CHAPTER 3

Renewable Energy Resources

3.1 Introduction

Development of renewable energy technologies, markets, and investments has been rapid in recent years. Although the world economy has been slow down; the United States, Germany, Spain, China, India, and Brazil continue to lead the world in renewable energy utilization [REN21, 2011]. Renewable energy sources have been utilized to replace fossil-fuelled sources in heating and cooling, transportation, and electricity generation. It is accepted that the growth of renewable energy utilization far exceeds the growth rates of fossil fuels. Technological progress in renewable generation results in cost reduction gradually. Besides, regulatory policies, by means of subsidies and tax exemptions, play important role in driving renewable generation. Renewable power capacity worldwide reached an estimated 1,320 GW in 2010 and comprised on quarter of global power capacity from all sources [REN21, 2011]. Thailand is one of many countries which emphasizes on improving and developing the use of renewable energy resource and renewable energy technology.

This chapter presents mainly on the renewable energy resources in Thailand which are presented in Section 3.2 and the simplified modeling of renewable energy resources presented in Section 3.3. These are used to find the renewable generation output in this research. The concept of net load and load duration curve is also explained in Section 3.4 to find the impact of renewable generation on electricity demand characteristic. By the results and discussion of the impact of renewable generation on electricity demand characteristic will be presented in Section 6.2.

3.2 Renewable Energy Resources in Thailand

Various renewable energy resources are available, but those commercially utilized for electricity generation are solar (photovoltaic, PV), wind, small hydro, biomass, and biogas. Renewable energy resources with limited potential for electricity generation are municipal waste and geothermal power. Photovoltaic and solar thermal capacities have been installed around the world and the investment trend is on the rise given that costs are falling gradually [IEA, 2012]. Wind power has significantly penetrated the renewable energy markets in North America and Europe for a decade and has recently driven its growth by China [REN21, 2011; IEA, 2012]. Hydroelectricity is widely used for a long time but half of hydro capacity in the world is belong to the United States, Canada, Brazil, Russia, and China. Typical sizes of hydro capacity are in a wide range (1-1,000,000 kW) but, by tradition, hydro power considered as renewable generation is limited to small-, mini-, micro-, and pico-hydro with capacity up to 10 MW [Paish, 2002]. Biomass is commonly used to produce heat and transformed to liquid fuel. The use of biomass for electricity generation can be either direct firing or co-firing with fossil fuel. Biogas can be produced from various kinds of biological sources, mostly from animal manure and organic waste. Biogas yields vary widely depending on composition of raw material, in particular, fat content [Prasertsan and Sajjakulnukit, 2006; Koottatep, Ompont and Hwa, 2005]. The power generation comparison between renewable energy resources is shown in Table 3.1.

Table 3.1 Power generation comparison between renewable energy resources.

Sources of energy	**Principle**	**Advantage**	**Disadvantage**	**Land condition**	**stability**
Solar (Photovoltaic)	Solar cells (Photovoltaic, PV) transfer solar energy into electricity.	• Free and unlimited. • Clean and silent. • Locally available renewable energy resource. • Suitable for remote area. • Can be constructed to any size based on energy requirements. • Small-scale solar plants can take advantage of unused space on rooftops of existing buildings. • Require minimum operating or maintenance costs.	• Only works when the sun shines. Cannot be generated at night. • Quite expensive. • Large area is needed. • Some chemical pollution in manufacturing process. • Efficiency level is limited. (Compared to other renewable energy sources. It has a relatively low efficiency level ranging between 12-20%) • Produces direct current which must be converted to alternating current (AC) before it can be used for consumption.	Wide open land	Depends on the amount of sunlight.
Wind	The wind blows the blade of a turbine which turns the generator to produce electricity	• Free and unlimited. • Clean. • The land around wind turbines can still be used for other uses. • Locally available renewable energy resource. • Suitable for remote area. • Wind turbines are available in a range of sizes. • Wind turbines take up less space than the average power station.	• Only works in windy places. • Unreliability. (Wind is uncertain and unpredictable.) • Many turbines are needed. • Large area is needed for setting up wind farms • Noisy. • Unsightly. • The average efficiency is very less as compared to fossil fuel power plants. • Good wind sites are often located in remote locations, far from cities where the electricity is needed. • The turbine blades may damage local wildlife.	Place where high wind speed constantly	Depends on wind speed.

Table 3.1 Power generation comparison between renewable energy resources (Continued).

Sources of energy	**Principle**	**Advantage**	**Disadvantage**	**Land condition**	**stability**
Hydro	The water flows through turbines then the electricity can be generated.	Free and clean. Easy to manage. (producing and shut down electricity generation) Quick response to demand for electricity. Can be used to store energy.	Expensive to build. Causes a lot of water access problems. Disturbance of habitat. (flood area) Effects on agriculture. Fish killing. Disputes between people. Breaking of dams caused serious flooding.	Place where a dam can be constructed.	Influenced by the amount of water.
Biomass/ Biogas	Biomass / biogas can be burnt as a fuel in conventional power plant.	Uses natural waste product. Abundant.	High initial cost. Causes air pollution. Replant of plants. Pre-conversion logistics such as harvesting/collecting, transportation, preparation and storage are needed. Competition with food.	Conventional power plant and plantation are needed.	Equivalent to conventional power plant.

Table 3.2 shows installed capacities and investments of renewable energy resources in Thailand. Renewable energy utilization in Thailand was dominated by photovoltaic and biomass. Wind power in Thailand is limited, which is opposite to other countries, because of wind speed is relatively low. Small hydro power is also limited given that the potential area is only in Northern Thailand. Biogas has been developed to saturation stage. On the other hand, waste power is considered to be at an initial stage. As of 2011, the installed capacity of renewable energy resources is approximately 8% of peak demand in Thailand. However, as shown in Figure 3.1, renewable generation is less than 3% of total generation. Renewable generation was low during rainy season (July-October) and high during winter (November-February). Time-of-day energy generation in 2011 is illustrated in Figure 3.2. Energy demand in Thailand is peaking during 2-4 PM and 7-9 PM. But, renewable generation is peaking from 9 AM to 3 PM and almost constant for the rest of time. The generation behavior of renewable energy resources is coincident with the operation of production processes which utilizes biomass and biogas generations [Chaiamarit and Nuchprayoon, 2014b].

