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Policies suggestion toward Low Carbon Electricity Development in Thailand

Mr. Narumitr Sawangphol

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Thesis Title	Policies suggestion toward Low Carbon Electricity Development in Thailand
By	Mr. Narumitr Sawangphol
Field of Study	Environmental Management
Thesis Advisor	Associate Professor Thavivongse Sriburi, Ph.D.
Thesis Co-Advisor	Supichai Tangjaitrong, Ph.D., Chanathip Pharino, Ph.D.

Accepted by the Graduate School, Chulalongkorn University in Partial Fulfillment of the Requirements for the Doctoral Degree

.... Dean of the Graduate School
(Associate Professor Pornpote Piumsomboon, Ph.D.)

THESIS COMMITTEE

.... Chairman
(Assistant Professor Manaskorn Rachakornkij, Ph.D.)

.... Thesis Advisor
(Associate Professor Thavivongse Sriburi, Ph.D.)

.... Thesis Co-Advisor
(Supichai Tangjaitrong, Ph.D.)

.... Thesis Co-Advisor
(Chanathip Pharino, Ph.D.)

.... Examiner
(Chantra Tongcumpou, Ph.D.)

.... External Examiner
(Twarath Sutabutr, Sc.D.)

นฤมิตร สว่างผล : ข้อเสนอแนะเชิงนโยบายเพื่อการวางแผนพัฒนาการผลิตไฟฟ้าโดยปล่อยคาร์บอนต่ำ (POLICIES SUGGESTION TOWARD LOW CARBON ELECTRICITY DEVELOPMENT IN THAILAND)
อ. ที่ปรึกษาวิทยานิพนธ์หลัก : รศ.ดร. ทวีวงศ์ ศรีบุรี, อ. ที่ปรึกษาวิทยานิพนธ์ร่วม: ดร. ศุภิชัย ตั้งใจตรง, ดร. ชนาธิป ผาริโน, 255 หน้า.

การพัฒนาการผลิตกระแสไฟฟ้าโดยปล่อยคาร์บอนต่ำนั้นนับว่าเป็นเป้าหมายที่ท้าทายรัฐบาลรวมทั้งผู้ที่มีหน้าที่เกี่ยวข้องเป็นอย่างมาก ซึ่งการจะบรรลุเป้าหมายดังกล่าวนั้น ต้องการทั้งมาตรการควบคุม และการร่วมมืออย่างจริงจังจากทุกภาคส่วน ที่สำคัญยังต้องคำนึงถึงความคุ้มค่าในด้านการลงทุน รวมทั้งความเท่าเทียมกันระหว่างภาคส่วนต่าง ๆ เพื่อลดการปล่อยก๊าซเรือนกระจกในภาคส่วนต่าง ๆ ให้มีมากยิ่งขึ้น การศึกษานี้มีเป้าหมายเพื่อวิเคราะห์ข้อจำกัดและเสนอแนะนโยบายในการวางแผนการผลิตกระแสไฟฟ้าโดยแบ่งการศึกษาออกเป็น 3 ส่วน ในส่วนแรกเป็นการวิเคราะห์สถานการณ์ของการปล่อยก๊าซเรือนกระจกจากการผลิตกระแสไฟฟ้าของประเทศ โดยใช้แบบจำลองทางคณิตศาสตร์เพื่อคาดการณ์อัตราการปล่อยก๊าซเรือนกระจกใน 3 แนวทาง ได้แก่ การปล่อยก๊าซเรือนกระจกตามนโยบายการพัฒนาพลังงานของรัฐที่มีอยู่ในปัจจุบัน (BAU), การปล่อยก๊าซเรือนกระจกตามแนวทางการพัฒนาการผลิตกระแสไฟฟ้าโดยที่รัฐสามารถพึ่งพาเชื้อเพลิงนิวเคลียร์ได้ในอนาคต (WNC) และการปล่อยก๊าซเรือนกระจกตามตามแนวทางการผลิตกระแสไฟฟ้าโดยที่รัฐไม่สามารถพึ่งพาเชื้อเพลิงนิวเคลียร์ได้ในอนาคต (NNC) จากการศึกษาพบว่าเมื่อเปรียบเทียบการปล่อยก๊าซเรือนกระจกในปี พ.ศ. 2573 ตามแนวทาง BAU กับการพัฒนาตามแนวทาง WNC และ NNC พบว่า สามารถลดการปล่อยก๊าซเรือนกระจกได้ไม่น้อยกว่าร้อยละ 9.46 และ 7.18 ตามลำดับ

การศึกษาในส่วนที่สอง เป็นการวิเคราะห์ศักยภาพรวมทั้งข้อจำกัดด้านต่าง ๆ จากการศึกษาพบว่าประเทศไทยยังมีศักยภาพสูงมาก เนื่องจากพื้นฐานของการผลิตของประเทศไทยซึ่งเป็นประเทศเกษตรกรรม มีผลผลิตรวมทั้งผลพลอยได้จากการเกษตรกรรม ตลอดจนมีทรัพยากรธรรมชาติที่สามารถจะพัฒนาไปที่จะพัฒนาไปสู่การผลิตกระแสไฟฟ้าที่ปล่อยคาร์บอนต่ำ เพียงแต่ขาดความชัดเจนของนโยบายในการส่งเสริม รวมทั้งการบริหารจัดการและการสนับสนุนอย่างเป็นระบบ การศึกษาในส่วนสุดท้ายเป็นการเสนอแนะนโยบายและมาตรการสำคัญที่ควรได้รับการส่งเสริมเพื่อนำไปสู่การผลิตกระแสไฟฟ้าที่ปล่อยคาร์บอนต่ำ ได้แก่ การลดปริมาณความต้องการในการใช้พลังงานในภาคส่วนต่าง ๆ รวมทั้งการเพิ่มศักยภาพของการใช้พลังงานอย่างเร่งด่วน, การส่งเสริมมาตรการจูงใจสำหรับการใช้เชื้อเพลิงที่ปล่อยคาร์บอนต่ำในการผลิตกระแสไฟฟ้า, การพัฒนาและแหล่งพลังงานทดแทนภายในประเทศ, การทบทวนศักยภาพเชิงพื้นที่ในการพัฒนาพลังงานหมุนเวียน, การส่งเสริมให้มีการค้นคว้าวิจัยและพัฒนาเทคโนโลยีพลังงานภายในประเทศ, การส่งเสริมให้มีการพัฒนาโครงการเพื่อรับประโยชน์จากกลไกการพัฒนาที่สะอาดหรือจากการขาย Carbon Credit รวมทั้งการวางแผนเพื่อปรับตัวของประเทศภายใต้กรอบการเจรจาสำหรับการดำเนินการภายหลังอนุสัญญาเกียวโต (Post Kyoto)

สาขาวิชา การจัดการสิ่งแวดล้อม	ลายมือชื่อนิสิต
ปีการศึกษา 2553	ลายมือชื่ออาจารย์ที่ปรึกษาหลัก
	ลายมือชื่ออาจารย์ที่ปรึกษาร่วม
	ลายมือชื่ออาจารย์ที่ปรึกษาร่วม

5087810820 : MAJOR ENVIRONMENTAL MANAGEMENT
KEYWORDS: LOW CARBON ELECTRICITY / FUEL DIVERSIFICATION / ELECTRICITY PLANNING / GREENHOUSE GASES / ENERGY POLICY

NARUMITR SAWANGPHOL: POLICIES SUGGESTION TOWARD LOW CARBON ELECTRICITY DEVELOPMENT IN THAILAND. THESIS ADVISOR: ASSOCIATE PROFESSOR. THAVIVONGSE SRIBURI, Ph.D., THESIS CO-ADVISOR: SUPICHAI TANGJAITRONG, Ph.D., CHANATHIP PHARINO, Ph.D., 255 pp.

Implementing the low carbon electricity policy is a huge challenge for political leaders and regulators. To achieve the aggressive emission reduction target, it requires stringent control measures and incorporation among various stakeholders. Importantly, the implementation plans have to concern on cost-effectiveness of such policy and equity sharing among many stakeholder groups to reduce GHG emission. This research aims to identify implementation barriers and suggested policies toward low carbon electricity development in Thailand. The research divided into three main sections; (1) evaluation of current GHG emission level from electricity sector using mathematical model, (2) identification of obstructers delaying low carbon electricity development and (3) develop appropriate policies suggestions. In the model study, three scenarios were evaluated to identify contributions and challenges of establishing a sustainable energy supply system, including Business as usual (BAU), with nuclear scenario (WNC) and without nuclear (NNC) electricity development options. When compared with BAU pathway, the WNC and the NNC pathway can achieve emission reduction of 9.43 percent and 7.18 percent respectively.

It should be noted that agriculture is a major sector for Thailand; high potentials for all types of renewable energies based on agricultural products exist in the country and can strengthen the national energy security. With high potentials of various renewable resources existed in the country, Thailand could potentially achieve it. Based on the analyses of potential sources and existing development conditions, the following low Carbon electricity development policies are formulated. The recommended policies toward low Carbon electricity development in Thailand include promotion of energy efficiency and demand reduction, strengthening collaborative and coordination among all governmental agencies, providing incentives for fuel diversification into low carbon emission, identification of new kind of renewable energy, revised the potential areas for renewable energy development, encouraging and promotional of local research and development and gaining more Benefits from CDM and preparing for GHG reduction burdens of the Post-Kyoto Protocol.

Field of Study: Environmental Management Student's Signature ......Narumitr S.......
Academic Year: 2010 .... Advisor's Signature ......T. Sriburi......
Co-Advisor's Signature ......Supichai T......
Co-Advisor's Signature ......Chanathip Pharino......

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CONTENTS

CONTENTS (CONT.)

LIST OF FIGURES

LIST OF FIGURES (CONT.)

LIST OF TABLES

LIST OF ABBREVIATIONS

BAP	The Bali Action Plan
BAU	Business as Usual Scenario
CERs	Certified Emission Reduction
CCS	Carbon Capture and Storage
CCTs	Clean Coal Technology
CDM	The Clean Development Mechanism under Kyoto Protocol
CEMs	The Continuous Emission Monitoring System
CHP	Combine Heat and Power or Cogeneration
COD	Commercial Operation Date
CSP	Concentrating Solar Power
DEDE	Department of Alternative Energy Development and Efficiency
DSM	Demand Side Management
ECF	The Energy Conservation Promotion Fund
ECMS	Energy Consumption Management System
EGAT	The Electricity Generating Authority of Thailand
EIA	The Environmental Impact Assessment Report
ENCON	The Energy Conservation Promotion Act 1992
ERPA	The Emission Reduction Purchase Agreement
ETS	The Emission Trading Schemes
HIA	The Health Impact Assessment Report
ICE	Internal Combustion Turbines
IGCC	Integrated Gas Combined Cycle Turbine
IPCC	Intergovernmental Panel on Climate Change
IPP	The Independent Power Producers
LEAP	The Long-range Energy-environment Alternatives Planning Model
LCE	Low Carbon Economy
GHGs	Greenhouse gases

LIST OF ABBREVIATIONS (CONT.)

