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Managing sustainable practices in cruise tourism: the assessment of carbon footprint and waste of water and beverage packaging

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ABSTRACT

This paper's aim is to present an analysis of the carbon - dioxide emissions and waste associated with water and beverage packaging. The assessment of the packaging's carbon footprint (CF) and waste is also considered for all passengers who visit Italian ports on cruise ships. These factors are considered at two points in time (2010 and 2018) to allow for the evaluation of changes due to technological innovations in the packaging sector. Finally, a best-case framework scenario for the management of water and beverage packaging materials is identified to evaluate whether the use of appropriate strategies can reduce CF and waste in this sector. The results indicate that adequate changes in packaging can minimize waste and reduce the consumption of materials and energy resources in the packaging production cycle, thus creating environmental benefits.

1. Introduction

In the last 15 years, the cruise sector has had particularly high growth and has been one of the most attractive sectors of the tourism industry; in 2018, this sector had a global economic impact of €134 billion (CLIA, 2018 and, 2019; MedCruise, 2018). In Europe, the cruise sector's revenues amounted to about €50 billion, including over €13 billion in Italy, which was the most popular Mediterranean destination, followed by Spain, Greece, and France (CLIA, 2018). Companies in this sector have made many investments to improve and differentiate their offerings, to set very high standards, to provide high-quality services, and to initiate new models of propulsion (Parnyakov, 2014).

As a result, the cruise industry has diversified into new forms, which has caused further pressures on ecosystems (MacNeill & Wozniak, 2018; Popiolek, 2014) and contributed to climate change. Generally, tourism comprises a set of social and economic activities that use large amounts of natural capital and that generate significant environmental impacts (Aljerf, 2015). For this reason, some international organizations, such as the United Nations World Tourism Organization, the United Nations Environment Program, and the Organization for Economic Cooperation and Development, as well as host countries and other stakeholders, are analyzing tourism's contributions to greenhouse gas (GHG) emissions in order to identify a suitable approach that can minimize such effects (Rico et al., 2019).

In any case, the cruise sector, due to its constant structural growth and global spread, requires greater international coordination than it currently has, as well as a tighter pollution-control framework, to stimulate the adoption of sustainable models (which, at present, are largely voluntary).

A new trend has been started since December 2016, when the Directive 2014/95/EU entered into force in the European States Members (European Parliament, 2014). It requires the "non-financial and diversity information by certain large undertakings and groups" to be included in the management report.

So a non-financial statement containing information to understand the performance, position and impact of companies' activity relating also to the environmental and social matters must to be published and controlled by supervisory bodies.

The main cruise companies are certainly among the categories of companies identified by the directive, so for the European ones started the obligation to report some environmental information, like the use of energy and water resources and greenhouse gas and pollutant emissions.

Caric & Mackelworth (2014) underline that "the absence of any international coordination of the industry at the region level leaves it open to exploitation, especially considering the lack of effective pollution control mechanisms in most States"; in addition, the United Nations Environment Program noted that cruise ships are among the most significant polluters of the sea ecosystem (Allsopp, Walters, Santillo, & Johnston, 2005). The cruise sector produces large quantities of waste and pollution, consumes significant natural resources, incites ecosystem

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changes and biodiversity loss, and has significant impacts on the landscape. For instance, this sector is responsible for a large quantity of solid waste (Mwanza, Mbohwa, & Telukdarie, 2018), especially that due to packaging (Klein, 2011), comprising about 25% of the waste produced by the total merchant fleet, despite having only 1% of all ships (Herz, 2002; Strazza, Del Borghi, Gallo, & Maran, 2013).

Moreover, cruise ships are increasing in size (and consequently, carrying more passengers), which is increasing the pressure on ports and host communities. Large vessels require significant infrastructure, including for waste management. Ports play a very complex role. On the one hand, they seek inclusion in cruise itineraries in order to attract more traffic and thus maximize the economic benefits that the port and its residents experience; on the other hand, ports seek to minimize the environmental impacts associated with those cruises (Karlis & Polemis, 2018).

In recent years, many cruise companies have voluntarily adopted various measures to reduce their impacts by minimizing waste, both on the ship and on land. The main waste streams are wastewater, grey water (that from wells, showers, and kitchens) (Gossling et al., 2012), solid waste, ballast water, and atmospheric emissions (Copeland, 2008; Sweeting & Wayne, 2011).

Cruise-ship waste is managed according to international protocols (e.g., the International Convention for the Prevention of Pollution from Ships, or MARPOL[1]), national laws and local regulations, as agencies at all those levels are involved in the disposal of cruise-ship waste. Furthermore, Caric & Mackelworth (2014) stressed that “the pollution they create it is difficult to attribute to a source, especially within the Mediterranean where multiple states and jurisdictions are located in close proximity.” In addition, organic waste can only be legally disposed of beyond 12 nautical miles from the coast of the Mediterranean Sea, and (under Annex V of MARPOL) directly disposing of plastic in the sea is strictly prohibited. Despite these rules, cruise ships’ waste disposal is usually difficult to control, and onboard waste storage is an important issue (Svaetichin & Inkinen, 2017) due to the ships’ limited space. This is aggravated when port facilities lack adequate disposal systems. Hence, many newly produced ships use onboard waste incinerators for solid waste and some plastics[2] (Gallo, Strazza, & Del Borghi, 2015). Nowadays, the adoption of policies to reduce such negative externalities is a major challenge for the territories involved, as well as for cruise-tourism companies.

In the early 2000s, the European Union (EU) passed Directive 2000/59/EC, which was meant to protect the marine ecosystem by restricting ships’ ability to dump waste and residue in the ocean, by enhancing port facilities, and by requiring ships to consign waste before departing from a port. To find an adequate balance between the smooth operation of maritime transportation and the protection of the natural ecosystem (Neele et al., 2017), this rule was amended to allow waste to be transferred to another port, provided that there is sufficient storage capacity on the ship (European Commission, 2000; Zuin, Belac, & Marzi, 2009). In 2015, the EU introduced a new, more detailed categorization of waste so as to include of data on the quality and quantity of waste that ships produce and that is then consigned to ports’ reception facilities. According to the European Commission (2015) “This new categorization of garbage is reflected in IMO [International Maritime Organization] Circular MEPC.1/Circ.644/Rev.1, providing a standard format for the advance notification form for waste delivery to port reception facilities, as well as in IMO Circular MEPC.1/Circ.645/Rev.1, providing a standard format for the waste delivery receipt following a ship’s use of port reception facilities.” Generally, however, sustainable practices still must be developed to further reduce waste and increase recycling and reuse, with the aim of efficiently managing waste.

Cruise-ship tourism also causes various forms of pollution and impacts tourist destinations; most importantly, as cruise visits to host destinations typically last a single day or a half-day, their environmental and social impacts on these places are very concentrated (Caric & Mackelworth, 2014; Copeland, 2008).

Therefore, it is often difficult for cruise companies to manage and protect the host destinations. Evidence of cruise ships’ impacts include the high disparity between cruise ships’ environmental standards and the host destinations’ own pollution indicators. Damage to the destinations’ ecosystems and social frameworks is not transferred to the cruise businesses because doing so could cause the cruise companies to choose other destinations.

