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Knowing electricity end-uses to successfully promote energy efficiency in buildings: a case study in low-income houses in Southern Brazil

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ABSTRACT

The objective of this paper is to show the importance of measuring electricity end-uses in order to promote energy efficiency in low-income houses in Southern Brazil. Sixty low-income houses were surveyed, and data of socioeconomic variables, electricity use, and usage pattern were measured and obtained. Confidence intervals were assigned to obtain representative electricity end-uses and usage patterns. The results showed that the electric shower has the greatest electricity end-use, i.e., 33.5 to 40.3%, followed by the refrigerators, with end-use of 27.4 to 33.1% with 90% non-parametric confidence interval. Usage patterns were obtained for appliances and lighting for each room and also for the electric shower. The results of this study will provide basis for determination of guidelines for low-income houses and government programmes for energy efficiency, rational use of energy and renewable energy.

Keywords:

Low-income houses,
electricity end-uses,
electricity usage pattern

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1. Introduction

Energy is a key resource for social and economic development worldwide. However, the economic growth may lead to an expansion of lifestyle aspirations, which, in turn, increases energy consumption and associated impacts [1].

The Brazilian electricity consumption has been increasing over the last decade. For instance, in the residential sector, such consumption increased from 72,752.0 GWh in 2002 to 111,971.0 GWh in 2011, as shown in Figure 1. Nowadays, the residential sector represents 23.6% of the total electricity consumption in Brazil [2]. Therefore, there was an increase of 53.9% of the total electricity consumption for the residential sector over the last decade, approximately 4.9% of Compound Annual Growth Rate (CAGR).

The energy consumption in residential buildings depends on the activities carried out by occupants, which refers directly to the household energy end-use [3]. Therefore, several studies addressing the electricity end-use of residential buildings have been undertaken in Brazil [4–6].

The estimation of the energy end-use in houses is a topic of interest for many stakeholders including utilities, customers, policy makers and appliance manufacturers, and it is an active research subject for at least four decades [7]. These studies can contribute to the development of strategies to enhance the energy efficiency in residential buildings.

Danielski (2012) [8] Danielski [8] studied the variation in energy end-use of apartments in Sweden. The buildings were constructed based on the Stockholm program for

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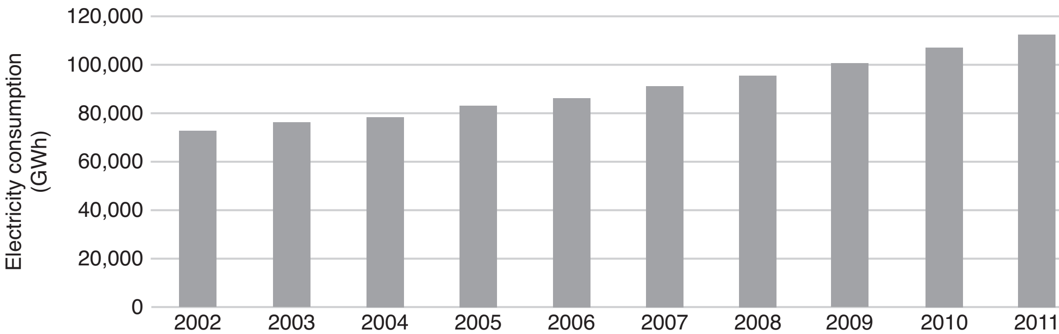


Figure 1: Total electricity consumption in the residential sector of Brazil from 2002 to 2011 [2].

environmentally adapted buildings, which has requirements for the efficiency of new buildings. The study showed that there is much variation in energy consumption between houses, although they were similar in use and shape. The energy simulation approach showed that the energy consumption prior to construction were underestimated by 19% relative to the actually measured values. The difference can be explained by the time interval the construction and energy measurement, the shape factor of the building and the relative size of the common areas.

Carlson et al. [7] analysed how the averaged data of household electricity consumption could be inadequate for energy policy and decision-making. Data from the Residential Energy Consumption Survey of the United States, containing information of 4382 dwellings from 1978 to 2009 were used. Four scenarios were defined for the study: the average scenario, the typical scenario, the scenario where natural gas is not used, and the last scenario where electricity is not used (only natural gas). The authors have found that the use of averaged data would overestimate the number of contributing appliances to a specific electric load. The consumption of certain equipment varies widely among houses, but the results showed that about eight appliances were responsible for 80% of the energy consumption. To achieve 50% of energy consumption, only four appliances need to be monitored for the averaged scenario (central air conditioners, refrigerators, water heating and lighting).

Kelly [9] used the English House Condition Survey to assess the main drives behind the residential energy consumption. 2531 cases were assessed through the Structural Equation Modelling statistical technique, which allows the calculation of both direct and indirect effects that explain energy consumption. The energy consumption were direct and indirectly correlated with several factors and showed that the largest factors explaining the energy consumption were the number of occupants, the household income, the floor area, the energy patterns, temperature effects and energy efficiency indicator.

McLoughlin et al. [10] analysed the influence of the dwelling and occupant characteristics on the residential electricity consumption patterns within a 4200 Irish houses survey. The authors conducted a multivariate linear regression to four parameters: electricity consumption, maximum demand, load factor and time of use, with occupant socioeconomic variables. The maximum electricity demand was influenced by the household composition, water heating and cooking type. The time of use was influenced more by the occupants characteristics, as the head of the household age and the household composition, rather than the dwelling characteristics. Another finding was that when the age of the head of the household was between 35–55, it generated the highest energy consumption, probably due to children. The number of bedrooms influenced the total electricity consumption and the load factor was influenced by both the dwelling type and the number of bedrooms.

