

## CHAPTER 3

### METHODOLOGY

This chapter presents a step-by-step procedure to develop an energy conservation plan for the residential and small commercial sectors in Thailand. The procedure consists of:

1. Investigation of the current trends of energy consumption of residential and small commercial sectors,
2. Establishment of various scenarios of the energy use of the sectors in the next twenty years,
3. Development of energy conservation programs and assessment of the energy conservation potential.

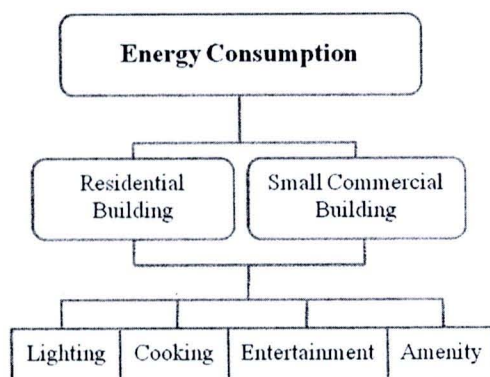
Each of the steps above is detailed as follows.

#### 3.1 Investigation of the Current Trends of Energy Consumption of Residential and Small Commercial Sectors

The first task in this step is to establish models of energy consumptions of residential houses and small commercial buildings. The models describe the appliances used in household as well as the characteristics or patterns of the equipment use reflecting to behavior of people and their life style.

##### a) Energy Consumption of Household

As shown in Fig. 3.1, this study adopted the results of the energy consumption in residential sector report (KMUTT, 2003) for the model's development. The models categorized the consumption of the sectors into 4 groups: residential buildings within and outside municipality and small commercial buildings within and outside municipality.



**Figure 3.1:** Categorization of buildings in residential and small commercial sectors

Table 3.1 exhibits the models of the electrical energy uses of the four building categories. Each model exhibits the shares of electrical energy used by each activity i.e. lighting, cooking, entertainment, amenity and others.

Equipment in each activity category;

- (1) lighting category: fluorescent lamp and incandescent lamp,

- (2) cooking category: electric rice cooker, electric stove, LPG stove, electric frying pan, oven, microwave, blender juice, toaster and electric kettle,  
 (3) entertainment category: television, stereo, VCD/DVD player, radio and computer,  
 (4) amenity category: fan, air-conditioning, vacuum cleaner, washing machine, water heater, electric water pump, iron, refrigerator and freezer.

**Table 3.1:** The shares of electrical energy uses of the four building categories

Activity	Appliance	Share of energy used in residential house		Share of energy used in small commercial building	
		Within Municipality	Outside Municipality	Within Municipality	Outside Municipality
Lighting	fluorescent lamp	11.93	15.64	11.46	8.73
	incandescent lamp	0.52	0.86	0.26	0.29
Cooking	electric rice cooker	4.25	7.31	2.93	3.47
	electric stove	0.29	0.21	0.33	0.02
	electric frying pan	1.24	0.99	0.54	0.66
	Microwave	0.97	0.34	0.49	0.1
	Oven	0.28	0.31	0.17	0.03
	electric kettle	3.69	4.62	2.54	2.55
	blender juice	0.12	0.19	0.19	0.25
	Toaster	0.26	0.32	0.1	0
Entertainment	TV	8.26	10.67	5.22	5.06
	VDO/VCD player	0.26	0.31	0.19	0.15
	Stereo	5.39	5.27	3.22	3.39
	Radio	0.38	0.58	0.25	0.2
	Computer	2.34	0.94	10.35	1.09
Amenity	Fan	6.09	7.13	3.97	3.66
	wall fan	1.06	0.97	1.45	1.16
	floor air-conditioning	12.83	2.9	7.7	2.66
	wall air-conditioning	10.38	2.88	5.8	0.97
	vacuum cleaner	0.52	0.2	0.33	0.1
	washing machine	1.4	1.17	0.91	0.79
	water heater	7.12	2.42	1.81	1.25
	Iron	5.23	7.16	3.27	3.56
	electric water pump	1.81	6.06	1.12	2.71
	Refrigerator	9.17	14.9	5.49	6.8
	Freezer	0.61	1.03	21.3	34.33
Other		3.59	4.65	8.62	16.03
Total		100	100	100	100

These models account only for electricity consumption. From the models, it is clearly observed that the equipment in amenity activity contributes the most significant share of electricity consumption for all building categories.

The uses of other fuel types were gathered from different responsible government agencies and institutes such as Petroleum Authority of Thailand (PTT), Department of Alternative Energy Development and Energy Efficiency (DEDE), Electricity Generating Authority of Thailand (EGAT), Metropolitan Electricity Authority (MEA) and Provincial Electricity Authority (PEA).

