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Study on Household-Level Electricity Consumption of Domestic Consumers in Romania: The Need to Check the Electrical Installation

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Abstract: With technological development and the decrease in the price of electrical appliances for domestic consumers, combined with users' desire for a certain level of comfort, the number of electrical devices in homes has increased. Although current equipment is largely energy-efficient, the high number of these devices, used simultaneously, has led to an increase in electricity consumption. Electrical installation in homes has been replaced in most cases, but the connections have remained the same, without any checks being carried out in terms of load and operational safety. This paper presents an exploratory case study based on a questionnaire answered by 678 individuals from Romania. The objectives of the questionnaire were to identify the characteristics of the domestic consumer and their opinion on the state of the installation, energy costs, and energy consumption. Based on the analysis, 74.15% of the respondents stated that the power installed in their homes as domestic consumers increased. Based on the analysis conducted on-site, the risk of fire outbreaks in the power supply columns of apartment buildings was identified. To avoid critical situations, it is necessary to periodically check the connection and supply columns so that they are functional and safe to operate.

Keywords: electricity consumption; domestic consumers; installed power; installation check

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1. Introduction

1.1. Energy Consumption and Issues Influencing Electricity Consumption in Households

In the context of technological development and process automation, electricity plays an essential role. Global energy sustainability aims to reduce pollution by replacing fossil fuels with renewable energy sources [1], contributing to the sustainable development of society [2]. Another aspect of sustainability is a reduction in energy consumption through the use of energy-efficient household appliances [3]. In order to achieve this goal, it is necessary to understand the information conveyed by the technical data from appliances and to provide consumers with correct and complete information when choosing these appliances [4].

The relevance of this paper comes from the importance of electricity in modern life. From waking up to an alarm clock/mobile phone and taking a daily shower to performing physical or intellectual work, all daily actions from waking up to going to bed involve consuming energy at home. According to data extracted in June 2022, in 2021, household energy consumption accounted for 27% of final energy consumption, which was 18.6% of the gross domestic energy consumption in the European Union [5]. The majority of the final energy consumption by domestic consumers was covered by energy generated using natural gas (33.5%) and electricity (24.6%) [5]. Regarding the considerable share of electricity in the gross energy consumption of domestic consumers, it is necessary to identify solutions to reduce it. At the same time, we need to produce electricity by using resources that ensure sustainability and sustainable development.

The energy produced from renewable sources contributed 21.2% of consumption, followed by oil and petroleum products (9.5%), with the difference being covered by other energy resources. Most of the energy consumed in U.S. homes (51%) in 2015 was used for space heating and air conditioning [6]. These two uses are considered seasonal, but, given global warming and the climate changes we are experiencing, a significant part of the year involves one of these two types of energy uses. Water heating, lighting, and refrigeration were three other uses that represented 27% of the energy consumption, and the difference was used by devices such as cooking appliances, washing and drying machines, televisions, computers, tablets, and other electronic devices [6].

According to a statistical study conducted in 2020, it was established that in the period of 1973–2018, electricity consumption worldwide changed in terms of the type of consumption. Thus, consumption in the residential sector increased by 3.8 percentage points. In the commercial sector and public services, it increased by 6.2 percentage points, while in the industrial sector it decreased by 11.4 percentage points (Figure 1) [7,8]. From this finding, it follows that electrical installations are systems that are heavily used throughout the year and must be in a constant state of operation and safety.

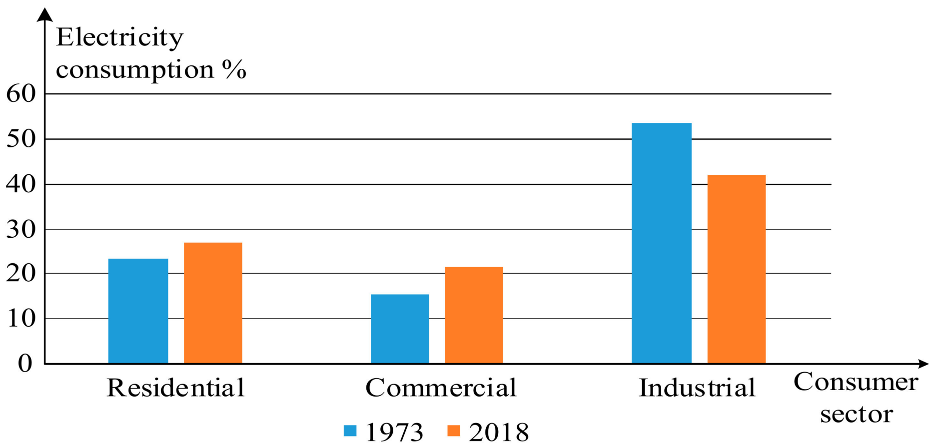


Figure 1. The evolution of the percentage allocated to electricity consumption worldwide [8].

According to some studies, the main factors that influence the electricity consumption among domestic consumers are as follows [9]:

- The number of people in the household. The larger the number, the higher the electricity consumption [10], since each person uses electrical equipment.
- The composition of the family members. It has been found that families with more children have higher electricity consumption. Additionally, the older age of the children also influences energy consumption [11], considering that at a certain age, they have their own communication devices.
- The age of the family members, with energy consumption being higher among individuals approximately between 45 and 64 years old [12].
- The mode of work activity, such as whether a person works at the employer's office or from home [13].
- The energy performance of household appliances [14];
- The level of education, such that in families with a higher level of education, the consumption of electricity significantly decreases [15]. This is due to the responsible choice of electrical equipment and the rational use of electricity.

- The social status of the family, with an increase in electricity consumption in families with a high status [16]. This fact is determined by the use, especially, of household appliances and many other types of personal or family electrical equipment.
- The economic situation of the family, which considers both the family's income and the disposable income for activities that are not strictly necessary. It has been found that an increase in income leads to an increase in electricity consumption, as families tend to live in large spaces that need to be heated and cooled. At the same time, using an energy management system for buildings leads to a reduction in energy consumption by 5–16% compared to the case of using conventional electrical equipment [17]. In this situation, the investment in systems for improving energy efficiency is considerable.

1.2. Requirements for the Proper and Safe Functioning of Household Electrical Installations

Following analysis, it has been established that 30% of the total electricity consumption is accounted for by residential consumers [18]. In this case, the largest electricity consumers are electric heating systems (electric radiator), electric stoves, air conditioning units, refrigerators, washing machines, microwave ovens, clothes dryers, and dishwashers. According to a study conducted at the national level in Romania by a national electricity provider (CEZ Romania), for an average household, the average consumption can reach 283 kWh, with the following distribution (Table 1):

Table 1. Average monthly electricity consumption of the most common household appliances used in an ordinary household from Romania [19].

Receiver Name	Average Monthly Consumption [kWh]
Lighting	18
Refrigerator	35
Television	30
Computer	35
Washing machine	55
Radio	20
Vacuum cleaner	10
Hair dryer	20
Iron	30
Microwave oven	30
TOTAL	283

For all these appliances, the existence of a properly sized and protected power supply system is necessary, and the entire system should be periodically checked to ensure proper and safe operation. It is known that the reliability of electrical installations is determined by the operating regime and period, leading to natural aging. Hence, there is a necessity for these installations to undergo periodic checks, eliminating the risk of endangering people's lives and ensuring the integrity of property, homes, commercial spaces, and public areas of interest. According to regulations in Romania, electrical installations must undergo periodic inspections and testing by qualified and authorized personnel for this purpose. For companies, these inspections and tests should be conducted annually, while for individuals, there is only a recommendation for inspections at least every 10 years [20]. Unfortunately, the vast majority of companies do not carry out these inspections, let alone domestic consumers.

Normative I7 provides requirements for checking against direct contact with parts that are normally under voltage and against indirect contact with parts that are not normally under voltage [21,22]. These requirements aim to limit the risks of electrocution to individuals and the occurrence of hazardous situations that can cause equipment/installation damage or even fires. The normative guidelines also specify how protection against overloads and short circuits should be implemented. However, there are still many situations where fires occur due to electrical installations. According to an analysis of the operational situation by the General Inspectorate for Emergency Situations in Romania, the number of fires in

2022 was 43,234, which was 41.3% higher than in 2021 [23]. Considering that the average number of fires per day was over 118, it was evident that the population and their property were in a significantly risky situation. Of all the fires, 26% (11,241 fires) were caused by defective electrical installations (approximately 31 fires per day), with the majority occurring in residential buildings (62.89%). Rural areas had the highest number of fires caused by defective electrical installations (59.38%) [23]. Unfortunately, the analysis presented does not specify the specific causes of the defective electrical installations that led to the fires.

Studies have found that a primary cause of fires is series-arc faults. By examining the waveforms of common household appliances in detail, it is possible to forecast the potential occurrence of such a fault. It has also been demonstrated that maintaining an arc current of 2A for 2 s can ignite PVC, which is used to insulate nearly all electrical conductors [24]. The detection of the electric arc can be achieved using an arc detection device, which interrupts the electric circuit upon detecting such an event, thus resolving this potential issue [25]. Another cause that can lead to both electrocution and fires is faults-to-ground, resulting in dangerous voltages being applied to the metallic parts of equipment [26]. This issue is addressed by the introduction of residual current devices, which can be used in situations involving both AC and DC voltage [27]. However, special attention must be given to measuring loop impedance, as these devices may trip during measurement, affecting the quality of the measurement [28]. The other identified causes of electrical faults in buildings include [29,30] the improper design and maintenance of electrical equipment/installations, the use of low-quality materials (cables/conductors, lighting fixtures, electrical panels, switches and sockets, protective devices), work being performed on electrical installations by unqualified and unauthorized personnel, and the improper use of electrical installations. Thermography is used to detect possible faults in sockets, switches, junction boxes, and electrical panels. This method requires the operator to know how to use thermal cameras and to have knowledge of thermal imaging and image processing. To simplify the method, a classifier has been developed, which, through computational processing, detects the operating status of components [31]. In the case of an energy audit, in addition to thermography, measurements of electrical parameters are also necessary [32].

It is known that the heating of conductors is caused by the high values of the currents associated with the power of electrical energy receivers. To predict energy consumption in the residential sector, various energy models have been developed based on information received from smart meters and sensor systems [18,33]. In the absence of these meters and sensor systems, as well as periodic checks carried out by qualified and responsible personnel, electrical installations in residential buildings, and beyond, can be affected by various defects and may cause fires. A study conducted in Jordan in 2014, analyzing questionnaires completed by residential consumers, found that most houses do not comply with local and/or international standards for electrical installations and do not have functioning monitoring systems [30]. Through these systems, the evolution of electricity consumption can be determined, allowing measures to be taken to reduce/limit it. In 2013, a method for comparing electricity consumption was proposed using a Facebook application called Social Electricity [34]. Through this application, household consumers can evaluate their electricity consumption compared to that of friends or residents in the same area. In this way, they can analyze and adjust their behavior regarding energy consumption and take measures to reduce it.

