

Research Article

# Typology of Housing and Household Energy Behaviors in Cameroon: Diagnosis for better Energy Efficiency

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## Abstract

*This research analyzes the determinants of domestic energy efficiency in Cameroon through a quantitative study of 333 households in Douala, Yaoundé, and Ngaoundéré. Using Chi-square  $\chi^2$  independence tests, the study explores correlations between sociodemographic factors, housing characteristics, and installed energy capacity. Key Results include: Material Inertia: A strong geographical dependence exists between cities and construction materials  $p < 0.001$ . Adobe bricks with cement mortar, dominant in Ngaoundéré, offer under-exploited thermal efficiency potential compared to the cement-dominated metropolitan areas of Douala and Yaoundé. Generational Transition: Refrigeration equipment follows a life cycle, with a critical acquisition phase between ages 25 and 35, identifying this as the pivot segment for introducing high-performance technologies. The Performance Paradox: Analysis demonstrates that physical size and equipment type are not reliable indicators of installed power. Only the Energy Class (A+, A++) allows for a real and significant reduction in power demand  $< 50$  kW. Information Deficit: A major obstacle was identified: 69% of users are unaware of their appliance's energy class, a technical ignorance that increases with the surface area of the dwelling.*

**Keywords:** Habitats, Behaviors, Households; Diagnosis, Energy Efficiency.

## Introduction

In Cameroon, the domestic sector accounts for approximately 70% of national energy consumption. According to the National Institute of Statistics (2002), 30% of energy consumed in households is attributed to refrigerators and freezers, making them the second most energy-intensive appliances in homes. Furthermore, nearly 60% of Cameroonian households own at least one cooling appliance, representing a stock of approximately 10 million units in service. In recent years, significant efforts have been made to improve the energy efficiency of domestic refrigeration. Methods such as energy consumption labeling serve as a primary guide for energy improvements. Additionally, various technical mechanisms such as optimized compressors, heat exchangers, adequate thermal insulation, and the analysis of compartment thermal behavior are extensively studied by researchers to enhance efficiency.

Improving domestic refrigerators not only increases manufacturer competitiveness but also reduces environmental impact and provides economic benefits to consumers.

However, factors such as ambient temperature and relative humidity significantly affect energy consumption, as well as the type and charge of refrigerant used.

Other critical factors depend directly on consumer habits, including: Door-opening frequency; Thermostat settings; Food load and storage practices; Cleanliness of compartments.

Literature highlights that consumers play a primary role in the energy and thermal behavior of these appliances. Studies by Janjic et al. (2016) revealed that nearly half of studied samples had inadequate storage practices, with internal temperatures significantly higher than manufacturer recommendations. Geppert and Stammiger (2010, 2013) demonstrated that energy consumption is highly sensitive to ambient temperature and nearby heat sources, concluding that specific consumer information on energy efficiency remains scarce. Further research by Hasanuzzaman et al. (2009) and James et al. (2017) confirmed that ambient thermal loads and appliance age have major impacts on heat transfer and health risks.

Consequently, it is necessary to analyze the impact of user habits on refrigeration energy consumption to propose better energy utilization. This study analyzes the various factors influencing the energy behavior of

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domestic refrigerators and freezers based on a series of surveys conducted specifically among consumers in the cities of Douala, Ngaoundéré, and Yaoundé.

## 1. Materials and methods

The methods presented in this study are based on a series of surveys conducted among consumers in three major cities in Cameroon, chosen for their climatic diversity. Consumers from various socio-economic classes were selected to ensure a representative sample of the central and northern regions of the country. Photographic examples were included in the questionnaire to facilitate participant understanding. The survey was administered to parents, friends, and neighbors, all of legal age, across diverse households of varying sizes.