Table 3.2 Installed capacities and investments of renewable energy resources in Thailand during 2009-2011 [DEDE, 2011].

Resource	Installed capacity (MW)			Investment (million Baht)		
	2009	2010	2011	2009	2010	2011
Solar (PV)	37.0	48.6	78.7	4,644	32,788	24,472
Wind	5.1	5.6	7.3	954	17,465	139
Small hydro	55.7	58.9	95.7	301	148	330
Biomass	1,618.1	1,650.2	1,790.2	5,349	11,846	13,901
Biogas	69.8	103.4	159.2	5,275	1,259	3,757
Waste	6.6	13.1	25.5	2,169	1,047	2,264
Total	1,792.3	1,879.8	2,156.6	18,692	64,553	44,863

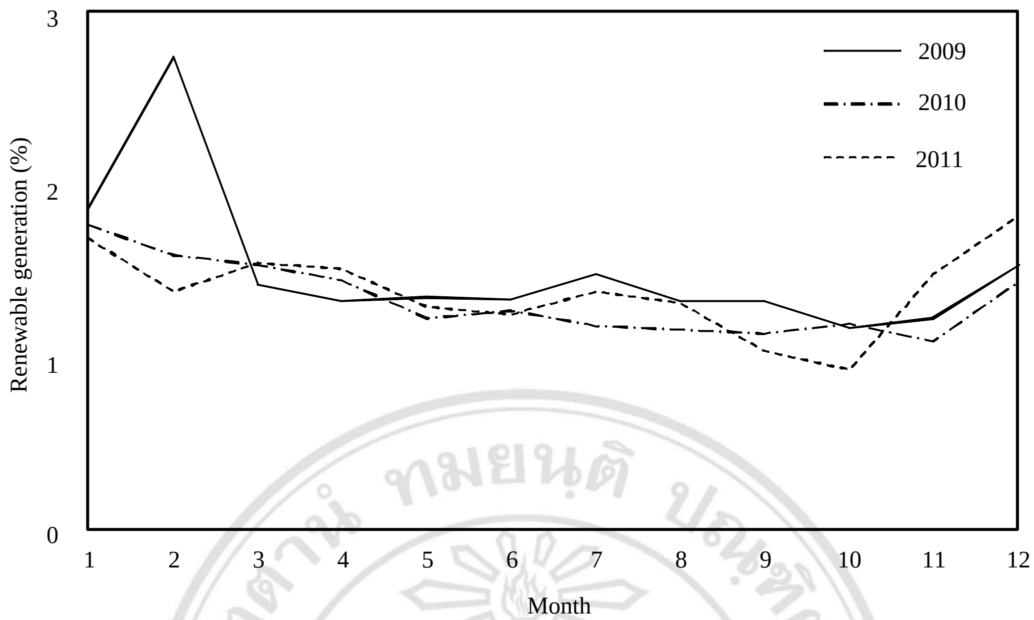

Figure 3.1 Monthly generation of renewable energy resources in Thailand during 2009-2011.

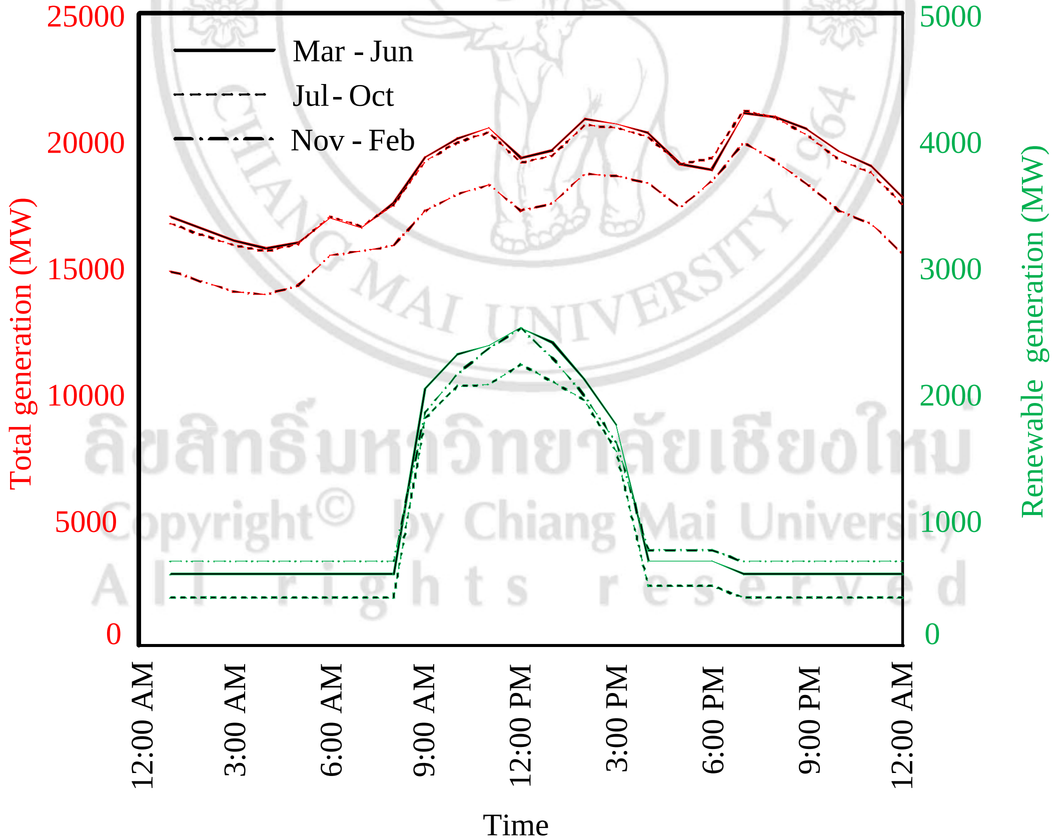

Figure 3.2 Comparison of hourly generations in Thailand in 2011.

