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APPENDICES

APPENDIX A

Status and Outlook for Thailand's Low Carbon Electricity Development[1]

Narumitr Sawangphol[2] and Chanathip Pharino[3]

Abstract

Thailand is facing an urgency to enhance its energy security and capacity to cope with global warming impacts, as demands on fossil fuel consumption keep rising. This paper reviewed the latest situation on renewable powers and developmental strategies toward low carbon electricity generation in Thailand. Government recently has spent tremendous financial and legislative supports to promote the uses of indigenous renewable energy resources and fuel diversification while contributing in reduction of global greenhouse gas. Major policy challenge is on which types of renewable energy should be more pronounced to ensure sustainable future of the country. Regions in Thailand present different potentials for renewable supply on biomass, municipal wastes, hydropower, and wind. To maximize renewable energy development in each area, location is matter. Currently, energy-derived biomass is widely utilized within the country, however if droughts happen more often and severe, it will not only affect food security but also energy security. Life cycle of biomass energy production may cause other social issues on land and chemical uses. Meanwhile, deployment of wind and solar energy has been slow and needs to speed up to the large extent in comparison with energy proportion from biomass. Nuclear power has already been included in the Thai power development plan 2010 (PDP-2010). However, public acceptance is a major issue. Setting up strategic renewable energy zone to support power producer according to pre-determined potential location may assist development direction. Furthermore, government has to strongly subsidize research and development to lower technology cost and promote private investment on renewable energy industry. In the future, revision of electricity price is needed to allow fair competition between non-renewable and renewable energy once subsidy programs are ended. Environmental tax according to fuel types could help government progressing toward low carbon electricity. Stimulating

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renewable energy development and utilization at local community is a key for Thai sufficiency economy.

Keywords

Low carbon electricity, renewable energy expansion, fuel diversification

1 Introduction

Power generation is the main source of carbon dioxide emissions and accounts for four in every ten tons of carbon dioxide dispatched to the Earth's atmosphere. How countries generate electricity, how much they generate, and how much carbon dioxide gets emitted with each unit of energy produced is critical in shaping the prospect for stringent climate change mitigation. International Energy Agency expressed the use of energy by far the largest source of GHGs emissions from human activities, dominated by the direct combustion of fuels [1]. Energy accounts for over 80 percent of the anthropogenic greenhouse gases in Annex I countries, with emissions resulting from the production, transformation, handling and consumption of all kinds of energy commodities. With climate change threats, the levels of GHG need to be stabilized and eventually reduced. Clearly, our consumption of fossil fuels must decrease, partly due to a limited and uncertain future supply and partly because of undesirable effects on the environment [2]. Essentially, a sustainable supply of energy for societal needs must be secured in long term for our future generations. With well-founded scientific supports and international agreement, renewable energy sources must be urgently developed and widely adopted to meet environmental and climate related targets and to reduce our dependence on oil and secure future energy supplies.

As developing country that heavily depending on imported fossil fuels for power generation, Thailand already experienced adverse impacts of energy crisis that could become major barriers for the country's future development. The country improves its power development plan for the next decades to enhance higher proportion of renewable energy generation. The critical questions are how realistic of the plan' s targets compared to existing physical supplies and technical potentials, which technology should be more pronounced, and how fast the plan's impacts can be acknowledged [3]. During 1993 to 2008, carbon dioxide emissions from electricity generation in Thailand have increased by 16.5 percent and this largely amount is the result of demand growth in electricity production (27.8 percent between 1993 and 2008). Department of Alternative Energy Development and Efficiency (DEDE) reported the forecasted amount of GHGs emission from Thailand would reach 559 $MtCO_2$ over period 2005-2020 (Figure 1). Average growth of total GHGs emission is estimated to be

3.2 percent per year while estimated emission from energy sector is 4.7 percent per year [4]. Ministry of Energy (MOE) reported the CO_2 emission per capita of Thailand increased from 1.85 to 3.06 during 1993 to 2008 and electricity consumption per population raised from 965 to 2,129 kWh per capita during 1993 to 2008 respectively [5]. The study of the Electricity Generating Authority of Thailand (EGAT) estimated every one kilowatt-hour of electricity produced in Thailand emits CO_2 approximately 0.5 kilogram. To strengthen national energy security and reducing GHG emission from energy sector, Thailand could effectively promote renewable energy generation from its main agricultural products and residues.

Agriculture is a major business for Thailand. High potentials for all types of renewable energies based on agricultural products exist in the country and can help strengthen the national energy security. Thai Government currently has launched ambitious programs to enhance investments in renewable energy e.g. wind, solar, biomass, and other clean renewable energy sources. In fact, to secure future energy supply and incorporate the government renewable energy efforts into actual utilization, it is not quite a straight thinking. There are some hurdles after implementation. One is that the commission of power plants and the transmission of power into grid may take between five to seven years. Thailand‘s power purchase from a foreign source is limited. Power plant investments especially in renewable energy involve large number of stakeholders, therefore require all partners to understand and negotiate their trade-offs, benefits and impacts. Thus, the power development plan must be strategically designed. Inevitably, a reliable medium and long run load forecasts are prerequisites for a well-conceived power development plan.

This paper intends to review a recent situation of power generation and renewable energy development strategies in Thailand including the nature of business operation, the governmental regulations, power development plan and its implementation/performance. Mainly, the analytical evaluation of the current technological capacity and country pathway toward low carbon electricity generation is a highlight of this review. The existing physical potentials and technological feasibility are examined and compared with the country's development targets. Factors supporting and hindering the achievement of future low carbon electricity in Thailand are elucidated. The paper aims to present useful information and lesson learned for other countries that may face similar situations.

2 General situation in Thailand's electricity sector

Electricity is one of the necessities in the ordinary business of life, and a major driving force for world economic growth and development, Thailand without exception. With un-storable nature of electricity, the supply of electricity must always be available to satisfy the growing demand. Since 1968, Thailand electricity supply services have all been taken over by the state government and operated under state enterprises under a law empowering its monopoly. The state utilities accumulated assets and built up their manpower to expand and operate the power system to serve the whole country [6]. Thai power system has a single buyer structure that the Electricity Generating Authority of Thailand (EGAT) currently provides about 53 percent of the country's electricity supply. EGAT plays the main role not only in generating country's electricity but also in operating all high voltage transmission lines and monopolizing the buying power of the country's electricity [7]. EGAT sells bulk power to two distribution utilities; (a) the Metropolitan Electricity Authority (MEA) responsible for the sale of electricity within Bangkok and surrounding areas; and (b) the Provincial Electricity Authority (PEA) responsible for electricity sale in the remaining parts of the country. Additionally, private power producers sell electricity to the electric utilities under power purchase agreements or to users located nearby. Since early 1990s when high growth in power demands existed, the government developed several initiatives to privatize state electric utilities and engage independent power producers (IPPs) with long-term power purchase agreements (PPAs) for supply of electrical power into the grid system (Figure 2).

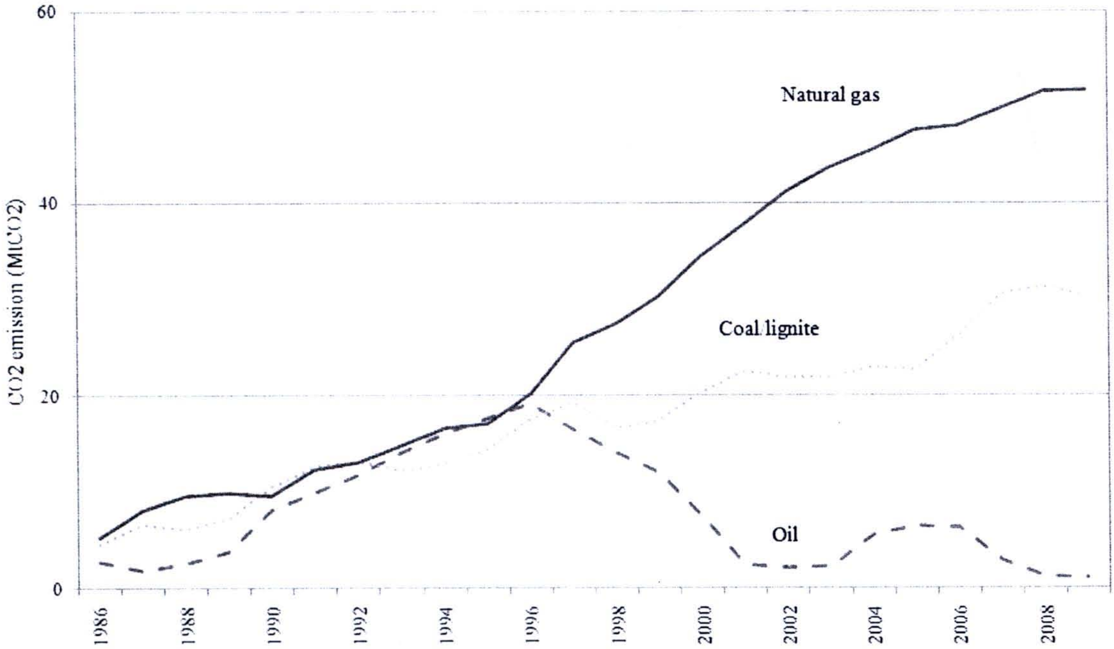


Figure 1 Carbon dioxide emissions from electricity generation in Thailand

Source: Ministry of Energy [8]

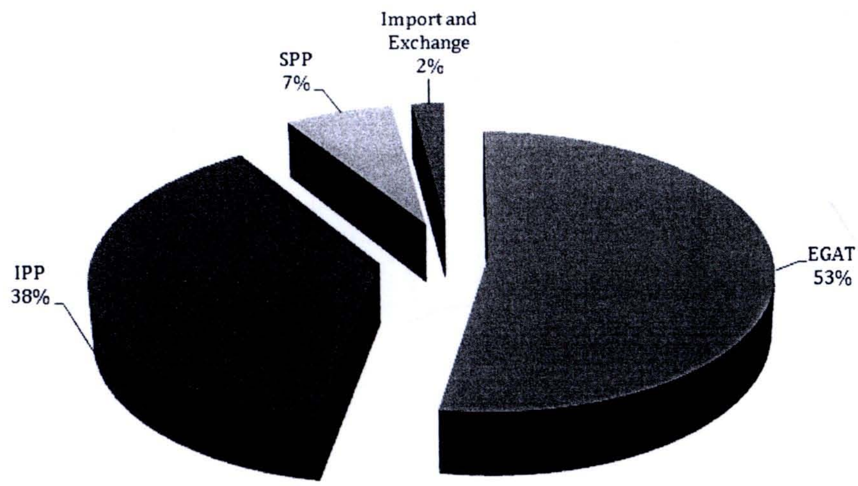


Figure 2 Share of electricity supply in 2009

Source: Ministry of Energy [8]

During the past 15 years (1993-2009), the electricity consumption in Thailand increased from 56,279 to 135,420 GWh and peak demand of electricity increased from 9,730 to 23,051 MW. As of January 2010, peak demand of electric power system was recorded at 12,569 MW and peak consumption of electricity was 148,518 GWh with 78.5 percent of load factor. Energy Policy and Planning Office (EPPO) [9] reported the total electricity consumption in 2009 can be categorized by economic sector as residential 30,258 GWh (22.5 %), commercial 32,634 GWh (24.2%), industrial 59,402 GWh (44.1%), agricultural 316 GWh (0.2%), direct customer 2,894 GWh (2.1%), and other 9,289 GWh (6.9%) respectively (Figure 3). The power sector in Thailand like in many other developing countries is heavily dependent on fossil fuels (Figure 4). The electricity installed capacity can be categorized based on power plant types as hydropower of 3,764 MW (13.6%), thermal power plants of 9,667 MW (34.8%), combined cycle power plants of 12,806 MW (46.0%), gas turbine and diesel power plants of 972 MW (3.5%), and renewable power plants of 279 MW (1.0%) including the Thailand-Malaysia interconnection grid at 300 MW (1.1%). Much of this capacity based on thermal and combined cycle generation where natural gas alone contributes to over 73.9 percent of total electricity generation, followed by lignite and coal at about 17.4 percent, hydropower at 3.6 percent and fuel oil at 1.4 percent respectively [10-11]. Figure 5 illustrated the distribution of conventional and non-conventional power plant in Thailand.

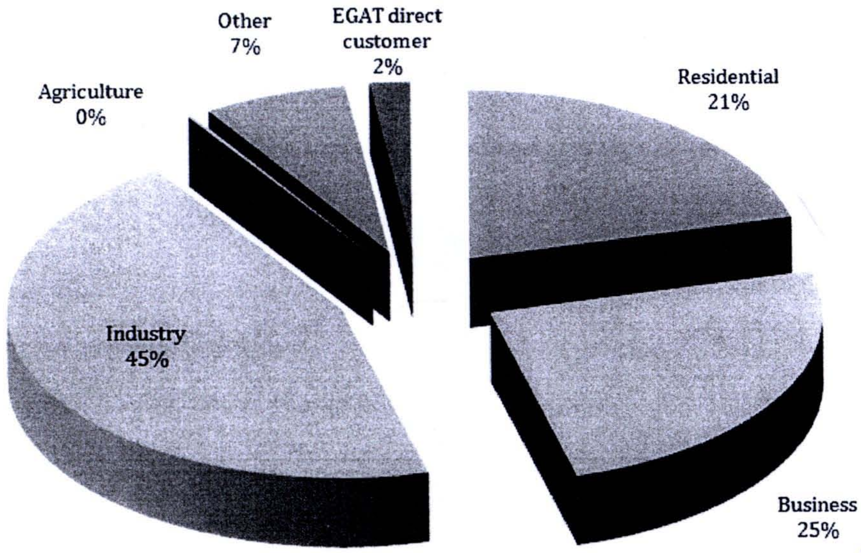


Figure 3 Electricity consumption in 2009

Source: Ministry of Energy [8]

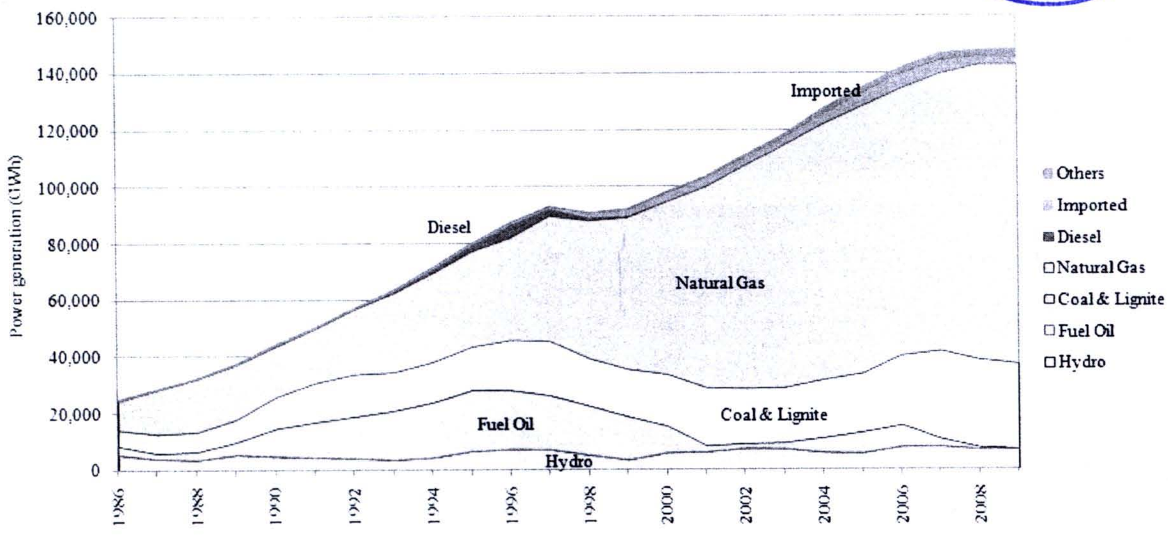
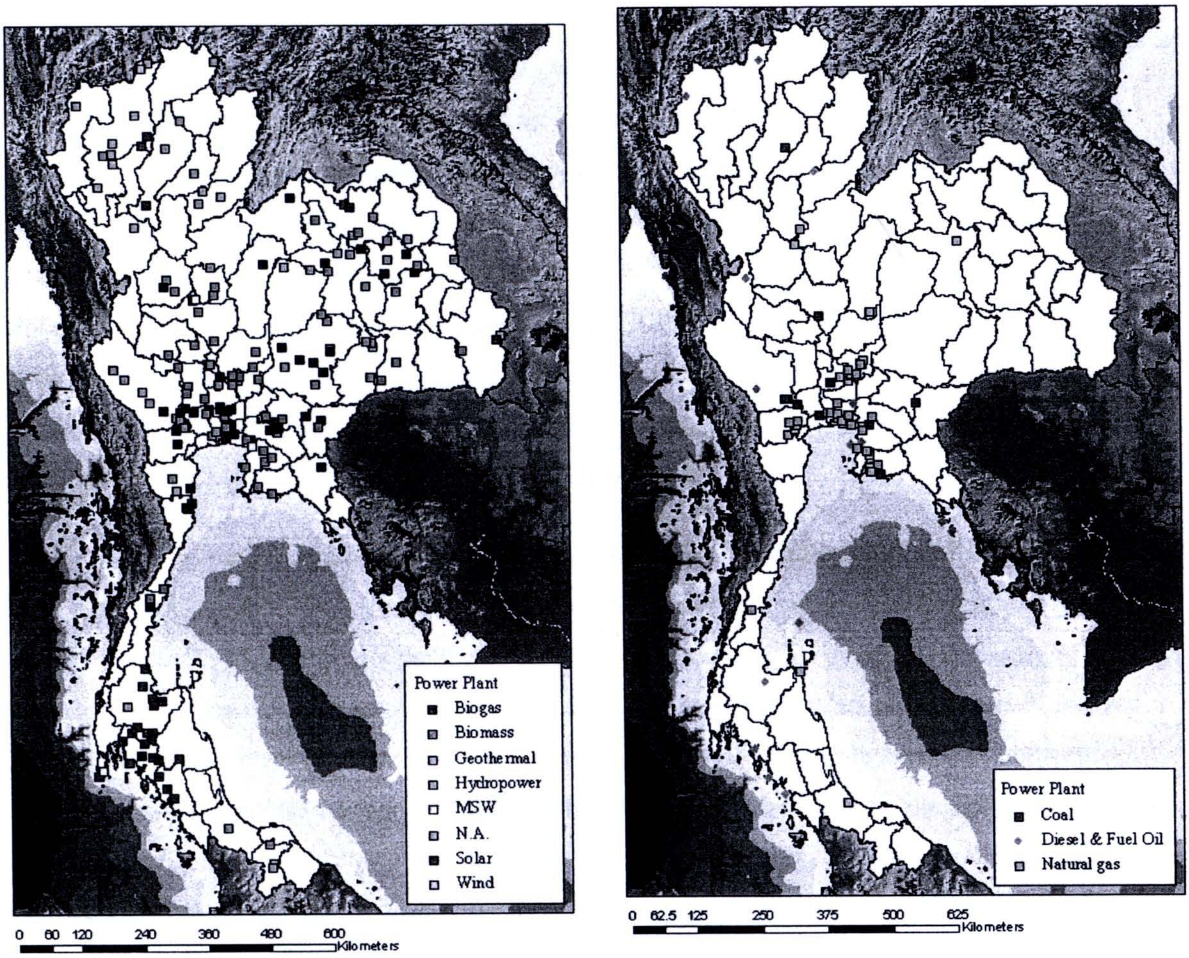


Figure 4 Capacity and fuel share of Thailand's electricity generation

Source: Ministry of Energy [8]



a) Conventional Fuel b) Non-conventional Fuel

Figure 5 Distribution of power plant in Thailand

Source: OERC [12] and EPPO [9]

3 Expansion policy and power plant technologies

Thailand is highly dependent on natural gas for electricity generation and its utilization accounts for about 74 percent of the total fuel used to produce electricity. About 75 percent of the gas used for all purposes, including for industry comes from the Gulf of Thailand and the rest from Myanmar and could be vulnerability for power generation. The country may face a risk of natural gas shortages as industrial activity rises in response to the improving economy, resulting in higher power demand; however, high dependence on single fuel type in power generation raises concerns about security of electricity supply that could affect competitiveness of Thai industries at the global level. The country has faced shortages of natural gas recently that could become a serious threat in the near future [10, 13-16].

To power future energy supply, Thailand issued the 20 years Power Development Plan covered a period 2010 to 2030 (PDP-2010), to enhance reliability of power supply, fuel diversification, power purchase from neighboring countries, power demand forecast and others. The PDP-2010 was approved by the National Energy Policy Council (NEPC) and endorsed by the cabinet in April 2010. The PDP-2010 aims to reduce the country's dependence on natural gas from 68.2 percent to 55.6 percent in 2030 while increasing the use of renewable fuel from 14.7 to 19.0 percent and nuclear power to 5.3 percent. At the same time, the use of lignite will be cut from 9.1 percent to only 6.4 percent. Under PDP-2010, the total install capacity is 36,335 MW and the total capacity of retirement of old power plants is 19,974 MW which is divided into 3,046 MW of EGAT thermal power plants; 4,776 MW of EGAT combined cycle power plants; 2,927 MW of Thermal IPP power plants and 9,225 MW of IPP combine cycle power plants [11].

