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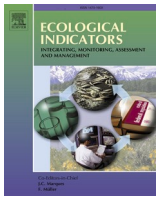

Empirical evidence, methodologies and perspectives on tourism, energy and sustainability: A systematic review

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ABSTRACT

The high dependence of tourism activities on energy consumption, and particularly on non-renewable energy, is a major barrier to building sustainable tourism models. For this reason, the analysis of tourism and energy use is a growing field of study within sustainability debates. Despite this, there is a gap in the literature and, to the best of our knowledge, there is no previous study that critically reviews the vast literature on the energy-tourism nexus. This paper aims to fill this gap in tourism knowledge. The main objective of this article is to conduct a systematic review of scientific studies with a quantitative empirical basis that examine this nexus, trying to answer the following questions: What are the main methodologies used to approach the tourism-energy nexus? which indicators or variables are relevant?; is there a consensus on the results?; and what are the main lines of discussion on the use of energy in tourism? To this end, we particularly focus on the main methodologies, results and perspectives during the period 2001–2021. A total of 1,189 articles were reviewed by abstract and title, 236 were included for the full review and 163 were finally selected. The results show how the nexus and energy dependence of tourism is assessed mainly from four major methodological groups: G1) econometric models, regressions and other statistical methodologies (67% of the sample); G2) surveys, questionnaires and energy audits (15%); G3) Life Cycle Analysis (13%) and G4) other approaches and environmental impact indicators to assess the relationship between energy and tourism (5%). The analysis between the causal relationships between tourism development, economic growth, energy use, environmental degradation and energy efficiency of accommodations are the main issues evaluated, considering a wide range of indicators/variables. Based on the gaps and limitations found in the literature review on tourism and energy, it is discussed how some findings should be interpreted with caution due to their methodological approaches and differences. Finally, some of the main lines of future research in this field are also presented.

1. Introduction

The high growth of tourism in recent decades has turned this activity into one of the most important industries in the globalized economy (WTTC, 2019). Low airfares, increased transportation connectivity and technological advances, as well as new business models, have fostered continued growth in tourism. Before the pandemic, tourism accounted for 10.4% of global GDP ($9.2 trillion) and generated one in four jobs worldwide, up to 334 million jobs (WTTC, 2020), but economic activity of such dimensions has a significant impact on the environment. For example, the relationship between tourism development and its contribution to global warming (measured through greenhouse gas emissions-GHG) is a well-documented issue (Govind-Mishra et al., 2022). Climate change is one of the main environmental problems that not only affects humanity (IPCC, 2022), but also influences all organic life on Earth, and can generate a substantial change in the territories/landscapes where tourism is developed (Varol et al., 2022; Tekin et al., 2022). Lenzen et al., (Lenzen et al., 2018) estimated that the tourism industry accounted for 8% of GHGs globally (2013). Transportation (49% of GHGs), services and hotels (14%) followed by goods production (12%) are the main hotspots of the supply chain, being visitors from high income countries those with the largest carbon footprints (ib). Despite the importance of climate change, according to the World Tourism Organization (UNWTO), the tourism industry will not only continue to grow - multiplying by 1.5 and 1.7 times international and domestic arrivals between 2016 and 2030 - but it is also expected to face greater

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environmental pressure in terms of emissions, even under the most optimistic technological assumptions (UNWTO, 2020).

Energy usage is a critical part of the climate change backlash, especially fossil fuels (Becken et al., 2001). In order for a tourist to travel to a destination and enjoy goods, services and infrastructure (e.g., hotels, attractions), the use of different primary energy sources is required (Nepal et al., 2019). In other words, the tourism supply chain is highly dependent on the use of energy carriers (i.e., diesel, gasoline, gas, electricity) (Becken, 2008; Becken, 2011). This dependence is especially worrisome in a context where peak oil (Murray and King, 2012; Alvarado et al., 2021; Laherrère et al., 2022) represents a real threat to the current economic model based on non-renewable sources that are being depleted (Becken and Lennox, 2012; Sun et al., 2022; Gössling and Humpe, 2023). It is therefore urgent to move toward sustainable tourism models that reduce dependence on fossil fuels, increase the weight of renewable energy, and improve their environmental efficiency (Hall et al., 2015; Dogru et al., 2020). In this sense, the debates on the energy and environmental sustainability of tourism are complex and there is no single position on this matter. On the one hand, many authors consider that the main challenge is the continuous improvement of efficiency and circularity measures that allow both reducing emissions and decreasing the number of materials and energy needed to support the tourism activity (Dogan and Aslan, 2017; Bano et al., 2021; Pata and Balsalobre-Lorente, 2021; Xu et al., 2022). On the other, some researchers defend that sustainability requires, irremediably, the decrease of tourism to adjust to the planetary biophysical limits (Flecher et al., 2019; De Luis Blanco, 2011; Blázquez, 2016; He et al., 2023).

In this sense, since the pioneering work of Hazari and Sgro (Hazari and Sgro, 1995), an important part of the literature has focused on analyzing the nexus between tourism activity, economic growth and environmental degradation (Narayan, 2004; Katircioglu, 2009; Tang and Tan, 2013; Danish and Zhaohua, 2018). These works usually have a macroeconomic perspective, and some of them focus on the Environmental Kuznets Curve (EKC) hypothesis (Katircioglu, 2014; De Vita et al., 2015; Bella, 2018; Mikayilov et al., 2019; Ghosh, 2020). Furthermore, and although with different methodologies, there are also studies that analyze the energy usage of some steps of the tourism supply chain, including energy efficiency in hotels (Lam and Chan, 2001; Cingoski and Petrevska, 2018; Salehi et al., 2021), transportation (Kuo and Chen, 2009; Tang et al., 2015; Rauf et al., 2021) or tourism behavior (Becken et al., 2001; Becken et al., 2003; Bajracharya et al., 2020), among others. In view of the wealth of research on tourism-energy and given its importance in the design of policies aimed at sustainability, it is crucial to conduct a systematic literature review of the topic to provide a holistic view of the main methodologies, results and debates (Page et al., 2021). In other words, a comprehensive, methodical and thorough review is necessary to facilitate further inquiry on the main perspectives, barriers and drivers of sustainable tourism and travel options (Peeters, 2017; Miller et al., 2015; Ehigiamusoe, 2020).

