

A REVIEW STUDY ON TRENDS TO WIND ENERGY IN A GLOBAL AND THAILAND CONTEXT

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Abstract

Energy plays a vital role in the development of a country. Global energy consumption was 11164 Mtoe in 2009 while global electricity generation reached 20093.6 Tera watt-hours. Renewable energy sources are promoted globally due to the limited storage, unstable price, and emissions of fossil fuels. In turn, 47% of new power plants that were added globally during 2008-2009 were for renewable energy sources. Wind energy has been one of the emerging renewable energy sources in the last few years. Global installed capacity reached 159.21 GW at the end of 2009 which contributed around 2% of the global electricity consumption. Demand for energy is also increasing yearly in Thailand and energy consumption reached 66339 Ktoe at the end of 2009. More than 2000 GWh of electricity is imported every year into Thailand where there has recently been only 5.4 MW of wind power installed capacity. However, the government of Thailand has planned to increase wind energy installed capacity to 800 MW by 2022.

Keywords: Renewable energy, wind energy, Thailand, power generation

Introduction

Economic development, along with an increasing population and advancement of lifestyle, leads to an increase in energy demand globally in contrast to a limited supply and source of energy. In the past few decades, fossil fuels have been the main source of energy but the drawbacks of fossil based energy are limited reserves and a high contribution towards global warming. Security of energy supply depends on the cost of fuels and long term physical availability. Like Thailand, countries without their own fossil fuel supplies are focused on renewable energy sources due to the uncertain price stability of fossil fuels and local availability. Renewable energy technologies comparatively produce little or no greenhouse gases and rely on virtually inexhaustible natural elements for their fuels. Some of these technologies are already competitive and widely available. For a global economic viewpoint, Table 1 shows comparisons on the estimated costs of the power generations

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among different energy sources. It can be seen that the large hydropower plant yields one of the most economical costs among the renewable energy technologies; however, it may cause impacts of changing native environments in and around large reservoir areas. The electricity generations from the onshore/offshore wind energy cost likely 5-15 U.S. cents/kWh, which is much lower than electricity generated by the solar energy technology while the biomass power generation costs quite the same as the wind energy. Apart from the renewable energy technologies, the costs of the electricity production from fossil fuels are relatively low such as 2.21 cents/kWh for the coal-fired plants, 8.09 cents/kWh for the oil, and 7.51 cents/kWh for the natural gas. Nonetheless, the electricity generation from the wind energy may bring in a preferable low-cost alternative of the renewable energy technologies once firstly concerning about less environmental degradation. Hence, the renewable energy sources are globally in

focus in order to keep pace with increasing demand and reduce global warming effects. There are significant numbers of recent scientific and educational projects and studies for the harnessing and optimization of renewable energy globally.

Wind energy has been renowned in European countries and it is becoming popular in other parts of the world according to open literature. Wind energy is one type of a clean and easily available energy resource among various sources of renewable energy. In the past, windmills were conventionally applied for grinding grain and pumping water. However, electricity generation has become a significant application of wind energy nowadays. Wind electricity is generated on a large scale so as to supply into a national grid and it is also an important source of supply for electricity in remote isolated areas where a national electricity supply is either not available or it would be very expensive to join into the national electricity supply.

Table 1. Costs of power generations (Electropaedia, 2010; REN21, 2010)

Energy source	Typical characteristics	Typical energy costs (U.S. cents/kilowatt-hour)
Large hydropower	Plant size: 10 megawatts (MW) –18,000 MW	3–5
Small hydropower	Plant size: 1–10 MW	5–12
Onshore wind	Turbine size: 1.5–3.5 MW Blade diameter : 60–100 meters	5-9
Offshore wind	Turbine size: 1.5–5 MW Blade diameter: 70–125 meters	10-14
Biomass power	Plant size: 1–20 MW	5–12
Rooftop solar PV	Peak capacity: 2–5 kilowatts-peak	20-50
Utility-scale solar PV	Peak capacity: 200 kW to 100 MW	15-30
Concentrating solar thermal power (CSP)	Plant size: 50–500 MW (trough), 10–20 MW (tower); Types: trough, tower, dish	14-18
Coal-fired plants	N/A	2.21
Oil	N/A	8.01
Natural gas	N/A	7.51

Remark: Costs may vary among sites due to its locations, environmental impacts and country policies.