The Energy Industry Act, B.E. 2550 (2007) came into force on December 11, 2007 and established a new regulatory regime for electricity and natural gas business. One of the main objectives of this act includes promotion of the use of renewable energy. The cabinet approved a 15-Year of Alternatives Energy Development Plan (AEDP) on January 28, 2009. The announced goal is to speed up the utilization of renewable energy to constitute up to 20 percents of total energy consumption by 2022. Policies that came out from the plan will promote energy security of the kingdom by reducing energy imports and increasing domestic energy resources, building competitive energy market for sustainable economic growth, and help reducing the emission of greenhouse gases in the long-run [17]. For increase sharing of renewable energy mixed to 20 percent of the final energy demand in 2022, the AEDP is divided in to three phases: the short term from 2008 to 2011, the mid-term from 2012 to 2016, and the long term from 2017 to 2022.

The ADEP detailed target for electricity generation from renewable sources is summarized in Table 1. The short-term focuses on extending renewable energy proportion to 15.6 percent of the total energy consumption by promoting of proven renewable technologies and high-potential renewable resources such as biofuels and thermal energy generation from biomass and biogas with full financial supports. The mid-term expansion goal is to boot up renewable consumption to 19.1 percent of the total energy consumption. The mid-term strategy is concentrated on the efforts to promote the renewable technology industry, to support the new renewable technology prototype development to make it economically sound, to encourage cutting-edge technologies in the biofuels production and the green city model development, and to strengthen the local energy production. The long-term development goal is to develop the renewable energy at 20.3 percent of the total energy consumption. The long-term development plan focuses on adoption of economically viable cutting-edge renewable technology including the further implementation of the green city and decentralization of the technology to local community, as well as on promotion Thailand to become the ASEAN biofuels and renewable energy technology hub.

Table 1 Target for electricity generation from renewable energy during 2008 to 2022

Unit (MW)	Actual 2009	Target		
		2008-2011	2012-2016	2017-2022
Solar	32	55	95	500
Wind	1	115	375	800
Mini/micro hydropower	56	165	281	324
Biomass	1,610	2,800	3,220	3,700
Municipal solid waste	46	78	130	160
Biogas	5	60	90	120
Total	1,750	3,273	4,191	5,605

Source: Ministry of Energy [17] and EGAT [11]

The National Energy Committee (NEC) approved tariff adders for certain categories of alternative energy on March 9, 2009. This allows government to encourage the renewable energy investment by awarding "adder tariff" or special purchasing rate higher than the price of power generated from mainstream fuels to private power producers depending on the types of renewable fuel used (Table 2). The efforts have been made to diversify the economy away from the use of oil and natural gas for power generation by, among others, increasing the use of indigenous renewable energy resources and implementing fuel energy-efficient technologies for power generation to enhance the security of national power supply as well as to reduce local and global environmental impacts.

Table 2 Adder to the normal tariff for increase incentives for renewable energy expansion

Fuel Type	Adder		Target in 2009-2021 (MW)
	Baht/kWh	US cents/kWh	
Biomass			3,700
< 1 MW	0.50	1.43	
> 1 MW	0.30	0.86	
Biogas			120
< 1 MW	0.50	1.43	
> 1 MW	0.30	0.86	
Waste			160
Fertilization/ Landfill	2.50	7.14	
Thermal process	3.50	10	
Wind			800
< 50 kW	4.50	12.86	
> 50 kW	3.50	10	
Hydropower			324
50 kW to <200 kW	0.80	2.29	
< 50 kW	1.50	4.29	
Solar	8.00	22.86	500
Total Capacity			5,604

Source: Ministry of Energy [17]

4 Status of renewable energy utilization

Since energy demand is projected to keep increasing, renewable energy and alternative energy are considered potential options to accommodate the increasing energy demand. Renewable energy utilization will help reducing not only the country's dependency on imported energy but also risks of volatility of imported fuel prices. At present, the development of renewable/alternative energy has become a country focus by promoting wider utilization of renewable energy to replace conventional energy consumption and motivating people to use energy efficiently and economically. This section gives an overview of alternative energy utilization in Thailand in several aspects including technological and supplying potential of biomass, biogas, municipal solid waste, hydropower, wind, solar, geothermal and nuclear energy to check on how obtainable for Thailand to achieve the latest AEDP target leading toward a low carbon electricity in 2022.

4.1 Biomass

Thailand is an agricultural country with huge agricultural stocks, such as rice, sugarcane, rubber sheets, palm oil, and cassava. The processing of these agricultural products generated large amounts of residues, which some parts are used as fuel in several industries. The amount of agricultural residues is about 61 million ton a year, of which 41 million tons, which is equivalent to about 426 PJ of energy, was left unused. Currently, biomass is the primary source about 4 percent of the country low carbon electricity. MOE indicated three main biomass sources in Thailand are from agricultural residues, forest industry and residential sector [18]. The employable biomass energy in Thailand mainly includes crop residues, firewood, manure, domestic garbage, industrial organic waste residue, and wastewater. The most promising residues used as fuel sources in electricity generation and cogeneration are rice husk, bagasse, oil palm residue and rubber wood residue. The utilization of biomass applies in wide range of conversion technologies such as direct combustion, thermo-chemical conversion, biochemical conversion, direct liquefaction, physical/mechanical extraction, and electrochemical conversion. Based on commercial application so far, direct combustion and thermo-chemical conversion are the most applicable technologies for utilizing biomass for heat and power generation [19].

The potential from biomass supply is widely distributed throughout the country depending on seasons. Particularly, rice is main agricultural product. The rice statistics data in Thailand were roughly represented according to major harvest and second harvest. Major harvest would be from May/June until November/December and second harvest is from December/January until May/June. Table 3 summarized the potential of major crops for biomass development in Thailand. The Office of the Energy Regulatory Commissioner (OERC) reported the installed capacity of biomass power generation in Thailand reached 1,751 MW. Of this, the power capacity from 632 MW from rice husk, 106 MW from bagasse and 32 MW from wood residue [12]. EPPO [9] reported in March 2010, there are 76 biomass power plants in operation (637 MW), 30 plants in the negotiation period with PEA and MEA (234 MW), 40 plants in acceptable period but not yet singing PPA contract (290 MW) and 211 power plants in the construction period and waiting for Commercial Operation Date (COD) at 1,586 MW [20]. Under the 15-years of AEDP, government set targets of biomass utilization in electricity generation in 2022 into three periods, short-term (2008-2011) at 2,800 MW, mid-term (2012-2016) at 3,220 MW, and long-term (2017-2022) at 3,700 MW respectively.

4.2 Biogas

Thailand is known as a food producing and supplying country. Food and agro industry generated significant amount of organic wastes, which are good ingredients for biogas production. The productions of biogas are mainly from anaerobic digestion or fermentation of biodegradable materials such as biomass, manure, sewage, municipal waste, and energy crops. In Thailand, biogas resources are from industrial wastewater and livestock manure, which have potential of 7,800 and 13,000 TJ per year, respectively. Central region produced highest BOD loading of 2,233 ton/day, which was more than half of the total BOD loading. The amount of wastes can be used to produce 620 million m^3 of biogas, which is equivalent to about 13,000 TJ or 308 ktoe of energy, in anaerobic digesters [21]. Although cattle residues show the highest energy potential of 41 percent of the total energy potential, the ongoing biogas promotion program is emphasized on manure utilization from pig farms. In the future, the government certainly has to put more focus to utilize resources from cows as well.

The OERC reported the installed capacity of biogas power in Thailand reached 146 MW. Of this, the power capacity from 74.96 MW from industrial waste water and 97 MWh from pig manure [12]. EPPO [20] reported in March 2010, there are 41 biogas power plants in operation and sale power to grid at capacity of 43 MW, 15 plants in the negotiation period with PEA and MEA (41 MW), 31 plants in acceptable period but not yet signing PPA contract (44 MW) and 33 plants in the construction period and waiting for COD (72 MW). Under the 15-years of AEDP, government set targets of biogas utilization in electricity generation in 2022 in three periods, short-term (2008-2011) at 60 MW, mid-term (2012-2016) at 90 MW and long-term (2017-2022) at 120 MW respectively.

Table 3 Evaluation of biomass potential in 2009

No	Main crop	Yield (million ton)	Biomass	Estimated biomass (million ton)	Non use fraction	Potential biomass (million ton)	Estimated potential energy	
							TJ	ktoe
1	Rice	31.50	Rice Husk	7.25	0.19	1.38	18,611.76	444.53
			Rice Straw	15.55	0.29	4.48	55,193.31	1318.27
2	Sugarcane	73.50	Sugarcane leaves	12.49	0.55	6.87	106,384.76	2,540.96
3	Casava	8.22	Casava trunks	0.74	0.41	0.30	4,727.26	112.91
			Casava rhizome	1.64	0.66	1.08	5,955.03	142.23
4	Corn	6.91	Corn cobs	1.66	0.70	1.16	11,160.29	266.56
			Corn trunk	5.66	0.61	3.40	33,397.17	797.68
5	Palm	8.16	Palm cluster	2.61	0.38	0.99	7,185.02	171.61
6	Rubber	232,008.94 (rai)	Rubber slap	0.70	0.41	0.29	1,874.89	44.78
			Roots	1.16	0.95	1.10	7,240.42	172.93
7	Other wood		Woodchips	1.89	1.00	1.89	12,407.45	296.35
	Total			51.35	6.15	22.94	264,137.36	6,308.81

Source: Office of Agricultural Economics, Ministry of Agriculture [22], Department of Livestock, Ministry of Agriculture [23]

4.3 Municipal Solid Waste

Management of municipal solid waste (MSW) has continued to be an important environmental challenge due to increase in production and consumption of goods. The threat of global climate change become a driving force and great opportunity to change MSW management practices to reduce greenhouse gas emissions in Thailand [24]. Huge amounts of waste are generated daily and its management is a considerable task to not only promote recycling and reuse, efficient waste collection and disposal system, but also increase financial capability and effective participation of government, public and private sectors. Thailand generates approximately 14.5 million tons of municipal solid waste (MSW) annually. Chiemchaisri et al. [25] clarify the physical composition of MSW varies according to consumer patterns, lifestyle, and economic status. The detailed composition of MSW in Thailand dominated by food waste (41–61%), followed by paper (4–25%) and plastic (3.6–28%). Within landfills, microorganisms that live in organic materials such as food wastes or paper cause these materials to decompose and produce landfill gas typically comprised of roughly 60 percent methane and 40 percent carbon dioxide. Total numbers of landfills in Thailand that actively operate are ninety while total incinerators are three. There are more than three hundred opened-disposal sites in the country. Despite large numbers of landfills, only a few of them properly operate and maintain (with methane gas collection) because no regulation mandates for methane collection.

The OERC reported the installed capacity of electricity from municipal solid waste in Thailand reached 13 MW [12]. EPPO reported in March 2010, there are 8 municipal solid waste power plants in operation and sale electricity to grid at 11 MW, 10 power plants in the negotiation period with PEA and MEA (305 MW), 15 plants in acceptable period but not yet signing PPA contract (68 MW) and 14 plants in the construction period and waiting for COD (96 MW). Under the 15-years of AEDP, government set target of biogas utilization in electricity generation in 2022 in three periods, short-term (2008-2011) at 78 MW, mid-term (2012-2016) at 130 MW and long-term (2017-2022) at 160 MW respectively [20].

4.4 Hydropower

Water supply for the whole part of Thailand is plentiful, except in the northeastern part of the country during the dry season. Thai's culture has long been intimately related with water, but not in a seafaring way, instead mainly in a local transport and irrigation mindset. Based on geographical characteristics watershed of Thailand divided into 25 river basins, average of annual rainfall is about 1,700 mm and total annual rainfall of all river basins is about 800,000 million m^3 of which 75 percent of the amount is lost through evaporation, evapotranspiration and the remaining is in streams, rivers, and reservoirs. Hydropower is the second major source of low-carbon electricity for Thailand. Hydropower produces only small amounts of CO_2 as a byproduct from dam construction and operation, but in some cases may produce significant amounts of another greenhouse gas, methane. However, hydropower resources are difficult to exploit due to the environmental impact on the resource areas a power project would entail. Therefore, future development of hydropower resources will be limited to a few small-scale projects that are considered most economical and environmental friendly. As part of the rural electrification program, the small hydropower developments are promising plan. From survey of MOE presented Thailand has potential to development of small hydropower at existing irrigation project. According to the PDP-2010, EGAT planned to increase capacity by constructing small hydropower at total capacity of 49 MW within 2012 [17]. There are many existing irrigation dams and reservoirs of Royal Irrigation Department (RID) designed and constructed for irrigation and flood control. Six existing and under construction dams of RID were studied and proposed by EGAT to develop the small hydropower projects with the total installed capacity of 78.7 MW. High potential micro-hydro powers are clustered in the northern areas of the country [11, 26].

EPPO [20] indicated hydropower existing potentials for development is at 15,155 MW [27]. By the end of December 2009, the OERC reported the installed capacity of hydropower in Thailand reached 3,438 MW [12]. EPPO reported in March 2010, there are 7 hydropower projects in acceptable period waiting for COD at capacity of 6.3 MW. Under the 15-years of AEDP, government set target of hydroelectric utilization in electricity generation in 2022 in three periods, short-term (2008-2011) at 165 MW, mid-term (2012-2016) at 281 MW and long-term (2017-2022) at 324 MW respectively.

4.5 Wind

Wind energy technology currently has conquered many startup problems and has attained in a new, more mature phase. It is one of the promising alternatives to implement for low-carbon electricity generation. The average wind speed in Thailand is moderate to rather low, usually lower than 4 meters per second; therefore, wind energy is currently used almost exclusively for propelling rooftop ventilators and water-pumping turbines. Throughout Thailand's long coastline, there is a rich resource of wind energy with great development potential. Currently, a further detailed study is being carried out in areas where the wind potential is high, mainly along the southern coastlines of Thailand, to obtain more data with a view determining the feasibility to develop projects for wind power generation [27-28]. The study of Prabamroong et al, [29] estimated total feasible areas for wind farm installations with respect to total area in each region of the country is found to be 95 percent for Central region, 88 percent for Eastern region, 94 percent for Northern region, 79 percent for Northeastern region, and 91 percent for Southern region. This study suggested that most of areas in Thailand have high potential for installing wind farms.

By the end of December 2009, the OERC reported the installed capacity of wind power in Thailand are in very small amount about 0.38 MW [12]. As of March 2010, EPPO reported there are 3 wind power projects in operation, 19 in the negotiation period with PEA and MEA (762 MW), 16 projects in acceptable period but not yet signing PPA contract (560 MW) and 6 power plants in the construction period and waiting for COD (26 MW) [20]. Under the 15-years of AEDP, government estimated potential of wind energy utilization with 1,600 MW capacity and set target of wind energy utilization in 2022, short-term (2008-2011) at 115 MW, mid-term (2012-2016) at 375 MW and long-term (2017-2022) at 800 MW respectively. Noticeably, the government proposed to increase renewable energy from wind power to 800 times more from the current capacity in 2022. This will require significant amount of investment, which the government needs to carefully develop an appropriate driving policy to succeed this ambitious goal in 12 years.

4.6 Solar

Almost every area in Thailand exposes to high sunlight intensity since locating near the equator. Therefore, high potential for solar utilization exists. Government promoted solar cells or photovoltaic (PV) cells for power generation with a demonstration project for utilization of solar energy and integrated systems of PV/hydropower and PV/wind energy [30]. Since 1976, the Ministry of Public Health and the Medical Volunteers Foundation used solar electricity for communication equipment in rural health station in isolated area that far from grid system. Several government agencies under the MOE have been undertaking studies and development of PV technology. For example, DEDE has studied and explored the potential of solar energy utilization by establishment of solar cell battery-charging station in various rural villages and Border Patrol Police Schools located outside the grid system [31].

By the end of December 2009, the OERC reported the installed capacity of solar power in Thailand are 7.8 MW [12]. EPPO [20] reported in the end of March 2010, there are 51 solar power projects in operation with capacity of 7.7 MW, 121 projects in the negotiation period with PEA and MEA (996 MW), 61 power plants in acceptable period but not yet signing PPA contract (218 MW) and 341 plants in the construction period and waiting for COD (3,265 MW). Under the 15-years of AEDP, government set target of solar energy utilization in 2022, short-term (2008-2011) at 55 MW, mid-term (2012-2016) at 95 MW and long-term (2017-2022) at 500 MW, respectively. The proportion of solar energy is about 10 percent compared to total renewable energy target, which seems to be relatively low, despite the great potential of solar intensity throughout the whole country. High investment cost per unit of electricity might be a major barrier, which suggests the government should find the way to develop R&D and support domestic solar industry.

4.7 Geothermal

Geothermal energy is natural energy from the internal heat of the earth; the temperature varies with respect to the distance from the earth surface (geothermal gradient) - the deeper from the earth surface, the higher temperature. At the depth of about 25-30 kilometers, the average temperature will be around 250-1,000°C. There are approximately 64 geothermal resources in Thailand, but major ones are in the northern part of the country, especially the geyser field at Fang District in Chiang Mai Province. Currently, EGAT is operating a 300-kW binary cycle geothermal power plant at Fang District, generating electricity at about 1.2 million kWh per year, which helps reduce oil and coal consumption for power generation. In addition, other benefits derived from the waste heat of hot water used in the power plant. The temperature of hot water, after being used in the power plant, will decrease from 130°C to 77°C, which can be used for drying agricultural products and feeding the cooling system for EGAT's site-office space. Some other non-energy uses of hot water from geothermal sources are for physical therapy and tourism [27]. Due to limited geothermal resources in the country, Thailand has small potential to produce more renewable energy from this area.

4.8 Nuclear energy

Thai Government is considering installing nuclear power to cope with future energy demand increases. Growing electricity demand, fluctuation of fossil fuel prices and climate change pressure bring all in a favor of nuclear power. The use of nuclear power will also help achieving emission reduction goal for climate change in the future. Therefore, Under PDP-2010, five thousand megawatt of nuclear power plant (5,000 MW) are expected to start operations during 2020-2030 and the first nuclear power plant will operate in 2020 [11].

Government believes that modern nuclear plants are safe and have high quality-control standards. Within 2012, the cabinet will make the final approval on the construction of the first nuclear power plant based on the results of the feasibility study on infrastructure information, utility and public acceptance. However, human factor is often weak point in the use of advanced nuclear technologies; education is very important, training also a key issue to develop specific behavior that can make the different between industrial culture and safety culture, which is critically required by nuclear operation. Now, the systematic process of nuclear development program will require both a strong political will and people's acceptance to be open and transparent in order to create public trust by providing essential and precise information to the public along with the benefits to the country.

5 Barriers for renewable energy development

Despite high potentials to generate electricity from renewable sources in Thailand, several barriers still prolong the speed of development and wide adoption of renewable energy. Systematic support and promotional policy guidelines of the government is currently necessary to help alleviate the investment costs for renewable power generation development so as to eventually enhance its commercial and competitiveness. Appropriate financial support is key mechanism to further promote the development of power generation technologies from each type of domestic renewable energy sources. Based on our investigation, major factors hinder progresses of renewable energy implementation in Thailand are following:

5.1 Fuel supply

The limitation of raw material supply has recently become the prominent barrier for expansion of renewable energy utilization especially for biomass. Due to seasonal and spatial variation of biomass supply, it restricts the power plants unable to have a continuous operation or operate to the full capacity. This greatly affects the cost-effectiveness of the business. Moreover, the quantity and quality of renewable resources has become the prominent barrier. Most of biomass resources can only produced during harvesting season; for example, period of sugar harvesting is limited (5 months from December to April). Thus, electricity from the sugar factory is mostly seasonal [32-33]. Moreover, the intensive cultivation of biomass may stress water resources, depleting soil nutrients, and displace open space by withdrawing land from other natural uses. Large-scale production of biomass for energy purposes could compete with use of land, water, and energy for production of foods or woods and grasses for construction of shelters.

Logistics and transportation of renewable resources especially biomass fuel are the another barrier of renewable energy utilization. Most of renewable energy is bulky and distributed over vast areas, which could cause high transportation expenses. Biomass resources should be utilized by nearby facility. If biomass has to be transported by farm equipment much over 100 km to a processing point or use facility, a substantial fraction of the energy content of biomass itself is consumed in the transportation process [34]. According to government policy on fuel diversification to renewable energy, the declaration of sufficient fuel supply to prevent fuel shortage is the main criteria used for selecting the small projects to receive feed-in tariff or "adder" from EGAT or PEA.

5.2 Technical barrier

The absence of efficient renewable energy generation technologies and supports of skilled manpower and spare parts is one of the prime technical barriers. For example, domestic wind power technology has not well developed in the country, so the advanced and large wind power sector has to rely on imported technology. Given the available wind resources and climatic conditions, it is difficult to further develop wind power sector in Thailand by using imported technologies. The technology has to be tailored to adopt in the hot and humid climate and low wind speeds prevalent in Thailand. In long-term, this can pose substantial barrier if we continue importing foreign technology for wind energy development in Thailand. Another example in solid waste utilization, characteristic of solid wastes in Thailand has high moisture contents therefore have low calorific value which is unsuitable to use in power generator and required additional processes to improve fuel quality e.g. installation of waste separation unit or manual waste separation [35]. Increase efficiency of waste separation can help increasing the yield of biogas generation but it also requires public education on waste management.

For technological R&D, Thailand needs to support researchers to carry out their research to extend our country potential, and create in-house technology to promote industrial start-up. Many believe that accelerating the pace of technology improvement and deployment could significantly reduce the cost of achieving this goal. The critical role of new technologies is underscored by the fact that most anthropogenic greenhouse gases emitted over the next century will come from equipment and infrastructure built in the future. As a result, new technologies and energy sources have the potential to transform the nation's energy system while meeting climate change as well as energy security and other important goals [36-37].