In general, the wealthier people are, the more energy they will consume. According to Druckman and Jackson [11], an increase in socioeconomic levels leads to an expansion of the energy consumption pattern and associated environmental impacts due to the enhancement of comfort, recreation and leisure. Ghisi et al. [6] found the same trend for Brazilian houses, where wealthier families consume more electricity than poorer families. In the last decade, the Brazilian minimal wage raised from R$200 to R$622 [12–13], which has probably contributed to the growth of the total electricity consumption in the residential sector nationwide.

In this context, the Brazilian government has been developing programmes to improve the energy efficiency at low-income houses.

In Midwest Brazil, for example, the energy utility performs donation of efficient refrigerators, compact fluorescent bulbs, and promotes the replacement of electrical conductors in the houses, benefiting so far, more than 32,000 low-income houses [14]. The estimated savings are 4,285.41 MWh per year and reduction of 536.48 kW on the peak load demand.

The National Institute of Metrology and Industrial Quality (INMETRO), through the Brazilian Labelling Programme, the National Energy Utility (Eletrobras), and National Programme of Electricity Conservation (Procel) performs labelling of various equipment, including electric showers, refrigerators, televisions and light bulbs according to their energy efficiency. These energy efficiency labels are indicators that help buyers in the decision making process and encourage them to save electricity.

As for the electric shower, government programmes such as the Growth Accelerating Programme (PAC) have encouraged the use of solar water heating in low-income houses. Researches indicate appropriate solar fraction in most regions of Brazil, justifying their feasibility against the use of electric shower, reducing electricity consumption and peak load demand, with low payback [15–16].

In order to improve such programmes, it is important to know the electricity end-uses and usage patterns of Brazilian low-income houses. Thus, the objective of this paper is to show the importance of measuring electricity end-uses in order to promote energy efficiency in low-income houses in southern Brazil.

2. Method

In order to estimate the electricity end-uses and usage pattern, the following steps were carried out: (1) Data collection, (2) Data treatment, and (3) Data analysis.

2.1. Data collection

Electricity end-uses could be drawn from generalized statistics with large amounts of data, as already done by some national Institutes in Brazil. However, these data consider general characteristics for electrical appliances in the houses, besides general conditions of use and operation. Considering these facts, this study chose to work with a small sample size, but high data quality through measurements and interviews.

Data collection was undertaken through household interview surveys using questionnaires and two weeks of monitoring electrical appliances to register the electricity consumption, for summer and winter seasons. Measurements were performed in 2012.

A researcher team was responsible for contacting the householders personally, by visiting each house of the social housing area, or with the help of social assistance service and community agents.

2.1.1. House selection

Sixty low-income houses were surveyed in the metropolitan region of Florianópolis, southern Brazil. These houses were randomly chosen due to the difficulty to find householders that showed motivation to participate in the research. Thus, the sample size does not intend to statistically represent the whole population of low-income housing of Florianópolis.

Low-income houses were classified in accordance with national laws and guidelines on Social Housing [17]. Figure 2 shows the characterization of the built area and the number of occupants in the sample. The built area of the houses varied in 25 m^2 to 85 m^2, with median of 53 m^2. The number of occupants in the houses varied in one to eight, with median of three occupants.

2.1.2. Questionnaires

Three questionnaires were used during the household interview surveys: (1) socioeconomic questionnaire; (2) electricity end-use questionnaire; and (3) electricity usage pattern questionnaire. An example of the electricity end-use questionnaire, for illustration purposes, is shown in annex.

In the socioeconomic questionnaire, the number of occupants, and total and per capita income were collected.

In the electricity end-use questionnaire, the characteristics of each electrical household appliance were determined, including: type, model, power rating, and the room in which the equipment is placed. The household monthly electricity consumption recorded by the local energy utility was also obtained, for the last 12 months from the measurement day of each house.

In the electricity usage pattern questionnaire, the usage pattern of each electrical appliance was estimated by interviewing householders. The questionnaire was structured as to allow the collection of data on an hourly basis, in which the duration of each usage event was estimated in seconds or minutes for each hour of the day.

