Trends in the use of domestic appliances in urban residential households in Burkina Faso : Results from a residential electricity consumption survey

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***Abstract* — It remains challenging to find accurate and reliable information on the actual characteristics of the electricity demand in Burkina Faso. However, due to the increase of the economic level in the country and, therefore, the demand, electricity patterns of use and consumption estimates become vital for energy planning and energy efficiency policy design and implementation. This study helps improve the weak body of literature, by using the results of a residential electricity use survey conducted within 387 households in the city of Ouagadougou, the first large-scale, city-wide household study undertaken in Burkina Faso, to identify the trends in the use of the domestic residential appliance. Findings showed that domestic electricity use patterns demonstrate three essential peak demand periods, with the maximum demand occurring between 7:00 and 8:00 p.m. The factor load is between 33 and 58%, suggesting the existence of potentials and opportunities for demand-side management strategies implementation. On the contribution of the appliances to the demand, the cooling appliances outstand the other appliances in the summer season, while lighting and information-communication-entertainment (ICE) appliances represent the major appliances of the domestic sector during the rainy and dry and cold seasons.**

Keywords* — *Urban dwellings, City-scale survey, Burkina Faso, Electricity patterns of use, Demand disaggregation.

I. INTRODUCTION

Electrical energy is that particular form of energy that most of the time, needs its supply and use to occur at the same time [1]. Such particularity makes it necessary to be able to know with accuracy, the characteristics of the demand either at the moment of use or in advance for predicting those of the supply. Whether worldwide or in the African region, the buildings sector is recognized as one of the biggest energy-consuming sectors. In this sense, information on actual patterns of use and characteristics of residential electricity is of very importance.

In residential buildings and more specifically domestic ones, electricity is mainly used for basic purposes including lighting, heating, ventilation and air-conditioning (HVAC), information, communication and entertainment (ICE), food preserving and cooking (FPC) and other non-common proposes like washing and working etc. Domestic appliances account, therefore, for the most part electricity consumption in dwellings. In this sense, appliance ownership, power and use are considered as direct determinants of domestic electricity consumption [2]. However, users' characteristics are also believed to influence (indirectly) electricity consumption in this sense that for example, households with various economic situation will demonstrate various ownership rates of domestic appliances as well as a different behavior [3].

In Burkina Faso, the residential sector accounts for 36% of the overall demand in electricity [4]. However, very few to none information exists on the characteristics of the residential electrical energy demand in terms of driving factors, patterns of use or contribution of the end-uses. Such observation is more remarkable at the individual (household) level. Studies reported at the individual level didn't take into accounts the characteristics of the demand. Instead, they have been most of the time focusing on the buildings' technology for enhancing energy performance (efficiency) of the buildings and enhance thermal comfort of the users [5], [6].

In short, none studies have been reported to the knowledge of the authors, on the driving factors of domestic electricity use or its characterization in Burkina Faso. As results, actual information on the characteristics of the residential electricity demand as well as its driving factors are quasi not available in the literature or for the electricity utilities. In a global way, many studies have been conducted on the patterns of use of residential electricity, even recently. However, such studies are mostly conducted in developed countries, with very few of them available regarding the developing countries.

This study aims, therefore, at providing the first ever comprehensive analysis on the characteristics of the domestic residential electricity consumption in urban areas. For the purpose, use is made of the data collected through a survey within 387 households to identify the trends in use of domestic appliances in urban zones of Burkina Faso. This helps to not only fill the gap of research but also provide useful information for actors of the sectors in order for example to make accurate prediction of electricity demand in the domestic buildings and design/implement more tailored policies aiming energy conservation/efficiency in such installations.

II. Methodology

A. *City of study, survey design and data collected*

The city of Ouagadougou was chosen for the study, because of its representativeness regarding the urban areas of Burkina Faso. Indeed, in addition to being the largest city in the country, Ouagadougou, which population size is 2,453,496 inhabitants living in 12 districts and 55 sectors [7], represents 45.4% of the country's urban population. Furthermore, the city is in the central region of the country Such location, place it in the Sudano-Sahelian climatic zone, which gives the climate, a hot and dry character, and makes therefore the city, a good case study for investigating seasonal variations in the demand. Finally, findings from the study in Ouagadougou can also serve as a basis for predicting the characteristics of electric use of the other urbanizing areas of Burkina Faso in the future.