GW	Gigawatts
GWP	Global warming potential
MACC	The Marginal Abatement Cost Curve
MEA	The Metropolitan Electricity Authority
MOE	The Ministry of Energy
MRV	Measurable, Reportable and Verification
MSW	Municipal Solid Waste
NAMAs	Nationally Appropriate Mitigation Actions in developing countries
NEPC	The National Energy Policy Council
NEPO	The National Energy Policy Office
NIMBY	Not in My Backyard
NNC	Without-Nuclear Scenario
OAE	The Office of Agricultural Economics
OERC	The Office of the Energy Regulatory Commissioner
PDP-2010	Power Development Plan 2010
PEA	The Provincial Electricity Authority
PPA	Power Purchase Agreement
PV	Solar Voltaic
AEDP	Renewable Energy Development Plan
RID	The Royal Irrigation Department
SPP	The Small Power Producer
SO	System Operator
T&D	Transmission and Distribution
TPES	Total Primary Energy Supply
VSPP	The Very Small Power Producer
UNEP	The United Nation Environment Programme
WMO	The World Meteorological Organization
WNC	With-Nuclear Scenario

CHAPTER I
INTRODUCTION

1.1 Statement of the Problems

Dealing with the cause of climate change from energy sector has directly impacted or related to economic activity in different aspect such as; how we produced, consumed and traded for energy and goods. The presence of certain gases, such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), enables the atmosphere to act like a greenhouse, retaining part of the solar heat. The natural greenhouse effect is desirable as it traps part of the incoming solar energy to maintain habitable temperatures on the earth's surface. Evidently human activity enabling economic and social growth is the primary suspect warming the planet. According to the Fourth Assessment Report (AR-4) of the Intergovernmental Panel on Climate Change (IPCC) stated that average temperatures since the mid 20th century is increased from anthropogenic sources (The Intergovernmental Panel on Climate Change, 2007). Human activities mainly burning of fossil fuels, deforestation, agricultural practices, and manufacturing caused increasing the concentration of greenhouse gases (GHGs) in the atmosphere and enhanced greenhouse effect resulting in higher global average temperatures.

For the past millennium, the Earth's average temperature varied within a range of less than 0.7°C; however. Over the past century manmade greenhouse gas emissions have resulted in a dramatic increase in the planet's temperature over the past century (The Intergovernmental Panel on Climate Change, 2007). The projected future temperature increase could possibly warm the planet by 5°C over the next 100 years due to growing emissions relative to the preindustrial period. Such warming has never been experienced in history of the mankind. The resulting physical impacts would severely affect economics development. Only through immediate and ambitious actions to curb greenhouse gas emissions may dangerous warming be avoided (The World Bank, 2010).

The rapid increase in the atmospheric concentration of carbon dioxide has raised the specter of severe climate change. From large emissions of carbon dioxide, the energy sector is dominated by the direct combustion of fuels[1], as by product of fossil combustion. In a complete combustion, the total carbon content of fuels would be converted to CO_2). During combustion, the carbon and hydrogen of the fossil fuels are converted mainly into carbon dioxide (CO_2) and water (H_2O), releasing the chemical energy in the fuel as heat. This heat is generally either used directly or used (with some conversion losses) to produce mechanical energy, often to generate electricity or for transportation (Sell, 2007).

A variety of human activities is contributing to the release of greenhouse gases into the atmosphere. Among the many human activities that produce greenhouse gases, the use of energy represents by far is the largest source of emissions. Anthropogenic greenhouse gas emissions are key factors in global climate change mitigation, especially carbon dioxide emissions from energy combustion activities. Global climate change can be considered a "Tragedy of the Commons" type of classic environmental problem for which no effective global coordination, regulation, or enforcement has yet been implemented by far. From study of the World Resources Institute (2008) illustrated a complete picture of global GHG emissions, energy-related emissions accounted for about 60 percent of the world total. At the sector level, the largest contributors to global emissions are electricity and heat (collectively 24.6 percent), land-use change and forestry (18.2 percent), transport (13.5 percent), and agriculture (13.5 percent). The International Energy Agency (2009a) present the concentration of CO_2 in 2005 was 379 ppm or about 35% higher than a century and a half ago, with the fastest growth occurring in the last ten years (1.9 ppm per year in the period 1995-2005).

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[1] Energy includes emissions from "fuel combustion" (the large majority) and "fugitive emissions", which are intentional or unintentional releases of gases resulting from production, processes, transmission, storage and use of fuels (e.g. CH_4 emissions from coal mining or oil and gas systems).

Emissions of carbon dioxide, the number one greenhouse gas amongst the six covered by the Kyoto Protocol. Moreover, energy development is a barometer of economic progress. The substitution of energy for human power in the performance of agriculture, industry and domestic services has contributed to the process of economic growth. Energy is also a key driver of social and economic development. A world without energy is inconceivable and would be incapable of development, sustainable or otherwise. The increased availability of energy services stimulates economic activity along different stages of the development process. Economic development accelerates when a society uses energy in new forms, adaptable to a range of needs based on its social and cultural characteristics (Reddy, Assenza et al., 2009). There is increasing consensus in both the scientific and political communities that significant reductions in greenhouse gas emissions are necessary to limit the magnitude and extent of climate change. Anthropogenic greenhouse gas emissions are key factors in global climate change mitigation, especially carbon dioxide emissions from energy combustion activities.

The use of fossil fuels for the production of energy is leading to buildup of carbon dioxide in the atmosphere, which traps heat and warms up the Earth. The result is changing patterns of precipitation and drought, increasing extreme weather events and sea-level rise (Sell, 2007). The largest emissions come from road transport (9.9 percent), residential buildings (9.9 percent), oil and gas production (6.3 percent), agricultural soils (6.0 percent), commercial buildings (5.4 percent), and 4.8 percent from chemicals and petrochemicals. The concentration of CO_2 emission increases from 21,283 million metric tons of CO_2 in 1990 to 25,579 in 2003. The emission per capita change from 4.0 to 4.1 metric tons of CO_2 per person in 2003 respectively When weighted by their GWPs, CO_2 typically represent over 99 percent of the greenhouse gas emissions from the stationary combustion of fossil fuels (The Intergovernmental Panel on Climate Change, 2006). These changes affect poor countries and vulnerable people disproportionately, in the form of failed crops, devastating floods and vector-borne diseases. Species and habitat loss is also exacerbated. Therefore, efforts to curb climate change particularly focus on how we use energy.

Impacts of climate change are likely to include changes in precipitation patterns, increased frequency and intensity of storms surges and hurricanes, changes in vegetation, and a rise in sea level. Developing countries, especially the poor ones, are more vulnerable to these changes given their high dependence on natural resources and their limited capacity—human, financial, and institutional—to adapt to extreme events. Climate changes can have severe adverse impacts on the health and livelihood of the poor. Extreme climate conditions exacerbated by climate change can divert scarce development resources from poverty reduction into disaster recovery.

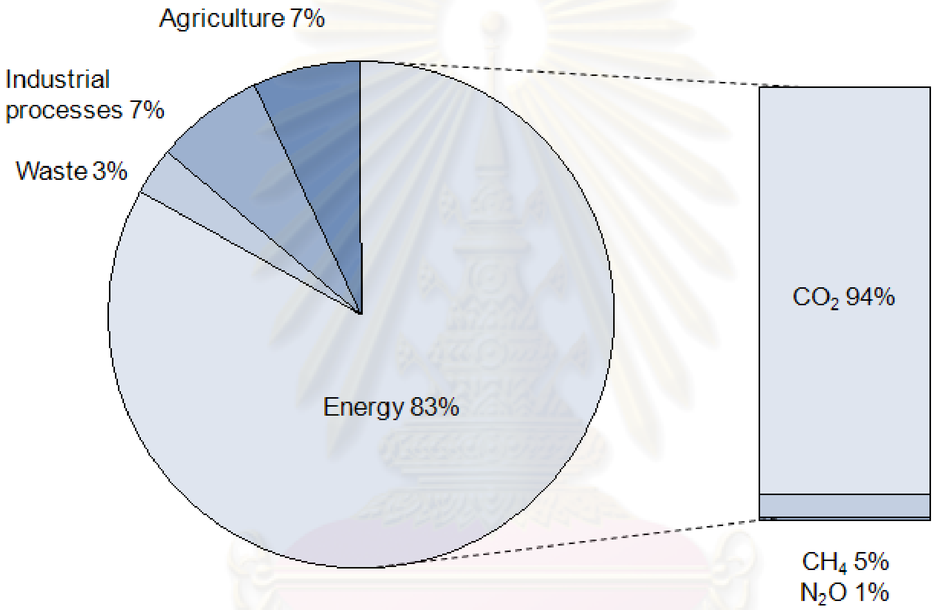

Figure 1 Greenhouse Gases Emission in 2006 Classified by Sources

Source: Using data from International Energy Agency (2009a)

The electricity utilities industry faces an enormous responsibility in the global fight against climate change. During 1993 to 2008, carbon dioxide emissions from electricity generation in Thailand have increased by 16.5 percent and this large amount is resulted from demand growth in electricity production (27.8 percent between 1993 and 2008). Ministry of Energy (MOE) reported the CO_2 emission per capita of Thailand increased from 1.85 to 3.06 during 1993 to 2008. Electricity consumption per population rose from 965 to 2,129 kWh per capita during 1993 to 2008 respectively (Figure 2). Department of Alternative Energy Development and Efficiency (DEDE) (2009) estimated amount of GHGs emission from Thailand would reach 559 $MtCO_2$ over period 2005-2020. The average growth of total GHGs emission is estimated to be 3.2 percent per year while emission from energy sector is 4.7 percent per year (Figure 3).

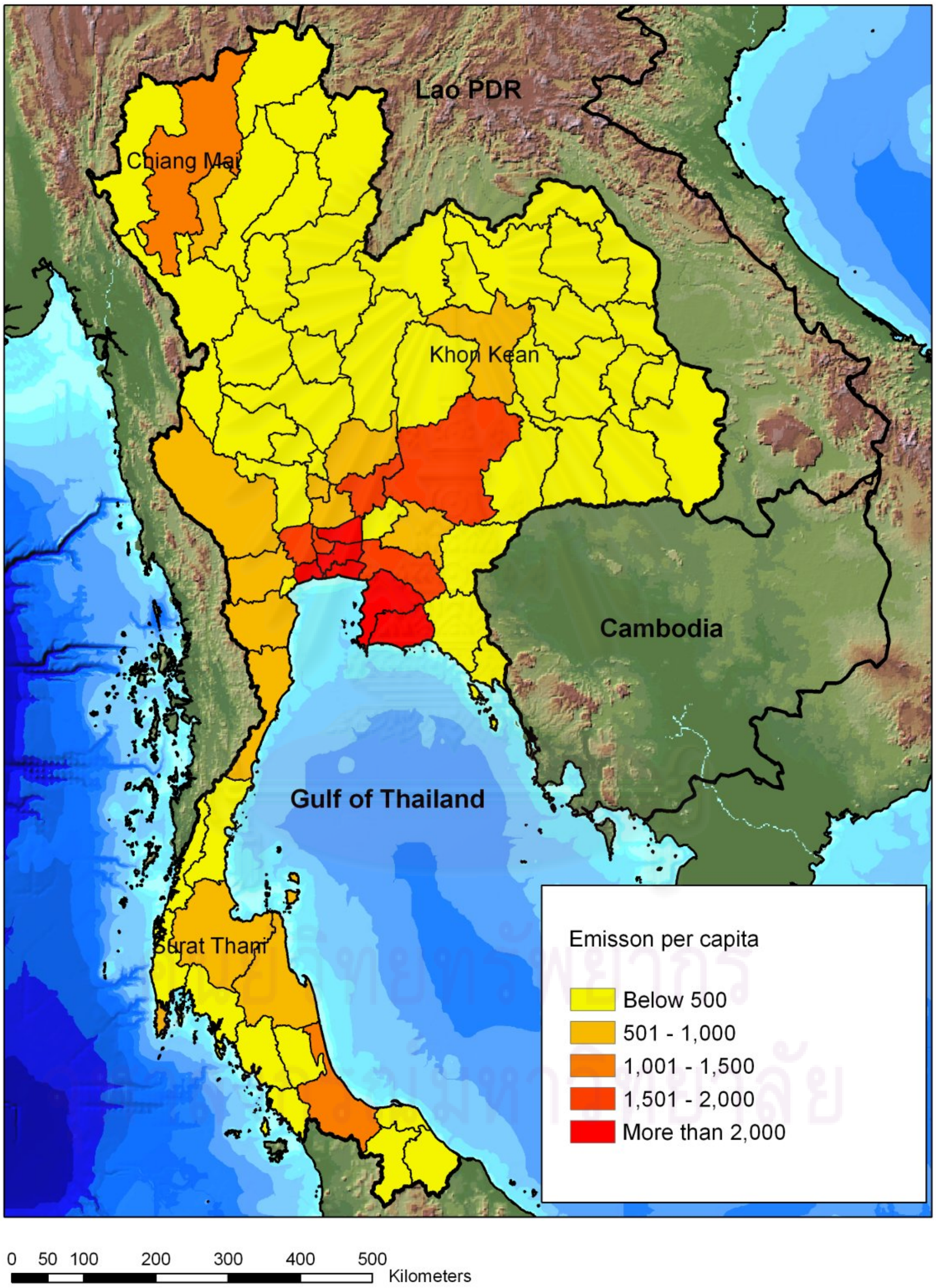

Figure 2 Emission per Capita in 2009

Source: Using data from OERC (2010)