This paper presents a case study regarding the electricity consumption of residential consumers from Romania. This study is based on self-proposed questionnaires regarding electricity consumption, which were completed by various consumers. Upon processing the questionnaires, an increase in installed power was observed due to the use of multiple household appliances. This was despite the promotion of choosing efficient appliances and committing to responsible consumption, driven by the desire for a sustainable lifestyle alongside the goal of reducing bills. Although most household consumers had replaced their electrical installations in apartments/houses, the main electrical supply column, especially in the case of apartment buildings, remained the same. Consequently, due to the physical wear on the installation, as well as the increase in installed power on the column, breakdowns or fires can occur at any moment. This fact was also demonstrated in the analysis of the installed power of various electrical appliances used by household consumers, as well as in on-field analysis. It was found that in many scenarios, the current values on the supply columns of apartments in blocks approach or even exceed the limit values imposed for the respective type of conductors. This poses a risk to the lives and property of residents in residential blocks. Based on the analysis, it is proposed to introduce into regulations from Romania the obligation of the periodic verification of connections and supply columns by specialized and appropriately authorized personnel. Additionally, it is necessary to verify electrical installations in homes to ensure compliance with the requirements imposed by current regulations regarding maximum permissible power and protective systems.

The conclusions of this research cannot be considered fully reliable (due to lack of samples), but they may raise an alarm about the increase in installed power and the need for regular checks of the power columns. At the same time, the respondents' interest in the use of renewable energy sources is also identified.

In this study, we intended to identify the opinions of the respondents concerning, mainly, the evolution of electricity consumption, the number of household appliances, and actions that lead to the overloading of the supply columns, especially in blocks of flats built during the communist period in Romania. Given the degradation of these power columns, caused by the poor quality of the materials used at the time, their physical aging, and the outdated and non-compliant installation technologies, combined with the exceedance of the maximum current, these installations can lead to damage or even fires at any time. Based on the conclusions drawn from the primary analysis presented in this paper, this research continues with a detailed analysis of the questionnaire responses. These results are compared with the outcomes obtained from another questionnaire that was applied to a well-defined sample.

2. Materials and Methods

2.1. The Development of the Questionnaire for Analyzing Electricity Consumption and Its Application

To assess electricity consumption among residential consumers, the working team members developed a questionnaire entitled "Questionnaire for Evaluating Electricity Consumption among Household Consumers". The questionnaire underwent evaluation by a team of three faculty members to introduce/remove questions and rephrase others. After evaluation by the evaluation team members, the questionnaire was tested by a team of graduates specializing in electromechanics and active in this field. Following the testing, minor adjustments were made to some questions with complex phrasing or the use of terms unfamiliar to the general public.

The elaborated, verified, and tested questionnaire was created and applied through the Google Forms platform. The questionnaire complied with legal provisions regarding confidentiality and personal data. From the analysis of the collected results through the questionnaire, the respondent cannot be identified, nor can any identifying data. A period of approximately 25 min was required to complete the questionnaire. This study was exploratory, and no specific sampling method was chosen; the questionnaire was distributed to various individuals within the authors' network. Therefore, the authors distributed the questionnaire completion link via email and social media platforms such as WhatsApp and Facebook. The individuals within the authors' network who received the link included faculty members (especially from the academic environment and faculties in the electrical domain); students; friends; and acquaintances of the authors, with or without specialized knowledge in the electrical field. Each respondent that was informed about the opportunity to complete the questionnaire deliberated whether to complete it or not, without any form of constraint.

2.2. Description of the Questionnaire for Analyzing Electricity Consumption

The questions in the survey were designed to identify the characteristics and opinions of the respondents, household consumers of electricity. The analysis of responses regarding electricity consumption was carried out via operationalizing 9 variables. The questionnaire included closed, open, and mixed-type questions, totaling 30 in number. Respondents were provided with predefined answer options by the authors or were encouraged to express their own point of view. Questions aimed at identifying the respondents were posed towards the end of the questionnaire. The questionnaire was administered from 24 October 2022 to 12 February 2023, covering a period of 3 months and 20 days. The questions were grouped on the basis of a logical structure, as shown in Figure 2.

2.2.1. Identifying the Respondents' Profile

To establish the profile, questions regarding gender, age, level of education, and occupation were posed. To identify the respondents' age, the following intervals were used: 18–25 years, 26–35 years, 36–45 years, 46–55 years, 56–65 years, and over 65 years. The level of education was categorized as follows: primary school, secondary school, high school, university studies, and postgraduate studies. To identify the occupational category, the following occupations were established: employee in the public sector, employee in the private sector, employer/administrator, student, self-employed person (S.E.P.), pensioner, unemployed, inactive.

2.2.2. Identifying the Household Profile

To identify the household profile, questions were asked regarding the following topics:

- Residence environment, specifically whether the referenced residence is located in a rural or urban area.
- Type of dwelling, where respondents had to choose one of the following options: apartment, house, student dormitory, or other type of residence.
- Number of occupants in the household. This objective was pursued because the number of individuals in the household influences electricity consumption, considering the number of individual electrical appliances used and their increased usage time. For this objective, respondents answered an open-ended question where they had to specify the number of people in the household.
- Number of rooms in the household, where respondents could choose one of the following answers: 1 room, 2–3 rooms, 4–5 rooms, and over 5 rooms.
- The year of the construction of the building, where respondents had to mention the year in which the building/house was constructed. This objective was pursued because the age of an electrical installation influences its safety in operation.

2.2.3. The Respondent's Connections with Electricity Services

To establish these connections, respondents had to answer whether or not they are the holders of an electricity subscription/contract and whether or not they personally pay the issued electricity bill.

2.2.4. The Characteristics of the Electrical Installation

For this item, we aimed to identify the respondent's type of connection and whether the interior installation of the dwelling or the main power supply column has been re-placed or not.

Regarding the identification of the type of electrical connection, respondents had to choose one of the options mentioned in the questionnaire: single-phase connection or three-phase connection. The same target has been identified in other similar research [35].

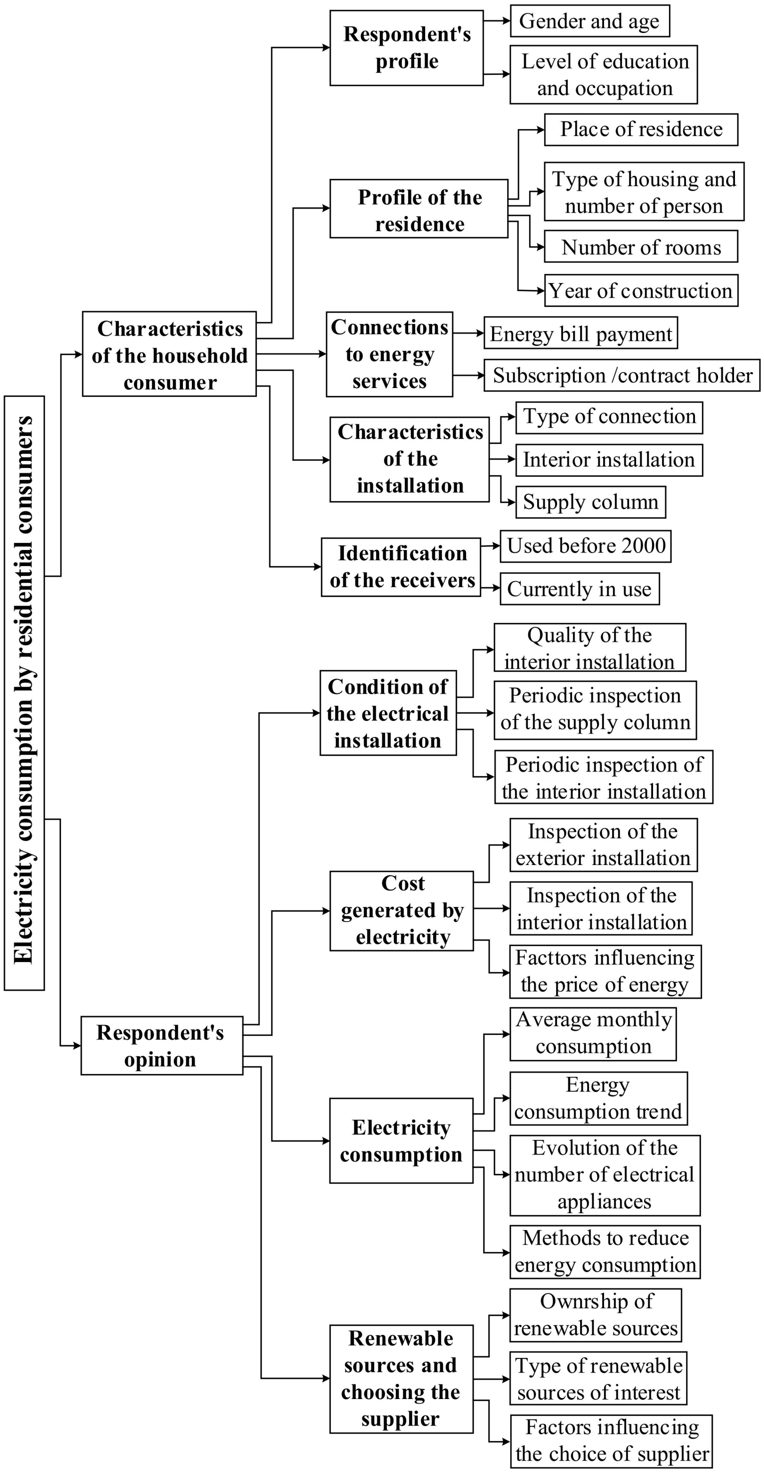


Figure 2. The block diagram that underlies the research. Source: Authors' own processing.

Regarding the interior electrical installation, the questionnaire aimed to identify whether it has been replaced or refurbished, and the period in which interventions were made on the interior installation. To answer this question, survey participants had to choose one of the response options:

- The electrical installation has been replaced in the last 5 years;
- The electrical installation was replaced 5–10 years ago;
- The electrical installation was replaced 10–20 years ago;
- The electrical installation was partially replaced;

- The electrical installation has not been replaced;
- I don't know if the electrical installation has been replaced.

Similar questions were asked to identify the characteristics of the main power column, namely whether it had been replaced and the period in which it was replaced (the options being in the last 5 years, 5–10 years ago, 10–20 years ago, it has not been replaced, or 'I do not know'). In this questionnaire, the main power column refers to the supply column delimited between the output terminals of the general electricity meter on the block's staircase and the individual supply panel of residential consumers, existing in apartments. For consumers living in houses, the power column is considered from the output terminals of the consumer's electricity meter to the main panel or to the electricity distribution panel.

2.2.5. Identifying the Number and Type of Electrical Appliances

Through the questionnaire, we aimed to identify the electric appliances currently used and those used between 1950 and 2000. To determine the evolution of household appliance use, two similar questions were asked, where respondents had to report the number of appliances they possessed for each predefined type or mention other appliances not included in the provided list. The predefined electric appliances were refrigerator/fridge–freezers, washing machine/dishwashers, iron/ironing stations, vacuum cleaners, radio/audio devices, computers/laptops/printers/multifunctional devices, televisions, microwave ovens, electric ovens, apartment heating boilers, electric heating boilers, air conditioners/air purifiers, lighting sources, small kitchen appliances, personal hygiene appliances, and coffee makers/espresso machines. This goal was set due to the continuing requirement to improve living standards, which results in a high level of dependence on many electrical appliances. In the context of this research, an electric heating boiler is a facility that only uses electricity to provide heating. In the case of an apartment heating boiler, electricity is only used to recirculate the thermal agent in the installation, with heating being achieved by burning fuels.

Since a lighting system is necessary in addition to the electric appliances used by household consumers, we aimed to identify the categories of lighting sources used (incandescent bulbs, fluorescent bulbs, and LED bulbs) and their quantity. For this objective, respondents had to choose the category and number of lighting sources used between the period of 1950–2000 and the present day.