### 1.1 Data Collection

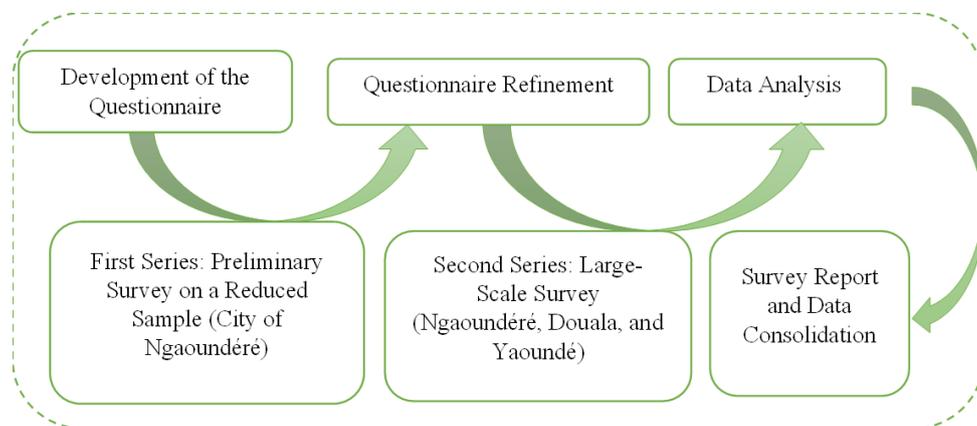
To obtain results that accurately reflect the usage habits of domestic refrigerators, approximately 333 households were surveyed. The questions were designed to highlight the energy behavior of the

appliances resulting from consumer habits and were administered online. The questionnaire consisted of four sections and approximately twenty questions, including multiple-choice options to further explore the main subject.

Based on the study's objectives, participants were asked about City of residence, Housing characteristics, Acquisition status (new vs. second-hand) and duration of ownership (appliance age), Household size (number of family members using the unit), Proximity to heat sources, Food load in compartments (very full, full, normal, almost empty), Average daily door openings, Interior and exterior cleanliness, Monthly energy consumption.

### 1.2 Survey Procedure

The survey process followed a two-stage procedure. The first stage involved a pilot study on a small sample (Ngaoundéré) to validate the questionnaire, followed by a mid-term report. The second stage utilized a large-scale sample to generalize the questionnaire across the cities of Douala, Yaoundé, and Ngaoundéré



**Figure 1** : Survey Procedure

### 1.3. Data Collection Tools

#### 1.3.1. Information Gathering Methods

The data collection was carried out using a dual-modality approach to ensure maximum reach and accuracy:

- Electronic Method: Leveraging Information and Communication Technologies (ICT), the questionnaire was distributed to participants via a Google Forms link ;
- Physical Method: Field visits were conducted to meet participants directly, allowing for the collection of responses in person and ensuring a higher response rate in specific neighborhoods.

#### 1.3.2. Questionnaire Design

The development of the questionnaire was structured around four main pillars : Individual Profile,

Demographic data of the respondents, Housing Characteristics: Building materials and thermal environment, Refrigeration Usage : Specific habits regarding food preservation, Household Energy Consumption: Power demand and billing data. The simplicity of the questionnaire was prioritized through the careful selection of question types based on the target information. It included open-ended questions, providing respondents the latitude to express themselves freely, as well as closed-ended questions (dichotomous or multiple-choice) for quantitative standardization.

### 1.4. Statistical Methodology

The primary objective of this analysis is to identify the factors influencing energy consumption and installed power within households. A quantitative approach based on survey data analysis was adopted.

#### I.4.1. Data Processing

Raw data collected were compiled and cleaned using Microsoft Excel prior to statistical treatment. To ensure test reliability, a regrouping of modalities (variable recoding) was performed for categories with low frequencies (less than 5). This process is essential to meet the validity conditions for comparison tests, specifically satisfying Cochran's Rule.

#### I.4.2. Chi-Square chi 2 Test of Independence

The primary statistical tool for analyzing contingency tables is Pearson's Chi-square test. This test determines if a statistically significant relationship exists between two qualitative or discretized quantitative variables.

