

Ecological footprint in a reverse osmosis seawater desalination plant. Case study: Canary Islands

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ABSTRACT

The case study of the Canary Islands (Spain) considered in this paper involves the historical problem of resolving the demand for freshwater. After many years, the focus in the islands turned towards seawater desalination processes to provide safe water for, above all, its citizens, agriculture, and tourism. Due to the high demand for freshwater, the Canary Islands have been a world pioneer in desalination issues, improving the techniques and materials used. While several desalination technologies are available, today the most used worldwide is reverse osmosis. The major drawback of desalination is the high energy cost that the process requires. To this can be added the peculiarities of the electricity generation system in the Canary Islands, which generates more emissions per unit of energy produced compared with the system in mainland Spain. In this study, we selected a desalination plant located on the island of Tenerife, specifically in the municipality of Granadilla de Abona and, after determining its technical characteristics, calculated its ecological footprint. For this, we performed various calculations, including the carbon fixing capacity of forests in the Canary Islands (expressed per hectare) and the total amount of emissions produced in the generation of energy to feed the desalination plant.

Keywords: Ecological footprint; Carbon footprint; Reverse osmosis; Desalination

1. Introduction

The ecological footprint is defined as the total ecologically productive area necessary to produce the resources consumed by an average citizen of a given community, as well as the area required to absorb the waste thereby generated irrespective of the location of these areas. That is, the ecological footprint corresponds to the area of ecologically productive territory (crops, pastures, forests, or aquatic ecosystem) necessary to produce the resources used and to assimilate the waste produced by a defined population with a specific standard of living indefinitely, wherever this area

is located [1,2]. It is, therefore, a variable directly proportional to resource consumption and population, as well as to waste generation. It could be argued that the ecological footprint is responsible for determining which productive areas are necessary to maintain a specific population indefinitely, wherever that area is located, highlighting the importance of the character and nature of the territory with respect to the population.

The ecological footprint computes the yield per unit of surface of the primary product flows to find the area necessary to be able to carry out a certain activity. For its part,

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the biological capacity or biocapacity is the supply created by the biosphere, this implies the measure of the amount of biologically productive land and the maritime zone available to provide the services of the ecosystems that humans consume.

Both the ecological footprint and biocapacity can be estimated for different uses of the territory and can, therefore, serve to account for variations in the estimated average territorial productivity for different purposes. They are expressed in terms of average global hectares, territory or biologically productive maritime zone, with the unit of measure being the global hectare (gha). A global hectare will have a productivity equal to the average productivity of the 11.2 million bio-productive hectares on the planet. Productivity does not refer to the rate of biomass production, similar to the net primary production. In this case, productivity is the potential to achieve a maximum agricultural production with a certain level of inputs. Thus, a hectare of highly productive land is equal to more global hectares than a less productive hectare of land. Global hectares are standardized so that the number of land and sea hectares is equal to the defined global number of hectares [3]. Thanks to this concept of global hectares, it is possible to compare the ecological footprint and biocapacity of different countries of the globe with different farmland, grazing lands and forests. The conversion factors applied to achieve this purpose are equivalence factors (constant for all countries and for a given year) and performance factors (country-specific and year-specific), translating each hectare of biologically productive areas into global hectares.

Equivalence factors represent the global average productivity potential of a given bio-productive area considering the concept of global average productivity of total bio-productive zones. The equivalence factors of farmland, forests, grasslands, and infrastructure-occupied areas are derived from the global indices established in GAEZ (Global Agri-Ecological Zones) 2000, a spatial model of the potential of agricultural yields (Table 1).

This factor describes the possible achievable yield by crops in an area with a theoretical assumption of inputs such as water and fertilizers, regardless of management practices or types of biomass production. Performance factors in each country seek to quantify the relationship between a biologically productive zone and the global average of the same bio-productive zone. In other words, it implies the relationship between the production of goods in a given category

of a country, nation, or territory, with their national yields and the amount of territory that would have to be established to produce the same goods with average global yields. Consequently, each country has its own set of performance factors, which need to be recalculated each year [4,5].