2.2.6. The Respondent's Perception of the Electrical Installation Status

This objective aimed to determine the following:

- If the quality of the interior electrical installation is considered relevant when purchasing a new appliance/electrical device;
- Whether periodic checking of the main power supply (branch connection) is considered relevant;
- If the periodic checking of the internal electrical power supply installation is considered relevant.

Answering these questions, the respondent quantified the relevance by assigning a score between 1 and 5, where 1 signifies a lack of relevance and 5 indicates very high relevance.

2.2.7. Respondent's Opinion Regarding Covering the Costs Generated by Electricity

For this variable, the aim was to identify respondents' opinions regarding the entity responsible for covering the costs generated by the following tasks:

- Checking the external electrical installation of the residence (connection from the building's staircase);
- Checking the consumer's internal electrical installation.

In both cases, respondents had to choose one of the following answers: the electricity supplier or the consumer. In terms of the consumer, the owner's association, consisting of all apartment owners allocated, was also considered. Also, with this variable, the aim was to identify respondents' opinions regarding the main factors influencing the price of electricity. For this item, respondents had the opportunity to choose one or more predefined answers in the questionnaire: regulations in the field; weather conditions; electricity transportation and distribution systems; the evolution of fuel prices, especially natural gas and oil fuels; the presence of electricity producers within the country; and the political system.

2.2.8. Respondents' Opinion on Their Own Electricity Consumption

With this variable, the aim was as follows:

- To identify the average monthly consumption, where respondents had to select one of the following options: below 100 kWh, between 100 kWh and 250 kWh, or over 250 kWh.
- To determine respondents' opinion on the evolution of electricity consumption compared to 5 years ago, 10 years ago, and 15 years ago. For this item, respondents had to choose one of the following options: decreased significantly, decreased slightly, remained approximately constant, increased slightly, or increased significantly.
- To identify the evolution of the number of electrical appliances, where respondents had to compare the number of current electrical appliances to those from 5 years ago, 10 years ago, and 15 years ago. The comparison was made by choosing one of the response options: decreased significantly, decreased slightly, remained approximately constant, increased slightly, or increased significantly.
- Identifying respondents' opinions regarding methods considered useful for reducing electricity consumption and associated costs. For this item, respondents had the opportunity to choose one or more responses from the provided options: choosing a different electricity provider, selecting an offer suitable for consumption needs, replacing electrical appliances and electronics, using an energy management system, or using alternative sources of electricity.

In several studies, electricity consumption has been analyzed by using questionnaires and applying them to smaller or larger numbers of respondents [36]. One such analysis was carried out in a Swedish city, and it also aimed to identify the type and use of household appliances. The analysis concluded that the total household income influences the electricity consumption behavior and that for a more complete analysis it is necessary to identify the technical characteristics of household appliances [37]. In another study in Japan, it was found that the evolution of electricity consumption is both influenced by the number of appliances and the number of household members [38].

2.2.9. Respondents' Opinions on the Use of Renewable Sources and the Choice of Electricity Provider

Taking into account the global energy crisis and rising electricity prices, respondents' opinions on the use of renewable energy sources were sought. They had to questions on the following issues:

- Regarding whether they owned or used renewable energy sources, respondents had to choose one of the following options: yes, no, I do not own but I'm interested, or I'm not interested;
- The type of renewable energy source of interest, a question to which respondents had to choose one of the following options: wind system, photovoltaic solar panels, heat pumps, solar collectors for thermal energy, or others.

The same interest in the use of renewable sources of electricity has been reported in other surveys both in Romania [39] and other countries [40], with respondents indicating that they are willing to invest in renewables if the payback time is less than 5 years [41].

Regarding the factors considered important in choosing an electricity supplier, respondents had to choose one or more options from the predefined answers in the questionnaire. The options provided to respondents were the price of active electricity, the cost of the transportation and distribution of electricity, the amount of fees regulated by ANRE (National Energy Regulatory Authority), the amount of fees set by the electricity supplier, the supplier's market experience, the stability of services offered by the supplier, and the fluctuation in the final electricity price offered by the supplier.

2.3. Identifying the Electricity Consumption of Various Household Appliances and Identifying the Type and Section of Conductors in the Supply Column

To correlate the power of different types of household appliances used with the maximum allowable current applied to the corresponding sections of the supply columns in apartment buildings, the minimum and maximum power for various types of equipment were identified. This documentation was performed by analyzing several types of equipment within the same category, regardless of the manufacturer. At the same time, factors such as having approximately the same washing capacity, cooling capacity, etc., were taken into account.

Based on the energy W consumed in one hour and the operating voltage, the longtime current I of the electrical equipment was determined:

$$I = W/U \cdot t \quad (1)$$

Since most household appliances indicated a voltage supply range of 220–240 V, we used the value of 230 V in our calculations.

3. Results

In terms of the questionnaire's transmission, it was completed by 681 individuals from Romania. Out of the total completed questionnaires, responses that were incomplete were excluded (3 responses), resulting in a total of 678 valid questionnaires.

3.1. Results from the Questionnaire Analysis

3.1.1. Respondents' Profile

Regarding the gender of the respondents, 58.55% were male, 40.27% were female, and 1.18% chose not to respond. From the analysis, it can be observed that the percentage of males is slightly higher than that of females involved in this issue. Most respondents were in the age range of 46–55 years (27.14%), followed by those in the age ranges of 36–45 years (23.6%), 26–35 years (18.58%), 18–25 years (14.75%), 56–65 years (11.95%), and over 65 years (3.98%). Considering the age range of the majority of respondents, it appears that they were able to accurately answer questions regarding the period from 20 years ago and to identify the trend in energy consumption and the evolution of household appliances.

Based on the analysis of the respondents' educational level, it was found that 61.06% reported having university studies, 19.76% had post-university studies, and 18.44% had high school studies, with the difference being represented by respondents with middle school and primary school education (0.74%). This criterion also confirmed that the majority of respondents had knowledge about the topics addressed in the questionnaire. Most respondents were employed in the public sector (43.36%), followed by those in the private sector (29.06%), students (12.69%), retirees (7.52%), self-employed individuals (2.51%), inactive people (1.18%), and unemployed people (0.29%). The fact that over 75% of respondents were active individuals in the labor market, facing issues and challenges related to electricity, demonstrates that the questions asked have a direct connection to their daily lives.

3.1.2. Household Profile

Regarding the residence environment, respondents declared that 75.07% live in urban areas, while 24.93% live in rural areas. This high percentage of respondents from urban areas leads to the conclusion that the responses of these individuals may highlight the necessity or lack thereof of the periodic inspection of electrical columns/connections in residential blocks.

Regarding the type of housing, it was found that 55.46% of respondents live in apartments, 42.77% in houses, 1.48% in communal housing (dormitory rooms), and 0.29% in other types of housing. The fact that over half of the respondents live in apartment buildings helps to draw conclusions regarding the necessity, or lack thereof, of inspecting electrical supply columns in such buildings. According to the responses provided by the respondents, the households referenced in the case study had 1 respondent in 6.93% of cases; 2 people—29.79%; 3 people—26.11%; 4 people—24.19%; 5 people—4.87%; and more than 5 people—8.11%. The analysis indicates that the vast majority (80.09%) of respondents' households were inhabited by 2, 3, or 4 people.

Regarding the number of rooms in the household, 1.33% of respondents mentioned having only one room, 39.38% had 2–3 rooms, 35.69% had 4–5 rooms, and 23.6% had more than 5 rooms.

Regarding the year of construction of the buildings, the responses given by this study's participants were grouped into 5-year intervals. Upon processing the results, it was found that approximately 73.16% of respondents stated that they owned a dwelling built before 1990, thus having an age of over 30 years. Figure 3 shows the distribution of the annual intervals of the construction years of the analyzed buildings. It is also observed that the highest number of homes were built between 1970 and 1989, representing 41.59% of the total number of homes analyzed in this case study.

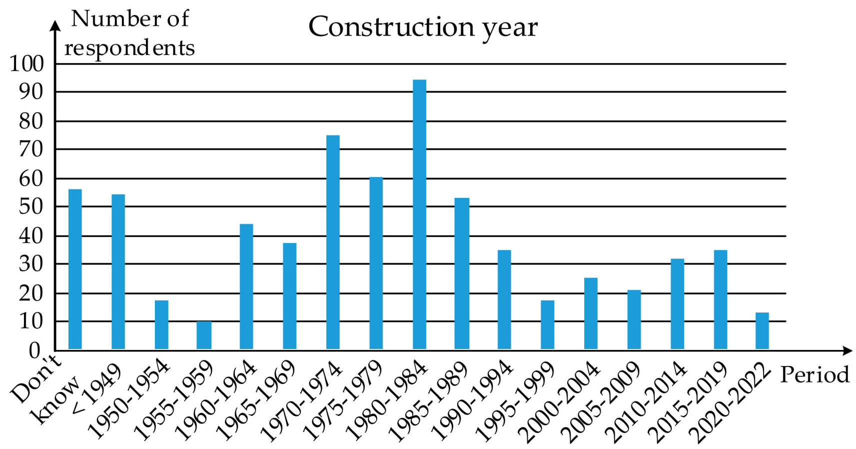


Figure 3. Annual building construction intervals. Source: Processed by the authors.

3.1.3. The Respondents' Connections with Electricity Services

Regarding respondents' connections with electricity bill payments, it was identified that 79.79% of respondents personally pay the electricity bill. Regarding respondents' contractual relationship with the electricity supplier, only 59% of respondents stated that they are the holders of an electricity supply contract.

3.1.4. The Characteristics of the Electrical Installation

Regarding the type of connection, the analysis found that 80.53% of respondents have a single-phase connection, while 19.47% have a three-phase connection.

Regarding the replacement/refurbishment of the interior electrical installation, the analysis found that 55.9% of respondents have replaced/refurbished their interior electrical installation in the last 20 years (Figure 4).

Considering that the normative lifespan of power electrical installations installed in protective tubes, channels, or tunnels is between 24 and 36 years [42], and taking into account that over 34.8% of respondents have not replaced their electrical installation or have only partially replaced it, the conclusion can be drawn that it requires replacement or at least verification.

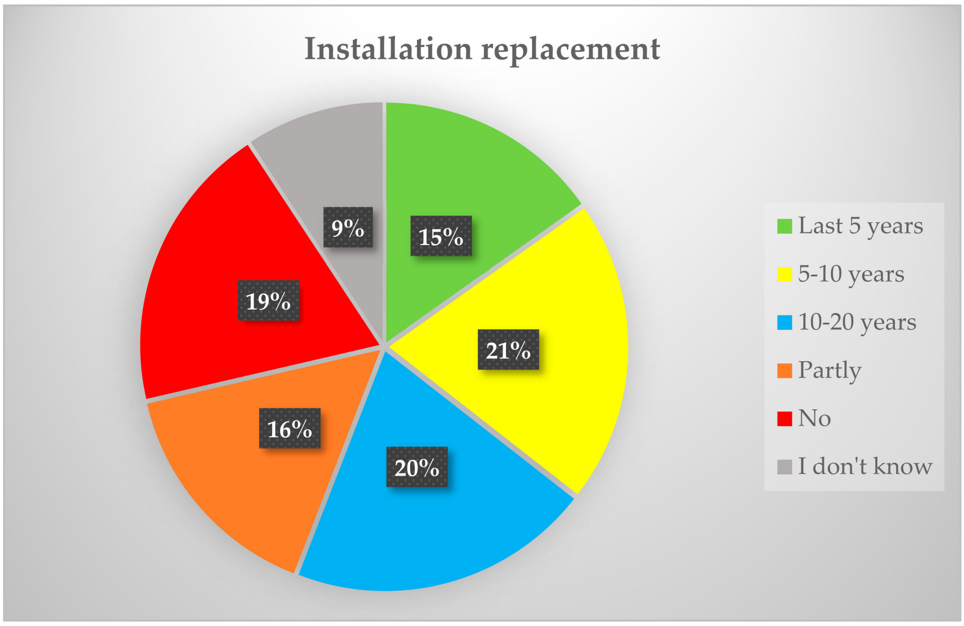


Figure 4. Electrical installation replacement. Source: Processed by the authors.

