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Review

Energy Efficiency Indicators for Hotel Buildings

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Abstract: Hotels are energy-intensive buildings; therefore, in this study, we investigate the indicators used for measuring the energy efficiency of one- to five-star hotels, in temperate and tropical regions of Asia, Europe, and Africa. There are several indicators for measuring energy intensity, but we found that the "total average annual energy use intensity index", measured in kilowatt-hours per square meter per year (kWh/m^2 year), was most often used. Surveys and energy audits are the methods used most often to collect the indicator data. Hotels in the tropics tend to consume more energy than those located in temperate zones, with four- and five-star hotels consuming the most energy.

Keywords: hotels; intensive use of energy; indicators; energy consumption

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1. Introduction

According to [1], hotel buildings are classified as one of the highest energy consumption building categories. Hotels, together with offices and retail, consume the most energy; for example, in the UK, these represent more than 50% of the total energy consumption; in the USA, 64%; and in Spain, 85% [2].

Hotel buildings make intensive use of energy [1,3–18], which generally comes from the burning of fossil fuels, such as oil and liquefied petroleum gas (LPG). Almost all of them offer services such as air conditioning, hot water, and laundry, which in many cases are provided by inefficient equipment [6,14]; the aforementioned aggravates the problem of environmental pollution. The majority of these hotel buildings were designed to be used throughout the year and with different schedules, and they also offer other services such as restaurants, swimming pools, spa, and conference rooms [1,4,6–8,10,11,14,15,17–21]. It should be noted that hotel guests tend to be very demanding in terms of thermal and visual comfort, since they are paying for these services, and sometimes they indiscriminately use these services offered in their rooms [5]. Therefore, hotels generate large amounts of CO_2, which leads to negative impacts on the environment [4,12] and also diminishes the companies' profits [14] due to the high energy costs.

Effective and objective energy benchmarking for hotels comprises a meaningful and useful method of ensuring the sustainable development of the lodging sector [22]. Monitoring energy consumption in hotel buildings can be carried out by an energy audit [23], and it is therefore important to identify the indicators that can be used to measure the intensity of energy consumption in hotels and identify if the same indicators are being used or if they are different.

Core Question and Specific Questions

The aim of this study was to identify the indicators that can be used to measure the energy efficiency of all areas in a hotel building, and their behavior in different climatic regions, as well as in different categories of hotels (Table 1). Studies have indicated that the following three specific questions should be considered:

1. Which indicators are used to measure the energy efficiency of hotel buildings?
2. Is there a relationship between hotel classification and energy efficiency?
3. Is there a relationship between the climatic region of the hotel and energy efficiency?

Table 1. Indicators for measuring hotel energy efficiency, central question, specific questions, and response variables. The response variables of each of the specific questions are shown in the row of variables or indicators.

	Central Question: What Are the Indicators to Measure the Energy Efficiency of a Hotel Building from 1995 to 2019?		
Specific Questions	What types of indicators are used to measure energy efficiency in hotels?	Is there a relationship between hotel classification and energy efficiency?	Is there a relationship between the climatic region of the hotels and energy efficiency?
Variables or Indicators	Total energy consumption vs. Floor area Consumption of Electric Energy (EE) vs. floor area Consumption of Thermic Energy (TE) vs. Floor area Consumption of EE vs. beds Consumption of TE vs. beds EE consumption vs. overnight stays TE consumption vs. overnight stays EE consumption vs. rooms TE Consumption vs. rooms	Total energy consumption vs. hotel classification	Total consumption vs. climatic region

2. Methods

2.1. Strategy for Information Search

The bibliographical search for this review mainly consisted of primary documents (original scientific papers), and the contributions from some conferences proceeding reports were also considered. The multidisciplinary ISI Web of Knowledge database was used since it is a system that offers a high-quality content platform and the tools to access, analyze, and manage research information. The Scopus database and Google Scholar were also used. The process is shown in Figure 1. Papers that were reviews, theoretical simulations, or that only reported some hotel services, such as air conditioning, laundry, and kitchen services, were not selected; only original papers that reported energy efficiency in all areas of the hotel were selected for this study.

