Carbon and Water Footprints of Marinas in the Canary Islands (Spain)

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Short title : Coastal Management

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Abstract

The Canary Islands have a maritime position, and there are many ports along their coasts, including commercial, passenger transport and marinas, which is the case studied here. This document aims to determine the impact of marinas on the environment. To achieve this, carbon and water footprint calculation tools were used. A survey was developed and sent to the managers of the marinas, with questions that addressed three areas of the carbon footprint and the blue water in the water footprint calculation. Once the completed surveys were received, the data were processed and converted into tons of CO_2 equivalent, using emission factors published in official Spanish sources. The amount of greenhouse gases produced by the marinas studied was obtained. One of the most remarkable findings is that companies working for the marinas (scope 3) have an important effect on the calculation, since not only the marina's own activities generate emissions but also the movement of vehicles of companies related to this facility.

Keywords: Climate change; greenhouse gases; carbon footprint; water footprint; marine sports

Introduction AQ2

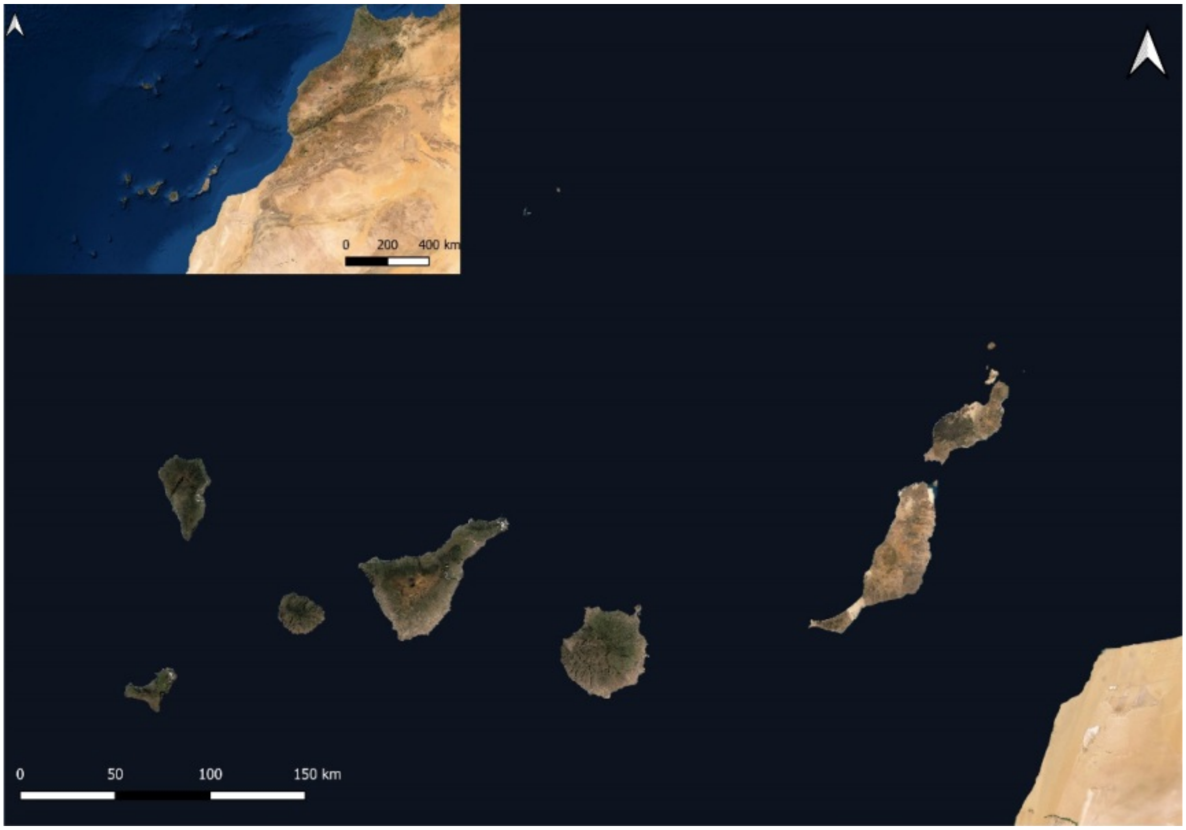
The financial crisis that began in 2008 and the recent economic slowdown caused by COVID-19 are clear examples that corroborate the link between GHG emissions and economic activity (Le Quéré et al. 2020). In this sense, the top five greenhouse gas generating sectors in Spain in 2016/2017 were transport (26%), electricity generation (20%), industry (19%), agriculture (12%) and the residential, commercial and institutional sector (8%) (Ministerio para la Transición Ecológica 2019). In the Canary Islands, due to their island status and strategic geographical location, the port system is an essential element of social and economic life (Herrera and Bel 2009). The Islands' ports have helped guarantee mobility of citizens by satisfying, to a large extent, the needs for passenger transport. The ports have also provided the fishing, commercial and industrial sectors with the facilities and infrastructure essential for carrying out the tasks of economic exchange and goods traffic (Tovar, Hernández, and Rodríguez-Déniz 2015). In addition, great development of tourism has led to the appearance of marinas and maritime facilities of a sporting or recreational nature, linked to leisure and quality tourism. These recreational facilities or marinas have had an impact on the economic model of the municipalities in which they are located in the territory. A marina is defined as an enclosure of naturally or artificially sheltered water, as well as the adjacent land surface and facilities and land accesses, which allow the operations required by the marina fleet and its users to be conducted independently of other facilities (Martín and Yepes 2019). Therefore, as the marinas have a land and a water environment, the tools that have been used to measure environmental impact are the carbon footprint and the water footprint.