The performance factor reflects the prevailing technology and management practices in the territory, as well as the productivity of domestic renewable resources. If agricultural production per hectare in a country depends on soil fertility as well as farming methods, the performance factor will reflect the national average with a subsequent weighting of the existing climatic zones. Given that there are many countries with markedly different climate zones, it is necessary to reflect with greater resolution the accuracy of their actual productivity in regional or local analyses, recalculating, as far as possible, the performance factors to reflect the circumstances of each place [8–10].

2. Materials and methods

In this section, a description is given of the calculation methods of the ecological footprint in the Granadilla de Abona desalination plant (Tenerife, Canary Islands, Spain). The production of desalinated water, with all the daily tasks that come with its production generate an impact on its environment, from the capture of seawater, the consumption of electricity, the generation of waste and the use of a surface of land for this purpose, to the generation of gases such as CO₂ in the production of the electricity consumed [11–15].

From an operational point of view, the procedure for calculating the ecological footprint in the strict sense is based on three stages:

- In the first stage, the average annual consumption per person of the specific goods to be considered is estimated. These goods can be classified into five main categories (food, housing, consumer goods, transport, and services) assuming access to regional or national data and the corresponding consumption is divided by the number of inhabitants.
- Second, the appropriate area (aa) per capita to produce each type of good is estimated. This is done by dividing the average annual consumption of each good (c_i in kg/per capita) by the average annual productivity per hectare (p_i in kg/ha).

Table 1
Average and equivalent CO₂ absorption per hectare of the different surfaces of planet Earth. Surface area equivalence factors [4]

Surface category	Abs. Average (t CO ₂ /ha/y)	Surface area (million ha)	%	Abs. hectare equivalent (t CO ₂ /ha/y)	Equivalence factor (fi)
Forests	19.35	3,858.10	7.56	1.46	9.66
Crops	8.09	1,958.32	3.84	0.31	4.04
Meadows and pastures	2.44	3,363.72	6.59	0.16	1.22
Oceans, seas, etc.	0.10	36,010.00	70.60	0.07	0.05
Deserts	0.00	3,600.00	7.06	0.00	0.00
Other	0.00	2,217.06	4.35	0.00	0.00
Total surface		51,007.20		2.00	1.00

$$aa_i = \frac{c_i}{p_i} \quad (1)$$

After this, we obtain the total ecological footprint (EF) per capita by adding up all the biologically productive areas for the n goods and services.

$$EF = \sum aa_i \quad (2)$$

- Finally, we obtain the total ecological footprint (EF_T) of a particular population as the product of the previous expression and the total number of inhabitants (N):

$$EF_T = N \times EF \quad (3)$$

In this way, the ecological footprint is calculated [6].

The main advantage of the ecological footprint as an indicator is in the simplicity of the unit of measurement, the hectare, which allows us to make comparisons between different footprints in different places in the world. Thus, we can compare the cost of producing 1 kg of tomatoes with the cost of consuming 1 L of kerosene. That is to say, the ecological footprint facilitates comparisons between otherwise contrasting products or services. Other advantages of the use of the ecological footprint include the following:

- It defines sustainability objectives in specific and measurable terms by providing important information to governments and non-governmental organizations to establish sustainability-oriented measures, creating a meaningful context for decision-making.
- It helps to visualize the areas where there is the greatest room for improvement in reducing consumption and promoting sustainability. Once the mostly guilty areas have been determined, the costs of reducing it can also be estimated.
- It involves the development of activities that maintain to interest of citizens in ensuring a sustainable future. It is a concept that is easily conveyed and helps to raise awareness of the importance of sustainability and to promote initiatives or actions for it. This footprint also provides additional information to existing sustainability projects.
- It facilitates the development of strategies to speed up the process. Promotion of the reduction of the ecological footprint improves the quality of life of people. It helps to create a platform to be able to properly plan important issues such as housing, transport or energy and its infrastructures.

As for the disadvantages, the complexity of the calculation of the ecological footprint can be a limiting factor. As for the statistical methods used, they have been criticized because they require acceptance of many hypotheses, many questionable.

It is also an indicator designed for use at the national level, as it is the level at which the most reliable data is obtained and handled for the calculation, while it is more difficult to ensure data reliability at the regional

level. The data in question are imports and exports, food consumption, global energy consumption, etc.