Thailand is located between the latitudes 5° 31'N and 20° 27'N and the longitudes 97° 22'E and 105° 37'E. Thailand has a population of around 66 million people (Wikipedia, 2010). Fossil fuels are a major source of energy supply in Thailand, mainly used for transportation, manufacturing industries, and household and agriculture areas in Thailand. Marginal fossil fuels are produced locally but the remaining fossil fuels are imported. At the moment, Thailand is focusing on renewable energy sources to provide a secure and sustainable energy supply. Thailand has planned to meet 20.3% of its total energy consumption from renewable energy sources by 2022 (Sutabutr, 2010). This paper focuses on the recent overall global and Thailand energy consumption so as to reflect the position of wind energy to fulfill energy demands.

Global Energy Situation and Wind Energy

Global Energy Consumption

Energy demands are increasing along with the economic development in the world. Global energy consumption is increasing on a yearly basis except for a slight drop in 2009. Energy consumption for 2009 was affected by the recent financial crises in many countries. Total primary energy consumption reached a maximum of 11315 Mtoe in 2008 and was

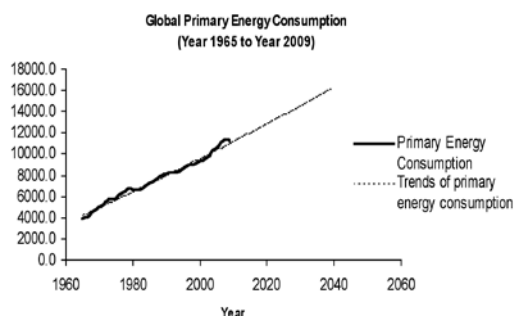


Figure 1. Global primary energy consumption

slightly down to 11,164 Mtoe in 2009. Figure 1 shows the primary energy consumption from 1965 to 2009 and its trend for the future (BP Statistical Review, 2010). Global primary energy consumption trends are increasing linearly and it can be interpreted that total primary energy consumption will increase to 12970 Mtoe and 18215 Mtoe in 2020 and 2050, respectively.

Fossil fuel is still the dominant source for Total Primary Energy Supply (TPES). Figure 2 shows the comparison between the fuel shares of the TPES for the 1973 and 2008. The renewable energy share, which includes energy from nuclear energy, hydropower, combustible renewable waste, and others like wind, solar, and geothermal power, has increased from 13.4% to 18.7% from 1973 to 2008 with the combustible renewables and waste being the dominant renewable energy source. The oil share in the TPES has decreased by 12.9% in the last 35 years. The TPES was 12,267 Mtoe at the end of 2008 which was double that of 1973 (IEA, 2010).

Global Electricity Generation

Electricity is widely used by industries, transportation, the agriculture sector, and household applications. Demand for electricity is increasing year by year. Nevertheless, the global electricity generation in 2009 also suffered from the recent financial crises. Electricity generation was 20093.6 Tera

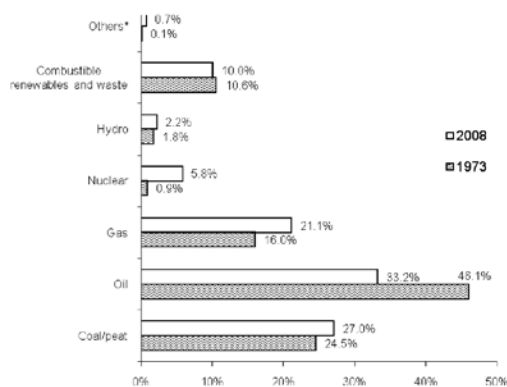


Figure 2. Fuel shares of total primary energy supply of 1973 and 2008

watt-hours which was a decrease of 0.9% in 2009 compared with 2008 (BP Statistical Review, 2010). Figure 3 shows the global electricity generation from 1990 to 2009 and includes the trend in the future. The trend reflects that the demand for electricity is increasing and it will be nearly doubled by 2030.

Figure 4 compares the fuel share for electricity generation for 1973 and 2008. Coal/peat was still the dominant source for electricity generation with 41% of the total share. 21.3% of electricity was generated from gas in 2008. Whilst electricity generation from oil drastically dropped to 5.5% in 2008 from 24.7% in 1973, the renewable energy contribution (nuclear, hydropower, and others category) has increased by 7.3% in this time. Furthermore, the hydropower contribution decreased by 5.1%, whereas the nuclear energy share and the contribution from other

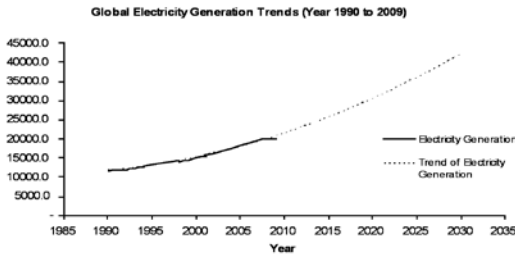


Figure 3. Global electricity generation

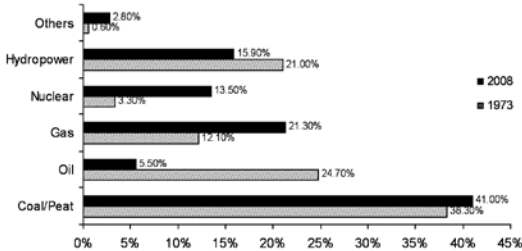


Figure 4. Fuel shares of total electricity generation of 1973 and 2008

energy sources like wind energy, solar energy, geothermal energy, etc. have increased by 10.2% and 2.2%, respectively.