Figure 3.3 illustrates the peak demand and renewable capacity of Thailand from 2001 to 2025. By 2015, renewable capacity would be one-third of the forecasted peak demand. But, given the data in Table 3.2, a realistic projection would have renewable capacity around 15% of the forecasted peak demand. As such, it can be said that renewable generation in Thailand would reach a significant level in a few years.

The generation mixes of Thailand from 2001-2025 sorted by fuel type and plant type are shown in Figure 3.4 and 3.5, respectively. Renewable capacity is projected to be around 15-20% and 20-30% of generation capacity when being sorted by fuel type and plant type, respectively. It is so obvious that the electric supply industry of Thailand depends on natural gas so that supply security and diversity must be critically considered. With a major concern on environmental impact caused by coal and lignite, renewable generation is emerging as a viable alternative for diversifying supply and boosting environmental-friendly generation [Chaiamarit and Nuchprayoon, 2014b].

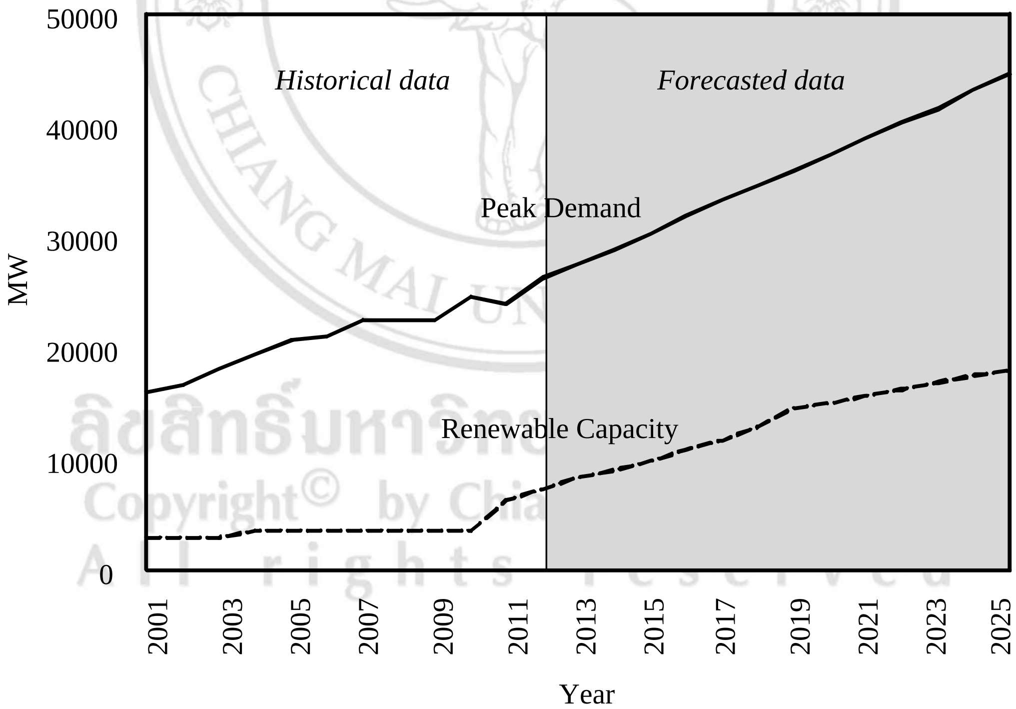

Figure 3.3 Peak demand and renewable capacity of Thailand.

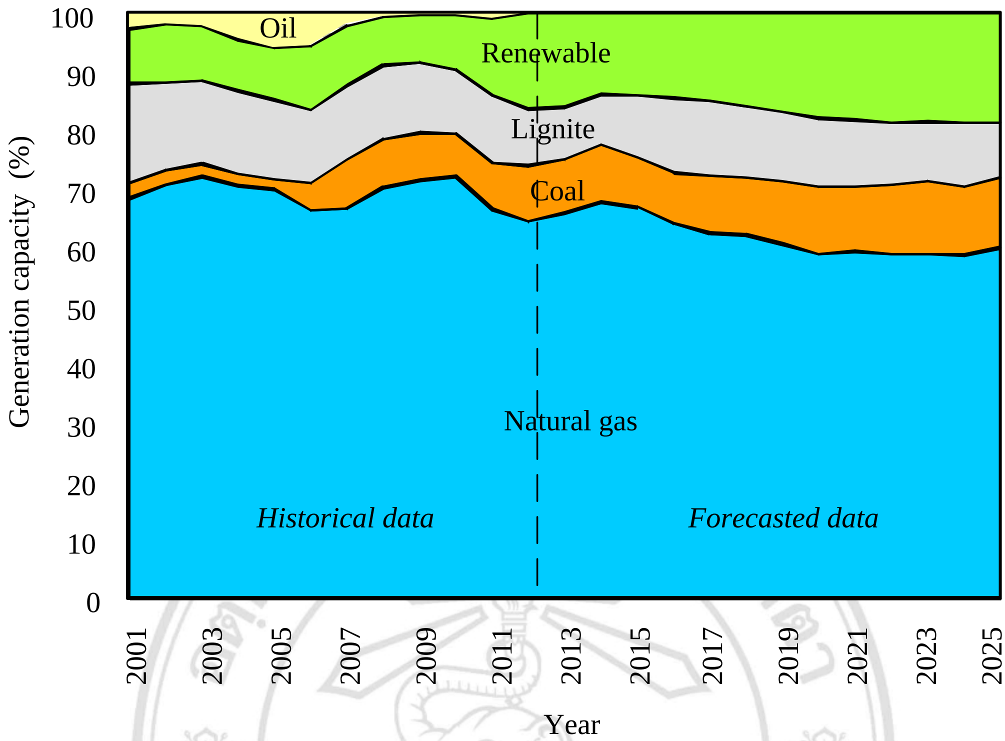

Figure 3.4 Generation capacity of Thailand sorted by fuel type.