The sample size (**n**) of the survey was calculated as 384 using a 5% margin of error (**e**) and a 95% confidence interval [8]. A questionnaire was designed in order to gather information mainly on seven items characterizing households and their patterns and behaviors regarding electricity use: appliances ownership, household's socio-economic and dwelling characteristics, electricity use patterns and behaviors, households' activities, and other various elements. The Questionnaires were used due to their demonstrated efficiency and suitability for data collection [9], especially in energy use studies [10].

For the selection of individuals, the in-person interview was used as the survey data collection method, with a random sampling used for ensuring an equal selection chance for each household. However, survey of a household also depended on the readiness and willingness of the respondents. Finally, attention was paid to selecting households with different backgrounds and economic levels.

The survey was conducted between September 2021 and February 2022, and helped to collect data from 387 households. Details on the survey design and data collected are available in [11].

B. *Research methodology*

Residential electricity characterization is defined as a process aiming at the description of domestic electricity use rather than attempting to predict its behavior over time [1]. In this study, use was made of the survey's results for yielding a comprehensive analysis on the characteristics of the domestic electricity demand. On-site measurement are acknowledged as the most accurate solution, however, their complexity and costly implementation makes it difficult to do it representative sample sizes (high initiation and operation costs of sensors [9] and efforts from both researchers and participants [12]). Therefore, for characterizing the domestic electricity demand in urban households in Burkina Faso, this study makes use of more traditional survey methods, which have also demonstrated effectiveness in use [13]. The research methodology is given in Fig. 1.

First, use is made of the survey results to generate data on the households' characteristics and energy behaviors, the appliance stock, the appliances patterns of use and the activities related. household energy behaviors (step 1). Following, a quantitative analysis of such generated data is proceeded (step 2), to identify the type and group of appliances, their probability of use, as well as their unitary consumption cycle and standby consumption (where applicable). Use is then made of such data as the entry data to generate the load curve for a typical appliance in a household. Such procedure is then iterated for the n end-uses, which generate the disaggregated total load profile for a household (step 3). The previous step (3), is then iterated for the n households and gives therefore the disaggregated load profile (step 4) for the sample as well as the disaggregated domestic residential electricity consumption (DREC).

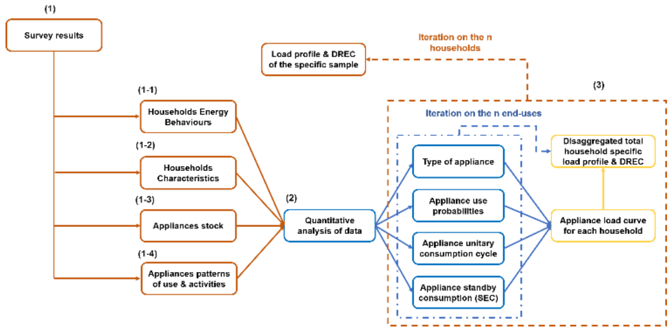

Fig. 1. Research methodology

For the analysis of the load profiles, the following four electrical parameters were defined as they are known as those characterizing an electricity demand [1], [14]: the total electricity consumption, the maximum demand, the load factor and the time of the maximum electricity demand.

From the load profile, the total electricity consumption (TEC) is given in (1). This parameter is a characteristic of the total amount of electricity which is used during a time period [1]. It is therefore important to use such a parameter as it is the one used most likely for billing domestic users [1].

$$TEC = \sum_{k=1}^{n} \sum_{t=1}^{m} P_t^k \quad (1)$$

The daily maximum demand (DMD) is given in (2). This parameter is a characteristic of the average daily maximum demand during a time period [14]. Such a parameter is therefore, very important for both the utility services and the users. Indeed, as a characteristic of the load profiles' shapes, the DMD is a very useful parameter, not only for the demand prevision, but also for the implementation of demand response (DR) based demand side management (DSM) programs [1].