Global Warming and Carbon Dioxide (CO₂) Emission from Energy Sources

CO₂ is the main gas that contributes to global warming. CO₂ is emitted from different sources within the energy conversion processes. Figure 5 shows the major sources of emission of carbon dioxide gas (IEA, 2010). Fossil based fuels like coal, gas, and oil are the prevailing fuels that contribute to global warming by emitting the most CO₂ gas. CO₂ emissions increased by 2.4% over the previous year to 29,381 Mt at the end of 2008. Clean renewable energy sources do not emit CO₂ gas directly. It means that an increase in the utilization of renewable energy resources will decrease the effects of global warming. Therefore, many countries are placing emphasis on employing renewable energy resources.

Renewable Energy in Global Context

Hydropower, wind energy, wave energy, solar energy, geothermal energy, combustible renewables, and waste, e.g. landfill gas, waste incineration, solid biomass, and liquid biofuel are the constituents of renewable energy. Despite high growth rates, renewable energy still represents only a small fraction of today's global energy consumption excluding traditional biomass. The renewable energy fuel share in global energy consumption reached 19% at

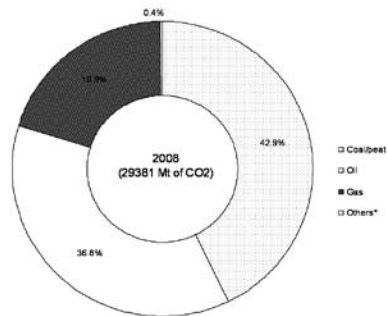


Figure 5. Fuel mix of total CO₂ emissions in 2008

the end of 2008. Figure 6 shows the distribution of the renewable energy fuel share in which traditional biomass contributed most with 13% out of 19% of global energy consumption and 69.1% of total renewable energy consumption. Hydropower was 17% of total renewable energy consumption. Alternative renewable energy sources like wind energy, solar energy, biofuels, etc. contributed 13.8% of renewable energy consumption. Around 150 billion USD was invested for renewable energy in 2009, which is 44.2% and 15.4% greater than 2007 and 2008, respectively (REN21, 2010). Figure 7 illustrates the clean renewable energy development for the last 3 years. The total of renewable power generation reached 1230

GW at the end of 2009 delivering 18% of global electricity supply (15% hydropower and 3% non-hydropower). All types of renewable power generation, hydropower, wind power, solar photovoltaic (PV) energy, solar heating, ethanol production, and biodiesel production increased by 7%, 3.2%, 31.7%, 55%, 20.8%, 10.1%, and 13.3%, respectively, in 2009 over the previous year. Germany, China, the United States of America, Italy, and Spain are the top 5 countries on the basis of newly installed renewable capacity in 2009 while China, the United States, Canada, Brazil, and Japan are the top 5 countries on the basis of total installed capacity at the end of 2009 (REN21, 2010).

Approximately 300 GW of new generating capacity of all types has been added to the world's grids over the past 2 years, with renewable capacity making up 47% of the total as illustrated in Figure 8. Overall, recent trends show that renewable energy sources are the most considered energy sources. Their contribution has a negligible environmental impact compared with fossil fuels and they are regarded as secure and sustainable energy sources. Traditional biomass is still the dominant renewable energy source while hydropower is the dominant power generating source. In the non-hydropower renewable energy categories, wind energy is the most dominant source of power generation (REN21, 2010).