In relation to tourism and environmental impact, there are some reviews in the scientific literature that need to be considered. De Camillis et al. (2010) and Campos-Herrero et al. (2022), reviewed and compared life cycle analysis (LCA) studies in the tourism sector with the aim of identifying approaches that can serve as a basis for developing sectoral LCA guidelines. Papavasileiou et al. (2021) and recently Sun et al., (2022) focused their attention on EKC applied to tourism, while Govind-Mishra et al. (2022) conducted a bibliometric study on tourism and GHG emissions, identifying the main studies, journals, affiliations and countries, as well as authors, citations, etc. In relation to climate change and tourism, Scott and Gössling (2022) investigate the main research topics, knowledge gaps and perspectives, while Gössling et al. (2022) study mitigation strategies according to scales, scopes of action and stakeholders. Other bibliometric studies have focused on the concepts of environmental taxation, energy or sustainable policies (Shahbaz et al., 2021; Zhang et al., 2017; Warren and Becken, 2017). To our knowledge, however, no previous studies address the vast literature on tourism and energy. This paper aims to fill this gap in tourism knowledge by systematizing in a novel way the main findings, debates and methodologies used in this field. Therefore, the main objective of this paper is to review the main empirical studies using quantitative methodologies to examine the tourism-energy nexus, trying to answer the following questions: (i) What are the main methodologies used to approach the tourism-energy nexus? (ii) Which indicators or variables are relevant?, (iii) Is there a consensus on the results?, and (iv) What are the main lines of discussion on the use of energy in tourism? To this end, we particularly focus on the main methodologies, results, and perspectives during the period 2001–2021. Based on the gaps found in the literature on tourism and energy, some of the main lines of future research in this field are discussed.

2. Materials and methods

2.1. Search methodology and exclusion/inclusion criteria

In this work, a review of the scientific literature has been carried out to analyze the nexus between tourism and energy. For this purpose, a cross-sectional perspective has been chosen. Unlike other works that focus on a single methodology (e.g., econometric models, regressions), this study aims to review all research that relates energy and tourism at any node of the tourism supply chain and provides empirical evidence. To this end, the four phases of the PRISMA protocol (Page et al., 2021) have been followed: 1) identification of records; 2) elimination of duplicates and screening of abstracts; 3) full text evaluation (suitability), and 4) final quality evaluations. A schematic of the key methodological steps and follow-up of the PRISMA (2020) guidelines is shown in Fig. 1, and a PRISMA checklist can be found in Table S3 of the Supplementary Materials.

The first searches (step 1) were carried out in November 2021 combining the terms *tourism* and *energy* in Web of Science and SCOPUS, as these are two of the most important databases of bibliographic and

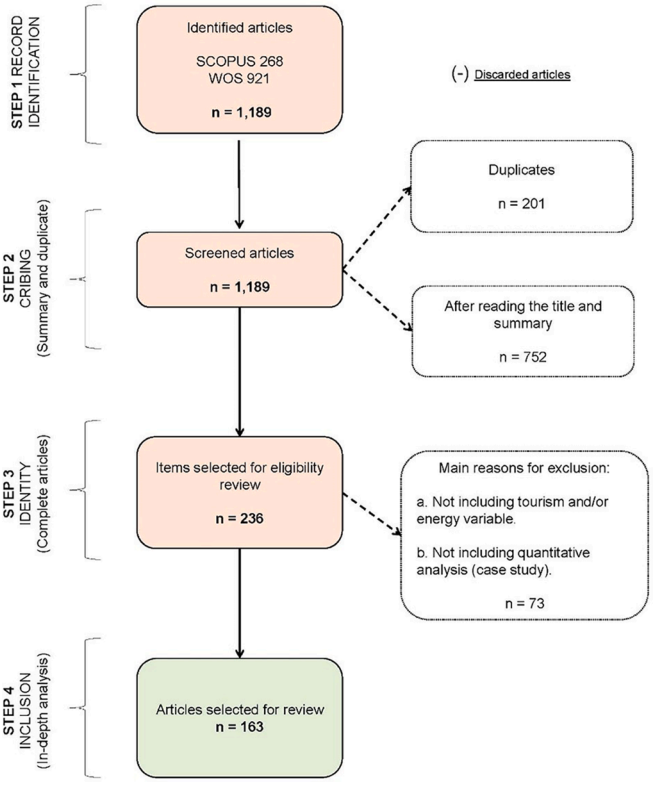

Fig. 1. Methodological diagram of the application of the PRISMA (2020) protocol for the literature review.

scientific information worldwide with over 46,000 indexed journals (Pranckuté, 2021). The search command was made more complex by using the Boolean operator OR to add the resulting records obtained with the following terms: energy analysis, energy consumption, LCA, energy metabolism, peak oil, environmental footprint. These searches yielded a large number of records (books, articles, conferences, etc. i.e. more than 5,650 records), but we focused our attention on scientific articles published between 2001 and 2021in indexed journals. Scientific articles were prioritized as they are documents that guarantee, to a greater extent, the scientific quality of the publications (i.e., rigorousness, transparency) by following a peer review process (Anhalt-Depies et al., 2019; Reifsnider, 2022). Moreover, the selected period (21 years) is sufficiently broad to have a good overview of the current debates on the topic (Shahbaz et al., 2021).