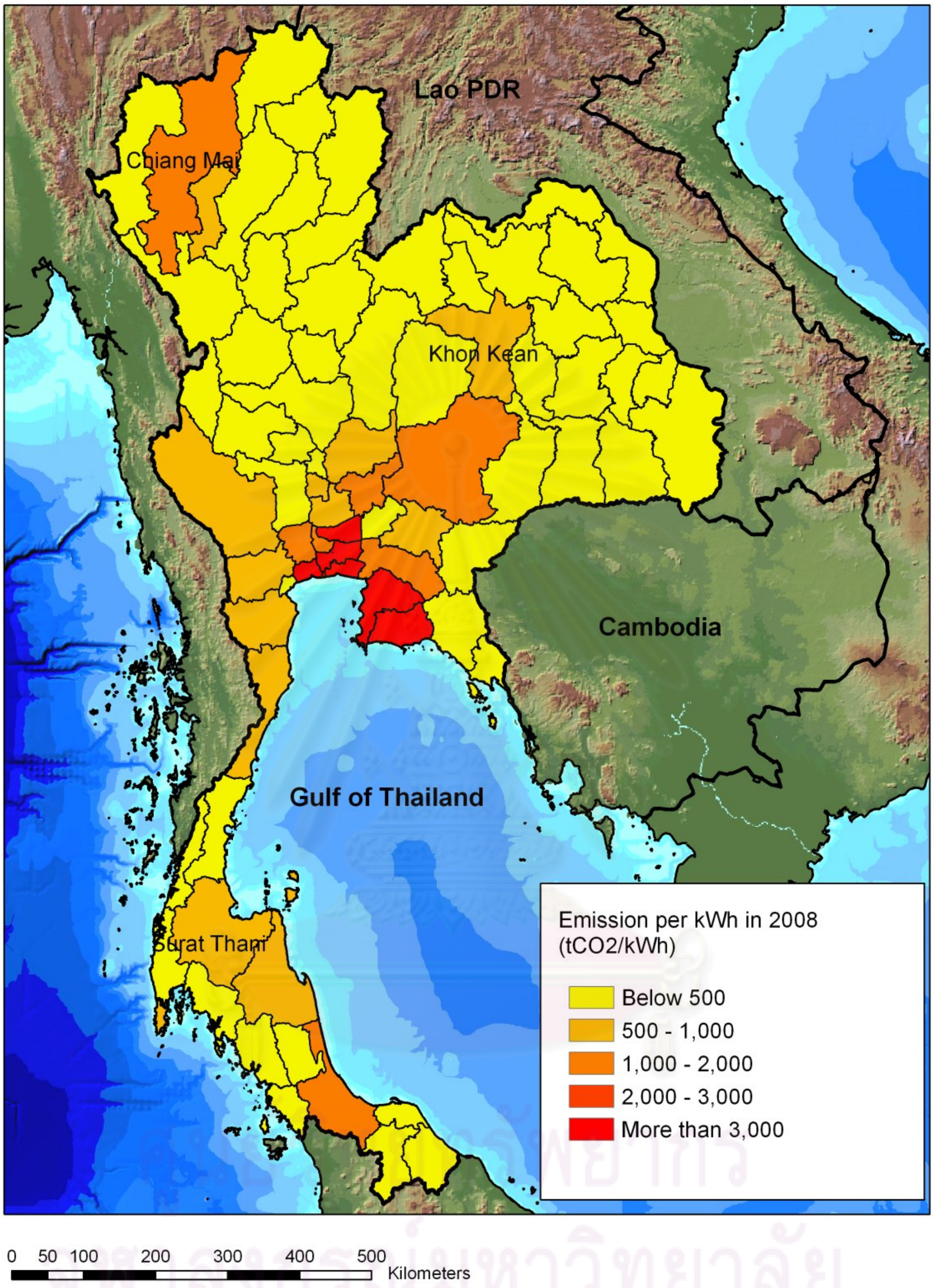

Figure 3 Emission per Unit in 2008

Source: Using data from OERC (2010)

Climate change is a serious and urgent problem, global in its cause and consequences. Stabilizing greenhouse emissions to limit climate change is a worthwhile insurance strategy for the world as a whole, including the richest countries. It is an essential part of our overall fight against poverty and for the

Millennium Development Goals (MDG)[2]. This dual purpose of climate policies should make them a priority for leaders around the world (United Nations Development Programme, 2007). Recent years have witnessed a fundamental change in the way governments approach energy-related environmental issues. Promoting sustainable development and combating climate change have become integral aspects of energy planning, analysis and policy making in many countries (The International Energy Agency, 2009a).

Low carbon electricity generation focuses on renewable energy resources such as wind, solar - Photovoltaic (PV) and Concentrating Solar Power (CSP) – hydroelectric power but also new technologies are emerging/maturing such as ocean energy, combined heat power (CHP) and fuel cells. At least one example of each of the above mentioned renewable energy resources is discussed in this section, with the appropriate renewable energy source indicated in the respective paragraph heading itself (KEMA Consulting, 2009). Thirty years ago, climate change problem was a theory. But in the past decade, global warming is now a household term, deemed one of the most difficult problems facing society in the new century (Randolph and Masters, 2008). Effective policy and regulation will be at the core of the response to global warming. In fact, the transition to a low-carbon economy might be the first global economic transition of this scale to be driven largely by policy. Designing this policy is a huge challenge to political leaders and regulators: it needs to achieve aggressive emission reductions, incorporate many sectors of the economy, be acceptable by many countries, be cost effective, and be equitable among the many stakeholder groups that are concerned.

Thailand should contribute to mitigate the impact of climate change as a member country of the world community, in a drive towards a decrease in GHG emissions resulting from activities in various sectors. It is likely that the main threat that will face fossil energy in the future is the development of catastrophic evidences

[2] The Millennium Development Goals (MDGs) are eight international development goals that all 192 United Nations member states and at least 23 international organizations have agreed to achieve by the year 2015. They include reducing extreme poverty, reducing child mortality rates, fighting disease epidemics such as AIDS, and developing a global partnership for development.

on the climate change. It will put strong pressure to reduce drastically the carbon emissions.

1.2 Objectives

The overall objectives of this research were to analyze pathways for implement low carbon electricity development in Thailand. This thesis combined processes investigation, emissions estimation to understand effects and environmental burdens from energy generation especially on power generation sector under different policy approaches. Based on the above considerations, this thesis has key objectives as follows:

– To analyze current situation and emission estimation of Thailand's electricity generation system under different policy approaches

– To identify the important obstructers or limiting factors affecting emission reduction and to examine options for implementation of low carbon electricity development pathways

– To recommended policies and potential outcomes of various combination of electricity generation system under possible policy approaches

1.3 Research questions

To meet the research goals in developing pathway for low carbon electricity development in Thailand, the research plan to examine the following key questions.

To evaluate policy instruments for emission reduction and management from electricity generation industry; this thesis focuses on the following research questions:

1. What is the current situation and emission rate of electricity generation industry in Thailand?

2. What are the key factors affecting the implementation of low carbon electricity development? How much impact of each factor from the past and into the future?

3. What are the strategies, options and cost for electricity industries for reducing greenhouse-gas emissions?

4. What pathways are the most appropriate comparing greenhouse gases emission reduction and cost for Thailand? How to achieve them?

1.4 Scope of this study

This study focuses on comparing the GHG emission under different scenarios or policy approaches to understand the potential of emission reduction and classify electricity generation activities to simulate emission scenario under three assumptions. First, project activities that generate electricity and delivered to the power grid, in effect displacing electricity from other sources. Secondly, project activities reduce consumption of grid electricity. The emission situations are estimated by determining GHG emissions of the sources of electricity that displaces or avoids from situation. This study excluded some of technology for low carbon electricity production. For example, stationary fuel cell, most research is currently aimed at fuels cells in the transport sector and less at stationary fuel cells. The use of fuel cells requires the shift towards another energy infrastructure, and such a shift is generally not expected to take place on a large scale before 2030. Therefore this option is excluded from this study.

1.5 Research methodology

This study focuses on comparing emission and constrain of low carbon development in Thailand. 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. To identify the contributions and the challenges of establishing a sustainable energy supply system, three scenarios are prepared in this research for Thailand's energy consumption and related carbon dioxide emissions up to 2030, which includes Business as usual (BAU), with nuclear scenario (WNC) and without nuclear (NNC) electricity development options (See also in Appendix B). 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. Field surveys and interviews have been carried out with people involved in electricity production activities.

The cost estimation presented in the study were calculated based on the International Energy Agency (IEA) methodology, using input parameters provided by literature reviews, site visiting, and interviewing. This study also estimated cost of power generation, and the cost data were collected from 43 power plants (See also in Appendix C). This comprises 4 coal-fired power plants, 19 gas-fired power plants, and 20 plants based on other fuels or technologies. The cost estimation presented in the study were calculated based on the International Energy Agency (IEA) methodology, using input parameters provided by literature reviews, site visiting, and interviewing.