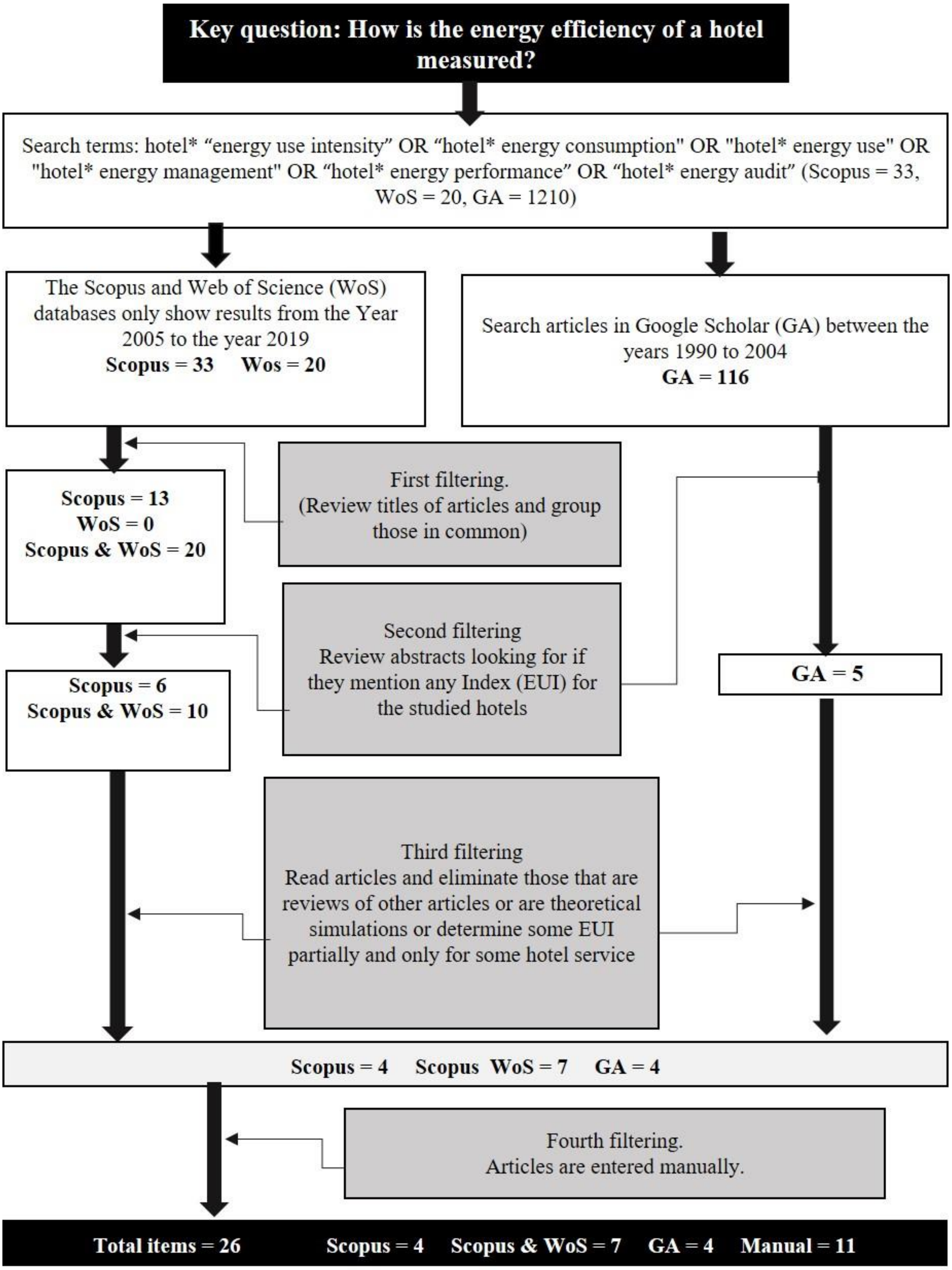

Figure 1. Flow chart showing the procedure used for the selection of the studies considered for this review.

The following main keywords in the subject and title, in English, were used in the search: energy, hotel buildings, energy consumption, indicator, use, and intensity. The scope of this review was from 1995, which is when the indicator that measures energy efficiency in all areas of a hotel was published for the first time, until the beginning of 2019.

2.2. Compilation of Information

Once the scientific papers were defined, we proceeded to collect the information in a database, which contained the bibliographic information, keywords, abstracts, support details, and other information (based on Scopus criteria). Additional information that was added included the number of authors, continent, climatic zone (temperate, tropical, or cold), number of hotels studied, the place where the study was conducted, years of data, type of hotel, and all the indices that were found. Finally, the type of method to collect the data was considered since it could be helpful to similar studies.

