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Review article

Energy consumption in buildings: A compilation of current studies

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ABSTRACT

Although the area occupied by cities is very small, they consume between 60% and 80% of the energy. Specifically, in buildings it reaches 36%. For this reason, any measure that favors the use of non-polluting energies or the reduction of energy consumption in them has a great multiplier effect. This has given rise, on the one hand, to government authorities having them as priorities for improvement, and on the other, to researchers increasing their studies on them. This work carries out a synopsis of the investigations that reveal or calculate the energy consumption of buildings. Prisma methodology has been followed for its realization. The investigation reveals that more than half of the publications have focused on residential buildings. The search for manuscripts in a systematic way did not give the expected results, so the identification of studies via other methods was necessary. In fact, more than 90% of the search has been carried out on publications obtained by other means. These have been based on the iterative search for references from those initially obtained by the Prisma methodology. In addition, a classification based on the use of the building and how the studies have been published is presented. A section including calculation methods has also been added because some studies have included buildings dedicated to different uses. Finally, approximate values of energy consumption according to the type of building and possible future variables to be used in certain buildings have been added. In this way, it is intended to facilitate the search for information for researchers interested in knowing the energy consumption in buildings based on their use.

1. Introduction

1.1. Overview

Currently more than half of the world's population lives in cities, and it is expected that by 2030 it will reach 60% and that by 2050 it will exceed two thirds. However, today, in Europe and America it is already over 75%, and it is estimated that in 2050 it will reach 85% (Department of Economic and Social Affairs, 2019). This means that between 60% and 80% of energy consumption is carried out in cities (United Nations, 2023). A very important part of this consumption occurs in buildings in the residential and tertiary sectors. In them the energy consumption reaches 36% (International Energy Agency, 2018). The usual form of energy consumption in buildings is electrical and thermal, in the latter case in the form of natural gas (Shahrokni et al., 2014). In addition, considering that the area occupied by cities is very small. For example, in the case of the European Union it only reaches 4% (Publications Office of the European Union, 2021). With this data, it is possible to understand the importance that buildings have for all government authorities: any action that is aimed at reducing energy consumption in them or on the type of energy consumed has a very important multiplier effect.

Globally, this is reflected in the Sustainable Development Goals of the United Nations Educational, 2023. Goals 7, 11, 12 and 13 refer to the use of clean energy, making cities sustainable, achieving responsible consumption and production, and combating climate change, respectively. At the continental level, the European Union has launched the Next Generation EU plan to achieve a more sustainable Europe (European Parliament News, 2022). It includes six fields of action, including buildings. And at the city level, the mayors from 8000 cities from 53 countries around the world have joined in the Covenant of

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Mayors for Climate & Energy with the aim of ensuring that citizens can have access to affordable and sustainable energy (Energy-Cities, 2023). In addition, 100 European cities have recently been selected to be climate-neutral by 2030 to serve as experimentation and innovation hubs for the rest of the European cities, which will have to achieve this goal by 2050 (COM(2021) 609 final, 2021).

Today, achieving zero-energy buildings is a goal to be achieved. The reduction of energy consumption and the use of renewable energy are means to achieve it and, therefore, the elimination of emissions will be achieved. Nevertheless, to reach an end it is necessary to be aware of the starting point: knowing the current consumption, it will be known what will have to be reduced. In other words, it is necessary to know the current consumption of the buildings.

1.2. Aim of the compilation

Cities and their buildings are very important for government authorities and society. The challenge to achieve is to reduce energy consumption in them. For this reason, the present manuscript is focused on buildings. A classification and compilation of the publications that show or calculate the energy consumption of buildings so far is shown. In addition, the main aspects of the published studies are those shown in the manuscript: calculation methods, types of buildings, energy sources and variables used to obtain the results. The groupings presented in the publications have been respected and the classification has been made according to them. The manuscript is not intended to be a standard review in which the most prolific journals, countries or authors are singled out. On the contrary, it is focused on the bibliographic needs that the researcher faces. In addition, it will show which are the least investigated areas so far. Therefore, it aspires to be a helpful tool for researchers interested in this subject. In this way, they will have easy access to the knowledge of the state of the art on the subject.

2. Search methodology

The search for manuscripts that calculate or show energy consumption in different types of buildings has been carried out following the Prisma methodology shown in Fig. 1 (Prisma, 2022). A systematic review including other sources has been carried out. Two different investigators have conducted the benchmark investigation. The WoS (Web of Science) and Scopus databases have been used. The limitations imposed have been: manuscripts published in journals, with English as the language. As the objective was to find evidence of global energy consumption in buildings, the following search elements have been used: building AND “energy consumption” AND calculate AND (mwh OR kwh OR mw OR kw). Initially wh OR w were also included. However, they had to be eliminated from the search due to the distortion caused by dealing with a single letter. The search was performed on title, keywords, and abstract.

The number of manuscripts initially obtained from WoS was 46 and from Scopus 18. By eliminating the duplicates, 60 remained. Of these, 47 were excluded for not including any estimate or calculation of energy consumption in buildings. Once those considered invalid were eliminated, 13 manuscripts remained. This selection has been expanded using the references of these manuscripts. Thus, from the manuscripts obtained, their references were sought out and analyzed. Those that were within the scope of the study, including calculation or estimation of energy consumption in buildings, were considered. In turn, from these new references, their references were analyzed again. And so on until a point was reached when all the references that appeared were either included or were not valid because they did not fit within the scope of the research.Following this iterative process, a total of 1569 manuscripts have been identified. Of these, those references that appeared re-peated in different manuscripts were identified and eliminated, leaving only once. Subsequently, the suitability with the scope of the present study was assessed. And 198 met the required scope. Finally, 211 have been selected, corresponding to the 13 initially selected plus the 198 subsequently identified. They are the ones that show or calculate energy consumption in buildings.

3. Classification

Based on published works, classifications on energy consumption in buildings can be made from different points of view: depending on the use of the building (residential, commercial, hospital, …); the year of construction; the type of energy used (electricity, gas, biomass, …); the climate of the studied area; its extension, etc. And within each of them, the level of detail can be greater or lesser. Thus, in the case of residential buildings they can be considered rural or urban; or including in their study other types of buildings with greater or lesser affinity. In the case of the year of construction, by certain dates on which the construction regulations were changed, or by periods of years. In the case of the energy consumed, depending on the most used source, since in many cases more than one is used.

