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The Impact of Residents' Behaviour on the Energy Consumption of Buildings: A Case study of Residential Building in Guelma, Algeria

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Abstract
Since the beginning of this century, energy consumption has grown rapidly in various regions around the world. It seems that energy consumption will continue to increase, partly due to economic growth and partly due to an increase in per capita energy consumption. Since the implementation of the first energy-saving measures, the issue of energy efficiency in buildings has always been at the heart of energy and climate policies, whether at the European, national or local level. In this context, this article is organized into parts, starting with an introduction that summarizes the situation and then the methodology that attempts to examine the energy efficiency of buildings by taking into account the synergy between urban planning and occupant behaviour through a questionnaire. So, the question that arises is how can energy consumption in residential buildings be influenced by occupant behaviour. Among the constraints that we found in this work were the gaps in the information and the subjectivity of the answers obtained by the occupants. The main results show a significant impact of occupant behavior on energy consumption. After a questionnaire on 20 dwellings, we obtained answers on the equipment used in all the dwellings. Then, we made a provisional calculation of the consumption according to the days and times that the occupants were present in their homes. Finally, energy efficiency offers governments and communities a cost-effective way to achieve a variety of goals, such as reduced energy consumption, lower emissions, financial savings, energy security, and positive health impacts.

Keywords: Energy efficiency; energy security; residential building; inhabitant behavior; city of Guelma.

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1. Introduction

In the context of sustainable development, the twin global challenges of the impending depletion of fossil energy resources and related environmental issues provide strong incentives for the development of renewable energy. Today, more than 85% of energy production comes from fossil fuels such as oil, coal, natural gas or nuclear power. However, these forms of production cause serious environmental pollution through the release of greenhouse gases, irreversible climate change or, in the case of nuclear energy, long-term exposure to radiation, which raises the issue of the storage of radioactive waste, which has not yet been resolved (Fabi et al., 2011, 2013).

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In recent decades, our planet has been depleted of its resources and wealth. The World Summit on Sustainable Development in Johannesburg in 2002 revealed an alarming picture (Beslay et al., 2014). This summit then paved the way for a series of international agreements in 2005, leading to the entry into force of the Kyoto Protocol, which states that "Sustainable development, combating climate change, reducing energy consumption in buildings and reducing greenhouse gas emissions"... "Greenhouse gas emissions are an important requirement" (Emery and Kippenhan, 2006).

The Fourth IPCC Report made particularly alarming statements about the effects of climate change and underlined the idea that controlling energy consumption will become one of the key issues of the 21st century, citing the gradual decline of fossil fuels and the resulting price increases related to these energy sources as well as the predicted effects of global warming (Haldi, 2010).

In the Action Plan and in the current emergency situation - to achieve these objectives - it is essential to address energy management and sustainable development in the building sector, and then to seek alternative sustainable energy solutions capable of meeting our long-term needs.

With this in mind, the building sector is the largest consumer of energy, representing between 30 and 40% of the world's final consumption (Haldi and Robinson 2009).

To understand why this sector poses important challenges in terms of energy and climate policy objectives, we must first recall its weight in terms of energy consumption and greenhouse gas emissions.

Factors that influence energy consumption include climate, building envelope, installation type, building operation and maintenance, occupant activities and behaviour, and indoor environmental quality (Al-mumin et al., 2003). According to Annex 53 of the International Energy Agency, occupant behaviour is one of the factors that influence building energy consumption (Liebard and De Herde, 2006).

Occupants influence energy consumption and indoor environmental conditions through various types of interactions:

1. Existence is the source of heat, moisture and CO_2 emissions associated with metabolism. It is also a prerequisite for the actions listed below (Brisepierre, 2011).
2. Opening/closing windows changes the temperature and quality of the indoor air (Bruno and Karliner, 2002).
3. The management of shading devices influences solar gains, as well as indoor lighting and, consequently, the use of artificial lighting (Gay J.B, 2001).
4. The use of artificial lighting and electrical appliances is synonymous with electricity consumption and internal heat gain through the Joule effect (Guerra Santin et al., 2009).
5. The management of temperature settings determines heating and cooling consumption (Haas and Biermayr, 1998).
6. The drawing of domestic hot water (DHW) generates energy consumption and modifies the indoor temperature and humidity conditions (Yoshino et al., 2017).

