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Carbon Footprint of Tourism Sector in Portugal—Calculator Development

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A carbon footprint (CF) calculator was developed to apply to a Portuguese touristic accommodation to contribute to a sustainable touristic activity. Although some calculators are available online, they are related to the country reality or use outdated emission factors. A calculator based on national emission factors is important. The calculator was developed in Microsoft Excel (version 365) and is based on the CO_2e emissions resulting from electricity, water, fuels and food use, laundry and waste production. The calculator development involved: study the accommodation emission sources, selection the environmental indicators, determination of the emission factors and development of the CF formulas. Total CF calculation was made considering the partial CF per component, a monthly and annual comparison of each indicator's emissions contribution using graphs. The emissions amount per overnight stay, per room, per area, were also assessed and these values were transformed into global hectare (gha). Avoided emissions calculation gives the information about the efforts in CF reduction, and two indicators were considered: electricity production from renewable energy sources and the amount of separated waste for recycling. It was considered reforestation measures to achieve carbon neutrality. This calculator incorporates four components not often used: water, laundry, waste, food, and avoided emissions.

Keywords: calculator, carbon footprint, greenhouse gases, environmental indicators, sustainable tourism

Introduction

The impact of human activities on the Earth's climate and temperature is increasingly more significant due to the increase in anthropogenic emissions of greenhouse gases (GHG) from fossil fuels burning, deforestation and livestock use (European Commission, 2016a; The Core Writing Team, Pachauri, & Meyer, 2015). Reducing GHG emissions and achieving sustainable economic development is the primary response to climate change (Liu & Lu, 2015). The European Union (EU) aims to become the first carbon-neutral continent by

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implementing ambitious policies setting targets for the current year 2020, 2030, and 2050 (European Commission, 2016b). In addition, growing environmental awareness in society, as well as increased legislation, has pushed most organizations in the various sectors of activity to move towards making their activities sustainable. There is also a tendency for tourists to be more concerned about the environmental effects of their products and services what has driven the development of sustainable tourism.

The calculation of the CF in terms of tourism allows not only the management of accommodation to monitor and control the emissions caused by them but also travellers, entrepreneurs and possible investors to choose the alternatives with less environmental impact. In this way, the CF can influence decision-making. Two of the methodological approaches used to calculate CF are PAS 2050-Publicly Available Specification and ISO 14067 (Garcia & Freire, 2014). PAS 2050 was developed to address the need for a consistent method for assessing life-cycle GHG emissions from goods and services (British Standards Institution [BSI], 2011). Its main objective is to provide an everyday basis for quantifying GHG emissions that will inform and enable significant GHG emission reduction programmes (BSI, 2011). According to Garcia and Freire (2014), PAS 2050 shows, for example, how to deal with common methodological issues and how to define and allocate the limits of the system. ISO 14067 arises to complement PAS 2050 and provides specific requirements and guidelines for the quantification and communication of CF products, based on existing ISO standards on life cycle evaluation and environmental labels and declarations (Garcia & Freire, 2014).

According to Birnik (2013), the CF calculators of private housing should be based on the 13 principles described in Table 1. Some of these principles are present in calculators developed by companies and organizations (see Table 2).

Table 1

Principles for the Elaboration of a CF Calculator

	Principles
1	Estimate at least CO_2, CH_4 and N_2O emissions
2	Present the units in CO_2 equivalent of GWP100
3	Estimating footprints based on consumption
4	Allow users to adjust their level of consumption and not the use of national averages
5	Adjust the relative distribution of consumption according to the level of invoicing
6	Adjust the number of people living in a house
7	Allow users to calculate housing emissions in detail
8	Analyse emissions from domestic energy use and emissions from furniture, household appliances, building materials and building maintenance
9	Allow users to calculate their food-related emissions in detail
10	Allow users to calculate their transport-related emissions in detail
11	Allow users to include the radioactive force of flights when calculating their emissions
12	Provide a comprehensive footprint, including the allocation of emissions to a variety of consumption categories
13	Emission factors should be updated and country/region-specific where possible

Padgett, Steinemann, Clarke, and Vandenbergh (2008) compared 10 CF calculators and concluded significant differences in CF estimates ranging from selected indicators to emission factors. Mulrow, Machaj, Deanes, and Derrible (2019) compared 31 calculators available online to identify the most important emission sources and environmental indicators and came to the conclusion that most emissions focus on electricity and fossil fuel consumption.