5.3 Financial barrier

A key role for government is to focus on policy design and legislation to attract private sector investment. As renewable energy technology becomes more commercially mature, government will become less significant as providers of the direct capital support needed to make up the cost difference relative to conventional generation. Mallon [38] express the importance of cost internalization (environmental and social damage cost) made cost of renewable comparable with thermal (nuclear and fossil) electricity generation. Siegel et al. [39] express investment of renewable energy companies not only generates revenues by providing clean, green power for consumers, but they can also generate additional revenues by simply offering an "offset" to companies that emit less greenhouse gas emissions (GHG). It is clearly beyond the budgets of most government to directly inject money into renewable in order to fast track a competitive industry. A handful of demonstration projects might be useful, good examples of financial incentive provided by the Ministry of Energy is "ESCO Venture Capital Funds" for providing equity for small renewable energy and energy efficiency projects undertaken by small entrepreneurs with limited capital. The fund should also be provided financial assistance for equipment leasing, credit guarantee facility, technical assistance and carbon market [7].

It should be noted that without subsidies, biomass power projects are unable to compete with fossil fuel power plants due to the difference in scale on which conventional plants and renewable energy plants operate [40]. Government set price at which they can sell their renewable power to the grid, thus effectively providing essentially a guaranteed return on the renewable energy investment and making it easier for renewable energy projects to obtain banking approval for the capital costs of the project. For example, waste incineration is not likely to be cost-effective at this time in Thailand. Incineration of municipal solid waste is a costly and operationally complex, as compared to landfills. Government subsidies are only possible sources of financing, however this issue is not a widely discussion upon by the public, politicians, and international financial institutions. Feed-in tariffs in practice have definitely provided a hugh boost for renewable energy projects.

Another barrier or driven constrains of biomass utilization are still high in price. Fluctuation of fossil fuel price also affects the competitiveness and utilization of renewable energy. Moreira expressed most of modern biomass utilization are being driven by energy security motivation [41]. Fossil fuel price has been increasing in the last 3 year due to various reasons, when fuel price are high, some industries change their main fuels from fossil fuel to use rice husk for lowering price. Average price of rice husk has increased from 767-

799 THB/ton in 2006 to 864-1,042 THB/ton in 2009. However, when the fossil price was dropped, demands for biofuels also decreased.

Tester et al. [34] indicated that if fossil fuel prices rise to include cost of carbon management, consumers may also modify their consumption patterns. Through a system known as carbon trading, a market - based mechanism that helps mitigate the increase of carbon dioxide in the atmosphere, renewable energy companies (as well as other entities that provide offsets, such as forestry management companies, for instance) can sell carbon credits to companies that emit carbon dioxide into the atmosphere and want to balance out their emissions. The government should refocus its energy development strategy and consider more on how to deliver the actual price of energy to the citizens, instead of lowering the price to favor industrial development without carefully considering externality environmental and social costs. The challenge is how to internalize all externality (e.g. environmental damages cost) caused by using fossil fuels, and set up a financial structure i.e. tax system to bring the right energy price to consumers. This will help promoting the fair competition between renewable energy and traditional fuels and bring the country to a sustainable future.

5.4 Institutional and legislative constrains

Today, even environmental friendly energy projects are also facing public protest. Hydropower projects can be particularly controversial because they can displace communities as large areas of land are flooded and prevent communities from having access to the water for current and future needs. Communities can be impacted greatly by having their water regime changed. Some hydro projects face several oppositions from groups that are not just local communities. No one wants this type of project to be located nearby his or her neighborhood. Though, renewable-energy projects would reduce pollution and combat climate change but on the other hands, the trade-off is that many people would have to see wind turbines, solar panels and other energy infrastructure near their homes in order to diminish the need for coal mines and other fossil-fuel facilities. Ball [42] express the increment of renewable energy development issues on public concern such as environmental, energy securities and social impact was the key parameters for policy-maker or project developer to concern.

In Thailand, the laws require the project that may potentially cause environmental damage and health impact to conduct an environmental impact assessment and require public participation. For instance, the hydropower development project must concern on the ecological environment warrants close scrutiny and should be evaluated in a systematic manner before and during construction and operation of hydropower station. In Thailand, most of the areas that have high potential for renewable energy development e.g. wind, small hydropower and geothermal are belonging to government and inaccessible by the project investor. For example, under Section 46 of the Enhancement and Conservation of National Environmental Quality Act B.E. 1992 required an environmental impact assessment (EIA) report before submitting for license. Therefore, government needs to set up a special task force to examine potential areas for renewable energy development, and set up a fast track of permit procedure that help fasten the development. Moreover, government should strengthen environmental regulation and enforcement especially emission controls from very small private power producer (VSPPs) because currently there are no rules and regulation to control emission from power plant that has capacity below 10 MW.

6 Conclusion

Thailand faces the energy and environmental challenges as being both a contributor and victim of the effects of climate change. Renewable energy was identified as having great potentials, due mainly to ample physical supply of the industrial by-product such as rice husk, wood chips, bagasse, and other available biomass on fields. Based on potential installment of energy technology (in Table 1), in 2022, the major proportion of renewable energy will mainly derive from biomass 33.9 percents of total energy. To meet a target of 3,700 MW biomass electricity generation capacity in 2022, Thailand need to increase about 129.8 percent from current capacity 1,610 MW in 2009. The expected goal under AEDP is not too hard to achieved, but government must help increase efficiency of technology and methodology of biomass utilization, and explore other energy-derived biomass that should be more utilized.

The climate change is a direct threat to energy security, particularly to existing energy infrastructure. Examples of disruptions to energy supplies that could cause disruptions to power supply include droughts reducing hydropower availability and withering field crop and other food supplies. The effects of climate change may affect the trade-off between food supplies in term of food plantation area and purposed uses for biomass energy supplies. According to target of wind energy development under AEDP, the government estimated that our future would very much depend on wind energy (800 MW in 2022). However, development of wind energy utilization must be as fast as possible, comparing with biomass. For solar energy utilization, it is still uncertain about technological breakthrough to drive down the economic cost for this type of technology. This is a major challenge that government has to solve in order to promote widely implementation of the solar energy.

The government released many tools for motivate utilization of electricity generation from renewable energy in many different ways e.g. BOI investment scheme in renewable energy by giving fiscal incentives and tax exemption in hardware and equipments using in construction of renewable power plants, special soft loans via ESCO funds. Before implement financial incentives for renewable development, the government may need to assess actual renewable potential and should revise the potential of renewable energy development in order to set up "precise" and "effective" target before implementation. In addition, government should promote the zoning policy for renewable energy because of each part of country containing different types of supplying potential on biomass, hydropower, and wind. The location is important, however, some technology might not depend on location in term of solar energy.

Thailand has plenty of resources to generate electricity from the sun and wind, however, the challenging action for government is whether it should wait for technology to maturely developed and later adopt the cost-effective technology or government right now should strongly subsidy research to develop low cost solar cell by encouraging the co-operation of research and development. Moreover, government may urgently need to set up a policy to promote the decentralized solar system to household to reduce energy demand from the whole system and increase energy efficiency as in Europe. Promotion of decentralized energy production in household sector is important and collectively could create a big impact, including technology transfer to the public to become energy self-sufficient at local level.

In summary, Thailand has set a very ambitious intention for developing low carbon electricity sector. With high potentials of various renewable resources existed in the country, Thailand could potentially achieve it, but eventually how soon. With the government strong will in providing financial & regulatory incentives for business investment, R&D and public involvement to be part of the development, is really the key to build a strong foundation to secure the country's economy and environment.

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APPENDIX B

Assessment of electricity development pathway [1] toward low carbon electricity development for Thailand

Narumitr Sawangphol[2,3] and Chanathip Pharino[4]

Abstract

The international community has begun to assess a range of possible options for strengthening the international climate change effort after 2012. Thailand also try its best to help reduce global GHG targets while (minimizing impact on) maintaining economic growth. This paper analyzed the realistic implementation potential for GHG emissions reduction from electricity sector in Thailand. Comparison mitigation options are crucial to identify active, cost-effective alternatives for the country. Modeling possible developmental pathway that include Business as usual (BAU), Maximum growth of renewable energy and nuclear energy (WNC) and Maximum growth of renewable and no nuclear (NNC) electricity development options.

Similar results are obtained for nuclear scenario, although the dependence shifts from coal and oil towards natural gas-based power generation. This may represent a better environmental pathway but an all out shift from coal to natural gas is likely to increase Thailand's dependence on imported fuel and making it more vulnerable to unstable global oil and gas prices. The without nuclear scenario that allows the country to confront its energy security dilemma whilst fulfilling its environmental commitments by giving renewable energy technologies a prominent place in the country's power generation mix. Over the study period, our result showed little difference between the three scenarios in terms of financing new generation plants despite an early misgiving about the viability of an ambitious renewable energy program.

Keywords

De-carbonizing electricity generation, renewable energy, emission abatement cost

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1 Introduction

Electricity is the most prominent target for climate policy because it is the largest sources of carbon dioxide emission and of potential carbon dioxide emission reduction however, growth in electric use is often correlated with a rise in GDP and improvements in the quality of life [1-2]. The energy sector is the major sources of anthropogenic greenhouse gas emissions; accounting for 61 percents of global GHG emissions (and almost 75 percents of all CO_2). According to IPCC, carbon dioxide emissions caused by the energy supply sector can be reduced with the use of some or all of the following options; increase more efficient conversion of fossil fuels; switching to low-carbon fossil fuels; decarbonisation of Flue Gases and Fuels, and carbon dioxide Storage and Sequestering; switching to nuclear power; and switching to renewable sources of Energy [3].

Recently, carbon dioxide emissions from electricity generation in Thailand increased by 16.5 percent during 1993 to 2008 and this increase is largely result of demand growth in electricity production (27.8 percent between 1993 and 2008). Department of Alternative Energy Development and Efficiency (DEDE) reported the forecasted amount of GHGs emission from Thailand would reach 559 $MtCO_2$ over period 2005-2020 (Figure 1). Average growth of total GHGs emission is estimated to be 3.2% per year while estimated emission from energy sector is 4.7% per year [4]. Figure 2 illustrate pattern of carbon dioxide emissions by fuel types in Thailand since 1986, showing both the substantial growth in emissions during the 1996 and a transition in fuel from oil to natural gas and coal. Ministry of Energy (MOE) reported the carbon dioxide emission per capita of Thailand increased from 1.85 to 3.06 during 1993 to 2008 and electricity consumption per population raised from 965 to 2,129 kWh per capita during 1993 to 2008 respectively [5]. To strengthen national energy security and reducing GHG emission from energy sector, Thailand could effectively promote renewable energy generation from its main agricultural products and residues.

To find appropriate mitigation options, the LEAP model is used to characterize the composition and structure of electricity, fuel consumption and evaluate greenhouse gas emissions for each scenario from 2010 to 2030. The BAU scenario serves as a reference scenario based on assumptions that reflect actual plans and forecasts by government body. The With-Nuclear and Without-Nuclear scenarios are constructed with some plausible policies and choices considered to be rational within the parameters of each scenario storyline. The year 2010 is used as the base year that provides the basis for building the various scenarios and establishes the analysis within the current energy system in Thailand.

This year is the first year of Thailand's power development plan and electricity generation calculation follows the load forecast for each sector under PDP-2010 assumption. The inputs of model required for demand analysis include the levels of activities and final energy intensity for each sector. In this case, levels of activities are the number of electrified customer units, while final energy intensity used is electricity consumption per electrified consumer. This study assumed that the effects of energy efficiency programs on the demand structure are already taken into account by the National Load Forecast assumption.

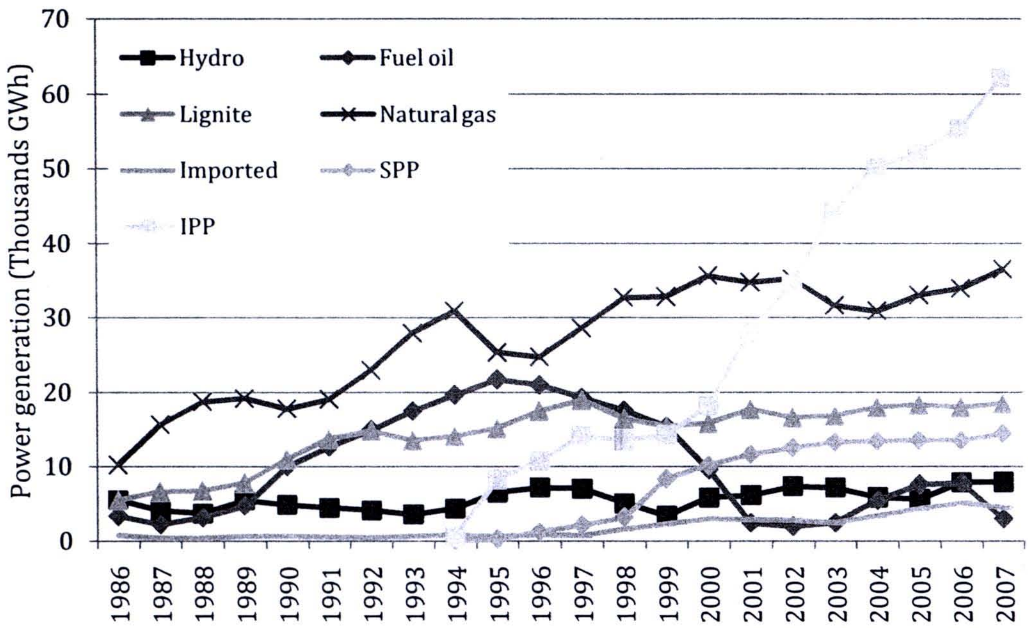

Figure 1 Capacity and fuel share of Thailand's electricity generation

Source of data: Ministry of Energy [6]

2 Methodology

Energy modeling is a popular and widely used approach to identify the energy consumption, pollutants emissions, technology pathway, energy policy and global scenarios. Scenario planning is a useful approach to design and plan long-term electric infrastructure to cope with the uncertain future demand for power [2, 9]. The power industry plays a unique role in climate change, being by far the largest sector both in emissions and opportunities to reduce them [10]. Most development concepts have achieved good quality of life in sense of GDP, but also resulting in a high-carbon and high resource society. Currently impact of climate change and international pressure from mitigate greenhouse gases emission, they need to achieve low-carbon economy and low emission from electricity generation as a new paradigm.

In order to assess the carbon dioxide emissions reduction potential of Thailand's electricity sector, this research employs three scenarios based on the "Long-range Energy-environment Alternatives Planning" (LEAP) software framework, developed by the Stockholm Environment Institute at Boston Center to simulate the different development paths in this sector. Many application of LEAP for energy-environment modeling carried out in many part of the world, Mulugetta et al. [2] applied LEAP model for characterize the comparison and structure of Thailand electricity, fuel consumption and greenhouse gases emission under various energy production assumption. At present moment, Thailand's energy structure is made up of following primary energies: coal, oil (diesel oil and residual fuel oil), natural gas, hydraulic, geothermic, wind and biomass (for example, bagasse of sugar cane, wood and forest waste, municipal solid waste, etc.). To power future energy supply, Thailand issued the 20 years Power Development Plan covered a period 2010 to 2030 (PDP-2010) aims to reduce the country's dependence on natural gas to 55.59 percent in 2030 while increasing the use of renewable fuel to 19.03 percent and added 5,000 MW of nuclear for sharing 5.31 percent of total energy.

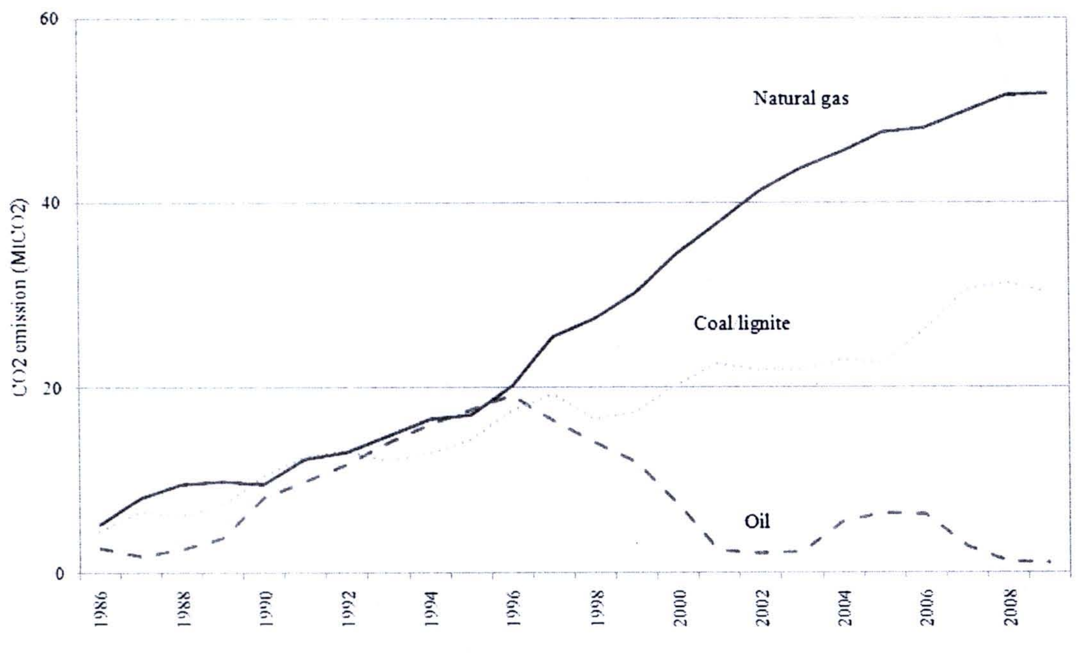

Figure 2 Carbon dioxide emissions from electricity generation in Thailand

Source of data: Ministry of Energy [6]

To identify the contributions and the challenges of establishing a sustainable energy supply system, three scenarios are prepared in this paper, which includes Business as usual (BAU), with nuclear scenario (WNC) and without nuclear (NNC) electricity development options. The energy modeling techniques was employed to quantitatively analysis the three scenarios, evaluate and compare against each other. The BAU scenario represents the energy pathway that is implied of current energy policies, supply and demands trend in Thailand persist. This scenario will also take into account current and anticipated government policy related to the power sector and how these policies actually shape the direction of the sector in future [2]. The aim of BAU scenario is to show the future through the prism of current policies and strategies, and delineate the relationship of the power sector with political economics and environmental institutions. The BAU scenario computes energy consumption and emissions for the base year (2010).

However, the diversification of energy sources is essential to reduce carbon dioxide emission. It helps to reduce the dependence on oil and coal imports and thus promote the security of supplies. It is not necessarily beneficial in terms of climate change. For fuel diversification policy, the cabinet approved a 15-Year of Alternatives Energy Development Plan (AEDP) on January 28, 2009. For increase sharing of renewable energy mixed to 20% of the final energy demand in 2022, the AEDP is divided in to three phases: the short term from 2008 to 2011, the mid-term from 2012 to 2016, and the long term from 2017 to 2022. The ADEP detailed target for electricity generation from renewable sources is summarized in (Table 1). Like renewable, nuclear power produces no GHG emissions during operation, but there are too many global carbon dioxide emitting generation sources. It will take decades for these plants to be replaced by cleaner technologies, such as "clean" coal, nuclear, or renewable [11]. Nuclear power generation has been considered by many policymakers to be the most important technological options and Thailand has availability to reduce national green house gas emission. The future of nuclear power will therefore depend on whether it can meet several objectives simultaneously such as economics, operating safety, proliferation safeguards and effective solutions to waste disposal. Within 2012, the cabinet will make the final approval on the construction of the first nuclear power plant based on the results of the feasibility study on infrastructure information, utility and public acceptance.

Purposes of the abatement scenarios focuses on how the power sector could reduce its emissions of greenhouse gases and other pollutants by reduce energy demand, switching to low carbon emission fuel and changing technologies. Increased investment in energy efficiency would take place mostly in those technologies that use oil products, or natural gas or that use electricity in countries where gas represents a substantial share in the power generation mix. The "With-nuclear" (WNC) demonstrates an overview of alternative energy utilization in Thailand in several aspects including technological and supplying potential, including biomass, biogas, municipal solid waste, hydropower, wind, solar, geothermal and nuclear energy to check out in reality how obtainable for Thailand to achieve the latest AEDP target leading toward a low carbon electricity by promoting renewable energy in 2022. On the other hands, the "Without-nuclear" (NNC) differs from With-Nuclear scenario in that it incorporates the following aspect (Table 2). First, increase proportion of renewable energy in electricity generation increase from 4,191 MW (14.07 %) in 2010 to 9,085 MW (19.98 %) in 2030. Refer to the AEDP target, the With-Nuclear scenario. Second, implementation of demand reduction from 2010 at 15 percents within 2030 and electricity consumption in Without-Nuclear scenario is projected to reduce from 152.95 TWh in 2010 to 295.75 TWh in 2030. Third, this scenario includes and substitution of some of the candidate fossil fuel plants by renewable energy based plants under REDP Plan target (800 MW of wind, 500 MW of solar, 160 MW of MSW, 120 MW of biogas and 3,700 MW from biomass respectively).

Each scenario is linked to framing of particular policies and defines the supply side characteristics and assumptions used, then employ energy modeling techniques to quantitatively analyze the three scenarios, evaluate them and compare them against each other. In this study, cost data were provided for more than 43 power plants. This comprises 4 coal-fired power plants, 19 gas-fired power plants, and 10 plants based on other fuels or technologies. The data provided for the study highlight the increasing interest in renewable energy sources for electricity generation, in particular in combined heat and power plants. The technologies considered were all conventional boilers except two advanced integrated coal gasification plants. Most of the coal-fired power plants for which cost estimates were provided would be equipped with pollution control devices that reduce atmospheric emissions of sulfur and nitrogen oxides, dust and particulate. Hydropower plants are excluded from this study because their costs are site specific and, therefore, not relevant for comparison to other alternatives in the framework adopted.