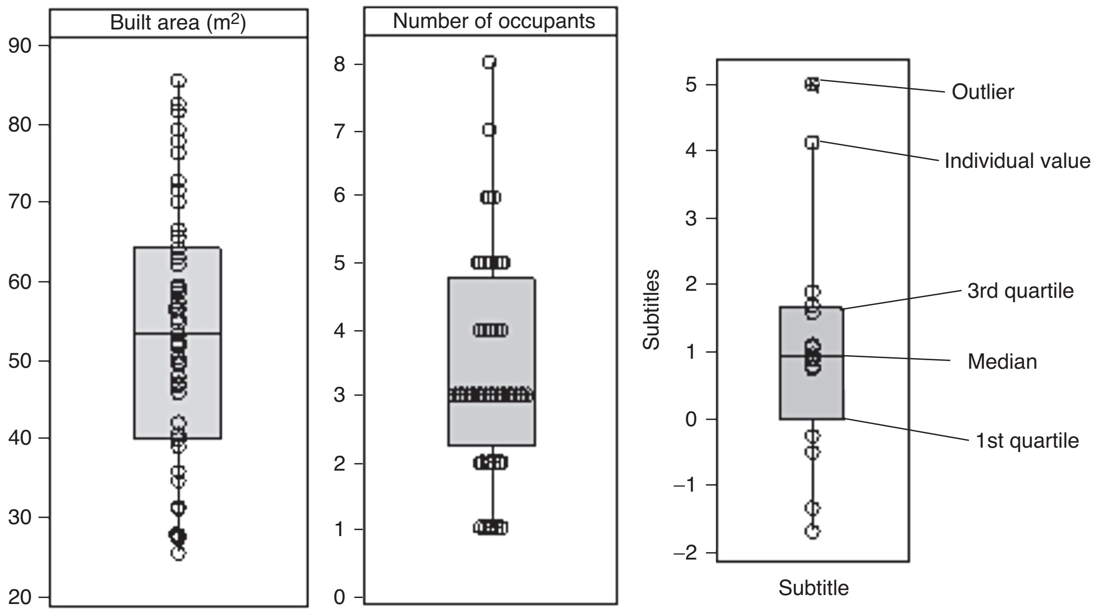


Figure 2: Built area and number of occupants of the sample.

The usage patterns of electrical appliances were estimated for both summer and winter seasons.

2.1.3. Monitoring equipment

The electricity consumption of electrical appliances was measured during a minimum period of two weeks in each household. For this purpose, two meters were used: (1) PowerBall T8 and (2) CEM 1000.

The PowerBall T8 meter was employed to determine the total usage time and total electricity consumption of electrical appliances during the monitoring period. This meter was used to monitor electrical appliances rated up to 2.2 kW, including, but not limited to: fridge, freezer, washing machine, microwave, television, computer, fan, iron, coffee machine, hair dryer. Electric shower heads were not monitored using this meter, because their power can range up to 8.0 kW.

Eq. 1 was used to determine the electricity consumption of electric shower heads, considering the manufacture power rating and the usage time pattern estimated by householders.

$$EC = P \times \sum_{0}^{t} T\ dt \qquad (1)$$

Where: EC is the electricity consumption (kWh); P is power rating (kW); T is the usage time (h); t is the evaluated period (days).

The CEM1000 meter was used to measure the electrical characteristics of lamps, including: instantaneous power, power factor, voltage and current. This equipment was not used to register the electricity consumption over the monitoring period, but rather to define the instantaneous power rating. Therefore, the electricity consumption of light bulbs was estimated using Eq. 1, considering the instantaneous power rating measured and the usage time pattern estimated by householders.

2.2. Data treatment

Data treatment was performed so as to determine representative values and confidence intervals of electricity end-uses and usage patterns estimations. Three analyses were carried out: (1) electricity usage patterns and end-uses; (2) electricity consumption validation analysis; and (3) confidence intervals.

2.2.1. Electricity usage patterns and end-uses

The usage patterns are related to how the occupants use each electrical appliance, and its time of use. These patterns were used to find representative schedules for each electrical appliance.

The data obtained with the electricity end-uses questionnaire and the measurements were used to calculate the average power rating of each appliance, using Eq. 2.

$$AP_a = \frac{EC}{T} \tag{2}$$

Where: AP_a is the average power rating for each appliance (kW); EC is the electricity consumption over the monitoring period (kWh); T is the usage time over the monitoring period (h).

The average power rating was grouped with the data of the electricity usage pattern questionnaire in order to determine the hourly electricity consumption, using Eq. 3.

$$ECH_a = AP_a \times T_h \tag{3}$$

Where: ECH_a is the electricity consumption of an appliance for each hour of the day (kWh); AP_a is the average power rating (kW); T_h is the usage time for each hour of the day (h).

The electricity consumption of each hour of the day was summed to find the total average daily electricity end-use for each appliance. It was calculated using Eq. 4, as each hour of the day would have different usage pattern.

$$ECD_a = \sum_{0}^{24} EC_h \tag{4}$$

Where: ECD_a is the total daily average electricity consumption (kWh); EC_h is the electricity consumption for each hour of the day (kWh).

The monthly electricity consumption for each appliance was estimated multiplying the total daily average electricity consumption by 30.42 days (365 days divided per 12 months). The total monthly electricity consumption at households was determined using Eq. 5.

$$ECM_t = \sum_{i=1}^{n} ECM_a \tag{5}$$

Where: ECM_t is the total monthly electricity consumption (kWh); ECM_a is the monthly electricity consumption for each appliance (kWh); n is the number of appliances.

Finally, the electricity end-use of each appliance was calculated using Eq. 6.

$$E\%_a = \frac{ECM_a}{ECM_t} \times 100 \tag{6}$$

Where: $E\%_a$ is the electricity end-use for each appliance (%); ECM_a is the monthly electricity consumption for each appliance (kWh); ECM_t is the total monthly electricity consumption (kWh).

2.2.2. Electricity consumption validation analysis

The estimated electricity consumption for each house was compared with monthly electricity consumption recorded by the local energy utility. When the difference between estimated and recorded total electricity consumptions was greater than 20%, the house was excluded from the sample. After the excluding process, 53 houses were left to perform the electricity end-use and usage pattern analyses.

2.2.3. Confidence intervals

Parametric and non-parametric statistical analyses were performed so as to determine the confidence intervals of electricity consumption patterns and average installed power in each room.

For the parametric statistical analysis, Student's t-test was used assuming the sample was normally distributed. For non-parametric statistical analysis, Wilcoxon rank sign test was undertaken assuming the sample was not normally distributed, but rather symmetric according to the median.