Spain is one of the European Union countries with the longest coastlines and, therefore, with substantial maritime infrastructure. In 2015, Mediterranean ports received 29% of European traffic for the transport of goods (Chatzinikolaou et al. 2018).

The strategic location of the Canary Islands has become a key element in commercial and passenger relations between Europe, Africa and America (Herrera and Bel 2009) due, among other things, to the trade winds (Baldasano et al. 2014). This maritime heritage continues to present day, with development of industry and renewed focus tourism and leisure. Today, tourism accounts for 35% of the Canary Islands' GDP, according to the Canary Islands Institute of Statistics in 2019. Therefore, there has been a proliferation of infrastructures along the coast of the islands, dedicated to maritime activities such as whale watching, tourist visits from the coast to other areas of the islands, a technical stop in the Canary Islands for international crossings, etc. (Delgado-Aguiar and Hernández Luis 2019). The aim of this study is to evaluate the carbon footprint and the water footprint of Canary Island marinas in order to draw conclusions about the environmental impact of the recreational marine sector on the islands, along with recommendations for improvement. As a first approximation in this research area, the marinas owned by the autonomous region of the Canary Islands have been chosen.

The Canary Islands are an archipelago of eight islands located off the coast of the Sahara, on the African continent. The Canary Islands are an outermost region of the European Union, where international tourism plays a major role in the archipelago's GDP. As tourism is constantly growing, according to the islands' official statistics, nautical tourism is also growing in this destination (Mateos 2010). Three of the Canary Islands (Figure 1) have been selected for the study, these are the islands of La Palma, Tenerife and Gran Canaria.

Figure 1. Canary Islands (Spain).



The carbon footprint accounts for all greenhouse gases associated with the production of a product, the provision of a service or the performance of an activity, generated either directly or indirectly by the organization (Blasco Hedo 2014). The measurement not only quantifies the magnitude of the emissions but also identifies their origin. Depending on the origin of the emissions, recommendations are made to reduce or offset them and, by putting these recommendations into practice, to act on the planet's climate.

The use of water consumption indicators to evaluate social behavior in water use and consumption is gaining much interest. The water footprint is one of these indicators, and its determination is of notable value in arid places and/or with a high consumption of water resources per inhabitant per year (Hoekstra and Hung 2002). Just as the carbon footprint accounts for GHG emissions, the water footprint accounts for the total volume of water needed to produce the goods and services consumed by an individual, community or organization (Hoekstra 2011).