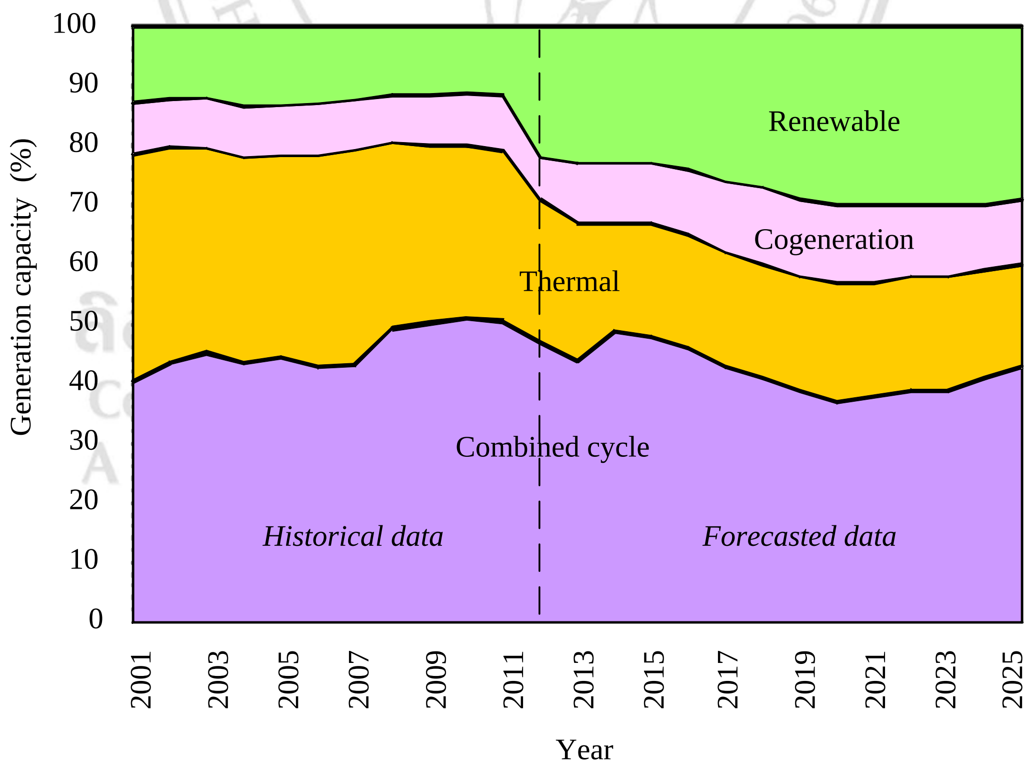

Figure 3.5 Generation capacity of Thailand sorted by plant type.

3.3 Variation in Generation of Renewable Energy Resources

The potential resources for electricity generation in Thailand are photovoltaic, wind, small hydro, biomass, and biogas. Their potentials for electricity generation have been assessed by using both literature review and data collection.

It is shown in Table 3.3 that solar resource in Thailand is considerably abundant throughout the country so that its potential generation is high. In this research, it is assumed that daily period of photovoltaic generation is available between 6 AM and 6 PM and the peak radiation is at 12 noon. On the other hand, wind power generation in Thailand is limited given that the average wind speed is low. Besides, the constant-speed areas are either high-mountain or coastal areas. As seen from Table 3.4, the average speed in most areas is less than 7 m/s. Thus, wind generation in Thailand is suitable with small wind turbines and available in the nighttime (9 PM-3 AM). Small hydropower generation in Thailand, as shown in Table 3.5, is mostly on the northern and northeastern regions due to geographical factor. Note that, practically, energy generation from small hydro in the northeastern region is much less than the generation capacity because of limited water. Biomass resource in Thailand is also abundant but seasonal dependent. It is shown in Table 3.6 that rice, sugarcane, corn and maize are available 4-8 months, while oil palm and Para rubber are available throughout the year. Biogas generation in Thailand is based on animal waste and waste water from the northeastern and central regions. Estimation of waste resource in Thailand is shown in Table 3.7. Biogas generation from municipal waste is under development. Biogas generation is assumed to be available 8-16 h/d depending on plant size. Table 3.8 shows contract capacities of renewable energy resources. However, some contracts may not proceed to commercial operation. It should be clarified that the contract capacity of wind power is unusually high and subject to further investigation.

Table 3.3 Annual radiation of solar resource in Thailand [DEDE, 2011].

Region	Annual radiation ($MJ/m^2/d$)
North	17.5
Northeast	17.9
Central	18.0
South	17.6

Table 3.4 Annual speed and potential area of wind resource in Thailand [Major, Commins and Noppharatana, 2008].

Wind speed (m/s)	0-6	6-7	7-8	8-9
Potential area (km^2)	477,157	37,337	748	13

Table 3.5 Installed capacity of small hydro resource in Thailand [DEDE, 2011].

Region	Installed capacity (MW)
North	42.5
Northeast	24.2
Central	12.9
South	5.2
Total	84.8

Table 3.6 Monthly availability of biomass resource in Thailand [EforE, 2011].

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rice husk												
Sugarcane												
Corn & Maize												
Oil palm & Para-rubber												

Table 3.7 Estimation of waste resource in Thailand [DEDE, 2011].

Region	Animal waste (million ton/y)	Waste water (million ton/y)	Municipal waste (million ton/y)
North	2.7	94.8	2.8
Northeast	6.3	412.7	4.4
Central	5.3	388.2	6.8
South	1.4	78.1	2.0
Total	15.7	973.8	16.0

Table 3.8 Contract capacities of renewable energy resources for electricity generation in Thailand as of 2012 [EGAT, 2012].

Region	Contract capacity (MW)
PV	447.6
Wind	1,506.5
Small hydro	13.3
Biomass	1,072.8
Waste	60.0
Total	3,100.2

Given the contract capacities of all renewable energy resources in Thailand in 2012, renewable generation can be estimated by summing up all renewable outputs of all resources on an hourly basis. The renewable power output of each resource can be estimated by multiplying its contract capacity with pre-determined conversion efficiency. As shown in Figure 3.6, the renewable power output was varied with both time of day and season. The renewable power generation in Thailand was high during daytime (8 AM-4 PM). On a monthly basis, the renewable power generation in Thailand was high in post-harvest months, i.e. November, December, March, and April and was low in pre-harvest months and rainy season, i.e. August and September. It was found that the maximum power output was in April at 12 noon, while the minimum power output was in September at 8 AM. Numerically, it was computed that the maximum and minimum power outputs are 85% and 25% of the total contract capacity, respectively. On average, the power output is 52% of the total contract capacity [Chaiamarit and Nuchprayoon, 2014b].