The main objective of this paper is to highlight the link between occupant behaviour and its impact on residential buildings. This study examines a methodology that investigates energy practices in residential buildings through a survey.

The question is: How does occupant behaviour affect the energy consumption of residential buildings?

This paper is divided into four parts. The first part presents the current state of the art. The second part presents the analysis methodology based on a questionnaire applied to our case study "City Guehdour Tahar" in Guelma. The third and fourth parts examine the results and discuss the main contributions of this paper.

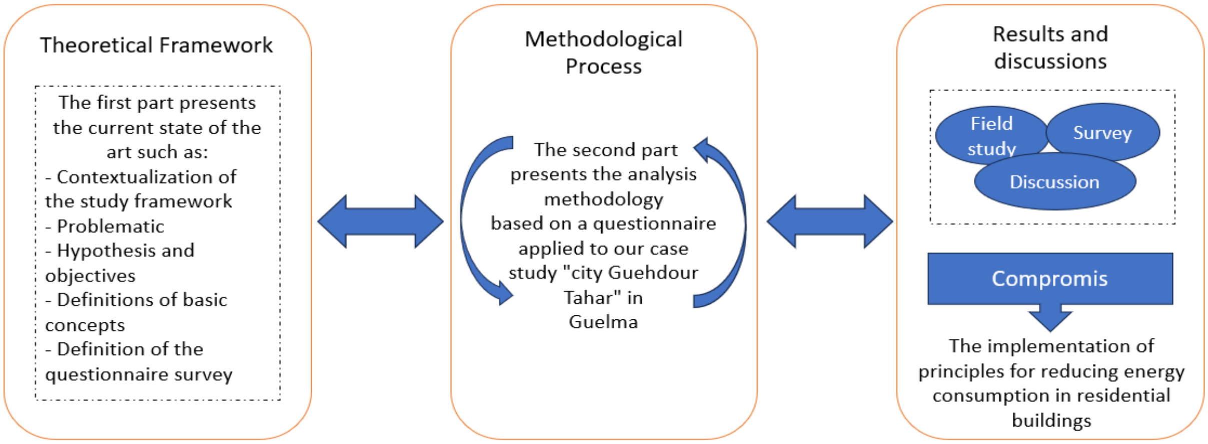

Figure 1. A graphical figure representing the theoretical framework and methodological process of the study.

2. Material and methods

2.1 Definition of the concepts

2.1.1 Energy efficiency

In economics, energy effectiveness or energy efficiency refers to the operating state of a system in which energy consumption is minimized for an identical service provided. It is a special case of the concept of efficiency. It concerns in particular motorized transport, buildings and industry (the latter being responsible for around 40% and 25% respectively of total energy consumption in the European Union) (Greening et al., 2000). Energy efficiency is generally based on optimizing consumption, which includes seeking the lowest energy intensity (for the same service), 'rational use of energy' and more efficient processes and tools. Energy-saving components are designed to reduce waste and unnecessary consumption. It is therefore also an important component of environmental performance. In some cases, energy savings can even improve service quality. In recent years, it has often been associated with the concepts of smart energy or smart grids.

Energy efficiency also aims to reduce the environmental, economic and social costs (direct and indirect) of producing, transporting and consuming energy. It contributes to reducing the environmental footprint (by reducing the energy footprint and sometimes the carbon footprint). It improves energy security, adaptation to climate change, the fight against greenhouse gas emissions, the environmental transition and, even more, the energy transition (Gerard et al., 2003).

Known as the "first fuel" in the clean energy transition, energy efficiency offers fast and cost-effective solutions to reduce CO_2 emissions, lower energy costs and improve energy security. In the Net Zero Emissions by 2050 (NZE) scenario, energy efficiency is the most important measure to curb energy demand, complemented by electrification, behavioural change, digitalization and material efficiency. Together, these measures determine global energy intensity, which is the amount of energy required to produce a unit of GDP. In the NZE scenario, global energy intensity is projected to fall by an average of 4% per year this decade, exceeding the 1.7% reduction observed over the past decade. While all measures to reduce energy demand contribute to improving energy intensity, this page focuses primarily on the energy performance of specific technologies (Andersen, 2012; Andersen, 2014).