$$DMD = 1/n \left(\sum_{k=1}^{n} Max\{P_t^k, 1 \leq t \leq m\} \right) \quad (2)$$

The daily load factor (DLF), which is a measure of the mean to maximum daily ratio of the demand is given in (3). This parameter is here again a characteristic of the shape of the load profile, as it consists of a measure of the "*Peakiness*" of the load profile [14]. A large value of the DLF typically indicates a more regular use of electricity throughout the day, whereas a small value reveals large electricity use within small intervals throughout the day.

$$DLF = 1/n \left(\sum_{k=1}^{n} \sum_{t=1}^{m} P_t^k / Max\{P_t^k, 1 \leq t \leq m\} \right) \quad (3)$$

The daily maximum demand time of use (ToU) is given in (4). This parameter is an indication of the period of the day at which the maximum occurs. It is therefore a reflection of the time at which households will use electricity the most [14].

$$ToU = Mode\,\{Max\,\{P_t^k, 1 \le t \le m\}, 1 \le k \le n\} \qquad (4)$$

Where P_t^k refers to the average electrical demand (in kW) for each one-hour period on a day k, m is the number of periods in a day and n the total number of days for which the demand is computed.

Such defined parameters were used for the analyses in the characterization of the demand both from the surveys and the measurements results.

III. Results and Discussions

Using the research framework given in the methodology section, the disaggregated (by appliances) load profiles of the surveyed households were determined.

For the purpose, three seasons are defined here including the hot or summer season running from March to May and October to November, the dry and cold season running from December to February and the rainy season running from June to September. For each type of these three seasons, the typical profile is given per type of day, including weekdays and weekends.

A. Electricty demand characteristics in summer season

Electricity demand profile of the surveyed households is presented for a typical weekday Fig. 2 for the summer season. **I**t can be seen that two main peak demand periods emerge from the load profile of the weekday. The first peak occurs in the midday period (1:00 to 2:00 p.m.), when most likely some of the people are home, back from schools and work (for some of them) as this corresponds to the break period. The second peak occurs in the starting of the night (7:00 to 8:00 p.m.), with the load almost tripled compared to that of the first peak, as everybody is almost home at that period of the day. Almost the same patterns can be noticed during the weekends, with an early raise of the load during the morning as more people are home during weekend (Saturday and Sundays), especially on Sundays and therefore doing some activities including washing and cooking. Therefore, the peak load of the domestic residential sector is represented by the evening peak in the demand, occurring early in the night.

On the hourly variation and contribution of the appliances to the daily demand, it is clear that cooling appliances outstand the other appliances almost whenever the daily period is (provided people are present). Indeed, in summer, temperatures can reach more than 40°C within the day and up to 30°C during the evening and nights. This results in the quasi-constantly use of the cooling appliances including ones like fans and air-conditioners (ACs). ACs and fans have the largest contributions within the end-uses during the two peak demand periods. Indeed, they contribute in average to 43 and 29% respectively of the demand during the midday and evening peaks of the weekends, and about to 42 and 30% respectively during weekdays. However, the peak demand periods are not those in which the cooling loads have their own highest contributions to the domestic residential demand in summer. As they are used in the night in summer, from 0:00 to 5:00 a.m., fans and ACs have respectively an average contribution to the demand of 27 and 50% during the weekdays, and 29 and 48% during the weekends. Such daily period consists of that in which the cooling loads have the highest contribution to the demand. This suggests that a technological improvement (efficiency) in cooling loads, (more specifically ACs) will therefore yield maximum reduction in the night load.

