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Improved Energy Management in the Hotel Industry, Energy Key Performance Indicators, Benchmarking, and Taxonomy Methodology

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Abstract

Energy management in the hotel industry remains a cornerstone in mitigating climate change. To successfully deploy energy management practices, correct energy KPIs are needed. Moreover, the development of a uniform taxonomy on how to classify hotel industry final energy use is crucial in succeeding with energy management in the hotel industry and to enable benchmarking beyond the supply of energy. This work proposes a methodology to develop a taxonomy of final energy use in hotels. The methodology consists of five steps and five levels, allowing them to gradually disaggregate the final use of energy following different classification criteria. The methodology is applied to a hotel, validating the feasibility of the proposed methodology to more accurately identify the areas of greatest final energy use and provide further insights. Results indicate that the main electrical energy use emanates from HVAC (30.4%), tap hot water (24.8%), food process (20.6%), and lightning (7.1%). Key findings include the development of a structured framework that allows hotel managers, energy professionals, and policymakers to systematically assess and benchmark energy performance; and the classification levels provide a standardized method for identifying energy-intensive operations, enabling the implementation of targeted energy-saving measures.

Keywords: taxonomy; hotel industry; energy use; energy management; energy key performance indicators (KPIs)

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1. Introduction

Tourism is an important part of the global economy; it contributes to ten percent of the world's GDP and contributes to more than 330 million jobs [1,2]. The US and China are the major markets for tourism followed [3]. However, one key challenge within the tourism industry is to improve its energy management practices [4]. The tourist industry constitutes about 5 percent of global greenhouse gases (GHGs) emissions, of which three-quarters emanate from transportation (e.g., air- and road-based), and around 20 percent from accommodation [5,6]. This magnitude and growth in travel is a consequence of higher income levels for parts of the world. Simultaneously, studies show that improved energy efficiency in the magnitude of up to 20% can be achieved in hotel buildings [7].

Alvares et al. developed a mathematical model for hammer mills integrating key operational and environmental factors, realizing high predictive accuracy while reducing energy use by 18% and improving particle size uniformity by 30%, thus boosting efficiency in the feed industry [8]. Jaen et al. [9] assessed Cuba's biomass potential for electricity generation, showing that with sustainable development and advanced conversion technologies, biomass could supply 57–100% of national electricity needs by 2050, significantly advancing the country's energy transition and decarbonization goals. In a study by Domínguez et al., the authors present a new methodology for high-resolution solar mapping in large regions such as Cuba's Matanzas province, enhancing understanding of solar resources and supporting sustainable energy development amid the country's ongoing crises [10]. Pérez et al. showed that optimizing solar protection based on building orientation and urban context could reduce cooling demand with short return on investment, offering an innovative way to improve energy efficiency and decarbonize Cuba's building stock [11]. Lakovleva analyzed four modernization scenarios for an aging 2.5 MW solar power plant in Cuba, showing that economic outcomes are most sensitive to the price per kWh [12]. In another study on power generation, Camaraza et al. assessed energy efficiency in a 250 MW thermal power plant boiler using algorithms, achieving more than 90% gross thermal efficiency, and improved operational performance through thermal and exergy analysis [13]. Hens et al. highlighted the establishment of the Cleaner Production Center at the University of Cienfuegos, enabling academic programs, measurable environmental improvements, and strengthened ties between academia and industry for sustainable development [14]. Suárez et al. reviewed Cuba's progress in sustainable development since 1959, highlighting major achievements in energy access, efficiency, and education, while identifying future challenges in economic productivity, environmental protection, and energy diversification to ensure continued sustainability [15]. In a more recent study, Ref. [16] evaluated Cuba's energy transition plans and found that a cost-optimized system could achieve over 80% renewable electricity by 2030.