Table 2 details the emission sources for each component analyzed and the principles used (mentioned in Table 1) in six of the calculators studied by Birnik (2013) and Mulrow et al. (2019). The six calculators chosen are common to both studies and have obtained similar ratings. In Birnik (2013), the calculators are ranked according to the number of principles they comply with and are rated strong (seven or more principles), medium (Five or six principles) and weak (below five principles). Mulrow et al. (2019) classified these same calculators using an index according to the level of detail of each calculator (number of emission sources) and were also classified as strong, medium and weak. Of these calculators, Carbon Footprint Ltd. and WWF obtained the best rating.

Table 2

Emission Sources, Principles Used in Different Calculators and Their Classification

	Carbon Footprint Ltd.	WWF	Conservation International	US EPA	TerraPass	Climate Care
Energy	Electricity, natural gas, oil, coal, LPG, wood and propane	Electricity, natural gas, propane and oil	Electricity, natural gas, oil, wood and propane	Electricity, natural gas, propane and oil	Electricity, Natural gas, oil, propane, diesel and gasoline	Electricity, natural gas, propane, oil, wood, renewable energy
Transport	Car, motorbike, bus, train, electric, metro and taxi	Car, motorbike, bus and train,	Car	Car	Car, electric car, boat, train, bus, ferribote and taxi	Car
Air transport	Origin and destination	Distance to the United Kingdom	Short or long flight	No	Distance, total fuel	Airports based
Food	Yes	Yes	Yes	No	No	No
Water	No	No	No	No	No	No
Extra categories	Pharmaceuticals, electronics, education and leisure activities	Miscellaneous	No	Waste	No	Events
Numbered principles of Table 1	6, 7, 9, 10, 11, 12, 13	6, 7, 9, 10, 13	6, 7, 9, 10, 11, 13	6, 7, 10, 13	7, 10	7, 10, 13
Classification (Birnik, 2013)	Strong	Average	Average	Weak	Weak	Weak
Classification of (Mulrow et al., 2019)	Average	Strong	Average	Weak	Average	Weak

Source: Birnik (2013); Mulrow et al. (2019).

From Table 2, it can be seen that none of the calculators gives results concerning emissions resulting from water treatment and that for the other components; a variation in the number of indicators chosen makes some calculators more comprehensive than others.

The various calculators already developed by organizations or entities can be applied to various sectors, like tourism. Green Key is one of the entities that have developed a calculator oriented to the tourism sector, more specifically to accommodations. This calculator can be used to calculate CO_2e emissions from electricity consumption, natural gas consumption, heating oil consumption, gas leaks from air conditioners, laundry and fuel-burning by cars belonging to the accommodation (Green Key, 2020).

In general, among the existing calculators, what varies are the indicators chosen and the emission factors. The database of emission factors usually comes from the country where the calculator is developed. However, the calculation methodology is the same, consisting of the multiplication between the quantification of the chosen environmental indicators and the respective emission factors.

This study focuses on a CF calculator development, which can be applied to calculate direct and indirect emissions from all types of tourist accommodation in Portugal.

Research Methodology

The methodology used for the CF calculation tool development associated with the accommodations was based on that defined by S. Jain et al. (2017) and is divided into two essential steps:

1. Selection of components and indicators;
2. Development of calculation formulas.

Findings and Analysis

The selection of components and indicators involved the sources (direct and indirect) identification of GHG emissions from the lodgings and defining the limits of this study. Subsequently, it was necessary to compile the GHG emission factors expressed in CO_2e.

The tourism CF should be assessed using methods that cover the life cycle or emissions of the tourism-related goods and services supply chain (Lenzen et al., 2018). Tourism infrastructure is responsible for direct and indirect emission of CO_2e from the construction to the use phase (these being the most significant emissions) (Castellani & Sala, 2012). In addition to these actions directly related to tourism, there are other associated impacts, particularly regarding food, water use and tourism activities.