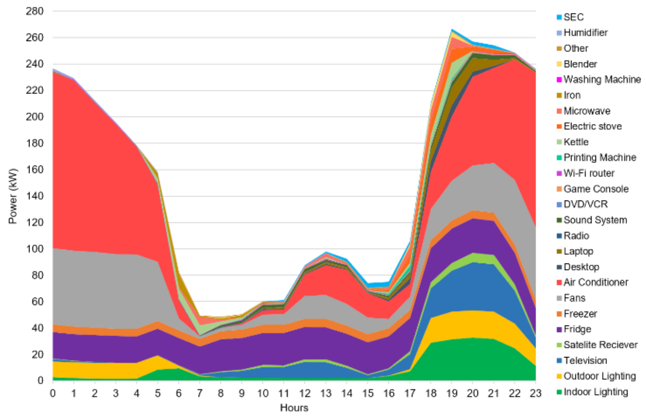

Fig. 2. Disaggregated load profile of the surveyed households in a typical weekday in the summer season

Table I, gives the four parameters characterizing the demand during the summer period. It can be noticed that the TEC increase slightly during the weekend as well as the DMD. However, the ToU (7:00 to 8:00 p.m.) corresponds to the same period no matter what the type of day is. Finally, the DLF is around 56% in the weekdays, and 57.5% in average in the weekend, suggesting the existence of potential and opportunity for demand side management strategies implementation.

TABLE I. CHARACTERISING PARAMETERS OF THE ELECTRICITY DEMAND IN SUMMER FOR THE SURVEYED HOUSEHOLDS

Parameters	Weekdays	Saturdays	Sundays
TEC (kWh)	3570	3780	3800
DMD (kW)	267	274	274
DLF (%)	56	57	58
ToU (hour)	7:00 – 8:00	7:00 – 8:00	7:00 – 8:00

B. Electricty demand characteristics in the rainy season

Unlike the demand in summer, three main peak demand period can be appreciated for the load profiles in the rainy season (Fig. 3). The first occurs early in the morning, the second at midday, and the last one in the starting evening, either for the weekdays or the weekend. The first peak in demand occurs from 5:00 to 6:00 a.m., corresponding to the period at which most people woke up for starting the daily activities. For example, the Muslims, which consist of 61.2% of the population in the region of the Centre in Burkina Faso [15], have to woke up at 5:00 for the morning payers. Such a peak is more appreciable thanks to the drop in the contributions of the cooling load to the demand which are less used in the rainy season compared to that in the summer. Indeed, the power demand from the cooling loads in that period drops by 84% and 83% respectively in the weekdays and weekend from the summer to the rainy season. This helps therefore to see clearer the early in morning peak demand.

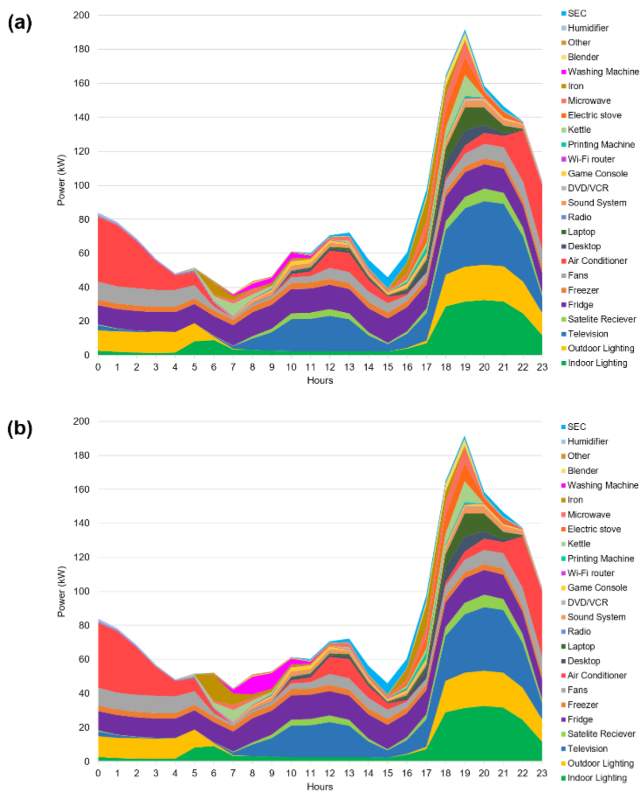

Fig. 3. Disaggregated load profile of the surveyed households in a typical weekend (Saturday (a) and Sunday (b)) in the rainy season

The second peak occurs like in the case of the summer season load profile (Fig. 1.), in the midday period (1:00 to 2:00 p.m.). During this period, the load increase by only 6% with respect to the load at the first peak period in the weekdays, and by 39% in average during the weekend. The third peak occurs in the starting of the night (7:00 to 8:00 p.m.), with the load tripled compared to that of the two first peak loads, as everybody is almost home at that period of the day.