Energy costs can be reduced by negotiating energy prices [17] or through energy management [18]. Improved energy management reduces energy costs and helps increase the hotel industry's competitiveness and overall profitability. Furthermore, improved energy management also reduces greenhouse gas emissions, thus contributing to improved sustainability of operation of hotels. This is becoming increasingly important for the hotel industry as highly sustainable hotels can serve as a marketing strategy, and sustainable (eco) tourism is an emerging trend in the hotel industry [19]. However, the energy performance of hotel buildings has so far been difficult to evaluate and compare because they have different building designs, functional facilities, and operational requirements. In [20], the authors developed eight key performance indicators (KPIs) for assessing the sustainability of building energy efficiency retrofit (BEER) projects in Chinese hotel buildings using fuzzy set theory where KPIs included, e.g., energy management [20]. In a study of Italian buildings in Sicily, an empirical method to prioritize energy-saving and CO_2 reduction measures in the hotel sector was developed, using a representative sample due to limited data availability. The study showed that by defining performance indexes based on energy, environmental, and economic factors, energy planners were able to implement and monitor efficiency and sustainability policies effectively. In [21], the authors developed and evaluated an AI-based hotel energy management optimization system integrating machine learning, data analysis, and intelligent control to enhance energy efficiency and reduce operating costs. This optimization model significantly improved energy efficiency through real-time monitoring and accurate energy demand forecasting [22]. A study from Sri Lanka analyzed energy use patterns in a star-class hotel, demonstrating significant energy savings by optimizing room allocation through a wing operation strategy [23]. Regarding benchmarking, three levels of detail can be defined: single equipment,

single processes, and entire sites [24], of which three types of benchmarking approaches can be deployed, namely, (1) longitudinal (internal), historic benchmarking of energy performance of the individual company over time; (2) external benchmarking with other sites; and (3) external benchmarking with, by the particular industry, accepted best reference value, e.g., "best practice" or best available technology (BAT). Li et al. [25] showed that US benchmarking programs achieved 6–8% energy savings and that a major challenge is assessment of efficiency and lack of standardization. The study presents a developed open-source tool to automate energy efficiency evaluations that was pilot tested in 36 hotels [25]. In [26], Pace (2016) explored how tourism firms adopt energy efficiency measures, showing that those with strong internal capabilities better leverage partnerships for innovation, and, by the study of hotels in Malta, advocated that policy should support capability-building alongside technology diffusion. In [27], Mardani et al. (2016) ranked key energy-saving technologies in Iran's 10 largest hotels using fuzzy set theory, identifying equipment efficiency as the top factor and active space cooling solutions as the most effective measure. In a study of 99 US upscale and luxury hotel managers, they found reluctance to adopt costly energy management programs or systems that might affect guest comfort [28]. Hotels prioritized short-term cost analysis, favoring a three-year payback period over long-term return on investment [28]. In [29], Filimonau et al. (2011) applied life cycle energy analysis to two UK hotels, finding them less carbon-intensive than industry norms. In [30], the authors analyzed energy-saving practices in 28 Macau hotels, finding higher-star hotels more proactive in energy efficiency than lower-star ones. In a study from Croatia, "Sustainable Hotels" were analyzed, and the finding was that they lag behind EU standards and have a large potential; while some hotels recognized eco-certification benefits, many managers lacked awareness of energy-saving measures, highlighting the need for better energy management education [31]. In a related scope of research, namely, rural schools, a study [32] developed a comprehensive methodology for improved energy efficiency in rural school buildings, showcasing that it was possible for these to reach net-zero energy self-sufficiency for a rural school building.

Cuba is a country dependent on the tourism industry. The importance of tourism in Cuba's economic development, thus, cannot be understated. Within the current national Cuban energy policy for tourism, the following is proposed: "Apply policies that guarantee the sustainability of its development, implementing measures to reduce the rate of consumption of water and energy carriers and increase the use of renewable energy sources in harmony with the environment" [33].

Tourism has established itself as one of the pillars of the Cuban economy. It is estimated that the tourism and hotel sector alone contributes to between 15% and 20% of the country's gross domestic product (GDP), demonstrating the sector's strategic importance for generating foreign currency and Cuba's economic development. At the end of 2024, Cuba had approximately 300 hotel establishments of different categories (from budget accommodations to larger, more luxurious hotels) and nearly 35,000 rooms available to serve both domestic and international tourists [34]. This infrastructure has been progressively modernized and adapted to meet the demands of the global market, despite facing challenges inherent to the process of technological updating and investment in services.