3. Results and Discussion

3.1. Characteristics of Publications

Only 26 scientific publications met the search criteria for this study. In Figure 2, publications per year and accumulated are shown. For the review period (1995 to 2019), the first publication was in 1995, and there were 9 years without publications, 10 years with one publication per year, 2 years with four publications per year, 2 years with three publications per year, and 1 year with two publications. The reasons for this behavior are unknown.

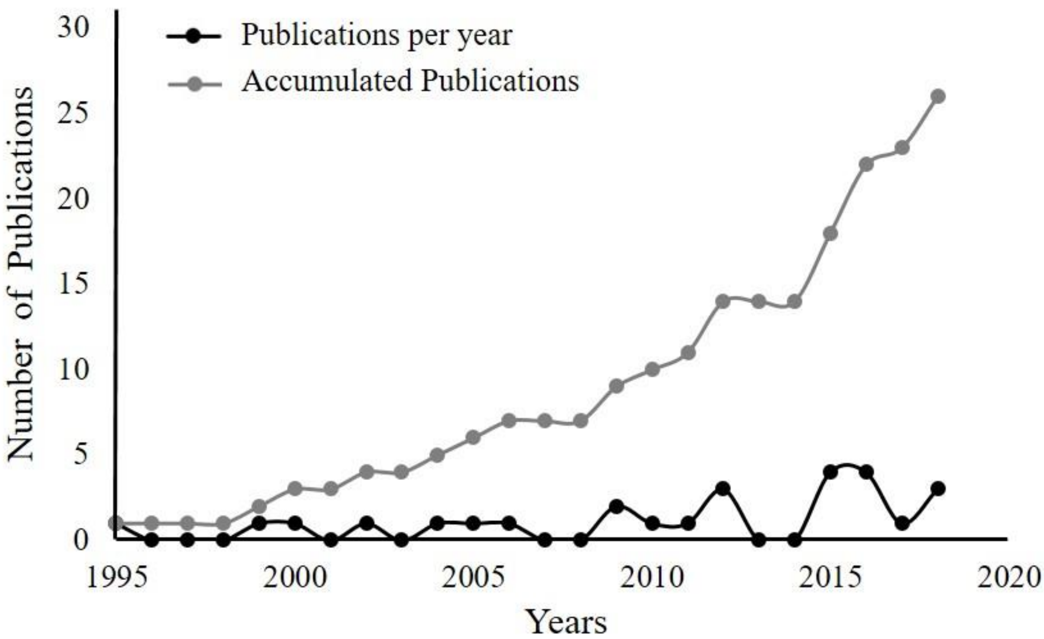

Figure 2. Publications per year and accumulated during the study period (1995–2019). The gray line indicates the frequency of accumulated publications and the black line the number of publications per year. The x-axis indicates the year, and the y-axis indicates the number of publications.

In Figure 3, the publications by type of document and source are shown. Among the 26 publications in this review, 22 are original scientific papers and four are conference proceeding reports. About the publications in indexed journals, 12 are published in the journal Energy and Buildings, while 10 are published in the following journals: Energy, HKIE Transactions, Hospitality Management, IEEE ICBEST, International Journal of Hospitality Management, Journal of Cleaner Production, and Journal of Science and Technology in Civil Engineering, and Renewable Energy and Sustainability (Switzerland). Finally, four of the publications were presented at the following conferences: Proceedings of the 15th IBPSA Conference, San Francisco, CA, USA, 7–9 August 2017; ICEAMM 2017 IOP Conference Series: Materials Science and Engineering, Proceedings of the 28th Chinese Control and Decision Conference, CCDC 2016, 9th International Symposium on Heating, Ventilation and Air Conditioning (ISHVAC); and Proceedings of the ICETCE 2011 International Conference on Electric Technology and Civil Engineering.