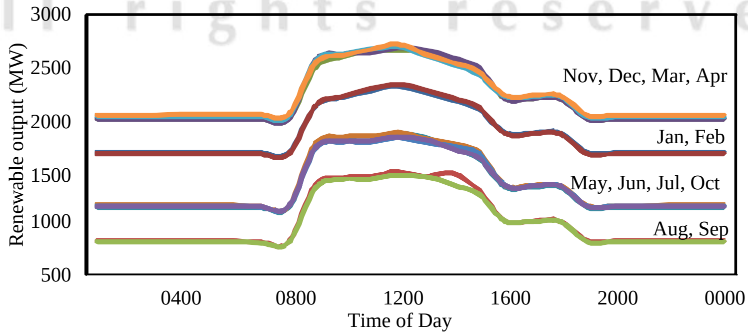

Figure 3.6 Estimation of renewable power output based on contract capacities of all renewable energy resources in 2012.

3.4 Modeling of Renewable Energy Resources

3.4.1 Solar (Photovoltaic)

The solar energy in this research considers only photovoltaic (PV) or solar cell for electricity generation, while solar thermal is neglected. Given that Thailand is near the equator, the annual average solar radiation is up to 18.2 MJ/m^2/d or 5.1 kWh/m^2/d [Janjai, 2008]. The simplified characteristic of daily irradiance is shown in Figure 3.7, with the insolation period of 12 hours per day.

The output power of photovoltaic panel depends on solar radiation and inclined surface of PV module and can be stated as shown in (3.1).

$$G_{PV} = \eta_I \eta_C I_r A_p , \tag{3.1}$$

where G_{PV} is output power of PV panel (W), η_I is inverter efficiency, η_C is cell efficiency, I_r is solar irradiance density (W/m^2) and A_p is panel area (m^2).

An efficiency of PV cells (η_C) is the ratio of the power at maximum power point to the irradiation power. η_C can be calculated from (3.2).

$$\eta_C = \frac{P_{MPP}}{I_r \times A_p} = \frac{FF \times V_{OC} \times I_{SC}}{I_r \times A_p}, \tag{3.2}$$

where P_{MPP} is power at maximum power point, FF is fill factor which is a measure of quality of the solar cell, V_{OC} is open circuit voltage and I_{SC} is short circuit current.

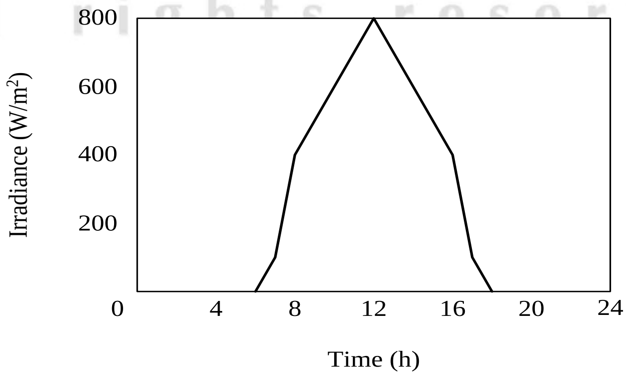

Figure 3.7 Simplified characteristic of daily irradiance of Thailand.

The PV cell characteristic is shown in Figure 3.8 and the illustration of fill factor is shown in Figure 3.9.

However, the short circuit current of PV cell depends on the irradiation density and the open circuit voltage of PV cell depends on the cell temperature (ϑ). The short circuit current increases as the irradiation density increases. And although the temperature increases, the open circuit voltage decreases but the short circuit current is not significant changed as shown in Figure 3.10. So that the standard test condition (STC) of PV cell is performed at the solar irradiance density ($I_{r,STC}$) is 1000 W/m^2, the cell temperature (ϑ_{STC}) is 25 °C and the air mass (AM_{STC}) is 1.5.

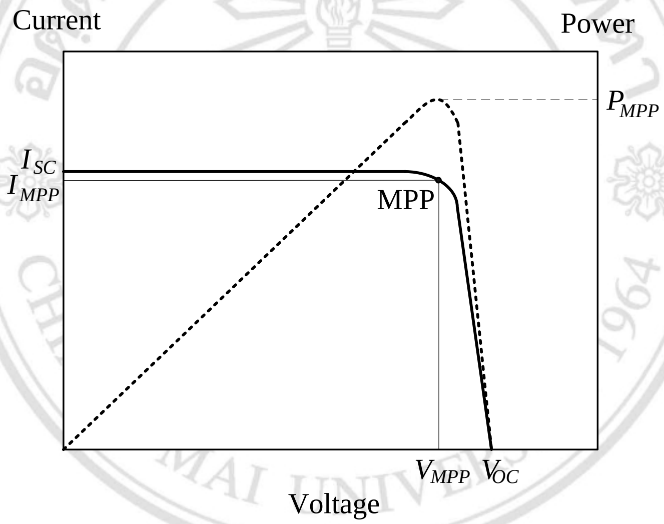

Figure 3.8 PV cell characteristics.

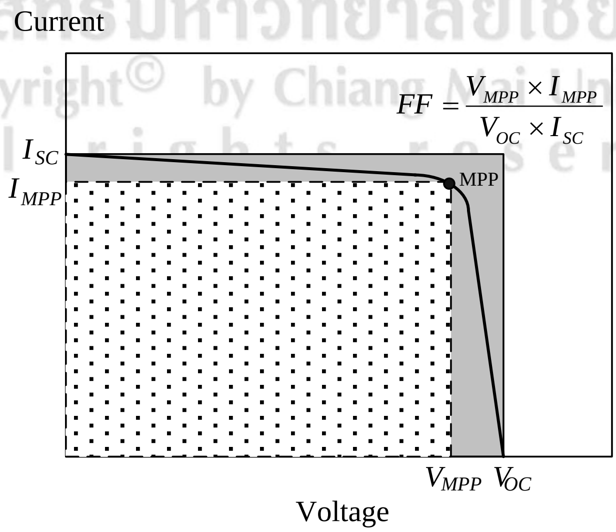

Figure 3.9 Illustration of fill factor.