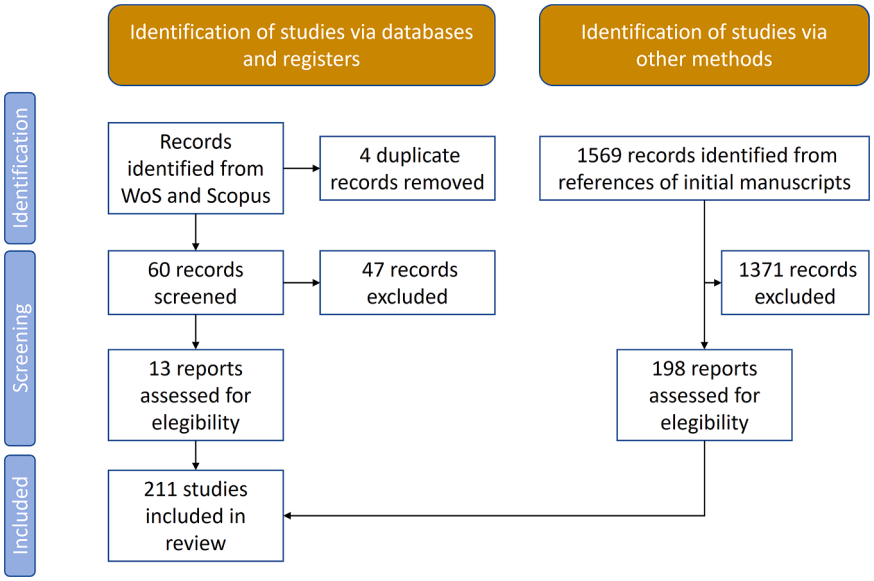


Fig. 1. PRISMA flowchart including searches of databases, registers, and other sources.

The present work wants to be an aid for researchers in the knowledge of the state of the art to facilitate their bibliographic search work. For this reason, a classification based on the type of building is presented, since, in the opinion of the authors, it is considered the most useful for its purpose. In addition, this classification favors the subsequent application of measures that can reduce energy consumption and greenhouse gas emissions, although the scope of this review does not include such measures, nor do the works analyzed.

The classification proposed in this manuscript is shown in Fig. 2. It has considered how the publications have been made. Thus, for example, studies of residential buildings have been carried out alone or with other types of buildings. That is the reason why the classification has been proposed in this way.

Some papers include buildings dedicated to different uses because their study focuses on the methods used to calculate energy demand. For this reason, this section has been added despite not fitting the proposed classification.

4. Hospital facilities

Despite the great energy consumption and the great importance they have, hospitals have been occasionally studied. Although consumption is lower at night, it is a sustained consumption every day of the year. The consumption of thermal and electrical energy in hospital facilities based on different variables has been studied in Spain. In one case, considering the built area and the number of beds (González-González et al., 2018) and in another, the type of activity carried out in them, also taking into account whether the buildings have been retrofitted (García-Sanz-Calcedo et al., 2019). It has also been studied in China. Differentiation between general and specialized hospitals has been considered, with consumption being higher in general hospitals. Almost half was produced in the heating system and design improvements to reduce consumption have been shown (Jiang et al., 2012). A summary of the parameters used to calculate consumption in hospital facilities is shown in Table 1.

Table 1
Parameters used for hospital facilities calculations.

Methodology	References
Built area and number of beds	González-González et al., 2018
Type of activity	García-Sanz-Calcedo et al., 2019
Type of hospital	Jiang et al., 2012

5. Teaching centers

In the classification of educational centers, both universities and schools and nurseries are considered. In all cases, their activity is focused on weekdays. However, in universities there may also be some consumption on weekends. Therefore, in the case of university centers, the day of the week and weather conditions are used as variables to calculate energy consumption (Yuan et al., 2018; Amber et al. 2017), highlighting the importance of meteorological variables (Faiq et al., 2023). The occupation of the center is another variable to consider. This is solved in Pombeiro et al. (2017) from the Wi-Fi traffic. With this, human activity is known; thus, the greater the Wi-Fi traffic, the greater the activity and the greater the energy consumption. And the prediction of energy consumption in air conditioning in the short-term has been obtained through occupants' behavior (Li et al., 2023). The analysis of electricity consumption has been studied from the occupancy ratios. It has been found to be directly proportional to the building area usage distribution (Kim and Srebric, 2017). Artificial Neural Networks (ANNs) is the methodology commonly used to make the prediction (Li et al., 2015), but other methods such as fuzzy systems and linear regressions models (Neto and Fiorelli, 2008) or deep learning (Fan and Xing, 2021) have also been used, showing the sensitivity of consumption to environmental conditions. It is common to calculate total energy consumption. However, in some areas the consumption of air conditioning is of special importance, as occurs in Hong Kong (Leung et al., 2012); or heating, as occurs in Norway (Jovanovic et al., 2015). In those cases, the study is circumscribed only to them.

Collections of consumption data in schools have been carried out to determine which are the relevant energy parameters. Among them, the year of construction, or the existence or not of a cafeteria in the school is important due to the energy consumption that occurs in them (it should be noted that in schools the areas that usually exist are: classrooms, gyms, laboratories and, sometimes, cafeteria) (Thewes et al., 2014). The data acquired in the centers allow proposals for construction

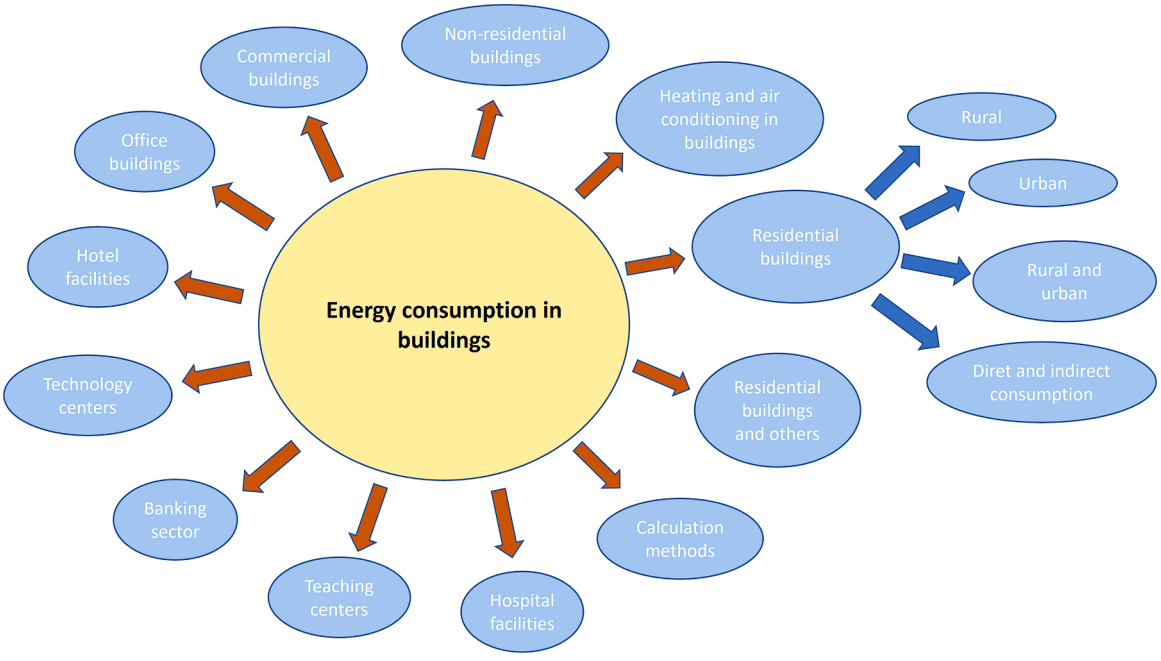


Fig. 2. Classification of research papers according to publications.

improvements to be made and are used to make a classification that allows evaluating the energy performance in comparison with other buildings (Santamouris et al., 2007) and also to carry out an energy benchmark to qualify the schools (Hernandez et al., 2008). A study covering both kindergartens and schools and universities has been carried out in Finland. With the collected data, it has been concluded that the design phase of educational buildings is very important to reduce energy consumption, with the year of construction being of great importance (Sekki et al. 2015). In some cases, schools and daycare centers have been included in the study. In the case of schools, consumption per m^2 is lower because they have larger gross floor area (Ruusala et al., 2018). Parameters used to calculate energy consumption in teaching centers is shown in Table 2.

