Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol. 9, No. 2, April 2021, pp.678-683

Estimation of domestic urban electricity consumption: A case study of Baghdad, Iraq

S. K. Al-Mosawy[1,a] , S. M. Al-Jawari [1,b] , I. J. Al-Yassri [1,c]
[1]Faculty of Physical Planning for University of Kufa

ABSTRACT

Electricity consumption for household purposes in urban areas widely affects the general urban consumption compared to other commercial and industrial uses, as household electricity consumption is affected by many factors related to the physical aspects of the residential area such as temperature, housing unit area, and coverage ratio, as well as social and economic factors such as family size and income, to reach the extent of the influence of each of the above factors on the amount of electricity consumed for residential uses, a selected sample of a residential area in the city of Baghdad was studied and a field survey conducted of the characteristics of that sample and the results analyzed and modeled statistically in relation to the amount of electricity consumed for residential units. Results showed that the annual electricity consumption is directly proportional to both the increase in the residential plot area and the increase in the number of residents of the housing unit and the increase in the monthly income of households, while it is inversely proportional to the plot coverage rate. Through the results of the field research, it was possible to build six quantitative models describing the behavior of electricity consumption in relation to the variables covered in the research.

Keywords: Domestic electricity consumption, Air temperature, Plot area, household size, income, Baghdad

Corresponding Author:
S. K. Al-Mosawy
Faculty of Physical Planning for University of Kufa
Iraq, Kufa, P.O. Box (21), Najaf
E-mail: **suhadk.almosawy@uokufa.edu.iq**

1. Intruduction

The availability of electricity in cities is a major factor in their economic and social sustainability; it reflects the quality of urban life. Since residential areas could be considered the largest part of the majority of cities in the world, therefore, household electricity consumption takes a large part of the general urban electricity consumption in cities [1], the household's consumption of electricity is affected by many factors, the most important of which is outdoor air temperature, as climate changes and global warming can contribute to an increase in household electricity consumption, especially in hot dry regions, in which electricity consumption for cooling purposes may reach in some areas, as in Kuwait, for example, to (72%) of the total electrical electricity consumption [2].

Indicators and characteristics of residential areas, such as the area of residential plots and the coverage ratio, can affect outdoor air temperature and thus electricity consumption could be decreased or increased [3]. When the coverage ratio in the residential area is high (and therefore a smaller ratio of the open spaces), the electricity consumption will be decreased due to the minimizing of the radiation effect, and shaded areas increased due [4].

Social factors also affect household electricity consumption, especially the factors of household size and their income. The greater the size of the family, the more electricity it consumes. But when taking the rate of per capita consumption, we find that the individual in large households consumes less electricity than the individual in medium or small households [5] it's also noted that electricity consumption of households reflects the housing pattern, where apartment blocks consume less electricity than individual housing units [6]. The household income widely affects the pattern of electricity consumption; the higher is the household income, the higher its electricity consumption. Income can be considered as a function of estimating or predicting the amount of electricity consumed by an urban household [7].

2. Research

The research assumes that household electricity consumption is affected by a set of physical and social factors and can be estimated by determining the levels of those factors in urban areas. The research aims to achieve quantitative models for estimating electricity consumption in residential areas of Baghdad. To achieve that goal, a broad field study should be made covering an urban area in the city of Baghdad through which the quantitative behavior of electricity consumption is analyzed and described according to the physical and social indicators of the study area.

2.1. Experimental part

The study was taken in the city of Baghdad/ Al-Karkh District/ Al-Mansour Sector/ Al-Yarmouk Community/ Neighborhood 616 for (43) months from May 2017 until November 2020, and for a sample size of 420 individual housing units.

A field survey was made for the selected sample through a dedicated questionnaire form that included recording data about housing units and households in terms of the amount of monthly electricity consumption estimated in kWh, as well as determining the areas of housing units (plot area), building coverage ratios, the number of household members and the average monthly income of the family.