Regarding the replacement of the supply column, it was found that 39.82% of respondents stated that they have replaced their supply column in the last 20 years. However, it was observed that over 26% of respondents declared that they have not replaced the electrical supply column (Figure 5). If we also consider respondents who said they do not know whether the supply column has been replaced, we reach the conclusion that over 60% of respondents have not carried out replacement work on it. This fact can be considered a major risk to which they are exposed, especially in the case of the tenants of apartment buildings.

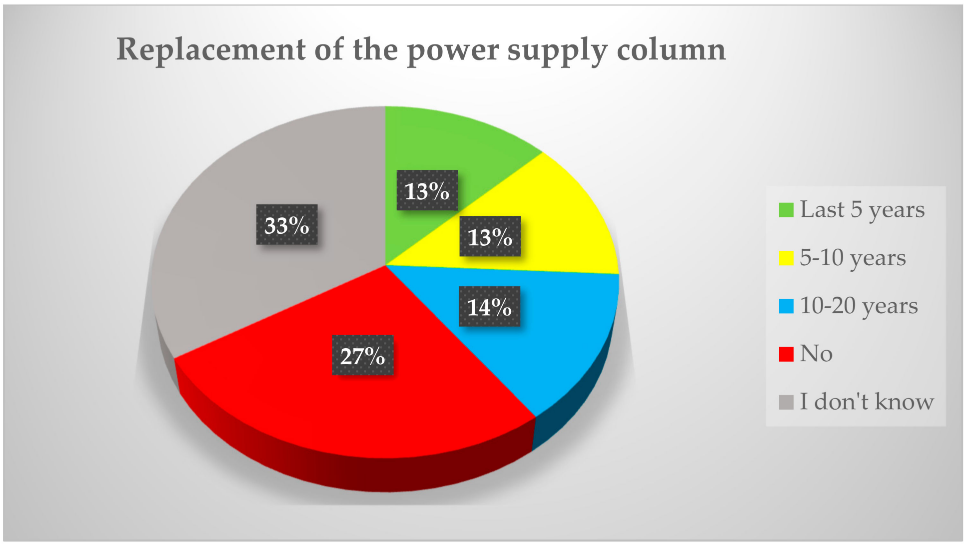


Figure 5. Replacement of the power supply column. Source: Processed by the authors.

3.1.5. Identification of Electrical Energy Consumers

Regarding the identification of the type and number of electrical receivers used currently and in the period of 1950–2000, the analysis of the results was conducted by categorizing the responses into three groups: those who stated that they did not have/use any identified receiver, those who had/used only one receiver of that type, and those who had/used two or more predefined receivers.

Figure 6 presents the percentage of those who stated that they did not have/use any predefined household appliance in the questionnaire in the period of 1950–2000 and do not do so currently. In relation to the current period, the analysis reveals a higher percentage of respondents who stated that in the period of 1950–2000 they did not have/use a refrigerator, washing machine, iron, vacuum cleaner, television, microwave oven, electric oven, apartment heating boiler, electric heating boiler, air conditioning, kitchen and personal hygiene appliances, coffee maker/espresso machine, and other household appliances. The fact that currently the percentage of respondents using the defined household appliances is much lower than the percentage of respondents who used them in the period of 1950–2000 is determined by the need to ensure a certain level of comfort, access to information, ease of work, and improvement in quality of life. Additionally, technological development, combined with increased living standards and decreased prices of household appliances, has made these devices accessible to a wide range of people.

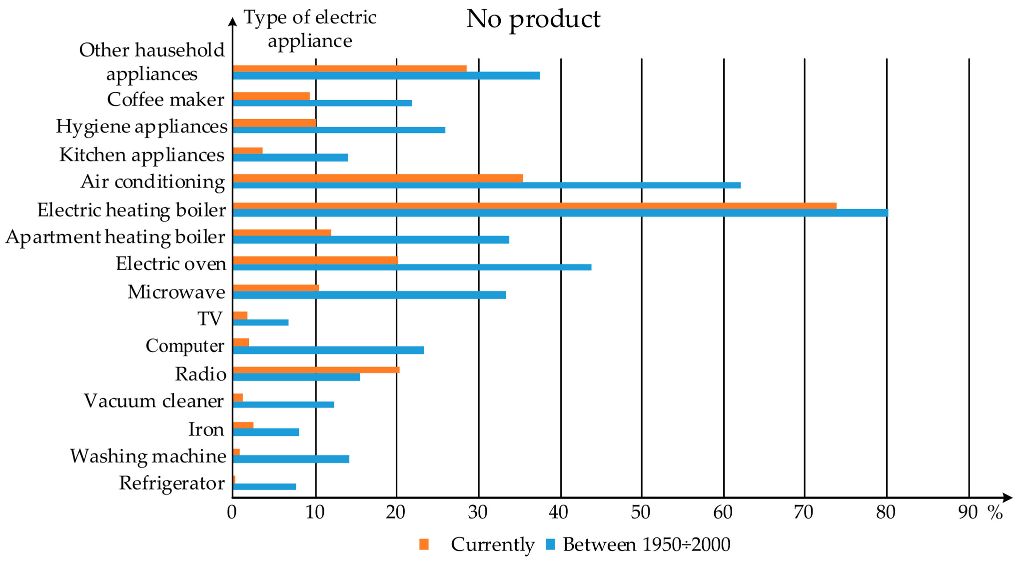


Figure 6. The percentage of respondents who stated that they did not have/use any predefined electric appliance. Source: Processed by the authors.

A comparison between the percentage of respondents who declared that they own and use a predefined electrical appliance and the percentage of respondents who declared that they had/used a predefined electrical appliance in the period of 1950–2000 is presented in Figure 7. From the analysis of the responses, it is observed that compared to the period of 1950–2000, the percentage of those who own/use a single product from the categories of vacuum cleaner, microwave oven, electric oven, electric heating boiler, apartment heating boiler, air conditioner, and coffee maker/expresso machine has increased. Almost all of these appliances are high consumers of electrical energy, which leads us to the conclusion that electricity consumption has increased since the period of 1950–2000 due to the use of these appliances. The highest percentage increase in those who use a predefined appliance, compared to the period of 1950–2000, was identified in the case of electric ovens (21.6 percentage points), followed by air conditioners (20.5 percentage points), microwave ovens (19.6 percentage points), apartment heating boilers (18.1 percentage points), and coffee makers (10.3 percentage points).

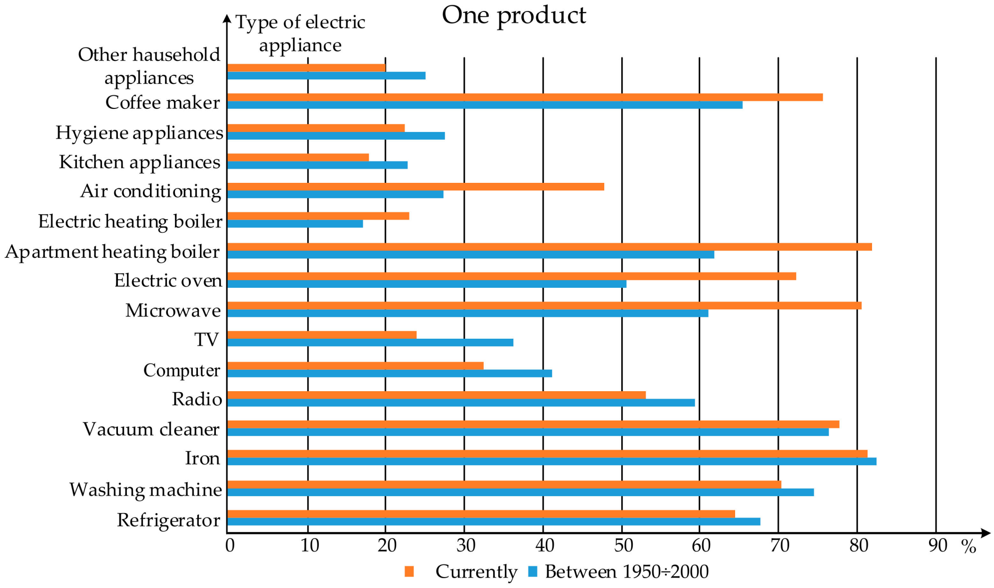


Figure 7. The percentage of individuals who declared that they had/used one predefined electrical appliance. Source: Processed by the authors.

It was observed for some categories of receptors that the percentage of respondents who answered that they had only one receptor of that type was lower than the percentage of respondents who answered that they had only one receptor of that type in the period of 1950–2000 (television—by 12.3 percentage points, computer—by 8.8 percentage points, radio—by 5.2 percentage points, personal hygiene appliances—by 5.1 percentage points, and kitchen appliances—by 4.9 percentage points). This fact can be attributed to the increase in the number of appliances of the same type, as can be identified from Figure 8. This figure presents a comparative analysis between the percentage of respondents who mentioned that they had 2 or more predefined receptors in the period of 1950–2000 and the percentage of respondents who mentioned that they currently have 2 or more predefined receptors.

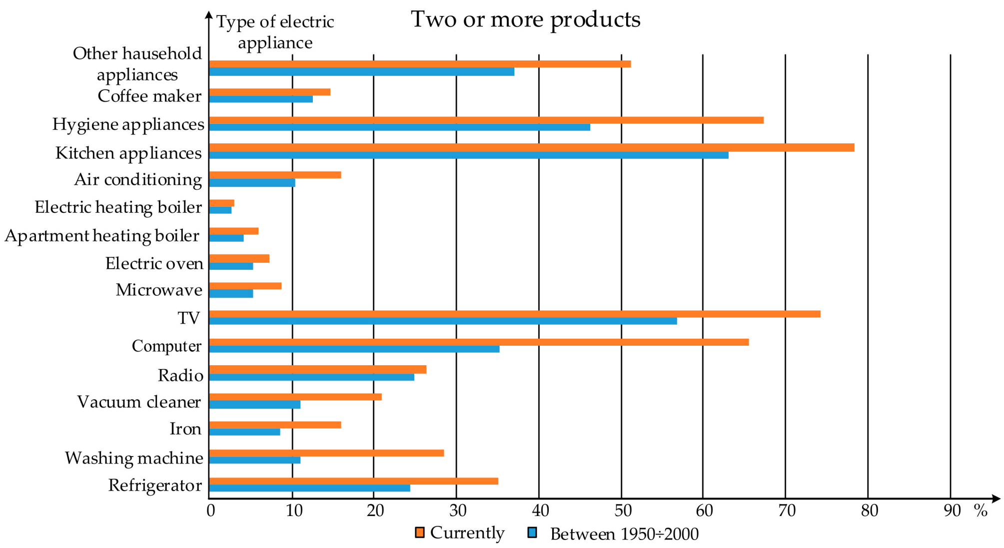


Figure 8. The percentage of respondents who declared that they had/used 2 or more predefined electrical receptors. Source: Processed by the authors.

