

Kittikun Poolsawat; Watcharapong Tachajapong; Sukon Prasitwattanaseree;  
Wongkot Wongsapai

## Article

# Electricity consumption characteristics in Thailand residential sector and its saving potential

Energy Reports

**Provided in Cooperation with:**

Elsevier

*Suggested Citation:* Kittikun Poolsawat; Watcharapong Tachajapong; Sukon Prasitwattanaseree; Wongkot Wongsapai (2020) : Electricity consumption characteristics in Thailand residential sector and its saving potential, Energy Reports, ISSN 2352-4847, Elsevier, Amsterdam, Vol. 6, Iss. 2, pp. 337-343, <https://doi.org/10.1016/j.egyr.2019.11.085>

This Version is available at:

<https://hdl.handle.net/10419/243899>

### Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

### Terms of use:

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*



<https://creativecommons.org/licenses/by-nc-nd/4.0/>

The 6th International Conference on Power and Energy Systems Engineering (CPESE 2019),  
September 20–23, 2019, Okinawa, Japan

# Electricity consumption characteristics in Thailand residential sector and its saving potential

Kittikun Poolsawat<sup>a</sup>, Watcharapong Tachajapong<sup>b,\*</sup>, Sukon Prasitwattanaseree<sup>c</sup>,  
Wongkot Wongsapai<sup>b</sup>

<sup>a</sup> PhD Degree Program in Energy Engineering, Faculty of Engineering, Chiang Mai University, Chiang Mai 50200, Thailand

<sup>b</sup> Department of Mechanical Engineering, Faculty of Engineering, Chiang Mai University, Chiang Mai 50200, Thailand

<sup>c</sup> Department of Statistics, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand

Received 4 October 2019; accepted 22 November 2019

## Abstract

The actual state of electricity consumption characteristics in the residential sector in Thailand was presented. They were an essential information for the total energy usage estimation. They were used for investigating the feasibility of energy conservation. A questionnaire interview survey of 7,192 households for 41 kinds of appliances usage was conducted covering the whole part of Thailand in 2018. The characteristics of household electricity consumption was identified for both rural and urban areas. The whole country electricity consumption was estimated from the survey results extrapolation. The energy model, used in extrapolation, implies the majority of household electricity consumption in the area level. The result shows that overall electricity consumption in the household was 35,624.37 GWh in the year 2018. It comprised of air conditioner (26.50 %), refrigerator (19.33 %), light bulb indoor (14.93 %), rice cooker (6.82 %), television (6.10 %), fan (5.75 %), Electric bottle (3.35 %), light bulb outdoor (3.30 %), automatic pump (2.61 %), water heater (1.86 %), computer (1.67%), iron (1.55%), and other appliances (6.23 %). Around 13.97 % of electricity consumption, i.e. 4,975.89 GWh or 2.39 MtCO<sub>2</sub>, could be reduced by means of replacement with higher efficiency appliances.

© 2019 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Peer-review under responsibility of the scientific committee of the 6th International Conference on Power and Energy Systems Engineering (CPESE 2019).

**Keywords:** Electricity consumption; Residential sector; Saving potential

## 1. Introduction

The residential sector consumed the electricity about 23.01% of total electricity consumption of Thailand in 2017 [1]. It increases continuously due to a growing of economic. The growth rate of electricity demand was 5.20% per year increased from 32,799.46 GWh in 2011 to 44,373.96 GWh in 2017 [2]. It was reasonable when compared to 10.00% per year for China [3] and 6.70% per year for Indonesia [4].

\* Corresponding author.

E-mail address: [wtacha@gmail.com](mailto:wtacha@gmail.com) (W. Tachajapong).

<https://doi.org/10.1016/j.egy.2019.11.085>

2352-4847/© 2019 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Peer-review under responsibility of the scientific committee of the 6th International Conference on Power and Energy Systems Engineering (CPESE 2019).

The monitoring of residential sector energy consumption is thus important for Thailand. A survey of household energy consumption is conducted regularly to update the actual state of electricity consumption and to assess the trend of electricity demand. It examines the electricity consumption characteristics to assess the electricity saving potential in residential sector.

## 2. Methodology

### 2.1. Data collection

Thailand has a land area of 513,115 sq km. It is covering 77 provinces. As official statistics registration system conducted by Department of Provincial Administration (DOPA) in 2018, the number of households in Thailand was 25.23 million in which 42.20% and 57.80% of households were in urban and rural areas, respectively [5]. Since an energy conservation scheme in the household sector needs the detailed data of electricity consumption characteristics, a survey was conducted to collect the data on characteristics of household electricity consumption. The details of the survey method were described below.

### 2.2. Selection of survey sites and the sample size

The method of stratified random sampling was used following [6]. All data samples were classified into five stages with two stratum as shown in Table 1.