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. Figure 4 illustrates the overall task in this study. After getting all data, scenario analysis are performed. All results will be used together

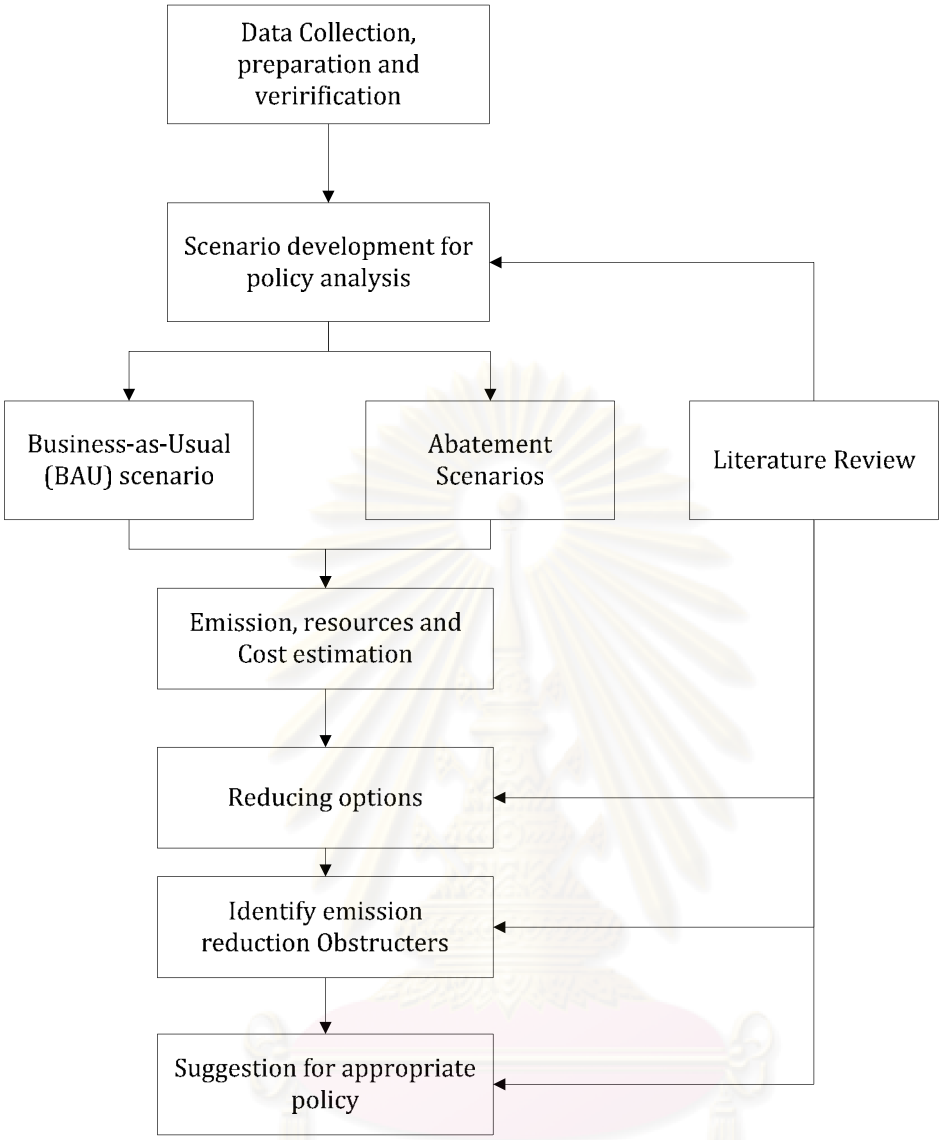

Figure 4 Overview of research methodology

1.6 Organization of the thesis

This thesis is structured into six chapters and seven appendices to provide information, results finding and published papers related to this study. The first chapter gives introduction in the work, including problem statement, objective and organization of the thesis. After the first chapter, a thorough literature review presents the concepts, frameworks and considerations for low carbon electricity. The third chapter describes Thailand's current electricity development situation. In the fourth chapter presents Thailand's electricity expansion policy, emission scenario, impact on energy consumption, greenhouse gas emissions and prospect for low carbon electricity development to year 2030.

In chapter fifth identifies barriers hindering the low carbon electricity development, options and challenges for promoting low carbon electricity development. Conclusions and Policy recommendations to implementation of low carbon electricity development in Thailand will present. In chapter sixth, policy suggestion for fuel diversification to low carbon emission in electricity generation, conclusion and recommendation for future study were presented.

Appendix A presents Status and Outlook for Thailand's Low Carbon Electricity Development by reviewing the latest situation on renewable powers and developmental strategies toward low carbon electricity generation in Thailand. In Appendix B gives an assessment of electricity development pathway toward low carbon electricity development for Thailand. The analysis presented realistic implementation potential for greenhouse gas emissions reduction from electricity sector in Thailand and compared mitigation options to identify active, cost-effective alternatives for the country.

Appendix C presents projected costs of generating electricity in Thailand and provides reliable information on the economics of electricity generation. Appendix D explains and gives information on capacity under Thailand Power Development Plan (PDP-2010). In Appendix E presents approved CDM methodology under UNFCCC. In appendix F presents review of Renewable Energy Promotion Policies in Different Countries (OECD and Non OECD). In appendix G present the general description of LEAP model.

CHAPTER II
CONCEPTS, FRAMEWORKS, AND CONSIDERATIONS FOR LOW CARBON ELECTRICITY DEVELOPMENT

2.1 Why does Greenhouse gases emission matter

The presence of certain gases, such as carbon dioxide (CO_2), methane, (CH_4) and nitrous oxide (N_2O), enables the atmosphere to act like a greenhouse, retaining part of the solar heat. The natural greenhouse effect is desirable as it traps part of the incoming solar energy to maintain habitable temperatures on the earth's surface. However, human activity is warming the planet. Anthropogenic greenhouse gas emissions are key factors in global climate change mitigation, especially carbon dioxide emissions from energy combustion activities. Global climate change can be considered a "Tragedy of the Commons" for which no effective global coordination, regulation, or enforcement has yet been developed. Impacts are likely to include changes in precipitation patterns, increased frequency and intensity of storms surges and hurricanes, changes in vegetation, and a rise in sea level. Developing countries, especially the poor ones, are more vulnerable to these changes given their high dependence on natural resources and their limited capacity—human, financial, and institutional—to adapt to extreme events.

Human activities, like burning of fossil fuels, deforestation, agricultural practices, and manufacturing are increasing the concentration of GHGs in the atmosphere and causing an enhanced greenhouse effect resulting in higher global average temperatures. For the past millennium the Earth's average temperature varied within a range of less than 0.7°C; however, manmade greenhouse gas emissions have resulted in a dramatic increase in the planet's temperature over the past century (The Intergovernmental Panel on Climate Change, 2007). The projected future increase over the next 100 years due to growing emissions could possibly warm the planet by 5°C relative to the preindustrial period. Such warming has never been experienced by mankind and the resulting physical impacts would severely limit development. Only through immediate and ambitious actions to curb greenhouse gas emissions may dangerous warming be avoided (The World Bank, 2010).

Electricity has become such a fundamental part of our lives that we take it for granted. Despite this fact, generating power has faced all challenges as it developed and now finds itself at the center of another storm: how to prevent massive disruption to the world's climate (Lewis, Chai et al., 2010). In facing this challenge, electricity curiously finds itself with looking both ways: simultaneously under pressure as the world's biggest source of greenhouse gas emissions, yet widely touted as the solution to other, even more intractable sources of carbon dioxide from transport and even heat. There is increasing consensus in both the scientific and political communities that significant reductions in greenhouse gas emissions are necessary to limit the magnitude and extent of climate change. Importantly, because electric power generator are among the largest point sources of important air pollutants such as sulfur dioxide, nitrogen oxides and mercury (Palmer and Burtraw, 2007).

Power generation is the main source of carbon dioxide emissions and accounts for four in every ten tones of carbon dioxide dispatched to the Earth's atmosphere (The International Energy Agency, 2009a). Therefore, this sector is the most prominent target for climate policy because it is the largest single source of carbon dioxide emissions and high potential for emission reduction. Reducing electric sector carbon dioxide emissions by significant levels will require major changes in how we use and produce electricity (Board on energy and environmental systems, 2010). Reducing electric sector carbon dioxide emissions by significant levels will require major changes in how we use and produce electricity (Board on energy and environmental systems, 2010). Whether electricity can really both decarbonizes and expands hinges on one main question: whether a carbon-constrained world can effectively foster low-carbon electricity generation at scale. 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 (The International Energy Agency, 2009c).

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 (United Nations Development Programme, 2007).

Thailand should contribute to mitigate the impact of climate change as a member country of the world community, in a drive towards a decrease in GHG emissions resulting from activities in various sectors. It is one thing to have the potential to make deep cuts in GHG emissions; it is another for policy makers to agree on and implement effective emission reduction policies, and for companies, consumers and the public sector to take action to make this reduction a reality. Capturing all the opportunities would entail change on a huge scale.

This chapter reviewed abatement opportunities, options challenges for promoting low carbon electricity development and commenced with importance of demand reduction; encouragement usage of renewable or low emission energy, and follow with emission reduction technology in electricity generation.

2.2 Abatement opportunities in electricity generation sector

In 2007, Nicholas Stern demonstrated that the cost of inaction could be as much as 10 per cent of global GDP (Stern, 2007). This got the attention of finance ministers and heads of governments, not just environment ministers. The abatement opportunities fall into three categories to promote low carbon electricity development. The first option is to use less energy by energy-savings, energy conservation, improvement of energy efficiency can help reducing the carbon problem, but they cannot by themselves solve the problem considering the huge growth in demand. The second option is to eliminate current fossil sources and replace them with non-fossil sources of energy that can fill the gap. This option is, in principle, feasible, but it would eliminate the foundation of the current energy infrastructure. The third option is to prevent the carbon dioxide that is associated with the consumption of fossil fuels from accumulating in the atmosphere. It is exceeding unlikely that any one of these three options will completely dominate the transition. For that, the constraints, even in the absence of climate change, would just be too large.

From study of McKinsey and Company (2009) reported the abatement opportunities in the period between now and 2030 fall into four categories: energy efficiency, low-carbon energy supply, terrestrial carbon (forestry and agriculture), and behavioral change. The first three, technical abatement opportunities, which are the focus of our study, add up to a total abatement opportunity of 38 $GtCO_2$ per year in 2030 relative to reference (BAU) emissions of 70 $GtCO_2$. There is potential by 2030 to reduce GHG emissions by 35 percent compared with 1990 levels, or by 70 percent compared with the levels we would see in 2030 if the world collectively made little attempt to curb current and future emissions.

Capturing enough of this potential to stay below the 2 degrees Celsius threshold will be highly challenging. They also stated that their research finds not only that all regions and sectors would have to capture close to the full potential for abatement that is available to them; even deep emission cuts in some sectors will not be sufficient. Action also needs to be timely. However, if this full potential was captured, emissions would peak at 480 ppm This would be sufficient to have a good chance of holding global warming below the 2 degrees Celsius threshold, according to the Copenhagen Accord that commits to limiting temperature increases to two degrees Celsius.

2.2.1 Reduced energy consumption with demand reduction

The question of how much tackling climate change is going to cost is a recurrent issue in today's global discussion e.g. how to transform in to a low-carbon economy, how large will capital investments need to be, which sectors offer the highest returns on those capital outlays? Ideally, energy use would be optimized by supply and demand interactions in the market. For electricity use in particular, the price paid on the market is often regulated or fixed, and in many cases does not reflect the full cost of production. Electricity use can vary dramatically on short and medium time frames, and the pricing system may not reflect the instantaneous cost as additional higher-cost ("peaking") sources are brought on-line. In addition, the capacity or willingness of electricity consumers to adjust to prices by altering demand (elasticity of demand) may be low, particularly over short time frames. In many markets, consumers (particularly retail customers) do not face real-time pricing at all, but pay rates based on average annual costs or other constructed prices.

The Demand Side Management[3] (DSM) is the process of managing the consumption of energy, generally to optimize available and planned generation resources. Without DSM programs, these energy and peak demand savings would not occur or would materialize only after significant delay, and in any case could not be relied upon, forcing utilities to construct expensive back-up capacity and causing higher rates. At that time, annual demand-side management expenditures measured in billions of dollars, energy savings measured in billions of kilowatts hours, and peak load reductions stated in thousands of megawatts.