There is a significant increase in the percentage of respondents who stated that they own 2 or more receptors compared to the period of 1950–2000. Specifically, there is a 30.3 percentage point increase for computers, a 21 percentage point increase for personal hygiene appliances, a 17.4 percentage point increase for washing machines and televisions, and a 14.1 percentage point increase for kitchen appliances. These findings are also validated by other research, showing that the purchase of electrical appliances increased [43] by more than 20% [44].

In the case of incandescent lighting sources (Figure 9), it is observed that 53.8% of respondents no longer use incandescent lighting sources. Furthermore, there was a decrease of 36.2 percentage points in the percentage of respondents who used 5 or more lighting sources of this category between 1950 and 2000 compared to the percentage of respondents who use them today.

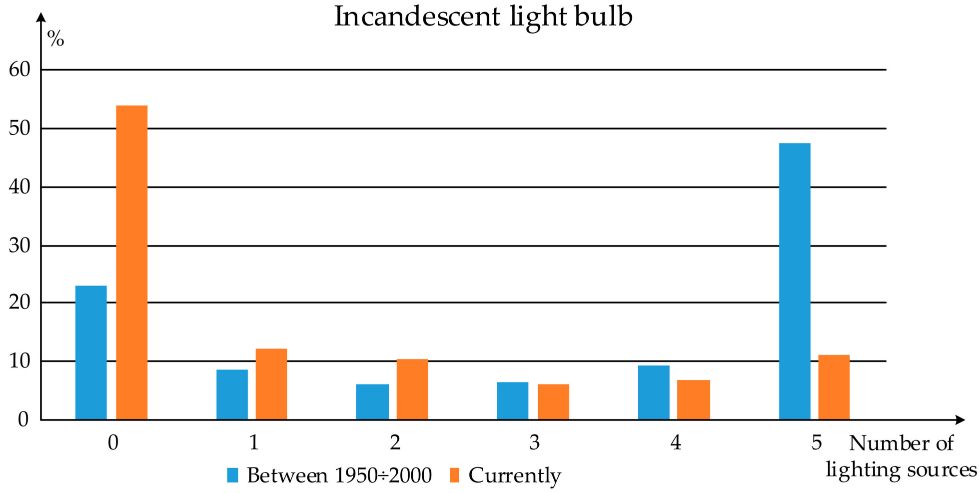


Figure 9. The percentage evolution of the number of incandescent lighting sources used. Source: Processed by the authors.

In the case of fluorescent lighting sources (Figure 10), a decreasing trend is observed in the number of lighting sources of this type used in the period of 1950–2000. The percentage of respondents who said they currently do not use any lighting source from this category is 53.5%. For this category of lighting sources, there is a certain balance between the percentage of respondents who mentioned that they used 5 or more lighting sources of this category in the period of 1950–2000 compared to the percentage of those who currently use them.

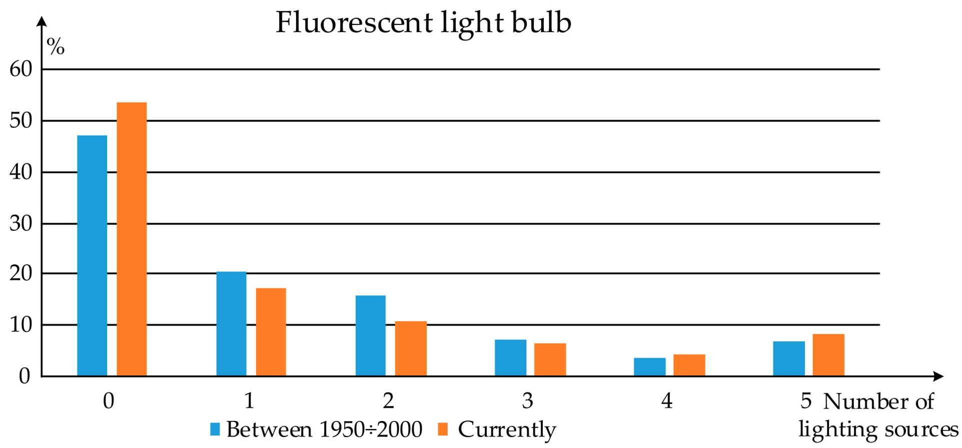


Figure 10. Percentage change in the number of fluorescent lighting sources. Source: Processed by the authors.

In the case of LED lighting sources, it was found that in the period of 1950–2000, the percentage of respondents who did not use such sources was 38%, whereas currently, the percentage has decreased to 6.1% (Figure 11). At the same time, there has been an increase of 31.7 percentage points in the respondents who currently use 5 or more LED lighting sources compared to the percentage of respondents who mentioned that they used them in the period of 1950–2000.

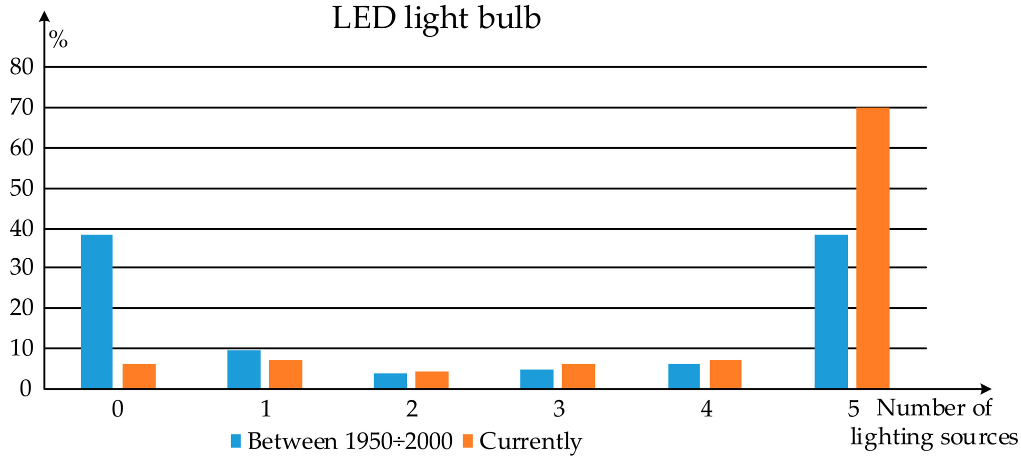


Figure 11. Percentage evolution of the number of LED lighting sources. Source: Processed by the authors.

In Table 2, we present the percentage values of the responses identified from the questionnaire, regarding the type and number of household appliances and lighting sources used currently and in the period of 1950–2000.

Table 2. Percentage of respondents who indicated that they had/used 0, 1, 2 or more predefined electrical devices in relation to the period analyzed.

Type of Equipment	No Product		One Product		Two or More Products	
	1950÷2000	Currently	1950÷2000	Currently	1950÷2000	Currently
Refrigerator	7.8	0.3	67.8	64.5	24.4	35.2
Washing machine	14.2	0.9	74.9	70.5	11.2	28.6
Iron	8.2	2.5	82.6	81.4	8.6	16.1
Vacuum cleaner	12.4	1.2	76.4	77.8	11.2	21
Radio	15.6	20.4	59.4	53.2	25	26.4
Computer	23.4	1.9	41.3	32.5	35.3	65.6
TV	6.8	1.7	36.3	24	56.9	74.3
Microwave	33.5	10.5	61.1	80.7	5.4	8.8
Electric oven	43.9	20.3	50.8	72.4	5.3	7.3
Apartment heating boiler	33.9	12	61.9	82	4.2	6
Electric heating boiler	80.2	73.9	17.1	23.1	2.7	3
Air conditioning	62.1	35.5	27.4	47.9	10.5	16
Kitchen appliances	14	3.6	22.8	17.9	63.2	78.5
Hygiene appliances	26	10.1	27.6	22.5	46.4	67.4
Coffee maker	21.9	9.5	65.5	75.8	12.6	14.7
Other household appliances	37.6	28.6	25.2	20.1	37.2	51.3
Incandescent light bulb	22.8	53.8	8.5	12	68.7	34.2
Fluorescent light bulb	46.9	53.5	20.3	17.2	32.8	29.3
LED light bulb	38	6.1	9.4	7	52.6	86.9

Source: Processed by the authors.

3.1.6. Condition of Electrical Installation

Most of the time, when purchasing an electrical appliance, the energy efficiency class and electricity consumption are taken into account. However, the electrical installation to which it is connected is of particular importance, as an inadequate installation can lead to poor operation or even damage. Regarding respondents' opinions on the quality of the interior electrical installation, 65.5% of them considered it to be very relevant, and 14.9% considered it quite relevant (Figure 12).

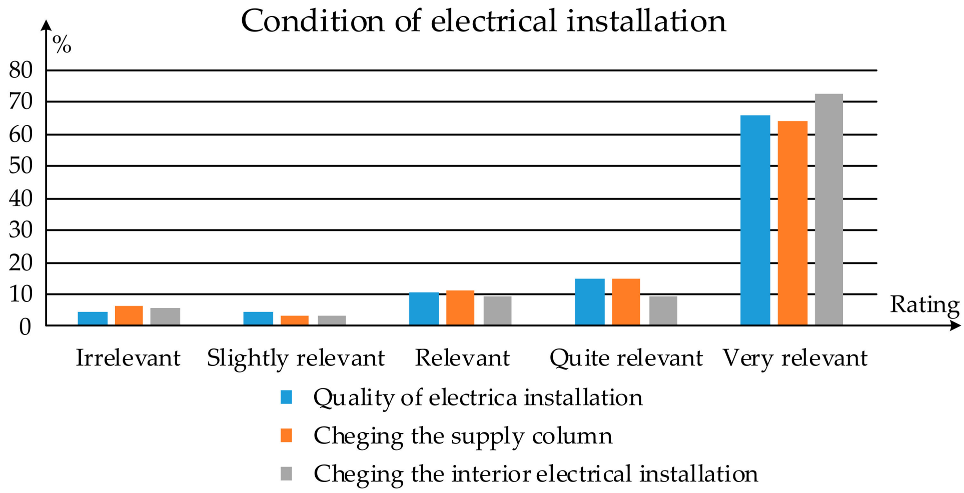


Figure 12. The relevance of the electrical installation condition. Source: Processed by the authors.

From the analysis conducted, it is observed that there is a certain balance between the respondents' opinions regarding the quality of the electrical installation and the necessity of checking the power supply column. Thus, 15% of respondents consider checking the power supply column to be quite relevant, and 64.1% consider it to be very relevant. Only taking into account the responses of people with qualifications from higher education, we find that 77.79% of them consider checking the power supply column to be very relevant or quite relevant. Analyzing the responses regarding the relevance of periodic checks of the interior power supply installation, it is evident that respondents are much more responsible. Accordingly, 72.5% of them considered this check to be very relevant, and 9.6% considered it to be quite relevant (Figure 12). From the analysis, there is an almost unanimous opinion regarding the relevance of the quality of the electrical installation and the checks performed on it and the connection. The percentage of those considering these objectives quite relevant and very relevant ranges from 79.1% (for checking the connection) to 82.1% (for checking the interior electrical installation).

3.1.7. Covering Costs Generated by Electricity Usage

For the normal functioning and safety of the electrical installation, it is necessary for it to be periodically inspected and properly maintained. While homeowners bear the cost of replacing the internal electrical installation, problems arise when it comes to the issue of the supply column in the case of apartment buildings. Regarding the costs generated by the verification of the supply column, 437 respondents (64.45%) were of the opinion that these should be borne by the electricity supplier, while 241 respondents (35.55%) believed they should be borne by the consumer (Figure 13). Considering that the electrical installation from the transformer station to the general distribution panel in residential buildings is part of the supplier's installation, it follows that from the general panel to the individual meters of the tenants, or the distribution panel inside the residences, the electrical installation falls under the ownership of the tenants'/owners' association.