#### b) Number of households

The projection of the number of households over time horizon is formulated as a function of the population and size of households as follows [10]:



$$H_t = \frac{P_t}{S_t},$$

(3.1)

where  $H_t$  denotes the number of households in year  $t$ ,  
 $P_t$  denotes the number of population in year  $t$ , and  
 $S_t$  denotes the size of households in year  $t$ .

In order to reflect a change in population, this study was built on the report of the Department of Provincial Administration, Population Statistics (DOPA, 2008), and another. Although the Thai population would not much increase but the family size is smaller so the assumption is that the average number of members in the household was 4 people in 2010 and linear decreased to 3.5 people in 2030 and estimated the projection of number of household both within and outside municipal areas for 2010-2030 by using Equation (3.1). It made the number household increase nearly 25% in the year 2030.

**Table 3.2:** Number of households within and outside municipal areas

									million
Year	2010	2011	2012	2013	2014	2015	2020	2025	2030
<b>Residential houses (RES)</b>									
In M	5.44	5.60	5.77	5.95	6.13	6.31	7.34	8.55	9.96
Out M	8.05	8.01	7.96	7.91	7.86	7.80	7.43	6.91	6.23
Total	13.49	13.61	13.73	13.86	13.98	14.11	14.77	15.46	16.19
<b>Small commercial buildings (SMC)</b>									
In M	1.59	1.64	1.69	1.74	1.80	1.85	2.15	2.51	2.92
Out M	0.94	0.94	0.93	0.93	0.92	0.91	0.87	0.81	0.73
Total	2.54	2.58	2.62	2.67	2.72	2.76	3.02	3.32	3.65
<b>RES&amp;SMC</b>	<b>16.03</b>	<b>16.19</b>	<b>16.36</b>	<b>16.53</b>	<b>16.70</b>	<b>16.88</b>	<b>17.79</b>	<b>18.77</b>	<b>19.84</b>

With the available data, this study determined the energy consumption of the residential and small commercial buildings on the base year of 2010. The trend of the consumption can be developed as well using the electricity demand forecasting of business as usual by the electric load forecast sub-committee under the committee for administration of energy policy (Table 3.3).

**Table 3.3:** The electricity demand forecasted by the electric load forecast sub-committee under the committee for administration of energy policy

Sector	2010	2011	2012	2013	2014	2015	2020	2025	2030
<b>Residential</b>	30,311	31,605	33,020	34,545	36,123	37,682	46,113	56,036	68,020
<b>Small Commercial</b>	12,645	13,313	14,061	14,892	15,766	16,704	21,949	28,754	38,053

The LPG consumption was obtained from reference (EPPO, 2010) and separated into each sub sector by proportion use in 2001 (KMUTT, 2003). Wood and charcoal consumption were same amount from 2001 (KMUTT, 2003).

3.2 Establishment of Various Scenarios of the Energy Use of the Sectors

Other than the scenario of the business as usual mentioned in Section 3.1, another four scenarios of the energy consumption were examined in the study.

#### **a) The Second Business as Usual Scenario II (Scenario II)**

This scenario is another scenario of business as usual but different from the first scenario due to its assumptions. The consumption of energy in BAU II is identical to that of BAU I. However, the trends of the energy consumption varies with the following factor

- the change of number of houses within and outside municipality (urbanization and immigration),
- saturation of energy consumption in some activities (lighting and cooking),
- increasing of units of air-conditioners and electric water heaters in the sectors.

#### **b) High Electricity Demand Scenario (Scenario III)**

In this scenario, there was no energy plan to improve energy efficiency in residential and small commercial buildings as with the BAU II. All of the useful heat consumption for cooking is identical to BAU II but the useful heat demand of LPG, fuel wood and charcoal were substitution by electricity.

#### **c) High liquid petroleum gas demand scenario (Scenario IV)**

In this scenario, there was no energy plan to improve energy efficiency in residential and small commercial buildings as same as the BAU II. The electricity and all of the useful heat consumption for cooking is identical with BAU II but the useful heat demand of fuel wood and charcoal were substitution by LPG.

#### **d) Energy Efficiency Program Scenario (EEP)**

This scenario examines a number of energy conservation programs to be implemented in the sectors. The programs include:

- energy labeling for fluorescent lamps and ballasts,
- replacement of incandescent lamps,
- energy labeling for small air-conditioners,
- the use of heat pumps for air-conditioning and producing hot water,
- the substitution of conventional air-conditioners with solar cooling systems in the far future.

### **3.3 Development of Energy Conservation Programs and Assessment of the Energy Conservation Potential**

After developing the scenarios of the energy consumption of the residential and small commercial sectors, this study next analyzed the programs to conserve the energy used in the sectors. The programs examine various technologies that can be implemented for different household activities:

- lighting : high energy efficient lamp, compact fluorescent lamp, electronic ballast,
- cooking : high energy efficient charcoal stove and LPG stove,
- amenity : high efficient air-conditioner, heat pump, solar cooling.

The developed programs include the period of time each technology will be implemented for the sectors.