The Wilcoxon rank sign test is employed to estimate confidence intervals for median values of small samples. According to Siegel [18], this test describes well behavioural variables, such as usage patterns. In comparison to the Student's t-test, the Wilcoxon test compares the difference between median values rather than the difference between mean values. The analyses were carried out with MiniTab 16 Statistical Software.

Two confidence intervals were used: the 90% and the 80%. The 90% interval was used for the electricity end-uses data, applied to mean and median values, as the data is well fitted with low variability. For the usage pattern schedules data, the 80% interval was used as the data present large variability.

2.3. Data analysis

Data analysis was carried by determining the usage pattern schedules for rooms and electrical appliances. The schedules were assumed to represent the whole year, by grouping information of summer and winter periods of the house sample. One year of measurement for obtaining only electricity end-uses would be impracticable.

The electrical appliances in the same room were grouped in order to determine the average daily usage pattern schedule. The usage pattern was considered ranging between 0 and 1 for events representing non- and full- power usage, respectively. These average schedules were weighted by both their average power and their share on the total electricity consumption of each house, in order to determine the representative schedules.

The power data was transformed in power density, by dividing the installed power in each room for each house for its floor area. These power densities are associated with the usage pattern schedules.

Pearson's correlation statistics was applied to the electricity consumption and socioeconomic variables in an attempt to find explanations to the achieved results; 95% reliability was considered for the correlation.

3. Results

The final results of the analysis performed in this research are presented in this section, which were divided by electricity end-uses, usage pattern and correlation analysis.

3.1. Electricity end-use

Table 1 shows the electricity end-uses for the houses with a 90% confidence interval by Wilcoxon's test. The outlier values were disregarded and the ranking was based on the median of the sample. The "other" end-use refers to appliances that individually do not contribute as a representative end-use and also exhibits large variability on the sample. It is noticed that no air conditioning equipment was found in the house sample.

According to Table 1, electric shower, refrigerators, television and lighting together represent from 73.8% to 91.7% of the total electricity consumption. The end-use results did not show significant difference between summer and winter seasons, and were generalized for the whole year.

The work of Ghisi *et al*. [6] showed that the electricity consumption of electric shower represents 14 to 28% in summer and 26% in winter for the region sampled. The refrigerator features 33 to 34% in summer and 30% in winter. The electricity consumption in the bioclimatic zone where Florianópolis is located ranges from 7.74 to 8.41kWh per day over summer and around 8.91kWh per day over winter.

The data collected in the 53-house sample showed daily average of 7.23 kWh and 7.79 kWh, for summer and winter, respectively. The monthly average electricity consumption is 214 kWh and its median, 194 kWh. Wide variation on the data can be identified, with values ranging from 80 to 400 kWh per month. Figure 3 shows the frequency of monthly and daily absolute electricity consumption of the 53-house sample.

3.2. Usage pattern schedules

Due to the large variability in the data regarding the appliances power and their usage pattern, the solution adopted was to create representative schedules for the 53 houses.

Figures 4, 7 and 8 show representative usage patterns, summarized in a power usage fraction per room, which is a value from 0 to 1 indicating the partial power usage in each hour of the day.

Figure 4 shows the usage patterns of all household appliances. It can be seen that the power fractions are small relative to total power installed in each room, reaching a maximum fraction of 0.33 in the bedroom. This fraction is somehow a concurrency coefficient of usage of electronic equipment of the building. It may be emphasized that the average values for each room are shown without confidence intervals.

Figure 5 shows the power density with appliances for each room with 80% confidence interval, which represents the whole sample with the parametric analysis test. To interpret Figure 5, for the bedroom the average power is 18.28 W/m^2, varying from 10.21 to 26.36 W/m^2, with 80% reliability.

Table 1: Median electricity end-uses for the whole year with 90% confidence interval with non-parametric test.

Value	Electric Shower	Refrigerator	Television	Lighting	Clothes Washer	Microwave	Other
Lower limit	33.5%	27.4%	8.4%	4.5%	0.7%	0.4%	8.0%
Median	36.8%	29.9%	10.2%	5.2%	0.9%	0.6%	10.5%
Upper limit	40.3%	33.1%	12.2%	6.1%	1.1%	0.9%	13.5%

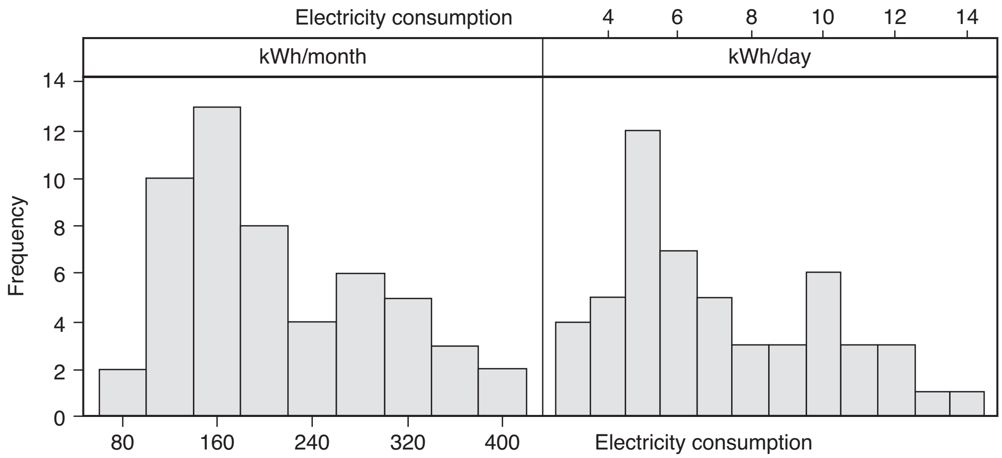


Figure 3: Electricity consumption of the 53-house sample in kWh per month and per day.