This indicator rewards the replacement of original ecosystems with high productivity agricultural monocultures so that biocapacity per hectare increases. In this way, it implies that organic agriculture, which has lower productivity, produces a higher ecological footprint than intensive crops.

It should also be noted that no other impacts are counted such as water pollution, erosion, soil pollution, air pollution (except CO_2), etc. [8–10].

In the Canary Islands, the desalination of large amounts of water is required and almost all the electricity that is produced is from fossil fuels. Thus, the problem involves a conversion of oil into water on a planet that demands reductions in harmful emissions. That is, the issue revolves around the resolution of a local water scarcity and CO_2 problem, which is contributing to the worsening of a global problem such as air pollution. The dependence of the Canary Islands on fossil fuels is extremely high due to their insular condition and because of the absence of facilities such as gas storage or nuclear power plants, among others. Altogether, water desalination in the Canary Islands corresponds to the annual generation of over 770,000 MWh, equivalent to more than 180,000 tons of fossil fuels (3,600 barrel/d), at a cost of more than 100 million euros and the emission of more than 450,000 tons CO_2 into the atmosphere [16]. Only 5.6% of energy production in the Canary Islands is produced by renewable energy sources. As the Canary Islands is a region with excellent potential for renewable energy resources such as wind or solar, it is vitally important to study how to apply such resources in the desalination process to reduce the energy demand from other non-renewable sources [17].

The impact of brine discharge and greenhouse gas emissions needs to be estimated in a full valuation based on the consequences for the natural environment and on the basis of the technologies employed. In the Canary Islands, the preservation of marine habitats is fundamental due to their economic and social importance for both tourism, the main economic source of income in the islands, and fishing, albeit to a lesser extent.

It is also very important to minimize damage to the environment as landscape degradation is extremely difficult to reverse.

These impacts on biocapacity of brine discharges in coastal regions are both direct (physical-chemical modification of the marine environment) and indirect (reduction of catches in fisheries and loss of habitats and species).

Energy analysis, costs, and emissions of desalinated water in the Canary Islands.

The cost of desalination is quite high when compared with freshwater exploitation where energy is only consumed when pumping water from where the consumer is extracted. In the Canary Islands, the predominantly employed technology is that of reverse osmosis (RO), with this process accounting for 77% of the total amount of desalinated water [18].

In RO, energy is consumed in the pumping system, the pre-treatment stage and in the generation of pressure in the actual RO stage, with this being the highest energy consumer.

High energy costs include the consequent environmental impact on energy generation, where greenhouse gases are emitted.

In 1970, the first RO desalination plants consumed up to 20 kWh. Over the years, this process has been improved through better materials, more efficient membranes, the use of energy recovery devices, etc., with a consequent reduction in energy consumption to about 3.5 kWh/m³ in the late 1990s. Today, energy consumption of below 2 kWh/m³ is technically possible.

In short, energy is the highest cost component in the operation of an RO desalination plant and at the same time is the factor with the greatest potential for cost reduction. The amount of energy consumption in the overall computation of an RO plant varies depending on its operating and other parameters. In our case, we will make an average estimate of the corresponding values to obtain the consumption of the Granadilla desalination plant.

The figure below shows the typical distribution of total energy cost in RO desalination plants. It should be noted that the largest contribution is directly related to the high-pressure pumping required by this technology (84.4%).

The production costs of one cubic meter of desalinated water are conditioned by several factors: facility depreciation, maintenance, chemicals, personnel, taxes, membrane changes and energy consumption. The latter is the most decisive factor in the overall analysis of investment in the production of desalinated water in the Canary Islands, amounting to 41% of the total costs [16].

As mentioned above, the model of electricity production in the Canary Islands is almost entirely produced from fossil fuels. In the case of the conventional generator plant, an yield of between 32% and 36% is estimated, with emissions related to an average thermal power plant estimated by the public administration at 0.402 kg CO₂/kWh [19].

Calculation of actual desalination energy consumption in the Canary Islands is complicated by a lack of data in different aspects, which means that some values have to be approximated to allow us to propose alternative scenarios to reduce the ecological footprint.