2.1.2 Energy security

The availability of natural resources for energy consumption and national security are combined to create energy security. The ability to access affordable energy has become critical to the functioning of modern economies. However, there are serious vulnerabilities as a result of the uneven distribution of energy supplies among nations. Globalization has been facilitated by international energy interactions, which can lead to both energy security and vulnerability, depending on the situation and the actors involved.

Unlike other energy sources, which are concentrated in a small number of nations, renewable energy, energy efficiency and energy transition measures can be implemented across large geographical regions. If energy efficiency and renewable are rapidly deployed and technologically diversified, energy security will be enhanced and there will be significant economic benefits (Aerts et al., 2014).

Energy security is defined as the continued availability of energy sources at a reasonable cost. This concept encompasses different dimensions, with long-term energy security emphasizing the importance of timely investment to meet energy demand in a manner that is economically and environmentally sustainable. In contrast, short-term energy security refers to the ability of the energy system to respond quickly to unexpected fluctuations in the supply-demand balance (Andersen, et al., 2013).

2.1.3 Urban design & architectural design

Urban design is understood as a process of collective definition of development choices that will outline and give substance to urban development projects. We understand this phase of defining development choices in the broadest sense, i.e. integrating both the preliminary project (or programming) phase and the detailed design phase.

Indeed, it seems simplistic to limit urban design to the work of a single urban designer (the one commissioned to design the development project) or even to the work of a multidisciplinary project management team. It is more likely to be the work of a group of actors, each with different roles, visions and resources (Andreou, 2014). By considering all relevant factors, architectural design is a conceptual approach to architecture that determines how the material and physical environment is produced. In developing an architectural design, an architect must consider the needs and resources of society when analyzing, conceiving and realizing buildings, urban complexes and rural areas. In addition, the architect must create a place that meets the standards and regulations of the building community, as well as aesthetic and technical requirements.

To maximize the efficiency of the space and create a cohesive whole, the intended use of the space must be considered from the design stage. The aim is to create spaces that are both pleasant and useful, while expressing the personality of the owner and the building's users. The architect manipulates the volumetry of spaces, artificial and natural light, colors, shapes, textures, fixtures, materials and other elements to achieve this. In addition to respecting the client's budget, he will also take into account the preferences of the occupants and the values of the company (Benzerari, 2013).

2.1.4 Occupant behavior in buildings

Occupant presence, mobility and interaction with building energy systems and equipment are all considered forms of occupant behaviour. However, there are gaps in the modeling of occupant behavior, as different energy modelers have used different data and technologies to mimic occupant behavior, leading to inconsistent and differing conclusions. (Xie et al., 2019).

Occupant behaviour (OB) is a broad category that includes all phenomena related to how building occupants respond to external variables that depend on the physical characteristics of the structure.

These include the time of day, the predicted state of the building systems, the indoor and outdoor environmental conditions, the individual attributes of the individuals (e.g. age and gender), and physiological, psychological, social and random factors (Abrahamse and Steg, 2009).

2.2 Occupant behaviour, energy efficiency and their relationship to architectural design

Occupant behaviour is a major source of uncertainty in predicting building energy use. Extensive studies have shown large differences in the performance of residential buildings with similar characteristics and climatic conditions, and how occupants interact with the building envelope and systems (Arab, 2007). In addition, more stringent energy regulations in recent decades have led to energy-efficient design strategies with the aim of achieving near-zero energy consumption. Occupant behaviour has a direct impact on building energy consumption and thermal comfort, as numerically demonstrated by many studies.

Cayla et al, (2010) have shown that using the same technical equipment, the energy consumption can change three times due to the temperature set point and the air change rate required by the occupants. As a result, energy consumptions are no longer those predicted by classical thermal simulations. Similarly, comfort levels can vary and sometimes the behaviours that the occupant considers beneficial can instead cause discomfort.

A better understanding of the interactions between people and buildings allows us to describe occupant behaviour more accurately.