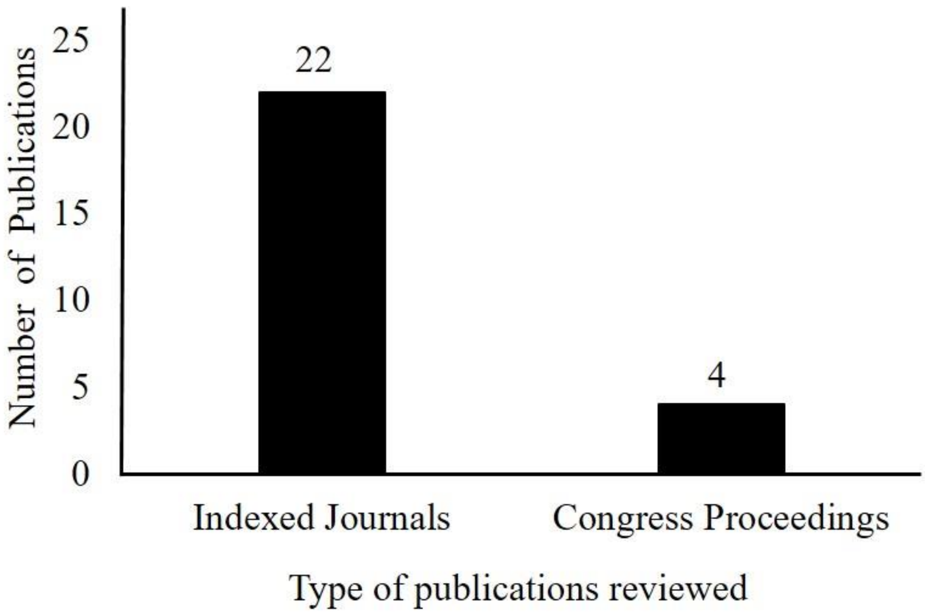

Figure 3. Publications by type of document and source. The x-axis indicates the type of publications and the y-axis indicates the number of publications during the period from 1995 to 2019.

Figure 4 shows the publications by climate region and country. It should be noted that China has 38.46% of the publications, followed by Taiwan and Greece with 11.54% of the publications each. The remaining 38.46% of publications is distributed among the other countries. There are 13 publications on tropical regions and 13 on temperate regions. Among the 26 scientific papers used for this study, 65.38% are papers from Asia, 30.77% from Europe, and 3.85% from Africa. No scientific papers were found for America or Oceania, based on the criteria of this review.

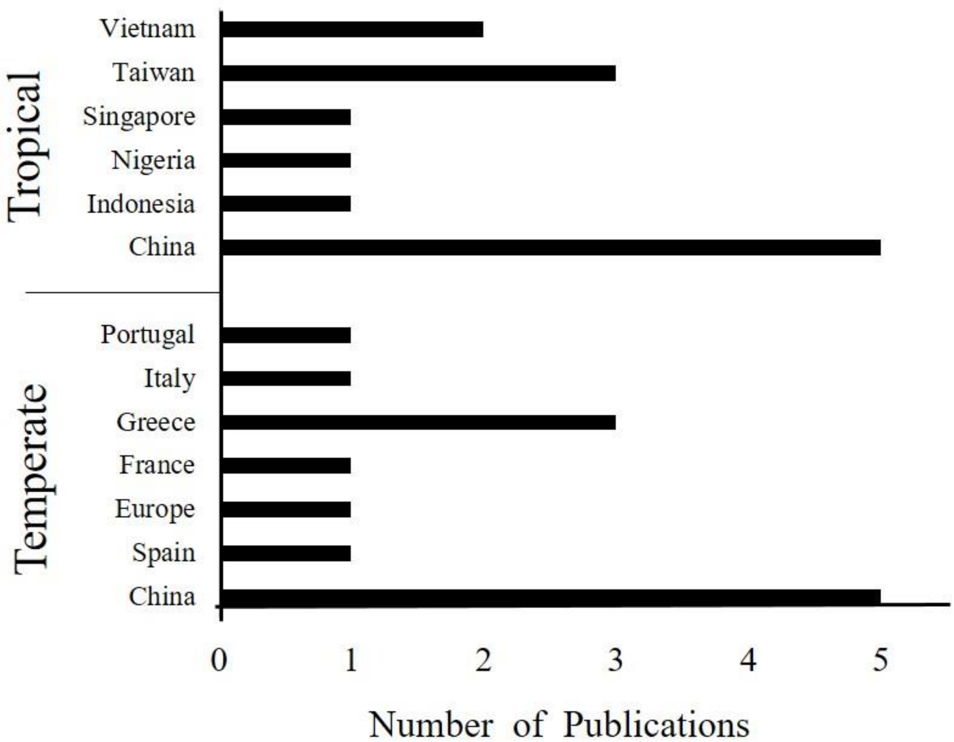

Figure 4. Publications by climate region (temperate and tropical) and country. The x-axis indicates the number of publications and the y-axis indicates the country by climate region.