In order to study energy performance of hotel buildings, some key KPIs like total energy per unit area, EUI (kWh/m^2/year), total energy per guestroom (MWh/room/year), total energy per guestroom-night, (kWh)/(number of rooms × occupancy × 365), and total energy per guest-night (kWh)/number of guests, should be established. However, energy use appears more relative to temperature, especially in the summer [35,36]. According to [37], there are different approaches to analyze the effect of ambient air temperature on energy consumption. Numerous studies have explored the use of the cooling degree days (CDD) indicator to understand the possible impacts of increased air temperature on

cooling energy demand in buildings. The degree day indicator could be one of the most practical and simple methods to determine the energy required for comfort [38,39].

The main objective of this paper is to develop a comprehensive methodology for the taxonomic classification of final energy use in hotels, addressed to more accurately identify the areas of greatest final energy use and provide further insights regarding energy key performance indicators (KPIs) and benchmarking methods specific to the hotel industry.

This paper is organized as follows: Section 1, the Introduction, presents the background and motivation for the study. Section 2, Materials and Methods, provides a review of fundamentals of taxonomic analysis of the final use of energy and requirements for the taxonomic analysis of the final use of energy in hotels. Section 3, Results, describes application of the taxonomic analysis methodology to the energy review in a hotel. Section 4, Discussion, provides a discussion of the results.

2. Materials and Methods

2.1. Fundamentals of Taxonomic Analysis of the Final Use of Energy

Taxonomic analysis is an approach used to classify and organize elements into specific categories, to identify patterns, interrelationships, and underlying causes. It is based on a taxonomy, which is the science of classifying living organisms into hierarchical categories, such as kingdom, phylum, class, order, family, and species. Taxonomy can be defined as the "theory and practice of delimiting and classifying different types of entities" [40]. The entity studied here is the final use of energy and, more particularly, final energy use in the hotel industry.

The taxonomic method can be applied to the energy analysis of different systems, processes, or sectors to evaluate their efficiency, consumption, environmental impact, and potential for savings or improvement, e.g., Johnsson et al.'s 2019 [41] study of the Swedish wood industry. In the context of tourism, taxonomic analysis can be applied to classify and organize the challenges faced by this sector into specific categories, facilitating a deep understanding of the situation and the formulation of effective responses.

Knowledge of the energy-related information of the processes allows these to be evaluated and optimized before and after their implementation [42]. Categorization allows administration and energy technicians, energy managers, and scholars to enhance understanding of these issues and improve knowledge about choosing energy efficiency improvements. For managers, categorization provides a basis for comparing the results achieved by the most competitive companies and other available technologies [43]. Categorization along with IDs helps in measurement and control, which are key to establishing an effective energy management system [43].

One of the antecedents of taxonomy or categorization of the final use of energy in industries is found in the research of Söderström (1996) [44]. It was later further developed by Thollander et al. (2013) [45] using the concept of unit process categorization. According to Söderström (1996) [44], processes can be divided into production processes "which means processes which directly are needed to produce products" and support processes "processes that primarily support production but which not directly are production". This taxonomy split unit processes into eleven production processes and ten support processes [46]. Some production processes in this paper could not be assigned according to the previous classification because production processes vary by industry. Also, the unit process approach does not sufficiently include hierarchical categorization depending on the complexity of energy use, i.e., from complex to simple. Hierarchical classification helps to retrieve information and also serves to compare research between different industrial systems. Therefore, a hierarchical classification limited to various industries can improve monitoring and analysis of energy use and helps search for optimal potential.

A critical issue is to determine which characteristics to apply [43]. Energy supply characteristics implies the kind of energy supplied to processes, and energy end-use characteristics implies how energy is applied in operations to add value to the material or service.

Hierarchical levels in this study were split by conditions such as the degree of complexity, the objective of energy flow, etc. By deploying the principles by McCarthy (1995) [40] and then transforming these into an energy use context, using energy flow as a core attribute, in [47], a hierarchical taxonomy structure was developed (Figure 1).