The cost estimates presented in the study were calculated based on the International Energy Agency (IEA) [12] methodology, using input parameters provided by literature reviews, site visiting, and interviewing. The coverage of capital, O&M and fuel costs is described in the main body of the report. In the context of the studies in the series, all the components of the capital, O&M and fuel costs falling on the utility that would, therefore, influence its choice of generation options are taken into account. Levelized cost of electricity is comprised of three components: capital charge, operation and maintenance costs and fuel costs. Capital cost is generally the largest component of COE. The levelized lifetime cost per kWh of electricity generated is the ratio of total lifetime expenses versus total expected outputs, expressed in terms of present value equivalent. This cost is equivalent to the average price that would have to be paid by consumers to repay exactly the investor/operator for the capital, operation and maintenance and fuel expenses, with a rate of return equal to the discount rate. The date selected as the base year for discounting purpose does not affect the levelized cost comparison between different plants. The absolute values of levelized costs will, however, differ from base year to base year in periods of inflation or deflation. Generally, levelized cost estimations are carried out in constant money, i.e. in real value, and inflation is not taken into account in cost elements. Nevertheless, projected price escalation or decrease is taken into account in the real price of goods or services such as fossil fuels or staff salaries (within O&M costs), when applicable.

3 Scenario description

The BAU scenario was designed according to the assumption of the PDP-2010 energy development plan and time period covers up to 2030. The growth in electricity demand projection of this scenario requires a corresponding increase in electricity generation, capacity, types of power plants likely to be added, on the mix of electricity generation capacity, output over the study period and summarize the implications of BAU case electricity sector development on the emissions of greenhouse gases from the electricity sector. In BAU scenario, the total install capacity is 65,547 MW and the total capacity of retirement of old power plants is 19,928.70 MW which is divided into 3,046 MW of EGAT thermal power plants; 4,776 MW of EGAT combined cycle power plants; 2,926.6 MW of Thermal IPP power plants and 9,225.1 MW of IPP combine cycle power plants [8]. At the same time, the use of lignite will be cut from 9.57 percent to only 2.47percent; however proportion of bituminous will be increased from 7.54 percent to 21.15 percent during the plan. Nuclear power plants will be constructed up to a maximum of five new units. The first new commercial operation will begin from 2020 onwards and then one new unit every 2 years until 2030 [13]. As illustrated in Table 2, it is assumed that final energy demand continues to rise in the long run.

Greenhouse gas mitigation potential depends on the underlying assumption, ambition and timing of reduction targets, the overlap among competing mitigation options and often-subjective assessment of technical and social feasibility. For example, more ambition reduction targets can shift the emphasis from technologies with less costly but often limited incremental mitigation potential (e.g. fossil fuel power plant efficiency or current generating biofuel) to technologies that are more costly in the near term, but can deliver far lower GHG emission per unit of output service (e.g. solar power or advance combustion) [14]. As a rule, natural gas generates less carbon dioxide per unit of heat than oil, and oil generates less than coal. Fuel switching to low carbon sources is thus an important strategy for emission reduction. However, renewable resources are both essential energy producers and important drivers of progress at the national and global levels.

The WNC scenario differs from BAU scenario in that it incorporates the following aspect (Table 2). First, increase proportion of renewable energy in electricity generation increase from 43.85 TWh (8.81%) in 2010 to 131.21 MW (13.59 %) in 2030. Refer to the AED target, the WNC scenario. Second, implementation of demand reduction at 15 percents within 2030 (70.30 TWh) and electricity consumption in WNC scenario is projected to reduce from 468.70 TWh under BAU scenario in 2030 to 398.40 TWh under WNC in 2030. Third, this scenario includes and substitution of some of the candidate fossil fuel plants by renewable energy based plants under REDP Plan target.

Under WNC scenario, the total capacity of retirement of old power plants is 19,928.70 MW which is divided into 3,046 MW of EGAT thermal power plants; 4,776 MW of EGAT combined cycle power plants; 2,926.6 MW of Thermal IPP power plants and 9,225.1 MW of IPP combine cycle power plants [8]. At the same time, the use of lignite will be cut from 9.57 percent to only 2.88 percent; however proportion of bituminous will be increased from 7.54 percent to 17.47 percent during the plan.

Under Without-nuclear (NNC) scenario, the total capacity of retirement of old power plants is 19,928.70 MW which is divided into 3,046 MW of EGAT thermal power plants; 4,776 MW of EGAT combined cycle power plants; 2,926.6 MW of Thermal IPP power plants and 9,225.1 MW of IPP combine cycle power plants [8]. At the same time, the use of lignite will be cut from 9.57 percent to only 2.91 percent; however proportion of bituminous will be increased from 7.54 percent to 25.20 percent during the plan.

4 Results and Discussion

4.1 Electricity consumption and emissions reduction spectrum

4.1.1 BAU

Over the study period, the electricity generation must rise to 468.70 TWh by 2030 in order to meet BAU electricity demand (plus transmission and distribution losses), implying an average annual growth rate of 2.97 percent per year from 2010 to 2030. Demand for electricity is expected to rise sharply over the coming two decades with nearly 179.61% increase predicted between 2010 and 2030.In 2010, over 74.09 percent of the electricity generated to power Thailand's economic recovery was derived from natural gas (Figure 1). The remaining balance came from lignite (and coal), hydro and oil-fired power stations with a small, albeit important, proportion of electricity imported from neighboring countries.

By 2030, the BAU scenario reveals that the share of natural gas drops to about 52.79 percent, coal increases its share to 23.62 percent; however, due to the low quality of Thailand's coal resources in the Northern part, in this scenario the incremental growth in coal will have to be imported, and in due course retire thermal plants using coal. The positive contribution of coal is somewhat tempered when viewed from an environmental stand point. Under BAU scenario, renewable entering the picture as an important contributor to overall electricity generation; moreover, government's plan to increase the share of renewable energy systems to 20.30% by 2030 to which hydro, solar and wind make modest contributions. Moreover, the generation fuel mix of Thailand under BAU scenario in 2030 will be 23.62 percent of coal, 52.79 percent of natural gas, 11.44 percent of nuclear power and about 12.15 percent fuel for generation based on other indigenous resources including, hydropower, geothermal, wind, solar and biomass. Diesel and natural gas fired power stations contribute 7.9% of total electricity power in 2030 as illustrated in Figure 3.

4.1.2 The abatement scenario

Compared with abatement scenario, the growth in electricity demand projection in With-Nuclear (WNC) and Without Nuclear (NNC) scenario were reduced energy demands in BAU scenario using energy efficiency improvement at 15 percent of total energy at 2030 of 70.30 TWh when compared with BAU scenario. In the With-Nuclear (WNC) Scenario, the electricity demand generation must rise from 260.96 TWh in 2010 to 397.40 TWh in 2030 in order to meet WNC electricity demand (plus transmission and distribution losses), implying an average annual growth rate of just under 2.14 percent per year from 2010 to 2030. For fuel shared in WNC scenario, the electricity generation by natural gas consumption of WNC scenario will remain dominant, which accounts for 369.48 TWh in 2010 to413.78 TWh in 2030 while nuclear and renewable energy sources supply 109.50 and 131.21 TWh of electricity in this scenario until 2030. The generation fuel mix of Thailand under WNC scenario will be 20.35 percent of coal (2.88 percent from lignite and 17.47 percent from bituminous), 50.36 percent of natural gas, 9.53 percent of nuclear power and about 15.97 percent fuel for generation based on other indigenous resources including, hydropower, geothermal, wind, solar and biomass as illustrated in Figure 3.

In the Without-nuclear (NNC) Scenario, the electricity demand generation is expected to rise from 260.96 TWh in 2010 to 397.40 TWh in 2030 in order to meet NNC electricity demand (plus transmission and distribution losses), implying an average annual growth rate of just under 2.14 percent per year from 2010 to 2030. For fuel shared in NNC scenario, the electricity generation by natural gas consumption of NNC scenario will remain dominant, which accounts for 369.48 TWh in 2010 to 434.66 TWh in 2030 while renewable energy sources supply shares 149.51 TWh of electricity in this scenario until 2030. The generation fuel mix of Thailand under NNC scenario will be 28.11 percent of coal (2.91 percent from lignite and 25.20 percent from bituminous), 53.49 percent of natural gas and about 18.40 percent fuel for generation based on other indigenous resources including, hydropower, geothermal, wind, solar and biomass as illustrated in Figure 4.

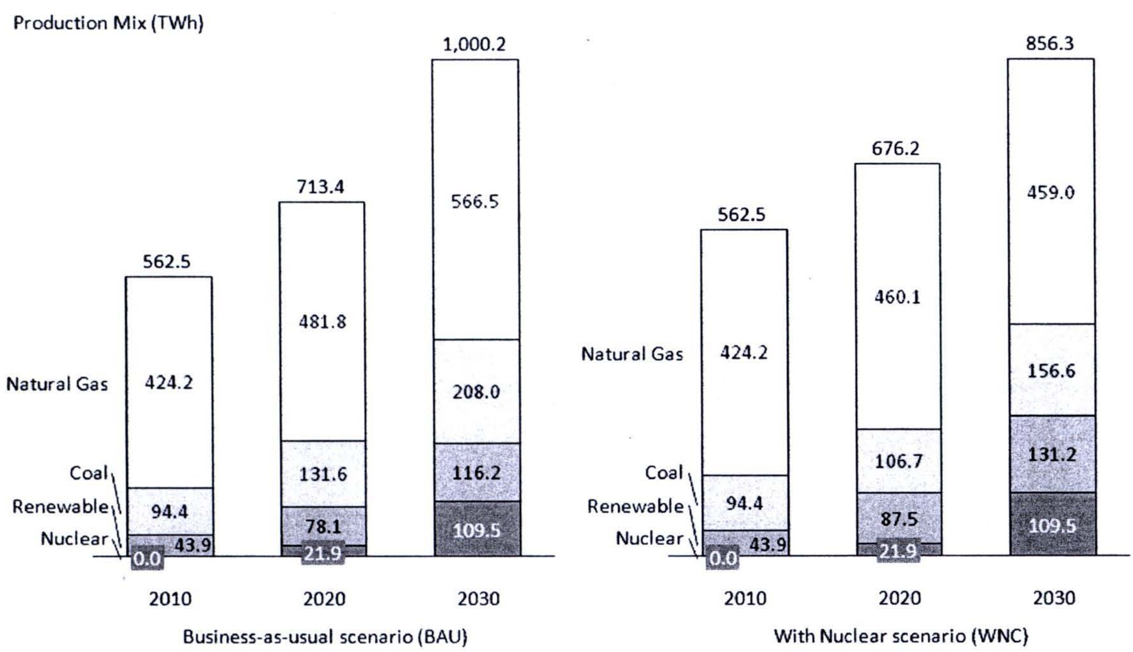

Figure 3 Comparison of production mix between BAU and WNC scenario

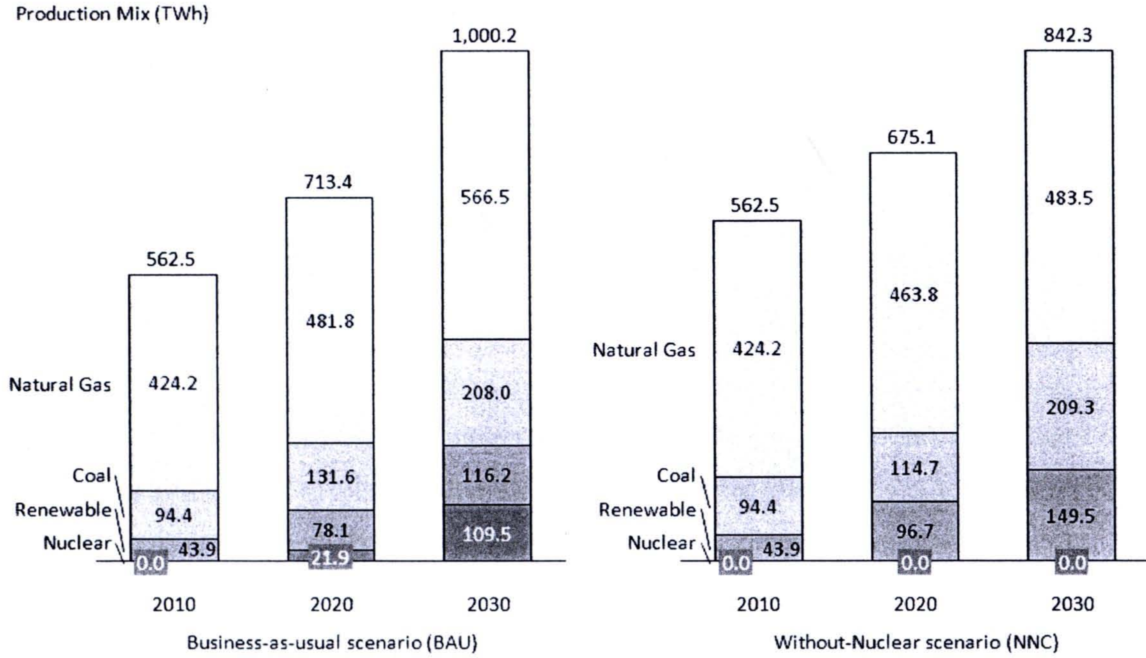

Figure 4 Comparison of production mix between BAU and NNC scenario

4.2 Carbon dioxide emission from each scenario

The evolution of greenhouse gas emissions from power generation, measured in terms of tones of carbon dioxide equivalent (tCO_2-eq.), shows three distinct patterns representing the different scenarios. As the development process continues, each scenario will experience decreasing energy intensity and carbon dioxide intensity. This is because energy-saving practices and environmental protection awareness have influenced each sector's development plans, rendering these measures as basic principles that all observe. However, when we compare amongst the three scenarios, an obvious trend emerges, namely that more aggressive scenarios have lower energy and carbon dioxide emission intensity. From all of the energy and carbon dioxide emission intensity perspectives in 2030, when compared with BAU scenario both abatement scenarios can affect an even greater reduction, the WNC can reduce 161.78 $MTCO_2$-eq or 15.95 percent and NNC pathway can reduce 116.78 $MTCO_2$-eq or 10.88 percent when compared with BAU scenario.

Table 6 illustrates the contributions of each carbon dioxide emission reduction activities. The BAU scenario represents the most conservative emissions projection, this scenario shows that if no controls were made in Thailand from 2010 to 2030, there is likely to be 1.11 million tons more carbon dioxide emitting from Thailand's electricity sector every year. Over the study period of BAU scenario the amount of greenhouse gases emissions increase from 118.97 $MtCO_2$ in 2010 to 141.07 $MtCO_2$ in year 2030. However, natural gas is the cleanest burning of fossil fuels and its utilization has increased dramatically in many part of the world during the last two decades. Of the total power sector emission in Thailand as of 2030, nearly 80.71 percent of the GHGs emissions come from natural gas combustion (113.86 $MtCO_2$-eq), 17.61 percent from coal based (15.91 $MtCO_2$-eq or 11.28 percent from Bituminous and 8.93 MtCO2-eq or 6.33 percent from lignite), and 1.38 percent from oil based, as shown in Figure 5 and Figure 6.

In the alternative scenarios under PDP-2010 thermal power plant at capacity of 5,972.6 MW and 14,001 MW of combined cycle power plant were decommissioned (illustrated in Table 5). The replacement of these amounts comes mainly from natural gas and renewable energy in both abatement scenario and from nuclear energy sources (mainly) in the case of the WNC scenario. The with-nuclear scenario (WNC), which considers the current national and sectoral polices, can achieve emission reduction of 118.97 $MtCO_2$ in 2010 and 117.79 $MtCO_2$ in 2030. The without-nuclear scenario (NNC), which considers the current national and sectoral polices, can achieve emission reduction of 118.97 $MtCO_2$ in 2010 and 124.68 $MtCO_2$ in 2030.

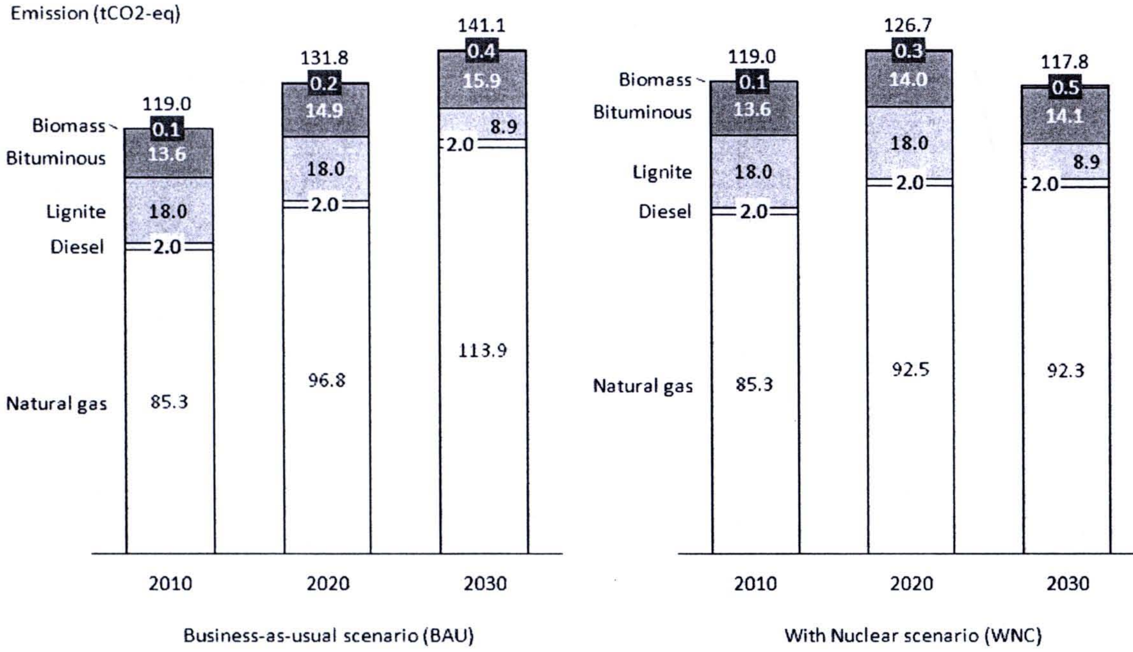

Figure 5 Comparison of GHGs emission between BAU and WNC scenario

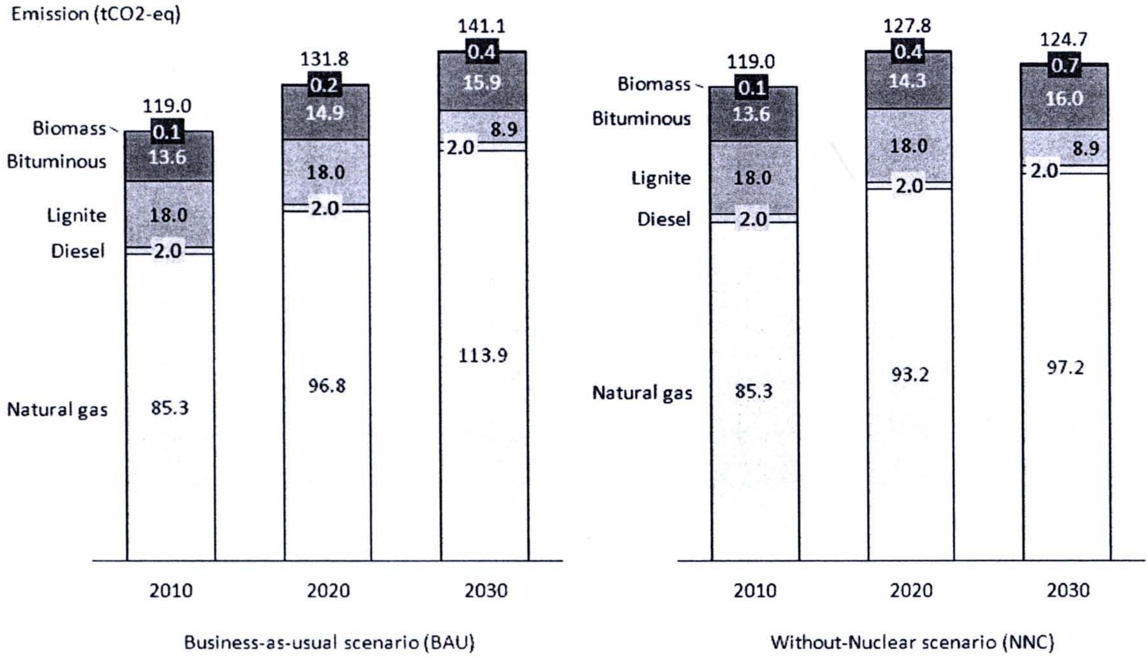

Figure 6 Comparison of GHGs emission between BAU and NNC scenario

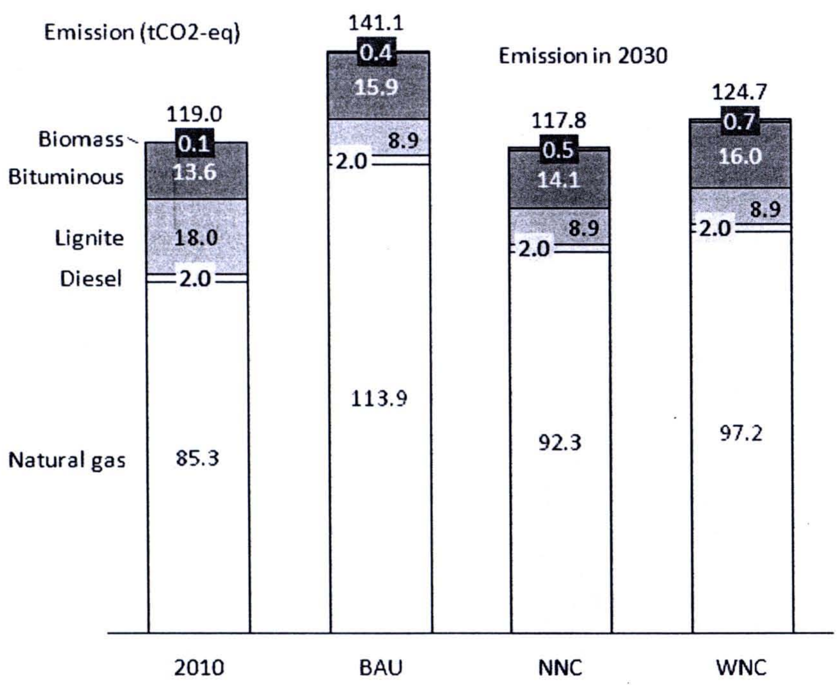

Figure 7 Comparison of GHGs emission of three scenarios in 2030

4.3 Cost comparison and abatement opportunities

Abatement costs are defined as the incremental cost of a low-emission technology compared to the reference case (BAU), measured as USD per tCO_2-eq abated emissions. Abatement costs include annualized repayments for capital expenditure and operating expenditure. The cost does therefore represent the pure "project cost" to install and operate the low-emission technology. For calculation of carbon dioxide emission saving, this study use methodology based on IEA [15] for calculating carbon dioxide emission saving under different of emission reduction options then chart the marginal abatement cost curve (MACC) which is the valuable tools for driving forecast of carbon allowance prices, prioritizing low carbon investment opportunities and shaping policy discussions around a national climate strategy [16-17].