It should be noted that desalinated water is produced on the coast, and so will then have to be pumped and stored for later distribution. This can increase the energy bill by 1 or 2 kWh/m³, as well as result in water losses and the potential need for subsequent water purification.

Using data provided by the Spanish Directorate-General for Industry (DGIE), an average specific energy consumption (SEC) of 4.89 kWh/m³ (desalination and first pumping of desalinated water) for desalination plants in the Canary Islands has been determined [6].

Table 2 shows the energy consumption of each island and the percentage of this energy used for desalination. It should be noted that these calculations were made on the basis of data present in the Energy Statistics of the Canary Islands along with information of the hydrological plans of each island. It should also be clarified that, for purposes of simplification, it is assumed that all desalinated water is obtained through RO, whereas in fact a small amount is obtained using other techniques. Finally, the calculations are also based on the above-mentioned average SEC of 4.89 kWh/m³.

The emission coefficients that are assigned to the power generation on each of the different islands are considered next. First, we consider the emissions data provided by Endesa, the company with a monopoly on power plant generation in the islands. The fact is 0.31 kg CO₂/kWh [20].

Subsequently, we consulted the emission values on the website of REE (Red Eléctrica de España), Spain's grid manager and transmission agent, and obtained values for each of the islands separately. To obtain an average emissions data from power generation, all daily emission coefficients per island were selected, taking a value every 2 h, and the daily average value for a random working day was obtained to be able to further approximate this emission coefficient. More specifically, we selected October 6, 2020. The corresponding 2-h values and the final average value are shown in Table 3 for each island.

Based on the results of Table 3, we can see how the values range between 0.5 and 0.7 t CO₂/MWh, with the island of Tenerife having the lowest coefficient, enhanced by the presence of more efficient and less polluting energy generation systems along with a greater presence of renewables. In contrast, Lanzarote and La Gomera have the highest coefficients of approximately 0.7 t CO₂/MWh, partly due to polluting generation systems and a low presence of renewables. It should be noted that these calculations are made for a specific day and no meteorological aspects are considered that could condition the amount of clean energy generated through renewables. Nonetheless, it is a value very close to the actual situation of the islands throughout the year. By taking this data on the same day for each island, we ensure that there is equality or parity in the climate aspect in the archipelago, which makes energy generation through renewables equitable. Finally, it is important to highlight the value of 0.525 t CO₂/MWh, which corresponds to the emission factor of the island of Tenerife, which will be used as a reference when performing subsequent calculations [21].

On the basis of estimates made with data obtained from the hydrological plans of the Canary Islands and the Energy Statistics of the Canary Islands, the annual production of desalinated water in the Canary Islands is estimated at 216.41 hm³, for which the generation of 1,058,240 MWh is required. The production of this volume of desalinated water results in the emission of a total of 694,445 tons of CO₂.

With respect to the calculation method of the ecological footprint of the Granadilla desalination station in Abona, the impact associated with natural resource consumption and waste production is determined based on CO₂ emissions of each consumption or type of waste produced by the desalination plant. These emissions into the environment will then be translated into the forest area necessary to assimilate them. Electricity and the construction of the desalination plant constitute the most significant consumption of natural resources.

Emission factors obtained from various sources are used for the calculation of the CO₂ emissions, some of which have been discussed above. To calculate directly from consumption, in some cases, emissions are obtained by multiplying consumption by emission factors. This usually applies to water consumption, consumption associated with building

Table 2
Energy consumption of desalination in the Canary Islands

Data of 2015 except for Tenerife (2012)	Annual gridded energy (10 ³ kWh)	Desalinated water production (hm ³)	Energy used for desalination at an SEC of 4.89 kWh/m ³ (10 ³ kWh)	Percentage of energy used to desalinate (%)	Desalination CO ₂ emissions by island (t)
Gran Canaria	3,376.68	78.15	382.15	11.31%	255,658.4
Tenerife	5,571.04	26.64	130.27	2.34%	68,391.8
Lanzarote	817.23	24.4	119.32	14.6%	85,910.4
Fuerteventura	640.79	79.78	390.12	60.88%	259,429.8
La Gomera	69.23	6.07	29.68	42%	20,954.1
El Hierro	42.99	1.37	6.7	15.56%	4,100.4