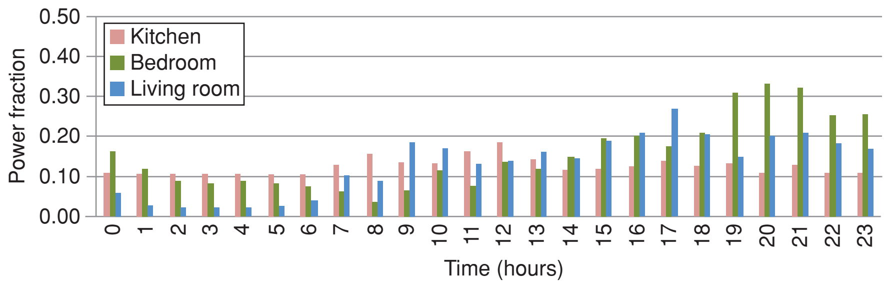


Figure 4: Household appliances usage patterns for each room (average values).

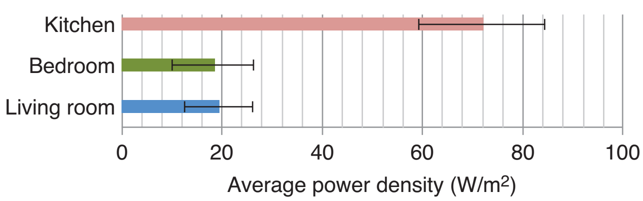


Figure 5: Household appliance power density for each room, with 80% confidence interval.

Figure 6 is shows the electricity consumption, when Figures 4 and 5 are analysed together by multiplying the power fraction in each hour of the day by the power density value. From Figure 6, it can be stated that at 20h, in the bedroom, 3.38 to 8.56 Wh/m^2 are used with 80% reliability.

The results did not follow any trend, but it is noticed that on later hours of the day for the bedroom, the electricity power fraction is greater in the bedrooms than on the other hours. In the kitchen, the electricity consumption is greater in 12:00. There are appliances in standby mode between 0:00 and 07:00 in all rooms, and a small fraction in the living room in this period.

Figure 7 shows the usage pattern of lighting, with the power fraction starting at 17:00, because in other hours of the day the fraction is zero. In this case, 80% confidence intervals are presented on lower, median and upper levels. Sometimes the lower level or the median is zero, and the bar does not appear in Figures. All routines for the environment are associated with power densities shown in the same Figure 7, with the Student's t-test and 80% reliability. For the bedroom, for example, the average lighting power density (Figure 7-d) is 3.82 W/m^2, with the average ranging from 3.35 to 4.29 W/ m^2, with 80% reliability.

It can be stated that in the case of the bedroom, at 20:00, lighting is used in a fraction from 0.167 to 0.333, which represents from 10 to 20 minutes in this full hour. By combining the power fraction with the average power in the room, for example, at 20:00, there is a consumption of 0.56 to 1.42 Wh/m^2, with 80% reliability.

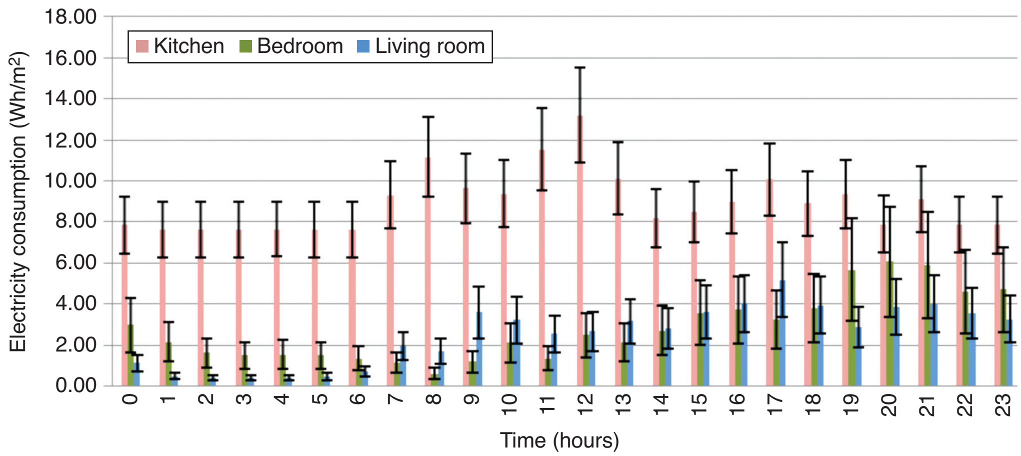
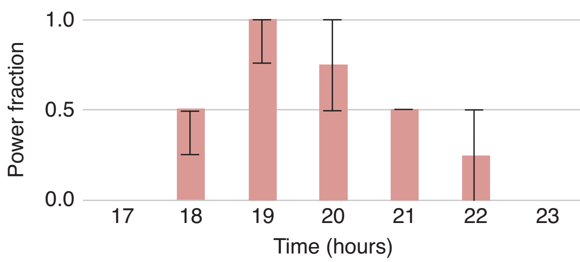
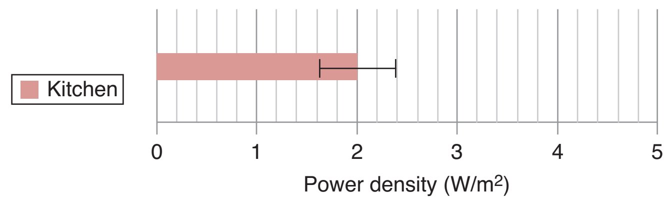