While the carbon footprint contemplates offsetting emissions between organizations or locations, water consumption or pollution cannot be offset (Egan 2011). Thus, the main action that can be derived from calculation of the water footprint is the proposal of recommendations that reduce the associated water footprint.

The calculation of these two indicators of environmental sustainability implies a management of energy consumption that not only produces environmental benefits but also significant economic savings. Furthermore, the calculation of these footprints can be understood as a business opportunity by making it possible to attract investors and customers who are aware of climate change and the environment.

Carbon footprint

Various international and national regulations govern the accounting of CO_2 emissions. Some countries have even devised their own system for calculating carbon footprint. The regulatory framework is such that a study promoted by the European Commission in 2010 found more than 140 different methodologies (CEPAL 2008).

The emissions inventory requires identification of the sources of gas emissions. Emission sources are classified into fixed and mobile sources. Among the fixed sources, a distinction can be made between point sources derived from the generation of electrical energy (generators) and those from industrial activities, as well as area sources, which include the emissions inherent in certain activities and processes. The definition of mobile sources includes all motor vehicles.

The activity data collected from the different sources and expressed in kWh, liters or m^3 should be expressed in tCO_2eq terms. Emission factors are the converters that enable us to transform units of measurement of consumption of different scopes into the unit of measurement of the carbon footprint, which is the ton of carbon dioxide equivalent. For this purpose, the emission factors published annually by the Spanish Ministry for Ecological Transition are used, depending on the type of fuel and/or electricity supplier, and the year of study.

Water footprint

The water footprint can be calculated from a consumption or a production perspective. The water footprint as a producer, or internal water footprint, quantifies the volume of water used within the limits of a defined area in the production of goods. The water footprint, as a consumer or standard water footprint, evaluates the water used in the products and services that are consumed by the inhabitants and that come from other places (Fundación Mapfre 2011). Likewise, the calculation of the water footprint can be focused on a consumer, a producer, a process, a product (De Fraiture et al. 2004) or a specific geographic area such as a country, region, watershed, or a specific economic sector (Botín 2014; Moratilla, Moreno, and Barrena 2010). A product water footprint assessment considers all stages of a product's life cycle, from raw material acquisition to final disposal, and an assessment of an organization's water footprint takes a life cycle perspective based on all its activities.

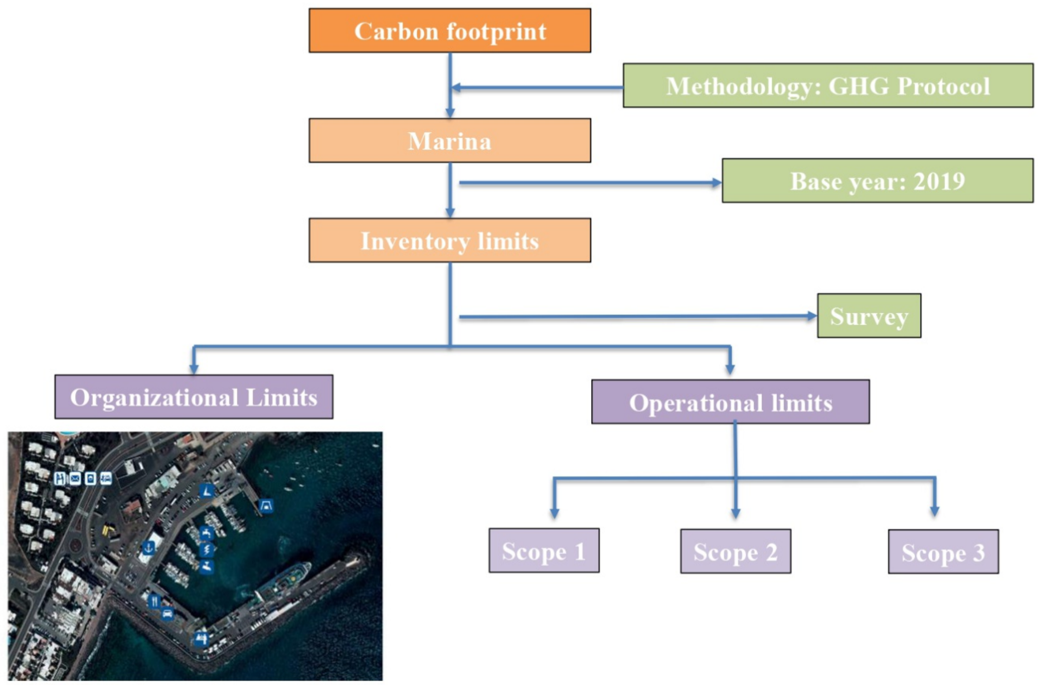
When using the methodology proposed by Hoekstra et al. (2012) (WFN methodology), the following three categories should be considered within the direct and indirect water footprint: blue water footprint, green water footprint and gray water footprint. The green water footprint may be negligible in sectors that are not related to agriculture (Veettil and Mishra 2016); the blue water footprint refers to the consumptive volume of drinking water needed to undertake the activities (Zhuo, Mekonnen, and Hoekstra 2016) and the gray water footprint represents the volume of drinking water needed to dilute the pollutants in the water so that it can be discharged into watercourses, in accordance with the parameters set by the regulations in force in each area (Gu et al. 2014).