Papagiannis et al. (2008) investigate the economic and environmental impacts that result from the implementation of an intelligent demand side management system, called Energy Consumption Management System (ECMS), at the European level. Implementation of DSM program can reduced 1–4 percent of primary energy, 1.5–5 percent in carbon dioxide emissions and a 2–8 percent saving in investment costs for power generation expansion.

Gellings and Parmenter (2008) discussed on benefits of implementation of DSM campaign in electricity sector reduces customer energy bills, the need for power plant, transmission, and distribution construction, stimulates economic development, creates long-term jobs that benefit the economy, increases the competitiveness of local enterprises, reduces maintenance and equipment replacement

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[3] Energy demand management, also known as demand side management (DSM), entails actions that influence the quantity or patterns of use of energy consumed by end users, such as actions targeting reduction of peak demand during periods when energy-supply systems are constrained. Peak demand management does not necessarily decrease total energy consumption but could be expected to reduce the need for investments in networks and/or power plants.

costs and reduces local air pollution. From study of WEC (2008) presented the implementation of energy efficiency policy is important as driving force for greenhouse gas emission reduction. Improving the efficiency with which electricity is produced is therefore one of the most important ways of reducing the world's dependence on fossil fuels, thus helping both to combat climate change and improve energy security. Additional fuel efficiency gains can be made by linking electricity generation to heating and cooling demands through high efficiency combined heat and power (CHP) systems (e.g. in industry and for district heating).

Thailand became the first country in Asia to formally adopt a nationwide DSM master plan. To support energy conservation activities, the Government of Thailand passed the Energy Conservation Promotion Act, or ENCON Act, in 1992, to provide a regulatory framework for energy conservation and efficiency programs and investments. This Act included the creation of an Energy Conservation Promotion Fund (ECF) to provide working capital, grants and subsidies to promote and facilitate energy conservation measures and renewable energy initiatives. Under the ENCON Act, the Department of Alternative Energy Development and Efficiency (DEDE) was appointed as the executing agency for the Compulsory (energy audits and public/private building efficiency investments) and Complementary (public relations and training) Programs.

The ENCON Act outlines major areas for energy conservation programs including a compulsory program for designated large commercial and industrial facilities and a voluntary program for small to medium sized enterprises. In January 2003, Thailand established the Energy Efficiency Revolving Fund to encourage involvement from financial institutions in energy efficiency projects, with initial funds of US$ 50 million. This government contribution provides capital at no cost to Thai banks to fund energy efficiency projects, and the banks in turn provide low-cost loans to project proponents. Owners of any commercial or industrial facility, whether or not it is a government-designated facility, are eligible to apply for loans from the fund. The payback period has been from less than a year to 4 years.

2.2.2 Reduced energy consumption by improvement of energy efficiency

End-use energy efficiency can be defined as the efficiency with which energy is consumed by end-users within the commercial, industrial and residential sectors. Through end-use energy efficiency improvements, the same economic benefits are achieved with less energy, meaning that fewer resources are consumed per unit of economic activity, and emissions are avoided. The efficiency of the existing electrical generating system which is not nearly as good as it could be, go on to what the charge for carbon emissions might be if the costs to society that come from emissions were to be included in the price of electricity generated from fossil fuels, and end with catching and storing the greenhouse gases. The reason for the inefficiency in generation and the larger than needed emissions that go with it is a combination of low fuel costs for fossil-fueled generation plants, and ignorance of the consequences of greenhouse gas emissions until relatively recently. Energy efficiency measures have not only been proven the most cost effective in terms of CO_2 mitigation, but also possess significant potential. High transaction costs, market and behavioral barriers have proven challenging to overcome. The emissions in electrical generation depend on the fuel used in the power plant. Energy and environmental policies cannot be implemented at an abstract level (Reddy, Assenza et al., 2009).

Investment in energy efficiency and investment in renewable are two different ways of balancing demand and supply in energy markets. Policies to promote energy efficiency may conversely make it harder for renewable to compete in electricity markets. If efficiency programs are cost-effective, electricity prices would be lower than they would be without the program, though not necessarily lower than before the program. There would be less demand for investment in renewable, and investment would be less profitable, all else being equal (Board on energy and environmental systems, 2010; Chandler, 2008). Peak-time electricity is expensive. Electricity demand peaks daily in any power system, and is also subject to sudden spikes, which may or may not be forecast. These relatively short periods, which may only amount to a few hours in the course of a year, are catered for by accessing reserves in the form of stored energy or flexible, “peaking” generators, which may only be operated at such times. Most of the Thailand’s electrical generating plants are old, when they were built, fuel was cheap and global warming was a thing few scientists worried about, much less citizens or governments.

Energy efficiency is a low-cost, rapidly deployable, and saving energy resource. Reducing growth in energy demand is essential to any clean energy strategy: without efficiency advances, clean energy supplies might not keep up with demand and carbon emissions could continue to grow (Reddy, Assenza et al., 2009). Despite efficiency's benefits, many of the policy mechanisms intended to reduce greenhouse gas emissions will not fully value energy efficiency in proportion to its economic potential unless policy and market barriers are reduced. Using electricity generated by conventional steam turbine power plants that burn brown and hard coal, the level of efficiency is between 35 and 45 percent. Modern gas and steam turbine power plants that use natural gas achieve up to 60 percent. However, this means that at least 40 percent of the primary energy fizzles out unused through the cooling tower of the power plant. When it comes to increasing efficiency, combined heat and power (CHP) or cogeneration[4] is often promoted as a promising candidate. CHP plants use the heat from electricity generation effectively and are able to exploit up to 90 percent of the fuel.

As a result, in an optimal case less carbon dioxide is produced than when electricity and heat are generated separately. Many comparisons of cogeneration power plants that generate heat and electricity separately using fossil fuels show possible carbon dioxide savings of up to 50 percent. However, these comparisons usually pit CHP plants against antiquated electricity plants. If the comparison is made on the basis of optimal functioning plants on both sides, the carbon dioxide savings are reduced to a meager 15 to 20 percent (See also in Figure 5). Furthermore, these savings are only possible with optimal plant operation. For example, in summer when a cogeneration plant is only supposed to generate electricity but not heat, it will have

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[4] Cogeneration is the co-production of electricity and useful heat. All electricity generation produces heat as a byproduct, of course, but in many cases the heat is not used because it is not of sufficiently high quality (i.e. not of high enough temperature) to be useful. Cogeneration is widely used in industries that need both heat and electricity (such as the pulp and paper and petrochemical industries) and in district heating systems.

great difficulty in even coming close to the dream efficiency level of 90 percent. The cogeneration plant can sometimes end up producing even more carbon dioxide than a straightforward electricity power plant.

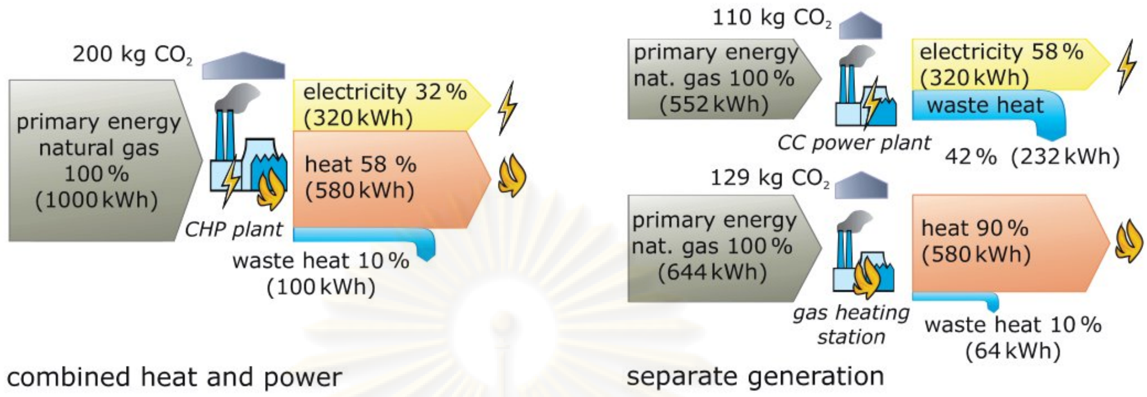

Figure 5 Comparison of Primary Energy Requirements and Carbon dioxide Emissions between Power Heat Coupling and Separately Generated Heat and Electricity in Modern Power Plants

Source: Quaschning (2010)

If, on the other hand, a sufficient requirement for heat exists over the entire year, cogeneration plants can help to reduce carbon dioxide. With cogeneration plants that use fossil fuels the savings for effective climate protection are too low. Those that use renewable energy sources, such as biomass and geothermal energy, are totally carbon-free and can continue to accelerate the switch to carbon-free energy supply. Prindle et al. (2010) describe efficiency's potential contribution to reducing carbon emissions, identify policy and market barriers to efficiency investments in a climate policy context, and outline policy and program solutions.

2.2.3 Decarbonisation of energy supply in electricity generation

Fossil fuels such as coal, oil and natural gas (primary energy) are converted into electricity (a form of secondary energy) with substantial losses during the conversion process. Reducing these losses, thereby increasing the overall efficiency of electricity generation, is the first opportunity in the chain of energy use for reducing the primary energy intensity of the global economy (Harvey, 2010). When a fossil fuel is burned, the chemical energy of the bonds in the fuel is converted to thermal energy. Some of this thermal energy is converted to electricity in the power plant, and the rest is lost as heat that is dissipated to the environment (the surroundings). The reported energy content of a fossil fuel is the thermal energy that is produced when the fuel is burned.

Carbon-free technologies, chiefly nuclear and renewable energy for electricity, will also play an important role in a carbon-constrained world, but absent a technological breakthrough that we do not foresee, coal, in significant quantities, will remain indispensable (Ansolabehere, Beer et al., 2007). Immense challenges are presented by the need to reduce the vulnerabilities associated with climate change, energy supply interruptions, and volatile fossil-fuel markets. Reducing electric sector carbon dioxide emissions by significant levels will require major changes in how we use and produce electricity. Cutting energy imports and substantially reducing our dependence on fossil fuels also will involve major changes (Board on energy and environmental systems, 2010). Decarbonisation of energy supply is among the key issues facing policymakers in the years ahead.

This section presented status of technology for prevents carbon dioxide that is associated with the consumption of fossil fuels from accumulating in the atmosphere.

2.2.3.1 Fuel switching to renewable energy supply

Generation of electricity from most renewable resources also reduces vulnerability to increases in the cost of fuels and mitigates many environmental impacts, such as those associated with atmospheric emissions of greenhouse gases and emissions of regulated air pollutants. REN21 (2009) reported annual renewable energy investment has increased fourfold to reach $120 billion in 2008. In the four years from 2004 to 2008, solar photovoltaic (PV) capacity increased six-fold to more than 16 Gigawatts (GW), wind power capacity increased 250 percent to 121 GW, and total power capacity from new renewable increased 75 percent to 280 GW, including significant gains in small hydro, geothermal, and biomass power generation.

There are many opportunities to shift energy supply from fossil fuels to low-carbon alternatives[5]. There are three categories of renewable energy, the first is solar energy that strikes the earth in vast amounts, providing heat for the oceans and land surfaces, drives the winds and waves, produces biomass and fuels through photosynthesis, and provides the energy for the hydrological cycle. The second source is the heat of the earth, which results primarily from natural radioactive decay. Finally, there is gravitational energy from tides and falling water. One can compare current societal energy use with natural energy fluxes to get some sense of the enormity of the renewable energy supply. While these renewable energy "fuels" are free, the challenge and the cost lie in the development and deployment of the multiple technologies to harvest the available energy and to integrate them into an efficient integrated system (Moomaw, 2008).