2.3 Methodology

2.3.1 Case study

Algeria is a North African country in the 'Maghreb' region. It has been known as the People's Democratic Republic of Algeria since 1962. Its capital is Algiers, the country's most populous city in the north on the Mediterranean coast. As of 1 January 2021, the resident population of Algeria had reached 44.6 million. The largest country in Africa, the Arab world and the Mediterranean basin, with an area of 2,381,741 km2, Algeria shares 6,385 km of land borders with Tunisia to the northeast, Libya to the east, Niger to the southeast, Mali to the southwest, Mauritania and Western Sahara to the west and Morocco to the northwest.

Our case study focuses on the wilaya of Guelma, an Algerian wilaya located 60 km southwest of Annaba, 110 km east of Constantine, 60 km from the Mediterranean Sea and 150 km from the Tunisian border. The wilaya of Guelma was established in 1974 and comprises 10 dairas: Guelma, Khezarra, Guelaat Bou Sbâa, Heliopolis, Oued Zenati, Ain Makhlouf, Hammam Debagh, Bouchegouf, Hammam N'Bails and Ain Hessaïna, and 34 communes. It covers a total area of 4101 km2 and has a population of 524,443 inhabitants (2014). Founded in 1854 as a mixed commune, it became the capital of the district (daïra) in 1858 and finally obtained the status of wilaya capital in 1974.

In its urban growth, the city of Guelma has experienced several successive forms of urbanization, and the current city is the result of its historical evolution. It can be divided into three main periods of urbanization (pre-colonial, colonial, post-colonial) and three types of urbanization (the Euro-Popean grid nucleus, spontaneous urbanization and planned urbanization).

The city of Guehdour presents these peculiarities, which we will discuss in this article. Situation of the city Guehdour in relation to the city of Guelma. The city Guehdour Taher is located in the center of Guelma.

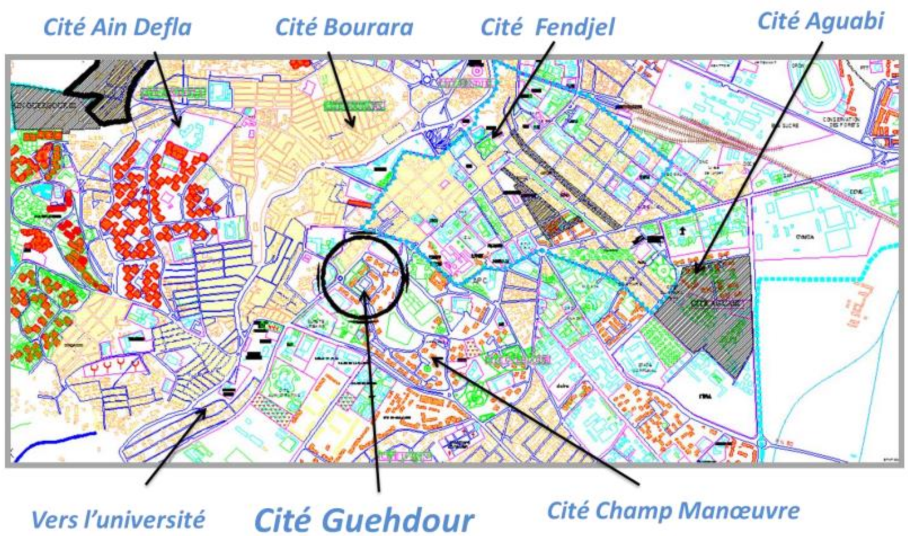

Figure 2. Location map of Guahdour Taher city. (Map of the municipality of Guelma, 2023).

3. Results

The study area is characterized by a type of collective housing with the presence of 5 individual houses scattered in the study area.

1. The heights of the buildings are between ground floor + 3 and ground floor + 4.
2. The size of the houses is between 3 and 4 rooms, which does not meet the needs of the Algerian family.
3. Lack of respect for the built environment.

The blocks have standard layouts, with each layout comprising four apartments, circulation areas and a central staircase. The bedrooms are located in the southern part, while the living rooms and kitchens are in the northern part (Figure 2). These buildings have high energy consumption, inadequate insulation in the building envelope, single glazed windows and inefficient appliances. Gas-fired boilers are used to meet space heating and domestic hot water requirements, while evaporative (electric) chillers are used for space cooling. Both electricity and gas are supplied from the national grid.