Emissions can be grouped by the level of their control. They can be divided into direct emissions (scope 1), indirect emissions of electricity (scope 2), and other indirect emissions (scope 3) (World Resources Institute [WRI], 2004; Larsen, Pettersen, Solli, & Hertwich, 2013; Kent, 2018; Carbon Trust, 2018; Lai, 2015).

The components that contribute the most to the CF of a lodge were selected for the calculation tool, namely electricity, water, fuel, food, laundry and waste. Each of the components has been assigned the indicators for calculating the CF (see Table 3). In this study, in addition to air emissions, avoided emissions involving the production of electricity from renewable sources and the recycling and/or reuse of waste were also evaluated.

Table 3

Components and Indicators Used in the CF Calculation Tool

Components	Indicators	Description	Emissions type
Electricity	Electricity consumption	Electricity consumption (purchased from a supplier)	Indirect Emissions (Scope 2)
	Electricity produced (renewable energy)	Electricity produced through renewable energy sources	Avoided Emissions
Water	Water consumption	Volume of water consumption	Indirect Emissions (Scope 3)
	Production of wastewater	Volume of wastewater produced	Indirect

			Emissions (Scope 3)
Laundry	Quantity of clothes washed	Amount of laundry to be done	Indirect Emissions (Scope 3)
Fuels	Fuel consumption used for stationary combustion	Quantity of fuels used (petrol, diesel, biodiesel, natural gas, butane, propane, mixture and wood)	Direct Emission (Scope 1)

Table 3 to be continued

	Distance travelled by cars	Fuel consumption by car, dependent of on distance made	
Waste	Production of Urban Waste	Quantity of unsorted waste (organic and undifferentiated	Indirect Emissions (Scope 3)
	Amount of waste recycled or reused	Amount of waste recycled (paper, plastic, glass, metal, oil)	Avoided Emissions
Food	Food consumption	Consumption of food (food purchased by the accommodation)	Indirect Emissions (Scope 3)

Source: S. Jain et al. (2017); Larsen et al. (2013); Kent (2018); Lai (2015).

Of the six components mentioned in Table 3, four will have to be updated annually (electricity, water, laundry, and waste) as their emission factors may differ significantly from year to year.

Calculation Formulas Development

The calculation formulas development was based on the GHG protocol premise that for most emission sources, the calculation of emissions is done by multiplying activity data (indicator) by the emission factor associated with the indicator being measured (Equation 1) (WRI, 2004).

$$EGHG = Activity\ data * Ef \tag{1}$$

where *EGHG*—emissions of greenhouse gases; *Ef*—emission Factor of the same activity; the activity data refer to the consumption and/or production of each component described in Table 1, as defined in the indicators.

The CF calculator was developed using Microsoft Excel (version 365). The type of results to be obtained for each component is shown in Table 4. The monthly emission variations for each indicator are also revealed by graphs, and a summary report of the calculated emissions is presented.

Table 4

Projected Results in Each Component

Component	Results
Electricity	Total consumption (kWh) Average monthly consumption (kWh) Consumption of kWh/guest-night KgCO_2e total Average monthly kgCO_2e KgCO_2e/guest-night
Water	Results for potable water Total consumption (m^3) Average monthly consumption (m^3) Total consumption (L) Average monthly consumption (L) Consumption L/guest-night KgCO_2e and total

	Results for the wastewater Total production (m^3) Average monthly production (m^3) Total production (L) Average monthly production (L) Production L/guest-night $KgCO_2e$ and total
	Result for potable water and wastewater $KgCO_2e$ total $KgCO_2e$/guest-night

Table 4 to be continued

Laundry	$KgCO_2e$ total Kgcloths/guest-night $KgCO_2e$/guest-night
Fuels	$KgCO_2e$ per fuel $KgCO_2e$ Total $KgCO_2e$/guest-night
Waste	$KgCO_2e$ for each waste $KgCO_2e$ total $KgCO_2e$/guest-night
Food	$KgCO_2e$ for each food $KgCO_2e$ total $KgCO_2e$/guest-night
Avoided Emissions	$KgCO_2e$ total $KgCO_2e$ and avoided in electricity $KgCO_2e$ and avoided in waste

The construction of the calculator involved a mass and energy flow assessment for each indicator analyzed. In general, the emission factors per indicator were researched and calculated to subsequently evaluate CO_2e emissions (monthly and annual). In some cases, it was necessary to make simplifications/adaptations as described below.