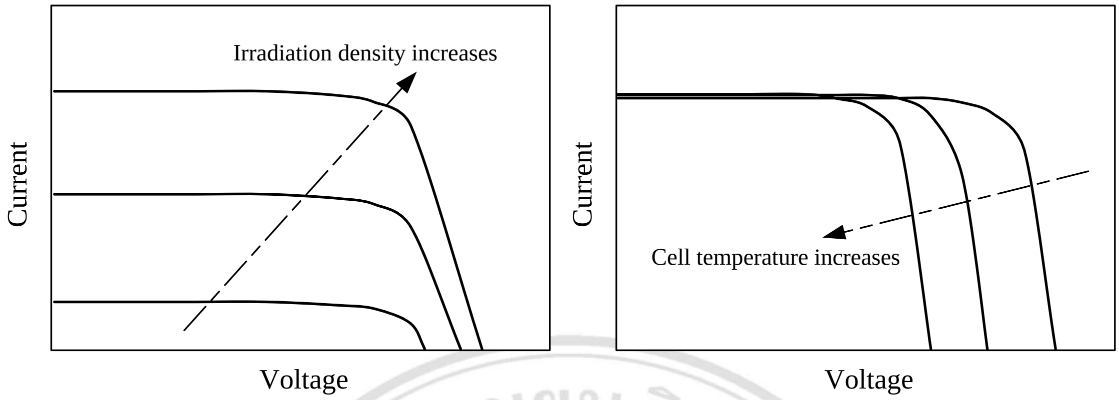

Figure 3.10 Irradiation dependence and temperature dependence of I_{SC} and V_{OC}.

3.4.2 Wind

The average wind speed in Thailand is moderate to low, typically in the range of 4-6 m/s, while the average wind power density is 4 MW/km^2 [Major, Commins and Noppharatana, 2008]. The simplified characteristic of daily wind speed is shown in Figure 3.11, with the average speed of 5 m/s. The output power of a wind turbine generator depends on wind speed at specific hub height and turbine characteristics [Capps, Hall and Hughes, 2011]. The output power may be computed by using (3.3) but, in this research, a linear power speed curve is assumed as shown in Figure 3.12.

$$G_W = \begin{cases} 0 & v < v_I \quad or \quad v > v_O, \\ 0.5\rho_A A_S v^3 C_p & v_I \leq v < v_R, \\ G_W^{rated} & v_R \leq v \leq v_O, \end{cases} \tag{3.3}$$

where G_W is output power of wind turbine (W), G_{WI}^{rated} is rated power of wind turbine (W), ρ_A is air density (kg/m^3), A_S is swept area of the rotor (m^2), C_p is the coefficient of performance [Major, Commins and Noppharatana, 2008], v is wind speed (m/s), v_I is cut-in wind speed (m/s), v_R is rated wind speed (m/s), v_O is cut-out wind speed (m/s).

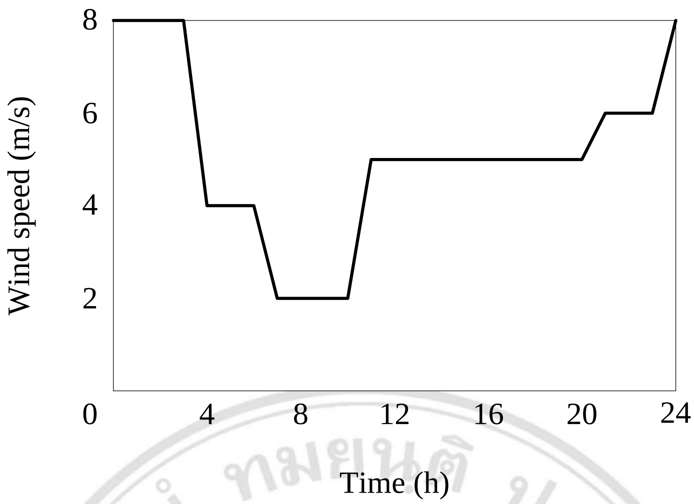

Figure 3.11 Simplified characteristics of daily wind speed in Thailand.

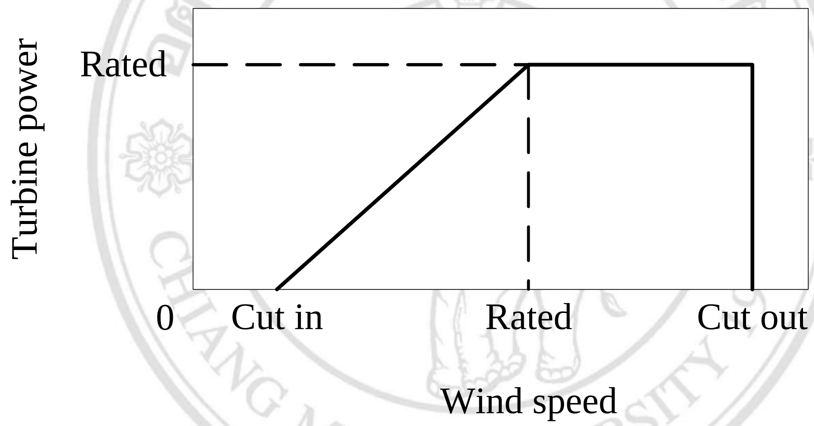

Figure 3.12 Linear power speed curve of a wind turbine.

The principles of wind energy conversion system are well known and have widely been presented in the literature. The power in the wind is proportional to the cube of wind speed and the square of the blade diameter. Meanwhile, the investment cost (except cost of land) of a wind turbine is roughly proportional to blade diameter. Thus, economies of scale on wind turbine investment are obvious. The power extracted from a wind turbine is definitely less than the wind power by the performance coefficient. The theoretically maximum value of the performance coefficient, known as Betz coefficient, is 59.3% [Masters, 2004]. The performance coefficient depends on tip speed ratio and blade pitch angle. As a result, the turbine power nonlinearly varies with the wind speed. By also considering losses in energy conversion, a simple estimate for conversion efficiency from wind power to electrical power would be 30-40%.