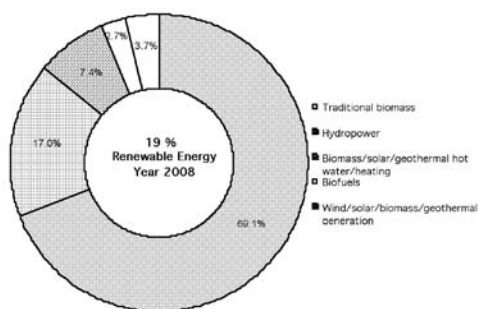


Figure 6. Renewable energy share of final energy consumption, 2008

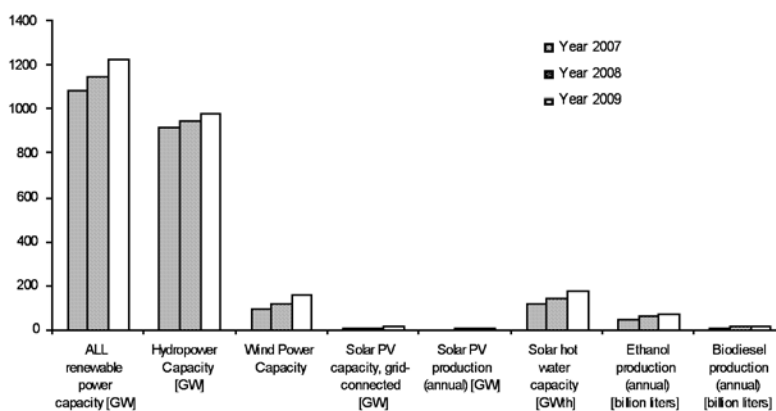


Figure 7. Renewable energy development in last 3 years (2007-2009)

Wind Energy in Global Context

Wind turbines were first used for electricity in Denmark in 1890. A 23 m diameter wind turbine was used at that time. By 1910, several hundred units of wind turbines having capacities of 5 to 25 kW were in operation in Denmark (Johnson, 2006). The average utility-scale wind turbine installed during 2009 was 1.6 MW, while the largest turbine installed overall was the 7.5 MW Enercon gearless turbine (REN21, 2010). Global installed wind turbine capacity reached 159213 MW generating 340 TWh per year and contributing around 2% of global electricity consumption at the end of 2009 (WWEA, 2010)

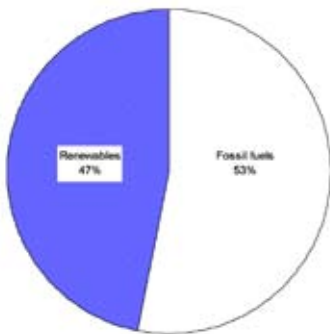


Figure 8. New power capacity added worldwide by source, 2008-2009

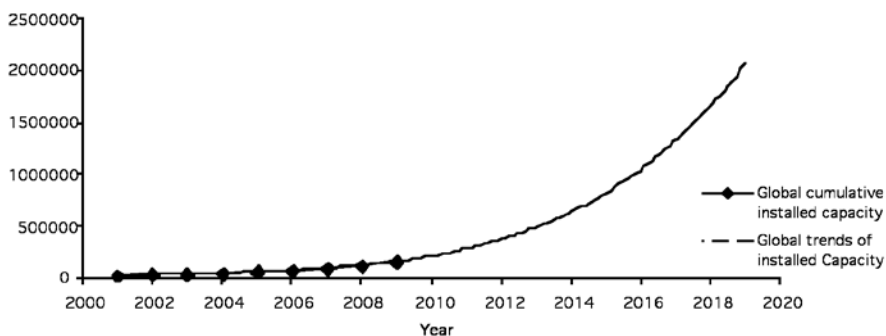


Figure 9. World total installed capacity and its future trend

Figure 9 shows the installed capacity in the world at the end of 2009 and also shows the future trend. After analyzing the past 8 years' data for the cumulative global wind energy installed capacity, it is found that the yearly average growth rate of the installed capacity of wind energy is 25% while it has increased by 57% every 2 years and it has almost doubled every 3 years. Wind energy installed capacity increased by 31.69% in 2009, the highest rate since 2001. After analysis of the trend of global electricity generation in Figure 3 and the growth of wind energy in Figure 9, it is found that the total share of wind electricity will cover more than 17% of total electricity generation in 2020.

Figures 10 and 11 show the top 10 countries based on cumulative and new wind energy installation capacity in 2009, respectively. China is nearly doubling its capacity every year. Wind energy installation capacity is increasing yearly in all the top 10 countries. The United States of America is the leading country with a cumulative total of installed wind energy capacity of 35159 MW at the end of 2009 while China is the leading country based on newly installed capacity of 13800 MW (36% of total global installed capacity for 2009) out of 38120 MW of the global total of installed capacity in 2009. China is also the second leading country in the category of total installed wind power capacity with 26010 MW and Germany, the second leading country in the previous year, is

in third position with a total install capacity of 25777 MW. China was the world's largest market in 2009, more than doubling its capacity from 12.2 MW in 2008 to 26 MW, adding an additional 13.8 MW of capacity.