Test Procedure:

- Null Hypothesis H0: The two variables are independent (no relationship exists). ;
- Alternative Hypothesis H1: The two variables are dependent (a significant relationship exists) ;
- Significance Level: The critical threshold was set at  $\alpha = 0.05$  (95% confidence interval).

The calculation is based on the deviation between observed frequencies  $n_{ij}$  and theoretical (expected) frequencies  $e_{ij}$ . The theoretical frequencies are calculated using the following formula:

$$\chi^2 = \sum \frac{(n_{ij} - e_{ij})^2}{e_{ij}} \quad (1)$$

#### I.4.3. Significance Analysis and P-value Interpretation

For each cross-tabulation of variables, the associated p-value was interpreted to determine the statistical weight of the observed relationships:

- If  $p < 0.05$  : The relationship is considered statistically significant. The null hypothesis H0 is rejected, indicating a confirmed dependency between the variables.
- If  $p > 0.05$  : The relationship is not significant. The null hypothesis H0 is maintained. Any observed variations are considered to be the result of sampling randomness.

#### I.4.4. Software Used

Statistical computations were performed using R software, version 4.0.3 (Open Source). The choice of this platform ensured high precision in calculating:

- Degrees of Freedom df: To adjust the test according to the size of the contingency tables.
- Probability Values p: To ensure the accuracy of the significance results.

## II. Results and Discussion

### II.1. Habitat Characterization

The selection of construction materials significantly influences the thermal behavior of buildings (Boursas, 2014). In this study, wall characteristics were categorized based on the following materials : concrete blocks, adobe or rammed earth, timber planks, and other miscellaneous materials. Concrete blocks and timber are classified as sustainable construction materials, whereas the remaining types are categorized as makeshift or non-durable materials.

**Table 1:** Distribution of construction materials across the studied cities

City	Cement Blocks	Adobe Bricks with Cement Mortar	Others	Total
Douala	104	10	10	124
Ngaoundere	88	37	10	135
Yaoundé	67	6	1	74
<b>Total</b>	<b>259</b>	<b>53</b>	<b>12</b>	<b>333</b>

From Table 1, it is observed that Ngaoundéré exhibits the highest utilization of adobe bricks with cement mortar (37 out of 53 cases, representing 70% of this material within the total sample). This reflects a climate adaptation strategy and the availability of local materials in the northern region. In contrast, Douala and Yaoundé are dominated by cement blocks (84% in Douala and 90% in Yaoundé). Rapid urbanization and industrial supply have established cement as the standard construction material in these cities. With only one case in the "Others" category and six in "Adobe," Yaoundé stands out as the most standardized city regarding construction choices.

Adobe brick, which is highly prevalent in Ngaoundéré, possesses thermal regulation properties

far superior to those of cement blocks. Consequently, the cooling and ventilation requirements could naturally be lower in Ngaoundéré's buildings. The fact that Douala (a hot and humid city) massively employs cement (which tends to accumulate heat) presents a significant energy efficiency challenge. The collected data demonstrates a shift away from local materials in favor of an industrial standard that is thermally less efficient.

Statistical analysis using the Chi-square test confirms a very strong dependency between geographical location and the choice of construction materials  $p < 0.001$ . Ngaoundéré is distinguished by the notable persistence of adobe brick with cement mortar a material with high thermal inertia whereas

Douala and Yaoundé illustrate a hegemony of cement. Regarding building energy efficiency in Cameroon, these results highlight the urgent need to rehabilitate

high-performance local materials in coastal and forest zones to mitigate future cooling demands.

