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Assessing the environmental impacts of three different types of accommodations in Portugal and Spain by using an LCA approach

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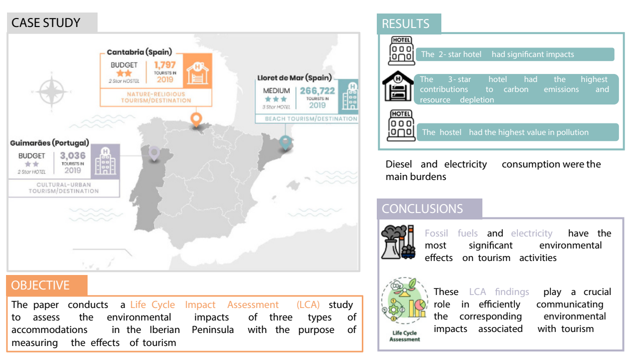
HIGHLIGHTS

- Tourism is an important global economic sector that has experience a huge growth in recent years.
- Environmental impacts of cultural-urban, nature-religious, an beach-tourism accommodations in the Iberian Peninsula.
- Life Cycle Assessment quantify the environmental impacts of tourism activities, identify the greenest solutions.
- The 3-star hotel had the highest contributions to carbon emissions and resource depletion.
- Fossil fuels and electricity are the main contributors in almost all environmental impact categories.

GRAPHICAL ABSTRACT



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ABSTRACT

The tourism industry, affected by COVID-19, must reduce greenhouse gas emissions. This study evaluated the environmental impact of three hotels in coastal and mountainous regions of Spain and Portugal using Life Cycle Assessment (LCA). Data was gathered via surveys in the Greentour tool. Results indicate that the 2-star hotel

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(focused on cultural-urban tourism) has the highest impacts in most categories, except for CC, FRD, and POF indicators. The 3-star hotel (beach tourism) contributes the most to CC and FRD indicators, while the hostel (nature-religious tourism) has the highest value in the POF indicator. LCA findings reveal that diesel consumption in the hostel and electricity usage in both the 2-star and 3-star hotels are major contributors to environmental impacts across various categories. Overall, evidence suggests that fossil fuel and electricity usage significantly affect tourism activities environmentally. Interestingly, this study highlights that a 2-star hotel can have a higher carbon footprint (CC indicator) compared to a 3-star hotel, challenging the notion that higher star ratings imply lower environmental impact.

1. Introduction

Despite the COVID-19 pandemic limited the economic growth of travel and tourism; the importance of this sector is alive, representing 7.6 % of global GDP, in 2022, only 23 % below 2019 levels (WTTC, 2023). In particular, Europe constituted 51 % of global international arrivals in 2018, with a total of 710 million tourists' arrivals and generated receipts amounting to 570 million USD (UNWTO, 2019).

Two countries that stand out in the tourism sector are those located on the Iberian Peninsula, Spain and Portugal. Some of the most important types of tourism in the Iberian Peninsula are beach, cultural (city tourism, wine tourism, experience tourism), nature and religious tourism (pilgrimage routes). In 2019, according to the United Nations World Tourism Organisation (UNWTO, 2019), Spain holds the position of the world's second most favoured tourist destination and Portugal ranked sixteenth as one of the most competitive tourist destinations globally (Santos and Oliveira, 2021).

In 2018, Spanish tourism significantly contributed to the nation's economy, accounting for 12.3 % of the Spanish GDP and providing employment for 12.8 % of the workforce (Arbulú et al., 2021). In Portugal, in the same year, the tourism sector created 1.047 million jobs positions (21.8 % of total employment), which contributed approximately 14.6 % to the national GDP (Almeida and Silva, 2020). It also plays a strategic role, representing 15.3 % of the country's exports of goods and services (Tourism Strategy, 2017). After COVID, 72 million foreign tourists arrived in Spain, in 2022, more than double the 31 million in 2021. In terms of revenue, the 69 billion EUR generated in 2022 is also well above the 29 billion EUR in 2021 and the 16 billion EURin 2020 (Global Trends, 2022). In Portugal, in that same year, international tourism performed better than expected, as a result of strong pent-up demand and the lifting of COVID-19 travel restrictions in many countries. This year, >900 million tourists travelled abroad, twice as many as in 2021, but still 37 % fewer than in 2019 (Fig. 1).

However, these tourism destinations are significant greenhouse gas (GHG) emitters. Accommodation, transportation and leisure activities account for approximately 5 % of global direct energy use and GHG emissions, according to first global estimates (Gössling et al., 2022). An analysis previously conducted by Lenzen et al. (2018) states that tourism is responsible for about 8 % of GHG emissions, being transport (road and air), shopping and food the most significant contributors to this sector.

Various national studies have indicated ongoing growth in GHG emissions within the tourism sector of different countries, such as Sweden (Gössling and Hall, 2008), Spain (Cadarso et al., 2015), China (Meng et al., 2016), Portugal (Robaina-Alves et al., 2016), Taiwan (Sun, 2016), New Zealand (Sun et al., 2020) or Norway (Sun et al., 2022). Despite the aim to halve GHG emissions from tourism sector by 2030, UNWTO (2022) estimates that the likely scenario is an increase of 25 %.

In order to assess the environmental impacts of tourism, it is necessary a holistic and integrated approach. For this purpose, Life Cycle Assessment (LCA) is an appropriate tool to determine the environmental impacts generated in this sector (ISO 14040, 2006a). LCA is a widely acknowledged methodology that has demonstrated its efficacy in evaluating the environmental effects of a product/service by studying the different phases of its life cycle (ISO 14040, 2006a).

Over the past 15 years, there has been a growing quantity of LCA research focused on tourism activities in different geographical locations. Precisely, LCA studies related to tourism activities focused on long-term viability of industrial products (facilities and infrastructures) (Giama et al., 2018), tourism products (cultural and natural resources of the destination services and tourism destination branding) (Javdan et al., 2023) (Castellani and Sala, 2012), and environmentally friendly types of transportation (tramway, train, bus, bus, car sharing)

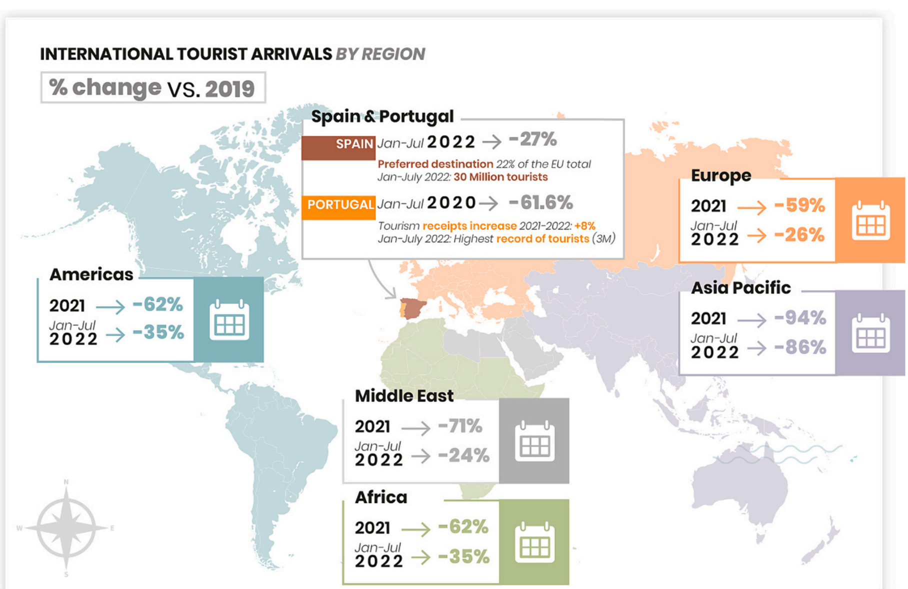


Fig. 1. Percentage change (%) of 2019 vs. 2021–2022 of international tourist arrivals by region highlighting the situation in Spain and Portugal (UNWTO, 2023).