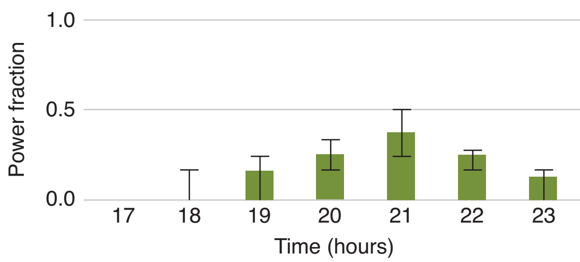
Figure 6: Household appliance electricity consumption for each room, with 80% confidence interval.



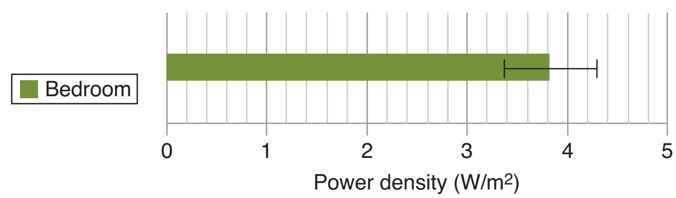
(a) Lighting usage pattern in the kitchen



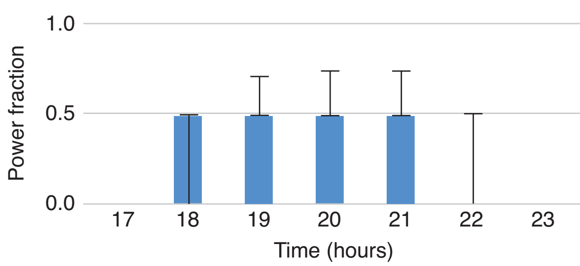
(b) Average lighting power density in the kitchen



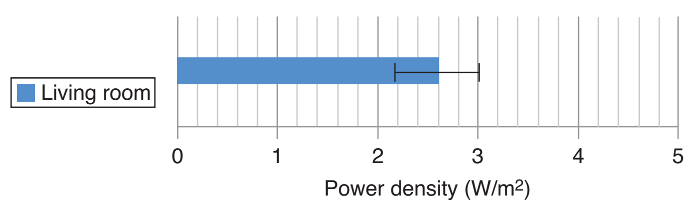
(c) Lighting usage pattern in the bedroom



(d) Average lighting power density in the bedroom



(e) Lighting usage pattern in the living room



(f) Average lighting power density in the living room

Figure 7: Lighting usage patterns and lighting power density for each room.

Figure 8 shows the usage pattern of electric shower, which is the largest electricity consumer of the sample. The ranges for the patterns are of 80% confidence with non-parametric test, and the power interval have 80% confidence with the Student's t-test. For the usage time (Figure 8-a), it is clear predominance at 7:00 and 19:00. The fraction of average power is 0.10, while varies from 0.06 to 0.16 with 80% reliability at 7:00. For 19:00, the average is also 0.10, but varying from 0.03 to 0.16.

3.3 Correlation analysis

The analysis shown in Table 2 presents some correlations between total income with the number of inhabitants, total and electric shower electricity consumption with 95% reliability. For example, the total income was correlated with the number of inhabitants in a proportional way (high and positive value for the Person's index), and the p-value is lower than 0.05, which meets the 95% reliability.

The number of inhabitants was correlated to the electric shower electricity, lighting, other appliances (see Table 1) and total electricity consumption. The total income was correlated with the electric shower electricity consumption and the total consumption.

In Figure 9 some correlations are shown, for the household total income and number of inhabitants, with the total and electric shower electricity consumption.

4. Conclusions

In this study, a sample of low-income houses in Southern Brazil was selected for the determination of electricity end-uses. The importance of measuring electricity consumption and to perform appropriate interviews and quantification was shown, helping to obtain more realistic results.

The greatest electricity end-use found was the electric shower, followed by refrigerator, television and lighting, although other studies indicate differently for some regions of Brazil. The usage patterns obtained are useful for system sizing that can be proposed (such as solar water heating, photovoltaic system, air conditioning system) and for the quantification of future energy savings. Besides, the usage patterns help to assess the

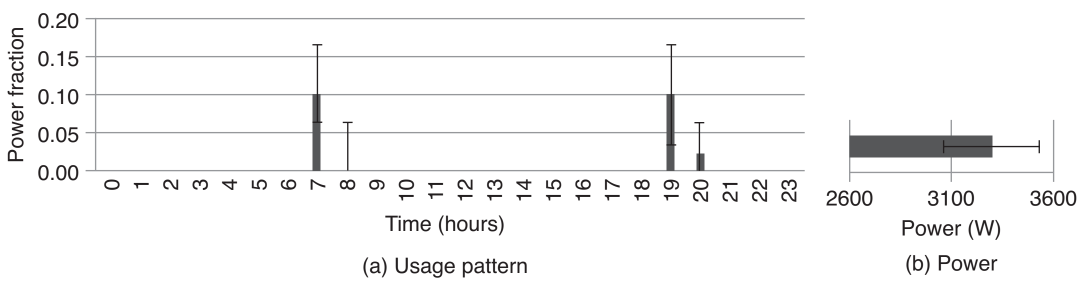


Figure 8: Electric shower usage patterns, with 80% confidence interval.