## II.2. Housing Area and Energy Consumption

**Table 2 :** Survey Cities and Construction Materials

Housing Surface Area	Less than de 50 kW	Beetwen 50 and 110 kW	More than 110 kW	Don't know	Total
Less than 50 m <sup>2</sup>	40	31	22	9	102
Beetwen 60 et 100 m <sup>2</sup>	32	38	39	25	134
Beetwen 110 et 150 m <sup>2</sup>	4	13	16	7	40
More than 160 m <sup>2</sup>	15	20	2	20	57
<b>Total</b>	<b>91</b>	<b>79</b>	<b>79</b>	<b>61</b>	<b>333</b>

This table crosses two discretized quantitative variables: Housing Surface Area m<sup>2</sup> and Installed Power (kW). The objective is to verify whether the size of the dwelling dictates the installed energy capacity. The analysis of this table provides crucial insights for the study:

- Energy Intensity per m<sup>2</sup>: The fact that dwellings smaller than 50 m<sup>2</sup> possess power capacities exceeding 110 kW suggests a high density of energy-intensive equipment in confined spaces (intensive use of air conditioners or electric water heaters).
- The Information Deficit in "Villas": As the size of the dwelling increases > 160 m<sup>2</sup>, the occupant's technical mastery of their installation decreases significantly (35% "Don't know"). This represents a major obstacle to conducting effective energy audits.
- The Transition Threshold: The 110 m<sup>2</sup> mark appears to be a tipping point where power demand

becomes structurally higher, likely due to the increased number of rooms requiring equipment.

Statistical analysis reveals a significant dependency between housing surface area and installed power  $p < 0.05$ . While an increase in surface area generally tends to drive up power demand, specific behavioral patterns emerge: high energy intensity in small dwellings and a growing technical knowledge gap among owners of large properties. These results emphasize that surface area is not the sole determinant of power; the level of equipment and the management of technical information play a predominant role.

## II.3. Preservation Equipment and Age

Out of a population of 333 surveyed households, 80% reported owning at least one refrigerator or freezer at home, while 20% stated that they do not possess any cold storage equipment.

**Table 3:** Cities and use of preservation equipment

City	Freeze	Refrigerator	Both	None	Total
Douala	18	46	38	22	124
Ngaoundéré	26	48	24	37	135
Yaoundé	8	32	25	9	74
<b>Total</b>	<b>52</b>	<b>126</b>	<b>87</b>	<b>68</b>	<b>333</b>

There is a statistically significant relationship between the city and household cooling equipment  $p < 0.05$ . The analysis shows that Ngaoundéré is distinguished by a higher proportion of unequipped households, while Douala and Yaoundé display more homogeneous and higher equipment rates, particularly for combined refrigerator-freezers.

## II.4. Age Group and Usage of Domestic Refrigeration Appliances

A total of 333 households were surveyed, of which 81.5% were headed by men and 19.5% by women. Regarding the age of the consumers, they are categorized into two groups: 25 to 35 years old and 36 years and older, as shown in Table 4. Dividing the participants' ages in this manner allows for an understanding of how refrigerator usage habits can change from one generation to another. According to this table, more than half of the participants are relatively young consumers, with their ages falling between 25 and 35 years.

**Table 4:** Age group of the household head and the use of preservation equipment

Age group	Freeze	Refrigerator	Both	None	Total
25 - 35 years	34	88	63	65	250
36 years and older	18	38	24	3	83
<b>Total</b>	<b>52</b>	<b>126</b>	<b>87</b>	<b>68</b>	<b>333</b>

**Table 4 highlights** à domestic transition illustrated by three distinct phases :

- The Installation Phase (25-35 years): This period is characterized by a lower equipment rate (26% have none). This corresponds to a stage where budgets are often limited or households are still becoming established ;
- The Consolidation Phase (36 years and older): The equipment rate climbs to 96%. From age 36 onwards, the refrigerator is no longer an option but a basic social asset ;
- Accumulation: It is noted that the possession of the "Both" combination (refrigerator and freezer) remains proportionally stable (approximately 25-28% in both groups). This suggests that the

transition toward "full equipment" begins with the purchase of a single refrigerator before moving upmarket.

The grouping of age classes confirms a highly significant dependency  $p < 0.001$  between the life cycle and cooling equipment ownership. The 25-35 age bracket emerges as the pivotal segment : it is where the equipment deficit is most concentrated, but it also represents the highest potential for future acquisition. For any energy efficiency policy, targeting these young households at the time of their first purchase is crucial to ensuring that the future appliance stock is composed of high-performance devices.

