TEST Engineering & Management

March - April 2020
ISSN: 0193-4120 Page No. 369 - 374

Analysis of Domestic Energy consumption: A Case Study for North-eastern Region of Thailand

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Article Info
Volume 83
Page Number: 369 - 374
Publication Issue:
March - April 2020

Article History
Article Received*: 24 July 2019*
Revised*: 12 September 2019*
Accepted*: 15 February 2020*
Publication*: 12 March 2020*

Abstract
Energy consumption in domestic sector was analysed for a selective north-eastern part of Thailand. 303 families in the region were randomly sampled. They are scattered and cover 14 provinces. All of them were classified into 2 groups namely municipal areas and rural areas. The 150 municipal families and 153 rural families were interviewed. The data were then analysed to determined energy consumption characteristics. The results showed that averaged energy consumption per year-family (ECFavg.) were 17,092.26 MJ/year-family and 16,462.21 MJ/year-family for the municipal and rural areas respectively. For municipal area, 51% of electrical energy, 12% of LPG and 37% of renewable energy were found while families in rural areas consumed 49% of electricity, 1% of LPG and 50% of renewable sources. The data were also plotted to determine the relation between average energy consumption per family (ECFavg.-n) and the number of family member (n). It was found that average energy consumption was in forms of power functions: ECFavg.-n=13,393n0.273 (R2=0.97) and ECFavg.-n=11,625n0.2702 (R2=0.97) for municipal and rural areas respectively. Moreover, energy use per person was found to decrease when number of members in the family was increased.

Keywords: *Energy consumption, Rural, Municipal, Domestic, residential.*

I. INTRODUCTION

Energy is one of the key factors for human life activities, such as lighting, fuels for transportations, fuel for cooking, energy for appliances providing life comforts. Energy consumption in domestic sector has therefore been of importance. In 2012-2016, Thai domestic energy consumption was risen from 7,379 ktoe to 11,071 ktoe (approximately 50%) and has an increasing trend corresponding to the economic growth. In addition, uniform coverage of electricity and fuel station has led to the higher energy demand [1]. In 2016, Thai total energy consumption was 79,929 ktoe including domestic sector of 11,071 ktoe (13%), transportation sector of 30,190 ktoe (38%) and industrial sector of 29,206 ktoe (37%) [1]. As higher energy consumption of Thailand, some energy-saving measures have been employed to control the energy demands. Factories and buildings have been classified as designated and non-designated groups. Their energy consumptions have been investigated. It was reported by Polila and Wongwuttanasatian [2]. that there would be energy saving potential of 41.71% for the 32 sampled non-designated factories. This could be used to estimate the energy saving for the whole non-designated factory sector. It has been indicated that domestic sector has played more important role on overall energy consumption of the country. However, domestic energy demands depend strongly on lifestyles, local culture, family income and region. In Thailand, north-eastern part is a big region having high population and various of

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lifestyles and low to moderate family incomes. Thus, characteristics of family energy consumption in the region has been of interest. Moreover, by knowing of energy demand characteristics, prediction and well planning can be possible. Based on literature reviews, electrical energy consumption in domestic sector has been reported by Kangwankich and Kiatsiriroj [3]. They found a relation between electrical demand, family member and income for a selected village. The relation was in forms of E_e = 9.1107N + 9.32 x 10-5C +62.1419 where E_e is electrical energy used (ktoe/Year), N is family member (Person) and C is the income (Baht). There have been also some international reports of energy consumption in domestic sector analyzing various factors affecting on the energy uses. These results have been used for estimations and related policies. For example, Elnakat and Gomez [4] studied an importance of women on residential energy consumption. They concluded that number of women in one family has been increased and resulted in energy demand of the family. Thus, women have shown a stronger effect on family energy consumption than men. In 2017, Pabalo-Romero et al. [5] reported that residential energy consumption had a significant impact on CO_2 emission in all part of the world. They suggested that renewable energies must be encouraged as indirect and direct policies. In 2018, fuel poverty in residential sector was analyzed using surveyed data in year 2009. It was found that there was no evidence of fuel poverty as it was earlier assumed [6]. In China, domestic energy consumption during 1998-2007, has shown a large increasement. This has led to an importance of domestic energy policies [7]. In Australia, there was a study of relation of income, area and energy saving behavior and energy consumption in domestic sector. It was indicated that for families in the city, energy consumption strongly depended on family income [8]. Similarly, in the US, the residential energy consumption (Y) was linearly related to the number of populations (X) as Y = 22.983X +19,880, R^2= 0.9524 [9]. The factors influenced the rural residential energy transition were reported by Han et al. [10]. They found that 6 main factors were deduction of electrical bill, increasing in motorbikes, rising in efficient stoves and fuel prices, increase of number of households and electrical appliances, higher education and more energy efficiency institutes. Chinese demand side management affecting the electricity demand was studied and found that energy label measurement could control the growth of electrical demand [11]. In 2017, Du et al. [12] found that good communication in energy information could influence the residential electricity demand. It was reported that as the Indian economy has been rapidly grown up. Hence, the energy consumption in domestic sector has been greatly changed and was estimated to be 4 times of that in 2010 [13]. Residential energy consumption in urban and rural Jiangsu, China, was reported to give high impact on total energy consumption of the region. [14]. As mentioned above, the energy consumption of domestic sector has had strong impact on total energy consumption. Therefore, it has been of interest to investigate its regional characteristics which is unique and vary from region to region. In present work, the north-eastern region of Thailand was selected. Sample of data were collected across the region. Analysis of energy demand was performed for both municipal and rural areas. Relation of energy use and family member was found and finally, prediction of energy consumption could be achieved.