Electricity

In Portugal, the accommodation and restoration sectors were responsible for the consumption of 1.92 TWh of electricity in 2018, which corresponded to a total emission of 487 thousand tons of CO_2e (Pordata, 2020; Associação Portuguesa de Energias Renováveis [APREN], 2019). Electricity is responsible for about 40% of the energy consumed in a hotel (Hotel Energy Solutions, 2011). The calculation for CF regarding electricity consumption was made using Equation 2. Table 5 shows all the emission factors of this component present in the calculator.

$$ECF = EC * \qquad (2)$$

where *CF*—electricity CF ($kgCO_2e$); *EC*—electricity consumption (kWh); *SEf*—supplier emission factor ($kgCO_2e$/kWh).

Table 5

Electrical Supplier Emission Factors

Electrical supplier		Emission factors ($kgCO_2e/kWh$)	
		2018	2019
EDP		0.257	0.216
SU electricity		-	0.211
ENDESA		0.399	-
Golden energy		0.337	-
GALP		0.355	-
ENAT		0.179	-
Simple energy		0.292	0.150
Madeira electricity	Madeira	0.427	0.531
	Porto Santo	0.545	0.603
Açores electricity	Santa Maria	0.624	-
	São Miguel	0.419	-
	Terceira	0.554	-
	Graciosa	0.705	-
	São Jorge	0.621	-
	Pico	0.634	-
	Faial	0.649	-
	Flores	0.424	-
	Corvo	0.747	-
APREN (national average)		0.254	0.213

Table 5 to be continued

Water

According to the Águas de Portugal (AdP, 2019) sustainability report, around 587 million m^3 were captured and transformed into potable water, and 512.5 million m^3 of wastewater were treated, meaning that about 87% of the water captured is treated and returned to watercourses.

Two emission factors were determined, one for potable water and the other for wastewater, assuming that the water treatment is the same in both indicators. The emission factor related to water consumption is related to the CO_2e emission for the treatment of the captured water, which considers the CO_2e emissions from electricity and fuels consumed by AdP. Thus, the emission factor used for potable water was 0.185 $kgCO_2e/m^3$.

Regarding the emission factor of WW treatment, the CO_2e emission factor related to the treatment of sludge produced in wastewater treatment plants (WWTPs) was added to the previous emission factor (0.185 $kgCO_2e/m^3$). The sludge emission factor was calculated using data available in Agência Portuguesa do Ambiente (APA) (2020a) and the 2018 sustainability report of the AdP group. After calculating the sludge emission factor (1.062 $kgCO_2e/m^3$), it was possible to reach the WW treatment emission factor, 1.25 $kgCO_2e/m^3$. The calculation of emissions for this component is done using Equation 3.

$$WCF = (WEf_{PW} * C_{PW}) + \left(WEf_{WW} * (C_{PW} * R_{WW/}\right. \quad (3)$$

where *WCF*—Water CF; WEf_{PW}—Water emission factor of potable water; C_{PW}—Consumption of Potable Water (m^3); WEf_{WW}—Water emission factor of wastewater; $R_{WW/PW}$—Ratio between wastewater production/Consumption of potable water.

Laundry

According to Styles, Schönberger, and Martos (2013), a medium-scale laundry needs an average of 1.5

kWh of electricity and 12 L of water to wash, dry and iron 1 kg of clothing. With these values and the emission factors of the electricity and water component, it was possible to calculate the emission from the washing process of 1 kg of clothes. The emission factor obtained was 0.396 $kgCO_2e$/kg clothing. The calculation of this component is only performed if the laundry is outsourced. The calculation can take two paths:

1. When the accommodation knows the weight of clothes sent to the laundry, the calculation is made using Equation 4.

$$LCF = CF_{1KgClothes} * Cw \quad (4)$$

where *LCF*—laundry CF; $CF_{1kgClothes}$—CF of the entire washing process of 1 kg of clothes; *Cw*—clothes weight (kg).