Almost the same patterns can be noticed during the weekends (Fig. 3), with a global higher use within the day as more people are home, and, therefore, doing some activities involving the use of appliances. Also, more smoothness in the shape of the Saturdays' first peak demand can be noticed as some people woke up lately as they don't have to go to school or work. Again, like in the summer season, the peak load of the domestic residential sector is represented by the evening peak in the demand, occurring early in the night.

On the contributions to the load, different patterns emerge in the rainy season compared to those of the summer. First, the cooling loads, especially the fans and ACs, which demonstrated an extensive use in the summer season, saw their daily contribution dropped by more than half (52%) in the weekdays and by 48% in average in the weekend from the summer season to the rainy one. This results in them not being the major contributors to the demand at any of the load peak demand periods.

The major contributors to the demand during the peak periods are the lighting fixtures and the televisions (TV) sets during the rainy season. During the first peak demand period (5:00 to 6:00 a.m.), the lighting fixtures demonstrate the highest contribution, sharing respectively 32% and 36% of the demand in the weekdays and the weekends, followed by the cooling loads (28%) and the food preserving ones (24%).

Lighting fixtures are also the major contributors to the demand at the third and main peak demand period (7:00 to 8:00 p.m.), with a share of 27% of the demand both during weekdays and weekends. More generally, lighting is the major contributor to the demand during the evening with average shares of 31 and 30% of the demand respectively in the weekdays and weekends in the 6:00 to 00:00 p.m. period.

The second peak demand period's major contributors are the TV sets, which share respectively 33 and 31% in average of the total demand in the weekdays and weekends. TV sets are followed both in weekdays and weekends by the cooling and the food preserving appliances during the second peak demand period which share respectively 25 and 25% of the demand during weekends, and 21 and 27% of the demand during the weekdays.

As for the demand in the summer season, other loads demonstrated various contributions ranging from 0% to 19%, with the maximum contributions coming from the morning end-uses such as irons, kettle, microwaves, which are used early on the morning by householders to prepare their clothes and the breakfast before living home. Another particular type of load which contribution is more remarkable on the load curves is the standby electricity consumption (SEC). This type of power which is used by some appliances when not operating for their primary functions was also assessed. SEC demonstrated a non-negligible share within the total demand, especially in some typical periods, including the starting of the afternoon until early in the evening (2:00 p.m. to 6:00 p.m.). Indeed, SEC reaches its maximum shares of 10% and 14% in average within the total demand during weekdays and weekends respectively, in the middle of the afternoon (3:00 p.m. to 4:00 p.m.). Indeed, at this time many householders are doing naps our out of the houses, this result in consumption from standby appliances in households in which users don't turn off standby appliances. Indeed, some of the surveyed households were not aware of standby consumption, whereas some do not pay much attention to turning off their standby appliances, considering that SEC's influence on their electricity bills is residual. More generally, in the afternoon period (2:00 p.m. to 6:00 p.m.), SEC accounts in average for 3 and 7% of the demand respectively during weekdays and weekends.

TABLE II. CHARACTERISING PARAMETERS OF THE ELECTRICITY DEMAND IN THE RAINY SEASON FOR THE SURVEYED HOUSEHOLDS

Parameters	**Weekdays**	**Saturdays**	**Sundays**
TEC (kWh)	1874	1980	2013
DMD (kW)	190	192	192
DLF (%)	41	43	44
ToU (hour)	7:00 – 8:00	7:00 – 8:00	7:00 – 8:00

Table II, gives the four parameters characterizing the demand during the rainy season. Like previously in the summer season, it can also be noticed that the TEC increase slightly during the weekend as well as the DMD. However, compared to the summer season, the maximum demand (kW) as well as the energy consumed were lowered respectively by 29 and 48% for the weekdays and in average by 30 and 48.5% for the weekends. The ToU (7:00 to 8:00 p.m.) corresponds here again to the same period no matter what the type of day is. Finally, the DLF is around 41% in the weekdays, and

43.5% in average in the weekend, suggesting the existence of more potentials and opportunities for demand side management strategies implementation in the rainy season than that in the summer season.

