they were justified to triangulate and corroborate old reports and to reduce statistical errors. Ideally, regular updates of reports are desirable; however, available data also helps to identify current industry gaps. An interesting future study would be to look into cruises that ply the Mediterranean and the Caribbean; however, this poses a complicated challenge because there are no unified laws around these regions, therefore data from these regions are hard to obtain.

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