6. Banking sector

The banking sector has characteristics that can resemble the commercial sector. However, it is not that big, nor does its activity reach every day of the week, nor such a high number of hours a day. In the investigation, the authors have only found one paper that calculates or shows energy consumption in this sector. In it, several energy consumption prediction models have been developed. The same regression model is used to predict energy consumption. However, the value of the parameters used in it will vary depending on the type of climate in which the bank office is located. Among the variables used, winter and summer climatic severity are the differentiators in terms of climate. The rest refer to surface area, number of employees, office height or number of ATMs (Aranda et al., 2012).

7. Technology centers

Although the increase in technology centers has been very high in recent years, their energy consumption has been barely studied. In this case, the authors have only found a manuscript that shows energy consumption in a technology center. This is the technology center located in Varennes, Canada. Although in many cases an ANN methodology is used for prediction, in this case adaptive ANN methods for real-time prediction have been analyzed; in particular, two types of them: cumulative training and sliding window training. The best results have been obtained with the latter type (Yang et al., 2005). This scarcity of studies may lead to future research on this type of building.

8. Hotel facilities

Hotel facilities have characteristics that make them different from other types of commercial facilities. Its use is seasonal, depending on its occupation of the date of the year. There may even be times of the year when the facilities are without consumption, or with minimal consumption because they are closed to customers and are only performing maintenance tasks. The importance they have is reflected in the fact that the number of research works carried out is higher than that of other types of facilities.

Gas and electricity are the main sources of energy in hotel facilities, with electricity predominating for the use of air conditioning in hot climates (Shiming and Burnett, 2002; Deng and Burnett, 2000). In addition, diesel is also used for backup generators, to feed the hot water boiler (Priyadarsini et al., 2009) or due to deficiencies in the electricity supply network, which causes a greater amount of emissions (Oluseyi et al., 2016).

Some studies have focused on electrical energy consumption and its emissions (Chan and Lam, 2002), and others on total energy consumption and climatic influence (Xin et al., 2012). However, energy consumption per unit area has been considered the most representative parameter of consumption compared to other variables, such as the age of the facility, occupancy rate, or number of rooms. Energy consumption depending on the level of the hotel has also been investigated. Thus, hotels of different categories depending on the number of stars, motels, bed and breakfasts, backpackers and campgrounds have been compared. The conclusion obtained is that the higher the category, the higher the consumption (Wang, 2012; Xuchao et al., 2010; Becken et al., 2001), with climate also being important (Bohdanowicz and Martinac, 2007).

The importance of efficiency and energy saving is reflected in the number of studies that deal with them. In some cases, it analyzes it together with another scarce good such as water (Deng, 2003), or also including the waste generated (Trung and Kumar, 2005). Although it is usual to analyze it independently: either considering a small sample that is representative of the existing hotel facilities in the country to extrapolate the conclusions obtained (Taylor et al., 2010); or with a sample that covers the entire hotel sector (Bianco et al., 2017), both cases including construction improvements that reduce consumption. There are also works that are limited to a specific area and a specific hotel category, in terms of the number of stars, including recommendations to reduce consumption (Önüt and Soner, 2006); or also consider the influence of the climate (Lu et al., 2013); or point to improvements in buildings (Santamouris et al., 1996). Although it is advisable to carry out an energetic evaluation of the installation in a systematic way to show the main points of improvement in the facilities (Dascalaki and Balaras, 2004).

The hourly loads of hotel facilities and schools have also been jointly analyzed (Norém and Purko, 1998), as well as the life cycle of the building. In this case, the period of operation of the building is the one with the highest energy consumption, reaching 80%; in addition, it is also when the amount of emission and waste generated is greater (Rosselló-Batle et al., 2010).

As in the studies of other types of buildings, linear regression, statistical analysis or correlation analysis are the most used methods to carry out the analyses and predictions.

Table 3 shows the singular parameters used in different manuscripts to analyze the energy consumed in hospital facilities.

9. Office buildings

Energy consumption in this type of building occurs mainly in heating, ventilation, air conditioning and lighting systems. The studies have referred to office buildings in general, although in some cases they have been limited to government buildings. However, basically the

Table 2
Parameters used to calculate energy consumption in teaching centers.

Singular parameters	References
Day of the week and weather conditions	Yuan et al., 2018; Amber et al. 2017; Faiq et al., 2023
Wi-Fi traffic	Pombeiro et al., 2017
Occupants´ behavior	Li et al., 2023
Building area usage distribution	Kim and Srebric, 2017
Classrooms, gym, laboratories, cafeteria	Thewes et al., 2014

Table 3
Parameters used to analyze energy consumption in hotel facilities.

Singular parameters	References
Category	Wang, 2012; Xuchao et al., 2010; Bohdanowicz and Martinac, 2007; Becken et al., 2001; Önüt and Soner, 2006
Climate	Lu et al., 2013
Hourly load	Norém and Purko, 1998
Life cycle of buildings	Rosselló-Batle et al., 2010

conclusions for one type of building or another are similar (Xiao et al., 2012). Energy performance in different countries has been analyzed, including efficiency measures to reduce consumption (Lam et al., 2008b; Saidur, 2009): in some cases, considering meteorological data (Yang et al., 2008; Kwak and Huh, 2016), and in others, in addition, energy bills (Geng et al., 2018) or energy rates (Chen et al., 2015). Simulation programs based on the location of the building and construction parameters (Eskin and Türkmen, 2008) or its need for cooling (Duanmu et al., 2013) have also been developed.

The configuration that buildings should have, as well as good and bad construction practices have been studied (Wang et al., 2012). In this way, the best characteristics of the building have been detected (Korolija et al., 2013); in some cases, the analysis has been limited to the building envelope (Yu et al., 2015), or to its life-cycle (Zhuang et al., 2021); and in others it has been examined which is the most efficient building depending on its location and orientation (Moreci et al., 2016). But in any case, the definition of the envelope design and building form at design time is the most appropriate (Chen et al., 2018).

Regression system has been the system used for the analysis of consumption in office buildings, although deep learning model has also been used recently with 20 variables both internal and external to the building (Lei et al., 2024). Furthermore, Table 4 shows the singular parameters used in different papers.