C. Electricty demand characteristics in the dry and cold season

Electricity demand profile of the surveyed households is presented for a typical weekday in Fig. 3 for the dry and cold season. Like the demand in rainy season, three main peak demand period can be noticed for the two types of days (weekdays and weekends) during the dry and cold season. The first occurring early in the morning, from 6:00 to 7:00 a.m. Such Peak is even more visible as compared to that of the rainy season profiles, as the cooling appliances which had non-negligible contributions to the load curve during the night, had contributions almost equivalent to zero. Indeed, use of cooling appliances is very rare during the dry and cold season due to the drop of the temperature to very low values such as 14°C. The second peak occurs like in the two previous seasons, in the midday period (1:00 to 2:00 p.m.), whereas the third peak occurs in the starting of the night (7:00 to 8:00 p.m.), with the load almost quadrupled compared to that of the two first peak loads.

On the contributions to the load, different patterns also emerge in the dry and cold season. During the first peak demand period (6:00 to 7:00 a.m.), the food preserving appliances (fridges and freezers) demonstrate the highest contribution, sharing respectively 27% and in average 29% of the demand in the weekdays and the weekends.

The second peak demand period's (1:00 to 2: 00 p.m.) major contributors are the TV sets, which share respectively 32 and 42% in average of the total demand in the weekdays and weekends. For the third and main peak demand period (7:00 to 8:00 p.m.), lighting is here again, the major contributor to the demand, with a share of 30% of the demand both during weekdays and weekends.

During the third period peak, as well as generally in the evening, lighting loads are closely followed by TV sets who share respectively 21% and 26% of the total demand in these two period for the weekdays, and 23 and 27% in average during the weekends.

As for the rainy season, SEC demonstrated a non-negligible share within the total demand, especially in the starting of the afternoon until early in the evening (2:00 p.m. to 6:00 p.m.).

Table III, gives the four parameters characterizing the demand during the dry and cold season. The TEC increase slightly during the weekend as well as the DMD. On the one hand, compared to the summer season, the DMD and the TEC drops considerably by 61 and 35% respectively for the weekdays and by 59 and 35% respectively for the weekends. On the other hand, lower decreases were recorded for the same parameters from the rainy season to the dry and cold one (they dropped by 26 and 9% respectively for the weekdays and by 21 and 7% respectively for the weekends). The ToU (7:00 to 8:00 p.m.) corresponds here again to the same period no matter what the type of day is. Finally, the DLF is around 33% in the weekdays, and 37% in average in the weekend, suggesting the existence of more potentials and opportunities for demand side management strategies implementation in the dry and cold than that in the rainy and summer seasons.

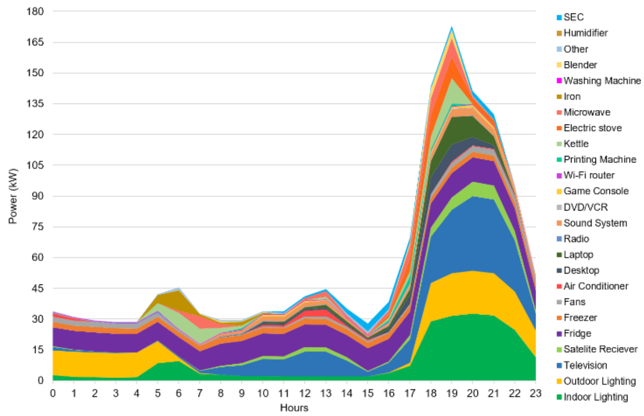

Fig. 4. Disaggregated load profile of the surveyed households in a typical weekday in the dry and cold season