Table 2: Pearson's correlation results between economic and electricity consumption variables with 95% reliability.

Variables	Value	Number of inhabitants	Total income (R$)	Lighting consumption (kWh/month)	Total consumption (kWh/month)
Total income (R$)	Pearson's	0.583	–	–	0.401
	p-value	**0.000**	–	–	**0.006**
Electric shower electricity	Pearson's	0.582	0.464	–	–
consumption (kWh/month)	p-value	**0.000**	**0.001**	–	–
Other electricity consumption	Pearson's	0.293	–	–	–
(kWh/month)	p-value	**0.041**	–	–	
Number of inhabitants	Pearson's	–	–	0.323	0.593
	p-value	–	–	**0.024**	**0.000**

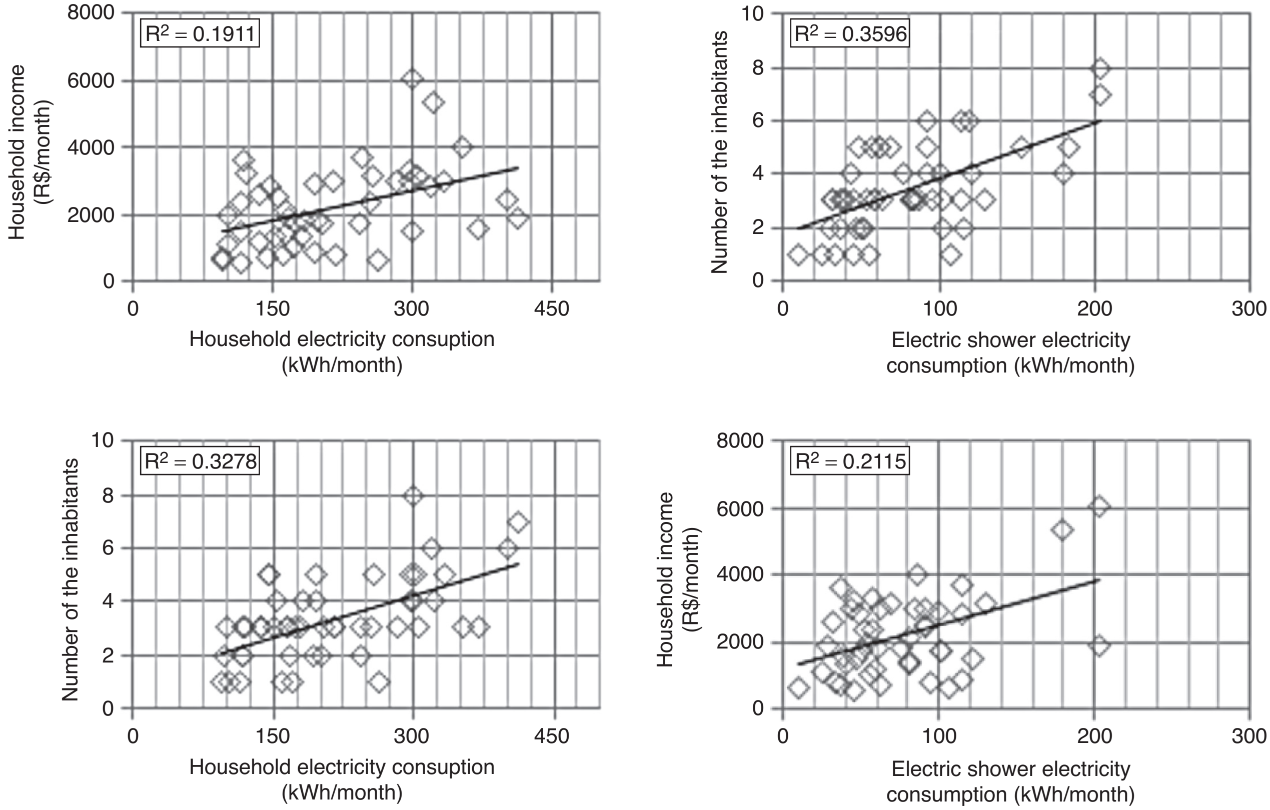


Figure 9: Correlation between household and electric shower electricity consumption with total income and number of inhabitants.

thermal performance of the building through thermo-energetic analysis, as they represent the occupant behaviour.

The correlation analysis showed high relationship between the household electricity consumption with the number of inhabitants and total income.

Through this method, it was possible to define the appliances responsible for larger electricity consumption in the low-income houses of Southern Brazil. Thus, it is possible to set goals to energy efficiency, such as investing in technologies of solar water heating and government programmes to encourage the use of energy-efficient appliances according to national laws and labels. However, these solutions are based on technical and economic feasibility, which can be different for each climate and solar irradiation availability in the regions of Brazil, which indicates that more specific researches must be performed.

In general, the results shown herein will provide a basis for other studies, whose primary focus is the determination of guidelines for low-income housing, guiding and reinforcing government programmes for energy efficiency, rational use of electricity and renewable energy use.

5. References

[1] Chung-Sheng, Z.; Shu-Wen, N.I.U.; Xin, Z. Effects of household energy consumption on environment and its influence factors in rural and urban areas. Energy Procedia, 14 (2012), pp. 1. *http://dx.doi.org/ 10.1016/ j.egypro. 2011.12.1015*

[2] Brasil. Balanço Energético Nacional 2012: Ano base 2011. Empresa de Pesquisa Energética (EPE). Rio de Janeiro, 2012a.