The probability density function of wind speed is usually expressed by using either Weibull or Rayleigh distribution [Masters, 2004]. The relationship between wind speed and output power of a wind turbine can be obtained from the (turbine) power speed curve which provided by the manufacturer or using empirical data. When the wind speed is lower than cut-in speed or higher than cut-out speed, there is no output power. When the wind speed is between rated speed and cut-out speed, the output power is constant at rated power for a pitch-regulated turbine and decreasing for a stall-regulated turbine. When the wind speed is between cut-in and rated speed, the output power increases with the wind speed and their relationship have been fitted as linear, parabolic, cubic, or quadratic form [Kongnam et al., 2009]. In this research, the wind power generation is modeled [Billinton and Gan, 1993] as follows:

$$G_W = \begin{cases} 0 & v < v_I, \\ \left(A + Bv + Cv^2\right)G_W^{rated} & v_I \le v < v_R, \\ G_W^{rated} & v_R \le v < v_O, \\ 0 & v \ge v_O. \end{cases} \tag{3.4}$$

For the sake of simplicity, the wind power generation may be linearized as follows:

$$G_W = \begin{cases} 0 & v < v_I, \\ \dfrac{v - v_I}{v_R - v_I} G_W^{rated} & v_I \le v < v_R, \\ G_W^{rated} & v_R \le v < v_O, \\ 0 & v \ge v_O, \end{cases} \tag{3.5}$$

where G_W is output power of a wind turbine, G_W^{rated} is rated power of a wind turbine, v is wind speed at the moment, v_I is cut-in wind speed, v_R is rated wind speed, v_O is cut-out wind speed. The quadratic coefficients in (3.4) can be computed as follows [Billinton and Gan, 1993]:

$$A = \frac{1}{\left(v_I - v_R\right)^2}\left[v_I\left(v_I + v_R\right) - 4v_I v_R\left[\frac{v_I + v_R}{2v_R}\right]^3\right], \tag{3.6}$$

$$B = \frac{1}{(v_I - v_R)^2}\left[4(v_I + v_R)\left[\frac{v_I + v_R}{2v_R}\right]^3 - (3v_I + v_R)\right], \tag{3.7}$$

$$C = \frac{1}{(v_I - v_R)^2}\left[2 - 4\left[\frac{v_I + v_R}{2v_R}\right]^3\right]. \tag{3.8}$$

3.4.3 Small Hydro

The definition of hydro power depends on generating capacity. Normally, large-scale hydro power is excluded from renewable generation. Micro and Pico hydropower are ignored given that their capacities are simply too small. Thus, small hydropower (in the range of 1-25 MW) with run-of-river type is fitted into the definition of renewable generation [Paish, 2002]. As shown in (3.9), the output power of small hydro depends primarily on flow rate, and is considerably independent of water head. The output power of small hydro is relatively constant over a day, but may be varied with seasons.

$$G_H = \eta_G \eta_T \rho_W gQH\ , \tag{3.9}$$

where G_H is output power of small hydro unit (W), η_G is generator efficiency, η_T is turbine efficiency, ρ_W is water density (kg/m^3), g is gravitational acceleration (9.8066 m/s^2), Q is flow rate (m^3/s), H is water head (m).

3.4.4 Biomass

Regardless of feedstock or conversion technology, electricity generation simply uses biomass in co-firing or in replacement of fossil fuel in conventional power plant, such as steam-turbine generator. Electricity generation from biomass in Thailand is highly season-dependent because the major resource is agricultural residue and waste. For the sake of simplicity, a direct firing of biomass is assumed so that the output power of biomass unit can be stated in (3.10).

$$G_{BM} = \eta_{TH} VF\ , \tag{3.10}$$

where G_{BM} is output power of biomass unit (W), η_{TH} is thermal efficiency of the plant, V is heating value of fuel (Wh/unit of fuel), F is feed rate (unit of fuel/h). Note that unit of solid fuel is usually ton or kg so that the heating value is then expressed as MJ/ton or MJ/kg which can eventually be converted into unit of electrical energy.

3.4.5 Biogas

Biogas is produced by biochemical conversion process of biomass. Biogas product is a mixture of methane (CH_4), carbon dioxide (CO_2) and other gases. Biogas yield varies with physical and chemical composition of raw material. In Thailand, the major resources are livestock manure (mainly, pig farms) and industrial wastewater [Sawangphol and Pharino, 2011; Prasertsan and Sajjakulnukit, 2006]. Biogas may be burned directly as fuel gas or burned in engine to generate electricity.

The amount of biogas can be calculated from the amount of feedstock, the moisture content, the dry and organic matters, and the gas rate of substrate [Asam et al., 2011]. Given the amount of biogas, operation period varies from 10-24 h/d [Sirichan, 2001]. The amount of energy can then be calculated from the amount of biogas, the percentage of methane in biogas (normally 50-70%), and the heating value of methane. Table 3.9 presents the amount of biogas generated from animal wastes and agriculture residues [Koottatep, Ompont and Hwa, 2005]. In Figure 3.13, the simplified characteristic of daily biogas rate is shown by using a typical size of biogas plant in Thailand. The flow rate is approximately 20 m^3/h based on 14-h daily operation. Biogas is usually fed into an internal combustion engine (with prior modification) so that the output power equation in (3.11) is similar to that of biomass unit.

$$G_{BG} = \eta_{TH} VF \,, \tag{3.11}$$

where G_{BG} is output power of biogas unit (W), η_{TH} is thermal efficiency of the plant, V is heating value of fuel (Wh/m^3), F is flow rate of biogas (m^3/h). Similarly, the heating value of biogas is expressed as MJ/m^3 which can be converted into unit of electrical energy.

Table 3.9 Amount of bio-gas generated from animal wastes and agriculture residues.