Methodology

The quality and completeness of the data require a systematic procedure for collecting information that will also facilitate this task in subsequent years. Following this premise, a 26-item questionnaire was developed to be completed by marina managers. The interview was conducted online and the questions were structured according to each scope of the carbon footprint. For Scope 1, fossil fuel consumption was requested for both fixed installations and vehicles. For Scope 2 the annual electricity consumption, as well as the supplier company, was queried, in order to obtain a value of the appropriate electricity mix in each case. For Scope 3, information was requested on the movements of workers, suppliers and waste management, as well as the frequency of such movements and the types of vehicles used for this purpose. In addition, questions were asked about water consumption, wastewater management, and other questions of interest in order to better understand the behavior of the marina, and thus be able to better analyze the results.

Calculation of the carbon and water footprints of the i-th marina in the Canary Islands, $i = 1, \ldots, n$, in year t is based on the methodology of the organization, the control approach and a level 3 scope. The control approach requires the definition of the organizational limit of the inventory of operations. In this sense, it is necessary to consider that in a marina service area, four types of emissions are distinguished, according to the point or area of emission. There are external emissions which include those that are located outside the service area, emissions located within the marina service area that are not produced by activities developed on the land, works and marina facilities, and emissions from concessionary or authorized companies produced by activities undertaken on the facilities by concessionary or authorized companies (Figure 2).

Figure 2. Methodology used in the study.



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Following the above classification and considering the emissions of concessionary or authorized companies and marina emissions, the scope of study of marinas includes the total area of the marina in the public domain, including the water mirror area and the land surface (Cruz-Pérez et al. 2021). The water surface area is defined by the number of berths and the average size of the boats operating. The land surface includes the surface area of buildings and facilities. Buildings are those used for administrative activities, toilets and showers, restaurants such as bars, cafes and restaurants and hotels. The facilities include the road network and parking lots, the dry dock, maintenance and sanitation work, the transformer power station, the fuel station, the recycling point, the drinking water supply facility, the surface drainage system and the electricity network.