A total of 1,189 articles were selected in step 1: 921 from Web of Science and 268 from SCOPUS (Fig. 1). The software parsif.al (https://parsif.al/) was used to eliminate duplicates and screen the abstracts (step 2). Parsifal is a specialized software designed to perform systematic literature reviews that allows working together on the basis of a common protocol. Through this software, duplicate papers were detected and eliminated (n = 201). From this point on, the eligibility phase occupied a central place in the analysis. The authors designed a three-category system to classify the eligibility of the articles. In the first category of article classification, the titles, and abstracts of all the documents in the sample were read, and 752 articles were discarded because they did not fit our research objective. Then, a total of 236 articles were selected for full reading and suitability assessment (step 3). The second category included papers that, while addressing energy consumption, tourism appeared tangentially or was addressed qualitatively (n = 73 articles). For example, some studies investigate the perception of peak oil among tourism consumers. These studies were excluded because they did not provide tangible information on tourism and energy dependence, i.e.: a) not presenting a quantitative case study whose methodology and results are replicable and/or b) not including the tourism and energy variable specifically in the analyses. Category 3 included papers examining some dimension of energy use and tourism through quantitative methodologies. To overcome possible selection bias, each article was reviewed independently by two authors through the title and abstract. There was broad agreement between the two authors in the first round of review (greater than 90%). When a different categorization occurred, the third author reviewed the article independently and resolved it in a second round.

2.2. Final study set and data processing

As stated above, 163 articles passed to the systematic review phase (step 4). In this phase, the articles were read again in-depth and analyzed to systematize their main methodologies, objectives, results, and the most relevant discussions and conclusions. Additional significant information (i.e., year of publication, journal, tourist destinations evaluated, authors, etc.) was also systematically recorded to contextualize the main discussions between tourism and energy. All this information was collected in a database that allowed to create groupings, as well as to investigate the common results and patterns, and the particularities of each paper. For operational reasons, a number was assigned to each article of the sample (see Table S1 of the methodological appendices) in order to cite them easily, as this facilitates the reading of the document without detriment to the information.

3. Results

3.1. Analysis of the evolution of the main articles on energy- tourism nexus

Fig. 2 shows the year and the main journals in which the 163 selected articles were published. Most of these papers were published between 2011 and 2021, being the latter the year with the highest number of publications (24%). Ten out of the sixty-eight journals monopolized 50% of the publications: Environmental Science and Pollution Research (14.7%), Sustainability (6.1%), Current Issues in Tourism (5.5%), Journal of cleaner production (4.9%), Energy (3.7%) and Energy and Buildings (3.7%). The remaining 50% were published in 57 journals with topics related to tourism, ecology, economics or engineering (complete information is given in Table S2). A substantial part of the articles (over 40) investigates the relationship between energy usage and tourism between 1995 and 2020, presenting a wide diversity of indicators and study variables, as can be seen in Table S4 of the Supplementary Materials. A great diversity of areas and countries have been analyzed: Asia and Europe account for 63% of the studies, while the Americas account for 10%; 6% of the papers analyze tourism from a global perspective by introducing a large number of countries, while 20% use different economic or geographic criteria to make their selection. China, Spain, Turkey, Pakistan, New Zealand, the United States, Taiwan and Italy are the most analyzed individual destinations (Fig. 3).

3.2. Methodological approach, objectives/hypotheses, and study areas on tourism and energy

After a detailed analysis of the articles, they were grouped according to the methodological approach used. Four major groups were identified (Table 1): G1) econometric models, regressions and other statistical methodologies; G2) surveys, questionnaires and energy audits; G3) life

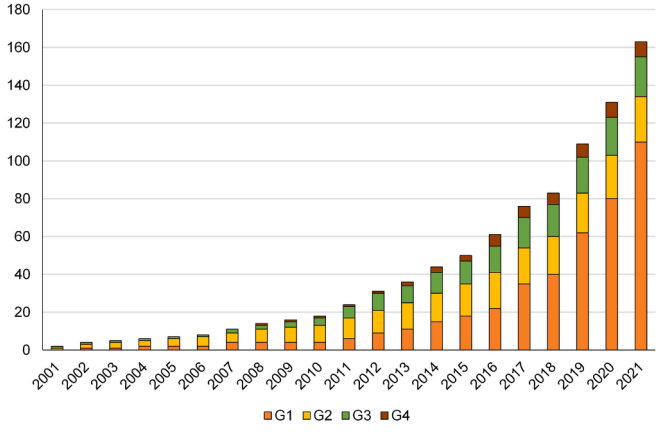

Fig. 2. Evolution over time of published articles according to the four groups (G1, G2, G3, and G4) (cumulative number).