3.2. Indicators, Units, and Their Description

It was found that the indicator most often used is the total average annual energy use intensity index (avg EUI total) in kWh/m^2 per year (kWh/m^2 year), defined as the annual energy consumption per gross floor area (energy use intensity (EUI)), used in 20 of the 26 reviewed publications [1,3,4,7,9,10,12–16,18,20,21,23–28] (Table 2); and it is also the indicator that is used by governmental instances in their guidelines [1,24,25]. The range of EUI varies from 621.14 [23] to 70.2 kWh/m^2 year [15], which shows that there is a huge variation in the index values. Four scientific papers presented their results for avg EUI totals in kWh/room and three presented their results for avg EUI totals in kWh/overnight stay. Another 19 indicators are also reported, but these show partial indices.

Table 2. Indicators, units, and the description of the terms related to energy efficiency. The first column shows the indicators and their units, and the second column lists the description of terms.

List of Indicators and Their Units	Description of Terms
1. Avg EUI EE (kWh/room) 2. Avg EUI EE (kWh/bed) 3. Avg EUI EE (kWh/overnight stays year) 4. Avg EUI ET (kWh/room) 5. Avg EUI ET (kWh/bed) 6. Avg EUI ET (kWh/overnight stays) 7. Avg EUI EE (kWh/m^2 year) 8. Avg EUI HVAC/EE (%) 9. Avg EUI lighting/EE (%) 10. Avg EUI Vertical transport/EE (%) 11. Avg EUI Miscellaneous/EE (%) 12. Ratio of EE to total (%) 13. Ratio of ET to total (%) 14. Avg EUI Total (kWh/room) 15. Avg EUI Total (kWh/overnight stays year) 16. Avg EUI Total (kWh/m^2 year) 17. Avg EUI HVAC/Total (%) 18. Avg EUI lighting/Total (%) 19. Avg EUI Vertical transport/Total (%) 20. Avg EUI Miscellaneous/Total (%) 21. EUI ET (kWh/m^2 year)	Avg EUI = Average Energy Use Index (Average Energy Usage Index, for its acronym in English) EE = Electric Power ET = Thermal Energy m^2 = gross floor area HVAC = Heating, ventilation and air conditioning Hotel classification: ○ 1 star, ○ 2 stars, ○ 3 star, ○ 4 stars, ○ 5 stars, ○ seasonal, ○ annual Climatic region: ○ Tropical ○ Temperate ○ Cold

3.3. Methods Used to Collect the Data in the 26 Scientific Papers

Figure 5 shows the methods that were used in the publications to collect the data. Surveys were the most frequently used method in 42.30% of the publications, followed by energy audits in 30.77%, both cases and interviews in 11.54%, and an audit with software in 3.85% of the publications.