Asia was the leading regional market in 2009 with a growth rate of 44.4% compared with 2008 (Figure 12). Figure 13 shows the continental share at the end of 2009. Europe is totally still the leading region with 47.9% of the total installed wind capacity and is dominant in offshore wind turbine installation with 99% out of the total global offshore wind capacity (WWEA, 2010). In 2009, the offshore

wind installed capacity reached 2.8% total of total capacity. The wind power installed in Europe produced 4.8% of the total European Union's (EU) electricity generation (EWEA, 2010). It is seen that the recent economic crises have not affected the growth rate of wind energy generation.

In 2009, European and Chinese companies dominated the wind turbine manufacturing sector. Among individual companies, the Danish company Vestas retained its top spot in 2009 from 2008, while GE Wind of the United States remained in second place with 13% and 12% market

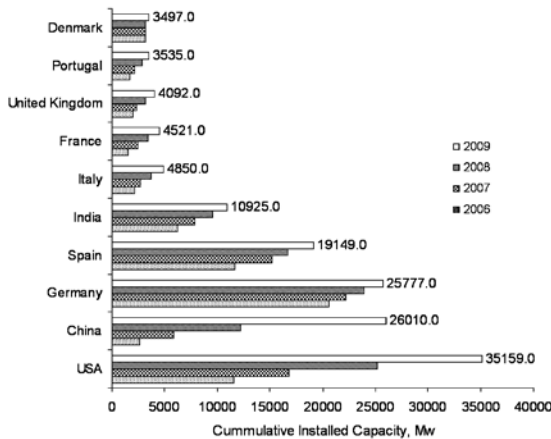


Figure 10. Top 10 cumulative installed wind energy capacity at end of 2009

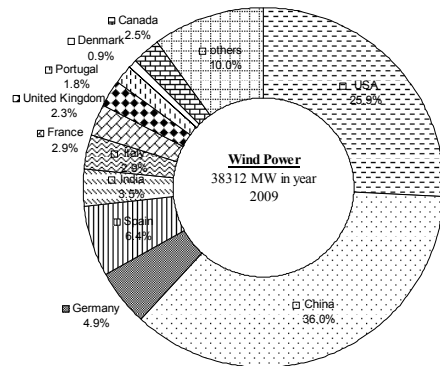


Figure 11. Top 11 newly installed wind energy capacity in 2009

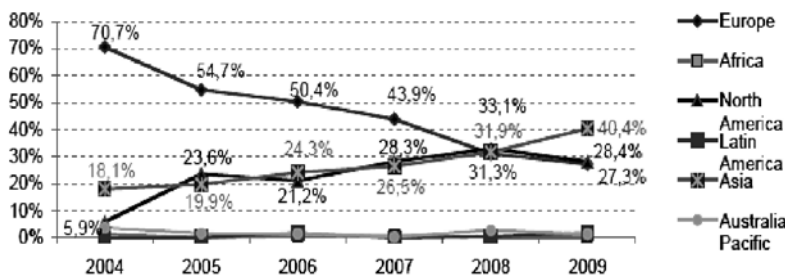


Figure12. Continental shares in new wind installed capacity (EWEA , 2010)

shares, respectively (REN21, 2010). The 2009 EU Renewable Energy Directive aims to increase the share of renewable energy in the EU from 8.6% in 2005 to 20 total% in 2020 (EWEA, 2009).

Energy Scenario in Thailand

Energy Consumption and Production in Thailand

In Thailand, final energy consumption (not including energy consumed in transformation of energy and own use) reached 66339 Ktoe in 2009 which was 0.7% higher than 2008 and it is increasing yearly at an average of 1.5%. In terms of value, final energy consumption was equivalent to 1,032 billion Baht in 2009

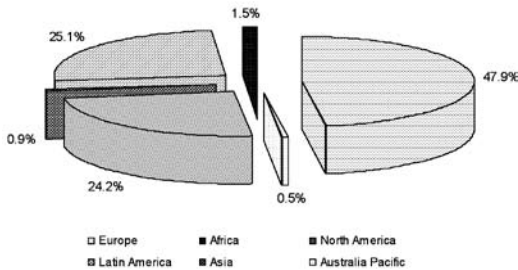


Figure 13. Continental shares in total wind installed capacity in the end of 2009

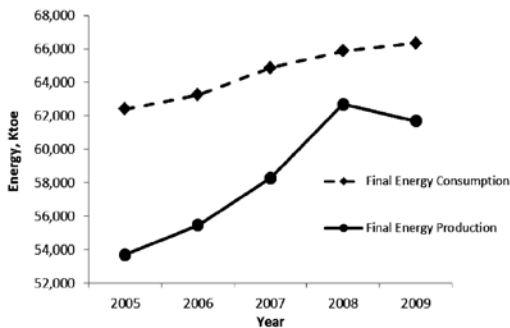


Figure 14. Final energy production and consumption Thailand

(DEDE, 2010). Figure 14 shows the final energy consumption and production of Thailand for the last 10 years. While final energy production was 61699 Ktoe and decreased by 1.6% in 2009, it was 14.9% more than 2005. Total energy import was 59386 Ktoe in 2009 which is nearly 4.7 times total energy export and 89.5% of final energy consumption (Figure 15).