A database was built for the selected urban area, statistical analyses were formulated through SPSS and Microsoft Excel software to explain the behavior of the variables (factors) that were studied, results can be reviewed as follows:

2.2. Modeling

Through the results of the experimental study, it is possible to achieve a set of statistical and mathematical modeling methods to describe the quantitative behavior of the variables affecting household electricity consumption for the study area, including:

Calculate daily electricity consumption in relation to temperature

For cold period

$$DEC = 616.88(C^{o})^{-0.839}$$

For hot period:

$$DEC = 0.0384(C^{o})^{2.311}$$

Where:
DEC: Daily Electricity Consumption (KWh)
C^{o}: Outdoor air temperature (Celsius)

Calculating the annual electricity consumption in relation to the plot area

$$AEC = 8.9983e^{0.0014a}$$

Where:
AEC: Annual Electricity Consumption (MWh)
a: plot Area (m^2)

Calculate the annual electricity consumption in relation to the residential plot coverage ratio

$$AEC = 10.032(ca)^{-0.977}$$

Where:
AEC: Annual Electricity Consumption (MWh)
Ca: Coverage Ratio

Calculate the annual electricity consumption in relation to the household size

$$AEC = 1.6739(n) + 5.8748$$

Where:
AEC: Annual Electricity Consumption (MWh)
n: Household size

Calculate the annual electricity consumption in relation to the household income

$$AEC = 12.192\ln(i) + 14.273$$

Where:
AEC: Annual Electricity Consumption (MWh)
i: Household monthly income (thousands of US$)
Through the six quantitative models referred to above, it is possible to estimate the amount of electricity consumed according to outdoor air temperature data, the plot area, the plot coverage ratio, the number of family members, and the average household income.

3. Results and discussion

3.1. Daily electricity consumption vs. temperature

The results showed that there are two patterns of electricity consumption in relation to outdoor air temperature, during cold periods, electricity consumption increases when the temperature is low due to the need for housing units for heating, in this period, the results show that a typical household (5-6 persons) can consume an amount of (85 KWh) per day, when the average daily outdoor air temperature is about (11º) Celsius in January, the lowest level of electricity consumption is achieved in the study area about (45 KWh) per day for a typical family when the average daily outdoor air temperature is (23º) Celsius during April (within the study period), figure (1).
During the hot period, which is the most electricity-consuming period due to the need for cooling, the results showed an increase in electricity consumption for a typical household, reaching its highest value of (169 KWh) when the average daily temperature is (39º) Celsius during July.
Results indicate that a typical household consumes electricity of (18 MWh) throughout the year, about (12.5 MWh) during the hot period (from mid-May to mid-October) which is (70%) of total electricity consumption compared to (5.5 MWh) during the cold period (from mid-November to mid-March) which is (30%), meaning that the electricity consumption for the hot period of the year is approximately two and a half times its value during the cold period (within the study period).

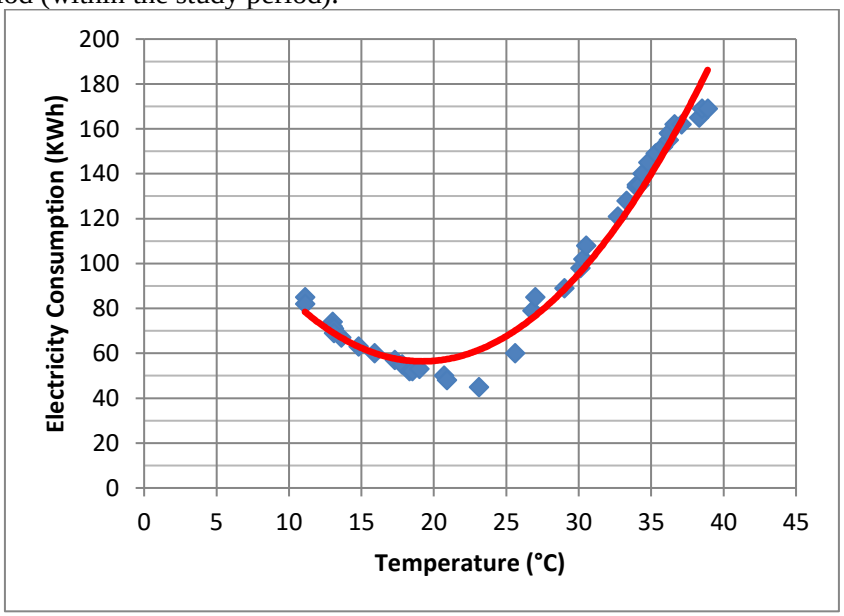

Figure 1. Daily electricity consumption vs. temperature

3.2. Annual electricity consumption vs. plot area

The results explained that the annual electricity consumption in the study area is directly proportional to the increase in the plot area of residential units, the results indicate that small plot areas ranging between (50-200 m^2) consume annually about (7-12 MWh), then the category of medium plots that range between (201-500 m^2) which consume between (13-20 MWh), and finally the category of large plots (more than 501 m^2), which can be consumed annually up to (21-37 MWh), Figure (2).