(Gühnemann et al., 2021).

Tourism activities differ depending on factors such as geographical location, tourist preferences, travel destinations, transportation methods, and types of accommodation. The primary types of tourism encompass leisure tourism (vacations), healthcare and recreational tourism, urban tourism, nature tourism, work-related tourism, and religious tourism (Campos et al., 2022b). This study focuses on three of these types of tourism: cultural-urban, nature-religious and beach tourism.

According to UNWTO (2022), cultural-urban tourism is a subcategory of tourism that occurs in urban environments and stands out due to its administration, manufacturing, trade, and services industries as well as its endpoints for transportation. Cultural-urban destinations offer a diverse range of natural, social, technological, and cultural experiences and products, catering to both leisure and business (UNWTO, 2022). Nature tourism focuses on experiencing and visiting natural environments and is closely related to the term of rural tourism. Nature tourists typically explore places such as beaches, forests, or national parks. Activities primarily center on the natural surroundings like stargazing, hiking and also religious pilgrimage routes (Wolf et al., 2019). Finally, beach tourism is defined as a way of travel for recreational, leisure or business purposes specifically on beaches as the main attractions (Hernández et al., 2016).

This work is considered a remarkable breakthrough as it is the first to address three types of tourism applied to three types of accommodation using LCA (and not focusing exclusively on the carbon footprint of accommodation), delving into the assessment of the environmental impact of tourism in the Iberian Peninsula.

The current research has three main objectives. Firstly, it aims to carry out a Life Cycle Assessment (LCA) to evaluate the environmental impacts of three types of accommodation in the Iberian Peninsula, representative of cultural-urban tourism, nature-religious tourism and beach tourism. The study allows for the comparison of the environmental performance of these accommodations in specific destinations, highlighting regions representative of the three most prominent types of tourism in the Iberian Peninsula. Secondly, it addresses a gap in the research of the tourist accommodation segment by including hostels, which had not been previously studied, and carries out an environmental assessment of this sector. Finally, the analysis identifies critical points, contributing significantly to the use of LCA to improve the sustainability of tourism in a destination.

2. Methods

2.1. Methodological approach: basic structure and components

The paper conducts an LCA study to assess the environmental impacts of three types of accommodations in the Iberian Peninsula. The purpose is to measure the effects of tourism and determine the most environmentally friendly solutions that local administrations should promote for the sustainable development of their region's tourism. This study follows ISO 14040 and ISO 14044 standards and is broken down into four stages: i) goal and scope definition, ii) inventory analysis, iii) impact assessment, and iv) interpretation (ISO 14040, 2006a; ISO 14044, 2006b).

Although LCA was initially designed for product analysis, it can also be easily applied to assess services (Campos et al., 2022a), making it applicable to the tourism sector. According to the European Sustainable Consumption and Production Action Plan's (SCP), the implementation of LCA as an environmental tool is profitable (Koide and Akenji, 2017).

2.2. Goal and scope definition

This study analyses the influence of the type of accommodation on the environmental impacts of our holidays. The aim of this paper is to assess the environmental consequences of an overnight stay with breakfast included, in three regions selected by analysing the different types of accommodation mentioned previously (Fig. 2).

The number of stars of a hotel is an example of a characterization system in Europe used in order to indicate the quality and level of the services provided by the hotel. The star rating in hotels is not regulated by a single classification system. Thus, within the same country, each autonomous community sets its own criteria, and hotels within each region must apply for this classification process before opening. However, while there are no extreme differences in granting between one area and another in Spain, greater differences can be observed between countries (Vincci hotels, 2022). Perhaps the greatest disparity lies in the mandatory nature of this classification, as while it is a compulsory system in Spain and Italy, hotel classification is completely voluntary in countries such as France, United Kingdom, the United States and Germany. In general, all regulations have four fundamental blocks: characteristics of rooms, bathrooms, basic hotel services (e.g., reception), and gastronomic services. Thus, we can find the following general classification in Spain and Portugal (see Fig. 2):

- 2-star hostel which is intended for short stays, generally located in a transit or strategic location. It is possible to distinguish youth, tourist and pilgrims' hostels. What differentiates a hostel from other types of accommodation is that they are places of meeting and coexistence where there are usually bunk beds and shared rooms, and the quality is lower than on a hotel. This type of accommodation belongs to the 'budget', 2-star hostel's category (European Parliament, 2007). This hostel in Cantabria represents the nature-religious tourism.
- 2-star hotel provides a clean and straightforward accommodation, featuring a single restaurant that only offers a coffee service and continental breakfast, without any additional amenities. In this case, it is qualified as 'budget' hotel. This establishment is related to a cultural-urban tourism.
- 3-star hotel is a premium hotel, focused on providing excellent service, available 24 h for room-related services, multiple restaurants and top-notch facilities. Additionally, these hotels often offer supplementary sport and/or health services, as well as heating facility in the bathroom, cleansing tissue, hair-dryer, audio or multimedia entertainment system, laundry and ironing service, among others. The categorization of this accommodation subsector is classified as 'medium' hotel. In this study, this hotel is associated to beach tourism.

The function of the system is staying one day in a hotel or hostel with the different services offered. To quantify this function, it is essential to establish an appropriate functional unit (FU) as a reference point for all the inputs and outputs of the system. Transportation and leisure activities define their FU based on the distance travelled '1 passenger per kilometre driven' and in the activities conducted '1 visitor activity performed' (Filimonau et al., 2013). Nevertheless, when it comes to a hotel stay, there is still no agreed-upon consensus regarding the suitable functional unit (Campos et al., 2022a). Some studies adopt the 'guest per night' approach, complying with the PAS 2050:2011 standards (PAS 2050, 2019). In some instances, the impact of hotel operations is expressed in terms of 'per capita' or 'per user' measurements (Dorta et al., 2021), whereas other authors consider the total 'm^2 of floor area' (Priyadarsini et al., 2009). However, when considering the entire journey, the most frequent FUs are 'one week of a holiday' (Michailidou et al., 2015) or 'per trip' (Luo et al., 2018). Assuming that the objective of the tourist is to stay during one day in the hotel/hostel —including breakfast—, the most appropriate FU is 'one overnight stay in a single room with breakfast included'. Only breakfast has been considered in the study because some of the establishments do not offer lunch or dinner. Additionally, some tourists or pilgrims do not have their meals at the hotel/hostel.