Renewable energy technologies such as wind power and solar photovoltaic (PV) devices have achieved major cost reductions over the last decades, which are expected to continue in the medium term as large global companies entering new energy markets for wind, solar and biomass technologies (Freris and Infield, 2008). By early 2009, at least 64 countries had some type of policy to promote renewable power generation (Board on energy and environmental systems, 2010). Multilateral agencies and private investors alike are "mainstreaming" renewable energy in their portfolios. Further, distributed renewable electricity generation located at or near the point of energy use, such as solar photovoltaic systems installed at residential, commercial, or industrial sites, can offer operational and economic benefits while increasing the robustness of the electricity system as a whole.

Renewable energy systems already reduce GHG emissions from the energy sector, although on a modest scale. The use of renewable electricity provides some significant advantages over the use of fossil-based electricity. Many types of

[5] If these low-carbon alternatives were to be fully implemented, from study of McKinsey and Company (2009: 192) estimate that they have the potential to provide about 70 percent of global electricity supply by 2030 compared with just 30 percent in 2005.

renewable electricity generating technologies can be developed and deployed in smaller increments, and constructed more rapidly, than large-scale fossil or nuclear-based generation systems, thus allowing faster returns on capital investments. Many renewable technologies and industries have been growing at rates of 20 to 60 percent, year after year, capturing the interest of the largest global companies (REN21, 2008). So much has happened in the renewable energy sector during the past five years that our perceptions lag far behind the reality of where the industry is today. Several of these low-carbon energy technologies are too expensive today to deploy on a large scale without financial incentives, emphasizing the need to provide sufficient support to make them travel down the learning curve allowing them to contribute to their full potential. Key examples include electricity production from wind, nuclear, or hydro power, as well as equipping fossil fuel plants with carbon capture and storage (CCS), and replacing conventional transportation fuel with biofuels.

Thailand has demonstrated its regional leadership in the South East Asia region during the last 20 years in energy and environment. Though having relatively low levels of GHG emissions in the last decades, now Thailand has increasingly experienced higher levels of GHG emissions and expects an even stronger increase in the future due to its continued economic development and population increase, among others.[6] As a result, Thailand should, therefore, contribute to mitigate the impact of climate change as a member country of the world community, in a drive towards a decrease in GHG emissions resulting from activities in various sectors (Ministry of Energy, 2009). It is likely that the main threat that will face fossil energy in the future is the development of catastrophic evidences on the climate change. It will put strong pressure to reduce drastically the carbon emissions. Even emerging countries will not escape penalization of the goods they produce on the export market if they are not carbon free.

[6] Thailand GHG emissions from the consumption and flaring of fossil fuels accounted for 1% of World's GHG emissions; ranking 22nd in the World's top GHG emitters. Thailand is the second largest contributor to fossil fuel GHG emissions in ASEAN after Indonesia.

To deal with the above issues, the Ministry of Energy has launched an ambitious program to increase investments in renewable energy such as wind, solar, biomass and other clean renewable energy sources. The Ministry has also set in motion the plans to speed up the preparation of the 15-Year Alternative Energy Development plan (AEDP) 2008- 2022 as well as the implementation pursuant to the Energy Conservation Program, Phase 3 (2005-2011), under which the target of energy saving has been adjusted from 10.8 percent to 20 percent by focusing mainly on energy saving promotion in the industrial and transportation sectors. These policies will promote energy security of the kingdom by reducing energy imports and increasing energy resources, building competitive energy market for sustainable economic growth, and help reducing the emission of greenhouse gases in the long run (Ministry of Energy, 2008).

The cabinet approved the 15-Year of Alternative 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. For increase sharing of renewable energy mixed to 20 percent of the final energy demand in 2022 (Ministry of Energy, 2009). 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.

This section 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 global greenhouse gas emission reduction. Major policy challenge is on which types of renewable energy should be more pronounced to ensure sustainable future of the country.

2.2.3.2 Generate electricity from nuclear power sources

The topic of electricity generation from nuclear power elicits strong emotions from supporters and critics. Although nuclear power supplies only the equivalent of 5.7 percent of the world primary energy at the time of writing this thesis, some believe this should be expanded massively. IEA (2009b) estimated the expansion of electricity generation from nuclear power plants rises from 2,719 TWh in 2007 to 3,670 TWh in 2030. Nuclear power generation capacity reached 371 GW in 2007 and is projected to rise to 410 GW by 2015 and to 475 GW by 2030. They also argue that it is an attractive source of electricity, having very low carbon emissions. Nuclear power plants produced 446 TWh or 4.9 percent of total gross electricity production reported for Non-OECD countries for 2007. Nuclear generation rose by 2.5 percent compared to 2006. Nuclear generation growth in Non-OECD countries expanded very rapidly from 1973 to 1985 with an annual average rate of 26 percent. Since, growth was noticeably lower with an annual average rate of 3 percent from 1985 to 2007.

After the Three Mile Island and the Chernobyl accidents there was a period of nearly ten years during which almost no new nuclear capacity was constructed. However, the recent concerns regarding fossil fuel security have prompted a number of countries to consider new building programmes (Rothwell and Graber, 2010). China and India are planning to build several tens of reactors each and the USA is posed to do the same. In contrast with Europe, only Finland has embarked on the construction of a new nuclear plant while, Sweden, Switzerland and Germany all have moratoriums in place leading to a phasing out of nuclear power. France on the other hand, remains committed to nuclear power which contributes about 80 percent of its present electricity needs.

Thailand will inevitably face energy crisis with the dramatic energy demand growth while oil and natural gas resources will be depleted sharply in the near future. Thai Government is considering for other promising alternative energy source that is nuclear power. Growing electricity demand, fluctuation of fossil fuel prices and climate change pressure bring all in a favor of nuclear power. From study of EGAT estimated every one kilowatt-hour of electricity produced in Thailand emits CO_2 by 0.5 kilogram (Electricity Generating Authority of Thailand, 2010b).

Therefore, the use of nuclear power will assist in achieving emission reduction goal for climate change in the future. 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. 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 2010 (Electricity Generating Authority of Thailand, 2010b).

However environmentalists, public policy makers, and financiers like to see a risk assessment of the nuclear option compared to other possible solutions (Eerkens, 2010). Such stakeholders want to be convinced that an expansion of nuclear power plants can be done safely and economically before they will give it their supports. They are apprehensive because a multitude of fear-instilling misrepresentations has been circulated in the media about nuclear power. Many of these stakeholders favor development of more diverse renewable energy e.g. solar, wind, and biomass energy at the exclusion of nuclear power without considering the scale, cost, and feasibility to replace the vast quantities of portable fuels presently extracted from oil fields. Government believes that modern nuclear plants are safe and have high quality-control standards.

Human factor is often weak point in the use of advanced 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 public along with the benefits to the country. 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.

2.2.3.3 Introduced clean coal technology

Coal is undoubtedly part of the greenhouse problem. The main greenhouse gas emissions from coal combustion are carbon dioxide, sulfur dioxide, nitrogen oxides, particulates, and mercury (Zhang, Zhuo et al., 2008). The three major uses of coal are: electricity generation, steel and cement manufacture, and industrial process heating. Coal-fired technologies are very common and widespread worldwide, both in developing countries and in industrialized countries. In 2006, total coal production increased by 7.6 percent, well above the 10-year average growth trend of 3.0 percent. Hard coal production increased by 8.8 percent (or 435.8 Mt) to 5,369.8 Mt. Brown coal production increased by 0.9 percent (or 7.8 Mt) to 913.8 Mt, a little above its 1997 level (The International Energy Agency, 2007).

Globally, the largest source of anthropogenic GHG emissions is CO_2 from the combustion of fossil fuels – around 75 percent of total GHG emissions covered under the Kyoto Protocol. Coal is the second source of CO_2 emissions within the OECD: between 1971 and 1985, coal was used as the main substitute to oil and its share increased, especially between 1978 and 1985, from its lowest point (31%) to its highest point (39%). Indeed, the challenge for governments and industry is to find a path that mitigates carbon emissions yet continues to utilize coal to meet urgent energy needs, especially in developing economies. Currently and for the near future, coal provides the major portion of global electric power supply. GHG emissions from coal-fired power generation arise mainly from the combustion of the fuel, but significant amounts are also emitted at other points in the fuel supply chain (Jaccard, 2005).

From study of MIT on future development of electricity generation from coal examines the role of coal as an energy source in a world where constraints on carbon emissions are adopted to mitigate global warming (Ansolabehere, Beer et al., 2007). The study suggested government should and will take more action to restrict the emission of carbon dioxide and other greenhouse gases. It should be noted that uses of clean coal technologies (CCTs) can reduce the environmental impact of burning coal. During the last two decades, significant advances have been made in the reduction of emissions from coal-fired power plants. In short, greenhouse gas reduction policies have, and will have, a major impact on the future use of coal. The coal industry's technical response to the environmental challenge is ongoing, with three core elements. First, to eliminating emissions of pollutants such as particulates, oxides of sulfur and nitrogen from electricity generation processes. Second, improving combustion technologies to increase efficiency and development of carbon capture and storage (Ansolabehere, Beer et al., 2007).

2.2.3.4 Introduce carbon capture and storage system

Growing concerns over the consequences of climate change may severely limit future access to fossil fuels. A forced choice between energy and environment could precipitate a major economic crisis, an environmental crisis, or both. Averting such a crisis will be difficult, because fossil energy resources are an essential part of the world's energy supply and climate change is mainly driven by the build-up of carbon dioxide in the atmosphere. Applications to fossil fuel power plants are especially important, since such plants account for the major portion of CO_2 emissions from large stationary sources. Recently, the concept of carbon capture and storage (CCS) as a means for reducing CO_2 emissions from power plants has emerged with several projects planned worldwide (Pocklington and Leese, 2010). The option of capturing CO_2 and storing it offers a means of allowing the large reserves of fossil fuels to be utilized while at the same time controlling GHG emissions. Methods of capturing and then storing CO_2 from major sources, such as fossil fuel burning power plants, are being developed in order to reduce the levels emitted to the atmosphere by human activities (Lackner, 2010).

Carbon dioxide is the unavoidable product of fossil fuel consumption. Therefore, the use of fossil fuels collides directly with global environmental concerns. Unfortunately, fossil fuels are difficult to replace, but stabilizing the atmospheric concentration of carbon dioxide requires a nearly complete transition to a carbon-neutral economy. This implies either the abandonment of fossil fuels or the introduction of carbon capture and storage, whereby for every ton of carbon extracted from the ground, another ton of carbon is put back. The capture of carbon dioxide from flue gases of industrial combustion processes and its storage in deep geological formations is now being seriously considered as one of the options for mitigating climate change. Given the growing worldwide interest in CCS as a potential option for climate change mitigation, the expected future cost of CCS technologies is of significant interest (Tondeur and Teng, 2008).

Schumacher et al. (2009) describe roles of CCS to provide low-emissions coal power station. CCS is an incremental innovation, representing a change within the existing system that does not endanger its overall structure. CCS allows for the continued use of fossil fuels, can be combined with the existing infrastructure (that is, mostly large-scale centralized power plants) and implemented by existing actors. Opponents therefore fear that CCS may further delay the urgent transition to a carbon-free electricity system. However, CCS may also be considered as an innovation that "buys time" for radical restructuring and may serve as a bridging technology towards a sustainable energy future. CCS could then be an innovation that paves the way out of the current carbon focus of electricity generation.