10. Commercial buildings

The main consumption in commercial buildings occurs in heating, ventilation, air conditioning and lighting systems, as occurs in office buildings. Some studies have shown that the highest energy consumption in buildings occurs in those dedicated to shops, with the air conditioning system being the one with the highest consumption and have proposed constructive efficiency measures (Zhao et al., 2009). To analyze consumption, it is necessary to consider both that corresponding to centralized services and that of each store (Lee et al., 2003). Different consumption prediction methods have been proposed. Some of them are based on programs that use the machine learning methodology (Li et al., 2017). To better adjust the prediction made, they sometimes consider the building envelope and its interior characteristics (Lam, 2000) and in others the meteorological data (Dong et al., 2005) and its evolution throughout the day (Sun et al., 2013).

In this case, in addition to traditional analysis methods, others based on machine learning and ANN have been used.

11. Non-residential buildings

Non-residential buildings have different behaviors depending on the use to which they are dedicated. From hospitals, which consume energy every day and at all hours, to schools, which only consume it during the week and at certain hours. However, some works have analyzed them together. In some cases, the creation of an energy consumption database has been proposed according to its location and the destination to which it is dedicated (Bruhns and Wyatt, 2011); or common points of reference have been sought in the consumption of different types of buildings with different types of energy (Jones et al., 2000). The in-fluence that the geometric shape of the building (Steadman et al., 2014) and climatic conditions have on its consumption has also been analyzed (Martellotta et al., 2022).

Four types of buildings have been compared in China, analyzing their external and internal characteristics, and showing energy saving measures, which in many cases are similar. Hospitals consume the most, followed by non-governmental offices, government offices and, lastly, school buildings (Ma et al., 2017). Consumption in mosque buildings and sports facilities has also been analyzed using deep learning techniques. In the first case, by analyzing the frequency of use of such buildings (El-Maraghy et al., 2024); and in the second, by studying the characteristics of these facilities and detecting the anomalies they may present (Fadli et al., 2024). In addition, a review of studies on sports facilities has been carried out, analyzing the prediction methods used as well as the energy optimizations that would be applicable (Elnour et al., 2022). Finally, the specific case of gas consumption in non-residential buildings has been analyzed at the country level in Italy (Bianco et al., 2014a).

Table 5 summarizes the references that calculate or analyze consumption in non-residential buildings with an indication of the main characteristic of the research.

12. Heating and air conditioning in buildings

Heating and air conditioning are two forms of energy consumption in buildings. However, since they are the two main forms of consumption in most buildings, they have been included in the classification.

Most research does not analyze it but covers all energy consumption. Some of the works that examine this type of consumption do so by mixing both, but others only analyze one of them.

Air conditioning consumption has been examined in both non-residential (Yik et al., 2001) and residential (Izquierdo et al., 2011) buildings, including their emissions. In the latter case, its consumption reached 33% of the total in the area studied. Urban morphological factors are the ones that most affect energy consumption in heating: building density, height (Song et al., 2020), thickness of the brick wall of the building (Ekici and Aksoy, 2009), country design regulations (Kazanasmaz et al., 2014). Another of the characteristics considered has been the ultra-low energy residential buildings, since if this is not taken into account, the facility is oversized because it is considered to have a higher consumption than it really has. For this, it is necessary to consider occupancy patterns in order to make a better approximation to consumption (Ju et al., 2024). Consumption prediction has been made with annual (Corgnati et al., 2008), monthly (Catalina et al., 2008), daily (Paudel et al., 2014) or hourly (Dombayci, 2010) anticipation; and using different variables, such as degree-day (Zhang, 2004; Sarak and Satman, 2003), degree-hours (Durmayaz et al., 2000), average ambient temperature (Izadyar et al., 2015) or gross domestic product, and energy structure (Tian et al., 2019). Prediction in buildings connected to a district heating system, and taking into account environmental conditions, has also been examined (Popescu et al., 2009). And, in order to better understand consumption in urban centers, the age of buildings, its representation on GIS systems (Todeschi et al., 2021; Fracastoro and

Table 4
Parameters used to calculate energy consumption in office buildings.

Singular parameters	References
Meteorological data	Yang et al., 2008; Kwak and Huh, 2016
Energy bills	Geng et al., 2018
Energy rates	Chen et al., 2015
Construction practices	Wang et al., 2012; Korolija et al., 2013; Yu et al., 2015; Zhuang et al., 2021; Moreci et al., 2016; Chen et al., 2018
20 parameters of the interior and exterior of the building	Lei et al., 2024

Table 5
Non-residential buildings references.

Main characteristic of the research	References
Type of consumption	Bruhns and Wyatt, 2011; Jones et al., 2000
Influence of geometry	Steadman et al., 2014
Influence of climatic conditions	Martellotta et al., 2022
Building functionality	Ma et al., 2017
Mosque buildings	El-Maraghy et al., 2024
Sports facilities	Fadli et al., 2024; Elnour et al., 2022
Gas consumption	Bianco et al., 2014a

Serraino, 2011) and 3D visualization to take into account urban morphology have been developed (Moghadam et al., 2019).

The works that analyze both energy consumptions are carried out jointly or separately. Regarding the type of fuel used, the use of biomass is well established globally, coal is gradually disappearing, and electricity is increasing (Ürge-Vorsatz et al., 2015). Taking into account the evolution of environmental parameters and the age of buildings, the energy demand for heating is expected to decrease, while that for air conditioning will increase considerably (Isaac and Vuuren, 2009; Wan et al., 2011); and the metropolitan areas with the highest energy consumption are those with the highest demand for heating (Sivak, 2008). Consumption in these areas decreased in relation to what was initially estimated due to population movements between cities (Sivak, 2009). Prediction of building consumption considering internal factors (Afzal et al., 2023); or both internal and external factors (Li and Yao, 2021); and programs that estimate the hourly consumption of buildings (Mihalakakou et al., 2002), both simulating their interior (Vidrih and Medved, 2008) and their exterior (Kalogirou et al., 2001) or azimuth angle (Ascione et al., 2013) have been used. In them, the climate and the use of the different appliances are considered (Laoufi et al., 2020). A study for the prediction of consumption during the pandemic and for the post-COVID-19 situation has been carried out. The variables used were both the characteristics of the dwelling and of the people living in it (Khalil and Fatmi, 2022). And, to have a graphic view of the real estate stock of cities, a methodology that uses a geographic information system has been used (Ekici and Aksoy, 2011). Also, a review on air conditioning systems in the office sector has been carried out (Pérez-Lombard et al., 2008).

Multiple regression and ANN methods have been used to carry out the analyzes and predictions. Table 6 summarizes the references that calculate or analyze consumption due to heating and air conditioning in buildings with an indication of the main characteristic of the research.

13. Residential buildings

Studies on residential buildings are the most numerous. This is due to the great importance they have in achieving the sustainable development goals set by government authorities and demanded by society. Even a review on the residential sector has been carried out (Geng et al., 2017).

Table 6
References form heating and air conditioning in buildings.