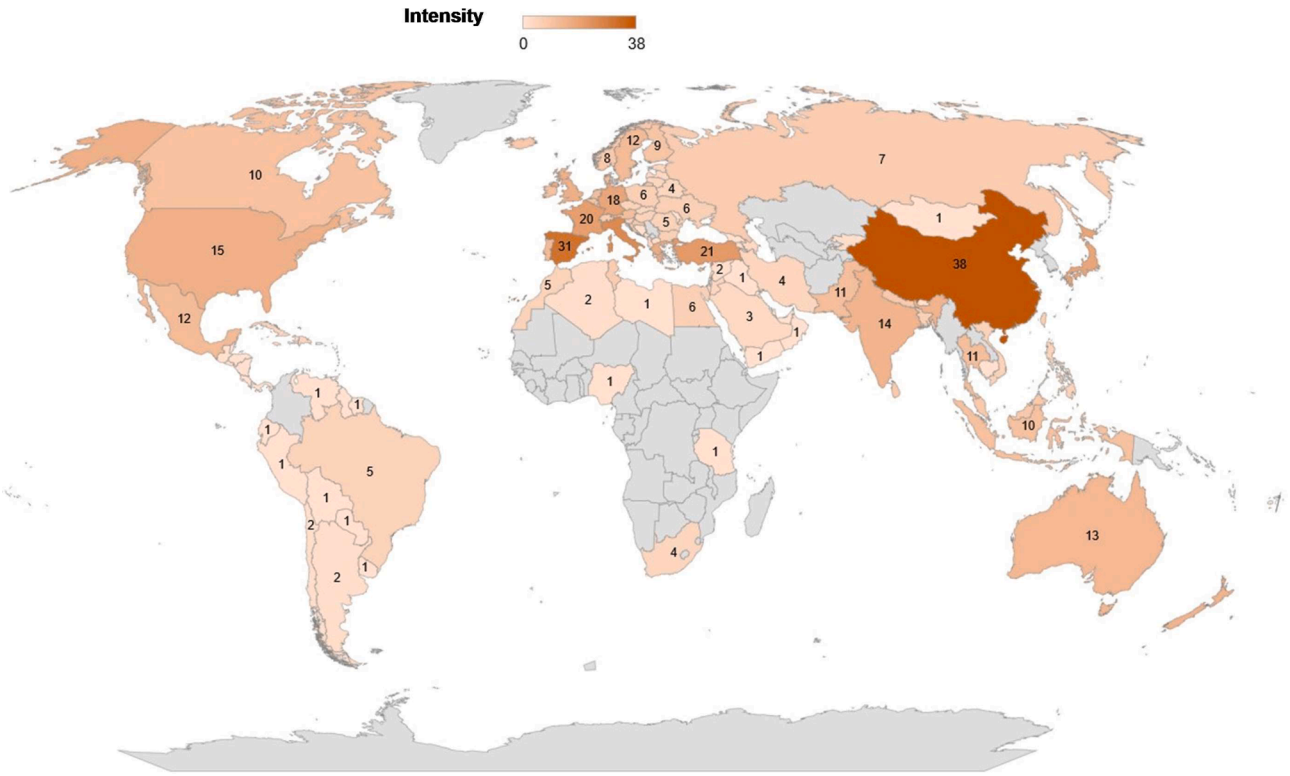

Fig. 3. Number of studies analyzed per country.

Table 1
Main methodological groups, hypotheses or objectives of the articles analyzing the relationship between tourism and energy.

Group	Name	Articles (%)	Main objectives or hypotheses
G1	Econometric models, regressions and other statistical methodologies	67	Contrast one or more of the following hypotheses: (H1) Tourism development drives economic growth; (H2) Tourist development increases energy demand; (H3) Tourist development increases energy demand; (H4) Tourism development increases environmental degradation.
G2	Survey, questionnaires and energy audits	15	Analyze energy use and consumption in a) tourist accommodations; b) restaurants; and/or c) assess tourist behavior
G3	Life cycle analysis	13	Assess the energy consumption of tourism in terms of its complete supply chain or any of its stages (transportation, lodging, services, food, etc.).
G4	Other approaches and environmental impact indicators	5	Energy consumption in tourism

cycle analysis; and G4) other approaches and environmental impact indicators.

G1 is the largest group in the sample (67%). The G1 group comprises papers that use econometric models, regressions or other multivariate statistical models to evaluate the interrelationships and causalities between: a) tourism development, b) economic growth, c) energy consumption, and d) environmental degradation; also introducing e) other non-core variables (e.g., population, urbanization, capital, etc.). In general terms, the main objective of these studies was to validate/reject one or more of the following hypotheses (See Table 2): H1) Tourism development drives economic growth, H2) Tourism development increases energy demand, and H3) Tourism development increases environmental degradation, mainly measured through the GHG emissions indicator – although other indicators such as the ecological footprint (87, 114, 127, 130, 142) or other impact indices (68) are also used. 30% of these articles start from the EKC to validate/reject these hypotheses. The main type of econometric data used, and on which this type of econometric study is based, is generally secondary data, compiled by international and national organizations such as the World Bank (WB), the International Monetary Fund (IMF), the Organization for Economic Co-operation and Development (OECD), the economic ministries of the different countries, etc. Among the most commonly used techniques and models are: autoregressive distributed lagged models (ARDL), generalized method of moments (GMM), regressions with orthogonal variables and boosted regressions (STIRPAT), dynamic linear panel data (DPD), dynamic ordinary least squares (DOLS), and vector error correction (VECM), etc. (see Table S5).

G2 is the second largest group in the sample, representing 15% of the total. This group includes works that analyze consumption, efficiency, energy intensity and environmental degradation based on interviews, questionnaires, surveys and primary data collection, mainly in tourist accommodations. These methodologies have been used to study and classify (See Table 3): a) tourist accommodations; b) restaurants; and c) tourist behavior and typology bases on energy use and consumption. G3 is the third largest group in the sample, representing 13% of the total of articles. This group includes papers that assess the environmental impact of tourism using the LCA methodology. LCA is a methodology for evaluating the environmental impact of a product, process or economic activity throughout its life cycle (from cradle to grave) (ISO, 2021). Within this group, it is common the use of bottom-up approaches to aggregate at larger scales. This is possible thanks to the conversion of the primary data collected through surveys (similar to G2) and interviews with tourists, normally carried out by public bodies, companies or other institutions related to tourism, and which are generally focused on four

Table 2
Main hypotheses, variables and geographic areas analyzed using statistical techniques and models (G1).