TABLE III. CHARACTERISING PARAMETERS OF THE ELECTRICITY DEMAND IN THE DRY AND COLD SEASON FOR THE SURVEYED HOUSEHOLDS

Parameters	**Weekdays**	**Saturdays**	**Sundays**
TEC (kWh)	1389	1566	1586
DMD (kW)	173	179	179
DLF (%)	33	37	37
ToU (hour)	7:00 – 8:00	7:00 – 8:00	7:00 – 8:00

D. Domestic residential electricity consumption breakdown

In order to determine the domestic residential electricity consumption (DREC) breakdown, the method explained in Fig. 1. was used. Table IV gives the descriptive statistics of the annual (theoretical) electricity consumption obtained from the load profiles (TEC_2), compared to the recorded (obtained from the households' bills) annual electricity consumption (TEC_1).

TABLE IV. DESCRIPTIVE STATISTICS OF THE THEORETICAL TEC (TEC_2) COMPARED TO THE MEASURED TEC (TEC_1)

Statistics	**TEC_1**	**TEC_2**	**Difference* (%)**
Mean (kWh)	2395	2378	0.70
St. dev. (kWh)	1687	2214	31.23
Overall sample's TEC (MWh)	926. 84	920. 58	0.67

It can be seen that the computed (theoretical) mean annual recorded electricity consumption was 0.70% less than the recorded. Furthermore, at the aggregated level, the theoretical aggregated electricity use of the overall sample is 0.67% lower than the aggregated measured electricity use. However, on the individual scale, it should be pointed out that calculated electricity consumption reached up to 80% above the recorded value and up to 63% below for some households. It can be explained by the differences between actual and reported values for average use times and because appliances are usually not operated at their total capacity. With regards to such estimations, it was judged therefore useful to proceed with the electricity use breakdown.

Figure 5 show the breakdown of annual TEC per appliance for the overall sample of surveyed households during the three studied season. On the one hand, it can be noticed for example that for both the rainy (Fig. 5 (b)) and dry and cold season (Fig. 5 (c)), lighting remained the most consuming appliances with respective shares of 21 and 28% of the TEC. During the rainy season, lighting was closely followed by refrigeration appliances, television sets and others appliances, whereas during the dry and cold season, they were followed by the same elements but in an inversed order. On the other hand, ACs (31%) and fans (19%), which have demonstrated high operating times during the summer season, have the biggest shares within the TEC during the summer season (Fig. 5 (a)). During such a season, the ACs and fans are followed mainly by refrigerators, lighting and others appliances, while TV sets and SEC demonstrated shares of less than 10%.

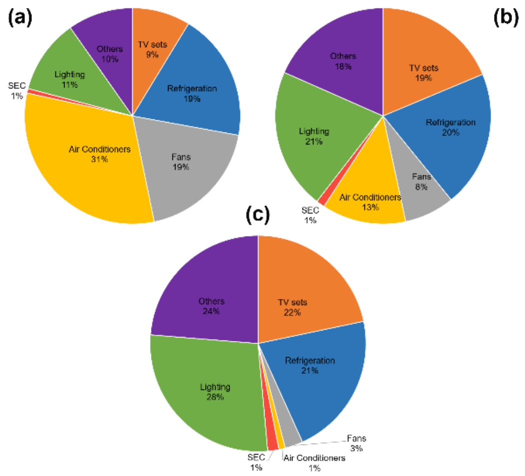

Fig. 5. TEC breakdown by appliance for the summer (a), rainy (b) and dry and cold (c) seasons

IV. CONCLUSIONS

This study investigated residential electricity use within 387 households in the city of Ouagadougou in Burkina Faso, to provide insights into the trends in use of domestic appliances in urban households of Burkina Faso. To the authors' knowledge, this is the first-ever survey study conducted to such information on city-scale electricity consumption in the country.

The study demonstrated three peaks in the patterns of the electricity demand, with the peak load of the domestic residential sector represented by the evening peak in the demand, occurring between 7:00 and 8:00 p.m. The load factor varies between 33% and 58% depending on the season, suggesting the existence of potentials for implementing DSM and energy efficiency actions and measures. In such a use, cooling appliances, televisions sets, lighting and food cooking and preservation appliances represent the main loads of the households' electricity demand and need therefore, to be set as a priority for energy planning and management actions.