The control approach also requires defining the operational limit or inventory of operations over which the marina exercises control, distinguishing according to the scope and the fixed or mobile nature of the operation. There is no doubt that the scope of the activities is conditioned by the regime of exploitation, in rent or ownership, of the available places in the marinas. Whatever the case, the main services offered by marinas are access to drinking water, electricity, petrol, mooring assistance, crane, waiting dock, maintenance service, weather information, towing, toilets, lockers, mechanics, nautical items, diving service, 24-hour surveillance, laundry, parking and catering. The issuing sources associated with operations of a fixed nature include facilities for administration, maintenance, toilet and shower activities, catering and hotels. In relation to administration activities, the number of offices and persons working in each of them is counted; in maintenance activities, a distinction is made depending on who carries them out, whether it is the marina's own personnel, hired personnel or others. Whatever the case, the frequency with which these activities are carried out on average and the consumption of water and electricity used on average when these tasks take place are quantified. As for food and catering activities, the number of activities of each modality is quantified, distinguishing whether the power source is that of the marina, the city, solar panels or others. The way the water is heated will require the marina to have solar panels or natural gas or oil boilers. Regarding toilets and showers, the consumption of water, electricity or diesel oil by the marina are included. Finally, boats can be habitual residences or for the private recreational use of their owners. However, they may also be used to carry out some professional activity like a recreational boat or for whale watching. Whatever the use, boats need energy and the way to obtain this energy can be a solar panel, a generator or by connecting to the electricity supply network.

Mobile sources include petrol or diesel and electric vehicles such as motorcycles, cars, vans and trucks used by sailors, personnel, visitors, suppliers and waste managers.

Under the same organizational constraints, the procedure followed in calculating the water footprint of a marina starts with approximation of the direct and indirect water footprints. The direct water footprint is the volume (m^3) of fresh water consumed and polluted in the provision of all the services offered by the marina, and the indirect water footprint is the volume (m^3) of fresh and polluted water associated with the production of the goods involved in the provision of the services. In this case, as these facilities provide a service, only calculation of the blue water footprint has been considered. That is, the volume of drinking water required for the different uses (toilets, boat cleaning, offices, restaurants, etc.) that remains contaminated after use in the marina (Eq. (1)).

$$WF_{blue} = blue\ water\ evaporation + blue\ water\ incorporation + lost\ return\ flow \quad (1)$$

The green and gray water footprints have not been considered, as no rainwater is used in any process (green WF) and none of the facilities studied have their own wastewater treatment (gray WF).

Results and discussion

The configuration of the marinas is quite variable among islands or within the same island, depending on whether or not the marina is located in an area oriented toward the tourism sector. In general, all the islands have both traditional marinas and marinas for sporting activities, and the users are both residents and transient users. However, the marinas on the islands in the western province of the Canary Island archipelago (La Palma, El Hierro, La Gomera and Tenerife) are usually base marinas, and leisure activities in general predominate. However, the marinas on the eastern islands (Fuerteventura, Lanzarote and Gran Canaria) are located in tourist areas and are more oriented toward transit tourists.

The results under this heading correspond to the marinas that responded to the questionnaire (Table 1). These marinas represent 21% of those that exist in the Canary Islands, and they are oriented toward recreational or private use.

Table 1. Description of the marinas.

Characteristics of the ports that answered the survey			
Island	Tenerife	La Palma	Gran Canaria
Boats (n°)	362	350	388
Size (m)	11 × 4	6 × 2.5/11 × 4	11 × 4
Workers (n°)	17	7	16
Restaurants (n°)	7	Not available	Not available
Boat power supply	Generator	Generator	Generator

Source: Prepared by authors from the answers to the survey and interviews with managers.

The water mirror of the marinas covers more than 350 boats, without reaching 400. The marinas of Gran Canaria and Tenerife are base ports. The marina of La Palma has the double function of base port and transit port; therefore, the users are not only residents but also sailors whose voyage has another destination. The base ports usually have a dry marina, where boats stay out of the water during the season when their owners are off the island or during the non-summer season. The rule is that the berths in the marinas are operated on a rental basis; however, the marina in Tenerife is an exception to the rule, with more than half its berths operated on a property basis. The maintenance of the boats is carried out either by staff of the marina, nautical companies or by the boat's own crew.

The typical number of employees in the marinas studied is approximately 15. These people perform functions in areas such as management, administration and maintenance. Marina staff is an important item in the calculation of the carbon footprint, since scope 3 accounts for fuel from mobile facilities such as vehicles in which workers travel to work.