The cruise sector could provide an advanced model for tourism management and development because of its specific characteristics (e.g., moving and intensive pollution), which provide a significant opportunity to tackle sustainability issues and to reduce negative externalities (Caric, 2016).

Hence, the idea of sustainable tourism has spread and stimulated cruise companies to address their burden on the environment and on communities (Caric, 2016; United Nations Environment Program & United Nations World Tourism Organization, 2005) so as to satisfy the needs of consumers who are aware of these environmental issues.

Regarding sustainability in the tourism sector, the European Commission deliberated in 2003 on the economic, social, and environmental sustainability of European tourism; in 2007, it adopted an agenda for a more sustainable tourism policy, with the purpose of “improving the competitiveness of the European tourism industry and creating more and better jobs through the sustainable growth of tourism in Europe and globally” (European Commission, 2007). The agenda also contained an analysis of the crucial role that tourism plays in the EU economy (Blancas, Lozano-Oyola, & Mercedes, 2015).

More European regulations were implemented in 2010, when the European Commission offered strong support for a framework to improve the sustainability and competitiveness of European tourism in order to retain that region’s leading position in the tourism industry (Europe, the world’s no 1 tourist destination - a new political framework for tourism in Europe. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, 2010). Afterward, in 2014, the EU produced “A European Strategy for more Growth and Jobs in Coastal and Maritime Tourism,” which underlined that the effects of climate change are exacerbating stresses in coastal and maritime areas and are potentially reshaping the geography and seasonality of the tourism industry (Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - a European strategy for more growth and jobs in coastal and maritime tourism, 2014).

Thus, for the EU, sustainable tourism provides a chance to implement services, products, and business models that will attract eco-focused tourists. The European Commission thus “invites Member States, regions, industry and other stakeholders to implement the Integrated Coastal Management Recommendation and Protocol,” which is a new framework to minimize environmental stresses (e.g., those related to biodiversity); to increase tourism’s economic benefits to natural areas; and to enhance resource efficiency, reduce waste, and restrict pollution in tourist regions. This framework provides sustainable management for tour operators and promotes environmentally friendly strategies, actions, and tools. Furthermore, the EU’s water-efficiency measures (from its Water Blueprint) still need to be adopted. Coastal and maritime tourism could be an important economic driver, but it requires the implementation of these valuable European regulations, as this kind of

[1] The International Maritime Organization, an agency of the UN, adopted this document in 1973 and amended it in 1978 (MARPOL 73/78).

[2] These incinerators produce ash and air emissions, which can contain toxic residues, including heavy metals and dioxins. As a result, MARPOL “recommends, but does not demand, that ash from incineration of some plastics not be discharged into the sea.” In light of this consideration, incinerator ash should be analyzed to determine whether it should be categorized as solid waste or hazardous waste.

tourism requires environmentally, economically, and socially adequate policies.

Moreover, in 2015, a conference entitled “Pan-European Dialogue between Cruise Operators, Ports and Coastal Tourism Stakeholders” promoted improved synergies and more structured dialogues on cruise tourism as best practices for this sector. The participants, which included stakeholders from various sectors of the cruise industry, agreed with the aims of the Europe 2020 Strategy, which stressed the relevance of sustainable cruise, coastal, and maritime tourism to the growth of the European economy. The participants also highlighted “the need to involve all the tourism chain in the benefits and deliveries for cruise tourism and recognized the contribution of cruise, coastal and maritime tourism to the social and economic development of coastal and insular destinations, the importance of coastal and insular destinations as touristic attractions and the need to preserve their authenticity and heritage” (AA.VV, 2015).

Despite the cruise sector’s growth and its increasing environmental impact, the scientific literature about this topic is still quite limited, as Fig. 1 illustrates. Only a small portion of studies on tourism are focused on cruise tourism (including on its environmental burden) in particular.

We conducted a literature search using Web of Science and on the basis of the five main topics listed in Fig. 1, we found a shortage of papers, amounting to 670 from the last 20 years (1998–2018).

The first topic (which has 174 papers that have been cited 1836 times) includes subjects such as eutrophication due to food consumption patterns, carbon footprint, the life cycles of food packaging, the sustainability of agricultural products, and the impacts of recyclable and renewable materials.

The second topic includes food safety and the bio-optical characteristics of phytoplankton; it has only 29 publications, which have been cited 85 times.

The third topic, cruise ships’ CFs, has only 13 publications, which have been cited a limited number of times (about 130); these studies focus on oceanographic measurements and data analysis.

The fourth topic has the greatest number of publications (304) and citations (3868) of the five topics, but the studies in this area are not very relevant to our research. Many of these articles are focused on the general impacts of tourism, including with regard to air traffic, air pollution, ocean acidification, PM10 application, air quality, and wastewater discharge. This topic also includes the use of gas turbines for power generation and the general energy efficiency of passenger ships.

The 147 studies on the last topic (cruise waste) have been cited 1865 times. This area includes articles that focus on the monitoring of vulnerable marine ecosystems (e.g., coral reefs), the prevention of pollution (e.g., wastewater discharge), and the operation of garbage-collection systems on cruises. For example, in terms of environmental impacts, some authors (e.g., MacNeill & Wozniak, 2018) have considered three areas that impact natural capital: waste, as measured by the frequency of withdrawal; sewage, as assessed on the basis of the number of passengers and impacts on the ecosystem, as measured with secondary qualitative data.

We proposed this analysis because the majority of the past studies have not dealt with the topic of this research. Our goals are to provide further insights in this area and to increase the scientific production on this topic; this research will be useful to cruise companies, public agencies, consortia from the industries involved in the production of beverage packaging, and other stakeholders who pay attention to environmental issues. Moreover, as European institutions have placed increasing attention on the need to reduce plastic pollution by restricting single-use plastic products, there is a need to rethink the issue by designing a new, sustainable approach also for the production and use of beverage packaging (Communication from the Commission to the