II. METHODOLOGY

A. Data collection

303 families were sampled and scattered over the region. It covered 14 provinces including Khon Kaen, Udonthani, Kalasin, Nakhon Panom, Mahasarakam, Mukdaharn, Yasothon, Roi-et, Loei, Sakonnakorn, Nongkai, Nongbualampu, Amnat Charoen, Buengkan and Ubonratchathani. The families were classified into 2 groups called municipal areas and rural areas. The 150 families in municipal areas (orange) and 153 families in rural areas (green) were shown in Fig.1 Number of family members were also listed in Table. 1

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Figure 1 Distribution of families in municipal areas (Orange) and rural areas (Green)

Table. 1 Number of family and member of sampled data.

Family member (person)	Municipal areas (family)	Rural areas (family)
1	4	6
2	21	22
3	38	28
4	37	34
5	25	35
6	25	28
Total	150	153

B. Data Analysis

Microsoft Excel was used as a tool to analyze the data. Pertinent parameters were defined as follows.

1. Energy consumptions were divided into three main parts called electricity (EEC), LPG consumption (LPG) and renewable fuel consumption (REC). The REC included wood, charcoal and rice husk

$$EEC = YE \times 3.6 \quad \text{(MJ/year)} \quad (1)$$

When YE is Yearly electricity consumption (kWh/year)

$$LPG = YV \times 26.620 \quad \text{(MJ/year)} \quad (2)$$

When YV is Yearly consumption of LPG (m3/year)

Heating value LPG 26.620 MJ/m3 [15].

$$REC = YW \times HHV_{(Wood)} + YC \times HHV_{(Charcoal)} + YP \times HHV_{(Rice\ Husk)} \quad \text{(MJ/year)} \quad (3)$$

When YW, YC, YP is Yearly consumptions of wood (kg.), Charcoal (kg.) and Rice Husk (kg.) respectively

Heating Values of Wood (16.00 MJ/kg), charcoal (28.88 MJ/kg), rice husk (14.40 MJ/kg) [15].

Thus, total energy consumption (TEC) can be determined by

$$TEC = EEC + LPG + REC \quad \text{(MJ/year)} \quad (4)$$

2. Average energy consumption per year-family ($ECF_{avg.}$) can be expressed by

$$ECF_{avg.} = \frac{TEC}{f} \quad (5)$$

f is number of families

3. Relation of average energy consumption per family and number of family can be expressed by

$$ECF_{avg.-n} = \frac{TEC(n)}{f(n)} \quad (6)$$

$ECF_{avg.-n}$. is average energy consumption per family (MJ/family), f(n) is number of families having member, n = 1, 2, 3, 4, 5, 6

III. RESULT AND DISCUSSION.

From the collected data, they were reduced and analyzed to illustrate the energy characteristics as follows.

From Fig. 2, Fig. 3 and Fig. 4, three main energy consumptions were depicted for municipal and rural areas. Average energy use per family in the municipal areas were found to be 17,652.71 MJ/year-family including EEC of 8,946.32 MJ/year-family (51%), REC of 6,589.36 MJ/year-family (37%) and LPG of 2,111.04 MJ/year-family (12%). Similarly, for rural areas, average energy use per family were 16,462.01 MJ/year-family including EEC of 8,123.17 MJ/year-family (49%), REC of 8,221.28 MJ/year-family (50%) and LPG of 117.56 MJ/year-family (1%). As seen in Fig. 4, the EEC of both municipal and rural areas were not different indicating that Thai electricity was uniformly distributed across the region and was the main energy source for living. It was also shown that REC for both areas were large since in the region, wood, charcoal and rice husk have been commonly used but in rural areas was higher than municipal areas. The difference was replaced by LPG in the

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municipal areas.

Fig. 5 demonstrated the relationship between average energy consumption per family and number of members for both municipal and rural areas. It revealed that average energy use per family slightly increased with number of members. However, the rising rate was decreased with members. The relations agreed well with the form of power function regarding to high R^2. As seen in Fig. 5, average energy use per one family for municipal areas was represented by $ECF_{avg.-n}=13{,}393n^{0.273}$ ($R^2=0.97$). For one-person family, minimum energy use was found to be 13,393 MJ/year-family for rural areas, average energy use in one family was denoted by $ECF_{avg.-n}=11{,}625n^{0.2702}$ ($R^2=0.97$). At least 11,625 MJ/year-family was needed for one-person family.