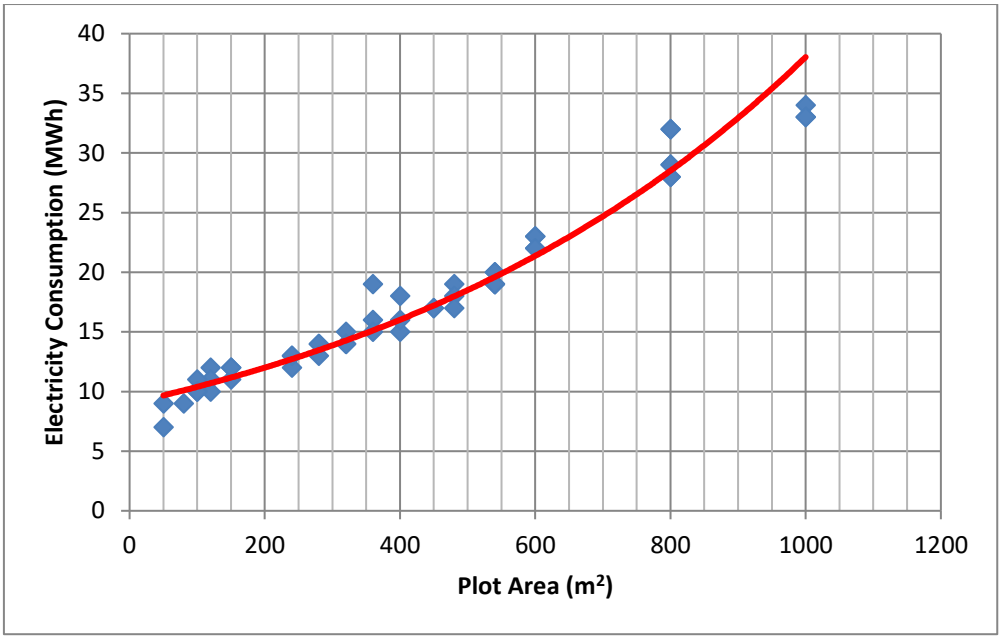

Figure 2. Annual electricity consumption vs. plot area

The direct relationship between annual electricity consumption and plot area can be explained by that increase in residential plot area allowing the possibility of building more large spaces as well as the availability of external spaces (gardens and open spaces), large areas of internal spaces need electricity for cooling and heating purposes more than small spaces, also the presence of open spaces around residential buildings reduces the resistance to heat transfer through the building envelope (walls and roofs), and thus the need for greater electricity loads compared to medium and small spaces of residential plots.

3.3. Annual electricity consumption vs. plot area

Results showed that the annual electricity consumption in the study area is inversely proportional to the increase in residential plot coverage. The results indicate that residential plots with a low coverage rate of up to (30%) achieve the highest annual consumption of about (34 MWh), while residential units with coverage of (100%) consume minimum electricity consumption of about (7 MWh) annually, figure (3).

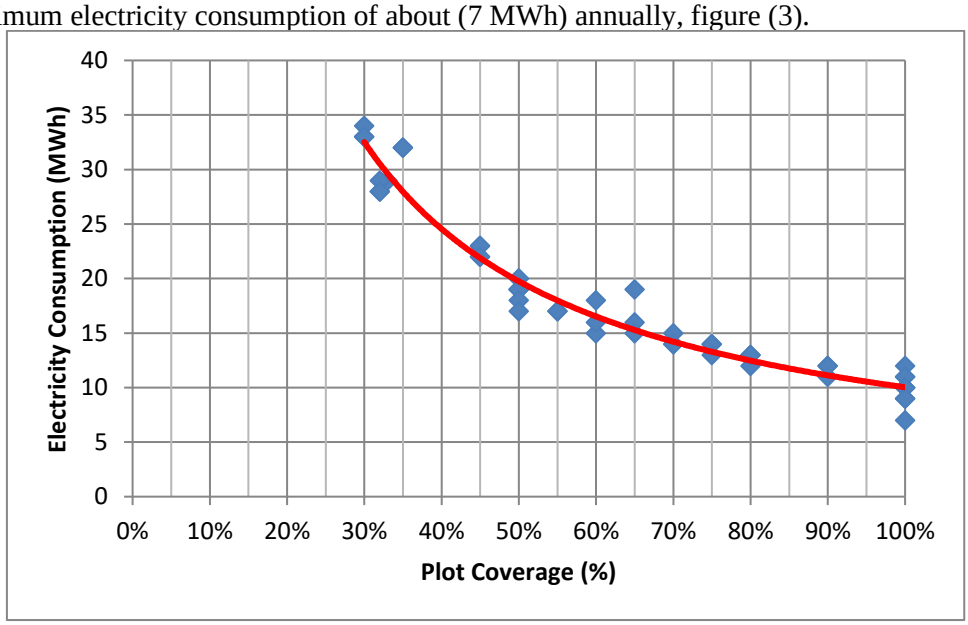

Figure 3. Annual electricity consumption vs. plot area

The results confirm what was referred to for residential plot areas, as an increase in the coverage ratio means less open spaces and more compact urban form for buildings and spaces, which leads to less exposure of the external surfaces to the effects of heat and increased resistance to heat transfer through the building envelope.