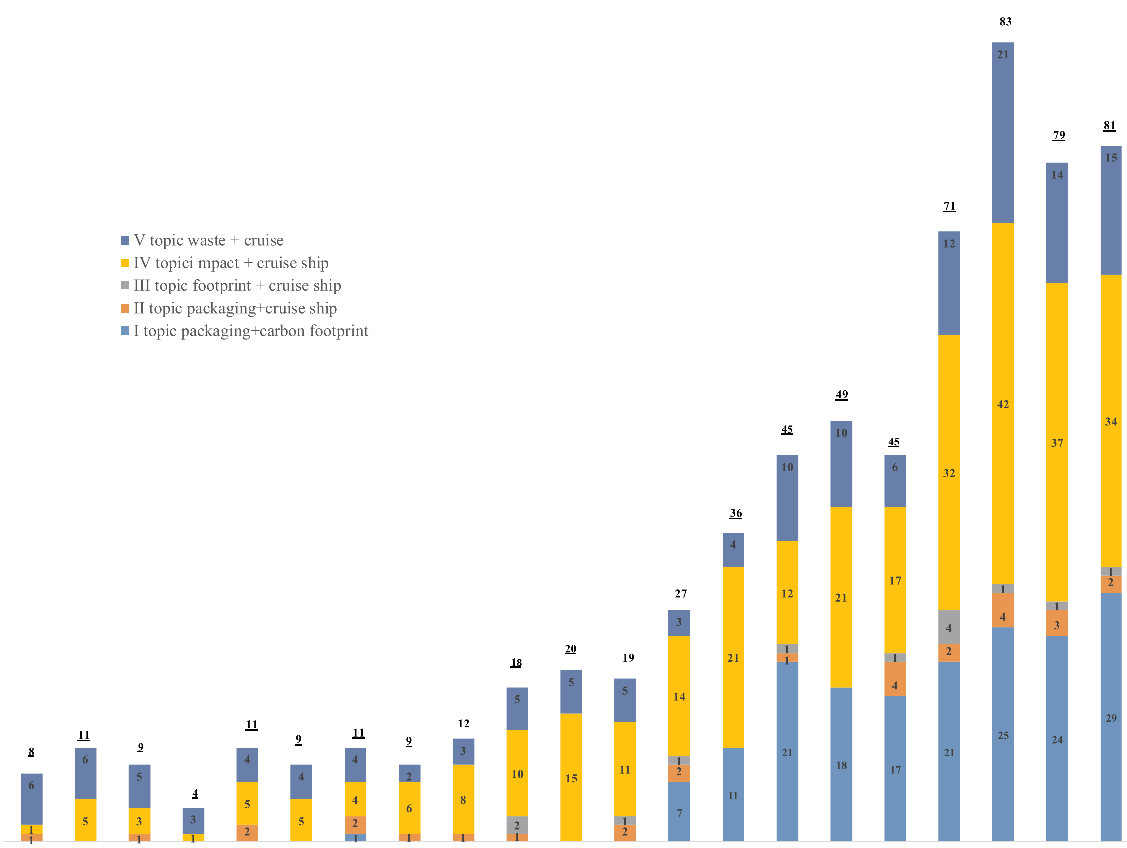

Fig. 1. Evolution of scientific literature according to the topic enquiry on Web of Science on 05 January 2019.

European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. A European strategy for plastics in a circular economy, 2018; 2018b). Keeping in mind the last consideration, it has to be stressed that the passenger is an important stakeholder who must share the environmental responsibility and play a leading role to shift the quality of the cruise supply towards more sustainable approach. Therefore, a suitable building of his awareness about the environmental issue becomes significant (United Nations World Tourism Organization, 2016).

In light of the aforementioned considerations, this study is meant to consider the impact of cruise tourism in terms of environmental issues, particularly the reduction of GHG emissions and packaging waste.

On cruise ships, the consumption of food and drink is an essential experience, especially for families. Therefore, both the production and consumption of food and drink are important concerns in the promotion of sustainable tourism development. Despite the obvious lack of empirical studies on CF in the tourism industry, it is clear that food production and consumption are key issues in climate-change mitigation. Scholars such as Gossling, Brian, Aall, Hille, & Peeters (2011) have confirmed the need to further study the role that food and drink play in tourism. The interrelationships between the production and consumption of food and drink, particularly in terms of packaging, should be a point of focus in tourism studies (Grunert, Hieke, & Wills, 2014). Analyzing these interrelationships is important to creating sustainable tourism because at least a third of tourist spending is on food and drinks and, thus, especially on cruise ships, this topic is very important.

In particular, this paper is meant to assess cruise ships' beverage and water packaging, in terms of its CF and waste, in order to identify ways of better managing such packaging by providing a more sustainable mix of materials and by evaluating the implementation of various measures for reducing packaging's impact.

The analysis focuses on solid waste, particularly glass, polyethylene terephthalate (PET), and aluminum, which are the main types of primary water and beverage packaging.

Packaging represents a high share (Gallo et al., 2015) of the total solid waste generated on cruise ships, so a minimization strategy for this waste type is necessary. The methodology adopted in this study involves a CF indicator. The term *CF* was coined in the 1990s, and it is based on the concept of an ecological footprint. A carbon footprint is meant to be a measurement of an item's climate change impact. This generally refers to human activities' impacts on the environment; in this paper, the focus is on tourism which affects climate conditions in terms of GHG emissions. CF is based on GHG emissions and it is necessary to manage and reduce such emissions (Wiedmann & Minx, 2008). CF measurements help scholars to identify weaknesses, such as high-emission areas, that can be eliminated or improved. Therefore, CF is an indicator of sustainable development (Radu, Scrieciu, & Caracota, 2013).

To provide replicable analysis, we chose a functional unit that corresponds to the use of water packaged in PET and glass, as well as beverage packaged in aluminum cans, on a per person, per day basis (Butt, 2007; Zuin et al., 2009). In addition, we extended the calculation of CF and waste to include all the passengers who come through Italian cruise ports. We used two points in time (2010 and 2018) to allow for a comparison of the data; this comparison reveals significant changes, which are due mainly to technological innovations in the packaging sector. Thus, we applied a best-case framework scenario (B_{est}) for the management of water and beverage packaging materials in order to determine whether the use of appropriate strategies can reduce CF and waste in this sector. The results indicate that adequate changes in packaging materials can minimize waste and generate environmental benefits (in terms of reduced GHG emissions) thanks to the reduced consumption of materials and energy in the packaging production cycle.

2. Materials and methods

This paper includes an assessment of cruise-ship passenger flows, particularly for Italian ports. It also includes measurements of packaging products' carbon dioxide equivalent (CO_2eq) emissions and weights, based on the published environmental product declarations (EPDs) for each type of packaging (Strazza, Del Borghi, Magrassi, & Gallo, 2016). In addition, for the missing data, we studied the literature related to this sector. Hence, we applied the CF methodology, with functional units as a reference, in terms of the consumption of water and beverages per cruise passenger per day. Based on the amount of CO_2eq emissions per person, we assessed the total emissions per weeklong cruise and the total amount produced by cruise passengers at Italian ports each year. We also measured the quantity of packaging waste produced for the identified categories.

We carried out this analysis according to various assumed use rates for the chosen formats and materials (particularly for water packaging). First, we considered a baseline scenario that cruise companies have used for many years, including during the reference period of 2010–2018; we also created a hypothetical B_{est} framework in which the best practices concerning packaging materials would be applied.

This analysis is twofold. First, we measured the amounts of packaging-related waste and CO_2eq emissions in the reference period, including an evaluation of decreases in these values due especially to technological innovation. Second, we assessed the potential for a more significant reduction in these indicators as a result of changes in the management of packaging materials (in the B_{est} scenario).

2.1. Methods

Before calculating the levels of GHG emissions, the types of primary water and beverage packaging must be identified so that the weights and emissions (in CO_2eq) per packaging type can be computed for the reference years (2010 and 2018).

The present analysis used secondary data, gathering from EPDs (EPD, 2010a; EPD, 2010b; EPD, 2017a - EPD, 2017c) for water packaging types and literature (Amienyo, Gujba, Stichnothe, & Azapagic, 2013; Del Borghi, Gallo, & Magrassi, 2016) for the other beverages respectively. The EPDs are based on the ISO 14040 and ISO 14044 standards and on the Product Category Rules specification (Environdec, 2011).