#### II.5. Age of the Refrigeration Unit and Acquisition Status

**Table 5:** Age bracket and acquisition status of the equipment

Age bracket of the refrigerator	New	Second hand	Total
Less than 5 years	90	73	163
between 6 and 10 years	61	28	89
between 11 and 20 years	5	1	6
More than 21 years	6	1	7
<b>Total</b>	<b>162</b>	<b>103</b>	<b>265</b>

- Predominance of Recent Units: The vast majority of appliances (163 out of 265, or 61%) are less than 5 years old. This is a positive point for the overall energy performance of the studied stock.
- The Second-hand Market: It represents a significant share (39%). It is noted that second-hand appliances are highly concentrated in the "Less than 5 years" bracket (73 units). This suggests an active resale market for relatively recent units.
- Longevity of New Units: Very old appliances (over 11 years) are rare, but they are almost exclusively of "New" origin. This may indicate that appliances purchased new are better maintained or of higher initial quality than those purchased second-hand.

The Chi-square test allows us to observe whether the mode of acquisition influences the lifespan of the equipment. Although 61% of the stock is less than 5

years old, the significant presence of recent second-hand appliances raises the question of their actual efficiency. Indeed, a 5 year old second-hand appliance can consume up to 30% more than a current Class A+ new model.

#### II.6. Effect of Refrigeration Appliance Size on Energy Consumption

The size of preservation equipment is directly related to household size as well as its energy consumption. We observe that larger families possess high-capacity refrigerators and home freezers, which could impact the household's energy bill.

Table 6 crosses appliance size (volume/dimensions) with its power (kW). This serves as a technical consistency test: normally, the larger an appliance, the higher its installed power should be.

**Table 6:** Appliance size and energy consumption range

Appliance size	Less than 50 kW	Between 50 and 110 kW	More than 110 kW	Don't know	Total
Large	25	55	7	18	125
Medium	36	66	11	27	140
<b>Total</b>	<b>61</b>	<b>121</b>	<b>18</b>	<b>45</b>	<b>265</b>

The Chi-square independence test with 3 degrees of freedom does not allow for the rejection of the null hypothesis of independence between appliance size and declared power. The power distribution follows an identical curve for both size categories, with a major concentration (approximately 45%) in the 50-110 kW range. This result highlights a technical standardization of the equipment stock, where physical dimensions do

not appear to be a determining factor of the installed electrical power.

#### II.7. Effect of the Energy Class of Refrigeration Units on Household Energy Consumption

The energy class is an index used to evaluate the level of energy savings of a piece of equipment; however, it

is a parameter that is very poorly understood by users of refrigeration units. The choice of a preservation appliance takes several parameters into account,

notably family size and energy consumption. Nevertheless, many users remain unaware of the energy class parameter.

**Table 7:** Energy Class and Energy Consumption Range

Energy class	Less than 50 kW	Between 50 and 110 kW	More than 110 kW	Don't know	Total
Efficient (A, A+, A++)	21	34	12	7	74
Low efficiency	2	5	1	1	9
unknown	38	82	25	37	182
<b>Total</b>	<b>61</b>	<b>121</b>	<b>38</b>	<b>45</b>	<b>265</b>

- The "Unknown" Group (68.7%): This represents the critical mass. Its power profile is very close to the general average, suggesting that this group contains a mix of all appliance categories, likely dominated by the second-hand market where the labels have been removed ;
- The "Efficient" Group (28%): It is observed that 28% of these appliances (21 out of 74) fall within the low power range (< 50 kW), compared to only 20% for the Unknown group.

The group of efficient appliances shows a higher propensity to be situated in the lower power ranges. This validates the idea that energy labeling is not merely a marketing argument but corresponds to a reality of lower consumption in the field.

The fact that 182 households are in a state of ignorance Unknown means that energy efficiency policies must first involve information and labeling campaigns before even discussing technological replacement.