3.4. Annual electricity consumption vs. household size

The results revealed that the annual electricity consumption in the study area is directly proportional to the increase in the number of family members or the number of inhabitants in the housing unit. The results indicate that a typical household consumes annually electricity ranging between (13-16 MWh), (4 people and below) consume from (7-14 MWh) annually, while large households appear more inclined to consume electricity, as a family of (10) people can consume up to 22 MWh.) annually, The study area contained large households whose number ranges from (15-17 individuals) whose annual consumption is estimated at (34 MWh). The annual electricity requirement can be estimated based on number of individuals. Annual per capita electricity consumption in the study area is estimated at (3 MWh), Figure (4).

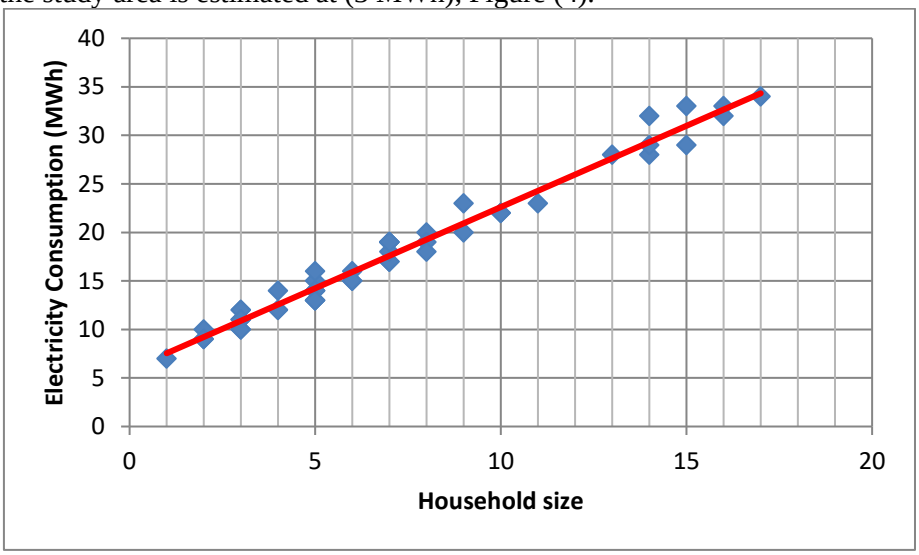

Figure 4. Annual electricity consumption vs. household size

3.5. Annual electricity consumption vs. monthly income

Results revealed a positive relationship between the annual electricity consumption and the average monthly income of the household in the study area. For households with monthly income (1000-2000 US$), it seems to consume about (13-23 MWh) annually, with the increase in the monthly household income, the annual electricity consumption increases to (34 MWh) when monthly income is about (5000 US$). A typical increase in electricity consumption to be directly related to the rate of income, due to the fact that income is a basic indicator of the level of well-being and the quality of life for households, figure (5).