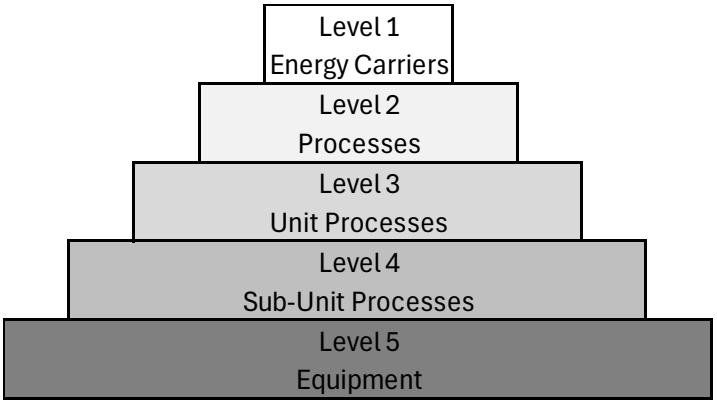

Figure 1. Hierarchical classification of the taxon for energy use in a hotel. Source: own elaboration.

The Level 1 taxon is energy carriers, illustrating the energy supply with low complexity, e.g., it only involves metering and monitoring supply of energy. It provides an overview of the industry's dependence on various energy carriers. The Level 2 taxon consist of core processes, i.e., production or support processes. This characterizes the aim of its energy use, that is, whether it contributes directly to the added value of the product or contributes to supporting services. The Level 3 taxon displays unit processes, founded on the purpose of a given industrial process. Both levels 2 and 3 are derived from [44]. The Level 4 taxon is a sub-unitary process that illustrates the different technologies used for the unit processes. The Level 5 taxon represents equipment/tools, which implies the machines or equipment that use energy for operation, in which different technologies display various forms of equipment. Other examples of using the taxonomic method for categorizing the final use of energy in industries refer to the food industry [46] and the pulp and paper industry [45]. However, examples applied to organizations in the service sector such as hotels are scarce in the literature.

2.2. Requirements for the Taxonomic Analysis of the Final Use of Energy in Hotels

Numerous national studies have been carried out in hotels in Cuba in search of an improvement in the energy efficiency of these facilities, either in relation to the efficient use of energy and the energy carriers that are consumed, or in the search for improvements in the operation of the technological systems that are used to provide comfort services to the client. These include air conditioning, lighting, pumping systems, and water heating systems [48–50]. Several authors highlight the importance of most consumer systems within hotel facilities, but there is a scarcity of studies that breaks down the final energy use in all the areas in a hotel by processes and levels [48–51]. This would allow for improved analysis and identification of where the main savings opportunities are, as well as proposing new consumption indicators by areas and levels. Moreover, there has been a scarcity of studies related to the development of energy management practices and energy KPIs and benchmarking from a bottom-up perspective. This study attempts to strengthen this gap. The aim of this study is to develop a taxonomy for final energy use

categorization and to develop key energy indicators for implementation in the hotel industry. This paper contributes to an enhanced methodology for developing improved knowledge of final energy use. Even though standards exist, e.g., ISO 50001 [44], 50002 [52], and 50006 [53], these are generic and not specifically developed for the hotel industry.

When applying the taxonomic method to energy analysis in hotels, some requirements must be followed, e.g., define the objective and scope of the analysis; identify and select the attributes or variables that characterize the energy behavior of objects or entities, such as final energy use, demand, production, intensity, emission, performance, and cost. This can then be followed by the establishment of a database where classification or grouping methods interpret and validate the results.

The distribution of final energy use in hotels depends on several factors, such as the type, size, equipment, and location of each establishment. Different classification criteria are, in general, used to determine this, such as the energy services provided. In principle, each hotel and corporation use their own means for classification. Previous studies identify air conditioning, domestic hot water production, lighting, ventilation, and mechanical drive as the main final energy-using processes in the hotel industry [54].

Another classification criterion used refers to the physical areas of the building, fundamentally referring to the rooms, leisure areas, offices, kitchen, laundry, elevators, and others [55].

2.3. Methodology for the Taxonomic Analysis of the Final Use of Energy in Hotels

A proposed methodology is explained in this section for a taxonomic analysis of the final use of energy in hotel facilities.

Step 1: Define the objective and scope of the analysis.

Objective: Classification of energy use in hotel facilities with a view to the implementation of an energy management system according to ISO 50001:2019.

Scope: According to ISO 50001:2019, scope is defined as the group of activities that an organization addresses through an energy management system. This requires establishing physical or organizational boundaries, for example, a process, a group of processes, a site, multiple sites under the control of an organization, or the entire organization.