The EPDs consider emissions for the whole material cycle, according to the Life Cycle Assessment (LCA) methodology; the functional unit in the EPD considered is represented by 1 L of mineral water bottled in PET (sizes 0.5 L and 1.5 L) and glass (size 1 L) packaging. System boundaries include stages related to raw materials, production, filling, transportation for distribution and end of life of mineral water. As regards the impact assessment categories, the value of the Global Warming, expressed in CO_2eq emissions, has been only considered for our hypothesis, based on the energy-flow model of packaging for the entire cycle, including the upstream, core and downstream phases.

In brief, the upstream phase entails the production of the materials for the primary, secondary, and tertiary packaging and it has the most significant CO_2eq emissions. The core phase includes the production of the packaging, the bottling and labeling processes, and the application of the secondary and tertiary packaging materials. The downstream phase concerns the disposal of the packaging materials and the end of the product's life. The primary packaging represents 90% of the total emissions related to packaging, so we considered only this kind of packaging in this paper. It has to be noted that more detailed information of LCA, for each kind of packaging considered, can be found in the EPD references of this paper.

To assess the impact of primary packaging emissions in the cruise sector, we used the Carbon Footprint Indicator, which the Intergovernmental Panel for Climate Change (2007) created, as well as the principles stated in the ISO/TS/14067 standards of 2013 (Pandey, Agrawal, & Pandey, 2011; Pattara, Salomone, & Cichelli, 2016). In this indicator, the total GHG emissions that are directly or indirectly associated with a commodity or service are expressed in tons of CO_2eq (Galli et al., 2012); this can be with reference to the entire life cycle or to only part of it. GHG emissions relate to global warming potential which, according to the Intergovernmental Panel for Climate Change, is the potential that a kilogram of GHG has in terms of climate change effects over a 100 year time horizon (Lucchetti, Romano, & Arcese, 2012; Mancini et al., 2016).

We applied the data on the CO_2eq emissions and packaging weight, as illustrated in Fig. 3, to the functional unit. We used the resulting values, with some simplifications to support our hypotheses, to measure the GHG emissions of water and beverage packaging, in addition to the quantity and quality of the packaging waste produced in the reference years. We also extended the analysis to include the cruise passengers who passed through Italian ports in the same years. We compared the data from the two reference years to identify any changes that occurred over time. We carried out this first analysis according to the assumptions, regarding the use rates of the chosen packaging formats and materials, which have been in use with regard to cruise ships for many years. In the second step of the analysis, we evaluated whether the actual figures from 2010 to 2018 could be improved using the B_{est} scenario for instance, by applying a mix of packaging materials (for water in particular), thus significantly reducing the use of glass and 0.5 L PET bottles on cruise ships.

2.2. Materials

2.2.1. Market data

In the last 15 years, the cruise sector has been characterized by exponential growth. The Caribbean is the leading area in this market, and Europe is second; the Mediterranean is the favorite destination of European tourists.

The passengers who passed through Mediterranean ports grew by over 216% between 2000 (8.6 million) and 2018 (27.2 million) (Fig. 2). Visitors to Italy represented about 40% of this Mediterranean traffic; this nation showed an even more significant increase between 2000 and 2018: over 360%. As can be seen from Fig. 1, the highest growth took place between 2006 and 2011, when the number of passengers landing in Italian ports almost doubled; in recent years, however, the trend has been more stable. In 2018, among the main Mediterranean ports, Barcelona had the most passengers, at almost 3 million; it was followed by Civitavecchia, with 2.4 million passengers. Among the other Italian ports, Venice registered over 1.47 million passengers, Naples had almost 1.1 million, Genoa had 1 million and Savona had 0.873 million.

2.2.2. Input data

First, it was necessary to estimate the consumption per person per day during a weeklong cruise; it was then necessary to identify the type and format of packaging. This first analysis covered only some types of packaging (those relating to water, which are analyzed in particular detail, as well as those relating to beverages). The data on consumption were based on the beverage packages that are most commonly distributed on cruise ships. This corresponded to a recommended daily water intake of 2 L. The assumed daily consumption of other beverages was about 0.66 L.

We considered these quantities per person and per day of a weeklong cruise in the Mediterranean Sea during the spring or summer. The formats and types of packaging that we considered were 0.5 L and 1.5 L PET bottles (Iacovidou, Velenturf, & Purnell, 2019) and 1 L glass bottles for water, and only 0.33 L aluminum cans for other beverages. Hence, for each packaging types, we identified the reference EPDs. We used the same brand of product for each type of packaging, with regard to the EPDs for the years 2010 and 2018, as this enabled us to show the reductions in both CF and weight during this period (Fig. 3). Respectively, we used data from San Benedetto for the PET water bottles, from Cerelia for the glass water bottles, and from the literature for the aluminum beverage cans (Amienyo et al., 2013; Niero & Olsen, 2016).[3] The EPD data, as the references indicate, refers to studies conducted from 2010 through 2017; however as these studies' data are the most recent available, we counted them for our calculations concerning the reference years 2010 and 2018.

The CO_2eq emissions of all these packaging types depend on the use of recycled inputs in their production processes (in the upstream phase) and on the waste management during the end-of-life process (in the downstream phase). In the consulted EPDs, the percentages of recycled material used in the production of these types of packaging are 10% for plastic materials, between 27 and 48% for aluminum, and 0% for glass (as Cerelia states in its EPD that it uses 100% virgin glass). These determinations are valid for both the reference years.

With regard to the end-of-life assumptions in the downstream phase, the EPDs from Italy usually referred to the percentages of waste disposed of in various ways.[4]

Hence, based on the packaging types' CO_2eq emissions and weights (from the EPDs and from data in the literature), we determined measures of both CF and waste per cruise passenger per day.

As mentioned in Section 2.1, the measurements for both CF and waste for the water bottles were based on the percentages of use in the reference years 2010 and 2018: 50% glass bottles, 25% 0.5 L PET bottles, and 25% 1.5 L PET bottles. For the B_{est} scenario, these values were 5% glass bottles, 35% 0.5 L PET bottles, and 60% 1.5 L PET bottles. Both the GHG emissions and the weights for each type of packaging were the same in the B_{est} scenario as in the 2018 measurements.

Regarding aluminum cans for beverages (Arena, Sinclair, Lee, & Clift, 2017), we applied the same rate of use in each calculation (2010, 2018, and the B_{est} scenario). This included both the production of waste and the CO_2eq emissions. We did not assume for this study that such cans would be replaced with other packaging materials, as that will be the topic of our next study.

[3] The primary packaging consists of not just the main material (PET or glass) but also the materials in the cap (often high-density polyethylene), glue, and label (almost always polypropylene). However, the share of PET or glass can be as high as 90% of the total emissions from the primary-packaging production. In addition, for ease of transportation, the primary packaging is also typically accompanied by secondary packaging (e.g., shrink film) to hold the bottles together and even tertiary packaging (e.g., a wooden pallet). However, such additional packaging comprises only a small percentage of the total GHG emissions related to the packaging as a whole. In fact, 60–90% of these emissions (depending on the packaging materials) are related to the production of primary packaging. Thus, it is appropriate to simplify the process and to consider only primary packaging: PET, glass, and aluminum.