The three accommodations include the consumption of water and energy (i.e., electricity and butane/natural gas), the production and

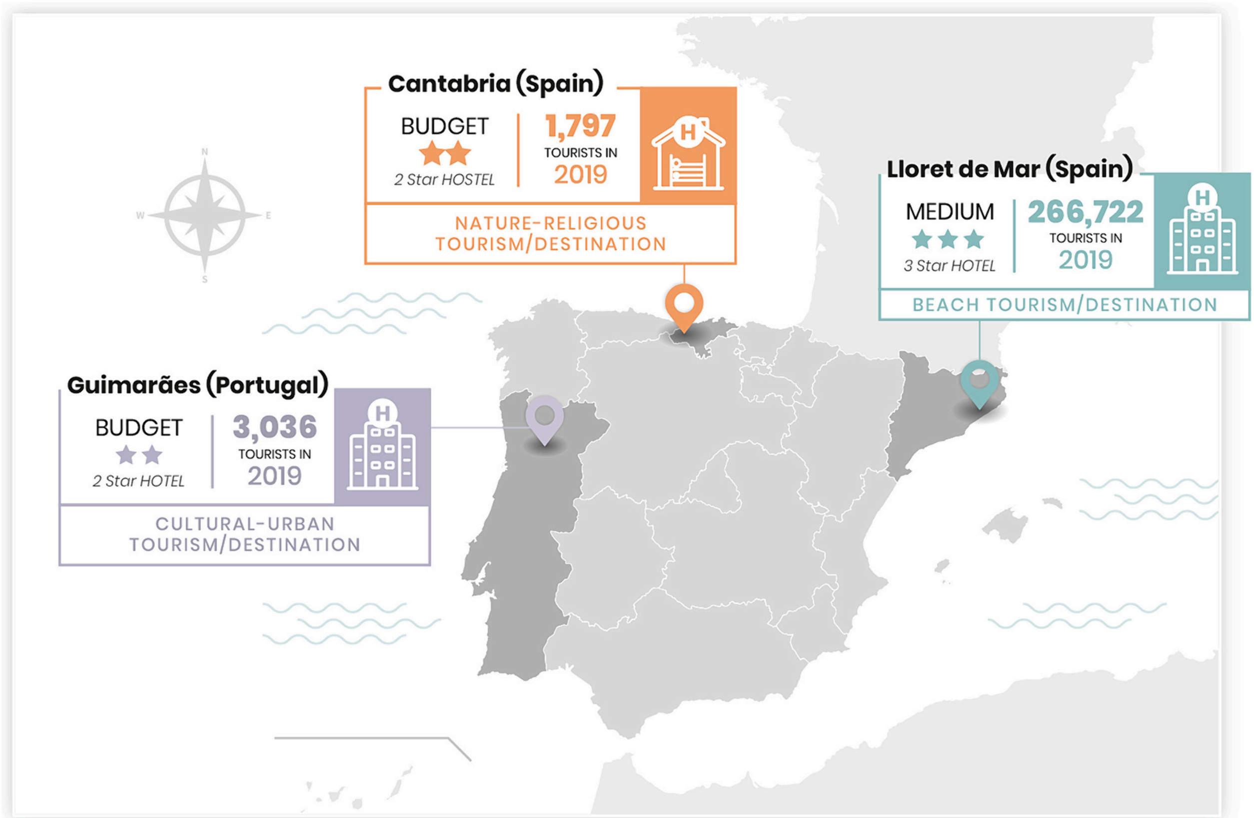


Fig. 2. Iberian Peninsula map with the three accommodations under study with the location, category and number of tourists.

consumption of cleaning and maintenance products; and the consumption of food and beverage for breakfast. Regarding laundry service, the hostel does not have laundry service, but it offers a washing machine. Due to its small rural nature, this hostel does not offer such service. In the case of the 3-star hotel, this laundry service is outsourced. The 2-Star hotel has an in-house laundry service. They also offer an in-house solution for cleaning rooms (housekeeping) and other hotel departments.

All these are equipped with electrical devices, including a refrigerator, ceramic hob, oven and microwave; or, failing that, they have a portable electric stove with one burner, as is the case in the 2-star hotel. The hostel and the 2-star hotel do not have swimming-pool. Moreover, the hostel does provide a green space although this location is not mentioned by the owner, as well as the 3-star hotel does offer it. In Table 1 all these characteristics are shown.

The management of municipal waste is not encompassed in the system boundaries of the current study since, according to environmental results obtained in destinations in Spain and Portugal by applying a calculation tool, it was found that waste management accounts for <2 % of the total impact of a destination/establishment (Greentour, 2023). The construction of infrastructure and its maintenance are also not considered because they have a minor effect on the overall system impact of the study (Žigart et al., 2018). Fig. 3 shows the system boundaries considered in this study for each of the three accommodations related to the energy sources, breakfast, water and cleaning products.

2.3. Data acquisition and life cycle inventory

Life Cycle Inventory (LCI) was collected in three accommodations of Cantabria (ES), Lloret de Mar (ES) and Guimarães (PT). A total sample of 198 accommodations was evaluated from the Greentour tool, of which 33 %, or 65 establishments, belong to the hostel/camping category, 20 % (24 accommodations) belong to 2-star hotels, and 45 % belong to 3-star hotels, which accounts for 89 establishments. The remaining 2 % belonged to the 5-star category and were not considered. After reviewing all the surveys, three accommodations were selected (one hostel, one 2-star hotel, and one 3-star hotel) that contained a complete inventory of data.

2.3.1. Primary data

Primary data and general characteristics of the accommodations were obtained from questionnaires filled in by the owners of the hotels and hostels (Campos et al., 2022b), collecting the annual consumption of the resources required (electricity, fuels, water, indoor and outdoor cleaning products and maintenance and food and drink for breakfast). Specifically, in all accommodations four components were considered in greater or lesser detail: i) cleaning products (toilet paper, detergents and bleach for sanitizing and cleaning the facilities); ii) water for bathrooms, swimming-pools and cooking; iii) electricity for the heating system, refrigerator and microwave, as well as the washing machine used in the hostel; iv) natural gas used in the two hotels and diesel in the hostel, as fuels intended to increase the temperature of water for the showers, cooking and heating; v) breakfast for tourists (milk, cereals, bread, butter, biscuits and/or fruit juice). Lunch and dinner were not included in the study, since two of the accommodations did not offer dinner and it was assumed not to be considered in order to compare the 3 accommodations properly.

Table 1 shows the main characteristics, number of guests registered per year, and the most relevant annual input and output data per functional unit of the accommodations. The quantities of food as well as the type of energy sources in each establishment and the breakdown of the types of cleaning products used are also shown.

2.3.2. Secondary data

Regarding secondary data it came from the Ecoinvent v3.7.1 database (Farjana et al., 2019) and Agribalyse v3.0 (Asselin-Balençon et al.,

Table 1
Average life cycle inventory per FU (overnight stay) for hostel/hotels in Spain and Portugal depending on their star rating.