Hypotheses (% on G1)		Main Variables	Result (% on hypothesis)	Geographical areas	No. Ref.
H1.	Tourism development drives economic growth (50%)	GDP, energy and foreign direct investment	Validated (66%)	Singapore, Turkey, Tunisia, Sri Lanka, USA, France, Spain, China, Italy, Turkey, Germany, Italy, Slovenia, Albania, Greece, Turkey, Lebanon, Israel, Tunisia, Egypt, Tunisia, Egypt and Morocco, Bahrain, Brunei, Cuba, Cyprus, Dominican Republic, Haiti, Iceland, Indonesia, Ireland, Jamaica, Malta, Mauritius, New Zealand, Singapore, and Trinidad and Tobago, etc.	3, 6, 7, 10-13, 16, 17, 19, 23-25, 31, 34, 35, 37, 38, 40-43, 48, 50, 53, 63, 65, 68, 77, 82, 84
			Rejected (33%)	Tunisia, Mediterranean countries, Nepal, OECD countries, Central and South American countries, Ten Northeast and Southeast Asian countries, BRI Countries, Bangladesh, India, Nepal, Pakistan, Sri Lanka, etc.	8, 15, 20, 26, 30, 32, 39, 43, 46, 47, 54-59, 61, 62, 64, 70-73, 75, 76, 79, 80
H2.	Tourist development increases energy demand (30%)	Tourism development, tourist arrivals, energy	Validated (97%)	OECD countries, China, Turkey, Asia Pacific, Taiwan, 10 major tourist destinations, Sri Lanka, Bangladesh, E7 countries, South Asian countries, BRI countries, etc.	1-6, 9, 11, 12, 15, 20, 22, 24, 26, 33, 35, 42, 43, 47, 53, 61-63, 65, 67, 69, 70-72, 77, 80, 86,
			Rejected (3%)	144 countries	9
H3.	Tourism development increases environmental degradation (26%)	Tourism development and GHG emissions	Validated (56%)	OECD countries, Cyprus, Turkey, Singapore, developed and developing countries, Taiwan, Mediterranean countries, Nepal, Tunisia, Egypt, Morocco, Central and South American countries, etc.	2, 4, 5, 9, 22, 24, 26, 32, 34, 36, 37, 40, 41, 46, 49, 59-65, 69, 71, 73, 74, 80, 84.
			Rejected (44%)	Tunisia, Pakistan, G20 economies	29, 34, 82, 6, 7, 10, 18, 19, 25, 31, 35, 43, 44, 51, 55, 72, 75, 76-78, 82, 85

Table 3
Main areas of study, objectives and countries regarding energy assessment through surveys, questionnaires and energy audits (G2).

Area of study	On G2 (%)	Main objectives	Countries/ destination	No. Ref.
a. Accommodations	75.0	To evaluate energy consumption and efficiency according to the different types of hotel accommodations. To evaluate the relationship between tourist typology and energy consumption.	New Zealand, Vietnam, Turkey, Jordan, Hungary, China, Dominica, Taiwan, Malaysia, Global, Malta, Macedonia	87, 93, 94, 96, 102, 106, 107, 114, 118, 120, 123, 127, 131, 133, 140, 144, 152, 161
b. Restoration	8.3	To evaluate energy consumption and efficiency	Vietnam, China	93, 106.
c. Tourist behaviors and types of tourism	33.3	To analyze energy impact of tourism on choices and behaviors	New Zealand, Nepal, Spain, China, Global,	87, 89, 91, 99, 104, 106, 122, 161
d. Transport				

areas: (1) basic tourism data, (2) actual transportation behavior of tourists, (3) type of accommodation and length of stay, (4) type of recreational activities. In this type of research, it is common to use secondary data already available, which allows estimates to be made with greater agility and provides added value when answering the research questions of the studies. Table 4 summarizes the main stages of the tourism supply chain analyzed, impacts and destinations (G3). The energy consumption of the transportation and accommodation segments are the two most frequently analyzed segments of the tourism supply chain, followed by other tourism activities (i.e., attractions, entertainment and destination activities) and the food segment. Seventy percent of the studies also use GHG emissions as a proxy for environmental degradation. Most of the articles in this group (60%) evaluate one or two stages of the tourism supply chain. Only 15% (3 articles) evaluated the entire tourism supply chain (a-g), implying that most papers focus on one or several stages of the supply chain.

Finally, G4 includes 5% of the articles reviewed. It groups together other proposals for measuring energy consumption in tourism using different indexes and/or measures. Different authors have proposed the creation of indexes to quantitatively measure the relationship between energy and tourism activity, disaggregating the energy cost of the different nodes of the tourism value chain according to tourism

Table 4
Main objectives, environmental impacts and steps of the tourism supply chain assessed through the LCA in different countries/tourism destinations (G3).

Stages in the supply chain assessed (a-g)	% on G3	Main impacts (%)	Countries/destination	Nº Ref
a. Transport	75.0	Energy (100%); GHG emissions (70%); water use (20%) and other impact categories (20%).	Main destinations China (26%), Taiwan (11%) and Spain (11%). Case studies in Austria, Canada, Croatia, Greece, Hong Kong, among others, are also analyzed.	88, 95, 101, 108, 109, 111, 115, 119, 121, 126, 130, 132, 136, 137, 143, 151, 153, 158, 160
b. Accommodation	70.0			
c. Food	25.0			
d. Buildings	30.0			
e. Entertainment	15.0			
f. Shopping	15.0			
g. Other tourism activities	35			

typologies (92). In some cases, this type of methodology allows to investigate in depth the main energy hotspots of each tourism activity (130), identifying which activity is consuming which energy resource (119, 129, 134, 142). These authors point out that this type of methodology provides reliable information for the design and implementation of public policies aimed at increasing the efficiency of energy consumption for each activity carried out in the territory.