[4] The end-of-life statistics for each material are as follows. PET packaging can be recycled (28.4% in 2010 vs. 37.9% in 2016) or converted to energy (10% in 2010 vs. 17.6% in 2016), but it is still often sent to a landfill (61.6% in 2010 vs. 44.5% in 2016). Glass, on the other hand, is recycled more often (56.9% in 2010 vs. 70.3% in 2016) and has seen a sharp increase in energy-conversion treatment (3.5% in 2010 vs. 29.7% in 2016); it is no longer sent to landfills (39.6% in 2010 vs. 0% in 2016). Aluminum is recycled most of the time (72.4% in 2010 vs. 69.9 in 2016) and is sometimes converted to energy (5.5% in 2010 vs. 5.6% in 2016) or sent to a landfill (22.1% in 2010 vs. 24.5% in 2016) (ISPRA, 2011, 2015, 2017).

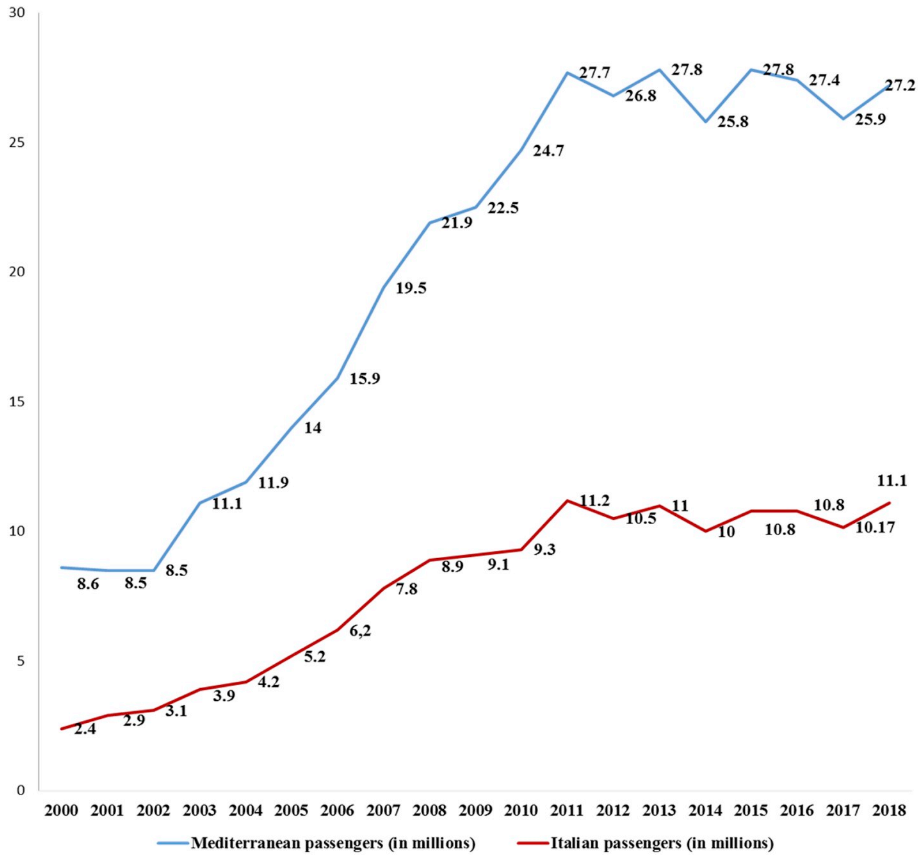

Fig. 2. Passengers in Mediterranean and Italian ports (millions).
Sources: Author's elaboration on data MedCruise (2016 and 2018), RisposteTurismo (2017 and 2018) and Italian Cruise Watch (2018).

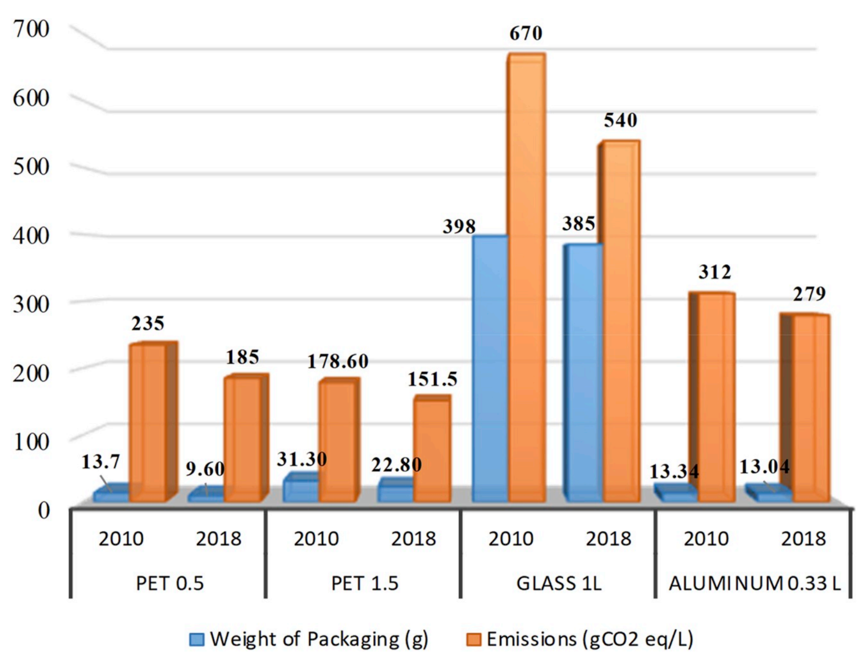

Fig. 3. Beverages packaging weight and emissions (gCO_2eq/L). Comparison years 2010–2018.
Sources: 2010: *PET 0.5*-EPD, 2010a; EPD, 2010b; *PET 1.5*-EPD, 2010a; *Glass*- EPD, 2010b; ICF International, 2016; *Aluminum*- Amienyo et al., 2013, 2018: *PET 0.5*-EPD, 2017a; EPD, 2017b; *PET 1.5*–2017b; EPD, 2017c; *Glass*- ICF International, 2016; *Aluminum*- Niero Olsen, 2016. The Aluminum Association, 2014.

Therefore, we assessed the CF and the waste of the primary packaging for the total number of people on a given ship during a weeklong cruise. With regard to the number of passengers, in our calculation, we assumed a tonnage between 110,000 and 140,000 tons, which matches the values reported by the Costa, MSC, and Royal Caribbean cruise lines, as well as a total of 4300 people (3300 passengers and 1000 crew members) per ship. We included the crew in the calculations because we considered only basic consumption, and the crew would also consume water and beverages.