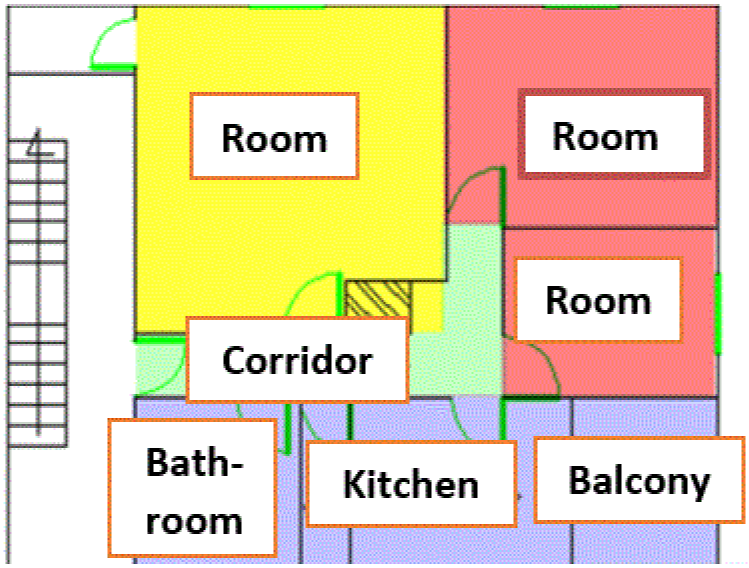

Figure 3. The plan of the buildings.

3.1 Field Study

This research uses the questionnaire technique to assess occupant behaviour in several areas that affect energy use in residential buildings. In order to mitigate the potential influence of respondent inertia, a number of questions were asked on an inverted scale. To validate the questionnaire and assess the clarity and accuracy of respondents' interpretations, a preliminary survey was first distributed. After minor adjustments, the revised questionnaire was then distributed to the residents.

The final questionnaire consisted of two sections: 1) characteristics of the building occupants and 2) behaviour related to the use of heating/cooling systems. A total of 20 valid responses were obtained from the 20 selected dwellings.

3.2 The content of the questionnaire

3-2) Content of the questionnaire

The first step of our study is to record the behaviour of the occupants by means of questionnaires filled in by the selected households. This questionnaire includes: the date of occupancy of the house, the type of occupancy of the house (permanent, occasional), the state of the building (original, modified, demolished and rebuilt) and finally the type and number of appliances used in the dwelling.

The final results included the characteristics of the building's occupants, the use of the heating/cooling system and the equipment used (mode of operation, duration of use, etc.).

The questionnaire was administered as follows:

Table 1: The content of questionnaire.

Question	Answer
When did you move into your home?	Answers are included between 1996 and 2007.
You have lived in your home since: - Permanently - Occasionally (for holidays or other)	- Permanently (the answers to this question are 80%) - Occasionally (for holidays or other) (the answers to this one is 20%)
What is the condition of your home? - In its original state - Raised - Demolished and rebuilt - Fence modified - Minor alterations - Other	- In its original state (all residents chose this answer)

If it is in its original state, it is for the following reason: - You like the style and want to keep it - You don't have the means to modify it	- You like the style and want to keep it - You don't have the means to modify it (the answers relate to this point)
How much equipment do you have in your home? What equipment do you have?	The majority of answers are 10 items Television + Demo Fridge 250 L Computer Mobile phone Heating Air conditioner Hoover Electric shaver Hair dryer
How many hours do you use the heating in winter?	Answers are included between (10-14 hours per day)
How many hours do you use cooling equipment in summer?	Answers are included between (4-8 hours per day)
How many people live in the house?	Responses are included between (02-07 people per dwelling)
How many active (working) people live in the house?	The answers are included between (01-03 people per dwelling)

3.3 Working limits

3.3.1 Lack of honesty:

While there are several advantages to using questionnaires, lack of respondent honesty can be a challenge. It is possible that individuals may not provide completely truthful answers for a variety of reasons, such as adherence to social norms or concerns about privacy. To address this issue, it is important to reassure respondents that their privacy is of the utmost importance and that their identity will not be revealed during the process.