3.3. Main findings and discussions on the energy-tourism nexus

3.3.1. Is there a decoupling between tourism growth and energy consumption?

The main topics of discussion around tourism and energy are focused on discussing the correlation between tourism development and economic growth, and how these have an impact on the increase in energy demand, GHG emissions, and other categories. The methodological diversity noted above applied to different geographical contexts (see section 3.2 and Table S5), and the fact that the same variables are not always used means that the quantitative results are not always very comparable with each other (see section 4.1). In relation to H1, 66% of the articles validate the idea that economic growth is driven by tourism. Some authors found a positive and unidirectional causality in which tourism promotes economic growth in geographic areas as disparate as Singapore, Turkey or USA. However, there is no full consensus on this issue. Others authors claim an inverse relationship: it is growth that drives tourism development. According to this group of authors, this occurs in destinations where the tourism activity is not sufficiently developed to have a determining impact on economic growth. Moreover, there is also a variety of research that shows the existence of a bidirectional causal relationship between tourism activity and economic growth, observing that both variables interact with each other and affect each other jointly and simultaneously (30, 32, 39, 46, 54–59, 61, 62, 64, 70, 72, 73, 76, 79). On the other hand, there seems to be a certain consensus (97%) that the growth-development of tourism increases energy demand (H2). This increase is related to the growth in the number of visitors, and therefore in mobility, infrastructure growth, consumption, etc., which in turn demands greater amounts of energy (i.e., electricity, fuel). However, there is no total unanimity (3%). For example, Ozturk et al. (9) stated that this relationship occurs only in middle-income countries, but not in low- or high-income countries.

The degree of disagreement increases when it comes to analyzing the relationship between tourism and environmental degradation (H3). For example, the studies that validated the EKC pointed out that technological efficiency allows for economic growth in certain regions of the planet, and this is compatible with a lower environmental impact. As in many destinations tourism activity is responsible for a high proportion of electrical energy consumption (98, 134, 145, 146), the advance of renewable energy is considered a determining factor in avoiding or alleviating the environmental pressure of tourist destinations (82) and should be a priority objective together with the improvement of energy forecasting, management and supply systems (104, 145, 146, 147). In this sense, the reasons most frequently mentioned to explain the fulfillment/rejection of the EKC hypothesis are related to: a) the capacity to develop and/or access energy and environmentally efficient technologies (technology effect); b) the level of income and tertiarization of the destination countries, which places them at the lower/upper part of the curve in terms of the development of their productive system focused on the primary sector (composition effect); and c) the scale effect, consisting of the axiom that the greater the economic activity, the greater the environmental degradation (9; also in (Zilio, 2012; Hsieh and Kung, 2013). Nevertheless, considering the results of the sample, we found that 94.6% of the works that validate the hypothesis EKC quantify environmental degradation only through the measurement of CO2. However, 85.7 % of the articles that refute the theory or, where appropriate, present mixed results have used a more complex multivariable index to define the variable of environmental degradation, such as the ecological footprint or the load carrying capacity, which collects more information on ecosystems degradation.

3.3.2. Energy consumption and efficiency in tourist accommodations

The energy efficiency of accommodations and associated services is the second most frequently addressed topic in research on tourism and energy. This theme is transversal to the different methodologies used (G1, G2 and G3). In addition to focusing on technology and energy efficiency, these investigations also examined the relationships between tourism development, energy, and environmental impact (GHG emissions) of different types of accommodations. In general terms, the energy consumption of tourist accommodation companies depends to a large extent on three variables:1) the size of the establishment; 2) the number of services offered to tourists; and 3) the number of overnight stays received. These studies discussed how the floor area, materials, building technology (88) or the number and type of tourists accommodated (117) are the variables with the greatest impact on energy demand and GHG emissions. Likewise, other studies focused their attention on evaluating ventilation, swimming pools, air conditioning and heating (HVAC) systems (154, 159), which, together with hot water, are the main hotspots in daily energy consumption in different types of tourist accommodations (87, 120, 133). Thus, for example, hotel services associated with HVAC can account for 30%-50% of electricity consumption (152), with the use of diesel or liquefied petroleum gas (LPG) for boilers, hot water and kitchens being another critical point of consumption (93, 152). Nevertheless, the size and occupancy rate are the most determining variables for energy consumption in lodging facilities (94). Another focus of analysis has been to evaluate the efficiency associated with the energy mix in hotels (96, 144), to analyze whether hotels hold energy efficiency certificates (140), to estimate energy expenditure of hotels per room per night (118) or to discuss the effectiveness of green marketing as a savings measure (127).

Studies based on LCA also estimate that lodging is the segment responsible for 3%-16% of tourist energy consumption (101, 121, 158), and it is discussed how hotels that offer more services are the establishments with the greatest impact in terms of emissions and energy consumption (88, 132, 137). Other types of accommodations, such as low-end hotels, are between 4 and 10 times less environmentally intensive (132, 160). For these reasons, it is argued and discussed how the energy efficiency of establishments depends on: i) improving the use of materials to cover buildings and make them more climatically efficient (heating and cooling); ii) combining heat pump systems and/or photovoltaic energy to heat water (148) and iii) implementing measures to replace refrigeration, heating and air conditioning systems with more efficient technologies (96, 99, 152). Some authors advocate the creation and standardization of an international classification of hotel establishments based on energy consumption (110), with the aim of promoting the use of efficient establishments through marketing focused on green tourism and responsible consumption (107, 127). These proposals are not free of technical difficulties when evaluating the energy consumption pattern of hotels (e.g., differences in size, age, materials, level of luxury, location) and may entail certain transaction costs when auditing the different types of establishments (124).