3. Results and discussion

The evolution of packaging weights and a reduction of GHG emissions from packaging have been illustrated in Fig. 3 and elaborated upon in the EPDs and the data from the literature. As the data show, glass has the highest weight and the most emissions of the main material types; as a result, its rate of use is reduced in the B_{est} scenario. However, the situation changes when other indicators are used. For instance, in 2018, for the ratio between emissions and packaging weight, the highest value was for aluminum (21.4 g of CO_2eq per gram of packaging), followed by 0.5 L PET bottles (19.4 g of CO_2eq per gram of packaging), 1.5 L PET bottles (with 6.6 g of CO_2eq per gram of packaging); glass had the lowest ratio (1.4 g of CO_2eq per gram of packaging).

Considering the total weight of the individual packages, each person produces about 3.14 kg of waste during an entire cruise trip (Table 1), according to data from 2010. This is in line with other findings: in particular, Caric (2016) assessed this factor and found that, "on board a large ship, 20 tons of solid waste are produced per week of cruising, for an average of over 4 kg/passenger." The average waste declined to 2.9 kg per passenger in 2018 and is only 0.67 kg per passenger in the B_{est} scenario. As a consequence, the total weight of waste per weeklong cruise decreased from 13,509 kg in 2010 to 12,891 kg in 2018. The B_{est} scenario would lead to an even more drastic reduction, with only 2, 900 kg of waste (Table 1).

Based on the number of cruise passengers who pass through Italian ports (Fig. 1), it is possible to measure the packaging waste generated on their cruises: 29.2 kt (thousand tons) of waste in 2010 and 33.3 kt of waste in 2018; this quantity is much lower, just over 7.44 kt, in the B_{est} scenario (Table 2). This comparison reveals a 14% increase in waste between 2010 and 2018; nevertheless, the number of passengers increased by 19.35% in this time. For the total waste in Italian ports, the B_{est} scenario would produce a decrease of 77.67% relative to the 2018 figure.

Hence, we calculated the CF. Table 3 highlights the reduction achieved over time and the potential improvements that could be made by changing the mix of packaging used for water and beverages. In particular Table 3 reveals the 17% reduction of CO_2eq emissions for all packaging materials on a per person, per week basis between 2010 (7.58 g of CO_2eq) and 2018 (6.25 g of CO_2eq). The emissions for the B_{est} scenario (3.85 g of CO_2eq) are 38% lower than those from 2018 and almost 50% lower than those from 2010.

We thus were able to multiply the per person emissions for a weeklong trip by the number of people on the ship to produce the CF of the reference packaging. This value was equal to 32.6 t of CO_2eq in 2010 and 26.8 t for 2018. For the B_{est} scenario, the emissions would be only 16.5 t CO_2eq per weeklong cruise. On the basis of the emissions per person per week, we compared the CF of all cruise passengers who passed through Italy (as shown in Fig. 2) in the two reference years (Table 4).

As the results highlight, in 2010–2018, the 19.35% growth in passengers did not correspond to an increase in emissions related to packaging considered, as the latter value actually decreased by 1.62%. This divergent trend is even clearer when comparing the emissions from 2010 with those from the B_{est} scenario, which indicates a reduction of almost 40%; this is equal to an GHG emissions saving of 27.8 kt.

This analysis showed that the cruise sector has a relevant CF, even if that value has significantly decreased in the period investigated.

This study's results demonstrate that a different strategy in terms of the selection of packaging materials would lead to better environmental sustainability within the cruise sector. Indeed, both CF and waste declined between the reference years of 2010 and 2018 (Tables 1 and 3), mostly due to technological innovations that reduced the weight and GHG emissions of this packaging. However, an even more significant reduction in both indicators would occur with the adoption of best practices, such as the partial substitution of glass with plastic packaging. Moreover, as the results from the last columns of Tables 1 and 3 indicate, the largest reduction in both CF and waste would occur when both of these factors (the use of technological innovations and the adoption of best practices) are considered together. A similar investigation about the environmental issue of the packaging has been made by Amienyo, Camilleri, and Azapagic (2014) which analyzing the UK wine packaging sector underline that "several options for reducing the impacts from wine have been considered based on the identified hot spots: shipping of bulk rather than bottled wine, increased recycling and light-weighting of glass bottles as well as using carton packaging instead of bottles". The switching from glass to bulk allowed to reduce of 13% CO_2eq emissions; for the second option, every 10% increase in the quantity of recycled glass reduced by about 2% and for the third option the reduction of glass packaging weight by 10% allowed a reduction by 4% of the CO_2eq emissions. In general it has to be highlighted that lack of efficient and common assessment guidelines for the environmental burden of packaging production and recycling is a critical issue, which makes difficult a comparison among unlike data.

As highlighted above, our paper represents only a part of an extensive analysis concerning the cruise sector, so the results are partial. Indeed, this analysis has some limits due to its evaluation of only one part of a cruise ship's environmental impacts, so its results may not apply to a more complete CF and waste assessment. A further research analysis could be extended to the measurements of the total cruise impacts according to the innovative methodology of Touristic Ecological Footprint (TEF) (Aljerf, 2015).

In any case, monitoring of these indicators will allow for constant auditing and analysis of any changes, as well as the implementation of efficient environmental and economic management for selected areas of the cruise business. A suitable support to sustainable strategies

Table 2
Water and beverage packaging waste generated by the passengers in the Italian ports (kt).

Packaging	2010	2018	B_{est}
PET 0.5	0.9	0.8	1.0
PET 1.5	0.7	0.6	1.4
GLASS	25.8	29.9	3.0
ALUMINUM	1.8	2.0	2.0
TOTAL	**29.2**	**33.3**	**7.4**

Table 1
Water and beverage packaging waste generated in the cruise (kg).

Packaging	Waste/person/day			Waste/person/cruise			Waste/cruise/day			Total waste for cruise			%		
	2010	2018	B_{est}	2010	2018	B_{est}	2010	2018	B_{est}	2010	2018	B_{est}	a	b	c
PET 0.5	0.01	0.01	*0.01*	0.10	0.06	*0.09*	59	41	*58*	412	289	*405*	*−29.9*	*40*	*−1.8*
PET 1.5	0.01	0.01	*0.02*	0.07	0.05	*0.13*	45	33	*78*	314	229	*549*	*−27.1*	*139.7*	*74.8*
GLASS	0.40	0.38	*0.04*	2.78	2.70	*0.27*	1711	1656	*166*	11980	11589	*1159*	*−3.3*	*−90*	*−90.3*
ALUMINUM	0.03	0.03	*0.03*	0.19	0.18	*0.18*	115	112	*112*	803	785	*785*	*−2.2*	*0*	*−2.2*
TOTAL	**0.45**	**0.43**	***0.10***	**3.14**	**2.9**	***0.67***	**1930**	**1842**	***414***	**13509**	**12891**	***2897***	***−4.6***	***−77.5***	***−78.6***

a: 2018/2010; b: B_{est}/2018; c: B_{est}/2010.

Table 3
Carbon Footprint of water and beverage packaging of the cruise (kg CO_2 eq).