As given in Table 5, numbers of cost and economic assumptions are made to construct the scenarios. The abatement potential is the amount of carbon dioxide emissions avoided each year using the new technology, more efficient machinery and fuel substitution to low carbon sources. Table 4 provides fuel prices (based on 2010) assumed in scenarios for estimated electricity generation cost under different scenario assumption. From emission estimation shows 194.62 $MtCO_2$ of abatement in 2030 in WNC development pathway at a cost less than $17.29/ton and WNC and NNC the abatement cost are 146.66 $MtCO_2$ and $27.89/ton respectively However, there are also many opportunities to reduce emission and these options fall into four board categories: renewable energy, carbon capture and storage (CCS), nuclear energy and demand reduction through energy efficiency. The emission abatement potential in power sector is achieved by various groups of abatement measures as follow. First, implement energy efficiency improvements and demand reduction. The 468.70 TWh of electricity demand in the BAU would be reduced to 398.39 TWh if all electricity saving measures were realized in electricity consuming sector and the total net emissions saving from this approximately 119.91 $MtCO_2$-eq in 2030. Second, diversification to low carbon sources fuel in short-term and long-term fuel switching. There are many promising renewable energy technologies and the key technologies providing abatement are wind, solar photovoltaic (PV), biomass, geothermal and hydropower. Then expansion of nuclear energy in fuel mixes and lastly, introduced CCS technology that can be used to address the emission from large point sources.

5 Discussion

5.1 Limitation of raw material supply

The carbon dioxide mitigation from the power sector in Thailand can be accomplished through both the technological substitutions in supply-side options, and the reduction of power generation through adoption of demand-side-management options. The traditional power generation expansion planning has focused only on supply-side options. The potential from biomass supply is evenly distribute throughout the country. In the North and Northeastern parts, farmers prefer open-field burning of the residue. However, in Southern part, rice straw is used as a fodder and would be collected by the farmers. Farmers in the central part of Thailand prefer to burn the rice straw due to wet conditions (rain/flooding at the time of harvest) and added expenses for waste collection. The rice statistics data in Thailand were roughly represented according to major harvest and second harvest. Major harvest would be from May/June until November/December and second harvest is from December/January until May/June. Table 7summarized the potential of major crop for biomass development in Thailand.

The limitation of raw material supply has recently become the prominent barrier for expansion of renewable energy utilization especially for biomass. Due to seasonal and spatial variation of biomass supply, it restricts the power plants unable to have a continuous operation or operate to the full capacity. This greatly affects the cost-effectiveness of the business. Moreover, the quantity and quality of renewable resources has become the prominent barrier. Most of biomass resources can only produced during harvesting season; for example, period of sugar harvesting is limited (5 months from December to April). Thus, electricity from the sugar factory is mostly seasonal [18-19]. Moreover, the intensive cultivation of biomass may stress water resources, depleting soil nutrients, and displace open space by withdrawing land from other natural uses. Large-scale production of biomass for energy purposes could compete with use of land, water, and energy for production of foods or woods and grasses for construction of shelters.

Logistics and transportation of renewable resources especially biomass fuel are the another barrier of renewable energy utilization. Most of renewable energy is bulky and distributed over vast areas, which could cause high transportation expenses. Biomass resources should be utilized by nearby facility. If biomass has to be transported by farm equipment much over 100 km to a processing point or use facility, a substantial fraction of the energy content of biomass itself is consumed in the transportation process [20]. According to government policy on fuel diversification to renewable energy, the declaration of sufficient fuel supply to prevent fuel shortage is the main criteria used for selecting the small projects to receive feed-in tariff or "adder" from EGAT or PEA.

5.2 Political and regulatory obstructers

Indeed, the barrier to greater renewable penetration is the lack of enabling policy and regulatory frameworks, which usually favor traditional energy sources. The key role for government is to focus on policy design and legislation to attract private sector investment. As renewable energy technology becomes more commercially mature, government will become less significant as providers of the direct capital support needed to make up the cost difference relative to conventional generation. Mallon express the importance of cost internalization (environmental and social damage cost) made cost of renewable higher when compared with thermal (nuclear and fossil) electricity generation [21]. Siegel et al. express investment of renewable energy companies not only generates revenues by providing clean, green power for consumers, but they can also generate additional revenues by simply offering an "offset" to companies that emit less greenhouse gas emissions (GHG). It is clearly beyond the budgets of most government to directly inject money into renewable in order to fast track a competitive industry [22]. A handful of demonstration projects might be useful, good examples of financial incentive provided by the Ministry of Energy is "ESCO Venture Capital Funds" for providing equity for small renewable energy and energy efficiency projects undertaken by small entrepreneurs with limited capital. The fund should also be provided financial assistance for equipment leasing, credit guarantee facility, technical assistance and carbon market [23].

It should be noted that without subsidies, biomass power projects are unable to compete with fossil fuel power plants due to the difference in scale on which conventional plants and renewable energy plants operate [24]. Government set price at which they can sell their renewable power to the grid, thus effectively providing essentially a guaranteed return on the renewable energy investment and making it easier for renewable energy projects to obtain banking approval for the capital costs of the project. For example, waste incineration is not likely to be cost-effective at this time in Thailand. Incineration of municipal solid waste is a costly and operationally complex alternative to landfills. Government subsidies are only possible sources of financing, however this issue is not a widely discussion upon by the public, politicians, and international financial institutions. Feed-in tariffs in practice have definitely provided a hugh boost for renewable energy projects. Another barrier or driven constrains of biomass utilization are still high in price. Fluctuation of fossil fuel price also affects the competitiveness and utilization of renewable energy. Moreira expressed most of modern biomass utilization are being driven by energy security motivation [25]. Fossil fuel price has been increasing in the last 3 year due to various reasons, when fuel price are high, some industries change their main fuels from fossil fuel to use rice husk for lowering price. Average price of rice husk has increase from 767 THB/ton in 2006 (maximum price is 799 THB/ton) to 864 THB/ton in 2009 (maximum price is 1,042 THB/ton). However, when the fossil price was dropped, demands for biofuel also decreased.

Tester et al. [20] indicated that if fossil fuel prices rise to include cost of carbon management, consumers may also modify their consumption patterns. Through a system known as carbon trading, a market - based mechanism that helps mitigate the increase of carbon dioxide in the atmosphere, renewable energy companies (as well as other entities that provide offsets, such as forestry management companies, for instance) can sell carbon credits to companies that emit carbon dioxide into the atmosphere and want to balance out their emissions. The government should refocus its energy development strategy and consider more on how to deliver the actual price of energy to the citizens, instead of lowering the price to favor industrial development without carefully considering externality environmental and social costs. The challenge is how to internalize all externality (e.g. environmental damages cost) caused by using fossil fuels, and set up a financial structure i.e. tax system to bring the right energy price to consumers. This will help promoting the fair competition between renewable energy and traditional fuels and bring the country to a sustainable future.

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Table 1 Target for electricity generation from renewable energy during 2008 to 2022

Unit (MW)	Actual 2009	Target		
		2008-2011	2012-2016	2017-2022
Solar	32	55	95	500
Wind	1	115	375	800
Mini/micro hydropower	56	165	281	324
Biomass	1,610	2,800	3,220	3,700
Municipal solid waste	46	78	130	160
Biogas	5	60	90	120
Total	1,750	3,273	4,191	5,605

Source: Ministry of Energy [7] and EGAT [8]

Table 2 List of scenarios in this study

Scenario	Policies and measures	Scenario description
Scenario 1: Baseline scenario (BAU)	Follows continuous trends in existing technologies and policies.	Of the three scenarios, this is the most conservative in project technical development in the electricity sector. Growth of demand in residential, commercial and industrial to follow Load Forecast Report 2010, reduced reserve margin from 28.10 % in 2010 to 15.0 % in 2030. Electricity expansion and fuel diversification follow PDP-2010 electricity development pathways.
Scenario 2: With-Nuclear (WNC)	Maximize growth of renewable energy and nuclear energy	Reduced electricity demand 15% at 2030 when compared with BAU scenario by implementation demand side management, energy efficiency policy, renovation of existing electricity plants to increase output per unit of fuel or energy input and replacement of older, less-efficient plant with latest technologies. Maximize utilization of low carbon content fuel e.g. renewable energy, hydropower and nuclear in fuel mixed to reach Alternatives Energy Development Plan (AEDP)'s target
Scenario 3: Without- Nuclear (NNC)	Maximum growth of renewable and no nuclear	Same energy demand as With-Nuclear scenario and increase proportion of renewable energy. But this scenario represent expansion pathway if nuclear development cannot implement because of unaccepted by public.

Table 3 Composition of energy supply compared with base year

Fuel	Base year 2010		Capacity at 2030					
			BAU		WNC		NNC	
	MW	%	MW	%	MW	%	MW	%
Natural Gas	21,378.00	71.76	28,692.00	53.62	23,048.78	50.68	24,335.78	53.51
Coal	3,897.00	13.08	10,827.00	20.24	8,026.47	17.65	11,029.48	24.25
Oil	320.00	1.07	315.00	0.59	315.00	0.69	315.00	0.69
Diesel	4.00	0.01	4.00	0.01	4.00	0.01	4.00	0.01
Renewable	4,191.00	14.07	8,667.00	16.20	9,085.00	19.98	9,795.00	21.54
Hydropower	3,453.94	11.59	4,138.00	7.73	3,663.94	8.06	3,777.94	8.31
Wind	163.32	0.55	475.19	0.89	963.32	2.12	963.32	2.12
Solar	65.61	0.22	1,218.09	2.28	815.61	1.79	565.61	1.24
MSW	79.53	0.27	118.27	0.22	239.53	0.53	239.53	0.53
Biogas	22.18	0.07	68.38	0.13	136.18	0.30	142.18	0.31
Biomass	406.43	1.36	2,649.07	4.95	3,266.43	7.18	4,106.43	9.03
Nuclear	0.00	0.00	5,000.00	9.34	5,000	10.99	0.00	0.00
Total	29,790.00	100.00	53,505.00	100.00	45,479.25	100.00	45,479.25	100.00

Table 4 Fuel prices (based on 2010) assumed in emission estimation

Fuel type	Fuel price (USD/MWh)	Escalation rate (%)
Domestic coal (Lignite)	14.76	1.5
Imported coal (Bituminous)	24.78	1.5
Diesel Oil	137.61	3.0
Domestic natural gas (GOT)	45.43	2.0
Domestic natural gas (Myanmar)	61.29	2.0
Biomass	77.96	2.0
Biogas	8.90	2.0
Nuclear	9.33	-

Table 5 Carbon dioxide emission comparison summary (million tones of CO_2)

Scenario	Year					Total (2010-2030)
	2010	2015	2020	2025	2030	
Emission ($MtCO_2$-eq)						
BAU	118.97	136.28	131.82	27.12	141.07	2,505.63
With-nuclear (WNC)	118.97	130.89	126.73	109.43	117.78	2,289.73
Without-nuclear (NNC)	118.97	130.65	127.81	114.99	124.68	2,337.69
Cost of electricity (million USD)						
BAU	-	673.83	1,255.89	2,571.22	3,750.44	33,918.03
With-nuclear (WNC)	-	674.40	1,099.85	2,213.73	3,096.04	29,097.61
Without-nuclear (NNC)	-	664.23	946.04	1,826.22	2,649.15	25,428.22
Emission per kWh (tCO_2/kWh)						
BAU	0.0004559	0.0004249	0.0003908	0.0003329	0.0003010	0.0003354
With-nuclear (WNC)	0.0004559	0.0004240	0.0004061	0.0003229	0.0002956	0.0003339
Without-nuclear (NNC)	0.0004559	0.0004232	0.0004096	0.0003393	0.0003129	0.0003409
Cost per kWh (USD/kWh)						
BAU	-	0.202252	0.104964	0.049438	0.037615	0.073873
With-nuclear (WNC)	-	0.194091	0.115225	0.049431	0.038043	0.078691
Without-nuclear (NNC)	-	0.196691	0.135104	0.062967	0.047063	0.091933
BAU vs. WNC reduction	-	-4.57	-3.79	-16.38	-21.98	-194.62
% reduction	-	-4.12	-4.02	-16.17	-19.77	-9.43
NPCWNC – NPCBAU (Billion USD)						.36
Abatement cost (USD/tCO2-eq)						7.29
BAU vs. NNC reduction		-4.82	-2.70	-10.82	-15.09	-146.66
% reduction		-4.31	-3.14	-10.54	-13.15	-7.18
NPCNNC – NPCBAU (Billion USD)						.09
Abatement cost (USD/tCO2-eq)						7.89

Table 6 Adder to the normal tariff for increase incentives for renewable energy expansion

Fuel Type	Adder		Target in 2009-2021 (MW)
	Baht/kWh	US cents/kWh	
Biomass			3,700
< 1 MW	0.50	1.43	
> 1 MW	0.30	0.86	
Biogas			120
< 1 MW	0.50	1.43	
> 1 MW	0.30	0.86	
Waste			160
Fertilization/ Landfill	2.50	7.14	
Thermal process	3.50	10	
Wind			800
< 50 kW	4.50	12.86	
> 50 kW	3.50	10	
Hydropower			324
50 kW to <200 kW	0.80	2.29	
< 50 kW	1.50	4.29	
Solar	8.00	22.86	500
Total Capacity			5,604

Source: Ministry of Energy [7]

Table 7 Evaluation of biomass potential in 2009

No	Main crop	Yield (million ton)	Biomass	Estimated biomass (million ton)	Non use fraction	Potential biomass (million ton)
1	Rice	31.50	Rice Husk	7.25	0.19	1.38
			Rice Straw	15.55	0.29	4.48
2	Sugarcane	73.50	Sugarcane leaves	12.49	0.55	6.87
3	Cassava	8.22	Casava trunks	0.74	0.41	0.30
			Cassava rhizome	1.64	0.66	1.08
4	Corn	6.91	Corn cobs	1.66	0.70	1.16
			Corn trunk	5.66	0.61	3.40
5	Palm	8.16	Palm cluster	2.61	0.38	0.99
6	Rubber	232,008.94 (rai)	Rubber slaps	0.70	0.41	0.29
			Roots	1.16	0.95	1.10
7	Other wood		Woodchips	1.89	1.00	1.89
	Total			51.35	6.15	22.94

Source: Office of Agricultural Economics, Ministry of Agriculture [26], Department of Livestock, Ministry of Agriculture [27]

APPENDIX C

Projected costs of generating electricity in Thailand[1]

Narumitr Sawangphol[2] and Chanathip Pharino[3]

1 Abstract

This study, cost data were provided for more than 43 power plants. This comprises 4 coal-fired power plants, 19 gas-fired power plants, and 10 plants based on other fuels or technologies. The data provided for the study highlight the increasing interest in renewable energy sources for electricity generation, in particular in combined heat and power plants. The technologies considered were all conventional boilers except two advanced integrated coal gasification plants. Most of the coal-fired power plants for which cost estimates were provided would be equipped with pollution control devices that reduce atmospheric emissions of sulphur and nitrogen oxides, dust and particulate. Hydropower plants are excluded from this study because their costs are site specific and, therefore, not relevant for comparison to other alternatives in the framework adopted.

The cost estimates do not substitute for detailed economic evaluations required by investors and utilities at the stage of project decision and implementation that should be based on project specific assumptions, using a framework adapted to the local conditions and a methodology adapted to the particular context of the investors and other stakeholders. Nevertheless, the projected costs provided by the present study, together with the assumptions adopted in cost calculations, are of interest to investors for benchmarking purpose as well as to investigate the impact of various factors on generation costs.

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1 Already submitted to Energy Policy since November 2009

2 International Postgraduate Program in Environmental Management, Graduate School, Chulalongkorn University and Center of Excellence for Environmental and Hazardous Waste Management (EHWM), Chulalongkorn University

3 Department of Environmental Engineering, Faculty of Engineering, Chulalongkorn University

2 Objectives and scope

The overall objective of the studies in the series is to provide reliable information on the economics of electricity generation. The study is to serve as a resource for policy makers and industry professionals as an input for understanding generating costs and technologies better. For this purpose, cost data provided by gathering information from literature review, environmental impact assessment report, site visiting, interviewing, etc., to estimate generation costs using a commonly agreed methodology and generic assumptions followed [1].

3 Background

Levelized Energy Cost (LEC, also called Levelized Cost of Energy or LCOE) is a cost of generating energy (usually electricity) for a particular system. It is an economic assessment of the cost the energy-generating system including all the costs over its lifetime: initial investment, operations and maintenance, cost of fuel, cost of capital. LCOE is equivalent to the average price consumers would have to pay to exactly repay the investor for capital O&M and fuel costs with a rate of return equal to the discount rate. A net present value calculation is performed and solved in such a way that for the value of the LEC chosen, the project's net present value becomes zero [1-2].

The LCOE is one analytical tool that can be used to compare alternative technologies when different scales of operation, investment or operating time periods exist. For example, the LCOE could be used to compare the cost of energy generated by a PV power plant with that of a fossil fuel generating unit or another renewable technology [1]. Nevertheless, LCOE approach often used to help assess economic profitability of a planned electricity generation plant or to compare two or more alternative plant investments. LCOE approach usually does not capture the following components:

– Systems factors like transmission costs and other network costs such as impact on system balancing, impact on state/system energy security.

– Externalities like government funded research, residual insurance responsibilities that fall to government, external costs of pollution damage or external benefits (e.g. value of learning to future generations).

– Business impacts like option value (differences in future flexibility), cost of information gathering, effects of fuel price and future revenue volatility, future changes in legislation, portfolio value (reduction of risks by diversifying plant structure), strategic meaning for the specific company.

The LCOE approach does not substitute for the economic analysis of electricity systems that needs to be carried out at the national level. However, it provides robust cost estimates for different generation sources and technologies that can serve as a reference for more detailed case-specific studies. The costs calculated are intended to include all the direct cost elements borne by electricity generators which, thereby, have an impact on their technology and energy source choices. The nature of the data collected and the choice to carry out cost calculations with generic assumptions for key parameters imply that the results presented in the report are not comparable with the outcomes of economic studies performed by investors or plant owners to support their decision-making process on a specific project.

4 Research Methodology and Tools

The cost estimates presented in the study were calculated based on (The International Energy Agency [1] methodology, using input parameters provided by paper analysis, site visiting, and interviewing. The coverage of capital, O&M and fuel costs is described in the main body of the report. In the context of the studies in the series, all the components of the capital, O&M and fuel costs falling on the utility that would, therefore, influence its choice of generation options are taken into account. For example, station specific overheads, insurance premium and R&D expenditures borne by producers are included, as well as the costs associated with environmental protection measures and standards, e.g., implementation of abatement technologies.

In the other hand, tax on income and profit charged to the utility and any other overheads that do not influence the choice of technology are excluded. External costs that are not borne by the utility, such as costs associated with health and environmental impacts of residual emissions, are excluded also. Capital expenditures in each year, including construction, refurbishment and decommissioning expenses when applicable, are provided in a table of expense schedule covering the entire period during which expenses are expected to be incurred. O&M costs per unit of net installed capacity and per year are provided for the period covering the entire economic lifetime of the plant. Fuel costs, at the power plant boundary, are provided for the year of commissioning and an escalation rate in each year is given, when applicable, during the economic lifetime of the plant. As most of the expenditures occur in multiple instances during the course of the year, rather than one single event, annual costs have been assumed to occur at mid-year for discounting purposes. With regard to outputs from the power plants, electricity generation in the year t was calculated taking into account the net capacity of the unit and the assumed capacity/load factor.