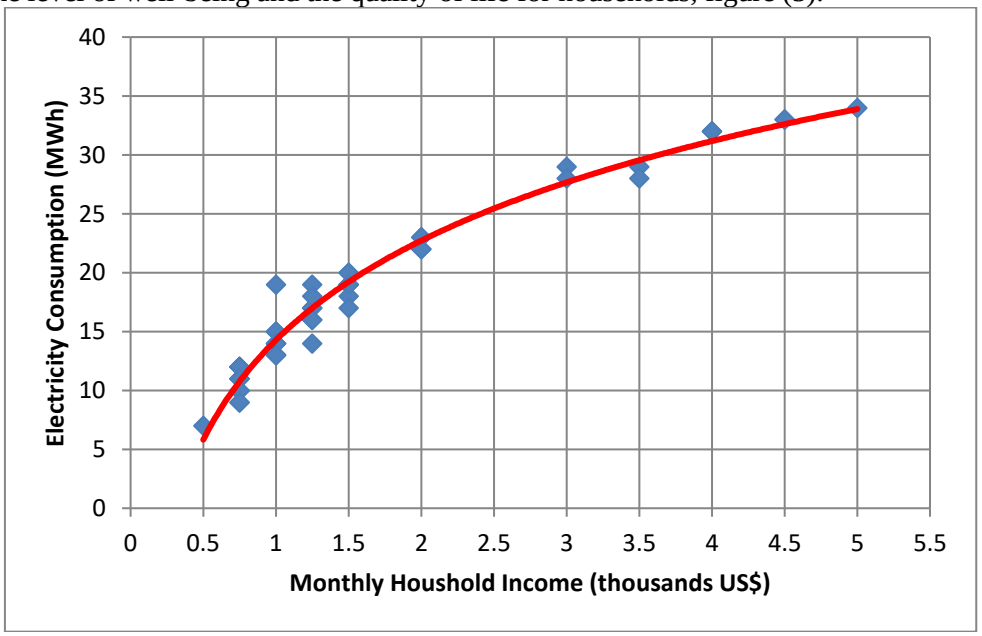

Figure 5. Annual electricity consumption vs. monthly income

4. Conclusions

1. Electricity consumption for domestic purposes is affected by a set of factors, the most important of which is the average daily outdoor air temperature, the plot area of residential units, the plot coverage ratio for residential units, the number of housing unit residents, and the average income of the household.
2. The electricity consumption for the hot period of the year is approximately twice and half its value during the cold period.
3. Reducing the area of plots leads to less electricity consumption, as the increase in the coverage ratio means fewer open spaces and more urban compactness, which leads to less exposure of the external surfaces to the effects of heat and increased resistance to heat transfer through the building envelope, thus reducing the amount of electricity consumed. .
4. Annual per capita electricity consumption in the study area is about (3 MWh).
5. An electricity consumption amount of (11 MWH) reflects a household of (1000 US$) monthly income.

A residential area was studied in the city of Baghdad with the aim to analyze household electricity consumption by studying a set of factors, which are the average daily outdoor air temperature, the plot area of residential units, the plot coverage ratio for residential units, the number of housing unit residents and the household income, it has been found that the annual electricity consumption is directly proportional with both the increase in residential plot area, the increase in the number of residents of the housing unit and the increase in the monthly income of households, while inversely proportional to the coverage ratio, as for the pattern of electricity consumption in relation to outdoor air temperature, the lowest electricity consumption achieved is (45 kWh) when the average daily temperature is (23°) Celsius during the month of April, while it reaches its highest value of (169 kWh) when the average daily temperature is (39°) Celsius during the month of July, results revealed that small plot areas and high coverage ratio residential units consumes electricity less than large plot units. Household size and income highly affect electricity consumption, results revealed that annual per capita electricity consumption in the study area is about (3 MWh) and an average household with an income of (1000 US$) consumes annually (11 MWh). Six quantitative models were formulated to describe the behavior of electricity consumption in relation to the variables covered by the research.

References

[1] European Union, *Manual for statistics on electricity consumption in households*. 2013.
[2] T. Alajmi and P. Phelan, "Modeling and forecasting end-use electricity consumption for residential buildings in Kuwait using a bottom-up approach," *Energies*, vol. 13, no. 8, 2020, DOI: 10.3390/en13081981.
[3] P. McKeen and A. S. Fung, "The effect of building aspect ratio on electricity efficiency: A case study for multi-unit residential buildings in Canada," *Buildings*, vol. 4, no. 3, pp. 336–354, 2014, DOI: 10.3390/buildings4030336.
[4] S. K. A. Al-Mosawy, S. M. Al-Jawari, and A. A. Al-Jabari, "The Effect of Urban Form on Temperature for Hot Arid Zones. the Case Study of Baghdad, Iraq," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 459, no. 6, 2020, DOI: 10.1088/1755-1315/459/6/062109.
[5] H. Nguyen and M. Ha-duong, "Family size, Increasing block tariff and Economies of scale of household electricity consumption in Vietnam from 2010 to 2014 To cite this version : HAL Id : Hal-01714899," *ExternalEconomicsReview*, no. 101, pp. 1–11, 2017.
[6] IDAE, "Analyses of the electricity consumption of the household sector in Spain," p. 76, 2011, [Online]. Available: www.cros-portal.eu/sites/default/files/SECH_Spain.pdf%5Cn.
[7] E. Rodriguez Oreggia and R. A. Yepez Garcia, "Income and electricity consumption in Mexican households," *Policy Res. Work. Pap. WPS6864 6864*, no. May, pp. 1–34, 2014, [Online]. Available: http://documents.worldbank.org/curated/en/2014/05/19489359/income-electricity-consumption-mexican-households.