Packaging	Emissions/person/day			Emissions/person/cruise			Emissions/cruise/day			Total emissions for cruise			%		
	2010	2018	B_{est}	2010	2018	B_{est}	2010	2018	B_{est}	2010	2018	B_{est}	a	b	c
PET 0.5	0.11	0.09	*0.13*	0.82	0.65	*0.91*	505	398	*557*	3537	2784	*3898*	−21.3	*40*	*10.2*
PET 1.5	0.09	0.08	*0.18*	0.63	0.53	*1.27*	384	326	*782*	2688	2280	*5472*	−15.2	*140*	*103.6*
GLASS	0.67	0.54	*0.05*	4.69	3.78	*0.38*	2881	2322	*232*	20167	16254	*1625*	−19.4	*−90*	*−91.9*
ALUMINUM	0.21	0.18	*0.18*	1.44	1.29	*1.29*	885	792	*792*	6198	5543	*5543*	−10.6	*0.0*	*−10.6*
TOTAL	**1.08**	**0.89**	***0.54***	**7.58**	**6.25**	***3.85***	**4656**	**3837**	***2363***	**32590**	**26861**	***16538***	−17.6	*−38.4*	*−49.3*

a: 2018/2010; b: B_{est}/2018; c: B_{est}/2010.

Table 4
CF of water and beverage packaging used by the passengers in the Italian ports (kt CO_2 eq).

Packaging	2010	2018	B_{est}
PET 0.5	7.6	7.1	10.1
PET 1.5	5.8	5.9	14.1
GLASS	43.7	42.0	4.2
ALUMINUM	13.4	14.3	14.3
TOTAL	**70.5**	**69.3**	**42.7**

implementation is the environmental management system (ISO 14001:2015), which can represent a key driver towards a sustainable innovation. Some cruise companies have just implemented it, even if only few years ago. In the next years this is going to become a management tool, allowing to differ from competitors and acquire new market shares.

The management actions that should be adopted to reduce and prevent packaging waste are twofold. For the first, an enhanced use of dispensers and packaging reusable, as tertiary packaging (e.g., pallets), are some management measures which can be used to minimize the use of certain primary packaging types, such as those with major impact (glass bottles, 0.5 L PET bottles, and aluminum cans). For the second action, measures, as recycling that uses technology to granulate PET waste and/or incinerators on board to recovery energy, can be introduced to tackle some environmental issues related to packaging.

Generally, end-of-life management for packaging (and other waste, such as organic waste) can be improved through the onboard use of technologies such as compactors, energy-recovery plants, and anaerobic digesters that allow for reduced packaging volume and more efficient energy recovery. The correct integration of these measures can lead to better management of packaging, thus helping to minimize its impacts.

In general, the waste hierarchy, clearly identified by the European Union regulations, listed the best practices to be used for the waste streams, considering the incineration and landfill the last disposal options. To enhance the packaging recycling, the collection on board has to be efficiently carried out, through a suitable separation of waste in the upstream phase, when passengers throw the packaging.

Indeed, some companies in the cruise sector have already applied such measures; in particular, Costa Crociere (an Italian company), Royal Caribbean (an American company), and AIDA Cruises (a German company) have each adopted unique but sustainable waste management policies (Wang, X.Li, & Yi Xiao, 2019).

Costa Crociere (2017) focused on a circular economic strategy: the reduction, recycling, and reuse of materials that otherwise would be disposed of. The company's Waste Management Plan, which has been adopted on all the units in its fleet, is essential to the company's sustainable development objectives. This plan goes well beyond the international regulatory standards (e.g., MARPOL). This plan starts with the categorization of 100% of ships' waste. Costa worked to facilitate the recovery of waste materials such as aluminum by establishing partnerships with third parties to ensure the correct start-up of the process and the correct use of the harnessed raw materials. Moreover, Costa was already involved in a project it called Sustainable Cruises, the aim of which was to measure the CF of the packaging used during its cruises (Costa Crociere, 2010).

Royal Caribbean Cruises (2018) also applied a virtuous model of sustainability standards. It aimed to reduce waste by cooperating with suppliers to reduce packaging materials and to use more sustainable resources. It also reuses many such materials by participating in container return programs. Royal Caribbean crew members are fully engaged in this process, which includes manually sorting the waste during the recycling step. Its ships also feature storage structures that allow the employees to keep recyclable materials so as to ensure optimal recycling, either onboard or at Green Loading hubs. The company has set up these hubs throughout all of its North American and Northern European routes (Royal Caribbean Cruises, 2018). Approximately 75% of the waste produced on Royal Caribbean ships does not reach a landfill, and the company's goal is to reduce landfill waste per passenger by 85%, thus reaching zero waste.

AIDA Cruises collects each type of waste separately; compacting is done in a designated room on each ship. Metal, paper, and plastic are compacted, whereas glass is crushed. Food waste is first compacted and then dehydrated for disposal, as it is a biodegradable substance. Oil waste, on the other hand, is collected separately and then transferred to a waste management company. To guarantee high standards, AIDA's environmental officers periodically visit the local waste management companies to carry out audits and inspections. The company's goal is to monitor the processing and localization of the company's waste. If environmental managers find that the waste management companies have not complied with the agreed upon standards, specific conditions are immediately imposed. AIDA's plan is to generate as little waste as possible by significantly reducing waste generation per guest (AIDA Cruise, 2019).

These companies' policies with regard to environmental and sustainable practices are efficient as long as both the crew members and the passengers are truly involved and have adequate information and training.

In light of the CF and waste measurements in this paper, it would be useful to inform passengers and crew members about the GHG emissions and waste that their lifestyles generate, the consumption of goods in particular, in order to increase their awareness of direct and indirect emissions, both in ports and on the ships. Generally, consumer behaviors should also be considered during packaging design. In particular, Gustavo, Pereira, Bond, Viegas, and Borchardt (2018) suggested "that a better packaging design/redesign requires a combination of actions that may: embrace the external demands (consumers, retailers and suppliers); facilitate technical improvements (on materials, design or properties); and lead to the adoption of better management practices." As regards the environmental issue of the packaging, Del Borghi et al. (2016) underlined that glass is perceived as a sustainable packaging by the consumers, not evaluating its high environmental impact. This issue affects materials advances, because if stakeholders do not require a change, decision makers and manufacturers don't make it. So, these authors suggested both to increase renewable energy sources for reducing the environmental burden of the glass bottle and to develop technological innovations and new materials in the glass production (e.g. weight reduction and alloys).

The role of the consumer is significant in the implementation of sustainable practices, but generally the merchandising policy of the cruise companies tend to weaken or counteract it. Brida and Zapata (2009) underlined that "A cruise ship represents all four faces of the tourism industry: transportation, accommodation (including food and beverages), attractions and tour operators". As a consequence, sale of products, provision of services and form of entertainments more and more newer, usually not included in the cruise package, spur many passengers to stay on the ship even during the on shore time.

Indeed, the onboard revenues account for 20–30% of the total revenues for the cruise lines. This issue linked with the many purchases of goods on a duty-free basis during the on a shore tours, can reduce effective contribution to activities more sustainable by the passengers (Polat, 2015).

In Fig. 4 we provided an action plan summarizing the implementation of sustainability planning for cruise tourism. It involved four levels of interest: environment, public policies and government measures, stakeholders (firstly, the passengers and then, the crew members), companies policies.