The constant-money Levelized lifetime cost method was adopted to calculate the generation cost estimates presented in this study. The formula applied to calculate, for each power plant, the levelized electricity generation cost (LCOE) is the following:

$$LCOE = \frac{\sum\left[(I_t + M_t + F_t)(1+r)^{-t}\right]}{\sum\left[E_t(1+r)^{-t}\right]}$$

With

LCOE = Average lifetime levelized electricity generation cost

I_t = Investment expenditures in the year t

M_t = Operations and maintenance expenditures in the year t

F_t = Fuel expenditures in the year t

E_t = Electricity generation in the year t

r = Discount rate

The levelized lifetime cost per kWh of electricity generated is the ratio of total lifetime expenses versus total expected outputs, expressed in terms of present value equivalent. This cost is equivalent to the average price that would have to be paid by consumers to repay exactly the investor/operator for the capital, operation and maintenance and fuel expenses, with a rate of return equal to the discount rate. The date selected as the base year for discounting purpose does not affect the levelized cost comparison between different plants. The absolute values of levelized costs will, however, differ from base year to base year in periods of inflation or deflation. Generally, levelized cost estimations are carried out in constant money, i.e. in real value, and inflation is not taken into account in cost elements. Nevertheless, projected price escalation or decrease is taken into account in the real price of goods or services such as fossil fuels or staff salaries (within O&M costs), when applicable.

5 Results

5.1 Overnight construction costs

The overnight construction costs is defined as the total of all costs incurred for building the plant accounted for as if they were spent instantaneously. For coal-fired power plant, the overnight construction costs vary between 29,319.75 THB/kW and 50,125.00 THB/kW. For natural gas power plant, the overnight construction costs vary between 55,015.65 THB/kW and 192,217.26 THB/kW. Renewable power plant, the overnight construction costs vary between 6,946.67 THB/kW and 64,428.64 THB/kW. The specific overnight construction costs of the power plants included in this study are displayed on figure 1.

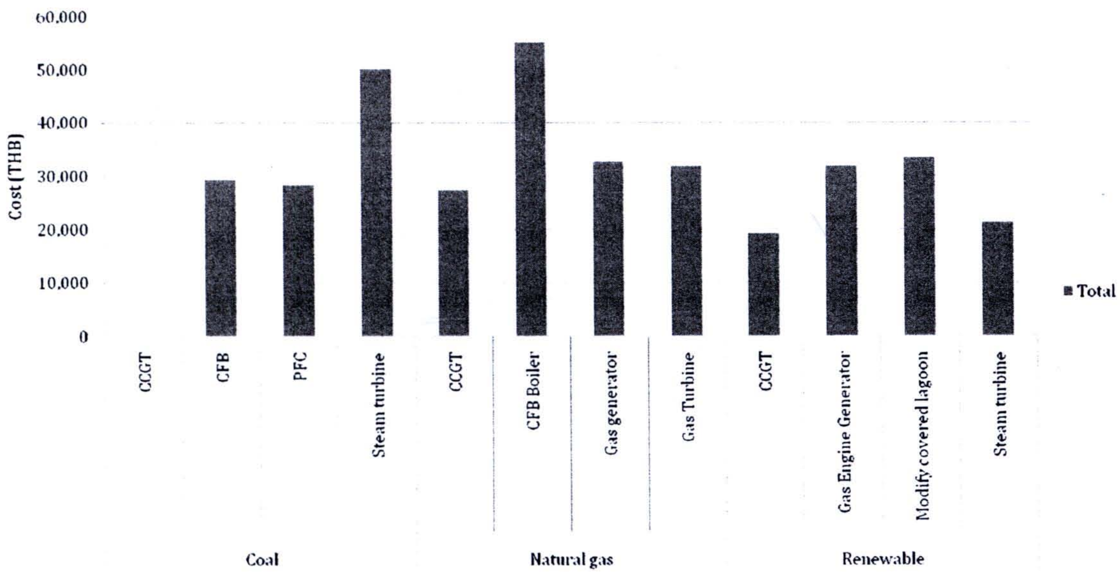

Figure 1 Overnight construction cost (THB/kW) of coal fired power plant

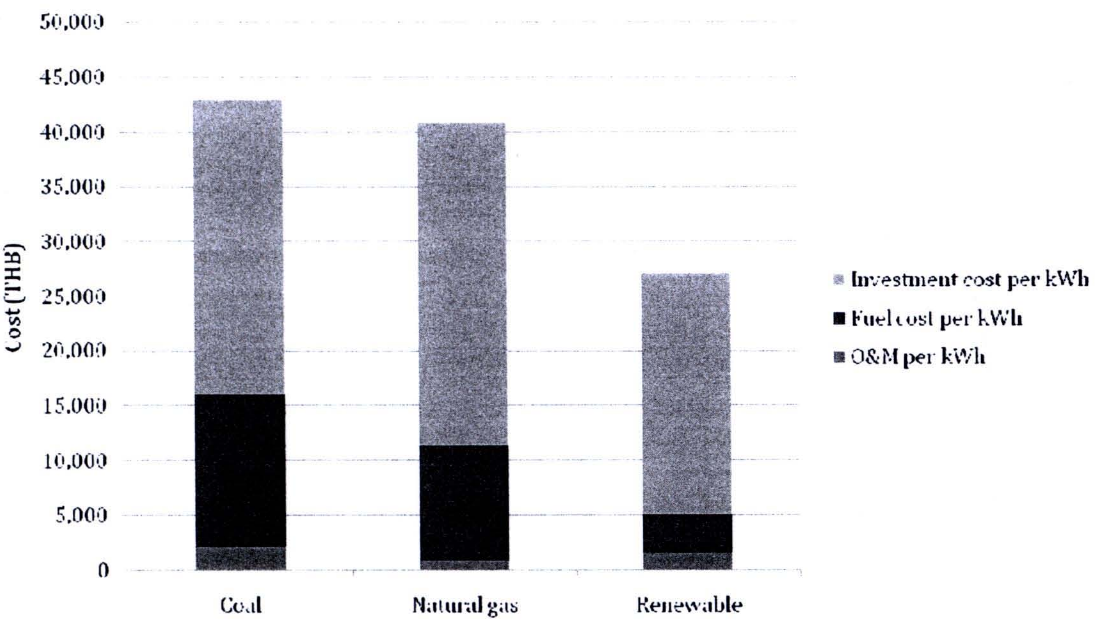

Figure 2 Cost of electricity classified by fuel type

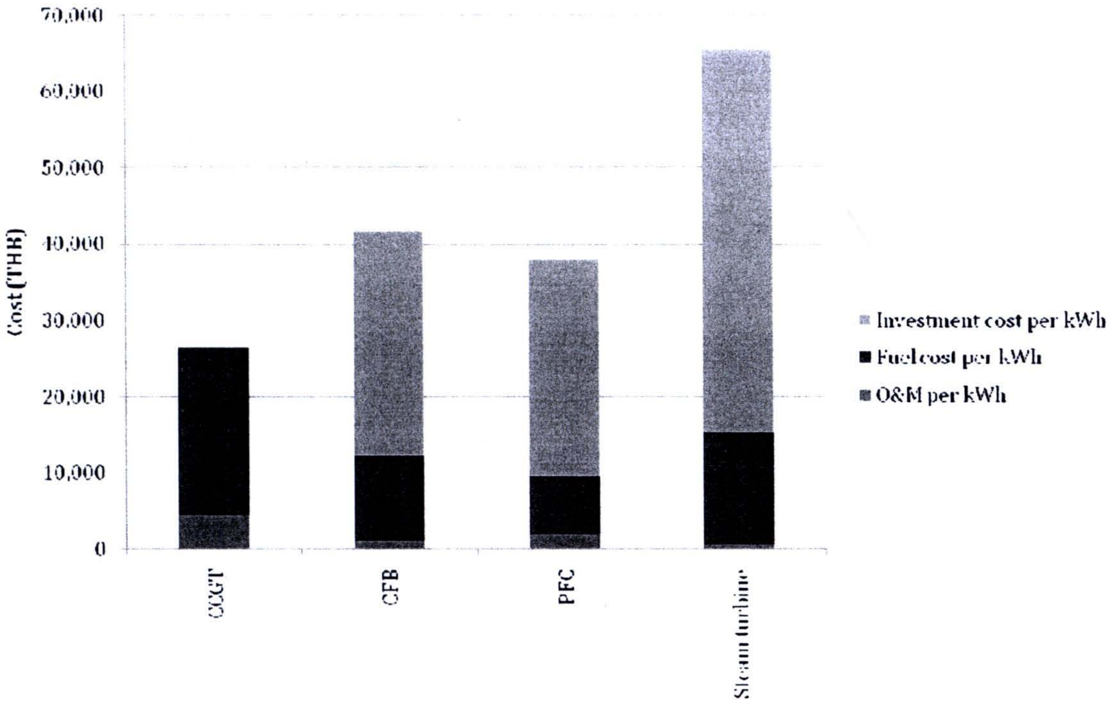

Figure 3 Cost of coal generation electricity classified by technology

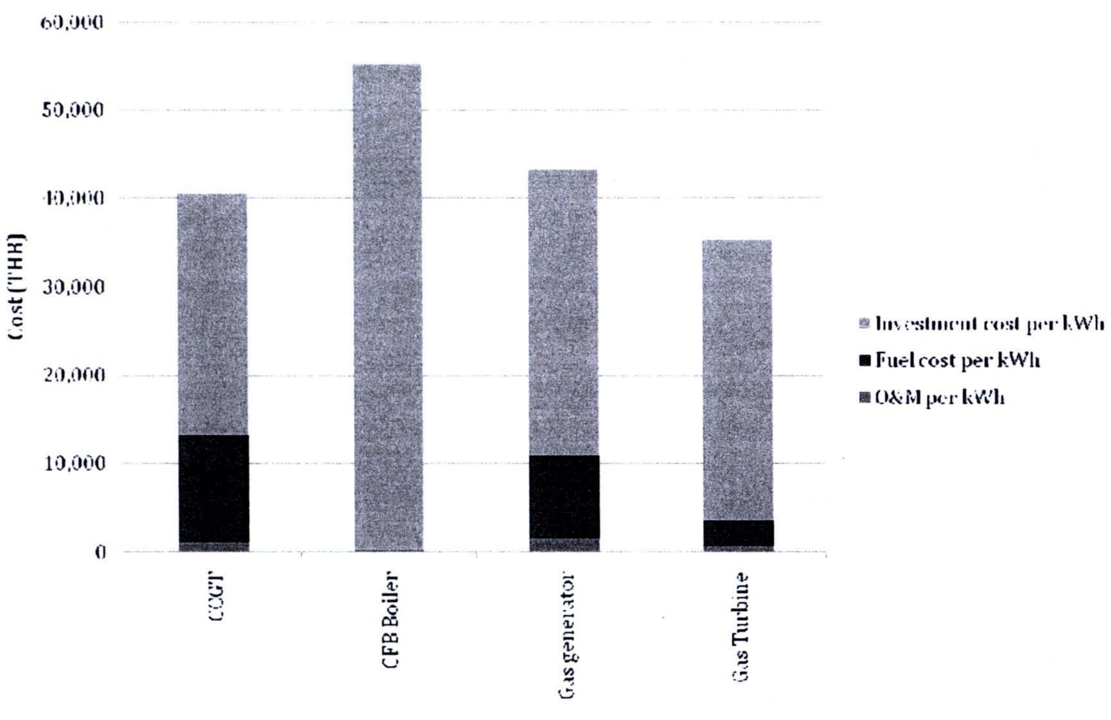

Figure 4 Cost of natural gas generation electricity classified by technology

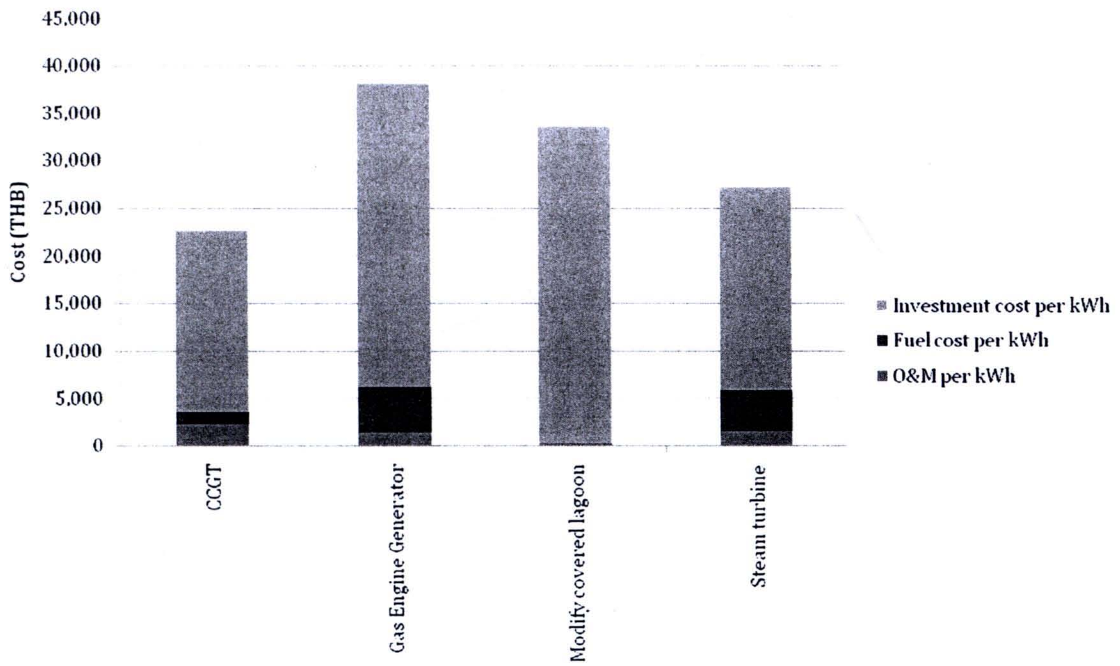

Figure 5 Cost of renewable generation electricity classified by technology

5.2 O&M costs

The O&M costs is defined as the total of all costs incurred for building the plant accounted for as if they were spent instantaneously. The specific overnight construction costs of power plants included in this study is displayed on Figure 6.

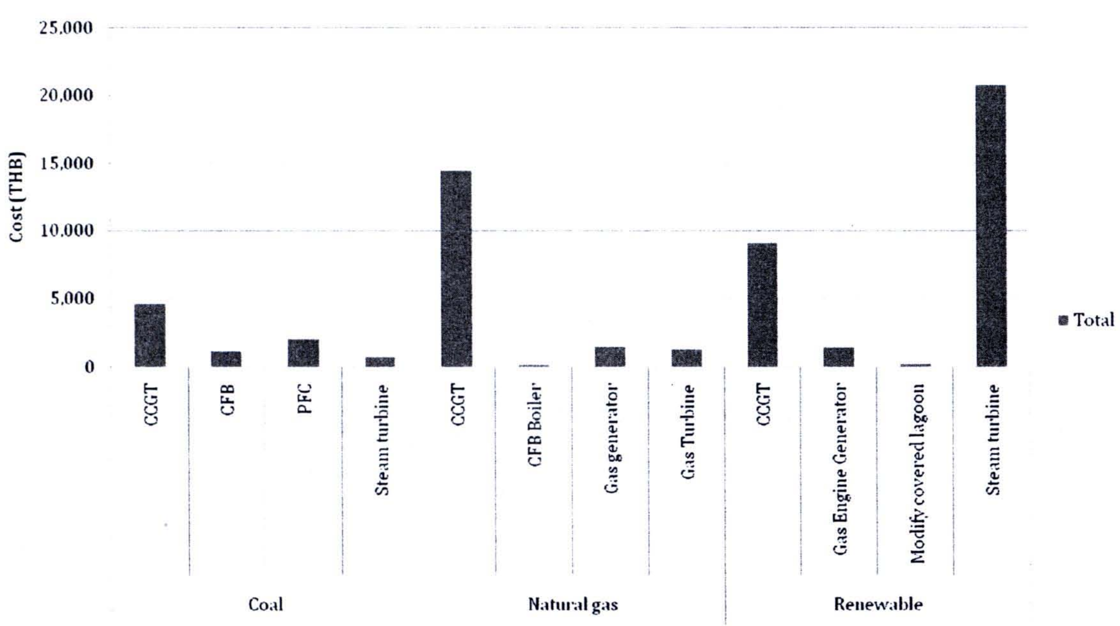

Figure 6 Specific annual O&M cost (per kW) of different types of fuel

5.3 Levelized cost of energy

At 5% discount rate, the levelized costs of generating electricity from coal-fired power plant vary between 29,155.33 THB/kW and 72,289.66 THB/kW. The levelized costs of generating electricity from natural gas power plant vary between 6,795.59 THB/kW and 70,969.50 THB/kW. The levelized costs of generating electricity from renewable power plant (vary between 53.19 THB/kW and 88,721.41 THB/kW.

At 10% discount rate, the levelized costs of generating electricity from coal-fired power plant vary between 31,998.14 THB/kW and 79,338.31 THB/kW, natural gas power plants vary between 7,458.20 THB/kW and 242,085.35 THB/kW, renewable power plant vary between 58.37 THB/kW and 97,372.25 THB/kW respectively. It should be noted that fuel cost represents in average nearly 23.26 % of the total levelized cost.

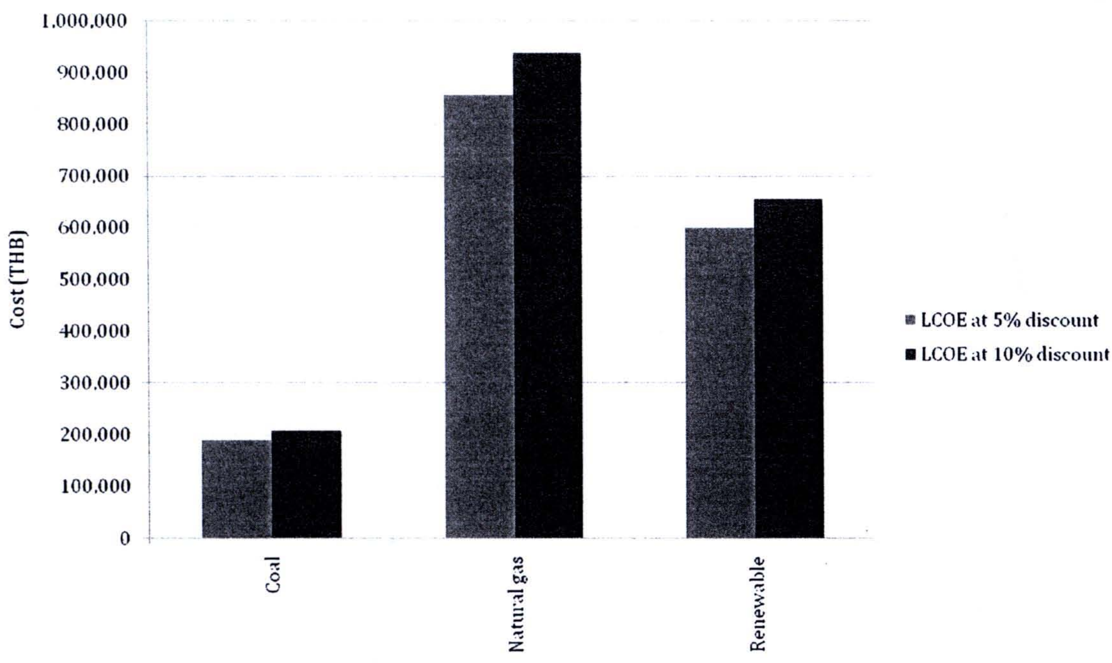

Figure 7 Levelized cost of coal generation electricity at different discount rate

Table 1 Coal plant specifications

No	Abbrev name of the plant	Plant type/emission control equipment incl. in cost	Turbine detail	Net capacity (MW)	Net thermal efficiency [LHV] (%)	Cost estimation source/date
1	COAL-1	PFC/low NO_x burner (LNB), ESP, FGD	2x717	1,430	38.7	P/2008
2	COAL-2	PFC/LNB, ESP, FGD	2x164	328	39.3	P/2008
3	COAL-3	CCGT, ESP,FGD	54+27+27	108	45.3	P/2008
4	COAL-4	STC/FGD	1x35.719	35.719	37.0	P/2009

Note:

STC = Steam turbine condensing plant, PFC = Pulverized fuel combustion, LNB = low NO_X burner, ESP = Electrostatic precipitator, FGD = Fuel gas desulphurization, NS = not specified, NA = not applicable, P = paper analysis

Table 2 Natural gas plant specifications

No	Abbrev name of the plant	Plant type/emission control equipment incl. in cost	Turbine detail	Net capacity (MW)	Net thermal efficiency [LHV] (%)	Cost estimation source/date
1	NG-1	CCGT/LNB	2x271.3, 2x284	1,600	55.0	P/2008
2	NG-2	CCGT/LNB	2x271.3, 2x284	1,600	55.4	P/2008
3	NG-3	CCGT/LNB, Water injection, Air filter	NA	1,468	56.1	P/2008
4	NG-4	CCGT/LNB	8x103, 4x100	1,232	54.4	P/2008
5	NG-5	CCGT/LNB	2x350	700	60.0	P/2008
6	NG-6	CCGT/NS	2x230, 1x260	720	57.0	P/2008
7	NG-7	CCGT/FF, ESP, FGD	6x45.529, 2x64.70	286	56.1	P/2008
8	NG-8	CCGT/NS	6x50.80	216	57.0	P/2008
9	NG-9	CCGT/ESP,FGD	NS	130	57.6	P/2008
10	NG-10	CCGT, CFB boiler/NS	NS	130	57.0	P/2008
11	NG-11	CCGT/NS	2x93.0	127	60.0	P/2008
12	NG-12	CCGT/NS	NS	122	57.3	P/2008
13	NG-13	ST/NS	NS	112	55.7	P/2008
14	NG-14	CCGT/NS	NS	110	54.0	P/2009
15	NG-15	CCGT/FF, ESP, FGD	2x51.260	77	57.3	P/2009
16	NG-16	CCGT/NS	NS	60	57.8	P/2008
17	NG-17	GT/NS	NS	23	61.0	P/2009
18	NG-18	CCGT/NS	1x24.33, 1x1.82	4.25	59.1	P/2009
19	NG-19	GT/NS	2x9.75	1.72	57.4	P/2008