3.3.2 Shallow responses

It is every administrator's wish to receive comprehensive responses, but it is impossible to determine whether the respondent has given adequate thought to the question before answering. In some cases, answers are selected before reading the question or the available options. Some people may even skip questions or make hasty decisions, which can negatively affect the reliability of your data. Although this drawback is difficult to overcome, limiting the length of your survey and asking simple questions can increase the likelihood of getting accurate responses.

3.3.3 Differences in comprehension and interpretation

Not presenting questions to users in person can lead to different interpretations of the questions. Without a thorough explanation of the questionnaire and ensuring that everyone understands it in the same way, results can become subjective. In addition, respondents may struggle to understand the intended meaning of certain questions that may seem clear to the creator. This miscommunication can lead to incomplete or truncated results. To avoid this, it is advisable to ask simple questions that require simple answers.

3.3.4 Feelings and meanings that cannot be conveyed

It is important to note that emotional responses and feelings of respondents cannot be fully captured by a survey or questionnaire. The lack of face-to-face interaction makes it impossible to observe facial expressions, reactions or body language, which are crucial to understanding the subtleties of the data. To avoid misinterpreting emotions, it is recommended to use a Likert scale, which offers a range of ratings from 'somewhat agree' to 'strongly disagree'. This approach allows the strength and clarity of responses to be assessed, rather than relying on multiple choice options.

3.3.5 Some questions are difficult to analyses

Questionnaires generate a considerable amount of data. Multiple-choice questions (MCQs) can be organized and presented graphically, but the situation is different for open-ended questions. Open-ended questions allow for personalized responses that cannot be measured and require human evaluation. An overabundance of open-ended questions can result in an overwhelming amount of data that exceeds analytical capabilities. To avoid this dilemma, choose your question types carefully. If you have ten questions, it is advisable to limit open-ended questions to no more than one, as this type of question is not quantifiable.

3.3.6 Respondents may have hidden interests

As with all forms of research, the presence of bias can be a challenge. Individuals taking part in your survey may have a vested interest in your product, concept or service. In addition, others may be inclined to participate due to the nature of the subject matter being explored in your questionnaire.

These biases have the potential to introduce inaccuracies into your data, leading to an uneven distribution of responses as individuals perceive your topic in an overly positive or negative way. To counteract the influence of these hidden interests, it is advisable to use pre-filtering techniques. By including indirect questions in your survey, you can effectively mitigate the impact of these factors that can distort the results.

3.3.7 Lack of customization

Customization is an essential aspect of marketing. Any marketing tool has the potential to come across as impersonal and therefore requires the investment of time and effort to personalize it. Failure to include personal touches can deter some respondents from engaging with the content. This challenge is particularly pronounced when questionnaires or surveys are completed voluntarily on a website, rather than in the context of a purchase or email. To address this, it is critical to consistently send personalized emails, use dynamic content on websites and make a concerted effort to include names, personal information and customized content across all communication channels.

3.3.8 Unanswered questions

In questionnaires it is possible to omit certain questions. If questions are not mandatory, there is always the possibility that they will go unanswered. Online questionnaires offer a simple remedy for this problem: require an answer to every question. Alternatively, make sure the survey is concise and the questions are straightforward. This will prevent questions from being omitted and will result in higher response rates.

3.3.9 Accessibility issues

When choosing a research method, it is important to remember that lack of accessibility can be a threat regardless of the mode of administration. Users with visual or hearing impairments, as well as those who are illiterate, may not be able to participate in surveys. It is therefore crucial to choose a survey platform that has built-in accessibility options to ensure inclusivity.

4. Discussion

After a questionnaire on 20 dwellings, we obtained responses on the equipment used in all the dwellings, and then we obtained the service modes of this equipment.

We then investigated the capacity of each piece of equipment used and obtained responses on the duration of use of these appliances.

Finally, we made a preliminary calculation of consumption according to the days and times that the occupants were present in their homes, which gave us the results shown in the table below.

Table 2: The equipment and consumption characteristics of the occupants in our case study.