If we analyze the responses regarding the costs generated by the verification of the internal electrical installation, 527 respondents (77.73%) stated that these costs should be borne by the consumer. At the same time, 151 respondents (22.27%) mentioned that these costs should be borne by the electricity supplier. This opinion is not correct, as there are no clauses of this type in the electricity supply contract, nor is it correct to introduce them.

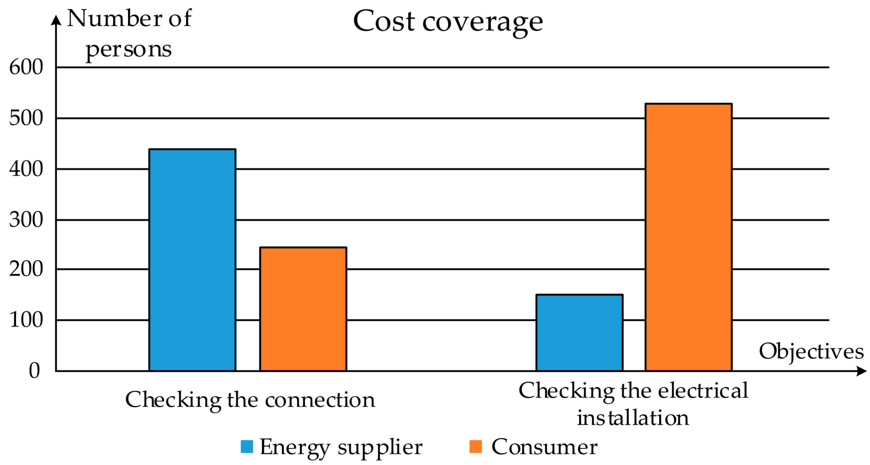


Figure 13. Covering verification costs. Source: Processed by the authors.

Regarding the factors considered to be influencing the final price of electricity (Figure 14), the main factor chosen was the political system (316 respondents—46.61%), followed closely by regulations in the field (293 respondents—43.22%). The fact that the political system influences the price of electricity, determined also by energy imports and exports, was identified based on an analysis of the evolution of electricity production in Romania during the period of 2010–2023 [45]. The next factors considered in terms of importance are the evolution of fuel prices (255 respondents—37.61%), the existence of electricity producers (170 respondents—25.07%), the operators of the electricity transmission and distribution systems (158 respondents—23.30%), and meteorological conditions (40 respondents—5.9%).

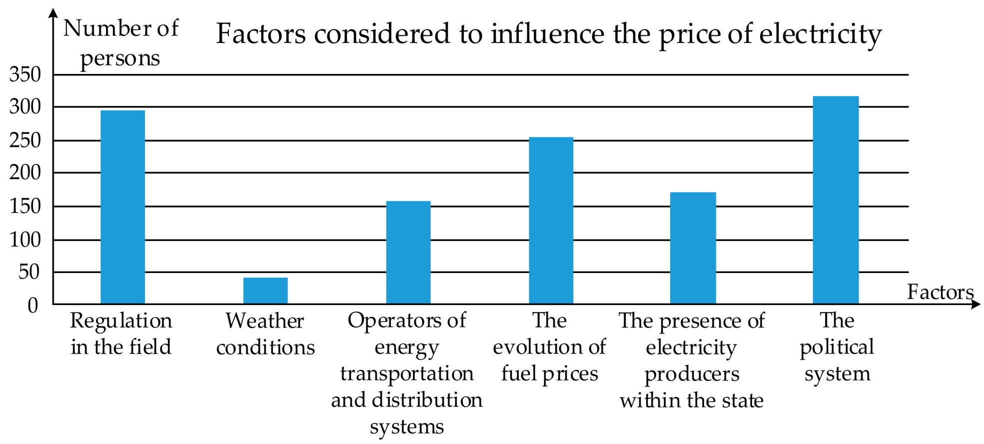


Figure 14. Factors considered to influence the price of electricity. Source: Processed by the authors.

3.1.8. Electricity Consumption

Based on the analysis of monthly electricity consumption, 14.9% of respondents stated that they have a consumption of less than 100 kWh, 61.36% have a consumption between 100 kWh and 250 kWh, and 23.75% have a consumption of more than 250 kWh. Analyzing the responses regarding the evolution of electricity consumption, it was found that 55.2% of respondents mentioned that it has increased significantly compared to 15 years ago, while 19.3% stated that it has increased slightly (Figure 15). As the largest share of respondents was from the university education category, we analyzed their opinion on energy consumption compared to 15 years ago. Thus, 47.1% of the sample analyzed stated that consumption had increased a lot, 15.22% that it had increased a little, and 2.9% that it had decreased.

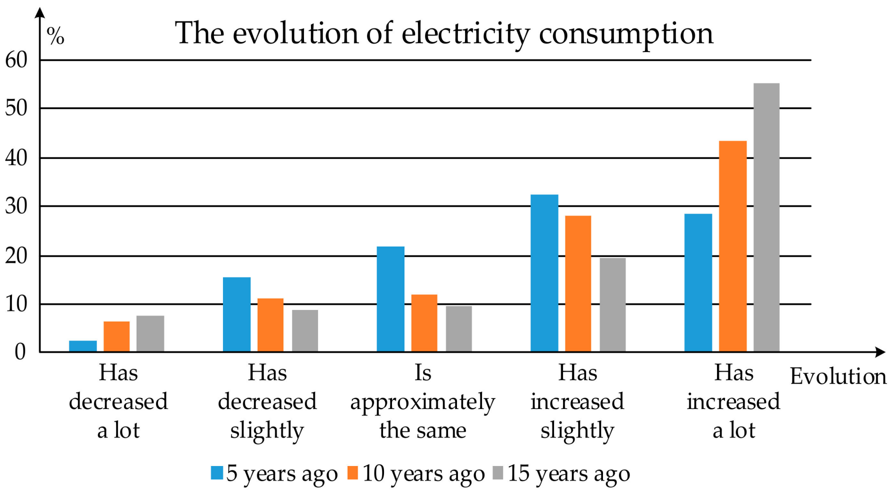


Figure 15. The evolution of electricity consumption. Source: Processed by the authors.

Analyzing the opinion of people with high school-level education on the evolution of electricity consumption, it was found that 34.92% of this category of respondents said that, compared to 15 years ago, it has increased a lot, 11.9% said that it has increased a little, respectively, and 2.38% said it has decreased. It can be said that the level of education may influence the respondents' perception of the evolution of electricity consumption. If we analyze answers on energy consumption according to the gender of the respondent, we find that 44.92% of women say it has increased a lot, while for men the percentage drops to 28.21%. The percentage of men who stated that the amount of energy consumption has decreased a little was 16.37%, while the percentage of women who gave the same answer was 13.92%. Analyzing the responses of those who said that the electricity consumption has decreased, it was found that the percentage of men who had this opinion (3.77%) was higher than that of women (1.47%). From this analysis, it can be identified that gender also influences the perception of energy consumption.

Approximately the same trend can be identified in the responses regarding the comparison with electricity consumption from 10 years ago, where 43.2% of respondents stated that it has increased significantly, and 28% stated that it has increased slightly. When comparing current electricity consumption with that from 5 years ago, 28.2% of respondents declared that it has increased significantly, while 32.2% declared that it has increased slightly. From this analysis, it can be inferred that individuals are interested in implementing measures to reduce electricity consumption.

Analyzing the evolution of the current number of electrical appliances (Figure 16) compared to that of 5 years ago, it is observed that 50.4% of respondents stated that it has increased slightly, while 23.9% stated that it has increased significantly. If we analyze the current number of appliances compared to that from 10 years ago, 84.9% of respondents stated that it has increased (slightly 42.1% and significantly 42.8%). Compared to 15 years ago, a significant increase was identified by 88.1% of respondents (slightly 22.9% and significantly 65.2%).

Regarding the choice of solutions considered useful for reducing electricity consumption and its cost, 370 respondents (54.57%) opted for replacing electrical appliances and electronics (Figure 17). This option was followed by the use of alternative energy sources (renewable energy sources—244 respondents—35.99%) and choosing an energy offer suitable for consumption needs (209 respondents—30.83%).

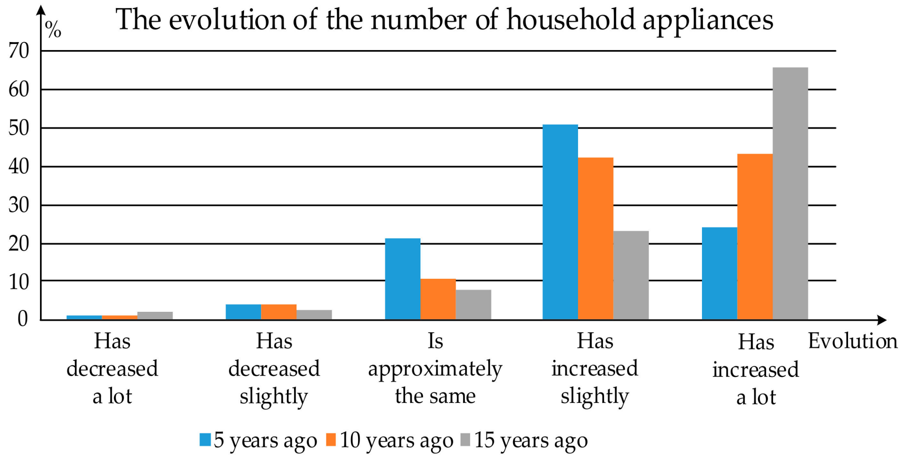


Figure 16. The evolution of the number of household appliances. Source: Processed by the authors.

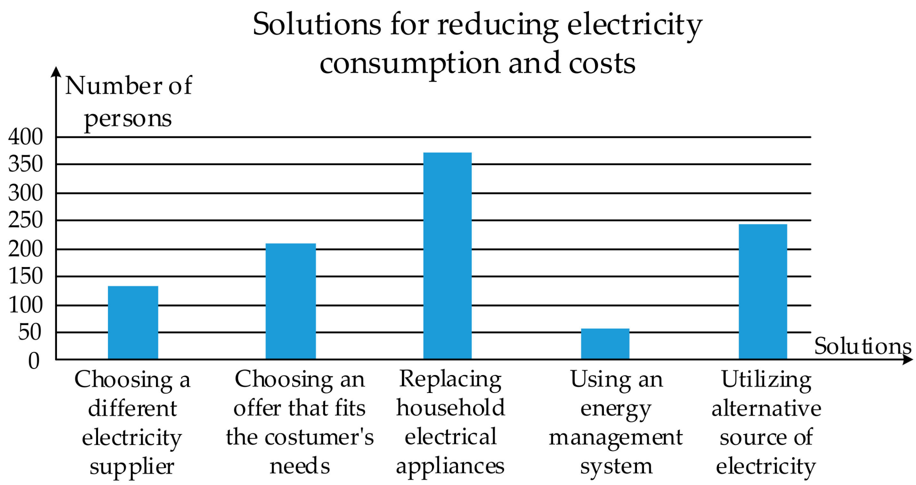


Figure 17. Ways to reduce electricity consumption and its cost. Source: Processed by the authors.