[3] Bin, S.; Dowlatabadi, H. Consumer lifestyle approach to US energy use and the related CO2 emissions. Energy Policy, 33(2) (2005), pp. 197–208. *http://dx.doi.org/ 10.1016/ S0301-4215(03) 00210–6*

[4] Jannuzzi, G.M. and Schipper, L. The structure of electricity demand in the Brazilian household sector. Energy Policy, 19(9) (1991), pp. 879–891. *http://dx.doi.org/ 10.1016/0301-4215(91)90013–E*

[5] Almeida, M.A.; Schaeffer, R.; La Rovere, E.L. The potential for electricity conservation and peak load reduction in the

residential sector of Brazil. Energy, 26(4) (2001), pp. 413-429. *http://dx.doi.org/10.1016/S0360-5442(00)00071–2*

[6] Ghisi, E.; Gosch, S.; Lamberts, R. Electricity end-uses in the residential sector of Brazil. Energy Policy, 35(8) (2007), pp. 4107-4120. *http://dx.doi.org/ 10.1016/ j.enpol.2007.02.020*

[7] Carlson, D.R.; Matthews, H.S.; Bergés, M. One size does not fit all: Averaged data on household electricity is inadequate for residential energy policy and decisions. Energy and Buildings, 64 (2013), pp. 132–144. *http://dx.doi.org/10.1016/ j.enbuild. 2013.04.005*

[8] Danielski, I. Large variations in specific final energy use in Swedish apartment buildings: Causes and solutions. Energy and Buildings, v. 49 (2012), p. 276-285. *http://dx.doi.org/ 10.1016/ j.enbuild.2012.02.015*

[9] Kelly, S. Do homes that are more energy efficient consume less energy?: A structural equation model of the English residential sector. Energy, 36(9) (2011), pp. 5610–5620. *http://dx.doi.org/10.1016/ j.energy.2011.07.009*

[10] McLoughlin, F.; Duffy, A.; Conlon, M. Characterising domestic electricity consumption patterns by dwelling and occupant socio-economic variables: An Irish case study. Energy and Buildings, 48 (July 2009) (2012) p. 240–248. *http://dx.doi.org/10.1016/ j.enbuild.2012.01.037*

[11] Druckman, A.; Jackson, T. The carbon footprint of UK households 1990-2004: A socio-economically disaggregated, quasi-multi-regional input-output model. Ecological Economics, 68 (7) (2009), p. 2066–2077. *http://dx.doi.org/ 10.1016/ j.ecolecon.2009.01.013*

[12] Brasil, 2007. Pesquisa de orçamentos familiares 2002–2003 - Perfil das despesas no Brasil. Instituto Brasileiro de Geografia e Estatéstica (IBGE). Rio de Janeiro.

[13] Brasil, 2011. Decreto n. 7655, de 23 de Dezembro de 2011.

[14] Brasil, 2012b. Programa de Eficiência Energética 2012 - Enersul: Rede Energia. São Paulo. Available in: < *http://www.redenergia.com/enersul/* > Acessed in: 2013, January.

[15] Naspolini, H.F. and Rüther, R. The impacts of solar water heating in low-income households on the distribution utility's active, reactive and apparent power demands. Solar Energy, 85(9) (2011), pp. 2023–2032. *http://dx.doi.org/10.1016/ j.solener.2011.05.011*

[16] Martins, F.R.; Abreu, S.L.; Pereira, E.B. Scenarios for solar thermal energy applications in Brazil. Energy Policy, 48 (2012), pp. 640–649. *http://dx.doi.org/ 10.1016/ j.enpol.2012.05.082*

[17] PMF - Prefeitura Municipal de Florianópolis, 2011. Plano Municipal de Habitação de Interesse Social: Produto 08. Secretaria Municipal de Habitação e Saneamento Ambiental (SMHSA), Florianópolis, SC, jun. 2011. Available in: < *http://www.pmf.sc.gov.br/*> Accessed in: 2012, October.

[18] Siegel, S. Estatísticas Não Paramétricas para Ciências do Comportamento. Editora Bookman. Second Edition, 2006.

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Annex: Example questionnaire of electricity end-use.

Questionnaire - Electronic equipment assesment	Interviewer	Date:	Time of application-beginning:	end:
Name: Adress:			House Code:	

Lighting characterization									**General Monitoring**	**Energy bills**								
Lighting characterization						Monitoring - CEM 1000				Date	Days among measu rements	Cons ump-tion (kWh)	Tax (R$/kWh)		Social tax?	Other taxes	Value (R$)
Room	Type of lamp	Position	Power rating (kW)	Vol-tage (V)	Cur-rent (A)	(Power) (kW)	Reacti-ve Pw. (kVAr)	Power factor (P.F)					1ª	2ª			
									Monit. Onset - Beginning:								
									__/__/___ hour___:___								
									Consumption:________ kWh								
									Monit. Onset - Ending:								
									__/__/___ hour___:___								
									Consumption:________ kWh								

Electronic equipment

Equipment characterization						Monitoring				Equipment characterization						Monitoring		
						T8										T8		
Room	Equipment	Label/model	Power rating (kW)	age (years)	Cicle time	Time (h:mm)	Consu-mption time	Consu-mption (kWh)		Room	Equipment	Label/model	Power rating (kW)	age (years)	Cicle time	Time (h:mm)	Consu-mption time	Consu-mption (kWh)