However, other vehicles, such as those of suppliers, visitors and waste management, also pass through the marina. This core of users uses a varied range of vehicles, but the most common are vans or cars among suppliers, cars among visitors and trucks among waste management staff. The type of vehicle is a relevant parameter, given that fuel consumption and therefore the emission of greenhouse gases depends not only on the kilometers traveled but also on the type of vehicle. The timetable of the marinas, 24 hours a day during 365 days of the year, is justified by the fact that the number of visitors reaches significant figures in some cases. All marinas have a recycling point, and waste management is carried out by specialized companies that provide the service four times a year in all cases.

The most common factor is that the boats, once berthed in the marina, obtain energy from the electrical system. However, the use of solar panels is spreading both on boats and in the marina's fixed installations to reduce their dependence on the electricity grid. Specifically, the toilets in the marinas of La Palma and Gran Canaria have solar panels to produce hot water. It should be noted that electricity consumption is counted in scope 2 of the carbon footprint. Although the energy demand is fed from the electricity grid, generators are frequent equipment in the marinas to deal with exceptional situations. These generators run on diesel, which is counted in scope 1 of the carbon footprint.

Table 2 shows the emissions in tCO_2eq of the three marinas studied, according to scope and emission source, for the year 2019. CO_2 emissions are higher in the scopes related to fossil fuels (scope 1 and scope 2), with scope 1 being more important, as it is related to the fuel consumed directly by the company. The figure for scope 3, related to fossil fuel emissions from marine-related vehicles, is the most striking because of the high value recorded in all three cases. The marina of Tenerife reports the highest carbon footprint. This result can be explained by the marina's accommodation capacity, its location in a tourist area far from urban centers with a significant population and its dependence on a large number of external suppliers.

Table 2. CO_2 emissions according to marina, scope and emission source (tCO_2eq) (year 2019).

	Emissions (tCO_2eq)			
	Source	**Tenerife**	**La Palma**	**Gran Canaria**
Scope 1	Fixed installations	934,75	736,18	894,74
	Vehicles	0	0	0
	Subtotal	**934,75**	**736,18**	**894,74**
Scope 2	Fixed installations	48,37	80,2	196,68
	Subtotal	**48,37**	**80,2**	**196,68**
Scope 3	Vehicles	1.885,02	576,74	422,68
	Subtotal	**1.885,02**	**576,74**	**422,68**
Total (tCO_2eq)		**2.868,14**	**1.393,12**	**1.514,10**

Source: Prepared by authors from the answers to the survey and interviews with the managers.

Scope 3 has the highest emissions figure in all marinas. This result can be explained by the fact that marinas are organizations that provide several services, such as leisure activities, waste management, boat maintenance and spare parts suppliers, among others. Scope 1 considers the diesel consumed by the organization itself, and the fact that the marinas are located in coastal areas means that they need a certain amount of autonomy. The marinas achieve this autonomy with generators that, in the event of a lack of electricity supply or obsolete facilities, provide them with sufficient energy. Finally, Scope 2 has registered the lowest value in all the cases studied. Most of the marinas studied use solar panels for hot water in the toilets.

A similar study calculated the carbon footprint for 12 European marinas, located in Spain (Balearic Islands), Sicily, Cyprus and Madeira (Cruz-Pérez et al. 2021). The results of this study show that the marinas analyzed in the Canary Islands have carbon footprint values very similar to those of the Balearic Islands; however, they differ in the way they are distributed. That is, in the Canary Islands the highest scopes are Scope 1 (fossil fuels consumed directly by the marina) and Scope 3, while in the Balearic Islands, the highest scopes are Scope 2 (electricity consumption of the marina) and Scope 3. From these studies, it can be deduced that if the electricity consumption of the marinas were to come entirely from renewable sources, Scope 2 would be canceled. If fossil fuel consumption is eliminated in Scope 1, replacing vehicles with electric vehicles and eliminating fixed installations that run on diesel, Scope 1 would also be nullified.

Energy generated by a renewable source does not emit CO_2 but, whatever the source is, the marina needs energy to operate. Energy generated by a renewable source has also been studied to reflect the impact that the use of such energy has on the carbon footprint. To measure the impact, it is assumed that energy from a renewable source is generated by a nonrenewable source and the CO_2 emissions are evaluated in tCO_2eq. However, the marinas that responded to this study do not use energy from renewable sources.