It has also been noted that cruise tourism generates levels of consumption that are much higher for passengers than for the local people in the host communities. For this reason, greater coordination is necessary among technological, natural, and social scientists so as to better understand the relationships among the ecosystem, local human populations, and tourists. A suitable coordination policy is necessary because, although cruise tourism can improve local communities' economic stability, especially in developing countries, they also generate hidden costs for the environment and in terms of natural resource use (Caric & Mackelworth, 2014).

In light of these considerations, cruise operators should spend significant amounts on upgrading to modern and efficient waste-collection systems and other infrastructure (Di Vaio, Varriale, & Trujillo, 2019) so as to reduce costs for the local residents and protect the local environment and economy.

Otherwise, "cruise tourism is likely to yield benefits only to foreign investors and local elites while the local community have no significant net gain and the environment suffers a negative impact," as MacNeill and Wozniak (2018) emphasized. The same authors also underlined that these kinds of outcomes could be implemented via governmental or market based options; for instance, sustainable ports could be given a label or trademark similar to the blue flag that is used for environmentally friendly beaches.

It has to be noted that the implementation of the sustainability issue in the company's activity can find some barriers, above all due to the complexity of functions and competitive needs. Hence, it could be advisable that policy makers adopt incentive schemes or other public support for companies implementing sustainable practices and strategies; so, they could be encouraged to invest in environmental friendly activities. Furthermore, evidence of the environmental policies and performance by the cruise companies could be well evaluated by the investors in their analysis.

From different point of view, other public measures could be suitable to decrease the environmental burden of the cruise sector. MacNeill and Wozniak (2018) evaluated the tax policy in Honduras and underlined that an high fees, taxes on cruise arrivals/passengers, payed for local development, allowed to reinvest in protection activities and monitoring, resulting in a minimum territorial burden, unlike where the low taxation and scarce investments in regional ecosystem conservation have been unable to preserve it.

4. Conclusions

The results of this analysis highlight the degree to which the cruise sector needs new management policies that will move it toward a reduction in the use of materials and energy throughout the entire system.

It is critical to identify methodologies and indicators that can achieve high impact improvements within this sector, both on ships and on land. The CF methodology allowed us to assess some of the impacts of complex goods and services, such as water and beverage packaging,

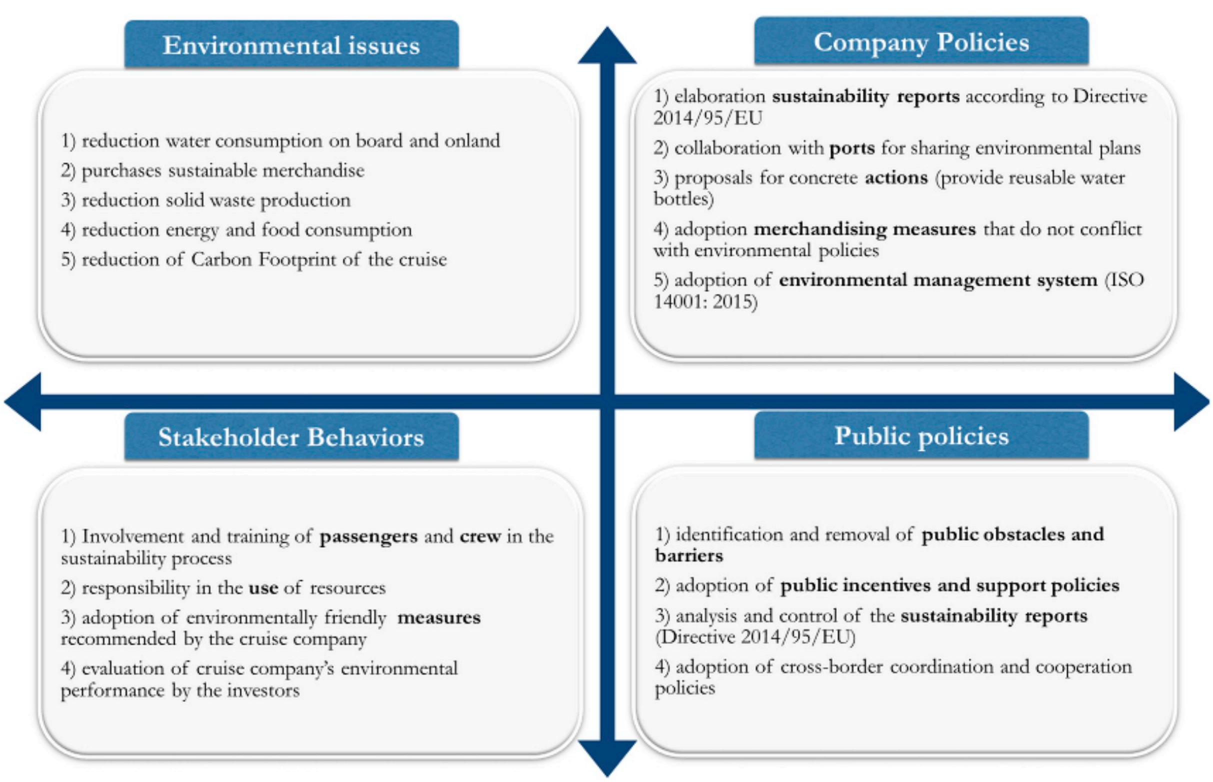

Fig. 4. Action plan towards sustainability implementation in the cruise sector.

specifically for the cruise sector, as that sector's features differentiate it from other economic sectors. This paper is the first step in an extensive analysis of the cruise sector; the aim of this project is a total assessment of the sector's environmental impacts. This study's results are, however, still representative of the multiple impacts of that sector. It is important to underline that monitoring the emissions and waste connected with the cruise sector allows for both better analysis of its relative impacts and the implementation of corrective measures. The scenario built into this analysis, for example, can provide useful information on best practices that can be adopted in the short and medium terms. Moreover, this study's results reveal that packaging materials, in particular, have to be constantly monitored also due to the current EU guidelines, which are meant to address climate change and to reduce plastic pollution through restrictions on single-use plastic products.

Finally, with regard to transboundary pollution from cruise ships, both international and regional frameworks are required if any significant improvement in sustainable practices (both on land and on ships) is to occur. In addition, any programs, actions, and proposals that are meant to enhance sustainability and tackle environmental and social challenges, such as the Horizon 2020 program and the EU's Blue Growth initiative, can be useful when implementing and coordinating research in this sector.

Furthermore, it also has to be noted that the cruise sector was based on specific and organized itineraries across the ports, differently from other form of touristic offer which usually promote a single and isolated destination. The interrelationship among the destinations and ports makes a cooperation and coordination very plausible in order to implement cross-border waste policies and benchmark data and practices on the environmental issue. This allows to trace waste streams across the territories involved and to implement coordinated waste disposal procedures and plants (United Nations World Tourism Organization, 2016). Probably, a supervisor committee could be able to monitor and control a standardized waste collection system on shore, ensuring that its environmental and economic performances are legal as well efficient.

Authors contribution

The authors' contribution is as follows: Paiano: section 1, section 2, section 3 and section 4. Crovella: subsection 2.2, section 3 and Bibliography; Lagioia: section 1 and section 4.

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