2. When the accommodation managers are unaware of the clothes weight that are sent to the laundry, the calculation is made using Equation 5.

$$LCF = CF_{1KgClothes} * (4 * Bedroo \quad (5)$$

where Bedrooms—number of rooms occupied per night.

Fuels

The fuels emission calculation factors were based on data from the Guidelines for National Greenhouse Gas Inventories (Eggleston, Buendia, Miwa, Ngara, & Tanabe, 2006). The amount of CO_2, CH_4, and N_2O released by terajoule of energy used is indicated. Through the Intergovernmental Panel on Climate Change (The Core Writing Team et al., 2015), the conversion was made to $kgCO_2e$/kWh (see Table 6).

Table 6

Fuel Emission Factors

Fuels	Emission factors ($kgCO_2e$/kWh)
Natural gas	0.203
Butane Propane	0.228
Gasoline	0.251
Diesel	0.268
Biodiesel	0.256

Subsequently, conversion was done to the units accepted in the calculator, fuels in cubic meters (natural gas), kilograms (butane, propane and wood), and litres (gasoline, diesel and biodiesel) (see Table 7). The values of electricity production (kWh) per unit of fuel consumption were all based on Portgás data except for gasoline and biodiesel, based on Ordinance No. 228/90 of March 27[1], and on Fruergaard, Astrup, and Ekvall (2009), respectively.

Table 7

Emission Factors per Measure Unit

Fuel	Emission factors ($kgCO_2e$/unit)
Natural gas (m^3)	2.179

[1] Portaria No. 228/901990. “Aprova o Regulamento da Gestão do Consumo de Energia para o Sector dos Transportes”, Diário da República I Série. No. 72/1990, de 1990-03-27, 1491-1493.

Butane (kg)	2.897
Propane (kg)	2.928
Gasoline (L)	2.255
Diesel (L)	2.688
Biodiesel (L)	2.4

Equations 6 and 7 were used to calculate the stationary combustion and cars emissions, respectively.

$$FCF = Fc * FEf \quad (6)$$

where *FCG*—fuels CF; *Fc*—fuel consumption; *FEf*—fuel emission factor.

$$ACF = Km * AEf \quad (7)$$

where ACF—automobile CF; Km—kilometers traveled; AEf—automobile emission factor (automobile document).

Waste

The waste produced in tourist accommodations has a composition and nature, similar to that produced in houses, so they are classified as urban waste. The calculation of the emission factor for undifferentiated urban waste was based on the waste destinations according to APA (2020b). It is assumed that about 90% of undifferentiated urban waste is landfilled, and the remaining 10% go through organic recovery, which is mainly by anaerobic digestion.

All emission factors and specific weights used in calculating this component emission are shown in Table 8.

Table 8

Waste Emission Factor Related With Material Production

Waste	Emission factor (kgCO_2e/kg or L)	Specific weight (kg/L) (1)
Undifferentiated (kg)	0.922	0.10
Organic (kg)	0.0224 (2)	0.52
Vegetable oil (L)	3.5 (3)	-
Paper (kg)	1.1 (4)	0.08
Plastic (kg)	2.1 (4)	0.05
Glass (kg)	0.9 (4)	0.27
Metal (kg)	6.7 (4)	0.05

Source: APA (2020a); WRAP (2011); Poore & Nemecek (2018); Hillman, Damgaard, Eriksson, Jonsson, & Fluck (2015).

From the data referred above and using Equation 8, the wastes CO_2e emission calculation from the accommodation was made except for the oil calculation (Equation 9).

$$WCF = LW * 0.8 * p_r * WEF \quad (8)$$

where *WCF*—waste CF; *LW*—litres of waste; 0.8—filling factor from containers; *pr*—specific weight; *WEF*—waste emission factor.

$$VoCF = L * VoEf \quad (9)$$

where *VoCF*—vegetable oil CF; *L*—liters of oil; *VoEf*—vegetable oil emission factor.