Main characteristic of the research	References
Non-residential buildings	Yik et al., 2001
Residential buildings	Izquierdo et al., 2011
Morphological factors	Song et al., 2020; Ekici and Aksoy, 2009; Kazanasmaz et al., 2014
Occupancy of residential buildings	Ju et al., 2024
Prediction with external factors	Corgnati et al., 2008; Catalina et al., 2008; Paudel et al., 2014; Dombayci, 2010; Zhang, 2004; Sarak and Satman, 2003; Durmayaz et al., 2000; Izadyar et al., 2015; Tian et al., 2019; Popescu et al., 2009
Representation systems	Todeschi et al., 2021; Fracastoro and Serraino, 2011; Moghadam et al., 2019
Evolution of demand	Ürge-Vorsatz et al., 2015; Isaac and Vuuren, 2009; Wan et al., 2011; Sivak, 2008; Sivak, 2009
Prediction with internal factors	Afzal et al., 2023; Li and Yao, 2021; Mihalakakou et al., 2002; Vidrih and Medved, 2008; Kalogirou et al., 2001; Ascione et al., 2013; Laoufi et al., 2020; Khalil and Fatmi, 2022
Graphic view of consumption	Ekici and Aksoy, 2011
Review	Pérez-Lombard et al., 2008

13.1. Rural residential buildings

Studies on energy consumption in rural areas exclusively are few. They have been carried out in developing countries and in areas with difficult access to modern energy sources, with labor, economic and demographic factors being important (Jin et al., 2019; Ekholm et al., 2010; Howells et al., 2005). In these cases, traditional fuels, such as firewood and biomass, are the main sources of energy. These types of fuels are highly polluting and cause numerous dangers, such as poisoning and fires. In those more developed areas, as well as in developed countries, the most frequent residential consumption is electricity and natural gas.

13.2. Urban residential buildings

Any action that favors the reduction of energy consumption in residential buildings has an immediate impact. If it is also about urban buildings, it is much greater. Hence, the investigations on them are, by far, the most numerous.

To carry out an in-depth study, it is necessary to know the starting point. Therefore, studies showing consumption in different countries have been carried out (Sandberg et al., 2011; Filippín et al., 2013); or in areas of a country (Sun et al., 2018; López-González et al., 2018) and depending on the climatic season and the type of construction (Chen et al., 2011; Chen et al., 2010); or analyzing the differences between countries (Xia et al., 2014); or in a certain city considering the climate, urban morphology(Salat, 2009) and the composition of the occupants (Wangpattarapong et al., 2008). Also, with the analysis carried out, it has been detected which are the devices that consume the most in households (Lam, 1996). Thus, the consumption of natural gas for domestic hot water has been studied for the importance it has for energy certifications of buildings (Ratajczak et al., 2021).

As with other types of buildings, there are several factors that influence energy consumption. Thus, its envelope and the climatic conditions of the area in which it is located (Naji et al., 2016b), or whether it is summer or winter, acquire great importance (Hu et al., 2013). Regarding the envelope, the construction material (Sandberg and Brattebo, 2012; Xu et al., 2024), its thickness and insulation capacity (Naji et al., 2016a) are important. In relation to the morphology of the building, the extension it occupies (Urquizo et al., 2017) and the shape of the envelope (Zerefos et al., 2012) also influence, in addition to the construction practices of each period (Filogamo et al., 2014). And through sensitivity analysis, it is possible to identify how changes in the envelope or its morphology (Yildiz and Arsan, 2011), or the age of the building or emissions (Firth et al., 2010), affect. In any case, at the time of design potential energy savings must be considered (Golbazi and Aktas, 2018), both internally and externally (Saari et al., 2012) and when retrofitting existing buildings (Rhodes et al., 2016).

The income factor (Liu et al., 2016), the area occupied by the dwelling (Houri and Ibrahim-Korfali, 2005), or the number of residents (Ali et al., 2021) have a great importance in energy consumption. However, in some countries, studies show that the influence of income is minimal (Wiesmann et al., 2011); or even within the European Union it has different weight depending on the country (Pablo-Romero and Sánchez-Braza, 2017). On the contrary, households with lower incomes are very limited for such consumption (Cayla et al., 2011). On the other hand, the level of education or the employment status of the person representing the household have no influence (Jones and Lomas, 2015). The price of energy also has an influence, so that the higher the price, the lower the consumption (Blázquez et al., 2013). Other factors also analyzed have been the GDP (Bianco et al., 2020), or urbanization (Wang et al., 2020; Wang and Yang, 2019), and depending on the country, they have a positive or negative influence. A detailed review of studies carried out, including 62 factors, has also been carried out (Jones

et al., 2015).

Prediction of energy consumption has been made by minutes (Sepehr et al., 2018), by hours, also considering the electrical appliances (Paatero and Lund, 2006) or the weather (González and Zamarreño, 2005); at the building or city (Yao and Steemers, 2005), provincial (Liao et al., 2017), or national (Aydinalp-Koksal and Ugursal, 2008; Bianco et al., 2014b) level. And even from the data of the consumption of an appliance in intervals of one minute (Marszal-Pomianowska et al., 2016). In those countries where electrification rates are very low, an estimate of consumption is made to develop a microgrid through distributed generators or through distributed solar energy (Shibano and Mogi, 2020). Reviews of calculation tools (Bourdic and Salat, 2012) and modeling techniques (Swan and Ugursal, 2009) for forecasting consumption have also been carried out (Buratti et al., 2014).

To have a vision of consumption, the energy use at the individual dwelling level is aggregated at the district, neighborhood, or community level (Urquizo et al., 2018), so that spatially referenced (Calderón et al., 2015) allows to represent maps of energy consumed (Pereira and Assis, 2013), energy performance (Dall'O' et al., 2012) and perform energy simulations (Ratti et al., 2005). Thus, the energy behavior of buildings has been identified according to their age (Aksoezen et al., 2015). Also, the consumption throughout the life cycle of the building has been calculated (Liu, 2021) or the use of alternative energy supply technologies (Meratizaman et al., 2014).

13.3. Rural and urban residential buildings

Globally, traditional biomass, electricity and natural gas are the most widely used energy sources at the residential level, although with a significant decrease in fossil fuels. Researchers studying more traditional sources often include emissions. The main difference between rural and urban residential buildings is the use of biomass in rural areas of developing and underdeveloped countries (Nejat et al., 2015) for cooking (Zheng et al., 2014), although it is affected if there is the possibility of using some other potential energy resource (Xing et al., 2017). Coal is also used as the main energy source in these areas (Donglan et al., 2010). Despite everything, the residential sector appears to be the most efficient in Saudi Arabia (Dincer et al., 2004).

Total energy consumption in rural households is higher than in urban ones due to the use of inefficient fuels (Pachauri and Jiang, 2008), which also cannot be substituted due to the lack of alternatives (Labandeira et al., 2006). However, residential energy consumption per capita is lower (Zhang et al., 2016). Therefore, as was the case with other factors, rural or urban location has a significant influence from the point of view of energy consumption (Druckman and Jackson, 2008) and, above all, the number of inhabitants in each house (Sood et al., 2023).

13.4. Direct and indirect residential consumption

Energy consumption can have a direct or indirect origin. Those of direct origin are those that make use of energy sources directly (home, personal travel), while those of indirect origin are those contributed to consumer goods and services that will later be used. Energy requirements vary from one country to another, and indirect energy is related to the total cost of the household (Reinders et al., 2003). Thus, direct needs represent 28% of energy consumption in the US, with indirect needs more than double (Bin and Dowlatabadi, 2005); in Korea, indirect consumption represents more than 60% of the energy for which the domestic sector was responsible (Park and Heo, 2007), in the Netherlands it is somewhat lower (Vringer and Blok, 1995) and in India it is similar (Pachauri and Spreng, 2002).