Step 2: Identify and select the attributes or variables that characterize the energy behavior of objects or entities, such as consumption, demand, production, intensity, emission, performance, cost, etc.

In this case, the energy use of the organization is defined as attributes, based on the chosen calculation basis: daily, monthly, or annual.

Step 3: Create a data array containing the values of the attributes or variables for each object or entity, normalizing or standardizing the data if necessary to make it comparable, e.g. as displayed in in Table 1.

The use of electronic spreadsheets (for example, the Excel software) is recommended for the collection, storage, and processing of energy use data.

Table 1. Spreadsheet for hotel equipment data collection.

Area	Equipment	Amount	Unit Power (kW)	Total Power (kW)	Estimated Daily Use Time (h)	Energy Use (kWh)/Daily

Step 4: Apply a classification or grouping method that allows the formation of groups or categories of objects or entities with similar energy characteristics.

Based on the analysis of the aforementioned bibliographic information and previous studies on the implementation of energy management in hotels, e.g., Ref. [39], it is proposed to structure the categorization in the following way:

1. Level 1: Total energy use of the hotel per energy carrier.
2. Level 2: Energy use by main and support services.
3. Level 3: Energy use of energy services: cooling, tap hot water, food process, lighting, offices, pool, internal transportation, entertainment, and other facilities.
4. Level 4: Energy use by specific systems (lightning, dx cooling, split AC, cooking, fridge, heat extraction, blending, grilling, ice maker, pump, chillers, cleaning devices, computing devices, pumps, entertainment devices, electric motors).

Step 5: Define energy performance indicators adjusted to each level.

According to ISO 50006 [53], EnPI values quantify the energy performance of the entire organization or its various parts (e.g., facilities, equipment, systems, or energy-using processes). Potential EnPIs need to be analyzed to decide if they are appropriate before being selected.

Step 6: Interpret and validate the results obtained by analyzing the similarities and differences between them, as well as their relationship with the objective and scope of the analysis.

In Figure 2, an overview of the six-step methodology for the taxonomic analysis of the final use of energy in hotels is presented.

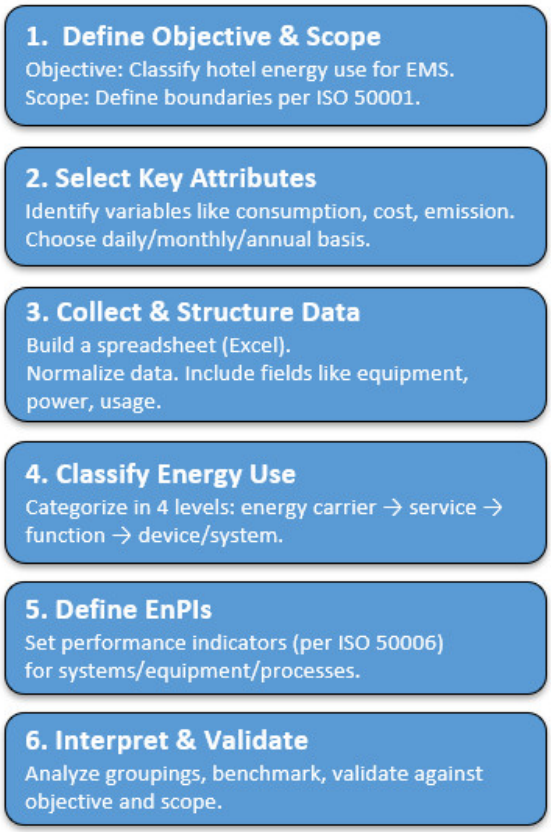

Figure 2. Six-step methodology for the taxonomic analysis of the final use of energy in hotels.

In Figure 3, the categorization by levels represented is generic for hotels of all categories, locations, and type of construction. The developed methodology was then applied to a typical five-star hotel, located in an urban area in Cuba; its design was in the form of a single main building. The hotel does not have a pool. It has a total of 56 rooms, a restaurant, a lobby bar, and a snack bar. In addition, the facility has two kitchens, staff offices,

and other common areas in the hotel facilities. The hotel selection is based on the results of previous studies [39,56] that support the typicality of energy processes and equipment in this context. In the following section, the proposed methodology is applied to this five-star hotel.