Table 3 Renewable plant specifications

No	Abbrev name of the plant	Plant type/emission control equipment incl. in cost	Turbine detail	Net capacity (MW)	Net thermal efficiency [LHV] (%)	Cost estimation source/date
1	REN-1	ST/NS	4x3.91,1x21.1,1x31.25	43.5		P/2008
2	REN-2	CCGT/NS	NS	42.0		P/2008
3	REN-3	ST/NS	3x12	36.0		P/2008
4	REN-4	ST/Multi-cyclone, ESP	NS	23.0		P/2008
5	REN-5	ST/NS	NS	27.5		P/2008
6	REN-6	ST/NS	2x3.0, 1x1.6, 1x12.0	19.6		P/2008
7	REN-7	ST/NS	1x12, 1x6	18.0		P/2008
8	REN-8	Condensing turbine/NS	1x12	12.0		P/2008
9	REN-9	ST/Multi-cyclone, ESP	1x10	9.9		P/2008
10	REN-10	ST/NS	NS	9.9		P/2008
11	REN-11	ST/NS	NS	9.5		P/2008
12	REN-12	ST/FF, NS	NS	8.64		P/2008
13	REN-13	ST/NS	NS	8.5		P/2008
14	REN-14	ST/ESP	NS	4.8		P/2008
15	REN-15	GT/NS	1x3	3.0		P/2008
16	REN-16	ST/NS	1x3	3.0		P/2008
17	REN-17	ST/NS	NS	3.0		P/2008
18	REN-18	GT/NS	NS	2.48		P/2008
19	REN-19	GT/NS	NS	0.31		P/2008
20	REN-20	GT/NS	NS	0.16		P/2008

Table 4 Coal fired plant investment cost coverage

Cost coverage	Name			
	COAL-1	COAL -2	COAL -3	COAL -4
Overnight capital costs: Construction				
Direct costs				
Site preparation	✓	✓	✓	✓
Civil work	✓	✓	✓	✓
Material, equipment & manpower for construction	✓	✓	✓	✓
Indirect costs				
Design, engineering & supervision	✓	✓	✓	✓
Provisional equipment & operation	✓	✓	✓	✓
Worksite administrative expenses	✓	✓	✓	✓
Owner's costs				
General administration	NS	✓	✓	✓
Pre-operation	✓	✓	✓	✓
R&D (plant specific)	×	×	✓	×
Spare parts	✓	✓	✓	✓
Site selection, acquisition, licensing & public relations	✓	✓	✓	✓
Taxes (local/regional, plant specific)	×	×	×	×
Others				
Major refurbish	×	✓	×	×
Decommissioning	✓	×	×	×
Credits	×	×	×	×
Contingency	×	×	×	×
Miscellaneous	NS	NS	NS	NS
O&M cost				
Operation	✓	✓	✓	✓
Maintenance (materials, manpower, services)	✓	✓	✓	✓
Engineering support staff	✓	✓	✓	✓
Administration	✓	✓	✓	✓
General expenses of central services (outside the site)	✓	✓	✓	✓
Taxes & duties (plant specific)	✓	✓	✓	✓
Insurance (plant specific)	✓	✓	✓	✓
Major refurbishment	✓	✓	✓	✓
Operating waste disposal (e.g. coal ash, sludge)	✓	✓	✓	✓
Credit	×	✓	✓	✓
Others	✓	✓	✓	✓

Abbreviations: ✓= include, × = exclude, NS = not specified

Table 5 Natural gas fired plant investment cost coverage

Cost coverage	Power plant Name			
	NG-1	NG-2	NG-3	NG-4
Overnight capital costs: Construction				
Direct costs				
Site preparation	✓	✓	✓	✓
Civil work	✓	✓	✓	✓
Material, equipment & manpower for construction	✓	✓	✓	✓
Indirect costs				
Design, engineering & supervision	✓	✓	✓	✓
Provisional equipment & operation	✓	×	×	×
Worksite administrative expenses	✓	✓	✓	✓
Owner's costs				
General administration	NS	✓	×	×
Pre-operation	✓	✓	✓	✓
R&D (plant specific)	×	×	×	×
Spare parts	×	NS	NS	×
Site selection, acquisition, licensing & public relations	✓	✓	✓	✓
Taxes (local/regional, plant specific)	NS	NS	NS	NS
Others				
Major refurbish	✓	✓	✓	✓
Decommissioning	✓	NS	NS	✓
Credits	✓	✓	✓	✓
Contingency	✓	✓	✓	✓
Miscellaneous	NS	NS	NS	✓
O&M cost				
Operation	✓	✓	✓	✓
Maintenance (materials, manpower, services)	✓	✓	✓	✓
Engineering support staff	✓	×	×	×
Administration	✓	×	✓	✓
General expenses of central services (outside the site)	✓	✓	✓	✓
Taxes & duties (plant specific)	✓	×	×	×
Insurance (plant specific)	×	×	×	×
Major refurbishment	✓	NS	NS	✓
Operating waste disposal (e.g. coal ash, sludge)	NS	NS	✓	✓
Credit	✓	✓	✓	✓
Others	✓	✓	✓	✓

Table 5 Natural gas fired plant investment cost coverage

Cost coverage	Power plant Name			
	NG-5	NG-6	NG-7	NG-8
Overnight capital costs: Construction				
Direct costs				
Site preparation	✓	✓	✓	✓
Civil work	✓	✓	✓	✓
Material, equipment & manpower for construction	✓	✓	✓	✓
Indirect costs				
Design, engineering & supervision	NS	✓	✓	✓
Provisional equipment & operation	NS	NS	✓	×
Worksite administrative expenses	✓	✓	×	×
Owner's costs				
General administration	NS	✓	✓	✓
Pre-operation	✓	✓	✓	×
R&D (plant specific)	✓	✓	✓	✓
Spare parts	✓	✓	✓	✓
Site selection, acquisition, licensing & public relations	✓	✓	✓	✓
Taxes (local/regional, plant specific)	NS	×	×	✓
Others				
Major refurbish	✓	✓	✓	✓
Decommissioning	✓	✓	✓	✓
Credits	✓	✓	✓	✓
Contingency	✓	✓	✓	✓
Miscellaneous	NS	NS	NS	NS
O&M cost				
Operation	✓	✓	✓	✓
Maintenance (materials, manpower, services)	✓	✓	✓	✓
Engineering support staff	✓	✓	✓	✓
Administration	×	NS	NS	✓
General expenses of central services (outside the site)	NS	NS	NS	NS
Taxes & duties (plant specific)	×	✓	✓	✓
Insurance (plant specific)	×	×	×	×
Major refurbishment	×	✓	×	✓
Operating waste disposal (e.g. coal ash, sludge)	✓	✓	✓	✓
Credit	✓	×	×	×
Others	×	×	×	×

Table 5 Natural gas fired plant investment cost coverage

Cost coverage	Power plant Name			
	NG-9	NG-10	NG-11	NG-12
Overnight capital costs: Construction				
Direct costs				
Site preparation	✓	✓	✓	✓
Civil work	✓	✓	✓	✓
Material, equipment & manpower for construction	✓	✓	✓	✓
Indirect costs				
Design, engineering & supervision	✓	✓	✓	✓
Provisional equipment & operation	×	✓	✓	×
Worksite administrative expenses	✓	✓	×	×
Owner's costs				
General administration	NS	×	✓	×
Pre-operation	✓	✓	✓	✓
R&D (plant specific)	✓	✓	✓	✓
Spare parts	✓	✓	✓	✓
Site selection, acquisition, licensing & public relations	✓	✓	✓	✓
Taxes (local/regional, plant specific)	×	×	×	×
Others				
Major refurbish	✓	✓	✓	✓
Decommissioning	✓	✓	✓	✓
Credits	✓	✓	✓	✓
Contingency	✓	✓	✓	×
Miscellaneous	✓	✓	NS	×
O&M cost				
Operation	✓	✓	✓	✓
Maintenance (materials, manpower, services)	✓	✓	✓	✓
Engineering support staff	✓	✓	✓	✓
Administration	×	✓	NS	✓
General expenses of central services (outside the site)	✓	✓	NS	✓
Taxes & duties (plant specific)	✓	✓	✓	✓
Insurance (plant specific)	✓	×	×	✓
Major refurbishment	✓	✓	×	✓
Operating waste disposal (e.g. coal ash, sludge)	✓	✓	✓	✓
Credit	×	×	×	×
Others	×	×	NS	×

Table 5 Natural gas fired plant investment cost coverage

Cost coverage	Power plant Name			
	NG-13	NG-14	NG-15	NG-16
Overnight capital costs: Construction				
Direct costs				
Site preparation	✓	✓	✓	✓
Civil work	✓	✓	✓	✓
Material, equipment & manpower for construction	✓	✓	✓	✓
Indirect costs				
Design, engineering & supervision	✓	✓	✓	✓
Provisional equipment & operation	✓	✓	✓	✓
Worksite administrative expenses	✓	✓	✓	✓
Owner's costs				
General administration	×	×	✓	×
Pre-operation	×	✓	×	×
R&D (plant specific)	×	✓	×	×
Spare parts	✓	✓	✓	✓
Site selection, acquisition, licensing & public relations	✓	✓	✓	✓
Taxes (local/regional, plant specific)	×	×	×	×
Others				
Major refurbish	✓	✓	✓	✓
Decommissioning	✓	✓	✓	✓
Credits	✓	✓	✓	✓
Contingency	✓	✓	✓	✓
Miscellaneous	×	×	×	×
O&M cost				
Operation	✓	✓	✓	✓
Maintenance (materials, manpower, services)	✓	✓	✓	✓
Engineering support staff	✓	✓	✓	✓
Administration	✓	✓	✓	✓
General expenses of central services (outside the site)	NS	×	×	×
Taxes & duties (plant specific)	NS	NS	✓	✓
Insurance (plant specific)	NS	NS	NS	×
Major refurbishment	NS	✓	NS	×
Operating waste disposal (e.g. coal ash, sludge)	✓	✓	✓	✓
Credit	NS	NS	NS	NS
Others	NS	NS	NS	NS

Table 5 Natural gas fired plant investment cost coverage

Cost coverage	Power plant Name		
	NG-17	NG-18	NG-19
Overnight capital costs: Construction			
Direct costs			
Site preparation	✓	✓	✓
Civil work	✓	✓	✓
Material, equipment & manpower for construction	✓	✓	✓
Indirect costs			
Design, engineering & supervision	✓	✓	✓
Provisional equipment & operation	✓	✓	✓
Worksite administrative expenses	✓	✓	✓
Owner's costs			
General administration	×	×	✓
Pre-operation	✓	✓	✓
R&D (plant specific)	×	×	×
Spare parts	✓	×	✓
Site selection, acquisition, licensing & public relations	✓	✓	✓
Taxes (local/regional, plant specific)	×	×	×
Others			
Major refurbish	✓	✓	✓
Decommissioning	✓	✓	✓
Credits	✓	✓	✓
Contingency	✓	✓	✓
Miscellaneous	×	×	×
O&M cost			
Operation	✓	✓	✓
Maintenance (materials, manpower, services)	✓	✓	✓
Engineering support staff	✓	✓	✓
Administration	✓	✓	✓
General expenses of central services (outside the site)	✓	✓	✓
Taxes & duties (plant specific)	×	×	×
Insurance (plant specific)	×	✓	✓
Major refurbishment	✓	✓	✓
Operating waste disposal (e.g. coal ash, sludge)	✓	✓	✓
Credit	×	×	×
Others	NS	NS	NS

Abbreviations: ✓= include, × = exclude, NS = not specified

Table 6 Renewable power plant investment cost coverage

Cost coverage	Power plant Name			
	REN-1	REN-2	REN-3	REN-4
Overnight capital costs: Construction				
Direct costs				
Site preparation	✓	✓	✓	✓
Civil work	✓	✓	✓	✓
Material, equipment & manpower for construction	✓	✓	✓	✓
Indirect costs				
Design, engineering & supervision	✓	✓	✓	✓
Provisional equipment & operation	✓	✓	✓	✓
Worksite administrative expenses	✓	✓	✓	✓
Owner's costs				
General administration	✓	✓	✓	✓
Pre-operation	✓	✓	✓	✓
R&D (plant specific)	×	×	×	×
Spare parts	✓	✓	✓	✓
Site selection, acquisition, licensing & public relations	✓	✓	✓	✓
Taxes (local/regional, plant specific)	×	×	×	×
Others				
Major refurbish	✓	✓	✓	✓
Decommissioning	✓	✓	✓	✓
Credits	✓	✓	✓	✓
Contingency	✓	✓	✓	✓
Miscellaneous	×	×	×	×
O&M cost				
Operation	✓	✓	✓	✓
Maintenance (materials, manpower, services)	✓	✓	✓	✓
Engineering support staff	✓	✓	✓	✓
Administration	✓	✓	✓	✓
General expenses of central services (outside the site)	✓	✓	✓	✓
Taxes & duties (plant specific)	×	×	×	×
Insurance (plant specific)	✓	✓	✓	✓
Major refurbishment	✓	✓	✓	✓
Operating waste disposal (e.g. coal ash, sludge)	✓	✓	✓	✓
Credit	×	NS	×	×
Others	NS	NS	NS	NS

Abbreviations: ✓= include, × = exclude, NS = not specified

Table 6 Renewable power plant investment cost coverage

Cost coverage	Power plant Name			
	REN-5	REN-6	REN-7	REN-8
Overnight capital costs: Construction				
Direct costs				
Site preparation	✓	✓	✓	✓
Civil work	✓	✓	✓	✓
Material, equipment & manpower for construction	✓	✓	✓	✓
Indirect costs				
Design, engineering & supervision	✓	✓	✓	✓
Provisional equipment & operation	✓	✓	✓	✓
Worksite administrative expenses	✓	✓	✓	✓
Owner's costs				
General administration	✓	✓	✓	✓
Pre-operation	✓	✓	✓	✓
R&D (plant specific)	×	×	×	×
Spare parts	✓	✓	✓	✓
Site selection, acquisition, licensing & public relations	✓	✓	✓	✓
Taxes (local/regional, plant specific)	×	×	×	×
Others				
Major refurbish	✓	✓	✓	✓
Decommissioning	✓	✓	✓	✓
Credits	✓	✓	✓	✓
Contingency	✓	✓	✓	✓
Miscellaneous	×	×	×	×
O&M cost				
Operation	✓	✓	✓	✓
Maintenance (materials, manpower, services)	✓	✓	✓	✓
Engineering support staff	✓	✓	✓	✓
Administration	✓	✓	✓	✓
General expenses of central services (outside the site)	✓	✓	✓	✓
Taxes & duties (plant specific)	×	×	×	×
Insurance (plant specific)	✓	✓	✓	✓
Major refurbishment	✓	✓	✓	✓
Operating waste disposal (e.g. coal ash, sludge)	✓	✓	✓	✓
Credit	×	×	×	×
Others	NS	NS	NS	×

Table 6 Renewable power plant investment cost coverage

Cost coverage	Power plant Name			
	REN-9	REN-10	REN-11	REN-12
Overnight capital costs: Construction				
Direct costs				
Site preparation	✓	✓	✓	✓
Civil work	✓	✓	✓	✓
Material, equipment & manpower for construction	✓	✓	✓	✓
Indirect costs				
Design, engineering & supervision	✓	✓	✓	✓
Provisional equipment & operation	✓	✓	✓	✓
Worksite administrative expenses	✓	✓	✓	✓
Owner's costs				
General administration	✓	✓	✓	✓
Pre-operation	✓	✓	✓	✓
R&D (plant specific)	×	×	×	×
Spare parts	✓	✓	✓	✓
Site selection, acquisition, licensing & public relations	✓	✓	✓	✓
Taxes (local/regional, plant specific)	×	×	×	×
Others				
Major refurbish	✓	✓	✓	✓
Decommissioning	✓	✓	✓	✓
Credits	✓	✓	✓	✓
Contingency	✓	✓	✓	✓
Miscellaneous	×	×	×	×
O&M cost				
Operation	✓	✓	✓	✓
Maintenance (materials, manpower, services)	✓	✓	✓	✓
Engineering support staff	✓	✓	✓	✓
Administration	✓	✓	✓	✓
General expenses of central services (outside the site)	✓	✓	✓	✓
Taxes & duties (plant specific)	×	×	×	×
Insurance (plant specific)	✓	✓	✓	✓
Major refurbishment	✓	✓	✓	✓
Operating waste disposal (e.g. coal ash, sludge)	✓	✓	✓	✓
Credit	×	×	×	×
Others	NS	NS	NS	NS

Table 6 Renewable power plant investment cost coverage

Cost coverage	Power plant Name			
	REN-13	REN-14	REN-15	REN-16
Overnight capital costs: Construction				
Direct costs				
Site preparation	✓	✓	✓	✓
Civil work	✓	✓	✓	✓
Material, equipment & manpower for construction	✓	✓	✓	✓
Indirect costs				
Design, engineering & supervision	✓	✓	✓	✓
Provisional equipment & operation	✓	✓	✓	✓
Worksite administrative expenses	✓	✓	✓	✓
Owner's costs				
General administration	✓	✓	✓	✓
Pre-operation	✓	✓	✓	✓
R&D (plant specific)	×	×	×	×
Spare parts	✓	✓	✓	✓
Site selection, acquisition, licensing & public relations	✓	✓	✓	✓
Taxes (local/regional, plant specific)	×	×	×	×
Others				
Major refurbish	✓	✓	✓	✓
Decommissioning	✓	✓	✓	✓
Credits	✓	✓	✓	✓
Contingency	✓	✓	✓	✓
Miscellaneous	×	×	×	×
O&M cost				
Operation	✓	✓	✓	✓
Maintenance (materials, manpower, services)	✓	✓	✓	✓
Engineering support staff	✓	✓	✓	✓
Administration	✓	✓	✓	✓
General expenses of central services (outside the site)	✓	✓	✓	✓
Taxes & duties (plant specific)	×	×	×	×
Insurance (plant specific)	✓	✓	✓	✓
Major refurbishment	✓	✓	✓	✓
Operating waste disposal (e.g. coal ash, sludge)	✓	✓	✓	✓
Credit	×	×	×	×
Others	NS	×	NS	NS

Table 6 Renewable power plant investment cost coverage

Cost coverage	Power plant Name			
	REN-17	REN-18	REN-19	REN-20
Overnight capital costs: Construction				
Direct costs				
Site preparation	✓	✓	✓	✓
Civil work	✓	✓	✓	✓
Material, equipment & manpower for construction	✓	✓	✓	✓
Indirect costs				
Design, engineering & supervision	✓	✓	✓	✓
Provisional equipment & operation	✓	✓	✓	✓
Worksite administrative expenses	✓	✓	✓	✓
Owner's costs				
General administration	✓	✓	✓	✓
Pre-operation	✓	✓	✓	✓
R&D (plant specific)	×	×	×	×
Spare parts	✓	✓	✓	✓
Site selection, acquisition, licensing & public relations	✓	✓	✓	✓
Taxes (local/regional, plant specific)	×	×	×	×
Others				
Major refurbish	✓	✓	✓	✓
Decommissioning	✓	✓	✓	✓
Credits	✓	✓	✓	✓
Contingency	✓	✓	✓	✓
Miscellaneous	×	×	×	×
O&M cost				
Operation	✓	✓	✓	✓
Maintenance (materials, manpower, services)	✓	✓	✓	✓
Engineering support staff	✓	✓	✓	✓
Administration	✓	✓	✓	✓
General expenses of central services (outside the site)	✓	✓	✓	✓
Taxes & duties (plant specific)	×	×	×	×
Insurance (plant specific)	✓	✓	✓	✓
Major refurbishment	✓	✓	✓	✓
Operating waste disposal (e.g. coal ash, sludge)	✓	✓	✓	✓
Credit	×	×	×	×
Others	NS	×	NS	NS

6 Conclusion

Cost estimates for power plants burning coal or lignite were provided by inspection of four power plants. The technologies considered were all conventional boilers except two advanced integrated coal gasification plants. Most of the coal-fired power plants for which cost estimates were provided would be equipped with pollution control devices that reduce atmospheric emissions of sulphur and nitrogen oxides, dust and particulate. Although the unit capacities of the coal plants considered range from 40 to 1,434 MW. Their net thermal efficiencies are generally close to or above 40 percent based on their lower heating value.

The cost estimates do not substitute for detailed economic evaluations required by investors and utilities at the stage of project decision and implementation that should be based on project specific assumptions, using a framework adapted to the local conditions and a methodology adapted to the particular context of the investors and other stakeholders. Nevertheless, the projected costs provided by the present study, together with the assumptions adopted in cost calculations, are of interest to investors for benchmarking purpose as well as to investigate the impact of various factors on generation costs.

7 References

[1] The International Energy Agency. Projected Costs of Generating Electricity. Paris: The International Energy Agency; 2005. p. 233.

[2] Wikipedia. Levelised energy cost. Wikipedia; 2009.