The study shows that the cooling equipment stock in Cameroon is marked by high heterogeneity. While the city and the user's age influence access to

equipment, actual energy performance remains a blind spot for nearly 70% of households. Chi-square tests demonstrate, however, that appliances labeled Efficient (Class A and above) pull the installed power downward (< 50 kW). Conversely, the size of the appliance does not appear to be a reliable indicator of its power, suggesting either a standardization of motors or a technical lack of knowledge that masks potential energy savings.

### II.8 Location of Refrigeration Units in Residences

Refrigeration equipment operates based on the principles of phase change of the refrigerant fluid within the circuit. Efficient cooling of the condenser is essential for optimal refrigeration output. It is therefore recommended to place the equipment in a well-ventilated environment that is not subject to significant temperature increases. Studies have shown that a 1°C increase in condensation temperature leads to a 3% increase in energy consumption. However, we observe that in most households, refrigerators are installed in kitchens, which frequently experience temperature spikes during cooking hours.

**Table 8:** Survey cities and appliance location

City	Douala	Ngaoundéré	Yaoundé	Total
Kitchen	80	35	42	157
Living Room	15	30	16	61
Store Room	5	20	5	30
Dining Room	10	2	4	16
<b>Total</b>	<b>110</b>	<b>87</b>	<b>67</b>	<b>264</b>

Data Analysis : A clear hierarchy is observed regarding the chosen locations :

- The Kitchen (Dominant): With approximately 157 occurrences, this is the most common location. As previously noted, this represents a major thermal risk, as proximity to heat sources during cooking increases condensation temperature ;
- The Living Room: Approximately 61 households choose to place their refrigerator in the main living area. This is often a compromise between accessibility and a potentially cooler environment than the kitchen ;
- The Pantry/Storage Room: Approximately 30 households utilize a dedicated storage space ;

- The Dining Room: This is the least frequent location, with approximately 16 occurrences.

Technical and Energy Interpretation: This distribution confirms a problematic trend for energy efficiency in Cameroon:

The Kitchen Paradox: While the kitchen is the most practical location for daily use, it is thermodynamically the least efficient. High ambient temperatures in this room force the compressor to run more frequently.

Impact on Consumption: Correlating this with the rule that a 1°C increase in condensation temperature leads to a 3% increase in energy consumption, the high concentration of appliances in kitchens suggests a significant opportunity for energy savings through

better spatial planning. Since the p-value is less than 0.05, we reject the null hypothesis  $H_0$ . There is a highly significant relationship between the city of residence and the placement of refrigeration machines.

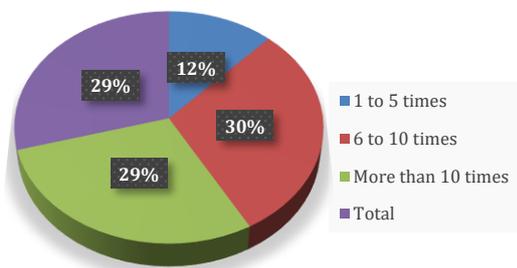
### II.9. Frequency of Door Openings

The frequency of door openings is a determining factor in the energy consumption of a refrigeration unit. Each time the door is opened, cold air escapes and is replaced by warm, humid ambient air, forcing the compressor to work harder to restore the setpoint temperature.

**Khan et al., (2014)** conducted an experimental study on various door-opening conditions for domestic refrigerators. Their findings demonstrate that energy consumption increases by up to **30%**, depending on the frequency of door openings, compared to a refrigerator under controlled experimental conditions. Door openings can increase the compressor's duty cycle by **2 to 5 times**, leading to a higher power demand and a subsequent rise in the system's overall energy consumption. Consequently, a higher door-opening frequency directly correlates with an increased number of compressor start-up cycles.