	Hostel	2-Star hotel	3-Star hotel
Location	Cantabria (Spain)	Guimarães (Portugal)	Lloret de Mar (Spain)
Operational season (months)	7	12	12
Number of hotel rooms	6	16	433
Overnight stay	1797	3036	266,722
Occupancy rate (%)	19.5	74.39	79.9
Laundry service	Not specified	Insourced	Outsourced
Number of swimming-pools	–	–	1
Energy and water resources			
Water [m^3/overnight stay]	$2.50{\cdot}10^{-1}$	$1.42{\cdot}10^{-1}$	$1.62{\cdot}10^{-1}$
Electricity [kWh/overnight stay]	1.28	5.60	9.60
Diesel [MJ/overnight stay]	$3.44{\cdot}10^{1}$	–	–
Natural gas [MJ/overnight stay]	–	$2.88{\cdot}10^{1}$	$3.58{\cdot}10^{1}$
R-417A (refrigerant) [kg/overnight stay]	–	–	$7.50{\cdot}10^{-6}$
Cleaning products [kg/overnight stay]			
Detergent	$5.61{\cdot}10^{-3}$	$2.77\ 10^{-2}$	$1.18\ 10^{-3}$
Bactericide	$8.35\ 10^{-3}$	–	–
Multipurpose spray	$7.71{\cdot}10^{-3}$	–	–
Hand cleaner soap	$2.23{\cdot}10^{-2}$	$2.64{\cdot}10^{-2}$	$1.97{\cdot}10^{-4}$
Laundry detergent	$5.61{\cdot}10^{-3}$	–	$1.18{\cdot}10^{-3}$
Bleach for cleaning	$3.01{\cdot}10^{-2}$	–	$1.37{\cdot}10^{-3}$
Ammonia	–	–	$6.91{\cdot}10^{-4}$
Hydrogen peroxide	–	–	$1.14\ 10^{-3}$
Kitchen product	–	$9.88{\cdot}10^{-4}$	$1.07{\cdot}10^{-1}$
Descaling agent	–	–	$1.80{\cdot}10^{-4}$
Cleaning products [kg/overnight stay]			
Dishwasher machine	–	–	$1.99{\cdot}10^{-1}$
Manual dishwasher	–	–	$4.37{\cdot}10^{-2}$
Dishwasher brightener	–	–	$1.01{\cdot}10^{-1}$
Sodium chloride	–	–	$1.13{\cdot}10^{-1}$
Algaecides	–	–	$9.37{\cdot}10^{-5}$
Carpet product	–	$3.29{\cdot}10^{-3}$	–
Disinfectant	–	$2.77{\cdot}10^{-2}$	–
Breakfast foods [kg/overnight stay]			
Semi-skimmed milk	–	$1.30{\cdot}10^{-1}$	$5.02{\cdot}10^{-2}$
Whole milk	$4.49{\cdot}10^{-1}$	–	–
Butter	$2.23{\cdot}10^{-3}$	$1.45{\cdot}10^{-2}$	$4.26{\cdot}10^{-3}$
Cereals	–	$1.69{\cdot}10^{-2}$	$7.52{\cdot}10^{-3}$
Bread	$9.30{\cdot}10^{-2}$	$3.45{\cdot}10^{-2}$	$6.25{\cdot}10^{-4}$
Biscuits	4.50·10	–	$6.16{\cdot}10^{-3}$
Deli meat	–	$2.12{\cdot}10^{-2}$	$2.42{\cdot}10^{-2}$
Juice	$1.25{\cdot}10^{-1}$	$2.05{\cdot}10^{2}$	$1.33{\cdot}10^{-2}$
Yogurt	–	$1.71{\cdot}10^{-2}$	$1.21{\cdot}10^{-3}$
Fruit	–	$1.13{\cdot}10^{-2}$	$2.86{\cdot}10^{-2}$
Olive oil	$3.07{\cdot}10^{-2}$	–	–
Coffee	$3.56{\cdot}10^{-3}$	–	–
Orange	–	$2.47{\cdot}10^{-2}$	–
Tangerine	–	$2.47{\cdot}10^{0}$	–
Apple	–	$1.13{\cdot}10^{-2}$	–
Melon	–	$1.42{\cdot}10^{-2}$	–

2020) database by following the 'cut-off' approach, which attributes all the impacts to the functional unit, and using the market processes as default. All food data was obtained from the Agribalyse v3.0 database. All other inputs such as energy consumption, water and cleaning products were obtained from the Ecoinvent v3.7.1 database. The process selection was determined by proximity to Spain and Portugal and their presence in the database. Therefore, the order of preference in the selection hierarchy was: Spain-Portugal, Europe, Europe excluding Switzerland and the Global option. However, some processes were adapted and modelled for the Iberian Peninsula, such as the residual electricity grid mix. The data for the electricity mix was retrieved from the Association of Issuing Bodies (AIB, 2022) who publishes the national residual mixes for 322 European countries. Also, other important information can be obtained in the publications of the International Energy Agency (IEA, 2022), as well as the corresponding national authorities in this regard: for instance, in the case of Spain, the Electric grid Group (EGG, 2022) and The National Commission of Markets and Competition (CNMC, 2022).

2.4. Life cycle impact assessment

This research employed the software SimaPro9.3 (PRé Sustainability, 2021) and the EF 3.0 method (adapted) that includes 17 midpoint impact categories (European Commission, 2019) to carry out the Life Cycle Impact Assessment (LCIA) stage. The European Commission endorsed this approach for comparing and enhancing the environmental performance of products and services, providing greater precision and uniformity than alternative methods (Saouter et al., 2020).

The 3 categories related to toxicity were excluded, namely, ecotoxicity freshwater, human toxicity cancer, and human toxicity non-cancer. This decision was made in accordance with the recommendation of the PEFCR guide itself to exclude them due to the current lack of robustness of the results and pending the development of new characterization factors for these categories based on data from the REACH Regulation. Based on the categories considered relevant for similar products in the UNE-EN 15804:2012 + A2:2020 standard, the following ones were discarded: eutrophication terrestrial, ionizing radiation, land use and resource use, mineral and metals. Thus with the aim of selecting the most relevant ones, seven conventional impact midpoint categories were examined in total: Acidification terrestrial and freshwater (AP), Climate change (CC), Eutrophication—freshwater (FEP), Eutrophication— marine (MEP), Photochemical ozone formation— human health (POF), Resource use —energy carriers (FRD), Water scarcity (WDP). The impact categories cover the environmental burdens on various protection areas, providing a comprehensive outlook on tourist accommodations, as advised in tourism assessment articles (PEFCR, 2018).

3. Results and discussion

This section explains the LCA results of the three accommodations and a sensitivity analysis of the hotspots of each accommodation, in order to identify possible improvements in these three types of tourism evaluated and to determine an alternative to reduce environmental impacts.

3.1. Environmental performance

Table 2 shows that the 2-star hotel, which represents cultural-urban tourism, exhibits the highest environmental impact in most of the impact categories, except in CC, FRD, and POF. In the case of AP, it has a value of $3.72{\cdot}10^{-2}$ mol H+ eq./FU due to the electricity used in the hotel. For FEP ($1.25{\cdot}10^{-3}$ kg P. eq./FU), both electricity ($6.84{\cdot}10^{-4}$ kg P. eq./FU) and cleaning products used in hotel cleaning ($4.64{\cdot}10^{-4}$ kg P. eq./FU) play an important role. For the MEP impact category, which reaches a value of $8.89{\cdot}10^{-3}$ kg N eq./FU, breakfast has the highest environmental impact, mainly due to the processed meat. Lastly, for the WDP indicator, the 2-star hotel presents the worst results with 21.2 m^3 world eq./FU due to water consumption in the hotel and water used in breakfast food production. On the other hand, the 3-star hotel, representing beach tourism, is the highest contributor to the CC category with 6.0 kg CO_2 eq./FU due to electricity consumption in all hotel facilities. In terms of energy sources, this hotel is also the main contributor in FRD, with $1.19{\cdot}10^{2}$ MJ/FU due to the use of air conditioning, driven by the Mediterranean climate conditions in this destination. In the POF indicator, the hostel (nature-religious tourism) presents the highest value with $1.96{\cdot}10^{-2}$ kg NMVOC eq./FU due to diesel usage for heating, hot water, and cooking.