Finally, this study could also serve as a reference for the identification of the characteristics and patterns of the residential electricity demand in the other growing cities in the country or other hot climate developing countries.

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REFERENCES

[1] F. Mcloughlin, "Characterising Domestic Electricity Demand for Customer Load Profile Segmentation," PhD Thesis 2013.

[2] R. V. Jones, A. Fuertes, and K. J. Lomas, "The socio-economic, dwelling and appliance related factors affecting electricity consumption in domestic buildings," *Renew. Sustain. Energy Rev.*, vol. 43, pp. 901–917, 2015, doi: 10.1016/j.rser.2014.11.084.

[3] S. Firth, K. Lomas, A. Wright, and R. Wall, "Identifying trends in the use of domestic appliances from household electricity consumption measurements," *Energy Build.*, vol. 40, no. 5, pp. 926–936, 2008, doi: 10.1016/j.enbuild.2007.07.005.

[4] UEMOA, *Atlas de l'énergie dans l'espace UEMOA*. 2020.

[5] C. Hema, A. Messan, A. Lawane, and G. Van Moeseke, "Impact of the Design of Walls Made of Compressed Earth Blocks on the Thermal Comfort of Housing in Hot Climate," *Buildings*, vol. 10, no. 9, p. 157, 2020, doi: 10.3390/buildings10090157.

[6] I. Neya, D. Yamegueu, Y. Coulibaly, A. Messan, and A. L. S. N. Ouedraogo, "Impact of insulation and wall thickness in compressed earth buildings in hot and dry tropical regions," *J. Build. Eng.*, vol. 33, p. 101612, 2021, doi: 10.1016/j.jobe.2020.101612.

[7] INSD-BF, "Résultats Préliminaires du Cinquième Recensement Général de la Population et de l'Habitation du Burkina Faso (RGPH 5)," 2020. [Online]. Available: http://www.insd.bf/contenu/documents_rgph5/RAPPORT_PRELIMINAIRE_RGPH_2019.pdf.

[8] W. G. Cochran, *Sampling techniques*, vol. 3. 1977.

[9] T. Hong, D. Yan, S. D'Oca, and C. fei Chen, "Ten questions concerning occupant behavior in buildings: The big picture," *Build. Environ.*, vol. 114, pp. 518–530, 2017, doi: 10.1016/j.buildenv.2016.12.006.

[10] C. Carpino, D. Mora, and M. De Simone, "On the use of questionnaire in residential buildings. A review of collected data, methodologies and objectives," *Energy Build.*, vol. 186, pp. 297–318, 2019, doi: 10.1016/j.enbuild.2018.12.021.

[11] K. H. S. Tete, Y. M. Soro, S. S. Sidibé, and R. V Jones, "Urban domestic electricity consumption in relation to households' lifestyles and energy behaviours in Burkina Faso: Findings from a large-scale, city-wide household survey," *Energy Build.*, vol. 285, no. 1, p. 18, Apr. 2023, doi: 10.1016/j.enbuild.2023.112914.

[12] Eurostat, *Manual for statistics on energy consumption in households*. 2013.

[13] U. Surahman, D. Hartono, E. Setyowati, and A. Jurizat, "Investigation on household energy consumption of urban residential buildings in major cities of Indonesia during COVID-19 pandemic," *Energy Build.*, vol. 261, no. January, p. 111956, Apr. 2022, doi: 10.1016/j.enbuild.2022.111956.

[14] F. McLoughlin, A. Duffy, and M. Conlon, "Characterising domestic electricity consumption patterns by dwelling and occupant socio-economic variables: An Irish case study," *Energy Build.*, vol. 48, no. July 2009, pp. 240–248, 2012, doi: 10.1016/j.enbuild.2012.01.037.

[15] INSD-BF, "Cinquième recensement général de la population et de l'habitation du Burkina Faso (5e RGPH): synthèse des résultats définitifs," 2022.