Animal / Agriculture residues	Biogas (*l*/kg-solid)
Pig	340-550
Cow	90-310
Chicken	310-620
Horse	200-300
Sheep	90-310
Straw	105
Grasses	280-550
Peanut shell	365
Water Hyacinth	375

Note: 1*l* = 1/1000 m^3 = 1 dm^3

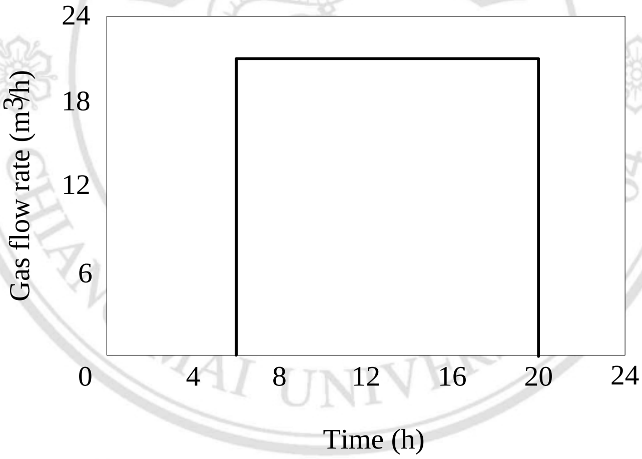

Figure 3.13 Simplified characteristic of daily biogas rate in Thailand.

3.5 Net Load and Load Duration Curve Concepts

At a single time instant, net load is defined as electricity demand minus total renewable generation at that time (every half hour or hour). On utility's viewpoint, net load will thus be delivered from electric grid. If the net load value is much lower than the demand (renewable generation is high) during peak-load period, either plant factors or operating durations of peaking plants would decrease substantially. This implies that the operating costs would be lower. But, if the net load value is low during base-load period, change in operating costs would not be substantial given that the operating costs of base plants are much lower than those of peaking plants. Hence, the impact of renewable generation on demand characteristics is time varying and can be visualized by using net load [Chaiamarit and Nuchprayoon, 2014b]. For instance, the illustration of daily load and net load of Thailand on 24 April 2007 is shown in Figure 3.14.

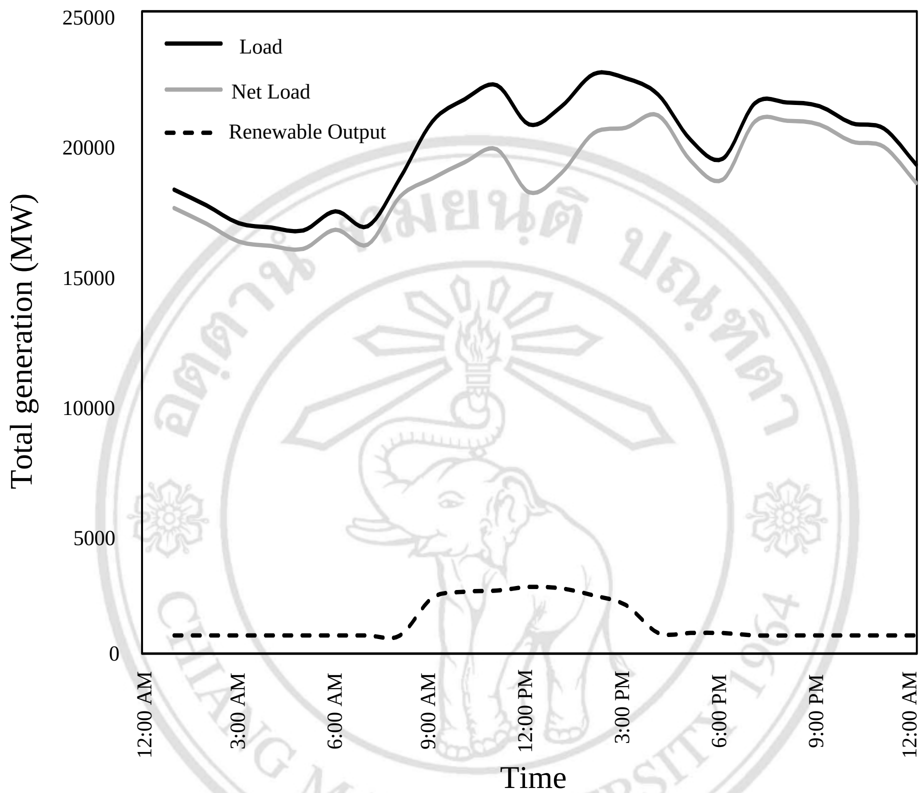

Figure 3.14 Illustration of daily load and net load on 24 April 2007.

Although hourly load curve provides information on time of occurrence and time-varying characteristic, it is not available to determine the relationship between load level and duration corresponding to operating durations of power plants. In power system, load duration curve (LDC) is usually employed to express frequency distribution of the load [Rahman and Rinaldy, 1993]. LDC is obtained from sorting chronological loads into descending order over a time interval (e.g. 8760 or 8784 h/y). The vertical axis represents load level, while the horizontal axis represents time duration. As a result, it is ready to determine time duration at certain load level. LDC appears to have three regions: the left- and right-ends are steep but the middle is considerably flat. For planning purpose, LDC is typically divided into peak, intermediate, and base loads, on either annual or seasonal basis.

To assess the impact of renewable generation, it is proposed to analyze two LDCs are analyzed: one obtained from hourly load (demand) data and another one obtained from hourly net load data. The shapes of the two LDCs can provide information that whether renewable generation has a correlation with load. The impact can be quantified by considering net load values, peak demand, energy demand, and load factor. The lower the net load value, the higher the renewable generation, and vice versa. The peak demand is obviously the first load level on the left-hand side of the LDC. The energy demand is computed from the area under LDC. By definition, the load factor is the ratio of average load to peak load. If, for instance, the load factor is high, it implies that the LDC is relatively flat and the demand of electricity is relatively constant over time.

3.5 Chapter Summary

This chapter presents the renewable energy resources. Renewable energy resources include solar (photovoltaic), wind, small hydro, biomass, and biogas. The renewable energy resources and the variation in generation of renewable energy resources in Thailand are also presented. The renewable generation output can be determined by using the simplified modeling of renewable energy resources. From the concepts of net load and load duration curve described earlier, it can be used to quantify the impact of renewable energy on electricity demand characteristic which is presented in Section 6.2.