Rural based energy sources like wood, paddy husk, biogases, etc. contributed 31.8% of final energy production for Thailand in 2009 while natural gas, crude oil, and lignite are dominant in the commercial energy source category as shown in Figure 16 Overall, there are no significant changes in the pattern of usage as seen in the final energy production mix in the last 5 years.

Figure 17 shows the status of different energy reserve sources for Thailand. Lignite is sufficient for more than 100 years while crude oil, condensate, and natural gas reserves have 15, 24, and 32 year reserves, respectively (EEPO, 2010).

Electricity Generation in Thailand

Electricity consumption was 138,904 GWh in 2009 and it is increasing by an average of 5.2% per year for the last 10 years but there was no significant increase in the last year as illustrated in Figure 18. The trend of the last 10 years shows that consumption of electricity in Thailand will go above 150000

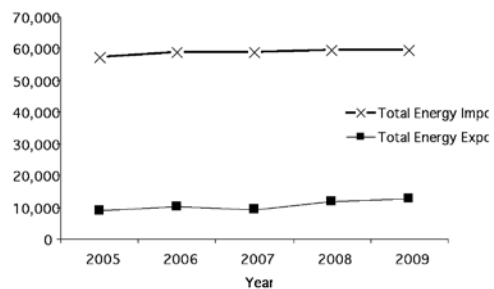


Figure 15. Final energy import and export for Thailand

GWh by 2020. Figure 19 shows the fuel shares for electricity generation between 1999 and 2000 in Thailand (EEPO, 2010). In 2009, 73.7% of electricity generation utilized natural gas, followed by coal/lignite 20.2%, fuel oil and diesel 0.7%, hydro and others (geothermal, solar cell, and wind power) shared 5.4% and the rest was alternative energy and other energy (paddy husk, bagasse, agricultural waste, garbage, biogas, black liquor, and residual gas from production processes) (DEDE, 2010).

Figure 20 shows imports of electricity for the last 10 years. It shows that Thailand imported more than 2000 GWh electricity every year whereas Figure 21 shows that the yearly hydroelectricity production and average value was 6495 GWh for the last 10 years

(EEPO, 2010).

Renewable Energy in Thailand

The dominate sources of energy are fossil-based in Thailand and are major sources of the emission of CO₂. Figure 22 shows sectorwise CO₂ emissions due to energy consumption in 2009. A total of 196022 Kton CO₂ emissions were estimated in 2009. The Ministry of Energy in Thailand made a 15-Year Renewable Energy Development Plan (REDP) in 2008. Its main objectives are to establish sustainable energy security, expedite and promote alternative energy, and protect the environment as well. This plan set a target of 20.3% renewable energy supplies of total primary energy supply by 2022 in Thailand (Ministry of Energy, Thailand, 2009).