Regarding the differences between urban and rural households in China have been investigated. The indirect consumption of urban residents is 2.44 times greater than direct consumption, while in rural residents exactly the opposite occurs: direct consumption is 1.86 times greater than indirect consumption (Wei et al., 2007).

Total energy needs, both direct and indirect, are also influenced by a few factors. The level of income in the family is the most influential, although the size of the dwelling or the age of the head of the household are also important (Pachauri, 2004). Households with higher incomes have higher total and indirect consumption (Wiedenhofer et al., 2013), however, in percentage terms, households with lower incomes have a higher percentage of indirect consumption with respect to the total (Cohen et al., 2005). References that calculate or analyze consumption in residential buildings with an indication of the main characteristic of the research are shown in Table 7. Linear regression and ANN methods are also commonly used in this case.

14. Residential buildings and others

The works that in the same study jointly analyze buildings dedicated to different purposes basically focus on residential and commercial buildings. This is due to the similar characteristics they share. Thus, in the case of electrical consumption, the supply voltage is usually the same; in addition, depending on the size of the business, the contracted power, in both can be similar. As for gas consumption, the consumption pressure in both cases is also usually the same and, as with electricity, consumption can be similar in many cases. This is the reason why many works carry out the study together and the consumption of both types of buildings is not differentiated. From the point of view of electricity consumption, these are two sectors with high consumption and growth and which are also affected by climatic conditions (Lam et al., 2008a). To assess urban energy consumption, the characteristics of buildings, such as date of construction, morphology, installed technology (Caputo et al., 2013), the needs in times of higher consumption in tourist areas

Table 7
References from residential buildings.

Main characteristic of the research	References
Review	Geng et al., 2017
Rural buildings	Jin et al., 2019; Ekholm et al., 2010; Howells et al., 2005
Urban buildings	Sandberg et al., 2011; Filippín et al., 2013; Sun et al., 2018; López-González et al., 2018; Chen et al., 2011; Chen et al., 2010; Xia et al., 2014; Salat, 2009; Wangpattarapong et al., 2008; Lam, 1996; Ratajczak et al., 2021; Naji et al., 2016b; Hu et al., 2013; Sandberg and Brattebo, 2012; Xu et al., 2024; (Naji et al., 2016a; Urquizo et al., 2017; Zerefos et al., 2012; Filogamo et al., 2014; Yildiz and Arsan, 2011; Firth et al., 2010; Golbazi and Aktas, 2018; Saari et al., 2012; Rhodes et al., 2016; Liu et al., 2016; Houri and Ibrahim-Korfali, 2005; Ali et al., 2021; Wiesmann et al., 2011; Pablo-Romero and Sánchez-Braza, 2017; Cayla et al., 2011; Jones and Lomas, 2015; Blázquez et al., 2013; Bianco et al., 2020; Wang et al., 2020; Wang and Yang, 2019; Jones et al., 2015; Sepehr et al., 2018; Paatero and Lund, 2006; González and Zamarreño, 2005; Yao and Steemers, 2005; Liao et al., 2017; Aydinalp-Koksal and Ugursal, 2008; Bianco et al., 2014b; Marszal-Pomianowska et al., 2016; Shibano and Mogi, 2020; Bourdic and Salat, 2012; Swan and Ugursal, 2009; Buratti et al., 2014; Urquizo et al., 2018; Calderón et al., 2015; Pereira and Assis, 2013; Dall'O' et al., 2012; Ratti et al., 2005; Aksoezen et al., 2015; Liu, 2021; Meratizaman et al., 2014
Rural and urban buildings	Nejat et al., 2015; Zheng et al., 2014; Xing et al., 2017; Donglan et al., 2010; Dincer et al., 2004; Pachauri and Jiang, 2008; Labandeira et al., 2006; Zhang et al., 2016; Druckman and Jackson, 2008; Sood et al., 2023
Direct and indirect consumption	Reinders et al., 2003; Bin and Dowlatabadi, 2005; Park and Heo, 2007; Vringer and Blok, 1995; Pachauri and Spreng, 2002; Wei et al., 2007; Pachauri, 2004; Wiedenhofer et al., 2013; Cohen et al., 2005

(Beccali et al., 2017), or energy savings measures applied (Ghaddar and Bsat, 1998) have been studied. Within the energy measures applied to reduce consumption, the application of green roofs has a special mention in a review carried out (Bevilacqua, 2021). The sensitivity analysis of certain factors has made it possible to verify the variation in consumption produced by modifying some factor (Fung et al., 2006), as well as that the results are not always extrapolated due to the great differences found in the conclusions (Sailor, 2001) due to the influence of the climate.

Studies focused on a certain variable that was desired to be valued have been carried out. In these cases, consumption per inhabitant and per household has been analyzed. When analyzing the influence of climate on energy consumption, it has been found that the more extreme the climate, the greater the consumption (Zarco-Soto et al., 2020); regarding the level of income, the case of total energy consumption (Zarco-Soto et al., 2021b) has been analyzed, and that corresponding to consumption for heating without considering the influence of the climate and taking into account the economy of scale of households (Zarco-Periñán et al., 2021c), finding that, higher incomes, higher consumption; in relation to the size of cities, the larger the city, the greater the consumption (Zarco-Soto et al., 2021a); and with respect to the effect of population density, it has been studied taking into account the area actually occupied by the city (Zarco-Periñán et al., 2021b) and eliminating the influence of the climate (Zarco-Periñán et al., 2021a), obtaining as a result that the denser the city, the more consumption exists. Another conclusion that was obtained in all cases is that electricity consumption is approximately constant, regardless of the variable analyzed.

The estimation of consumption from different variables, such as radiation (Soldo et al., 2014), housing construction and household appliance consumption (Ozturk et al., 2004), consumption data (Akpinar and Yumusak, 2016), or consumption characteristics (Tavakoli and Montazerin, 2011; Forouzanfar et al., 2010) has been investigated, obtaining predictions one hour in advance considering the ambient temperature (Yun et al., 2012).

In addition to the joint study of the residential and commercial sectors, a model to estimate the consumption of buildings in a city has been developed, obtaining that its consumption depends on the function of the building (Howard et al., 2012). Prediction for UK and Canada in different types of buildings has been carried out (Jogunola et al., 2022); and the influence that the building environment has on the prediction of consumption has been analyzed, reaching the conclusion that the building environment and building configuration have notable influence (Wang et al., 2024), with surrounding vegetation and the existence of water being two factors that reduce energy consumption (Bucarelli and El-Gohary, 2024). Also including the industrial sector, it has been concluded that the residential sector is the most sensitive to the price of energy (Wang and Lin, 2014).

As in the analysis and calculations referred to other types of buildings, linear regression and ANN methods have been used to perform them. Table 8 shows the references that calculate or analyze consumption due to residential buildings and others with an indication of the main characteristic of the research.