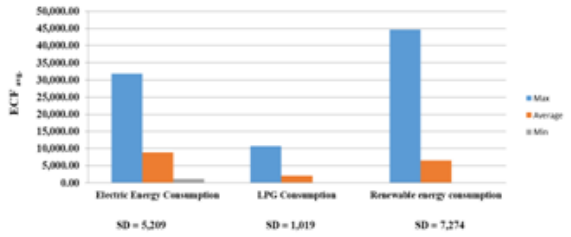

Figure 2 Types of energy consumption for municipal area

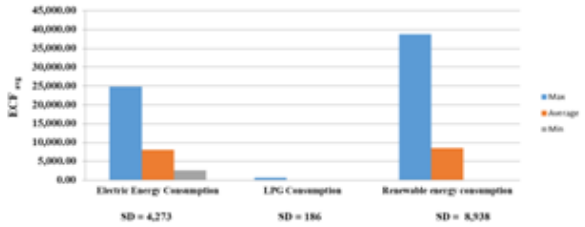

Figure 3 Types of energy consumption for rural area

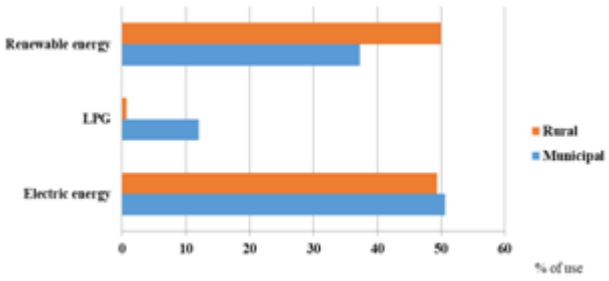

Figure 4. Percentage of energy consumptions for municipal areas and rural areas

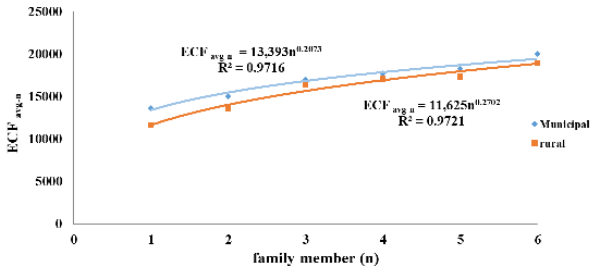

Fig. 5 Average energy consumption per family and family member for municipal and rural areas

In addition, based on the discovered characteristics, prediction of energy use in domestic sector in the region could be obtained. In 2017, the region had 3,474,780 families. The average values of 17,652.71 MJ/year-family and 16,462.01 MJ/year-family for municipal and rural areas were used to estimate total energy consumption in the region. The prediction showed approximately $57.7\text{x}10^9$ MJ/year total energy consumption. Then, if the ratios depicted in Fig. 4, the electrical energy use would be $28.54\text{x}10^9$ MJ/year, LPG use and REC would be $2.08\text{x}10^9$ and $27.25\text{x}10^9$ MJ/year, respectively.

Further analysis was focused on rising rate of energy use per person in families having different number of members. It was simply obtained by the slops of the graphs in Fig. 5. Slops were then plotted as shown in Fig. 6

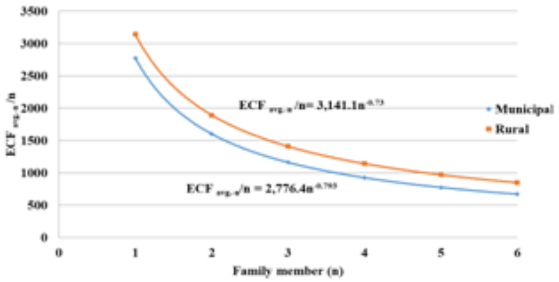

Figure 6 Average energy consumption per person in families having different members

From Fig. 6, it was evident that average energy use per person was decreased with increasing member. For example, when member changed from 1 person to 2 persons the average energy use

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decreased from 2,776.37 MJ/person to 1,602.69 MJ/person equivalent to 42.3% decrease. The reduction was less as the member increased

IV. CONCLUSION

This work aimed to study the energy consumption characteristics in domestic sector. North-eastern region of Thailand was selected to collect data from 303 families. They were classified into municipal and rural areas. The results showed that average energy use for both areas were 17,652.71 MJ/year-family and 16,462 MJ/year-family respectively. The details of energy consumptions were found to be 51 % EEC, 12% LPG and 37% REC for municipal areas and 49% EEC, 1% LPG and 50% REC for rural areas. Based on the data, relations between average yearly energy consumption and family member were obtained and agreed well with power function. They were $ECF_{avg.-n}$=13,393n0.2073 (R^2=0.97) for families in municipal areas and $ECF_{avg.-n}$.=11,625$n^{0.2702}$ (R^2=0.97) for families in rural areas. Then, minimum energy uses for one-person family were estimated as 13,393 MJ/year-family and 11,625 MJ/year-family for municipal and rural areas respectively. It was also concluded that energy use per person in a family depended on the family members. This was decreased with the increase of member. Increasing member from 1 person to 2 persons showed a great reduction in energy use per person.

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