Food

The entire food supply chain emits approximately 13.7 billion tons of CO_2e annually, equivalent to more than a quarter of anthropogenic GHG emissions (Poore & Nemecek, 2018). The food CF calculation is based on emission factors (see Table 9) determined in a study by Poore and Nemecek (2018).

Table 9

Emission Factors of Food Products

Foods	Emission factors	
	$KgCO_2e$/kg or L (Worldwide)	$KgCO_2e$/kg or L (European)
Beer (L)	1.2	1.2
Wine (L)	1.8	1.9
Tomatoes (kg)	2.1	1.1
Onions and Leek (kg)	0.5	0.5
Root vegetables (kg)	0.4	0.4
Cabbage/cabbages (kg)	0.5	0.8
Other vegetables (kg)	0.5	0.8
Citrus (kg)	0.4	0.5
Banana (kg)	0.9	-
Apple (kg)	0.4	0.4
Wild fruits and grapes (kg)	1.5	1.3
Other fruits (kg)	1.1	0.6
Avocado (kg)	2.5	-
Table 9 to be continued		
Soy milk (L)	1.0	0.9
Milk (L)	3.2	2.2
Almond milk (L)	0.7	-
Oat milk (L)	0.9	0.6
Rice milk (L)	1.2	0.9
Soybean oil (L)	6.3	4.5
Palm oil (L)	7.3	-
Sunflower oil (L)	3.6	3.5
Rapeseed oil (L)	3.8	3.5
Olive oil (L)	5.4	5.3
Beans/broad beans (kg)	1.8	1.1
Peas (kg)	1.0	1.1
Nuts (kg)	0.4	2.4
Peanuts (kg)	3.2	-
Tofu (kg)	3.2	2.5
Beef (kg)	99	46
Bovine meat (dairy cattle) (kg)	33	37
Beef (average) (kg)	71	39
Sheep/goat (kg)	40	43
Pork meat (kg)	12	10
Poultry meat (kg)	10	8.7
Cheese (kg)	24	16
Eggs (kg)	4.7	5.1
Fish (aquaculture) (kg)	14	14
Crustaceans (aquaculture) (kg)	27	-
Bread (kg)	1.6	1.5
Corn flour (kg)	1.7	1.5
Oat flakes (kg)	2.5	1.7

Rice (kg)	4.5	3.4
Potatoes (kg)	0.5	0.5
Cassava (kg)	1.3	-
Coffee (kg)	29	-
Tea (kg)	21	-
Chocolate (kg)	47	-
Sugar (sugar cane) (kg)	3.2	-
Sugar (beet) (kg)	1.8	1.7
Dark chocolate (70% cocoa) (kg)	34	-
Milk chocolate (kg)	23	-
Mass (kg)	1.6	-
Lentil (kg)	2.8	-

The equation used to calculate the emission of this component is as follows:

$$FdCF = FdEf * Fc \tag{10}$$

where *FdCF*—food CF; *FdEf*—food emission factor; *Fc*—Food consumption.

Total Carbon Footprint Calculation

The total CF calculation of the accommodation is carried out, taking into account the partial values of the CF per component, and the results are presented as defined in Table 2. Additionally, a monthly and annual comparison of the contribution of each indicator's emissions is made using graphs. The emissions amount per overnight stay (annual and monthly), per room, per m^2 of the accommodation, is also calculated. The total emission value is also transformed into global hectare (gha), which, according to Lin et al. (2019), each ton of CO_2e emitted is equivalent to 0.256 gha.

Calculation of Avoided Emissions

The avoided emissions were defined as a correct environmental action taken by the accommodation management. Two indicators were considered, the production of electricity from renewable energy sources (solar thermal, photovoltaic, hydro and wind) installed by the accommodation and the amount of recyclable waste separated and/or reuse.