CCS has issues of concerns, i.e. CCS is an energy-intensive process, which lowers the overall efficiency of the power plant. In order to compensate for this efficiency loss, more fossil fuel per unit of electrical output must be used thus leading to further emissions. Furthermore, while capturing CO_2 from the power plant can reduce direct emissions from the power plant itself, upstream emissions resulting from fuel and material procurement and downstream emissions resulting from waste disposal cannot be captured. These upstream and downstream emissions are small when compared with emissions from combustion. However, when CCS is included, these emissions become dominant and so they must be included in the assessment (Odeh and Cockerill, 2008). CCS has an important and inevitable energy cost, implying that when it is applied, more primary energy is needed and, ultimately, more carbon dioxide is generated to produce a given amount of final energy. Clearly, this has to be accounted for carefully in accounting the benefits. The analysis of energy consumption is strongly related to the technology, in particular to the mode of combustion employed in the power plants.

Table 1 Summary of Availability of New Technologies Affecting the Electricity Industry

Generation Technologies			
Technology	Impact	Limitation	Availability
Integrated gas combined cycle turbines (IGCC)	Reduce CO_2 emissions; higher conversion efficiency; well suited to meet intermediate and peak demands	Gas price and supply uncertainty; still emits some CO_2	Now
Nuclear Power	No direct CO_2 emissions	High cost, public perception, spent fuel, security	Now
Biomass	Large CO_2 reduction	Cost of collection; aesthetics; technical limits to % that can	10 years
Wind Power	Most competitive renewable energy option; recent growth driven by incentives (taxes, credits) and renewable portfolio standards	Land availability; aesthetics; high cost of storage	10 years
Solar Photovoltaic (PV) power	High % of CO_2 reduction	Intermittent; conversion is both expensive and inefficient	25 years
Hydrogen (used in fuel cells)	Potentially large CO_2 reduction from electric power	Hydrolysis of water is costly; natural gas (CH_4), coal gasification the most likely sources	40 years
Internal combustion engines (ICE)	Use of natural gas reduces CO_2 emissions; use of CHP; increases end-use efficiency	Many current regulations limit distributed generation and micro-grids	Now
Micro-turbines	Use of natural gas reduces CO_2 emissions; use of CHP increases end-use efficiency	Many current regulations limit distributed generation and micro-grids	15 years
Advanced flow control systems	Improved system efficiency and reliability	Market learning needed to bring costs down	5 years
Superconducting material	Reduced line losses Greater control over power flow		
Energy Efficient End-Use Devices and Advanced Load Control Energy-efficient end-use devices and advanced load control	Reduce energy consumption More efficient end-use appliances	Mainly behavioral and institutional	Now

Source: Modified from Labatt and White (2007)

31

2.2.4 Capacity building in clean energy industry

In order to address the global climate change challenge, the electricity sector recognizes the need for more efficient electricity consumption and less carbon-intensive electricity supply. This shift will require the use of all technology and energy use management options available today, as well as future solutions currently face technological or commercial barriers to deployment. The decarbonisation of electricity is the key enabling factor for reducing emissions from power consumption sectors. It has a smaller role in enabling reductions in emissions from industry. Varieties of options exist for the utility sector; including the expansion of renewable energy like wind and solar, improving the thermal efficiency of electric generation as well as co-firing fossil fuel with biomass.

Collaborative Economics (2010) described the clean energy economy comprises five categories: (1) Clean Energy; (2) Energy Efficiency; (3) Environmentally Friendly Production; (4) Conservation and Pollution Mitigation; and (5) Training and Support. However, the clean energy economy also generates jobs, businesses and investments while expanding clean energy production, increasing energy efficiency, reducing greenhouse gas emissions, waste and pollution, and conserving water and other natural resources. Although specific jobs and businesses will change over time, the categories will not providing a clear, practical and consistent framework for policy makers and the private sector to track investments, job and business creation, and growth over time. Investing in clean energy already provides tens of thousands of workers with good jobs during hard times. The renewable energy industry in the United States opened 450,000 jobs in 2006 (Board on energy and environmental systems, 2010).

Table 3 and Table 4 show breakdown of renewable energy specific positions in US. Examples of jobs: Financial analysts and consultants specialize in clean technology investments, lawyers and paralegals provide legal services, researchers and engineers develop new energy generation technologies, and vocational teachers train new workers for the clean energy economy.

Table 2 Direct Jobs in US Renewable Energy Sector in 2006

Industry Segment	Revenues/Budget (billion USD)	Direct jobs
Wind	3.0	16,000
Photovoltaics	1.0	6,800
Solar thermal	0.1	800
Hydroelectric power	4.0	8,000
Geothermal	2.0	9,000
Bio-power	17.0	66,000
Federal government (including direct-support contractors)	0.5	800
DOE laboratory (including direct-support contractors)	1.8	3,600
State and local governments	0.9	2,500

Source: Board on energy and environmental systems (2010)

Table 3 Green Job Industry Segment in US

Green Job Industry Segments	Included within Industry Segment
1. Low Carbon Power & Renewable Power	Renewable/conventional equipment & power sales, project design & development
2. Carbon Capture & Storage (CCS)	Systems, equipment
3. Energy Storage: Equipment & Systems	Equipment & systems (batteries, hydrogen, etc.)
4. Energy Efficiency and Demand Response	Systems, equipment & appliances, audit & studies
5. Green Buildings	Design & development, building materials
6. Transportation	Vehicles, fuels & systems
7. Carbon Markets: Trading & Projects	Carbon trading, project development & operation
8. Climate change Adaptation	Risk assessment, planning, engineering & construction
9. Public-sector/ Government	Conservation & pollution prevention, rules & enforcement
10. Consulting & Research	Consulting & engineering, climate science
11. Waste Reduction & Management	Recycling & waste treatment
12. Non-Profit Sector	Policy analysis & advocacy

Source: Environmental Defense Fund (2009)

Table 4 Example of Breakdown of Renewable Energy Specific Positions

Wind	Solar	Biomass	Geothermal
Electrical, mechanical, engineers and technicians	Electrical, mechanical, chemical	Chemist and biochemist	Geologist, geochemist and geophysicists
Aeronautical engineers	Material scientists	Agricultural specialist	Hydrologists
Construction workers	Physicists	Microbiologist	Hydraulic engineers
Meteorologists	Construction worker, architects and builders	Electrical, mechanical, chemical engineers and technicians	HVAC contractors

Source: Board on energy and environmental systems (2010)

2.3 International Response for Greenhouse Gas Mitigation

The problem's political dimension is further complicated by the different time horizons affecting climate change (decades to centuries); the time horizon of assets in the electricity generation business (decades); and the time horizon of consumers, voters, and politicians (typically months to years). Decision making in these various segments necessarily follows different patterns with different priorities. To address these significant disparities, yet again, an integrated approach is need. This could be the most difficult challenge we are facing to address the carbon problem. This call for international cooperation to address environmental challenges was reiterated during the 1992 United Nations Conference on Environment and Development (commonly referred to as the "Earth Summit"). Among other things, the Rio Declaration[7] identified a clear link between sustainable development, economic growths, environmental protection, and called on countries to "cooperate to promote a supportive and open international economic system that would lead to economic

[7] The Rio Declaration on Environment and Development defines the rights of the people to be involved in the development of their economies, and the responsibilities of human beings to safeguard the common environment. The declaration builds upon the basic ideas concerning the attitudes of individuals and nations towards the environment and development

growth and sustainable development in all countries, to better address the problems of environmental degradation."

The Earth Summit was also crucial from a climate change perspective, as it led to the adoption of the United Nations Framework Convention on Climate Change (UNFCCC); the first global effort to address climate change. The Intergovernmental Panel on Climate Change (IPCC) established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), is widely recognized as the principal authority for objective information on climate change, its potential impacts, and possible responses to these. The "ultimate objective" of the UNFCCC is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference (i.e. resulting from human activity) with the climate system." The Convention elaborates a number of principles to guide parties in reaching this objective: for instance, the Convention calls on parties to employ a "precautionary approach" to climate change. The UNFCCC also manifest the principle of "common but differentiated responsibilities," which recognizes that even though all countries have a responsibility to address climate change, they have not all contributed to the same extent to cause the problem, nor are they all equally equipped to address it (Tamiotti, Teh et al., 2009). In the current period of concern regarding climate change, activity has taken place at both scientific and political levels (Table 5). The following section summarizes the progress made in these two areas.

Table 5 Major Milestones in the International Climate Change Regimes

Date	Activities
1954	The World Conservation Union Meeting in Copenhagen
1972	The First Earth Summit at Stockholm
1979	The first World Climate Conference
1987	The UN General Assembly declares climate change as "common humanity concern"
1988	UNEP and the World Meteorology Organization (WMO) establish the Intergovernmental Panel on Climate Change (IPCC)
	Toronto Scientific Conference on the Changing Atmospheric
	Calls for a 20 percent cut to 1988 GHG emission by 2005
1990	The IPCC first Assessment Report concludes that the planet seems to be warming and human activities seems to be responsible for it.

Date	Activities
1992	The UN Framework Convention on Climate Change (UNFCCC) is agreed to at the Rio Earth Summit
	The Rio Convention calls for a stabilization of GHG emissions by 2000
1994	The UNFCCC enters into force
1995	The UNFCCC COP-1 Meeting at Berlin
	The IPCC Second Assessment Report concludes that there is evidence suggesting a discernible human influence on the global climate
1997	The COP-3 meeting at Kyoto
	Adoption of the Kyoto Protocol to the UN Climate Convention
1998	The COP-4 meeting at Buenos Aires and call for action plan on how to reach the targets
2001	The IPCC Third Assessment Report on scientific evidence of global warming
	The IPCC finds stronger connection between human activities and global climate system
	The UNFCCC COP-10 meeting at Marrakesh
2002	The Third Earth Summit at Johannesburg
2004	Russia ratifies the Kyoto Protocol
2005	Kyoto Protocol enters into effect on February 16th
	First Meeting of the Parties (MOP) of the Kyoto Protocol takes place in Montreal, Canada
	The UNFCCC COP-11 meeting at Montreal and release Montreal Action Plan
2006	The Fourth Assessment Report on "warming of climate system is unequivocal"
2007	The UNFCCC COP-12 meeting at Bali and adoption on the Bali Road Map
2008	The UNFCCC COP-13 at Poznan
2009	The Bangkok Climate Change Talk
2009	The UNFCCC COP-14 meeting at Copenhagen
2010	Expected to draft the post Kyoto Protocol

Source: Summarized from Baumert et al. (2005), Staley and Freeman (2009) and UNEP GRID-Arendal (2009)

2.3.1 The Kyoto Protocol

The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) entered into force on February 16, 2005, following ratification by the Russian Federation. As of May 11, 2007, 172 countries and the regional economic integration organization (European Economic Community) have ratified, accepted, approved, or acceded to the Kyoto Protocol (The World Bank, 2008). The UNFCCC includes the principle of "common but differentiated responsibilities[8]" to reduce GHG concentration in the global atmosphere (The United Nations, 1998; UNFCCC, 2010c).