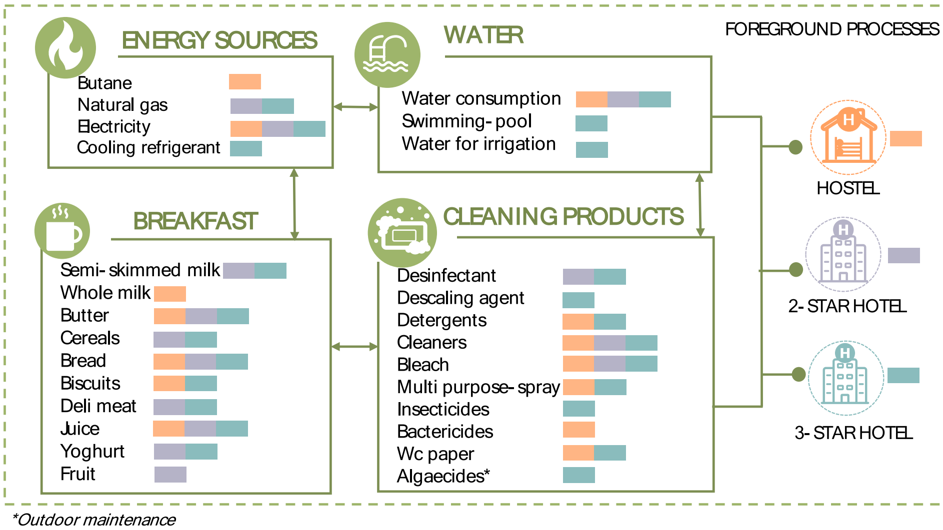
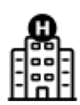
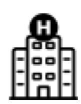


Fig. 3. System boundaries considered in the study.

Table 2
Adapted environmental impact indicators (EF 3.0 method). Values correspond to the total results per FU (one overnight stay including breakfast) for the three establishments.

	Units per FU	Hostel  Nature religious tourism	2-Star hotel  Cultural-urban tourism	3-Star hotel  Beach tourism
Acidification terrestrial and freshwater (AP)	mol H^+ eq.	$3.46{\cdot}10^{-2}$	$3.72{\cdot}10^{-2}$	$2.50{\cdot}10^{-2}$
Climate change (CC)	kg CO_2 eq.	4.68	5.94	6.00
Eutrophication - freshwater (FEP)	kg P. eq.	$7.43{\cdot}10^{-4}$	$1.25{\cdot}10^{-3}$	$8.23{\cdot}10^{-4}$
Eutrophication - marine (MEP)	kg N eq.	$1.29{\cdot}10^{-2}$	$8.89{\cdot}10^{-3}$	$5.88{\cdot}10^{-3}$
Photochemical ozone formation - human health (POF)	kg NMVOC eq.	$1.96{\cdot}10^{-2}$	$1.54{\cdot}10^{-2}$	$1.48{\cdot}10^{-2}$
Resource use - energy carriers (FRD)	MJ	67.6	83.4	$1.19{\cdot}10^{2}$
Water scarcity (WDP)	m^3 world eq.	13.0	21.2	8.82

3.2. *Identification of environmental hotspots*

As depicted in Fig. 4, the consumption of diesel in the hostel and the electricity both in the 2-Star hotel and in the 3-Star hotel, were the main carriers of environmental burdens.

For the hostel, the consumption of diesel had the highest contribution in almost all of the environmental categories, with $1.40{\cdot}10^{-2}$ kg NMVOC eq. in POF, 40.2 MJ in FRD and 2.52 kg CO_2 eq. in CC. These results align with the anticipated outcomes for this establishment where the consumption of diesel to heat the hostel is extremely high compared to the rest of the accommodations under study, due to the Atlantic weather conditions. By contrast, the use of disinfectant for indoor maintenance and cleaning was the main contributor to FEP ($4.47{\cdot}10^{-4}$ kg P. eq.), breakfast to MEP ($6.89{\cdot}10^{-3}$ kg N. eq), due to milk and fruit juice consumption, whereas water consumption was determinant for WDP indicator (10.8 m^3 world eq). The inputs exhibited insignificant contributions in most of the impact categories (<3 %).

With respect to 2-Star hotel, the environment was most affected by electricity demand except in the indicators of MEP and WDP. The electricity shows a very high contribution in most of the environmental impact categories, such as $1.94{\cdot}10^{-2}$ mol of H^+ eq. in AP, 3.15 kg CO_2 eq. in CC or $4.39{\cdot}10^{+1}$ MJ in FRD, among others. This is due to the use of electricity in lighting, elevators, air conditioning, and heating in the hotel. For the MEP and WDP cases, the breakfast is the major critical point. In the case of MEP ($4.33{\cdot}10^{-3}$ kg N eq.), deli meat represents the highest environmental impact with $1.20{\cdot}10^{-3}$ kg N eq. In the WDP category, the consumption of fruit in the breakfast has the main environmental burden. The water depletion caused by the consumption of fruit depends mainly on the region in which it is grown and the ratio of irrigated water required to the yield (Stoessel et al., 2012).

For the 3-Star hotel, the electricity was the main contributor in almost all impact categories: FRD with $6.78{\cdot}10^{1}$ MJ, AP with $1.41{\cdot}10^{-2}$ mol H^+ eq., FEP with $4.51{\cdot}10^{-4}$ kg P eq. and POF with $7.45{\cdot}10^{-3}$ kg NMVOC eq., except for CC, MEP and WDP. In the case of CC, the other major critical point is the use of natural gas. These results are within the interval of values found in existing literature where electricity and other energy sources, such as natural gas, are often the hotspots in the hotels (Puig et al., 2017). This could be due to the higher use of air-conditioning in summer as it is a beach destination where summer temperatures are very high. This hotel has also a heat pump system for air-conditioning operation. On the other hand, the natural gas used for hot water and heating in the establishment was responsible on average for between 15 and 30 % of the CC, MEP, POF and FRD. Furthermore, without taking into account the use of diesel and natural gas, it was observed that indoor maintenance and cleaning accounted for 42–82 % of the total loads measured. Regarding to WDP, the phase of water consumption is the main contributor with 83.50 %. This is due to the large amount of water used for the swimming pool and for watering the green areas.

3.3. *Best environmental alternatives through a sensitivity analysis*

The results allowed the identification of the main environmental burdens of the 3 systems studied. In this sense, a sensitivity analysis is needed to check which would be the most sustainable alternative to decrease the impact of each of them and thus, to improve the type of tourism in each destination.

For the hostel (representative of a natural destination) the diesel in the heating and cooking has been the most critical point. Therefore, three other types of energy sources have been examined to find out