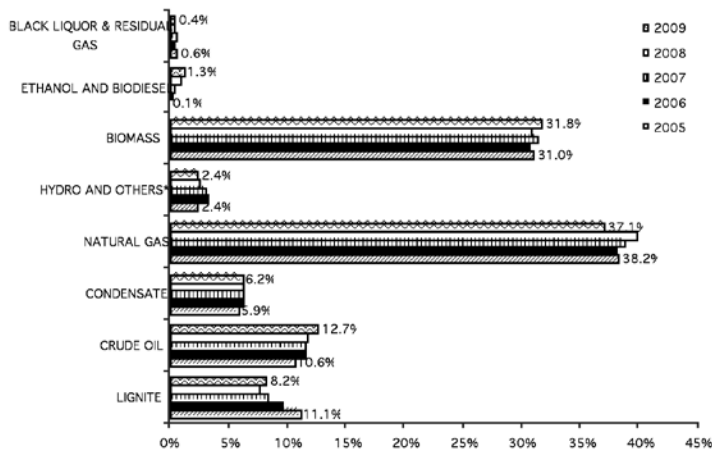


Figure 16. Final energy production mix from 2005 to 2009

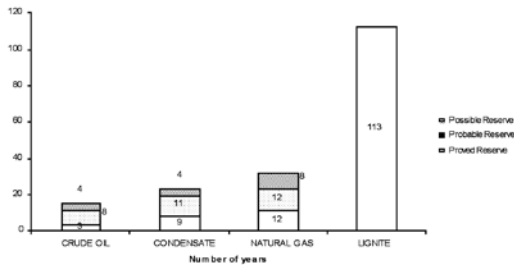


Figure 17. Energy reserves at end of 2009

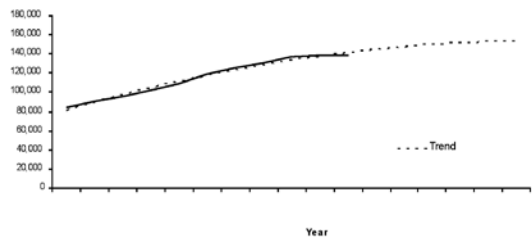


Figure 18. Electricity consumption and its trend in Thailand

Figure 23 shows the target points of different sources of renewable energy considered in the 15-Year RDEP 2008. The total target for electricity generation is 5608 MW while the existing capacity is 1750 MW. The target for electricity generation from biomass is to reach 3700 MW from an existing 1610 MW in 2008 (Ministry of Energy, Thailand, 2009).

The consumption of solar energy, wind energy, biogas, garbage, biofuel (ethanol and biodiesel), and Natural Gas Vehicles (NGV) in forms of electricity and thermal heating increased by 21.7% and it reached a cumulative 5861 Ktoe, which is 8.8% of total final energy consumption (DEDE, 2010).

Wind Energy status in Thailand

Wind energy has been utilized in water pumping applications for a long time in

Thailand. The Electricity Generation Authority of Thailand installed 4 small wind turbines (18.5, 2, 1, and 0.83 KW) at Prom Thep Cape in 1983 and connected them to the grid system in the 1990s (Waewsak *et al.*, 2002). Thailand has a 1600 MW wind energy potential of which the installed capacity was 5.4 MW (Ministry of Energy, Thailand, 2009; Waewsak *et al.*, 2010).

Figures 24 and 25 show the wind atlas of Thailand developed from different studies (DEDP, 2010; Manomaiphiboon, 2010). These atlases show the wind speeds of Thailand with the potential for wind power in some regions. The average wind speed in Thailand is classified as moderate and is less than 4 meters per second; the highest wind speeds are found in various coastal areas of islands in the south Gulf of Thailand area (Chantavorapap