Table 3
Emission coefficients per island (t CO₂/MWh) on 13/10/2020

Time (h)	Gran Canaria	Tenerife	Fuerteventura	Lanzarote	La Gomera	El Hierro
1:00	0.503	0.437	0.604	0.637	0.747	0.591
3:00	0.562	0.441	0.649	0.699	0.738	0.453
5:00	0.584	0.5	0.658	0.671	0.75	0.453
7:00	0.682	0.468	0.594	0.663	0.753	0.564
9:00	0.758	0.571	0.593	0.78	0.656	0.564
11:00	0.721	0.427	0.591	0.778	0.672	0.637
13:00	0.766	0.453	0.568	0.753	0.68	0.61
15:00	0.776	0.429	0.657	0.752	0.688	0.637
17:00	0.730	0.480	0.713	0.791	0.671	0.75
19:00	0.738	0.650	0.637	0.823	0.658	0.702
21:00	0.717	0.708	0.874	0.769	0.725	0.66
23:00	0.596	0.636	0.666	0.639	0.718	0.703
1:00	0.568	0.629	0.836	0.605	0.729	0.625
Average value	0.669	0.525	0.665	0.72	0.706	0.612

construction, electricity consumption, heat energy or natural gas consumption, among others.

In our case, we will calculate the area, in hectares (ha) of forest or forest area required to absorb the emissions produced by the consumption of resources and the generation of waste mentioned above. The required forest area is obtained from the amount emitted into the atmosphere dividing by the fixing capacity of the Canarian forest mass. To this amount of forest will also be directly added the space occupied by the desalination plant.

According to data obtained from the Government of the Canary Islands in its last measurement of greenhouse gases in 2008 in the Canary Islands, CO₂ emissions amounted to 13,517,320 tons. Carbon fixation by forest masses is around 16.13% of CO₂ emissions. A total of 2,180,343 tons of CO₂ were thus fixed in the study year. To compare this measure, we must obtain the capacity to fix of forest masses by hectare, and so we have to divide the CO₂ emissions by the area of the Canary Islands in hectares (about 749,300 ha) [22].

A final fixing capacity is thus obtained of $2.91 \frac{t CO_2}{ha \cdot y}$.

Considering the above explanations, the ecological footprint is then calculated using the following formula:

$$\text{Footprint} \left(\frac{ha}{y} \right) = \frac{\text{emissions} (t CO_2)}{C. \text{fixing} \left(\frac{t CO_2}{ha} \right)} + \frac{\text{emissions construction} (t CO_2)}{C. \text{fixing} \left(\frac{t CO_2}{ha} \right)} \tag{4}$$

To compare different ecological footprints, the global hectare (gha) is used, which is defined as the average global capacity to produce resources and absorb waste. To express the results in this way, the different types of existing areas have to be normalized. This can be done using equivalence factors, which translate a specific type of land into the

universal unit for the productive area (gha) and are based on measures of land productivity according to their use and year.

The next step involves a simple calculation of emissions related to electricity consumption based on the consumption data mentioned above, the daily production of the desalination plant in m³, and finally the appropriate emission factor. The following formula clarifies the process:

$$\text{Emissions (kg CO}_2\text{)} = \text{consumption (kWh/y)} \cdot \text{emission factor} \left(\frac{\text{kgCO}_2}{\text{kWh/y}} \right) \quad (5)$$

3. Results

As mentioned above, the average SEC of desalination plants in the Canary Islands is 4.89 kWh/. The Granadilla de Abona desalination plant has a production capacity of 14,000 m³/d, which will be used as the reference value. Finally, as also mentioned above, we use the emission coefficient obtained from the REE website for October 13, 2020, on the island of Tenerife (0.525 kg CO₂/kWh or 0.525 t CO₂/MWh).

$$\text{Emissions}_{(\text{Electric consumption})} (\text{kg CO}_2) = 24,987,900 (\text{kWh/y}) \cdot 0.525 \left(\frac{\text{kg CO}_2}{\text{kWh}} \right) \quad (6)$$

$$\text{Emissions}_{(\text{Electric consumption})} (\text{kg CO}_2) = 13,118,648 \text{ kg CO}_2 / \text{y} \quad (7)$$

It is this found that the Granadilla de Abona desalination plant emits 13,119 tons of CO₂ into the atmosphere through its energy consumption.