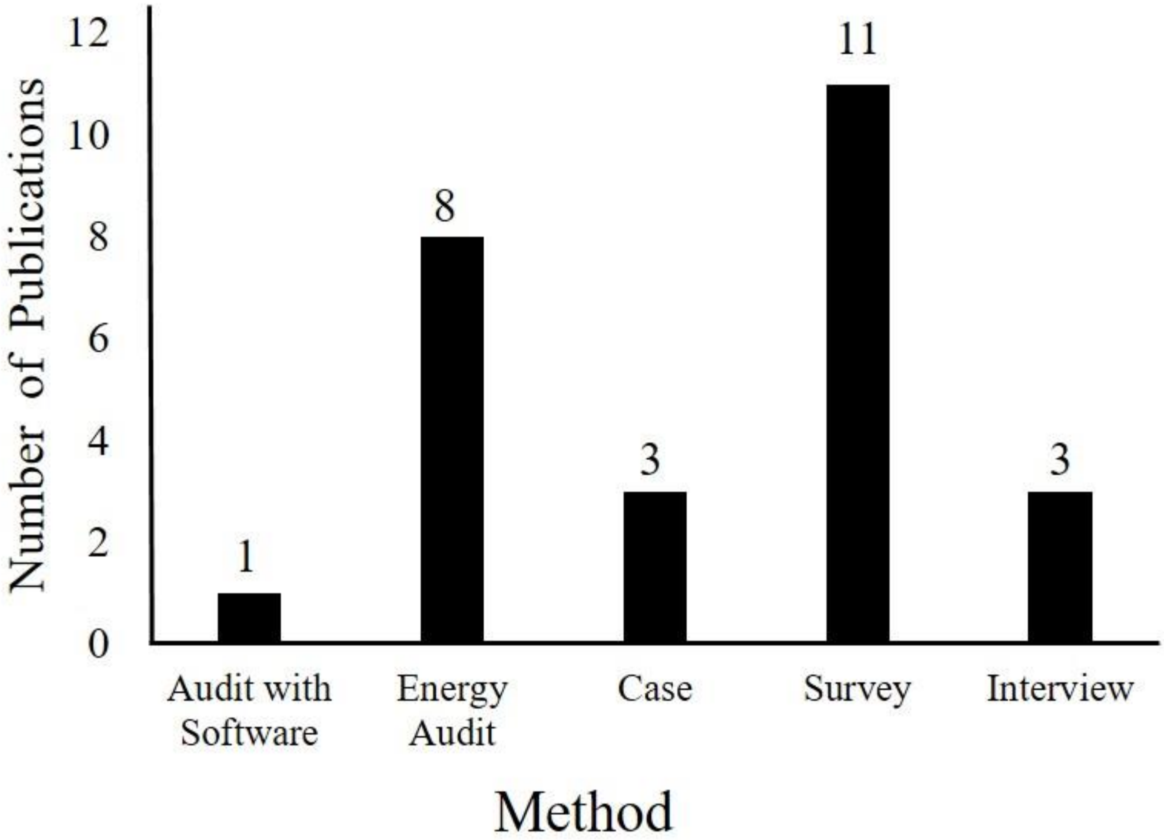

Figure 5. Methods used to collect data. The x-axis indicates the method used and the y-axis indicates the number of publications.

3.4. Average Energy Use Index for Hotels from 1 to 5 Stars

The average energy use index for hotels by category (one to five stars) is shown in Figure 6. Hotels in the tropics have higher average annual energy use intensity (avg EUI) rates than those in the temperate zones; the range of indexes in the tropical zone varies from 143.6 kWh/m^2 year in one-star hotels to 621.14 kWh/m^2 year in four-star hotels; while in the temperate zone the range is of 70.2 kWh/m^2 year for one-star hotels and 237.15 kWh/m^2 year for four-star hotels. The index of the four-star hotels was higher than that of the five-star hotels for the two climatic regions, temperate and tropical. The reason for this behavior was that the four-star hotels studied were older than 20 years; therefore, most of their HVCA systems and electrical installations were obsolete, which caused reduced performance and high energy consumption [23]. Regardless of the climate zone, the highest category hotels (i.e., five-star hotels) have a higher energy use index (429.1 kWh/m^2 per year) than the one-star hotels (106.9 kWh/m^2 year).

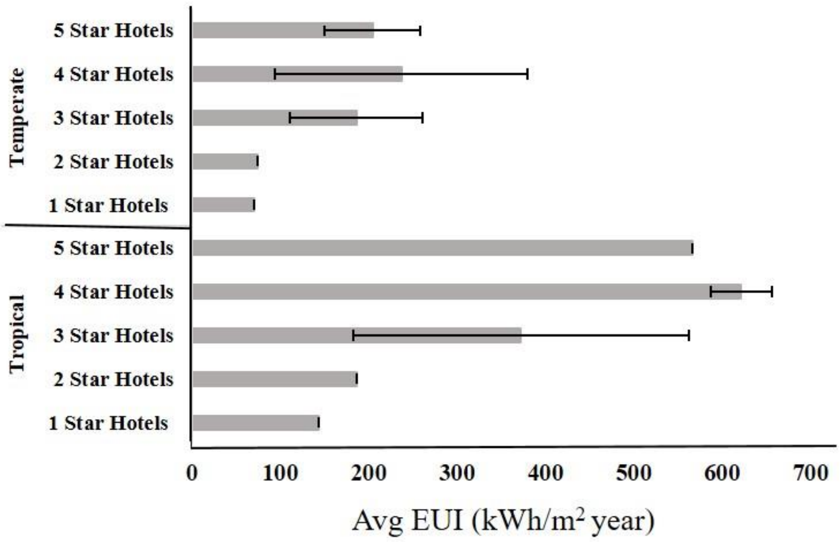

Figure 6. Total average annual energy intensity use index for hotels from 1 to 5 stars per climate zone. The black bars show the value of one standard deviation. For hotels without standard deviation, only one hotel was considered in the evaluation. The x-axis indicates the average annual energy use intensity (avg EUI) measured in kWh/m^2 year, and the y-axis indicates the category of the hotels by climatic zone.