Analyzing the responses by the level of education shows that 41.13% of respondents with higher education would consider replacing appliances, while for respondents with secondary education the percentage is 34.92. The next option for reducing energy consumption is to choose another offer that is appropriate for consumption needs. Some 21.42% of respondents with secondary education are interested in this option, while the percentage of respondents with tertiary education is 18.83. The use of renewable energy sources is another option and is favored by 15.87% of respondents with a high school education and 11.52% of respondents with a university education. This analysis shows the importance of conveying concrete and user-friendly information regarding solutions that can reduce electricity consumption.

3.1.9. Renewable Sources and Choosing the Electricity Supplier

To reduce the cost associated with electricity consumption, some household consumers have become prosumers, utilizing renewable energy systems, especially photovoltaic systems. This solution of generating electricity at the point of consumption reduces losses in transmission and distribution lines, having a beneficial effect on the related costs [46] and ensuring the energy supply [47].

In the operation of these grid-connected systems, problems can occur due to grid short circuits affecting PV systems [48], as well as due to energy being fed into the grid. In this case, there are problems managing the amount of electricity fed into the grid [49], the quality of the energy supplied [50,51], and the stability of the system in steady state and transient mode [52,53].

Regarding the use of renewable energy sources, respondents' interest in their utilization is identified, with 296 respondents (43.66%) declaring that they do not have these sources but are interested in using them (Figure 18). This interest coincides with the interest shown by other people all over the world [54,55]. From this analysis, it is observed that the percentage of those who stated that they own/use renewable energy sources (31 respondents—4.57%) is higher than that of those who neither own nor are interested in these energy sources (31 respondents—3.39%). A significant percentage of respondents stated that they do not own such renewable sources (328 respondents—48.38%). The correlation of responses shows the low level of interest of people with higher education in the use of renewable sources. Of the 414 respondents with higher education, only 19.81% said they were interested in these sources and 4.59% owned such sources. Analyzing the answers of respondents with high school studies, on the same topic it was found that the percentage of those interested in the use of renewable sources is much higher, reaching 37.3%. The percentage of those with secondary education who have such sources of electricity remained approximately constant (4.76%) compared to the percentage of respondents with high school studies. An analysis of the responses by gender shows that the percentage of men (44.58%) interested in the use of renewable energy sources is higher than that of women (38.83%). This analysis shows that it is necessary to adopt policies to raise public awareness of the need to use renewable energy sources.

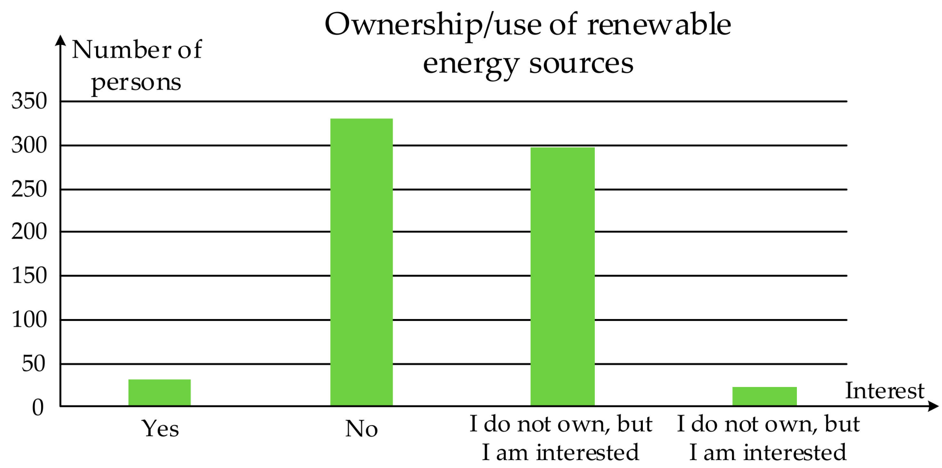


Figure 18. Ownership/use of renewable energy sources. Source: Processed by the authors.

Regarding respondents' interest in a specific category of renewable energy source (Figure 19), the majority of respondents were interested in photovoltaic systems (61.95%), followed by heat pumps (13.72%) and solar collectors (12.98%).

Since we operate in a liberalized electricity market, where ANRE does not have the right to regulate the final price [33], the price offered by the supplier is determined based on supply and demand. Based on the responses given in the questionnaire, it was established that the most important factor determining the choice of a specific electricity supplier was the price of active energy (Figure 20), chosen by 491 respondents (72.42%). This was followed by "the stability of the services provided by the electricity supplier" (219 respondents—32.3%), "the fluctuation of the final price of electricity" (215 respondents—31.71%), and "the costs of transport and distribution of electricity" (157 respondents—23.16%). Very close to these factors were the amount of fees charged by the electricity supplier (135 respondents—19.91%), the seniority of the supplier in the electricity market (116 respondents—17.11%), and the amount of fees regulated by ANRE (103 respondents—15.19%).

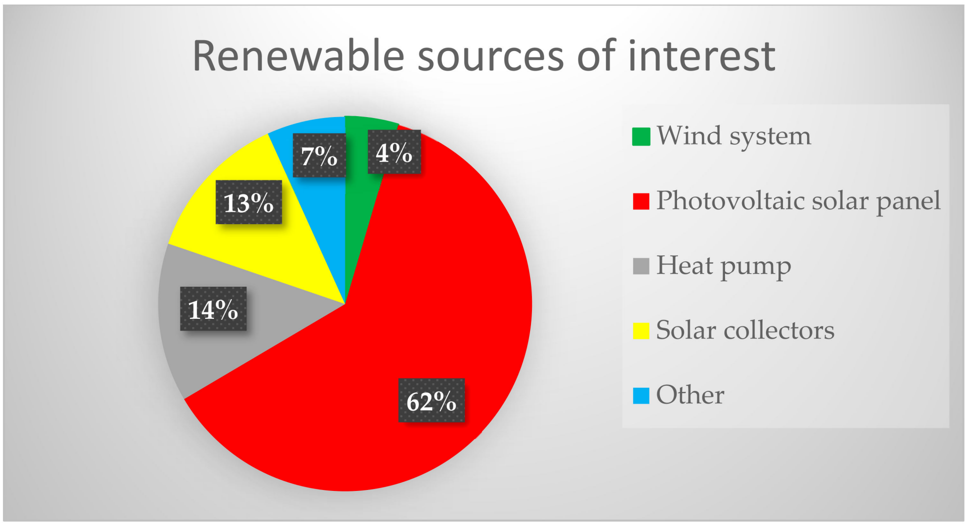


Figure 19. Respondents' interest in a specific renewable energy source. Source: Processed by the authors.

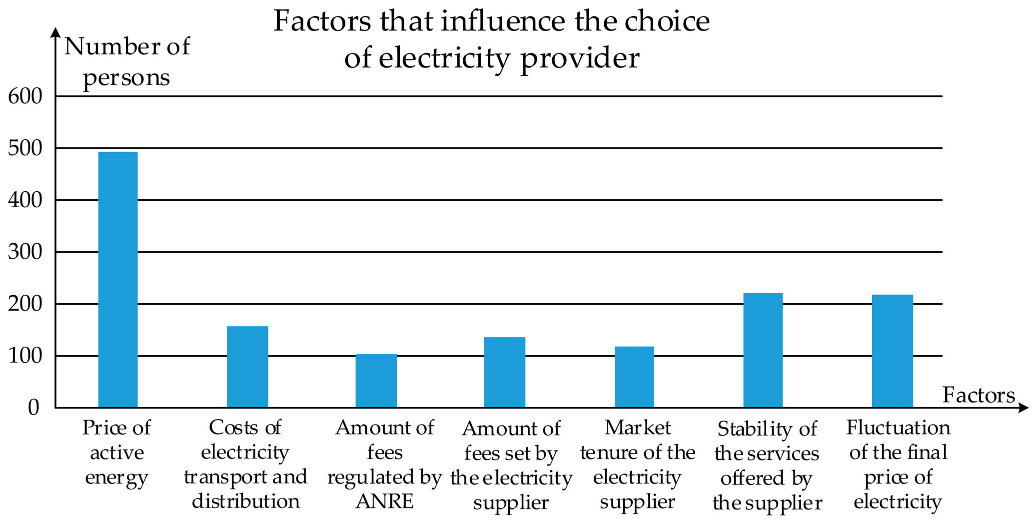


Figure 20. Factors that influence the choice of electricity provider. Source: Processed by the authors.

3.2. Estimating the Electricity Consumption of Household Appliances and Identifying the Type and Section of Conductors in the Power Supply Column of Residential Buildings

3.2.1. Estimating the Energy Consumption of Electrical Appliances Used by Household Consumers

To estimate the energy consumption of various household appliances, we analyzed their technical specifications from several equipment sellers' websites in Romania. The values of the technical characteristics were not influenced by the age factor, as the analyzed equipment was new. We denoted W_1 as the minimum energy identified from the technical specifications for a certain type of equipment, corresponding to the current I_1, and W_2 as the maximum energy for equipment from the same category and with approximately the same specifications, corresponding to the current I_2. To determine the current corresponding to the operation of washing machines and washer–dryers, we considered the duration of a cycle to be 1 h. For electric stoves and cooktops, we considered a level of energy corresponding to operation at maximum power. For printers, we considered the power absorbed during printing. The aggregated results are presented in Table 3.

Table 3. Technical characteristics of electrical equipment used by household consumers.

Type of Equipment	U [V]	W_1 [Wh]	I_1 [A]	W_2 [Wh]	I_2 [A]
Refrigerator	230	23.4	0.102	36	0.157
Freezer	230	619	2.691	885	3.848
Washing machine	230	41	0.178	91	0.396
Washer–dryer	230	2450	10.652	3770	16.391
Dishwasher	230	659	2.865	840	3.652
Microwave oven	230	700	3.043	1000	4.348
Electric oven	230	1380	6	4000	17.391
Induction hob	230	2000	8.696	2100	9.13
Built-in hob	230	3700	16.087	7400	32.174
Electric stove	230	8600	37.391	10,500	45.652
Electric grill	230	900	3.913	2460	10.696
Multicooker	230	1000	4.348	1600	6.957
Deep fryer	230	1400	6.087	2000	8.696
Toaster	230	700	3.043	2000	8.696
Food processor	230	700	3.043	1500	6.522
Kitchen mixer	230	250	1.087	1000	4.348
Espresso machine	230	1050	4.565	1600	6.957
Coffee maker	230	600	2.609	1200	5.217
Extractor hood	230	110	0.478	300	1.304
Air conditioning unit—cooling	230	1080	4.696	3400	14.783
Air conditioning unit—heating	230	1050	4.565	1600	6.957
Apartment heating boiler	230	69	0.3	110	0.478
Electric radiator	230	2000	8.696	3000	13.043
Vertical ironing appliance	230	1100	4.348	1600	6.957
Iron	230	1750	7.609	3200	13.913
Vacuum cleaner with bag	230	650	2.826	1000	4.348
Hair dryer	230	1200	5.213	2500	10.870
Hairbrush	230	750	3.261	1200	5.217
Television	230	50	0.217	98	0.426
Computer	230	450	1.957	850	3.696
Printer	230	313	1.361	1725	7.500
Audio system	230	300	1.304	2400	10.435
LED chandelier	230	84	0.365	132	0.574
LED ceiling light	230	22	0.574	252	1.096

Source: Processed by the authors.