The emissions related to the construction of the building (in this case the desalination plant) are then calculated. According to a report by the Polytechnic University of Catalonia, the emission factor in the construction of buildings is 520 CO₂/m², taking into account an estimated useful life for buildings of a typology similar to the Granadilla de Abona desalination plant of between 15 and 50 y as set out in Royal Decree 1247/2008, of July 18, on instructions for the use of structural concrete [23–27]. For the purposes of this study, a mid-term of 35 y is selected resulting in an emission factor of 14.86 kg CO₂/m².

Finally, calculation of the area of construction of the Granadilla de Abona desalination plant is performed including the plant itself (1,144 m²) and the semi-buried deposit (1,695 m²) using the GRAFCAN viewfinder. A final total of 2,839 m² is obtained.

$$\text{Emissions}_{(\text{Building})} (\text{kg CO}_2) = \text{Area (m}^2\text{)} \cdot \text{emission factor} \left(\frac{\text{kg CO}_2}{\text{m}^2 \cdot \text{y}} \right) \quad (8)$$

$$\text{Emissions}_{(\text{Building})} (\text{kg CO}_2) = 2,839 (\text{m}^2) \cdot 14.86 \left(\frac{\text{kgCO}_2}{\text{m}^2 \cdot \text{y}} \right) = 42,187.54 \frac{\text{kg CO}_2}{\text{y}} \quad (9)$$

It is thus determined that 42.19 tons of CO₂ are emitted for the construction of the desalination plant.

As for the waste generated, this will have a considerably lower impact on the generation of CO₂ emissions and so will not be considered in this study [1]. CO₂ emissions from the construction of the seawater RO desalination plant are much more significant.

It is vitally important to know the CO₂ emissions related to the desalination plant and to try to reduce them and thus reduce the ecological footprint. This has been a priority since the drawing up of the Kyoto Protocol, an international agreement aimed at reducing emissions of six greenhouse gases. This document commits industrialized countries to controlling greenhouse gas emissions and setting future targets for the progressive reduction of greenhouse gas emissions.

To obtain the ecological footprint of the desalination plant, the different emissions have to be added together and divided by the carbon fixing capacity of the forest mass in the Canary Islands. The resulting calculation is as follows:

$$\text{Footprint} \left(\frac{\text{ha}}{\text{y}} \right) = \frac{13,119 (\text{t CO}_2)}{2.91 \left(\frac{\text{t CO}_2}{\text{ha}} \right)} + \frac{42.19 (\text{t CO}_2)}{2.91 \left(\frac{\text{t CO}_2}{\text{ha}} \right)} \quad (10)$$

$$= 4,522.75 \text{ ha / y}$$

Translated into global hectares (gha), the value is 6,060.5 gha/y.

The final step considers the size of the population under study. In the case of the Granadilla de Abona desalination plant, the population of the corresponding urban center is 70,000 inhabitants. An ecological footprint is, therefore, calculated of 0.065 ha/inhabitant/y or 0.087 gha/inhabitant/y.

The gha values for each land type can be displayed based on the calculated ecological footprint (Table 4) and a world map of the ecological footprint (Fig. 1).

Table 4
Global hectare values based on the calculated annual ecological footprint

	Gha
Desalination according to a SEC of 4.89 kWh/m ³	6,060.5
Agriculture (main lands)	13,393.71
Agriculture (marginal lands)	10,848.3
Forest	6,060.5
Livestock	2,969.65
Fishing (sea waters)	2,181.78
Fishing (inland waters)	2,181.78
Artificial	13,393.71