15. Energy demand calculation methods

Some papers include buildings dedicated to different uses because their study focuses on the methods used to calculate energy demand. For this reason, this section has been added despite not fitting the proposed classification.

In recent years, numerous studies have addressed the prediction of energy demand in buildings. This has given rise to numerous works on Deep learning techniques, one of the most widely used techniques. This technique has been very widespread because of the way it models nonlinear problems and its ability to work with large amounts of data (Runge and Zmeureanu, 2021). Yu et al., (2022) reviews prediction methods using different techniques.

Table 8
References from residential buildings and others.

Main characteristic of the research	References
Variations in consumption	Lam et al., 2008a
Characteristics of buildings	Caputo et al., 2013; Beccali et al., 2017; Ghaddar and Bsat, 1998; Bevilacqua, 2021
Sensitivity analysis	Fung et al., 2006
Extrapolation of results	Sailor, 2001
Influence of factors in consumption	Zarco-Soto et al., 2020; Zarco-Soto et al., 2021b; Zarco-Periñán et al., 2021c; Zarco-Soto et al., 2021a; Zarco-Periñán et al., 2021b; Zarco-Periñán et al., 2021a
Consumption prediction	Soldo et al., 2014; Ozturk et al., 2004; Akpinar and Yumusak, 2016; Tavakoli and Montazerin, 2011; Forouzanfar et al., 2010; Yun et al., 2012; Howard et al., 2012; Jogunola et al., 2022; Wang et al., 2024; Bucarelli and El-Gohary, 2024
Price sensitivity	Wang and Lin, 2014

16. Discussion

Publications that analyze or calculate energy consumption in buildings have been identified and grouped according to the proposed classification. The classification has been based on the publications made by the researchers. The analysis has been focused on the types of buildings studied, calculation methodology used, energy sources, greenhouse gas emissions and variables used in the studies.

The number of references for each of the proposed classification groups is shown in Table 9. The largest number of studies have been carried out on urban residential buildings, with more than 25% of the studies. This is followed by studies on heating and air conditioning in buildings, with a difference of more than 10 points. On the opposite side, hospital facilities and rural residential buildings with 1.42% each, and banking sector and technology centers with 0.47% are the buildings on which the fewest studies have been carried out. This may guide future research. In them, analysis methodologies used for other types of buildings can be applied in the future. Other sectors, such as commercial and residential, are the most investigated. Being the most widespread, they are where any measure implemented can generate greater savings in energy consumption. These sectors have been analyzed independently or grouped according to their common characteristics. It should be noted that the consumption and characteristics of the facilities can coincide in many cases, hence their grouping in the studies.

Table 9
Percentage of references by classification group.

Classification group	Percentage (%)
Hospital facilities	1.42
Teaching centers	7.58
Banking sector	0.48
Technology centers	0.48
Hotel facilities	9.48
Office buildings	7.58
Commercial buildings	2.84
Non-residential buildings	4.27
Heating and air conditioning in buildings	16.11
Residential buildings	0.47
Rural residential buildings	1.42
Urban residential buildings	26.54
Rural and urban residential buildings	4.74
Direct and indirect residential consumption	4.27
Residential buildings and others	11.37
Energy demand calculation methods	0.95

The studies have served both to identify the current energy consumption situation and to make predictions about it. For both cases, regression methods are commonly used. However, other experimental methodologies for this type of studies have been used, such as ANN or machine learning, which has been increasingly used in the past few years.

Regarding the fuels used, there are differences between countries depending on their level of development. Even within the same country, there are differences between areas with a higher or lower level of development. As the degree of development increases, the use of electricity and natural gas is greater. On the contrary, in less developed areas, the use of biomass and fossil materials is the most common. For this reason, electricity and natural gas are the most studied energy sources.

All the research presented shows energy consumption in buildings, however, few do so in a similar way. In some cases, they are presented as annual values, in others by season, monthly or by day of the week, and in others by hour or by minute. In other cases, they are presented by m^2, by room, by bed, by occupancy or by per capita values according to the size of the home. There is also diversity in the way of expressing it: in some cases, in Mtoe (Million ton oil equivalent), or in MTSCE (million tons of standard coal equivalent), in other cases in Joules or kWh, and sometimes the results are presented according to the type of energy consumed or the consumer equipment. Although most studies are carried out at the level of individual buildings, others are carried out at the level of a specific area, city or country and sometimes even a distinction is made between the climatic zones in which the building is located. Despite all this, and in order to have an order of magnitude of energy consumption according to the type of building, Table 10 shows the consumption of buildings per kWh/m^2. These data have been obtained from those investigations whose results are shown in comparable units. The highest consumption occurs in hotel facilities and commercial buildings, with very similar values, followed by hospital facilities with 11% lower consumption. Next, with 58% less consumption, are office buildings and technology centers. Consumption in urban residential buildings is 73% lower than that of hotel facilities, with teaching centers in last place with only 9% of that consumption.

Concern about greenhouse gas emissions has led to a more in-depth study of energy consumption. The main objective is to seek measures to reduce them, although the studies are not concerned with analyzing these methods, but only with showing the data for further research to develop them. Despite this, numerous investigations have already included gas emissions and other possible improvement methods to reduce energy consumption. As cities are places where any measure applied has a large multiplier effect, it is on urban residential and commercial buildings that researchers have focused. In some cases, research has been limited to heating and air conditioning because that is where energy consumption is increasingly being used. In other cases, only electricity consumption has been considered because it is considered by the authors to be the most relevant. However, to obtain a true global vision, the consumption of all energy must be considered, regardless of the source from which it comes, and the use made of it.

The characteristics of energy use in each type of building are considered in the studies when the study variables are chosen. Thus, hospital and hotel facilities make intensive use of energy 24 hours a day, every day of the year, although consumption decreases at night; furthermore, in the case of hotels, the greater or lesser consumption is seasonal. Something similar occurs with commercial buildings, where intensive use is made every day of the year, although most of them do not do so 24 hours a day. Office buildings are used intensively during their operating hours, which are usually during the day and on weekdays, and do not consume energy during the weekend. Something similar occurs in teaching centers, with the difference that they have less intensive use. Finally, urban residential buildings have specific characteristics that depend on the work environment and the number and age of residents, but, as with other buildings, they have a recurring consumption.

All the above has led researchers to use a wide variety of variables in their research. They have depended on the intended use of the buildings. From the most common, such as the climate, the income of the inhabitants, the population density, the type and use of the building or its geometry; to others in which bills, the existence of cafeterias in buildings for public use or Wi-Fi traffic are considered. In all cases, the results presented in the investigations are favorable for the desired purpose. The latter are mainly used to show that they are viable alternatives, although their scope of application is very limited. Thus, they would only be applicable in buildings in which they have been used or similar, since in others the results obtained would not be satisfactory.

Other characteristics that have been studied in some studies in different types of buildings are the year of construction and the climatic conditions in which they are located. The younger buildings have the lowest consumption due to the technological innovations introduced in their construction and the use of better insulating materials. And with respect to the environmental conditions in which the buildings are located, in places with more extremely climatic conditions, both hot and cold, these buildings have the highest consumption; in one case due to the intensive use of air conditioning and in the other to heating respectively.