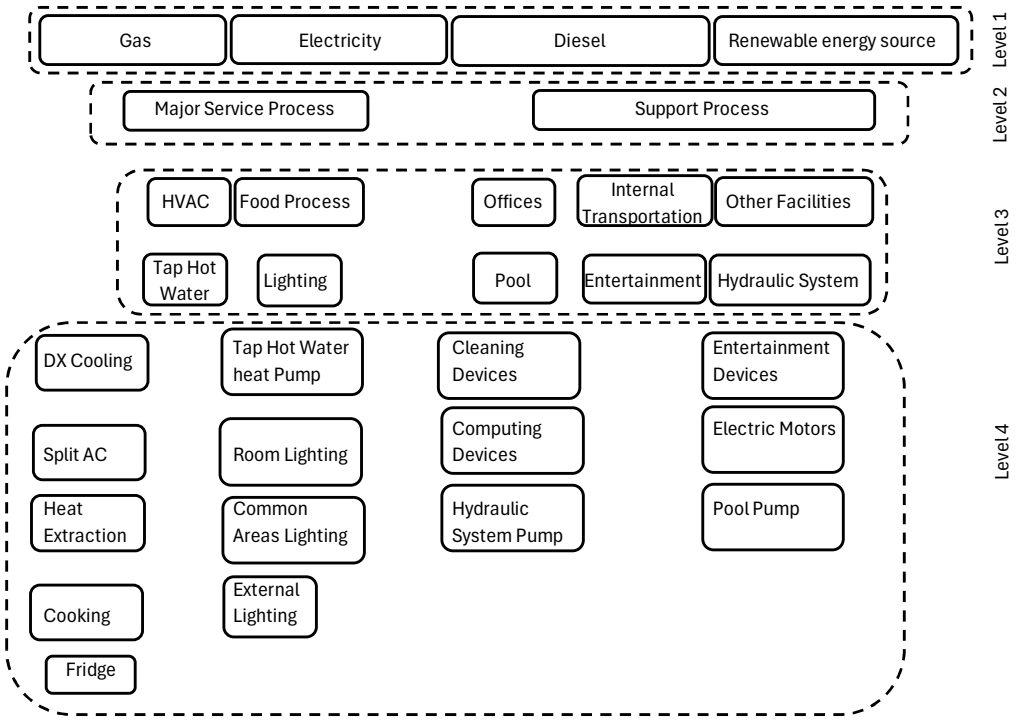

Figure 3. Energy categorization by levels.

3. Results

Application of the Taxonomic Analysis Methodology to the Energy Review in a Hotel

Level 1: Identification of energy carriers.

At the hotel, the main energy carriers are electricity, liquefied gas, diesel, and renewable energy sources. The analysis of the energy carriers allowed us to determine which of these has the greatest impact on final energy use within the hotel. These are commonly represented in a Pareto diagram in order to determine the level of use.

From Table 2, it can be seen that electricity represented 73% of the total final energy use for all carriers for the hotel in 2022, followed by liquefied gas (13.6%) and diesel (13.3%). This indicates that with a marked difference, it is electricity that predominates in all energy use in the year 2022. This coincides with what Iturralde Carrera (2023) [51] reported in his study.

Table 2. The final energy use of the year 2022 for each carrier represented in tons of conventional fuel and its percentage in relation to the total.

Carrier	U/M	Consumption	TCF	Carbon Footprint TCO_2/Year
Electricity	MWh	383,200	121,800	105,649.32
Diesel	M.L.	21,600	22,700	593,151
Gas	M.L.	19,100	22,200	365,697
Total			166,700	

Level 2: Distribution of electrical energy use by main and support processes.

At this level, it can be seen that the main services represent 89% of the hotel's total final energy use as shown in Table 3. Previous studies noted that 70% of the total energy use is utilized for production in the food industry, which shows that the major processes are more intensive for the food sector and the remaining 30% of the energy is used by the support processes [45].

Table 3. Level 2 consumption values. Source: own elaboration.

Level 2	Energy Use (Annual kWh)
Major Services Process	427,000
Support Process	51,900

Level 3: Distribution of electrical energy use by energy services.