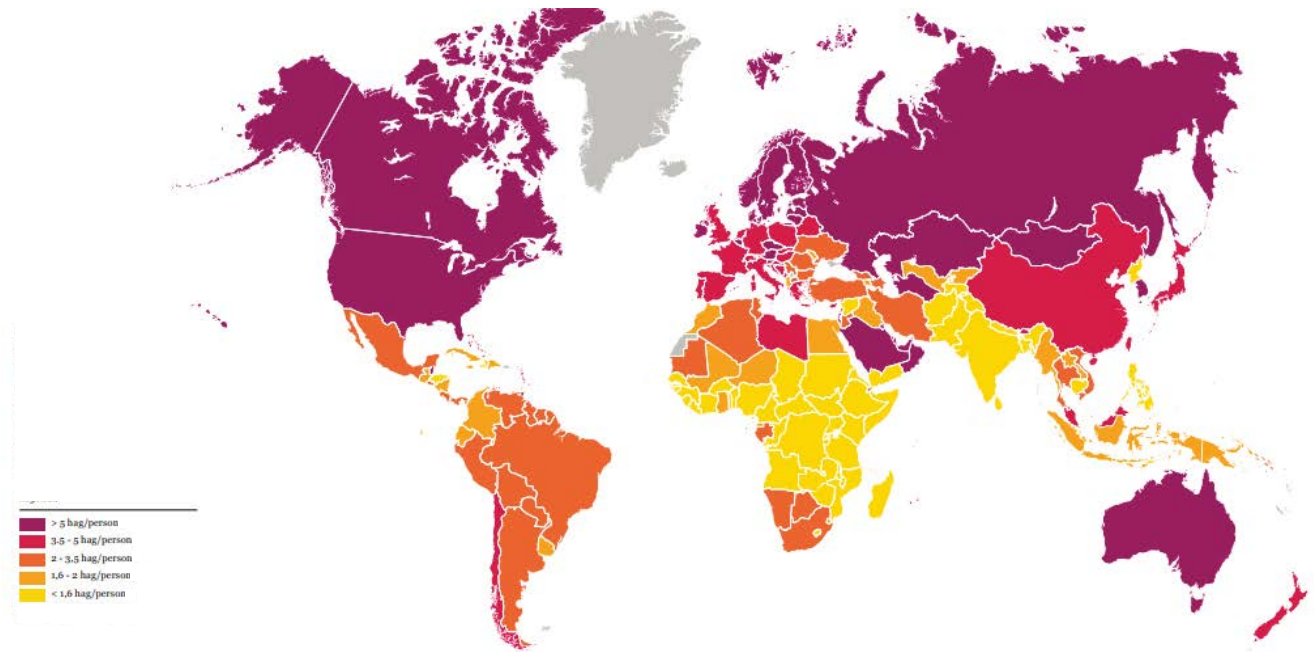


Fig. 1. World map of ecological footprint in 2016.

4. Conclusions

The main advantage of the ecological footprint as an indicator is in the simplicity of the unit of measurement, the hectare, allowing us to make comparisons between different footprints in different places in the world.

In the Canary Islands, the desalination of large amounts of water is required and almost all the electricity that is produced is from fossil fuels. Thus, the problem involves a conversion of oil into water on a planet that demands reductions in harmful emissions.

Water desalination in the Canary Islands corresponds to the annual generation of over 770,000 MWh, equivalent to more than 180,000 tons of fossil fuels (3,600 barrel/d), at a cost of more than 100 million euros and the emission of more than 450,000 tons CO₂ into the atmosphere.

The results of the case study considered in this paper show an annual production of desalinated water in the Canary Islands of 216,41 hm³, for which 1,058,240 MWh are required. Generating this volume of desalinated water generates a total of 694,445 tons of CO₂. The average SEC of desalination plants in the Canary Islands is 4.89 kWh/m³. Granadilla de Abona desalination plant has a production capacity of 14,000 m³/d and the emission coefficient obtained from REE, Spain's grid operator and transmission agent, for October 13, 2020, on the island of Tenerife was 0.525 t CO₂/MWh.

Based on the emission factor of 14.86 kg CO₂/m² and the area of construction of the Granadilla de Abona desalination plant (2,839 m²), an annual emission of 42.19 tons of CO₂ corresponds to the construction of the different infrastructures of the desalination plant. Translated into global hectares (gha), this is equivalent to 6,060.5 gha/y. Considering the size of the Granadilla de Abona population

(about 70,000 inhabitants), the ecological footprint is 0.065 0.087 gha/inhabitant/y.

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