Ways to reduce energy consumption have also been shown in various investigations, regardless of the use of the building. These methods are valid for all of them: improved insulation of buildings, mainly in walls, doors and windows; adaptive use of air conditioning to existing conditions; use of low-consumption equipment; control of air access points to the interior of the building; use of lighting when only necessary; green roofs; adequate maintenance of installations and equipment; use of efficient equipment; and responsible use of energy. An improvement, in terms of losses in the distribution of energy, is the use of renewable energy produced in the same building. In the case of newly constructed buildings, all these measures must be considered and, whenever possible, appropriate guidance must be given to reduce consumption.

To analyze where the most studies have been carried out, the country of origin of the first author was considered and the authorship of the paper was assigned to that country, even if there were researchers from other countries. The studies were grouped by continent. On this basis, almost half of the studies were carried out in Asia (46.19%). This was followed by Europe, with 41.43%. On the opposite side are Africa and Oceania, from where 1.43% and 0.95% of the studies were conducted in

Table 10
Energy consumption by type of building.

Type of building	kWh/m^2
Hospital facilities	306
Teaching centers	33
Technology centers	142
Hotel facilities	345
Office buildings	146
Commercial buildings	343
Urban residential buildings	94

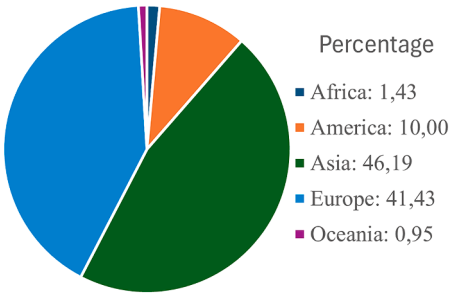


Fig. 3. Percentage of papers by continent.

each of them respectively. Fig. 3 shows the percentage of papers by continent.

By country, China, with more than 50 references and more than 25% of the total, is the country from which most studies have been developed. This is followed by Spain and Italy with 17 studies each, the United Kingdom with 14, the USA with 13 and Turkey with 12.

The same analysis has been carried out from another point of view. In order to confirm their studies, the researchers applied them to buildings in different locations. Grouping them again by continents, the results shown in Fig. 4 are obtained. In this case an additional element has been included in addition to the continents. This is because some studies have not focused on countries in a single continent. As was the case previously, it is in Asia where most of the research has been applied, reaching 43.81%. Europe is again in second place with 37.14%. The last place is occupied by Oceania with 0.95%. This is due to the fact that the researcher chooses a location close to his place of work to apply the methodology of his studies.

By country, China is once again the country on which the studies have been directly applied, with more than 25%. This is followed by the United Kingdom with 16, Spain with 14 and Italy, Turkey and the USA with 13 each.

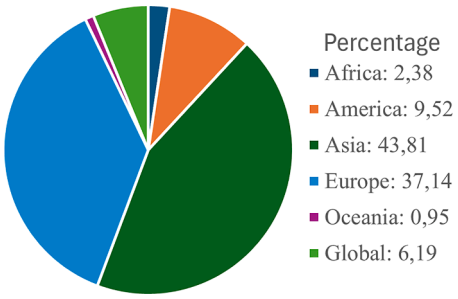


Fig. 4. Percentage of application of studies by continent.

17. Conclusions

Although the area occupied by cities is very small, more than half of the population lives in them. In addition, it is in them where more than 60% of the energy is consumed and in buildings it reaches 36%. Therefore, any action that affects the type of energy consumed in buildings or its reduction has a great multiplier effect. This importance is reflected in the recommendations or instructions of government authorities at the global, continental, or city level, whose goal is the improvement of environmental quality.

A classification and compilation of published studies that show or calculate the energy consumption of buildings in cities has been carried out. The groups presented in the publications have been respected. The classification has been made considering the purpose for which the building is dedicated and its location in the case of being residential. In this way, researchers will have access to the state of the art of energy consumption according to the type of building they are studying.

Regarding energy consumption by type of building, hotel and hospital facilities and commercial buildings consume the most energy per m^2, followed by office buildings and technology centers with almost 50% less consumption. Finally, urban residential buildings and teaching centers consume the least energy.

Being calculation methods, types of buildings, energy source and variables used to obtain the results the most significant characteristics in these studies, they are the ones that have been shown in the manuscript. Regarding analysis methods and calculations, regression and ANN methods are the most frequent in all cases. Other experimental calculation methods have also been used, also obtaining good results. Regarding the most studied buildings, they are those that can generate greater savings from an energy point of view. Thus, Commercial and residential buildings have been the most analyzed. This is largely due to the fact that they are the most numerous and any improvement introduced in them can cause significant savings in consumption. As for the fuels used, their use basically depends on the degree of development of the area in question: as it becomes more developed, the use of electricity and natural gas increases to the detriment of biomass and fossil fuels. Likewise, the variables used to carry out the studies have been shown, indicating how the most common ones influence.

Some research makes use of very specific characteristics of the use of the building. For this reason, using these characteristics as variables for other buildings is not feasible. Thus, the use of the number of hospital interventions as a variable for other buildings is not applicable. However, the variable of the number of beds or the energy consumption based on the surface area can be used in both the hospital and hotel sectors, as has occurred in some studies. Something similar happens with the variables used to calculate energy in teaching centers, such as the existence or not of a cafeteria; however, the Wi-Fi traffic variable used there could be of interest for future studies in the banking sector. In the case of hotel buildings, a variable that is very important for calculating energy consumption is their category, but this cannot be extrapolated to other cases. The same occurs with the number, composition and characteristics of household members, which are only applicable to residential buildings.

However, other variables are of interest to all buildings, although they have not been widely used, nor in all sectors. For example, the year of construction, which affects the construction and insulation materials, and the possible deterioration produced; or whether the building has been retrofitted to make use of the latest energy-efficient solutions. This has a similar effect on all types of buildings. In this case, older buildings have higher consumption. Also, the economic conditions and GDP of the area in which the building is located are variables used mainly in residential buildings and that can be applied to all buildings.

On the other hand, other variables have been widely used in all cases, such as those related to climatic conditions; or in most of them, such as the orientation of the building, its external and internal geometry, its envelope or the urban morphology that surrounds it. In this case, buildings located in very cold or very hot areas are those that consume the most energy, mainly due to the air conditioning required for buildings. Closely related to this, measures to improve the insulation of buildings and make more responsible use of energy have also been presented. These measures are valid for all types of buildings.

References on the main buildings have been presented: hospitals, schools, banking sector, hotels, offices, commercial buildings, non-residential and residential buildings. With this, the researchers interested in the consumption of each of the buildings in these sectors will be able to consult the references shown in each section and will have knowledge of the state of the art.

CRediT authorship contribution statement

Fco Javier Zarco-Soto: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Irene M Zarco-Soto:** Writing – review & editing, Writing – original draft, Validation, Investigation, Formal analysis, Data curation, Conceptualization. **Sharif Shofirun Sharif Ali:** Writing – review & editing, Supervision, Formal analysis, Conceptualization. **Pedro J Zarco-Periñán:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

We have nothing to declare.

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Data availability

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

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