**Table 1.** Stratified random sampling by five stages.

Stage	Detail
1st stage	Urban and rural area
2nd stage	Regions with high and low levels of ratio household
3rd stage	Provinces with high and low levels of ratio household
4th stage	Districts with high and low levels of ratio household
5th stage	Local area with high and low levels of ratio household

All members of population in each stratum were categorized into a homogeneous group based on their similar characteristics defined by the purpose of samplings. The sample units were selected randomly with the proportional allocation in each stratum. Sample size was determined by type of variables to measured, error estimation and estimation of variance. Two factors for error estimation were 5% level of precision and 95% level of confidence. The sampling size for discrete random variables can be represented by [7].

$$n = \frac{Z_{1-\frac{\alpha}{2}}^2 \cdot \left( \sum_{h=1}^L W_h (P_h Q_h) \right)}{e^2} \quad (1)$$

where  $Z_{1-\frac{\alpha}{2}}$  is a standard normalized value which corresponds to the selected confidence level,  $W_h$  is a weight of stratum  $h$ ,  $P_h$  is a proportion of interested outcome in stratum  $h$  and,  $e$  is specified level of precision of the estimated true mean value which is normally specified as a percentage of the true mean of a population.

In this study, the sample size was 7190 households, by the proportion of gas consumption for cooking in urban and rural areas was estimated to be 0.72 and 0.58 [8]. The household sample were proportionally allocated into both stratum in each stage as shown in Table 2.

## 3. Attribution of questionnaire and survey

The questionnaire was designed following [6] which covers household characteristics, dwelling characteristics, and energy consumption in electricity appliances. The survey was conducted by interviewing 7190 respondents between December 2017 and May 2018. None of questionnaires was rejected.

**Table 2.** Sampling frame in this study by area of Thailand.

Stratum area	$W_h$	Samples	Stratum region	$W''_h$	Samples
Urban	0.4517	3308	Bangkok	0.3163	1154
			Central	0.1414	452
			North	0.1018	321
			Northeast	0.0838	241
			West	0.1205	380
			South	0.1110	360
			East	0.1252	400
Rural	0.5483	3882	Central	0.1441	554
			North	0.1767	679
			Northeast	0.1915	772
			West	0.1613	618
			South	0.1691	649
			East	0.1574	610

### 3.1. Estimation electricity consumption

An annual electricity consumption for each appliance (E) (e.g. lighting, cooking, entertainment, and other purposes) was estimated based on input power and average usage period per unit as [9].

$$E = \sum_{i=1}^n P_i \cdot N_i \cdot U_i \cdot F_i \quad (2)$$

where  $P_i$  is a rated power of appliance (kW),  $N_i$  is a number of appliances (unit),  $U_i$  is a length of time in using an appliance (h/year),  $F_i$  is a factor of appliance.

Load factor, seasonal factor, and utilization factor were used to improve the accuracy of prediction according to usage behavior such as air conditioner, fan, refrigerator, water heater and washing machine.

### 3.2. Load factor

The load factor refers to a ratio of the actual power consumption to a nominal rated power consumption of an appliance due to the on/off cycle behavior of operations. It was used to estimate the actual electricity consumption for air conditioner, fan, refrigerator, water heater, and washing machine in which the actual power consumptions are less than its rated power consumption due to the on/off cycle operations. The load factors for air conditioner, fan, refrigerator, water heater, and washing machine were assumed to be 0.75, 0.70, 0.45, 0.60 and 0.55 [9].

### 3.3. Seasonal factor

The seasonal factor refers to a ratio of the actual power consumption to a nominal rated power consumption of an appliance due to non-usage in particular season. It was used to estimate the actual electricity consumption for water heaters and air conditioners because they are inactive during winter and summer. The seasonal factors were average value from survey to be 0.83 for air conditioners and water heaters.

### 3.4. Utilization factor

The utilization factor refers to a ratio of the actual power consumption to a nominal rated power consumption of an appliance due to hanging out, business trip, and weekend excursion. It was used to estimate the actual electricity consumption for all appliances and average value from survey was 0.70 for all appliances.

## 4. Results

### 4.1. Household characteristics

Thailand has 25.23 million households with the average size of 3.64 persons per household. The average size increased from the previous census round in the year 2010 in which the average size was 3.00 persons per household [8] as shown in Table 3.

**Table 3.** Number, size, income and expenditure of household characteristics by area.

Household characteristics	Total	Area	
		Urban	Rural
Number of households	25,233,077	10,648,358	14,584,719
Average size of household	3.64	3.48	3.69
Average income	21,794	29,041	20,705
Average expenditure	17,524	19,969	14,804

When compare with the northern region data from [6], it was found that average size of households was the same between the whole country and the northern region of Thailand as shown in Table 4.