3.3.3. Transportation and other discussions on energy consumption in tourism

The movement of tourists from the origin to the destination using different modal distributions of transport constitutes the main critical point in terms of energy use and GHG emissions. Some articles of group 3 show how transport is the step with the highest energy demand in tourism (consuming between 49 and 73% of total energy), discussing to what extent energy efficiency policies implemented in the last two decades have reduced its energy weight in the total (101, 105, 115, 153). The efficiency of modes of transport is a recurring theme in these studies, pointing out how air travel is the most impactful, followed by road transport (mainly automobiles), while trains are the most efficient

option (108, 121). We found that the analysis of energy consumption derived from tourist transportation is not a topic that has been specifically analyzed in the study sample. It seems that there are many authors who prefer to examine the cost of tourist transport in GHG emissions rather than focusing on the huge consumption of non-renewable energy vectors necessary for tourist transport. The remaining discussions on energy use and tourism carry much less weight. Some studies show that energy consumption associated with food is estimated at between 13.8% and 28.4% of the tourism supply chain in different countries and contexts (108, 111, 137, 153, 160). There are also a small number of articles that evaluate the environmental impact in relation to behaviors and types of tourism (29, 36, 37, 43, 91, 122, 161) and discuss how cultural tourism has a lower impact in terms of energy consumption (89). Research has also discussed what the margins are for energy savings in catering, either in aviation with the aim of reducing weight and material consumption (153) or at other points of the tourism supply chain (8). These authors point out that this type of methodology provides reliable information for the design and implementation of public policies aimed at increasing efficiency of energy consumption for each activity carried out in the territory.

4. Discussion

4.1. Tourism-energy nexus: Between methodologies, indicators, interpretation and extent of main empirical evidence

The correlation between tourism development and economic growth, and how these impacts increased energy demand, GHG emissions and other categories (G1), is the main point of assessment between the tourism and energy nexus. The strength of these studies lies in their macro and structural approach, which facilitates the analysis of the temporal evolution of destinations, as well as of the causalities and interrelationships of a large number of variables (Greene, 1999). However, these studies also have some weaknesses that should be pointed out. For example, despite having common objectives, it is not always easy to compare their quantitative results with each other. We may point out at least three reasons: (a) there is a wide variety of methodologies when addressing the relationship between tourism and energy consumption/environmental degradation; (b) wide heterogeneity of destinations analyzed with different socioeconomic, technological and finally, and (c) the variables used in the models and the way they are measured do not always coincide, even when the nomenclature is similar. Some authors define the dependent variable tourism development through the indicator of the number of international arrivals (82, 85, 86, 94, 95, 102, 107, 107, 115, 123, 147, 149, 153, 160, 162, etc.), while others additionally introduce information on tourism income and expenditure (111, 121, 157). Other weaknesses are related to the heterogeneity of the information, spatial problems, structural changes in the series, or possible sample selection biases (Atwi et al., 2018; De Arce and Mahía, 2007).

In their literature review on the relationship between tourism development and emissions, Sun et al. (2022) also provide evidence in this direction. The authors argue that EKC models often fail to account for two key aspects of understanding these interrelationships: a) 'indirect' emissions embodied in imports, and b) emissions from international aviation and shipping. Based on these considerations, there is very limited evidence that tourism leads to decarbonization, even considering the EKC scenario. Moreover, the fulfillment of the EKC hypothesis is highly related to the approach and the environmental impact indicators selected. The works that mostly validate this hypothesis, i.e., that affirm that there is dematerialization (impact/growth), use GHG emissions as the only proxy for environmental deterioration. Models that, in addition to emissions, include in their estimate's indicators such as ecological footprint or other indices that contemplate more dimensions of environmental impact (more along the lines of strong sustainability), have their hypotheses mostly refuted (Bagliani et al., 2008; Caviglia-Harris et al., 2009; Wang et al., 2013; Hervieux and Darné, 2015; Almeida et al., 2017; Figge et al., 2017; Asici and Acar, 2018; Ozcan et al., 2018; Destek and Sinha, 2018). Many low-carbon technologies shift emissions to another stage of the energy supply chain, assuming that renewable energy has zero emissions (as is the case in some papers collected in the sample (8, 17, 28, 32, 39, 52, 59, 64, 72), which is an unrealistic assumption.

The energy efficiency of accommodations and associated services is the second most addressed topic in the research on tourism and energy, studied mainly in G2 and G3 using surveys and/or the LCA methodology. These methodological approaches, particularly LCA, allow to analyze the tourism supply chain, thus obtaining a comprehensive view of its impact and comparing different travel alternatives (Nae-Wen and Pei-Hun, 2009; Kuo et al., 2012), such as assessing differences regarding energy use in relation to types of transportation, accommodation, or menu options (Jiao and Shi, 2013; Castellani and Sala, 2012; Kitamura et al., 2020). This type of methodology can help public institutions and travel agencies to design tourism itineraries with low environmental loads and discourage the consumption of high impact activities (Sanyé-Mengual et al., 2014; Salehi et al., 2021). However, the LCA approach is still scarce, and we have found some limitations (De Camillis et al., 2010 and Campos-Herrero et al., 2022): a) There is still a methodological diversity when performing this type of analysis that results in different system boundaries, functional units and primary data collected; b) The complicated nature of the tourism system makes it difficult to analyze the sector, which may imply conservative and partial results; c) There is no specific LCA database for tourism and related sectors; and/or d) Energy use, but above all GHG emissions, is the most widely analyzed indicator, and other impacts, such as water use, are much less evaluated (Lok and Chan, 2001; Michailidou et al., 2016). These limitations can make it difficult to translate the results into understandable and usable policies, particularly regarding low industry involvement. In this sense, it is still necessary to promote research in this direction, as well as to evaluate the possibility of integrating this type of analysis into other management tools or eco-labeling strategies (Campos-Herrero et al., 2022).