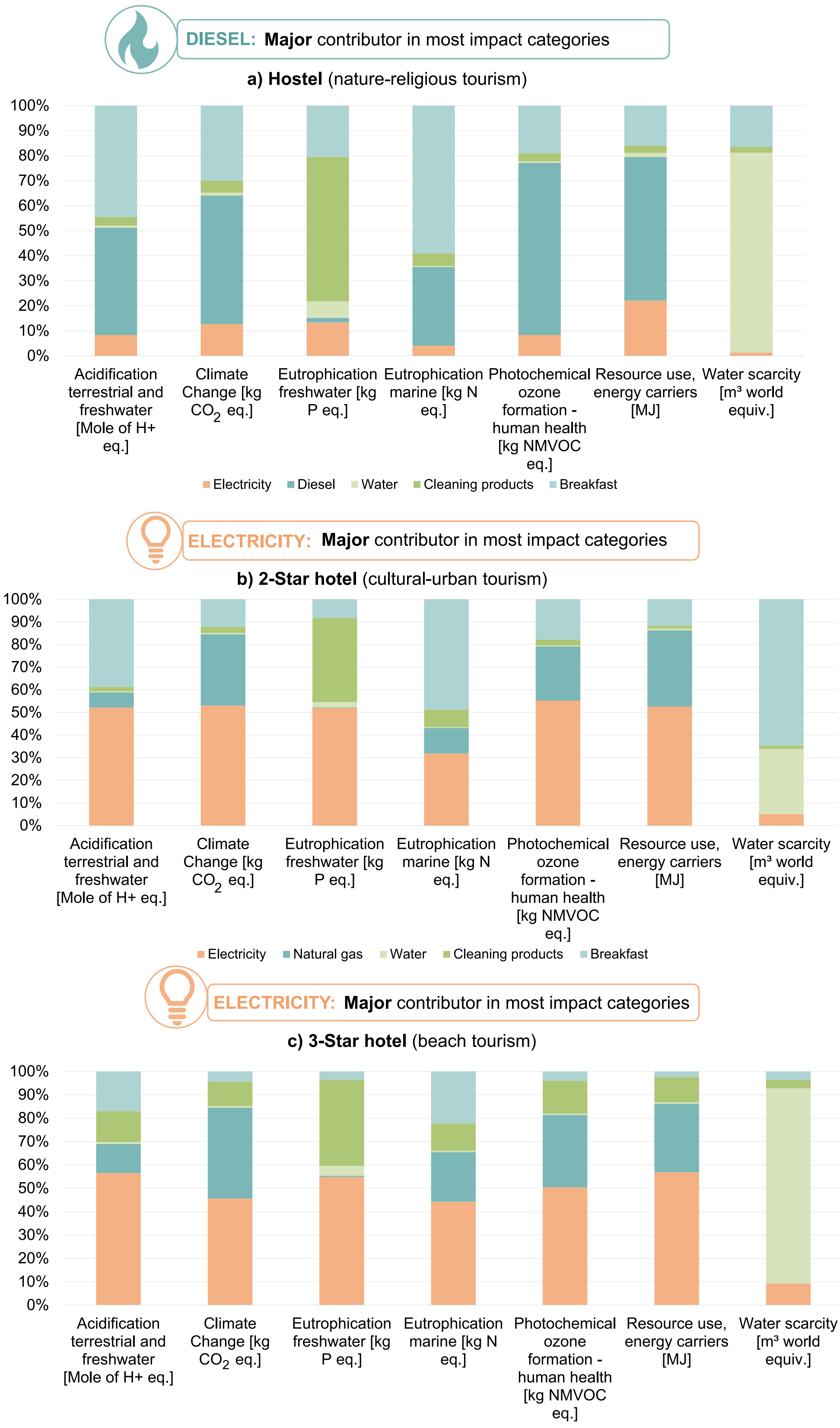


Fig. 4. Adapted environmental impact indicators (EF 3.0 method). Values correspond to the total results per FU in percentage (%) for the total establishments taken into account—Global activity.

which one is the most environmentally friendly option. As can be observed in Fig. 5, natural gas can be an alternative to the hostel problem with an overall contribution of 1–29 % in almost all environmental categories compared to 36 % for diesel used in the hostel. A second option could be to use biomass-pellets. However, it is found that for FEP it is the largest contributor (84.26 %) of the total impact in that category. This could be due to the solid biomass (i.e., pruning residues, forestry, etc.) supply chain where nitrogen and phosphorus rich fertilizers are used, which generates a large impact on this indicator (Hasler et al., 2015). Notwithstanding, butane has been identified as the worst alternative to decrease the environmental impact in the hotel with a contribution of 38 % in most of the indicators (AP, MEP, POF, FRD). Based on the diverse outcomes obtained in this research concerning various energy sources and through a comparison with the current literature (Soratana et al., 2021), it can be generalized that energy efficiency of a hostel in a natural destination is highly dependent on the fossil fuel used, with natural gas being a better option. This is a commonly known observation, as numerous studies pointed out the direct utilization of fuel as the main contributor (Filimonau, 2016; Ali et al., 2008; Gössling et al., 2022), accounting for approximately 21 % of the greenhouse gas emissions (Trull et al., 2019).

Regarding the impacts on the 2-Star hotel, which represents urban-cultural tourism in Portugal, electricity has been identified, as mentioned before, as the primary contributor to the hotel's environmental impacts (Fig. 6). These findings align with current literature (Puig et al., 2017), highlighting that most hotels and resorts rely on fossil fuel combustion (coal, oil, and natural gas) for their energy needs, contributing significantly to environmental problems like global climate change. Another major concern in hotels is the high amount of energy and fuel consumption required for the air-conditioning systems and other operations, mainly due to the limited use of renewable energy sources such as solar power (Beccali et al., 2018). The research results indicate that the contribution of self-consumed renewable energy to environmental indicators is minimal, ranging from 0 % to 0.02 %, compared to the dominant residual mix at 99 %. An alternative for these hotels would be to source electricity from a grid with green certification, which could reduce the impact by 0.4 % to 20 % across most indicators. All these results are similar to those occurring in the 3-star hotel which will be explained below.

Hotels catering to this type of urban-cultural tourism often have higher electricity demands due to the need to provide services to guests, such as lighting, air conditioning, heating, and other electrical devices. To reduce electricity consumption in these hotels, several measures can be implemented, such as improving energy efficiency by installing LED lighting, efficient HVAC systems, and low-power electronic equipment. Additionally, the installation of motion sensors can be considered to automatically turn off lights in rooms and common areas when they are not in use (Cabello Eras et al., 2016). By implementing these measures, hotels serving urban-cultural tourism in Portugal can significantly reduce their electricity consumption, decrease their environmental impact, while improving operational efficiency and sustainability image.

We must not overlook the second critical point of this hotel, which is a problem in urban-cultural tourism: breakfast, with deli meat being the