It is important to know how the marina works energetically, with studies such as this, so that the carbon footprint works as a starting point to apply already published methodologies (Sadek and Elgohary 2020; Uche-Soria and Rodríguez-Monroy 2019) on how to have renewable energy supply to the marinas.

With regard to the water footprint, only the volume of direct water consumed by the marina has been assessed, leaving aside the rest of the services that external companies provide at the sports complex, due to the difficulty involved in carrying out plausible estimates of all the variables involved. For the three marinas studied, water consumption was very similar, ranging between 10,000 and 12,000 m^3.

Although all marinas confirm that they treat their wastewater responsibly, numerous studies have proven that the waters around marinas have varying degrees of pollution. For example, a study in Spain (Gómez et al. 2019) analyzed the quality of the water in all marinas and it emerged that, in the Canary Islands, the environmental risk is mainly moderate or high (in Tenerife, Fuerteventura and La Palma). Naturally, not all pollutants in the water are derived from the marina itself; some are derived from the people who use the facilities, as is the case with emerging pollutants related to sunscreens and other cosmetic products (Montesdeoca-Esponda et al. 2019).

Conclusions

The three scopes of the carbon footprint have been studied. Scope 1 is high in all cases, more so than Scope 2, which refers to emissions associated with electricity consumption. Therefore, it is vital to reduce the consumption of fossil fuels in the Canary Islands marinas in order to reduce their carbon footprint. Regarding Scope 2, the use of renewable energies is essential to reduce the emissions associated with electricity supply. Regarding Scope 3, a series of measures can be taken to minimize fossil fuel consumption related to vehicle travel, such as: a) Promote the use of public transportation among marina workers and visitors, indicating on the marina's website the public transport service lines between the marina and different locations on the island; b) Implement a purchasing plan to reduce the frequency of suppliers going to the marina and c) Encourage the hiring of distributors with efficient transport fleets such as electric or low emission vehicles.

In addition, it is important to evaluate the carbon and water footprints in the coming years, to analyze whether practices in terms of CO_2 emissions and water consumption of marinas are moving in the expected direction with respect to the base year and to check the effect of the measures taken.

Acknowledgments

The development of this study has been possible thanks to the Government of the Canary Islands under grant agreement N° 20160026, *"Analysis of the carbon and water footprint of the three main economic activities in the Canary Islands: Tourism, Agriculture and the Integral Water Cycle."* {**Comment by Author:** The development of this study has been possible thanks to the European project Erasmus+ INCAMP (https://www.incamp-project.eu/), which studies European marinas and has allowed this analysis to be carried out and the European Union's Horizon 2020 research and innovation programme under grant agreement No. 776661, European Union Erasmus Plus programme under grant agreement Num. 2018-1-UK01-KA203-047958 and grant agreement Num. 2017-1-UK01-KA203-036521. This article reflects only the authors' view and the European Union is not liable for any use that may be made of the information contained therein.}

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4. **Comments** [Author - 5/27/2022 12:32:45 PM]: Fraiture, C. de; Cai, X.; Amarasinghe, U.; Rosegrant, M.; Molden, D. 2004. Does international cereal trade save water? The impact of virtual water trade on global water use. Comprehensive Assessment Research Report 4. Colombo, Sri Lanka: Comprehensive Assessment Secretariat

5. **Comments** [Author - 5/27/2022 12:37:53 PM]: The development of this study has been possible thanks to the European project Erasmus+ INCAMP (https://www.incamp-project.eu/), which studies European marinas and has allowed this analysis to be carried out and the European Union's Horizon 2020 research and innovation programme under grant agreement No. 776661, European Union Erasmus Plus programme under grant agreement Num. 2018-1-UK01-KA203-047958 and grant agreement Num. 2017-1-UK01-KA203-036521. This article reflects only the authors' view and the European Union is not liable for any use that may be made of the information contained therein.

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1. F002.png

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