APPENDIX D

Capacity under Thailand Power Development Plan (PDP-2010)

Year	Power plants	Capacity (MW)	Peak Demand (MW)	Reserve Margin (%)
2009	Total installed capacity (as of December 2009)	29,212	22,044.9	27.6
2010	VSPP	+367		
	SPP renewable	+ 90		
	Power purchased from Lao PDR (Nam Theun 2)	+920		
	North Bangkok combined cycle power plant #1	+670		
	SPP Cogeneration	+90		
	2010 Capacity	31,349	23,249	28.1
2011	Retirement of Kha Nom #1	-70		
	VSPP	+258		
	EGAT Renewable	+18		
	Power purchased from Lao PDR (Nam Ngum 2)	+597		
	Chao Phraya Dam #1-2	+12		
	SPPs renewable	+160		
	Naraesuan Dam	+8		
	Geco-one	+660		
	2011 Capacity	32,992	24,568	27.1
2012	VSPPs	+162		
	Mae Klong Dam #1-2	+12		
	Khun Dan Prakarn Chol Dam	+10		
	Pasak Jolasit Dam	+7		
	SPPs renewable	+65		
	SPP Cogeneration	+704		
	Power purchased from Lao PDR (Theun Hinboun)	+220		
	2012 Capacity	34,172	25,913	23.7
2013	VSPP	+187		
	Kwae Noi Dam #1-2	+30		
	EGAT Renewable	+24		
	SPP Cogeneration	720		
	Siam Energy #1-2	+1,600		
	National Power Supply #1-2	+270		
	2013 Capacity	37,003	27,188	25.4
2014	Retirement of Bang Pakong #1-2	-1,052		
	VSPP	+192		
	EGAT Renewable	+18		
	National Power Supply #3-4	+270		
	Wang Noi #4	+800		
	SPP Cogeneration	+90		
	Power Generation Supply #1-2	+1,600		
	Chana #2	+800		
	2014 Capacity	39,720	28,341	23.4
2015	Retirement of Rayong Power Plant #1-4	-1,175		
	VSPP	+167		
	EGAT Renewable	+14		
	Bang Lang Hydropower	+12		
	Power purchased from Lao PDR (Hong Sa #1-2)	+982		
	SPP Cogeneration	+270		

Year	Power plants	Capacity (MW)	Peak Demand (MW)	Reserve Margin (%)
	2015 Capacity	39,990	29,463	26.0
2016	Retirement of Kha Nom #2	-70		
	Retirement of Kha Nom Unit 1	-678		
	EGAT Renewable	+17		
	Power purchased from Myanmar (Mai-Kok #1-3)	+369		
	Power purchased from Lao PDR (Hong Sa #3)	+491		
	VSPP	+231		
	SPP Cogeneration	+270		
	New Southern EGAT power plant	+800		
	2016 Capacity	41,419	30,754	27.2
2017	Retirement of Bang Pakong Unit 3	-314		
	Retirement of SPP	-180		
	VSPP	+229		
	EGAT Renewable	+11		
	Power purchased from Lao PDR (Nam Ngum 3)	+440		
	Lam Takong Chon Wattana Hydropower #3-4	+500		
	SPP Cogeneration	+270		
	2017 Capacity	42,374	32,225	23.2
2018	Retirement of Bang Pakong Unit 4	-314		
	Retirement of Nam Pong Unit 1	-325		
	Retirement of SPP	-42		
	VSPP	+176		
	EGAT Renewable	+30		
	SPP Cogeneration	+270		
	Power purchased from Neighbor Country	+450		
	2018 Capacity	42,619	33,688	17.3
2019	Retirement of SPP	-185		
	VSPP	+177		
	EGAT Renewable	+8		
	SPP Cogeneration	+270		
	Power purchased from Neighbor Country	+600		
	New EGAT Clean coal #1	+800		
	2019 Capacity	44,289	34,988	15.0
2020	Retirement of South Bangkok Unit 1	-316		
	Retirement of Nam Pong Unit 2	-325		
	Retirement of Tri Energy	-700		
	Retirement of SPP	-188		
	VSPP	+190		
	EGAT Renewable	+22		
	SPP Cogeneration	+270		
	EGAT Nuclear Power plant #1	+1,000		
	Power purchased from Neighbor Country	+600		
	2020 Capacity	44,842	36,336	15.6
2021	Retirement of SPP	-200		
	VSPP	+135		
	EGAT Renewable	+61		
	SPP Cogeneration	+380		
	EGAT Nuclear Power plant #2	+1,000		

Year	Power plants	Capacity (MW)	Peak Demand (MW)	Reserve Margin (%)
	Power purchased from Neighbor Country	600		
	New EGAT Clean coal #2	800		
	2021 Capacity	47,618	37,856	15.4
2022	Retirement of Nam Pong Unit 3	-576		
	Retirement of SPP	-150		
	VSPP	+294		
	EGAT Renewable	+36		
	SPP Cogeneration	+360		
	New EGAT Natural Gas Unit 1	+800		
	Power purchased from Neighbor Country	+600		
	2022 Capacity	48,982	39,308	16.0
2023	Retirement of Wang Noi #1-3	-1,910		
	Retirement of South Bangkok Unit 2	-562		
	Retirement of Bang Pakong #4	-576		
	Retirement of Teun Hinboun	-214		
	Retirement of Eastern Power	-350		
	Retirement of SPP	-41		
	VSPP	+146		
	SPP Cogeneration	+360		
	New EGAT Natural Gas Unit 2-6	+4,000		
	New EGAT Clean coal #3	+800		
	Power purchased from Neighbor Country	+600		
	2023 Capacity	51,235	40,781	16.7
2024	Retirement of SPP	-680		
	Retirement of Mae Moh #4	-140		
	VSPP	+148		
	SPP Cogeneration	+360		
	EGAT Nuclear Power plant #3	+1,000		
	Power purchased from Neighbor Country	+600		
	2024 Capacity	52,523	42,236	16.5
2025	Retirement of Mae Moh #5-6	-280		
	Retirement of SPP	-244		
	Retirement of Independence Power	-700		
	Retirement of Ratchaburi #1-2	-1,440		
	VSPP	+163		
	SPP Cogeneration	+360		
	EGAT Nuclear Power plant #4	+1,000		
	New EGAT Natural Gas Unit 7	+800		
	Power purchased from Neighbor Country	+600		
	2025 Capacity	52,782	43,962	16.3
2026	Retirement of Mae Moh #7	-140		
	Retirement of SPP	-5		
	VSPP	+159		
	SPP Cogeneration	+360		
	New EGAT Natural Gas Unit 8-9	+1,600		
	New EGAT Clean coal #4-5	+1,600		
	Power purchased from Neighbor Country	+600		
	2026 Capacity	56,956	45,621	15.9

Year	Power plants	Capacity (MW)	Peak Demand (MW)	Reserve Margin (%)
2027	Retirement of SPP	-15		
	Retirement of Ratchaburi Unit 1-2	-1,360		
	Retirement of Ratchaburi Unit 3	-681		
	VSPP	+169		
	SPP Cogeneration	+360		
	New EGAT Natural Gas Unit 10	+800		
	Power purchased from Neighbor Country	+600		
	2027 Capacity	56,830	47,344	15.4
2028	Retirement of SPP	-95		
	Retirement of Glow IPP	-713		
	VSPP	+173		
	SPP Cogeneration	+360		
	EGAT Nuclear Power plant #5	+1,000		
	New EGAT Natural Gas Unit 11-12	+1,600		
	New EGAT Clean coal #6-7	+1,600		
	Power purchased from Neighbor Country	+600		
	2028 Capacity	61,355	49,039	16.3
2029	Retirement of Mae Moh #8	-270		
	VSPP	+179		
	SPP Cogeneration	+360		
	New EGAT Natural Gas Unit 13	+800		
	New EGAT Clean coal #8	+800		
	Power purchased from Neighbor Country	+600		
	2029 Capacity	63,824	50,959	16.3
2030	Retirement of Mae Moh #9	-270		
	Retirement of Huay Ho	-126		
	VSPP	+179		
	SPP Cogeneration	+540		
	New EGAT Clean coal #9	+800		
	Power purchased from Neighbor Country	+600		
	2030 Capacity	65,547	52,890	15.0

Source: Electricity Generating Authority of Thailand (2010: 123)

APPENDIX E

Approved CDM methodology under UNFCCC related with electricity generation

Methodology number	Methodology Title (including baseline and monitoring methodologies)	Version	Sectoral Scope	Approval History
AM0007	Analysis of the least-cost fuel option for seasonally-operating biomass cogeneration plants	1	1 , 4	NM0028
AM0014	Natural gas-based package cogeneration	4	1 , 4	NM0018-rev
AM0009	Recovery and utilization of gas from oil wells that would otherwise be flared or vented	4	10	NM0227 NM0026
AM0017	Steam system efficiency improvements by replacing steam traps and returning condensate	2	3	NM0017-rev
AM0018	Steam optimization systems	2.2	3	NM0037-rev
AM0019	Renewable energy project activities replacing part of the electricity production of one single fossil-fuel-fired power plant that stands alone or supplies electricity to a grid, excluding biomass projects	2	1	NM0053
AM0024	Methodology for greenhouse gas reductions through waste heat recovery and utilization for power generation at cement plants	2.1	1 , 4	NM0079-rev
AM0025	Avoided emissions from organic waste through alternative waste treatment processes	12	1 , 13	NM0174-rev NM0178 NM0127 NM0090
AM0023	Methodology for zero-emissions grid-connected electricity generation from renewable sources in Chile or in countries with merit order based dispatch grid	3	1	NM0076-rev
AM0029	Methodology for Grid Connected Electricity Generation Plants using Natural Gas	3	1	NM0080-rev NM0153
AM0035	SF6 Emission Reductions in Electrical Grids	1	1 , 11	NM0135
AM0036	Fuel switch from fossil fuels to biomass residues in heat generation equipment	3	1 , 4	NM0140-rev
AM0042	Grid-connected electricity generation using biomass from newly developed dedicated plantations	2.1	1 , 14	NM0133-rev
AM0044	Energy efficiency improvement projects: boiler rehabilitation or replacement in industrial and district heating sectors	1	1	NM0144-rev
AM0045	Grid connection of isolated electricity systems --- Version 2 (286 KB)	2	1	NM0152-rev
AM0048	New cogeneration facilities supplying electricity and/or steam to multiple customers and	3	1	NM0141-rev

Methodology number	Methodology Title (including baseline and monitoring methodologies)	Version	Sectoral Scope	Approval History
	displacing grid/off-grid steam and electricity generation with more carbon-intensive fuels			
AM0049	Methodology for gas based energy generation in an industrial facility	3	1 , 4	NM0161-rev
AM0052	Increased electricity generation from existing hydropower stations through Decision Support System optimization	2	1	NM0186
AM0053	Biogenic methane injection to a natural gas distribution grid	2	1 , 5	NM0210
AM0055	Baseline and Monitoring Methodology for the recovery and utilization of waste gas in refinery facilities	1.2	1 , 4	NM0192-rev
AM0056	Efficiency improvement by boiler replacement or rehabilitation and optional fuel switch in fossil fuel-fired steam boiler systems	1	1	NM0211
AM0058	Introduction of a new primary district heating system	3.1	1	NM0181-rev
AM0060	Power saving through replacement by energy efficient chillers	1.1	3	NM0197-rev
AM0061	Methodology for rehabilitation and/or energy efficiency improvement in existing power plants	2.1	1	NM0202-rev
AM0062	Energy efficiency improvements of a power plant through retrofitting turbines	2	1	NM0203-rev
AM0067	Methodology for installation of energy efficient transformers in a power distribution grid	2	2	NM0243
AM0072	Fossil Fuel Displacement by Geothermal Resources for Space Heating	2	1	NM0261
AM0074	Methodology for new grid connected power plants using permeate gas previously flared and/or vented	2	1	NM0270
AM0075	Methodology for collection, processing and supply of biogas to end-users for production of heat	1	1 , 5	NM0248
AM0076	Methodology for implementation of fossil fuel trigeneration systems in existing industrial facilities	1	1	NM0264
AM0084	Installation of cogeneration system supplying electricity and chilled water to new and existing consumers	1	1	NM0288
AM0085	Co-firing of biomass residues for electricity generation in grid connected power plants	1	1	NM0304
AM0087	Construction of a new natural gas power plant supplying electricity to the grid or a single consumer	2	1	NM0322 NM0080-rev NM0153

Source: UNFCCC (2010)

Approved Consolidated Methodologies under UNFCCC related with electricity generation

Methodology number	Methodology Title (including baseline and monitoring methodologies)	Version	Sectoral Scope	Approval History
ACM0002	Consolidated methodology for grid-connected electricity generation from renewable sources	11	1	NM0001-rev NM0012-rev NM0023 NM0024-rev NM0030-rev NM0036 NM0043 NM0055 Replaces: AM0005
ACM0006	Consolidated methodology for electricity generation from biomass residues	10.1	1	NM0050-rev NM0081 NM0098 Replaces: AM0004 AM0015
ACM0007	Consolidated methodology for conversion from single cycle to combined cycle power generation	4	1	NM0070 NM0078-rev
ACM0009	Consolidated methodology for industrial fuel switching from coal or petroleum fuels to natural gas	3.2	1	NM0131 NM0132 Replaces: AM0008
ACM0011	Consolidated baseline methodology for fuel switching from coal and/or petroleum fuels to natural gas in existing power plants for electricity generation	2.2	1	NM0200-rev NM0213 NM0226

Methodology number	Methodology Title (including baseline and monitoring methodologies)	Version	Sectoral Scope	Approval History
ACM0012	Consolidated baseline methodology for GHG emission reductions from waste energy recovery projects	3.2	1 , 4	NM0155-rev NM0179 NM0192-rev Replaces: ACM0004 AM0032
ACM0013	Consolidated baseline and monitoring methodology for new grid connected fossil fuel fired power plants using a less GHG intensive technology	3	1	NM0215 NM0217
ACM0017	Production of biodiesel for use as fuel	1.1	1 , 5	NM0228 NM0233 Replaces: AM0047
ACM0018	Consolidated methodology for electricity generation from biomass residues in power-only plants	1.1		

Source: UNFCCC (2010)

APPENDIX F

Renewable Energy Promotion Policies

Country	Feed-in-tariff	Renewable port-folio standard	Capital subsidies, grants or rebates	Investment or other tax credits	Sales tax, energy tax, excise tax or VAT reduction	Tradable renewable energy certificates	Energy production payments or tax credits	Net metering	Public investment, loans or financing	Public competitive bidding
Developed and transition countries										
Australia		✓	✓			✓			✓	
Austria	✓		✓	✓		✓			✓	
Belgium		✓	✓		✓	✓		✓		
Canada	(*)	(*)	✓	✓	✓			(*)	✓	(*)
Croatia	✓			✓					✓	
Cyprus	✓		✓							
Czech Republic	✓		✓	✓	✓	✓		✓		
Denmark	✓				✓	✓		✓	✓	✓
Estonia	✓				✓					
Finland			✓		✓	✓	✓			
France	✓		✓	✓	✓	✓			✓	✓
Germany	✓		✓	✓	✓				✓	
Greece	✓		✓	✓						
Hungary	✓				✓	✓			✓	
Ireland	✓		✓	✓		✓				✓
Israel	✓									
Japan	(*)	✓	✓			✓		✓	✓	
Korea	✓		✓	✓	✓				✓	
Latvia	✓								✓	✓
Lithuania	✓		✓	✓					✓	
Luxembourg	✓		✓	✓						
Malta	✓					✓				
Netherlands	✓		✓	✓		✓	✓			
New Zealand			✓						✓	
Norway			✓	✓		✓				✓
Poland		✓	✓		✓					✓
Portugal	✓		✓	✓	✓					
Romania					✓					
Russia			✓			✓				
Slovak Republic	✓			✓					✓	
Slovenia	✓								✓	
Spain	✓		✓	✓					✓	
Sweden		✓	✓	✓	✓	✓	✓			
Switzerland	✓									
United States	(*)	(*)	✓	✓	(*)	(*)	✓	(*)	(*)	(*)

Country	Feed-in-tariff	Renewable port-folio standard	Capital subsidies, grants or rebates	Investment or other tax credits	Sales tax, energy tax, excise tax or VAT reduction	Tradable renewable energy certificates	Energy production payments or tax credits	Net metering	Public investment, loans or financing	Public competitive bidding
Developing countries										
Algeria	✓			✓	✓	✓				
Argentina	✓		✓	(*)	✓		✓			
Brazil	✓								✓	✓
Cambodia			✓							
Chile			✓							
China	✓		✓	✓	✓				✓	✓
Costa Rica	✓									
Ecuador	✓			✓						
Guatemala				✓	✓					
Honduras				✓	✓					
India	(*)	(*)	✓	✓	✓		✓		✓	✓
Indonesia	✓									
Mexico				✓				✓		
Morocco				✓						
Nicaragua	✓			✓	✓					
Panama							✓			
Philippines			✓	✓	✓				✓	
South Africa			✓							
Sri Lanka	✓									
Thailand	✓		✓					✓	✓	
Tunisia			✓	✓						
Turkey	✓		✓							
Uganda	✓								✓	

Note: Entries with an asterisk (*) mean that some states/provinces within these countries have state/province-level policies but there is no national level policy. Only enacted policies are included in table; however, for some policies shown, implementing regulations may not yet be developed or effective, leading to lack of implementation or impacts. Policies known to be discontinued have been omitted. Many feed-in policies are limited in scope or technology. Some policies shown may apply to other markets beside power generation, for example solar hot water and biofuels.

Source: REN21 (2008: 51)

APPENDIX G

Generation Description of LEAP Model

The Long-range Energy Alternatives Planning system (LEAP) is a scenario-based energy-environment modeling tool. Its scenarios are based on comprehensive accounting of how energy is consumed, converted and produced in a given region or economy under a range of alternative assumptions on population, economic development, technology, price and so on. With its flexible data structures, LEAP allows for analysis as rich in technological specification and end-use detail as the user chooses. With LEAP, user can go beyond simple accounting to build sophisticated simulations and data structures. Unlike macroeconomic models, LEAP does not attempt to estimate the impact of energy policies on employment or GDP, although such models can be run in conjunction with LEAP. Similarly, LEAP does not automatically generate optimum or market-equilibrium scenarios, although it can be used to identify least-cost scenarios. Important advantages of LEAP are its flexibility and ease-of-use, which allow decision makers to move rapidly from policy ideas to policy analysis without having to resort to more complex models.

LEAP serves several purposes: as a database, it provides a comprehensive system for maintaining energy information; as a forecasting tool, it enables the user to make projections of energy supply and demand over a long-term planning horizon; as a policy analysis tool, it simulates and assesses the effects - physical, economic, and environmental - of alternative energy programs, investments, and actions.

A Short History of LEAP

LEAP was created in 1980 for the Beijer Institute's Kenya Fuelwood Project, to provide a flexible tool for long-range integrated energy planning. It was conceived and designed by Paul Raskin, President of Energy Systems Research Group (ESRG was renamed Tellus Institute in 1990). LEAP provided a platform for structuring data, creating energy balances, projecting demand and supply scenarios, and evaluating alternative policies, the same basic goals as the current version of LEAP. Major funding was provided by Swedish SIDA, German GTZ, the Government of the Netherlands (DGIS), and US-AID.

LEAP was originally implemented on a mainframe computer. In 1983, ESRG, with funding from US-AID, converted it for use on a minicomputer and a first user-interface was added with the aim of transferring it to energy planners in Kenya and elsewhere. By 1985, LEAP had been ported again, this time to the newly emerging IBM PC microcomputer, making wider dissemination and a more user-friendly interface possible. In the course of the 1980s, LEAP-based studies were conducted in a dozen countries in Africa, Latin America, and Asia as collaborations between ESRG, Beijer Institute, and in-country partners. When the Stockholm Environment Institute (SEI) was established in 1989, Tellus Institute became host to the SEI-Boston Center (SEI-Boston). Development of LEAP continued at SEI-Boston. With concern about the environmental impact of energy systems growing, LEAP was one of the first energy modeling tools to address this concern through the addition of the Environmental Database (EDB) and enhancements for computing emissions loadings in LEAP. The United Nations Environment Programme provided major funding for this phase of development.

The early 1990s saw a broadening of LEAP's user-base. In 1991, the first major LEAP- based study in an OECD country was conducted by Tellus, America's Energy Choices: an analysis of the potential for energy efficiency and renewables in the USA. In 1992, the first global energy study using LEAP was published by SEI-Boston, Towards a Fossil Free Energy Future (a report to Greenpeace). Meanwhile, studies continued throughout the developing world, including a World Bank sponsored project to integrate LEAP with an emission dispersion model for studying air quality in Beijing. The spread of the Internet in the mid-1990s allowed for much wider dissemination of LEAP. With the issue of climate change rising on the international agenda, LEAP was further enhanced as a tool for Greenhouse Gas (GHG) mitigation assessments. Many countries used LEAP for their national communications to the UNFCCC, and for their contributions to the U.S. and UNEP Country Studies Programs on Climate Change.

By the late 1990s, with support from the Dutch Government (DGIS), a new Windows- based version of LEAP was created by Charlie Heaps, allowing the original goal of a highly user-friendly energy and environment planning tool to be more fully realized. The first version of the new tool was made public in early 2001.

LEAP for Windows continues to be maintained and further developed based on user- requirements. Recent years have seen major initiatives to develop vehicle stock-turnover modeling capabilities, better modeling of electric power systems. LEAP has also been enhanced to support multi-regional modeling of energy systems for use in major Global and regional energy studies. By 2003, with the number of LEAP users approaching 500 with most in the developing world, a new project was launched to upgrade the support provided to these users and to foster a community among Southern energy analysts working on sustainability issues. With support from DGIS, a new web-based community called COMMEND (http://www.energycommunity.org) was created, with the number of participating LEAP users growing to over 1500 in more than 130 countries by early 2006.

BIOGRAPHY

Narumitr Sawangphol was born on August 15, 1974 in Bangkok, Thailand. He received a Bachelor of Science in 1995 and Master of Science in 1999. After that, he entered the Degree of Doctor of Philosophy Program in Environmental Management, Graduated School of Chulalongkorn University.