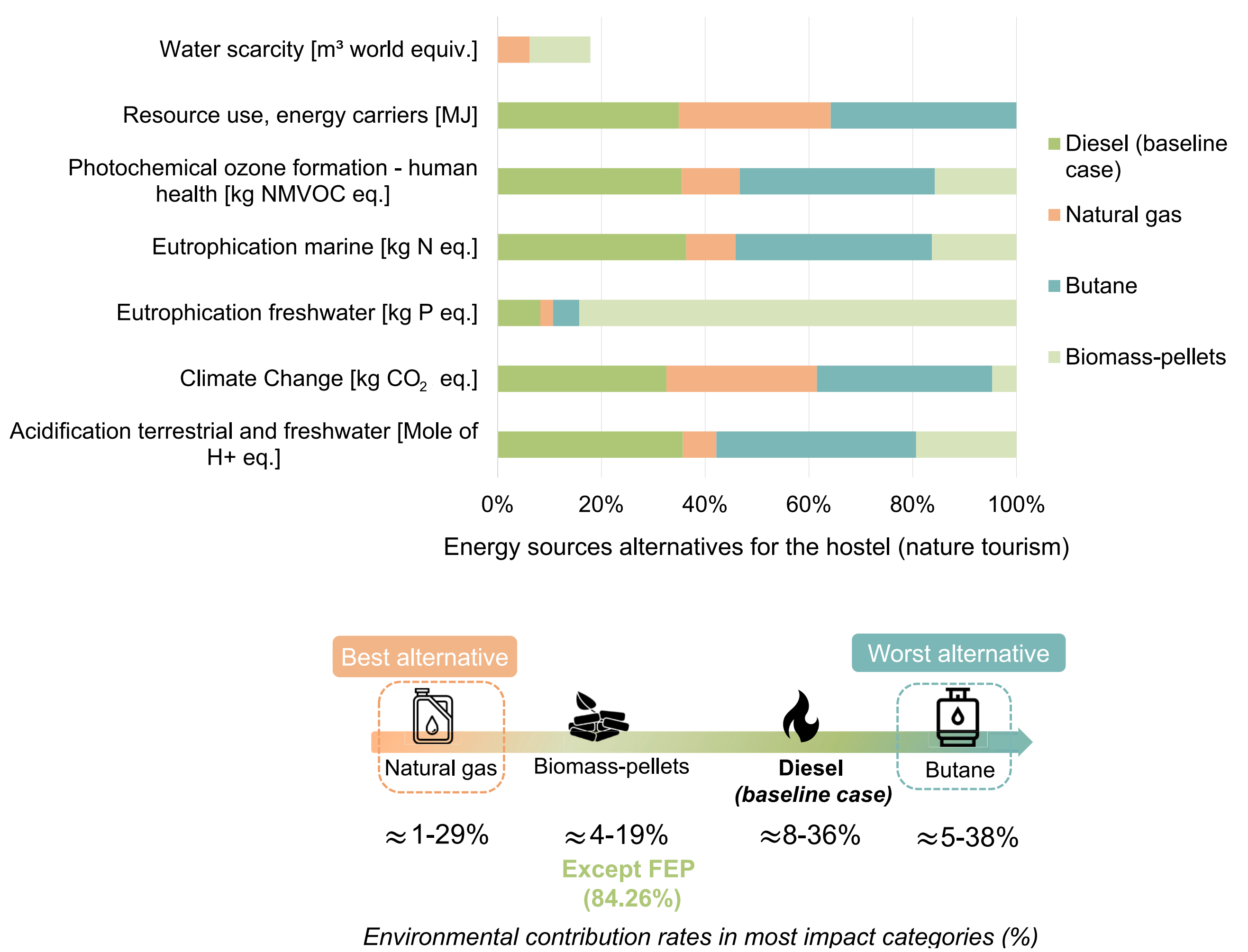


Fig. 5. Adapted environmental impact indicators (EF 3.0 method). Values correspond to the energy sources alternatives per FU in percentage (%) for the hostel.

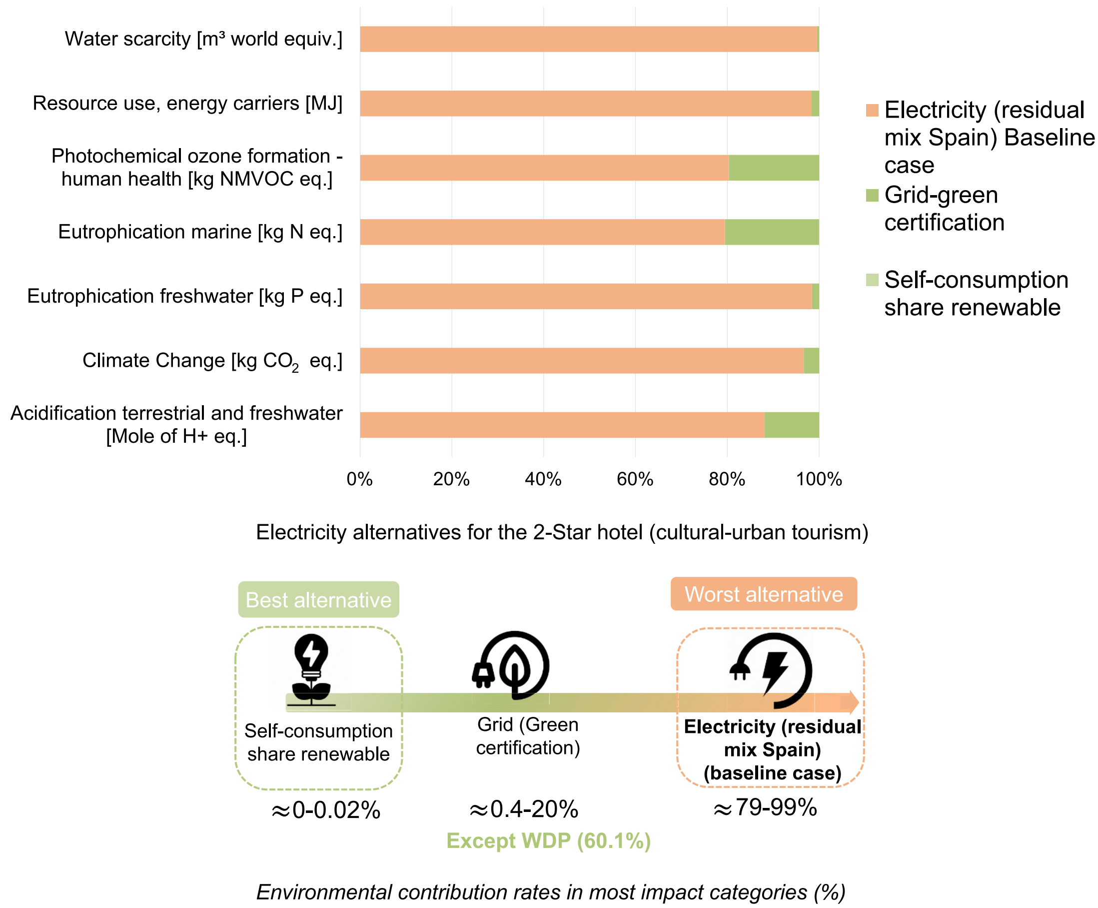


Fig. 6. Adapted environmental impact indicators (EF 3.0 method). Values correspond to the cleaning products alternatives per FU in percentage (%) for the 2-Star hotel.

main culprit. For this reason, it is recommended that hotels of this type offer vegan breakfast options to reduce the environmental impact of these tourist accommodations. An example would be a breakfast consisting of oats, berries, and Greek yogurt, which provides a high nutritional value with rich dietary fiber, functional protein, lipids, and starch (Takacs et al., 2022).

Finally, according to the 3-Star hotel located in the Mediterranean area of Spain, electricity was identified as the main critical point (Fig. 7). These results are within the interval of values found in existing literature (Candia and Pirlone, 2022). The vast majority of hotels and resorts purchase the energy they require from the burning of fossil fuels (coal, oil, and natural gas), which is a major cause of various environmental issues, such as global climate change (Gössling et al., 2022). Another important issue in Spanish Mediterranean hotels is the substantial energy and fuels consumption resulting from air-conditioning systems and other operations (Puig et al., 2017). This is due to failure to use solar system and other forms of renewable energy sources (Campos et al., 2022b). The average outcomes of this study indicated that self-consumption share renewable had a contribution of 0–0.02 % in most of the environmental indicators compared with the 99 % from residual mix. Another option not as harmful as the existing one in this hotel would be to get electricity from grid with a green certification (0.1–29 %) of the impact in the majority of the indicators. However, in CC and WDP indicators would not be a sustainable option (99.95 % and 99.98 %, respectively). Moreover, it is essential to bear in mind that these numbers stem from the electricity consumed in the hotel and in the hotel's swimming pool, so they should be viewed with caution.

4. Challenges and recommendations for the three types of tourism

In the three accommodations, the environment is predominantly affected by the utilization of electricity and fuels (diesel and natural gas) concerning all the global and regional environmental effects taken into account (acidification terrestrial and freshwater, climate change, eutrophication-freshwater and marine, photochemical ozone formation-human health, resource use-energy carriers and water scarcity). The initial step that local governments need to take involves mitigating the impacts associated with accommodation facilities by investing in building energy. Following this, interventions to decrease water consumption and heat loss are crucial. It is possible to implement these interventions through a collaboration between the public and private sectors. The public sector, for instance, can assist building owners by providing its own technicians to evaluate the condition of the structure from the perspective of energy and heating performance. Likewise, the local government can provide a sustainable tourism plan that considers the state of existing lodging facilities, as well as raise awareness among tourists and tourist destinations about the importance of energy conservation and adopting sustainable practices. This can be achieved through the placement of informative signs, training programs, and the promotion of environmentally friendly behaviors.