**Table 9 :** Frequency of door openings

Daily Opening Frequency	Number of Households	Total
1 to 5 times	45	17%
6 to 10 times	112	42%
More than 10 times	108	41%
<b>Total</b>	<b>110</b>	<b>100%</b>



**Figure 2 :** Frequency distribution of refrigerator door openings

The data shows that more than **80% of households** open their refrigerator more than 6 times a day, with a high concentration (**41%**) opening it more than 10 times daily :

- Impact on Energy Load: This high frequency leads to a significant increase in the "latent load" (moisture) and "sensible load" (heat) within the appliance ;
- Thermal Loss: In a tropical climate, such as in the cities studied, the temperature difference Delta T between the interior of the unit and the kitchen can exceed 25°C. Each opening causes a rapid rise in internal temperature, which explains why the declared power of the units often falls into the 50-

110 kW range to compensate for these frequent losses.

This behavior highlights the need for user awareness campaigns regarding "energy-saving gestures," such as grouping the removal or storage of food items to minimize the duration and frequency of door openings.

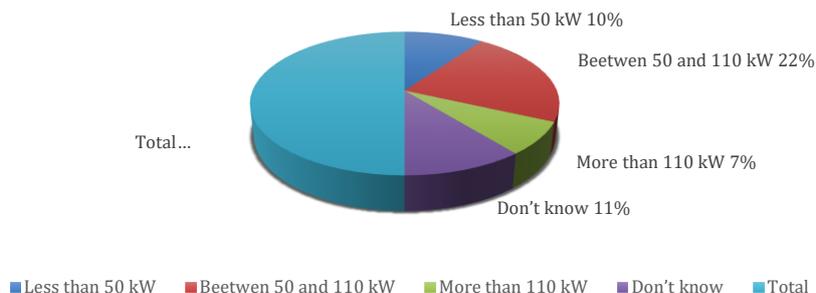
### II.10. Effect of Proximity to a Heat Source on Refrigeration Unit Energy Consumption

Placing refrigeration units near heat sources may compromise internal thermal stability and elevate energy demand. Research by Lepthien (2000) quantifies this additional energy consumption within a range of 0.9% to 1.3%.

The data in Table 10 reveals that the 50–110 kW range is the most prevalent energy class across all categories, representing 45.7% of the total sample. Interestingly, the 'Cooker / Stove' category shows a higher proportion of low-power units (30.6% in the < 50 kW class) compared to the other groups. Furthermore, the 'None' category (referring to households without specific heavy equipment) surprisingly displays the highest rate of uncertainty, with 21.6% of respondents unable to identify their energy class.

**Table 10 :** Energy consumption range based on nearby heat sources

Nearby Heat Source	Less than 50 kW	Between 50 and 110 kW	More than 110 kW	Don't know	Total
None	20	45	15	22	102
Others	22	52	14	13	101
Cooker/stove	19	24	9	10	62
Other	61	121	38	45	265



**Figure 3** : Energy consumption range based on nearby heat sources

*II.11. Type of Cooking Energy Source and Energy Consumption*

The choice of cooking energy significantly influences the overall energy profile of the household. Modernizing energy sources often correlates with a broader increase in the home's total electrical capacity.

**Table 11** : Energy consumption and cooking fuel used

Energy Source	Less than 50 kW	Between 50 and 110 kW	More than 110 kW	Don't know	Total
<b>Biomasse</b>	12	7	2	5	<b>22</b>
<b>Gaz</b>	90	127	38	52	<b>307</b>
<b>Total</b>	<b>102</b>	<b>134</b>	<b>40</b>	<b>57</b>	<b>333</b>

*II.11. Statistical Analysis and Interpretation*

The Biomass group includes all users of fuels such as wood and charcoal. The analysis of the data reveals a clear distinction between the two groups:

- The Biomass Group: More than half 54% of biomass users fall within the low-power range < 50 kW.
- The Gas Group: Only 29% of gas users are in this low-power bracket, while the majority (41%) are concentrated in the 50 to 110 kW range.
- Statistical Significance: The proportional differences are marked enough that a Chi-square test is highly likely to be significant  $p < 0.05$ .
- Correlation: It can be affirmed that a link exists between the cooking energy source and the installed power. The transition to a modern energy

source (Gas) is statistically correlated with an increase in the power demand within the household.