Equipment	Service mode	Energy (W)	Duration / Day	Average consumption/Day (Wh/Day)
Television + Demo	In service In standby mode	90-250 3	5h 19h	757
Fridge 250 L	/	150-200	Continue	551
Lighting	/	75	1h – 6h	1875
Computer screen	In service In standby mode	70-80 3	4h	306
Phone charger	/	5	4h	0,5
Heating	/	/	Winter period	/
Air conditioner	/	900-1200	Summer period 4h	2400
Vacuum cleaner	/	650-800	12 min	144
Electric shaver	/	8-12	3 min	0,5
Dryer	/	300-600	10 min	37,5
Total energy/day	/	/	/	6071,5

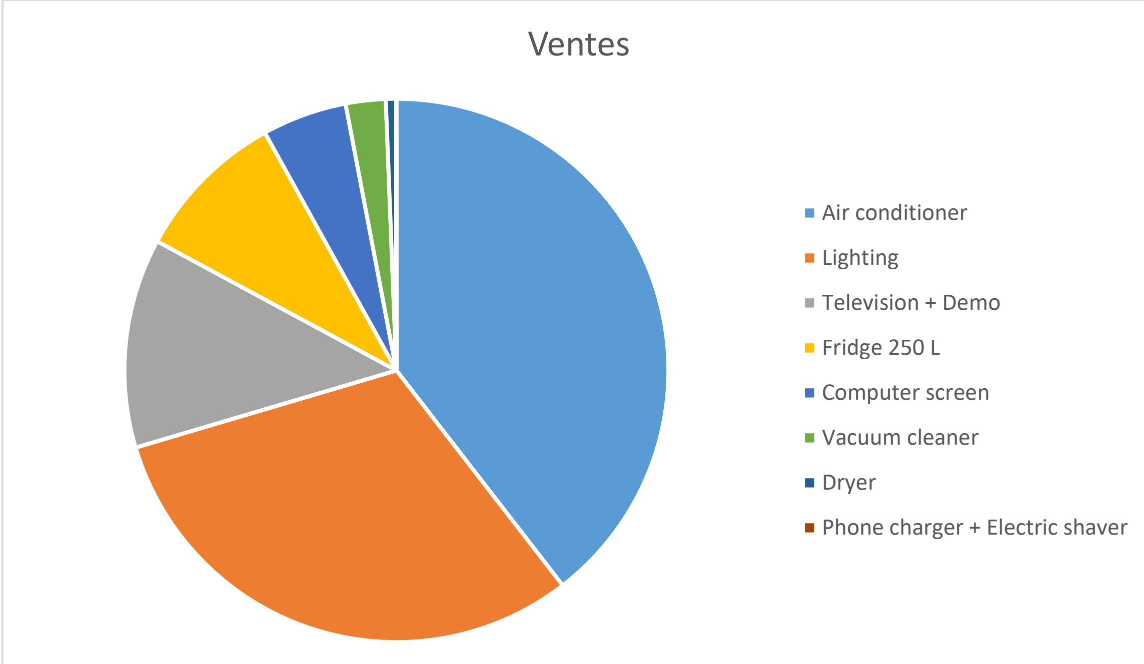

Figure 4. Graphic of the equipment in our case study.

The focus of this paper is to investigate the relationship between occupant behaviour and its impact on residential buildings using a questionnaire-based approach. The primary findings indicate a significant influence of occupant behaviour on energy consumption.

However, there are some limitations to this study. Firstly, the questionnaire survey was carried out over a limited period of time and was not repeated. To obtain a more accurate analysis of occupant behaviour, it is necessary to monitor occupancy over time, rather than relying on one-off surveys. In addition, it is important to note that occupant behaviour in this study is based on self-report rather than direct observation, which may affect the accuracy of the data. Finally, the sample size of the buildings studied is relatively small, with occupants from similar cultures and occupations living in the same building.

Nevertheless, this study highlights the importance of considering specific occupant behaviour in building research, particularly when developing building retrofit strategies. Retrofit designers, policy makers and standards should priorities educating occupants to change their energy consumption behaviour in order to effectively reduce energy consumption. This recommendation is in line with previous studies in this area (Jami et al., 2020).

Empowering occupants and increasing their energy awareness through educational methods could be effective and practical (Blight and Coley, 2013). In addition, motivational programmes, such as displaying real-time consumption data to occupants, could be crucial in changing energy-wasting behaviours. Getting instant feedback on energy consumption from smart appliances could be helpful (Emeakaroha et al., 2012).