Going a step further, the need for tourism sustainability should not be underestimated: in fact, increasing number of destinations are experiencing the detrimental impacts from the fast expansion of this phenomenon, contributing to a global rise of 7 % of carbon emissions per year (Candia and Pirlone, 2022). The COVID-19 pandemic-induced crisis in the tourism sector presents a chance to create more effective and

Fig. 7. Adapted environmental impact indicators (EF 3.0 method). Values correspond to the electricity alternatives per FU in percentage (%) for the 3-Star hotel.

sustainable services that can fulfil the demands of travelers more and more aware and attentive. Cultural cities and beaches have returned to being crowded with tourists, despite the numerous restrictions imposed to reduce the risk of infection. This proves that the need for sustainable tourism is an unquestionably real concern. The economic and environmental models on which the tourism sector was largely based prior to the arrival of COVID-19 were not sustainable, incapable of achieving the objectives of the 2030 Agenda and the 2050 climate neutrality demanded by the European Union (European Commission, 2020). Therefore, it is essential to shift towards sustainable tourism and genuinely embrace it. The use of LCA methodology facilitates a reduction in the consumption of local resources (e.g., by enhancing the energy and thermal efficiency of accommodation services, better insulation). However, for the method presented in the paper to be effective in promoting sustainable tourism, it should be incorporated into local policies and planning tools. Without this practical implementation, it poses the risk of remaining a mere theoretical tool, incapable of bringing about real changes in the tourism industry. In the case of Lloret de Mar (3-Star hotel), which suffers from mass tourism, they should embrace sustainable tourism strategies that analyse ways to mitigate the adverse environmental effects of this economic sector. Such a plan would also prove beneficial for tourist municipalities which have not yet reached a state of overcapacity, such as Guimaraes (cultural-urban tourism), with the aim of directing the growth of the sector towards sustainable alternatives and preventing the repetition of the mistakes made in other locations. For instance, in Spain there are numerous municipal tourism plans (Ministry of industry, trade and tourism, 2022). In this case, the municipal level has achieved compelling outcomes through improved distribution of tourism across the region, facilitated by diversifying the range of tourist attractions. Regarding Cantabria, there is already a tourism sustainability plan that will turn the Camino Lebaniego's pilgrimage route into a reference point for nature and culture tourism (Camino Lebaniego, 2021).

In order to examine the case studies in Spain and Portugal, major differences were observed between beach tourism and cultural and nature tourism. In the case of nature tourism in the north of Spain, a high use of fossil fuels (just think of heating) was observed due to the very low temperatures. However, in the Mediterranean, something similar has been found for the consumption of air-conditioning. Along the same lines, in Portugal, it was the electricity used in air conditioning, heating, electric cookers and electrical appliances the main environmental barrier. Breakfast would also be a critical point in the system because of the deli meat. Going a step further, in terms of food waste, this may be due to the large amount of food served (with high impact) that is not consumed at the end: the buffets. This type of eating habits could have a significant influence on the potential for food loss, waste generation and management and GHG emissions (Aldaco et al., 2020).

Therefore, it is observed that despite the climatic and cultural differences, one of the major contributors to the environment are energy sources, so it would be necessary to implement measures in these three establishments and, consequently, in these three destinations. Given that energy use is strongly connected to GHG emissions, implementing energy saving measures and using suitable energy sources would present significant opportunities to encourage sustainable consumption practices in hotels in Spain and Portugal. The findings obtained can be extended to other regions within the Mediterranean since the authors employed European and Spanish, French and Portuguese databases to assess accommodation facilities (PRé Sustainability, 2021).

5. Conclusions

In this initial investigation, the environmental impact of three hotels located in coastal and mountainous areas of Spain and Portugal was evaluated using the life cycle perspective.

The results show that 2-star hotel (cultural-urban tourism) has the largest impacts for most of the categories, except in CC, FRD and POF indicators. The 3-star hotel (beach tourism) is the highest contributor to the CC and FRD indicators. Regarding the hostel (nature-religious tourism), it presents the highest value in the POF indicator. LCA outcomes showed that diesel consumption in the hostel and the electricity both in the 2-Star hotel and in the 3-Star hotel were the main carriers of environmental loads for the majority of conventional impact categories. Nevertheless, social and economic impacts also have to be considered in order to establish the most sustainable tourism alternative. Although it may seem that by increasing the number of stars, the environmental impact may increase, it should be noted that this is not always the case. This study shows that a 2-star hotel can have a higher carbon footprint (CC indicator) than a 3-star hotel. Therefore, a higher number of stars is not synonymous with a higher environmental impact.

It would also be necessary to distribute visitors more evenly between the different types of tourism in order to avoid saturation in specific areas. All this leads to the conclusion that perhaps natural or religious tourism are more environmentally optimal than the other two types of tourism, but economically and socially they have a lower impact. Therefore, it is necessary to look for a sustainable tourism highlighting the importance of maintaining tourism in a sustainable way, generating more value with less environmental and social impact.

In conclusion, scientific evidence outlines that the utilization of fossil fuels and electricity has the most significant environmental effects on tourism activities. Considering that tourist activity heavily depends on environmental resources, it is essential for it to adopt a more proactive approach towards making sustainable decisions. Thus, forthcoming endeavors should prioritize researching the possibility of substituting the conventional heating and air-conditioning systems by new devices using green and renewable technologies with low emissions, such as biomass heating system by burning pressed wood pellets in a chimney (Thomson and Liddell, 2015). In order to put into action viable substitutes to traditional fuels, another improvement actions could also be the use of highly efficient systems such as heat pumps (they could be used for climatization –heating or air conditioning— or hot sanitary water). In addition, in terms of electricity consumption it would be desirable to go for self-consumption share renewable instead of the conventional grid mix. The findings from LCA are vital for effectively conveying the environmental impacts linked to tourism. Given the rapid growth of the global tourism industry and its associated consumption and environmental effects, an urgent response is required. Decision-making tools should be available to tourism stakeholders and managers to steer the industry towards a sustainable future. Inputting inventory data from different accommodations into these tools and system models is crucial to attain genuine sustainability goals. This data is then employed to compute key sustainability indicators. The proposed approach empowers public administrations to assess the environmental effects of tourism and propose more sustainable alternatives.

CRediT authorship contribution statement

Cristina Campos: Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation. **Ana Cláudia Dias:** Writing – review & editing, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Paula Quinteiro:** Writing – review & editing, Visualization, Validation, Methodology, Investigation, Data curation. **David Gutiérrez:** Writing – review & editing, Visualization, Methodology, Formal analysis, Data curation. **Pedro Villanueva-Rey:** Writing – review & editing, Visualization, Methodology, Investigation, Formal analysis, Data curation. **Sara Oliveira:** Writing – review & editing, Data curation. **Jara Laso:** Writing – review & editing, Visualization. **Jaume Albertí:** Writing – review & editing, Data curation. **Alba Bala:** Formal analysis. **Pere Fullana-i-Palmer:** Project administration, Funding acquisition. **Lela Melón:** Project administration. **Margalida Fullana:** Writing – review & editing. **Ilija Sazdovski:** Project administration. **Mercè Roca:** Writing – review & editing, Visualization, Supervision. **Ramon Xifré:** Writing – review & editing, Visualization, Supervision. **María Margallo:** Writing – review & editing, Validation, Supervision, Data curation. **Rubén Aldaco:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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