3.5. Average Energy Use Index for All the Studied Hotels

Figures 7 and 8 show the results for all publications that reported the total average annual energy intensity use index by hotel type and climate zone, in kWh/m^2 year. Various combinations of hotels were included, such as four- and five-star luxury hotels, hotels used all year, seasonal hotels, and averages by climate zone in general, which were reported in this way in the publications studied.

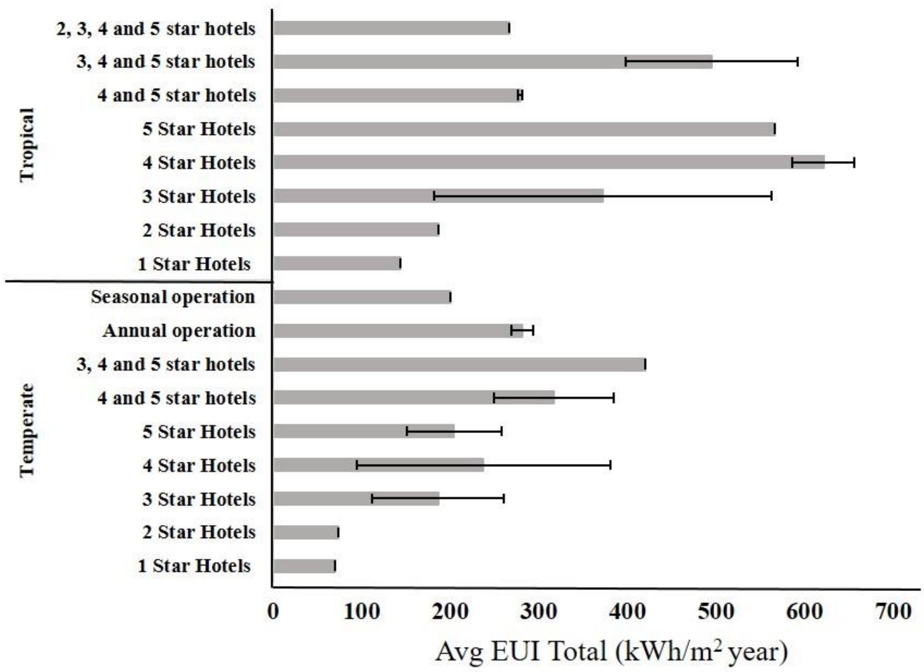

Figure 7. Total average annual energy intensity use index by hotel type and climate zone. Hotels without a standard deviation line included one case. The black bars show the value of one standard deviation. The x-axis indicates the total average annual energy use intensity index (avg EUI total) measured in kWh/m^2 year, and the y-axis indicates the category of all the studied hotels by climatic zone.