As regards the electricity indicator of production through the use of renewable energy sources, the calculation for photovoltaic, wind and hydro energy is made by multiplying the kWh produced monthly by the CO_2e emission factor and the electrical supplier emission factor (Equation 11). Since solar thermal energy kWh produced is difficult to obtain, it was decided to multiply the area of the panels by the monthly solar irradiation of the district of the accommodation (see Table 10) and by the yield which, according to the study on "Solar Thermal Energy" carried out by the Energy Portal of 2004, would be 35% to 40% (Equation 12).

$$Ea_{shw} = \mathrm{SEf} * kWh \tag{11}$$

where Ea_{shw}—Emissions avoided with solar, hydro and wind energy; *SEf*—Electrical Supplier Emission factor ($kgCO_2e/kWh$); *kWh*—Kilowatt-hour produced in the accommodation.

Table 10

Annual Solar Radiation (kWh/m^2)

District	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.

Faro	85	103	154	191	229	241	253	222	173	128	91	76
Setúbal (Sines)	76	98	144	183	226	234	245	218	168	119	83	70
Beja	83	99	147	176	216	241	259	223	169	122	86	72
Évora	74	96	142	176	215	237	254	222	165	115	78	64
Lisboa	70	93	136	174	212	229	242	215	160	113	76	63
Portalegre	68	90	131	162	209	226	249	213	159	105	72	57
Leiria	66	88	134	167	210	202	215	188	152	111	71	57
Castelo Branco	71	93	136	174	218	238	255	220	166	110	73	61
Coimbra	64	84	125	157	203	209	225	199	153	104	69	59
Guarda	71	89	136	146	202	227	252	212	160	96	65	53
Viseu	61	87	119	154	198	217	234	207	153	97	65	55
Porto	61	82	126	167	207	213	223	195	149	98	65	51
Vila Real	49	75	114	151	201	219	233	204	146	90	56	43
Bragança	53	80	127	160	206	222	241	209	154	98	59	47
Braga	65	82	107	138	178	195	190	166	128	80	65	56
Santarém	66	100	131	171	218	223	245	212	155	105	66	53
Aveiro	64	91	126	166	209	203	220	196	148	98	67	58
Viana do Castelo	52	78	111	159	193	205	216	185	140	87	59	46

Source: Cavaco et al. (2016); Vieira, Neto, & Silva (2008).

$$Ea_{st} = Fe_f * A * SI * n \quad (12)$$

where Ea_{st}—emissions avoided with solar thermal energy; *A*—panel area (m^2); *SI*—solar irradiation (monthly) (kWh/m^2); *n*—panel yield (35%).

Concerning the indicator of the amount of recyclable waste separated and/or reused, the calculation is made through the difference between the emission factor of primary production and the secondary production of recyclable and/or reused materials in order to calculate the CO_2e emission is avoided, when it is not necessary to extract the raw materials following a circular economy (see Table 11). This difference was calculated according to Hillman et al. (2015). As previously considered, the metal emission factor used is the average of aluminium (10.6 $kgCO_2e/kg$) and steel (2.1 $kgCO_2e/kg$).

Table 11

Emissions Avoided With Recycling

Waste (kg)	Emissions avoided $kgCO_2/kg$
Paper	0.4
Plastic	0.8
Glass	0.4
Metal	6.35

Source: Hillman et al. (2015).

Organic waste is only considered as avoided emissions if it is reused (for animal feed, fertilizer or biogas production). When this happens, the emission avoidance factor adopted is the same as in the CF of organic waste calculation (assuming that there is no production of this waste), which is 0.0224 $kgCO_2e/kg$. The calculation of the avoided emissions for the indicator of recyclable and/or reuse waste generation is made from equation 13.

$$Ea_w = Lw * 0.8 * \rho_r * Efa_w \tag{13}$$

where *Eaw*—Emissions avoided in waste; Efa_W—Emission factor avoided in waste.

Also, concerning this indicator, it should be noted that the formula for determining the emissions avoided by oil recycling is carried out differently. The kgCO_2e avoided per litre of recycled oil is 0.288. This figure was calculated by the difference in emissions between diesel and biodiesel from recycled cooking oil. The calculation of the emissions avoided by the recycling of oil is made using the following equation:

$$Ea_{vo} = L_o * 0.94 * Ef_{vo} \tag{14}$$

where Ea_{vo}—Emissions avoided by vegetable oil recycling; L_0—Litres of oil; 0.94—Percentage of cooking oil processed into biodiesel (Haigh, Abidin, Saha, & Vladisavljević, 2012; Sahar et al., 2018); Ff_{vo}—Emission factor for avoided oil vegetable emissions.