This research study has highlighted the significant role that occupant behaviour plays in the energy consumption of residential buildings in Algeria. It has also highlighted the potential for reducing energy consumption through various measures, such as the implementation of double glazing and the use of high-performance systems. In addition, it is crucial to raise awareness among occupants about the impact of occupant behaviour models on the optimization of energy consumption.

The aim of this study is to analyze the influence of the actual behaviour of individuals on the architectural design by evaluating the thermal comfort and energy performance of the energy consuming and energy producing stations installed in the building.

During the implementation of the questionnaire methodology, it was found that an increasing number of household appliances and electrical equipment have become an integral part of our daily lives. In order to achieve the objectives outlined in our research, we have proposed the use of devices such as Voltalis or Eco Watt. These devices have been specifically designed to regulate national energy consumption peaks, while providing users with improved visualization and control of their electricity consumption.

These devices are provided free of charge and have the potential to reduce a household's annual energy consumption by up to 15%. In addition, there are other methods of reducing electricity consumption in the home, such as using LED light bulbs and lamps, avoiding leaving appliances on standby or plugged in, charging mobile phones only when needed rather than overnight, regularly defrosting freezers, using 'eco' modes on household appliances (preferably those with an 'A' energy label or better), favoring cold cycles on dishwashers and washing machines, and avoiding 'boost' modes on induction hobs, microwaves, electric ovens and similar appliances.

5. Conclusion

Buildings consume energy in the production of materials (cement, bricks, sand, tiles, etc.) and throughout their life cycle. According to global statistics, existing buildings consume more than 40% of energy, not including the energy consumed by materials, and are therefore at the heart of the fight against global warming.

The building sector is therefore a major source of energy savings that can create a dynamic of innovation and employability. In order to reduce energy consumption in the building sector, it is important to

- Catalogue the energy consumption of building materials, tackle the causes and penalize energy-guzzling products.
- Reduce energy consumption throughout the life cycle of the building by using new and innovative techniques and materials.
- Raising awareness among building users to reduce consumption.

There are also many ways to increase the energy efficiency of a building, and many components that can be upgraded to increase this value.

Better insulation, more efficient windows, doors and skylights, as well as high efficiency air conditioners and furnaces can all contribute to a more efficient home by keeping warm air in or out of the house. Similarly, the ability to regulate the temperature of a home using a thermostat is an important part of energy efficiency, as having the right equipment is just as important as using it correctly.

Overall, there are many strategies to increase energy efficiency. These include:

1. Using appropriate amounts of insulation in the walls and roof, according to local standards.
2. Properly weatherproofing the building with weatherstripping and caulking
3. Installing high quality windows with low emissivity coatings and gas fills, using the most environmentally friendly glazing and frame materials.
4. Installing high performance systems and equipment and evaluating their performance throughout their lifecycle Monitoring and verifying performance by using energy audits to identify where energy is wasted in a building and where it is most cost-effective to make improvements through retrofits.

The need to reduce energy consumption in the residential sector has prompted researchers to investigate the impact of a building's physical characteristics and the behaviour of its occupants on energy consumption.

The energy consumption of a house can vary depending on the quality of its insulation, its heating system and the lifestyle of its occupants. It is therefore crucial to improve the accuracy of understanding and predicting occupant behaviour, given its influence on the energy performance of buildings. Several international studies, including a study by Vorger (2015), support this hypothesis.

The study found that occupants influence the energy consumption of buildings through various activities, such as opening and closing windows (2400 Wh/day for air conditioning), managing dimming devices, using artificial lighting (1875 Wh/day) and electrical appliances (1245,5 Wh/day), and managing heating setpoints and water consumption.

This study aims to investigate the impact of occupant behaviour on energy consumption in a residential neighborhood using a questionnaire. The main conclusions and future research are summarized below:

1. The contribution of our study to the existing literature is that occupant education and encouragement can play a key role in changing consumption habits in residential buildings to optimize energy consumption.
2. Further research should assess the impact of occupant behaviour on energy consumption in other climates, cultures, large samples and building types (e.g., offices, educational buildings).

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Conflicts of interest

The Author(s) declares(s) that there is no conflict of interest.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

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