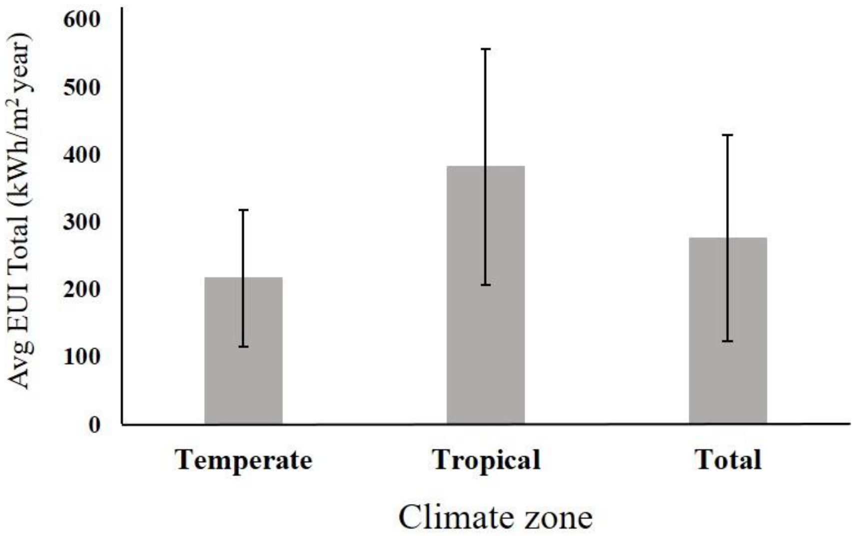

Figure 8. Total average annual energy use intensity index by climate zone. The gray bars show the value of one standard deviation. The x-axis indicates the climate zone, and the y-axis indicates the total average annual energy use intensity index (avg EUI total) measured in kWh/m^2 year.

The behavior of the energy consumption index of hotels in the tropics is determined by the average monthly temperature, which, in turn, influences the use of air conditioning systems [1,4,7,11,16,18–21]. The air conditioning, ventilation, and heating (HVAC) systems are usually powered by electrical power, and the highest consumption is in hotels located in tropical areas (Figure 9).

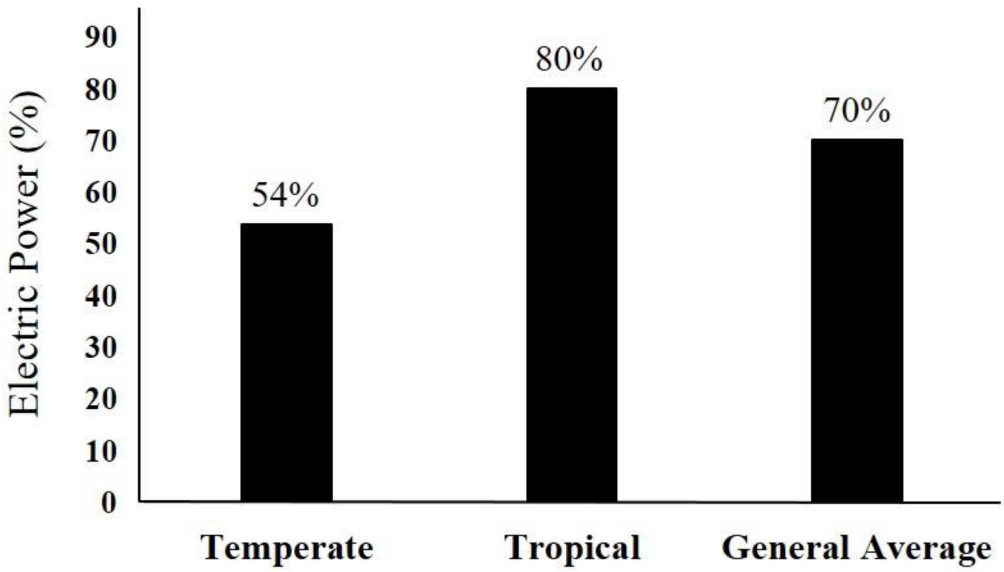

Figure 9. Relationship between the electric energy consumption (i.e., electrical power (EE)) with respect to the total consumption (%) for the temperate and tropical zones, as well as the general average. The x-axis indicates the climate zone and the y-axis indicates the electrical power (EE).

Hotels in tropical climates used more electricity than hotels in temperate zones since hotels in temperate zones use less air conditioning than hotels in tropical zones, but hotels in temperate zones use more heating than those in the tropics, which is usually obtained through burning fuel. Hence, in the temperate zones, the use of electrical energy decreases, but the use of thermal energy increases.

4. Conclusions

The energy efficiency of hotel buildings is measured by energy use intensity (EUI) indicators; 21 indicators were found in the 26 publications and used for this review (Table 2). The most widely used indicator is measured in kWh/m^2 year. A wide interval was observed between the measurements of these indicators ranging from 60 to 700 kWh/m^2 year, which is explained by the fact that they are found in two climatic regions, that is, temperate and tropical, in addition to the fact that categories from one- to five-star hotels were considered.

The selection criteria for this review only resulted in the use of 26 publications for this study, which reported studies carried out only in Asia, Europe, and Africa. We did not find scientific publications for the other continents, which indicates an area of opportunity for future studies.

The most widely used indicator for measuring energy efficiency in hotel buildings is the total average energy use intensity index measured in kWh/m^2 year. This represents a base indicator and is recommended for future studies in the area of energy efficiency in hotel buildings.

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