4.2. Perspectives for future research on energy and tourism

This study has examined more than 20 years of research on the relationship between tourism development and energy use, thus providing an overview of the main methodologies used and objectives to assess the energy dependence of tourism, as well as of the main results discussed. This analysis has therefore allowed us to approach a complex field of study, to understand some of the gaps in the literature in order to propose future lines of research that will allow us to move towards sustainable tourism models (Gössling et al., 2015; Merrilees and Coghlan, 2015; Ehigiamusoe, 2020). The debate on alternatives to conventional mobility is one of the gaps found in the literature reviewed. Air and car travel are the cornerstone of tourism and energy, as well as of emissions-demanding modes (95, 105, 108, 109, 121, 126, 132, 143). Some authors have argued that the aviation industry will have serious difficulties in introducing technologies to maintain current air traffic levels (Nygren et al., 2009); Peeters et al., 2017; (Gössling and Humpe, 2023). Many low-carbon technologies shift emissions to another stage of the energy supply chain or increase other impact categories. An example of this is the case of mobility electrification technologies, which increase the footprint of scarce materials in the earth's crust, such as nickel, lithium, cobalt, indium, selenium, gallium, tellurium, etc. (Valero et al., 2021; Del Pero et al., 2018). Moreover, the processes of extraction, refining and transport these materials to the manufacturing site are usually ignored in the final accounting of GHG emissions in most of the studies that analyze these low carbon technologies (Del Pero et al., 2018). Finally, it should be noted that these technologies, sold as possible sustainable alternatives to the consumption of fossil energy vectors, also present the problem of competition for land use. Solar panel farms or biomass plantations for the generation of biofuels present

an economic cost of production, which is from 15% to 500% higher than conventional jet fuel; and at the same time, the production of these biofuels and solar panel farms compete with other land uses, such as grain production for animal or human consumption (Dahal et al., 2021). More research is therefore needed on the environmental implications of the application of these new technologies to tourism, as well as on the barriers to their implementation.

Another gap found in the literature concerns the economic effects of the promotion and massification of low energy impact forms of tourism: in many tourism business niches it is not possible to simultaneously achieve economic and environmental objectives, which implies making concessions in some sense (Luncie et al., 2007). A less energy-dependent and more efficient travel demand management is a strategic line of research for effective and equitable policy design (Scott and Gössling, 2022). The way in which such an energy transition is interconnected with other dimensions of the sustainable tourism literature, such as, for example, slow, responsible or pro-poor tourism (Gössling and Higham, 2021). It is for these and other reasons that some researchers claim that the debate on overtourism and resource limitations offers a valuable opportunity to re-politicize the discussion of tourism development and contribute to further exploiting the potential of degrowth to facilitate sustainable tourism (Flecher et al., 2019; De Luis Blanco, 2011; Blázquez, 2016). Visitors from high-income countries account for higher levels of environmental impact (Lenzen et al., 2018), so these discussions need to be contextualized in terms of countries, destinations and type of tourism. As our study shows, some geographical areas are underrepresented in academic studies on energy and tourism (also in Scott and Gössling, 2022). This is especially important in regions such as Africa (North or sub-Saharan), Central America, Asia (North, Central and Southeast) and the Pacific, where tourism is projected to increase by more than 4% over the period 2020–2030 (Scott et al., 2019).

Furthermore, some methodological issues should be pointed out, especially in relation to the discussions on the decoupling between tourism development and energy consumption. For instance, depending on the type of means of transport and the distance from the tourist destination there are large differences in the generation of GHG emissions that can vary between 5 and 30 times more (Gössling et al., 2015). Most of the analyzed works use aggregate indicators of inbound tourism for modeling, which a monitoring of the impact depending on the type of visitor would generate useful information for the design of impact reduction strategies (Sun et al., 2022). Furthermore, focusing on relative increases in energy use or emissions is not useful for achieving absolute impact reduction targets. For example, UNWTO itself (2020) recognizes that low-carbon mobility remains a major challenge that needs its own agenda. Even so, and under the most optimistic technological assumptions, the agenda itself foresees an increase in emissions associated with tourism, which is bad news if the objectives of the Paris summit are to be met. All tourism destinations will have to adapt to the consequences of the future energy scarcity and climate change to either minimize their negative impacts (Varol et al., 2022; Tekin et al., 2022) or optimize opportunities in territorial tourism planning (Sun et al., 2021a). In this sense, researchers should continue to play an important role in the development of novel methods that provide rigorous and contrasted information for the design of policies in specific contexts, evaluation of technologies, infrastructure, logistics, etc. that encourage debate and allow for the definition of responsibilities and concrete commitments to sustainability.

5. Conclusions

In this paper, an exhaustive analysis has been made of the main scientific publications that provide empirical evidence of the nexus between tourism and energy during the last two decades. The results show that this is a growing field of study, due to the weakness that high dependence on non-renewable energies represents in terms of sustainability, among other reasons. The relationship between indicators that measure tourism development, growth, energy use and GHG emissions from a macro approach is the most recurrent topic. To measure this interrelationship, different econometric models, regressions, and other statistical methodologies are applied based on available official statistics. These studies show how tourism development increases energy demand. However, less consensus was observed in relation to emissions, with contradictory results between regions. The comparability between studies is compromised, and the degree of validity of the results is limited, since the role of (air) transport continues to be omitted and underestimated, focusing only on one type of environmental impact (GHG emissions). This suggests the need to rethink existing theories and approaches to measurement and comparison.

The efficiency of tourist accommodations is the second most important issue assessed from the collection of primary information through surveys and evaluation, and in many cases through the LCA methodology. These methodologies allow to determine the critical points of tourist accommodations as well as other steps in the tourism supply chain. These two major topics are the focus of many of the discussions on the perspectives of policy analysis and change. Other topics such as energy alternatives to globalized transport or the economic implications of promoting more sustainable and low-impact tourism, or the risk of drastic reduction in the fossil energy vectors necessary for the maintenance and development of the current tourist activity as a consequence of peak oil in the coming years, are addressed in a less exhaustive manner. These and other lines of empirical and theoretical work undoubtedly constitute future lines of research to be considered in order to continue investigating the possibilities of sustainable tourism within the planetary limits considering the climatic demands of our time.

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

No data was used for the research described in the article.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolind.2023.110929.

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