The avoided emissions calculation gives the accommodation management information about the results obtained from its efforts in CF reduction.

Carbon Sequestration Calculation

It is of utmost importance to compensate for the CF of the accommodation as it is somehow impossible to reduce the whole CF. Therefore, to move towards carbon neutrality, it is necessary to invest in compensation forms. One of the leading compensation forms is reforestation, and this option has been considered in the calculator.

In order to calculate the number of trees needed to be planted to offset the CO_2e emitted, Table 12 provides the tCO_2e retention of different tree species per hectare/year.

With these values and with the number of trees per hectare appropriate to each type of species, an average of CO_2e retained per tree can be calculated. Thus, it was possible to associate the total (annual) CO_2e emitted with the number of trees to be planted to compensate for this emission. It is essential to mention that this value considers the survival of the tree for 20 years.

Table 12
Data About the CO_2e Retention by Species

Species	CO_2e retention (tCO_2e/ha/year)
Pine Tree	6.08
Cork Oak	1.24
Eucalyptus	13.17
Holm Oak	1.23
Oak	6.10
Chestnut	6.33
Meek Pine	12.88

Source: APA (2020a).

Discussion

The tourism sector growth is causing an increase in GHG emissions. However, to reduce tourism emissions, it is not necessary to reduce the number of tourists. The solution is to implement CO_2e reduction and compensation measures. In order to reduce and compensate for the emissions, it is necessary to measure and monitor them, and this is precisely where the CF calculator for the tourism sector comes in.

The development of this calculator is important because, although there are already some calculators online, they present the reality of the country where they were developed (the emission factors of that country) or use the outdated emission factors. Given this, it was important that the calculator was based on the emission factors of Portugal since it is the territory where it was intended to act, giving this information as accurate as possible. However, despite intensive research to obtain Portuguese emission factors, it was not possible to develop a calculator with exclusively Portuguese emission factors. Other sources for food (European emission factors), recyclable waste (emission factors from the Inventory of Average GHG Emissions from Denmark, Norway and Sweden), and fuels (universal emission factors provided by the IPCC) were used.

The developed calculator incorporates the most-used components in this field, such as electricity and fuels, and four others that are not customarily integrated, water, laundry, waste and food. This calculator also includes the avoided emissions.

Analyzing all the formulas and calculations made, the most general formula for CF calculation in the tourism sector that can be presented is the following:

$$CF = \sum(\text{Data of each component} * \text{Emission factor}) \tag{15}$$

The use of this tool in other countries implies the change of the indicators emission factors discussed above. It allows the CO_2e calculation on a scientific basis and supports the reduction targets up to 2100 since the tourism sector significantly weighs CO_2e emissions. Moreover, it permits travellers, entrepreneurs and investors to choose alternatives with less environmental impact. It can be applied in restaurants and residences since the indicators are similar in all cases.

This calculator must be validated, and more components and environmental indicators must be added to perform a broad analysis in all life cycle of a tourism accommodation.

Conclusions

The calculator developed in Microsoft Excel (version 365) was based on the accounting of GHG emissions resulting from the consumption of electricity, water, fuel and food, laundry and wastewater production. The ten indicators used to perform this accounting were: electricity consumption, electricity produced (renewable energy), potable water consumption, wastewater production, laundry production, consumption of fuels used in stationary combustion, distance travelled by automobiles, production of urban waste, amount of recycled or reused waste and food consumption.

The CF calculator could be a powerful tool for monitoring and reducing CO_2e emissions from the Portuguese tourism sector, particularly regarding the accommodation sector.

Although the calculator has been developed for the tourism sector, more specifically in lodgings, it can be applied in restaurants and even in residences since the indicators are similar in all three cases, extending the scope of application of the calculator with the same reliability.

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