Table 4 shows the main processes in the hotel facilities, their annual final energy use, and accumulated percentages, respectively. A general finding is that for a hotel facility in a country near the equator, air conditioning, tap hot water, food preparation, and lighting seem to be the largest final energy users within.

Table 4. Level 3 consumption values. Source: own elaboration.

Level 3	Energy Use (Annual kWh)
HVAC	193,800
Tap Hot Water	158,300
Food Process	131,200
Internal Transportation	96,400
Lightning	45,100
Offices	12,600
Entertainment	700

Figure 4 displays that the main electrical energy use is due to HVAC (30.4%), tap hot water (24.8%), food process (20.6%), and lightning (7.1%), which together reach 82.8% of the total. According to Ref. [57], air conditioning and domestic hot water (DHW) systems both account for 60% to 70% of the total energy use. In [49], Díaz Torres et al. (2021) report that in the case of Cuban hotels with air-condensed chiller plants, the HVAC section represents an average of 35–40% of total electricity consumption. Regarding HVAC, variable speed drives (VSDs) can reduce energy use by 20–30% compared to fixed-speed systems. Another key energy efficiency measure for HVAC is the use of smart thermostats enabling occupancy-based zoning, reducing overcooling/heating. Regarding tap hot water, heat recovery systems remain an option, capturing waste heat from HVAC or refrigeration to preheat water (e.g., in laundries or kitchens). Regarding food processing, thermal energy storage can remain as one option for energy efficiency.

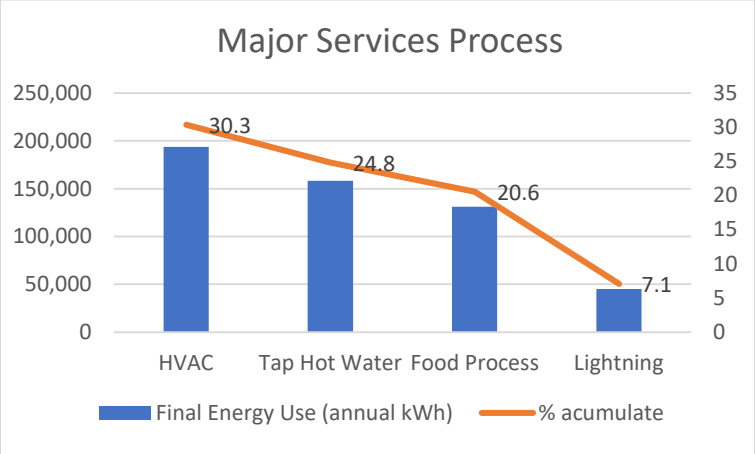

Figure 4. Level 3 major services process.

This shows the importance of monitoring and controlling these systems for effective energy management in a hotel facility. Results are comparable with the analysis of the final energy use of Greek hotels, which showed that 72–75% of the total final energy use was used in space heating, tap hot water, and air conditioning, 15% was used in catering, 8–9% for lighting, and the rest for the operation of various machinery [58].

Level 4: Distribution of electrical energy use by specific location.

The final energy use distribution shown in Level 4 in Table 5 confirms that within any hotel facility the largest energy users are found in the main processes cooling (DX cooling, split AC), cooking, and lightning, with a total value of approximately 94% for our case study.

Table 5. Level 4 consumption values. Source: own elaboration.

Level 4	Energy Use (Annual kWh)
DX Cooling	148,800
Cooking	72,300
Lightning	45,100
Split AC	45,000
Fridge	20,600
Electric Motors	6800
Heat Extraction	4900
Cleaning Devices	3400
Computing Devices	2600
Entertainment Devices	803

4. Discussion

This study is a small step towards improved energy management practices in hotel facilities. As formerly shown by Ref. [32], it is possible to reach net-zero self-sufficiency for rural school buildings. Likewise, we advocate that the ambition for hotels in general, and Cuban hotels in particular, intensifies the strive for self-sufficiency and net-zero hotel operations. By presenting a comprehensive methodology for the taxonomic classification of final energy use in hotels in this paper, the significant gap in the literature regarding energy management practices, energy key performance indicators (KPIs), and benchmarking methods specific to the hotel industry is addressed. Some limitations to the study are that the taxonomy was validated in a case study, wherefore further research is suggested to further validate the taxonomy. Moreover, even though the dataset emanates from a whole year, variations in the actual year may need to be taken into account when

analyzing the single values for the various processes. It is, therefore, of particular importance, not the least if the study's results are planned to be used for, e.g., policy design, to undertake a new study involving several years.