This correlation suggests that as households move up the "energy ladder," they do not only change their cooking fuel but also tend to acquire more powerful or numerous electrical appliances, thereby increasing their overall energy footprint.

*II.12. Influence of Cooking Duration on Household Energy Consumption*

This table crosses the daily cooking duration with the installed power. This data is fundamental for energy efficiency, as it allows for the transition from the concept of power (capacity) to that of consumption (actual energy used over time).

**Table 12** : Energy consumption range and cooking duration

Cooking duration	Less than 50 kW	Between 50 and 110 kW	More than 110 kW	Don't know	Total
<b>1h</b>	36	26	1	18	<b>81</b>
<b>2h</b>	46	75	20	30	<b>171</b>
<b>3h</b>	16	29	14	7	<b>66</b>
<b>4h</b>	4	4	5	2	<b>15</b>
<b>Total</b>	<b>102</b>	<b>134</b>	<b>40</b>	<b>57</b>	<b>333</b>

A clear visual correlation is observed between the time spent cooking and the power of the equipment:

- Short Cooking Duration (1h): These households predominantly use low power (36 out of 81, or 44% are at less than 50 kW). Only one household in this category uses high power > 110 kW.

- Standard Cooking Duration (2h): This is the core of the sample (171 households), where the power shifts toward the 50-110 kW range (75 households).
- Long Cooking Duration (3h and more): It is noted that as cooking time increases, the proportion of households using high power (> 110 kW) also

increases. For those cooking for 4 hours, 33% are in the high-power category, compared to only 1.2% for those cooking for 1 hour.

This table reveals what is known as the energy intensity of the household:

- Cumulative Factors: Households that cook the longest are also those with the highest installed power. This represents a "double energy penalty": they consume a lot of power for a long duration.
- Priority Target: The 81 households cooking for 3 hours or more represent the most significant potential for energy savings. Improving the efficiency of their burners or cookware (insulated pots, pressure cookers) would have a major impact on the overall load.
- Link with Energy Source: It would be valuable to verify if these long cooking sessions (3h-4h) are performed using Gas or Biomass. If Gas is used, the financial cost for the household is very high.

The **Chi-square test** demonstrates a very significant dependency  $p < 0.01$  between cooking duration and installed power. The study reveals a linear progression: prolonged culinary needs are systematically accompanied by an increase in equipment power. This correlation indicates that lifestyle habits (cooking time) dictate technological choices, creating high-energy-intensity households that should be the primary targets of energy efficiency awareness policies.

## Conclusion

The objective of this work was to conduct a study on the challenges of energy efficiency in Cameroon. A statistical survey was carried out among 333 households across three Cameroonian cities using a two-part questionnaire. The study focused on individual demographics, housing characteristics, the usage of refrigeration units for food preservation, and household energy consumption patterns.

The raw data collected were compiled and cleaned in Excel before undergoing statistical processing. To ensure the reliability of the tests, a regrouping of modalities (variable recoding) was performed for categories with low frequencies (less than 5). The primary statistical tool used for analyzing the contingency tables was Pearson's Chi-square test, which determined whether statistically significant relationships existed between qualitative (or discretized quantitative) variables. Calculations were performed using R software (open-source version), ensuring precise degrees of freedom  $df$  and probability values  $p$ -values).

The results of this research lead to the conclusion that improving residential energy efficiency in Cameroon requires a multidimensional approach. On the one hand, the construction analysis reveals that the

thermal inertia of building materials, such as adobe bricks, offers a significant thermal advantage over cement, although its use remains geographically limited. On the other hand, the study of household energy behavior identifies the 25–35 age group as the pivotal segment for the introduction of high-performance technologies. However, the final diagnosis shows that 69% of users are unaware of their appliances' energy class, making physical size a misleading indicator of actual power demand. Therefore, a public policy integrating energy certification and the promotion of high-thermal-inertia materials is essential to ensure a sustainable energy transition in the urban areas of Douala, Yaoundé, and Ngaoundéré.

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