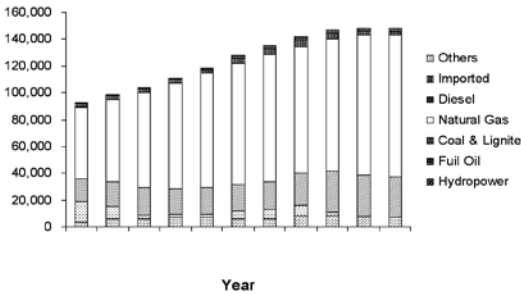


Figure 19. Fuel shares for power generation in Thailand

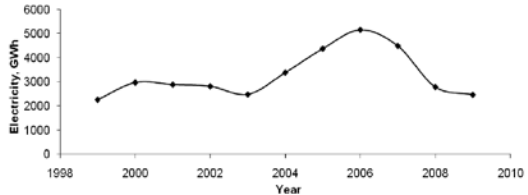


Figure 20. Imports of electricity between 1999 and 2009 in Thailand

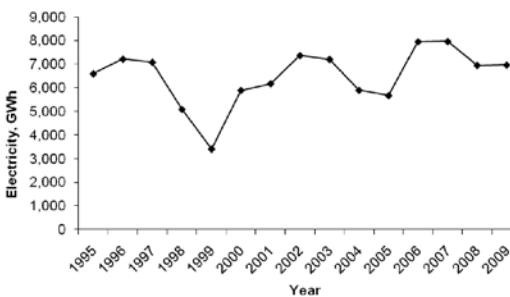


Figure 21. Hydroelectricity production between 1999 and 2009 in Thailand

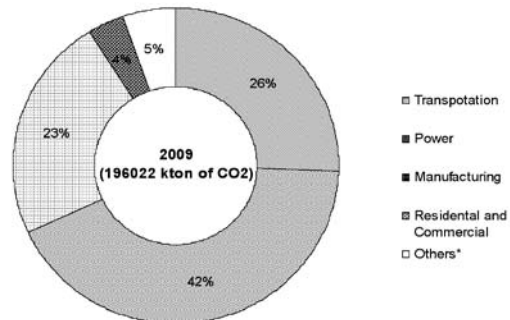


Figure 22. Sectorwise CO₂ emissions due to energy consumption in 2009

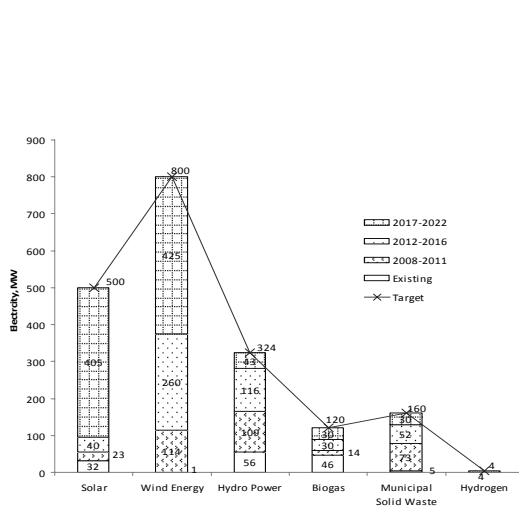


Figure 23. 15-year REDP Goals of Electricity Generation (excluding electricity from Biomass)

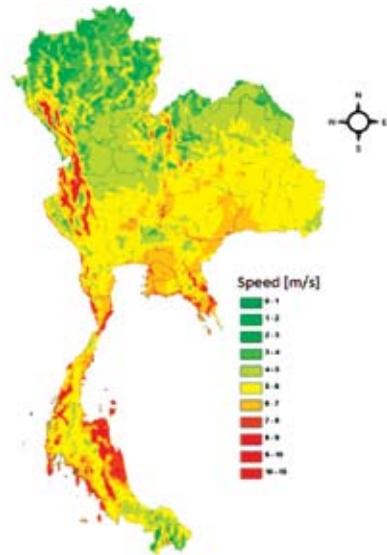


Figure 24. Wind Atlas (at 100 m elevation) of Thailand (Manomaiphiboon, 2010)

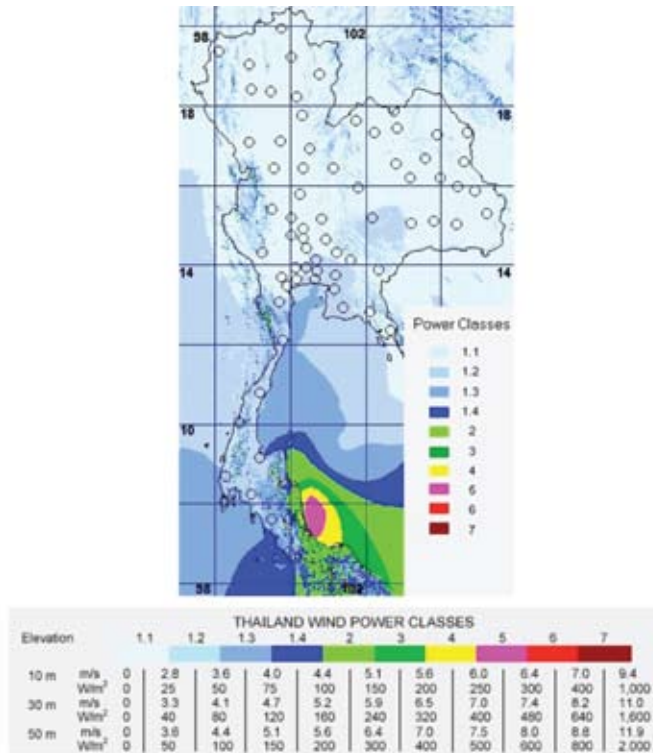


Figure 25. Wind Atlas of Thailand 10 m above ground level (DEDP, Thailand, 2010)

and Suwantragul, 2010). However, wind energy will be promoted to 800 MW by 2022 according to the 15-year REDP 2008 as depicted in Figure 23.

Conclusions

Energy consumption is increasing along with economic development. Total energy consumption was 11164 Mtoe in 2009. Fossil fuels are still the dominant source of energy in the world, providing over 80% of total demand. Fossil fuels are criticized for the CO₂ emission and the instability in the price of petroleum products. Global warming is a warning for every country to reduce emissions and produce clean energy. Clean renewable energy is globally promoted.

Wind energy is becoming the fastest growing type of renewable energy in the world. Installed capacity triples every 3 years and it provides 2% of the world's electricity. Wind energy is one of the cleaner alternative renewable sources of energy in the world. It should be promoted in every country. Wind energy can be utilized for water pumping in large scale power generation for the national grid. Thailand is importing electricity every year. Wind energy promotion reduces the required amount of imported electricity. Thailand plans to increase in its utilization of wind energy in the coming years. A series of research and studies is needed to implement this plan successfully in Thailand.

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