The taxonomic classification adds to an already existing body of literature, e.g., Ref. [20], which had developed KPIs for assessing the sustainability of building energy efficiency retrofitting, and Ref. [21], which showed that performance indexes related to, among others, energy, served energy planners in implementing and monitoring efficiency and sustainability policies. Moreover, our study provides a further step based on former research, e.g., Ref. [25], of the US hotel benchmarking programs achieving 6–8% energy savings but advocating the need for improved data standardization. This paper has taken a small step towards improving this by enabling, in accordance with ISO 50006, the structuring of benchmarking beyond the whole site, through the developed taxonomy. By defining a taxonomy for final energy use in the hotel industry and adequate energy KPIs on more detailed levels, benchmarking is in turn enabled. Thanks to the developed taxonomy, both individual energy managers at the hotel level as well as energy managers among groups of hotels can apply longitudinal benchmarking as well as benchmarking with other hotels. Future research is suggested to also enable the third type of benchmarking, namely, benchmarking towards best available technologies (BAT) or best practices, such as the European BAT documents for industry and the European Energy Performance Building Directive aiming for zero emission buildings. Such development would pave the way for even more excellent energy management of hotels across the globe.

The comprehensive methodology was applied to a five-star hotel in Cuba and validated the soundness of the methodology, showing that cooling (30.4%), tap hot water (24.8%), and food processing (20.6%) were the major final energy users, which aligns with previous research in the field. One of the key contributions of the study is the development of a structured framework that allows hotel managers, energy professionals, and policymakers to systematically assess and benchmark energy performance. One general challenge related to energy data collection in energy management is to gain accurate data. For hotels in the EU, this is already handled via the energy performance of building directive where users need to invest in building automation at a certain threshold. For hotels in the EU and beyond, it is recommended that the installation of a building automation system is guided by the taxonomy developed in this paper. The building automation system can in turn be designed to showcase relevant energy KPIs, occupancy profiles, calculation of consumption and loads, etc.

Even though the taxonomy was validated at Cuban hotels, the taxonomy can be generalized to any hotel regardless of climate zone. Moreover, the classification levels provide a standardized method for identifying energy-intensive operations, enabling the implementation of targeted energy-saving measures.

The findings also emphasize the necessity of enhanced data collection and monitoring to support energy optimization efforts where former research [7] has indicated vast potentials, e.g., 20% or more. It is suggested that further research is undertaken that studies in which processes of final energy use the major energy efficiency improvements can be found. Additionally, the categorization of energy use by service and equipment provides a practical foundation for developing energy performance indicators (EnPIs) tailored to the specific operational characteristics of hotel facilities. Despite the contributions of this study, more case studies are suggested in the field, from other regions as well as other types of hotels.

In conclusion, the proposed taxonomy methodology provides a valuable tool for the hotel industry to advance its energy management practices. By adopting a structured approach to energy classification and benchmarking, hotels can achieve greater energy efficiency improvements. As the global tourism industry continues to grow, the need for

sustainable energy management in hotels is becoming increasingly important, making methodologies such as the one proposed in this paper one of many small steps in this direction.

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Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

AC	Air conditioning
CDD	Cooling degree days—an index to estimate the energy demand for cooling
DHW	Domestic hot water
DX Cooling	Direct expansion cooling—a type of air conditioning system
EnPI	Energy performance indicator—a measurable value used to quantify energy performance
EUI	Energy use intensity—typically measured in kWh/m^2/year
GDP	Gross domestic product
GHG	Greenhouse gas
HVAC	Heating, ventilation, and air conditioning
ISO	International organization for standardization
KPI	Key performance indicator
kWh	Kilowatt-hour—a unit of energy
MWh	Megawatt-hour—1000 kWh
TCF	Tons of conventional fuel—used to quantify different energy types on a common scale
TCO_2/year	Tons of CO_2 emitted per year—indicates carbon footprint
VSD	Variable speed drive—an energy-efficiency technology for motors and pumps

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