**Table 4.** Comparison of household characteristics between the whole country and the northern region of Thailand.

Characteristics	The whole country	The northern region
Survey area	Northern region	Whole Kingdom
Number of provinces	17	77
Number of households	4,467,077	25,233,077
Average size (persons/household)	3.64	3.64

### 4.2. Dwelling characteristics

Almost 80% of households in Thailand are detached houses (45.90%) and town house duplex and townhome (33.76%). The rest of them are row house (19.72%) and condominium apartment and flat (0.62%). Urban area has detached house more than rural area by 18.85%. While rural area has row house, and town house duplex and townhome more than urban area by 5.40 and 13.52%, respectively. Condominium apartment and flat are almost the same in urban and rural areas. Most of construction material dwelling were cement or brick 45.90%, followed by 33.76% brick and wood, 19.72% wood, and 0.62% non-permanent material as shown in Table 5.

**Table 5.** Number and percentage of dwelling characteristics by area.

Dwelling characteristics	Total		Area	
	Number	Percent	Urban	Rural
Type of living quarters	25,233,077	100.00	100.00	100.00
Detached house	11,581,982	45.90	56.80	37.95
Town house, duplex, townhome	8,518,687	33.76	25.94	39.46
Row house	4,975,963	19.72	16.60	22.00
Condominium, apartment, flat	156,445	0.62	0.66	0.59
Construction material	25,233,077	100.00	100.00	100.00
Cement or brick	11,581,982	45.90	56.80	37.95
Brick and wood	8,518,687	33.76	25.94	39.46
Wood	4,975,963	19.72	16.60	22.00
Non-permanent	156,445	0.62	0.66	0.59

When compare with the northern region data from [6], it was found that most of dwelling characteristics for the whole country were town house, duple, townhome instead of detached house in northern region as shown in Table 6.

**Table 6.** Comparison of dwelling characteristics between the whole country and the northern region of Thailand.

Characteristics	The whole country	The northern region
Detached house (%)	93.67	45.90
Town house, duplex, townhome (%)	1.89	33.76
Row house (%)	3.35	19.72
Condominium, apartment, flat (%)	1.09	0.62

#### 4.3. Electricity consumption

By extrapolating 7190 survey results, it was found that electricity consumption in Thailand was 35,624.37 GWh. It was lower than 45,205 GWh measured by PEA and MEA in which small and medium enterprises were included [10]. It was investigated that 41 appliances consumed energy substantially (higher than 1% of total electricity consumption) which are air conditioner, refrigerator, light bulb indoor, rice cooker, television, fan, electric bottle, light bulb outdoor, automatic pump, water heater, computer, iron and other appliances. They consumed energy 944.34 GWh, 6884.96 GWh, 5319.41 GWh, 2430.10 GWh, 2172. GWh, 2050.16 GWh, 1193.01 GWh, 1174.12 GWh, 930.04 GWh, 663.68 GWh, 595.41 GWh, 552.24 GWh and 2218.81 GWh; respectively, as shown in Table 7.

**Table 7.** Electricity consumption in appliances by area.

Appliances	Total		Area	
	Number	Percent	Urban	Rural
Air conditioner	9440.34	26.50	65.72	34.28
Refrigerator	6884.96	19.33	44.30	55.70
Light bulb indoor	5319.41	14.93	45.79	54.21
Rice cooker	2430.10	6.82	41.07	58.93
Television	2172.07	6.10	43.96	56.04
Fan	2050.16	5.75	45.71	54.29
Electric bottle	1193.01	3.35	41.61	58.39
Light bulb outdoor	1174.12	3.30	44.37	55.63
Automatic pump	930.04	2.61	60.81	39.19
Water heater	663.68	1.86	52.46	47.54
Computer	595.41	1.67	61.58	38.42
Iron	552.24	1.55	43.62	56.38
Others	2218.81	6.23	–	–

The comparison of electricity consumption and saving potential between the whole country and the northern region of Thailand is shown in Table 8.

**Table 8.** Comparison of dwelling characteristics between the whole country and the northern region of Thailand.

Characteristics	The whole country	The northern region
Electricity consumption and saving potential		
Electricity consumption (GWh)	5248.36	35,624.37
Saving potential (GWh)	847.24	4,975.89

#### 4.4. Saving potential

The result shows that Thailand has 13.97% of the energy reduction potential or about 4975.89 GWh. This could be done by replacing the old appliances with the higher efficiency ones as shown in [Table 9](#).