According to the data presented in Table 1, there are situations where a single household appliance (such as the electric stove) has a much higher power rating than what single-phase electrical installation allows. Additionally, it is mentioned in regulations that "connecting electrical appliances through sockets with powers up to 2 kW is allowed" [22]. However, there are electrical appliances (including hair dryers) whose power consumption exceeds 2 kW, and they are not supplied through dedicated sockets. Analyzing various possible scenarios where multiple electrical appliances operate simultaneously, we conclude that there are numerous situations where the current through the feeder conductors approaches the maximum allowed values, without considering their physical aging.

Each electrical appliance is classified into a specific energy efficiency class, based on the energy efficiency index I, defined by the following relation [56]:

$$I = C/C(R), \tag{2}$$

where C represents the actual consumption of the household appliance and C(R) is the reference consumption. The reference index values for appliances in class A+ are $30 \leq I \leq 42$, while for an appliance in class F, they are $110 \leq I \leq 125$. It follows that, when choosing household appliances, increased attention must be paid to the energy efficiency class. Additionally, to determine the current value during operation in different modes, measurements with specialized devices are necessary.

Studies have found that the age at which appliances are replaced differs depending on the type of appliance. For example, in the case of freezers, 40% of them have been in use for more than 20 years [57]. Based on this finding and measurements, it has been established that the technical aging of electrical refrigeration equipment can increase electricity consumption by up to 36% [58] over its 18-year lifetime. Periodic measurements of new refrigeration appliances identified that, after only two years of operation, electricity consumption increased by up to 11%. Moreover, in the same study, 21 refrigerators were tested after 21 years of usage, which resulted in an increase in electricity consumption of 28% compared to when they were put into service. Based on the measurement results, models were created that can be used to estimate the increase in electricity consumption due to aging. After applying the models, it was determined that for refrigerators with 16 years of usage, the average increase in energy consumption is 27% [58]. Thus, it can be said that the amount of electricity consumption will be higher as this equipment is used for a longer period of time. For this reason, it is recommended that old household appliances be replaced by new, energy-efficient appliances [59]. The action of replacing old refrigerators resulted in a reduction in electricity consumption by about 8% [60]. At the same time, it is necessary to use equipment that consumes as little electricity as possible in stand-by mode [61].

3.2.2. Identification of the Type and Cross-Section of the Conductors in the Supply Column of the Blocks

It is known that currently, for a single-phase connection, the maximum power is 11 kVA (9.9 kW). If the power requested by users is greater than 11 kVA but less than 30 kVA, a three-phase connection is requested [62]. The power absorbed by consumers from the network is limited by intelligent controls, set at the values approved by the technical notice of connection.

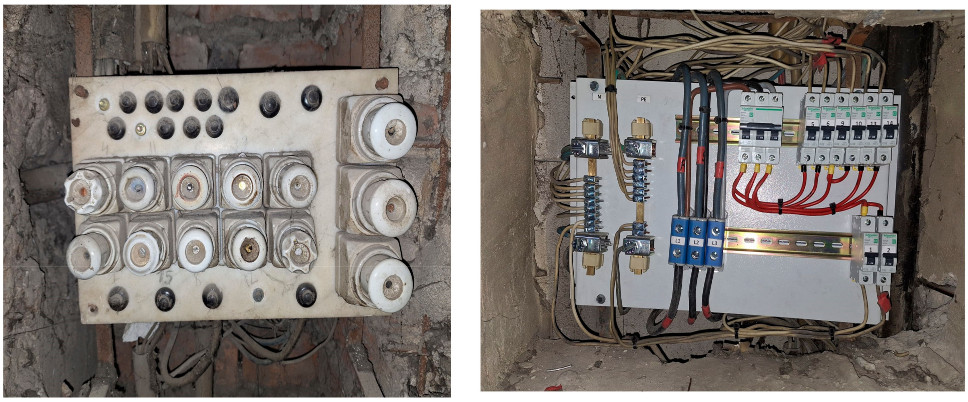
According to some verifications conducted in this study, we found that in buildings constructed between 1960 and 1990 [63], FY-type aluminum conductors with a cross-section of 6 mm^2 were used for the columns, both for the phase conductors and for the neutral conductor. In many cases, the neutral conductor was common for two or even three apartments, resulting in an overload. According to the regulations, the maximum current for such conductors should be 30 A for two conductors installed in a tube, and 27 A for 3 conductors installed under the same conditions [64,65]. The poor quality of the work performed during that period can also be identified in Figure 21.

(**a**) (**b**)

Figure 21. Rear view of a panel in a residential building: (**a**) conductors used for the apartment columns; (**b**) neutral and PE conductors connected together. Source: Photos by the authors.

Currently, in some buildings, work is being performed to replace the consumer supply panels, using 6 mm2 copper conductors for both phase and neutral conductors (Figure 22). For this type of conductor, installed in groups of 3 in conduits, the current rating is 40 A [22].

Protection against overcurrent is provided by 32 A fuses for each apartment, and 63 A fuses are used for the general supply. From the image, it can be seen that only the service entrance has been replaced, without any interventions on the apartment supply columns.



(**a**) (**b**)

Figure 22. View from the front of a distribution board in a residential building: (**a**) old panel; (**b**) new panel. Source: Photos by the authors.

4. Discussion

Based on the analysis of the questionnaire responses, it was found that over 50% of the respondents were in the age range of 36–55 years. This suggests that their answers regarding the evolution of electricity consumption, the type, and number of electrical appliances are genuine and accurate. The fact that over 60% of the respondents have higher education and that over 75% are active in the labor market confirms that the topics addressed in the questionnaire are familiar to the respondents and have direct relevance to their perceptions.

According to the analysis conducted, it was found that over 70% of the buildings owned by the respondents were over 30 years old. Considering that the electrical installation was carried out at the time the buildings were constructed and given that the materials used at that time have a finite lifespan, there is a need for the periodic inspection of these installations.

From the analysis of the questionnaire responses, it was found that over 55% of the respondents stated that they have replaced their internal electrical installation. However, in many cases, dedicated outlets were not provided for single-phase devices with an installed power greater than 2 kW. There was a significant percentage of respondents who stated that they have not replaced their internal electrical installation or have only partially replaced it (34.8%). This may lead to the conclusion that periodic inspection of the internal electrical installation is necessary for the safety of residents. An even more significant risk is posed by the feed columns of the apartment buildings, which have either not been replaced or it is unknown whether they have been replaced. Field checks revealed that a 6 mm^2 AFY-type neutral conductor was used for 2–3 apartments. Since this conductor can withstand a continuous current of 30 A, and considering that often the current absorbed for a single apartment approaches that value, it follows that in the case of feed columns in apartment buildings, they are undersized. The quality of the work performed at that time, the quality of the materials used, and their wear and tear should also not be overlooked.

Regarding the replacement of the feed column, it was found that 39.82% of the respondents stated that they have replaced their feed column in the last 20 years. Howe-er, it was observed that over 26% of the respondents declared that they have not replaced their electrical feed column (Figure 5). If we include respondents who said they do not know whether the feed column has been replaced in this category, we reach the conclusion that over 60% of the respondents have not carried out replacement works. This fact can be considered a major risk which they are exposed to, especially the tenants of apartment buildings. These risks can be reduced or even eliminated, especially considering the respondents' opinions regarding the inspection of the internal electrical installation and the feed column. Thus, over 64% of the respondents considered the inspection of the feed column to be very relevant, and over 72% considered the inspection of the internal electrical installation to be very relevant. The respondents' responsibility regarding the inspection of electrical installations can also be identified from their opinions regarding the coverage of the costs associated with these inspections.

From the analysis of the number and type of electrical equipment used by household consumers, it was found that the percentage of respondents who have purchased one or more of the devices predefined in the questionnaire has increased. This trend has also been identified in other research [43,44]. There has been an increase in the percentage of respondents using power consuming electrical equipment such as air conditioners, electric stoves/ovens, microwave ovens, and coffee makers. Based on the analysis of the technical characteristics of these types of appliances, the need for special connections or dedicated outlets can be identified. Furthermore, a change in respondents' preferences regarding the use of lighting sources is observed. Currently, most respondents use LED lighting sources, considering the electricity savings they provide. Hence, the respondents are in line with the global trend of using energy efficient lighting sources [66,67].

Regarding the evolution of electricity consumption, it was found that over 55% of respondents stated that it has increased significantly compared to energy consumption 15 years ago, given the availability of Class A (or A+ or A++) products on the market. This increase has also been identified in other countries, with the research predicting an even more significant increase in the coming years [68–70].

However, the increase in consumption is also influenced by the growing number of electrical and electronic devices, a growth considered very significant compared to that period by over 88% of respondents. The analysis also revealed that respondents are interested in reducing electricity consumption by replacing appliances with more energy-efficient ones (identified by over 54% of respondents) and by using renewable energy sources (identified by over 35% of respondents).

Other measures proposed by authors to reduce electricity consumption include the following:

- For lighting, authors propose using energy-efficient bulbs (such as LEDs), utilizing motion sensor lamps, implementing intelligent lighting systems, and employing artificial light only when necessary;
- For appliances, authors propose keeping devices connected only when they are in use, reducing screen brightness, washing rugs or dishes efficiently, and adjusting the boiler or heating system to the lowest temperature.

Based on the analysis of the technical characteristics of electrical and household appliances, it was found that there are devices with powers exceeding 2 kW. These required specific designs and execution for their power supply and protection. In the case of using an electric stove, its power exceeds the maximum power for a single-phase connection. Analyzing various scenarios of the simultaneous operation of electrical equipment, it is noted that there are situations where the power of these devices approaches the maximum allowable value. From these considerations, it follows that the electrical supply installation must correspond both functionally and in terms of safety in operation; therefore, the periodic verification of electrical installations is necessary.

By analyzing the correlations between the received answers, one can notice the need to inform the entire population regarding reductions in electricity consumption. This information should be clear and easy to understand, even for those with secondary education. Effective energy sustainability can be ensured by implementing different solutions.

Due to the lack of a representative sample, these conclusions represent the opinions/attitude of the respondents as expressed via the questionnaire. These opinions will be checked for their validity on well-defined samples in a future paper. For this purpose, a detailed analysis of all responses to the questionnaire will be performed in a future paper, and another similar questionnaire will be applied to a well-defined sample. The aim will be to identify the evolution of electricity consumption in Romania, the evolution of the number of household appliances, and the use of renewable energy sources. At the same time, electrical measurements will be taken, by survey, at various power columns in residential blocks in Romania to determine whether the current value is below the maximum value for which the power column was dimensioned.

5. Conclusions

Analyzing the electricity consumption of household appliances in use, correlated with their aging factor, shows that the electricity consumption of domestic users has increased. This finding is also underlined by the analysis of the responses to the questionnaire. This high level of energy consumption has an impact on the supply columns in the older blocks of flats, which have not been upgraded.

Considering the overloading of the supply columns in residential blocks and their age, we proposed that the competent authority introduce into legislation the obligation of the periodic inspection of these installations. To increase operational safety, additional methods of current limitation and the detection of overheating of electrical conductors can be used. Additionally, the use of electrical equipment with power levels exceeding 2 kW requires the proper sizing of the installation and specific power supply using appropriate protection systems. From these considerations, it follows that the interior electrical installation of consumers must also be periodically inspected by specialized personnel. Thus, the introduction of the obligation of periodic inspection of electrical installations is necessary.

This analysis underlines both the need to replace old household appliances and to ensure energy needs by using renewable energy sources. This will reduce electricity consumption and costs, and therefore pollution.

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