**Table 9.** Electricity consumption and saving potential by appliances.

Appliances	Electricity consumption		Policy	Saving potential	
	GWh	%		GWh	%
Light bulb indoor	5319.41	14.93	FL to LED	3510.88	66.00
Light bulb outdoor	1174.12	3.30	FL to LED	689.03	58.68
Television	2172.07	6.10	CRT to LED	649.11	29.88
Refrigerator	6884.96	19.33	Energy label	35.91	0.52
Air conditioner	9440.34	26.50	Energy label	30.46	0.32
Rice cooker	2430.10	6.82	Energy label	17.96	0.74
Automatic pump	930.04	2.61	Energy label	14.12	1.52
Fan	2050.16	5.75	Energy label	12.88	0.63
Electric bottle	1193.01	3.35	Energy label	7.43	0.36
Iron	552.24	1.55	Energy label	5.76	1.04
Water heater	663.68	1.86	Energy label	2.35	0.35

## 5. Discussion

From this study, energy reduction potential was 4975.89 GWh. It was equivalent to greenhouse gas mitigation about 2.39 MtCO<sub>2</sub> by using the grid emission factor of 0.48 tCO<sub>2</sub>/MWh [11] as shown in [Table 10](#). According to Energy Efficiency Development Plan (EEDP), the target of Thailand Nationally Appropriate Mitigation Actions (NAMAs) was 5.91 MtCO<sub>2</sub> Carbon dioxide (CO<sub>2</sub>) reduction in 2020 [12]. Therefore, the CO<sub>2</sub> reduction potential in this study could decrease the CO<sub>2</sub> about 40.41% of EEDP's target.

**Table 10.** Energy reduction potential greenhouse gas by appliances.

Appliances	Saving potential (GWh)	Reduction potential (tCO <sub>2</sub> )
Light bulb indoor	3510.88	1.6552
Light bulb outdoor	689.03	0.3307
Television	649.11	0.3116
Refrigerator	35.91	0.0172
Air conditioner	30.46	0.0146
Rice cooker	17.96	0.0086
Automatic pump	14.12	0.0068
Fan	12.88	0.0062
Electric bottle	7.43	0.0036
Iron	5.76	0.0028
Water heater	2.35	0.0011

## 6. Conclusion

A survey of household energy consumption was conducted. The sample size was 7190 households which were chosen randomly by using the method of stratified random sampling. Load factor, seasonal factor, and utilization factor were used to improve the accuracy of data. By extrapolating survey results, it can be concluded that Thailand has potential to save energy and greenhouse gas in household sector about 4975.89 GWh and 2.39 MtCO<sub>2</sub>, respectively, by improving the efficiency of appliances. In short term, the government should focus on the implementation of LED lighting as the first priority, as their investment cost is the most effective and due to a large amount of deployment among poor people. While in long term, the efficiency of air conditioner, refrigerator, and light bulb have to be considered because of their high rated electricity consumption.

## Acknowledgments

The authors would like to thank the Energy Conservation Promotion Fund, Thailand and Energy Policy and Planning Office (EPPO), Thailand for all funding and support. We remain culpable for any remaining errors.

## References

- [1] DEDE. Energy balance of Thailand 2017. Bangkok: Department of Alternative Energy Development and Efficiency; 2017.
- [2] EPPO. Energy statistics of Thailand 2017. Bangkok: Energy Policy and Planning Office; 2017.
- [3] Murata A, Kondou Y, Hailin M, Weisheng Z. Electricity demand in the chinese urban household sector. *Appl Energy* 2008;85:1113–25.
- [4] Batih H, Sorapipatana C. Characteristics of urban household's electrical energy consumption in Indonesia and its saving potentials. *Renew Sustain Energy Rev* 2016;57:1160–73.
- [5] DOPA. Official statistics registration system. Bangkok: Department of Provincial Administration; 2017.
- [6] Poolsawat K, Wongsapai W, Tachajapong W, Prasitwattanaseree S. Modelling of end-used electricity consumption and saving potential in household sector in northern thailand. *Chem Eng Trans* 2017;61:1117–22.
- [7] Cochran WG. Sampling techniques. 3rd ed.. New York: John Wiley & Sons; 1977.
- [8] NSO. The 2010 population and housing census in Thailand. Bangkok: National Statistical Office; 2010.
- [9] Meng LS. Meeting on household energy consumption survey in northern area. Jakarta, Indonesia: Economic Research Institute for ASEAN; 2016.
- [10] EPPO. Energy statistics of Thailand 2018. Bangkok: Energy Policy and Planning Office; 2018.
- [11] EGAT. Grid emission factor from power sector 2016. Bangkok: Electricity Generating Authority of Thailand; 2016.
- [12] Wongsapai W, Bunchuaidee R, Wayuparb N, Ritkrerkkrai C. Policy-based greenhouse gas mitigation tracking and institutional framework development under thailand's NAMAs in energy sector. *Chem Eng Trans* 2017;56:295–300.