The objective of the Kyoto climate change conference was to establish a legally binding international agreement, whereby all the participating nations commit themselves to tackling the issue of global warming and greenhouse gas emissions. At the same time, an intense debate is underway regarding the technical and economic feasibility of different target levels, which emission reduction opportunities should be pursued, and the costs of different options for meeting the targets. Countries that have accepted greenhouse gas emissions reduction obligations must submit an annual greenhouse gas inventory. Non–Annex I countries (developing countries) that have ratified the Protocol do not have to commit to specific targets because they face potential technical and economic constraints. Nevertheless, they have to report their emissions levels and develop National Climate Change Mitigation Programs (UNFCCC, 2010b).

Leaders in many nations are discussing ambitious targets for reducing emissions of greenhouse gases (GHGs). Some regions have already set reduction targets. The EU, for example, has set a target that 2020 emission levels should be 20 percent lower than those of 1990, and has stated its intention of aiming for a 30 percent reduction if other countries with high emissions also commit to comparable emission cuts (McKinsey and Company, 2009). Under Kyoto Protocol requires Annex I countries[9] to collectively reduce their emissions of the six main greenhouse gases (i.e. carbon dioxide, methane, nitrous oxide, hydro fluorocarbons, per fluorocarbons, and sulphur hexafluoride) to at least 5 per cent less than 1990 emission

[8] UNFCCC adopts a principle of "common but differentiated responsibilities" on three board topics: (1) the largest share of historical and current global emissions of greenhouse gases originated in developed countries; (2) per capita emissions in developing countries are still relatively low; and (3) the share of global emissions originating in developing countries will grow to meet social and development needs

[9] Annex I countries include the industrialized countries that were members of the Organization for Economic Co-operation and Development (OECD) in 1992, plus countries with economies in transition (the EIT parties), including the Russian Federation, the Baltic states, and several Central and Eastern European states

levels. This target must be achieved over the five-year period from 2008 to 2012 (See also in Table 6).

Table 6 Emission Reduction Targets in the Kyoto Protocol for Annex I Countries

Countries	Target (1990-2008/2012)
EU-15, Bulgaria, Czech Republic, Estonia, Latvia, Liechtenstein, Lithuania, Monaco, Romania, Slovak Republic, Slovenia, Switzerland	-8%
United States	-7%
Canada, Hungary, Japan, Poland	-6%
Croatia	-5%
New Zealand, Russia, Ukraine	0
Norway	+1%
Australia	+8%
Iceland	+10%

Source: UNFCCC (2010a)

Although 172 countries and a regional economic integration organization (the European Economic Community) are parties to the agreement (representing over 61 percent of emissions), only a few industrialized countries are actually required to cut their emissions. The United States, the world's largest emitter, has conditioned its entry on further engagement of major developing country emitters, such as China and India. In countries that have begun to implement the Kyoto regime, this disparity in commitments has fueled a debate on issues of competitiveness and other economic impacts. The Kyoto Protocol remains the key international mechanism under which the industrial countries have committed to reduce their emissions of carbon dioxide and other greenhouse gases. The target agreed upon was an average reduction of 5.2 percent from 1990 levels by the year 2012. According to the treaty, in 2012, Annex I countries must have fulfilled their obligations of reduction of greenhouse gases emissions established for the first commitment period (2008–2012).

2.3.2 The Bali Road Map

After the 2007 United Nations Climate Change Conference on the island Bali in Indonesia in December, 2007 the participating nations adopted the Bali

Road Map as a two-year process to finalizing a binding agreement in 2009 in Copenhagen (UNFCCC, 2010d). The conference encompassed meetings of several bodies, including the 13th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP-13) and the 3rd Meeting of the Parties to the Kyoto Protocol (MOP-3 or CMP-3).

The Bali Road Map includes the Bali Action Plan (BAP) that was adopted by Decision 1/CP.13 of the COP-13. It also includes the Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol (AWG-KP) negotiations and their 2009 deadline, the launch of the Adaptation Fund, the scope and content of the Article 9 review of the Kyoto Protocol, as well as decisions on technology transfer and on reducing emissions from deforestation. The Bali Action Plan highlighted the importance of "Measurable, Reportable and Verifiable (MRV)" greenhouse gas mitigation actions and commitments for a post-2012 climate framework.[10] The Climate Change Conference in Bali laid key foundations for negotiations on a post-2012 climate regime. It emphasizes the willingness of all Parties to contribute to a future climate regime in line with their respective capabilities and determines that all Parties must report on their measurable and verifiable activities. Together with a range of other decisions it forms the Bali Roadmap, the negotiation mandate. The negotiations are to be concluded at the Climate Change Conference in Copenhagen in 2009.

2.3.3 Copenhagen accord

The UN Climate Change Conference, held in December 2009 in Copenhagen, was a crucial moment in the international fight against dangerous climate change. Representatives from hundreds of governments and other organizations around the world gathered to make their voices heard. The Copenhagen Accord commits the world to limit temperature increases at two degrees Celsius (2˚C)

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[10] Currently, experience with measurement, reporting and verification (MRV) of GHG mitigation has been focused in three areas: project-based reductions in non-Annex I countries through the clean development mechanism (CDM); entity-based emission levels in Annex I countries (e.g. through emission trading schemes); and national-level GHG accounting in Annex I countries.

and contains plans for finance reaching a hundred billion dollars a year by 2020 (Department of Energy and Climate Change, 2010; Verbruggen, 2009).

Since Copenhagen, over 100 countries have associated themselves with the Accord and as a result of the targets and actions put forward; around 80 percent of emissions are covered by the agreement. It is a political agreement, which includes a number of substantial commitments:

– Endorses the continuation of the Kyoto Protocol

– Underlines that climate change is one of the greatest challenges of our time and emphasizes a "strong political will to urgently combat climate change in accordance with the principle of common but differentiated responsibilities and respective capabilities"

– Recognizes that "deep cuts in global emissions are required according to science" (IPCC AR4) and agrees cooperation in peaking (stopping from rising) global and national greenhouse gas emissions "as soon as possible" and that "a low-emission development strategy is indispensable to sustainable development"

– Agreement to reduce global emissions and limit average increases in global temperature to no more than 2°C.

– Developed and developing countries pledge to put their emissions reduction targets and mitigation actions into appendices to the Accord by January 31, 2010.

– The developing nations (non-Annex I Parties) would "implement mitigation actions" (Nationally Appropriate Mitigation Actions) to slow growth in their carbon emissions, submitting these by 31 January 2010. LDS and SIDS may undertake actions voluntarily and on the basis of (international) support.

– The developing countries would report those actions once every two years via the U.N. climate change secretariat, subjected to their domestic MRV. NAMAs seeking international support will be subject to international MRV

– Recognizes "the crucial role of reducing emission from deforestation and forest degradation and the need to enhance removals of greenhouse gas emission by forests", and the need to establish a mechanism (including REDD-plus) to enable the mobilization of financial resources from developed countries to help achieve this

– A commitment from developed countries to provide approaching $30 billions of immediate fast start funding over the period 2010-2012 to support developing country action on mitigation and adaptation.

– A commitment from developed countries to work towards long-term public and private climate finance flows reaching $100 billion a year by 2020.

– Agreement to establish a High Level Panel to explore the potential sources of climate finance that would help achieving this $100 billion goal.

– Agreement to set up a new Copenhagen Green Climate Fund (the 'Green Fund') to deliver a significant portion of this finance to developing countries.

– Agreement to establish a technology mechanism to achieve greater coordination and scaling-up of global action on technology development and deployment.

– Agreement to establish a new mechanism to help developing countries tackles deforestation.

– A commitment to review progress in implementing the Accord by 2015.

2.3.4 Clean Development Mechanism (CDM)

Countries with commitments under the Kyoto Protocol (KP) to limit or reduce greenhouse gas emissions must meet their targets primarily through national measures. The Protocol does not prescribe how emission reductions should be met. As additional means of meeting these targets, the Kyoto Protocol introduced three market-based mechanisms, now known as the "carbon market." It does, however, propose three flexible mechanisms designed to help Annex 1 countries meeting their emission reduction obligations: namely emissions trading schemes (ETS), Joint

Implementation (JI), and the Clean Development Mechanism[11] (CDM) (Labatt and White, 2007).

The Clean Development Mechanism (CDM) is one of the two project-based flexible mechanisms of the 1997 Kyoto Protocol. The CDM allows industrialized countries to meet their emissions reductions targets in part through 'carbon credits' bought by investment in low-carbon projects in developing countries. CDM projects are also supposed to result in benefiting developing countries by helping them to achieve sustainable development (Volpi, 2005). The CDM enables the project owner to sell the ER credits, once they are certified, to an interested buyer. The CDM allows developed countries listed in Annex 1 of the UNFCCC to invest in greenhouse gas emission reduction projects in non-Annex 1 developing countries to claim Certified Emission Reduction[12] (CERs) to assist them in compliance with their binding GHG emission reduction commitments under the protocol (The World Bank, Ministry of Science and Technology. P.R. China et al., 2004).

The CDM allows industrialized countries to invest in emission reductions wherever it is cheapest globally. Between 2001, which was the first year CDM projects could be registered, and 2012, the end of the Kyoto commitment period, the CDM is expected to produce some 1.5 billion tons of carbon dioxide equivalents (CO_2-eq) in emission reductions (Figure 6 and Figure 7 illustrate status of CDM in term of types and amount of CERs). Most of these reductions are through renewable energy, energy efficiency, and fuel switching. However, a number of weaknesses of the CDM have been identified. The benefits of CDM for the developing country are new financial resources, technological transfer, and achievement of its sustainable development objectives, while the benefit for developed countries is access to less expensive ER opportunities in a developing

[11] The CDM is a financing instrument defined in Article 12 of the Kyoto Protocol. A project in a developing country that reduces GHG emissions, relative to a baseline project, generates emissions reduction (ER)

[12] Certified Emission Reductions (CERs) are a type of emissions unit (or carbon credits) issued by the Clean Development Mechanism (CDM) Executive Board for emission reductions achieved by CDM projects and verified by a DOE under the rules of the Kyoto Protocol

countries. As emissions have the same global effect irrespective of their geographical origin, CDM provides a cost-effective way of addressing the adverse effects of global warming (World Bank Carbon Finance Unit, 2006).

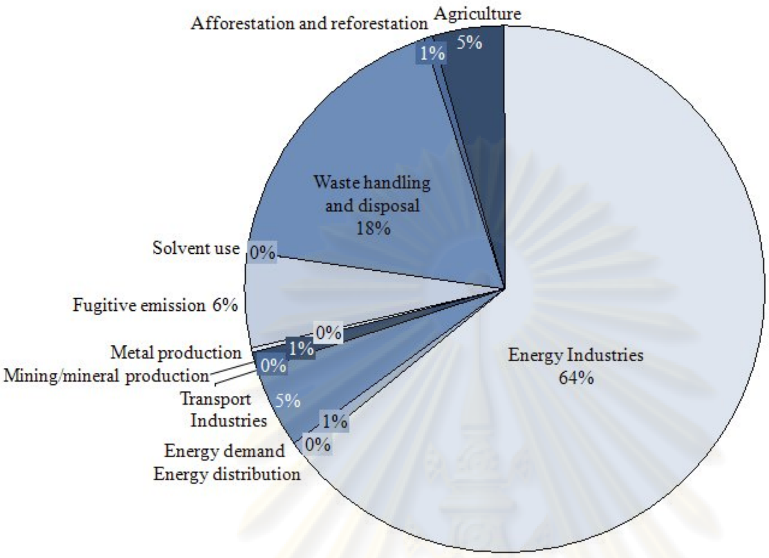

Figure 6 Distribution of Registered Project Activities by Scope

Source: Using data from UNFCCC (2010a)

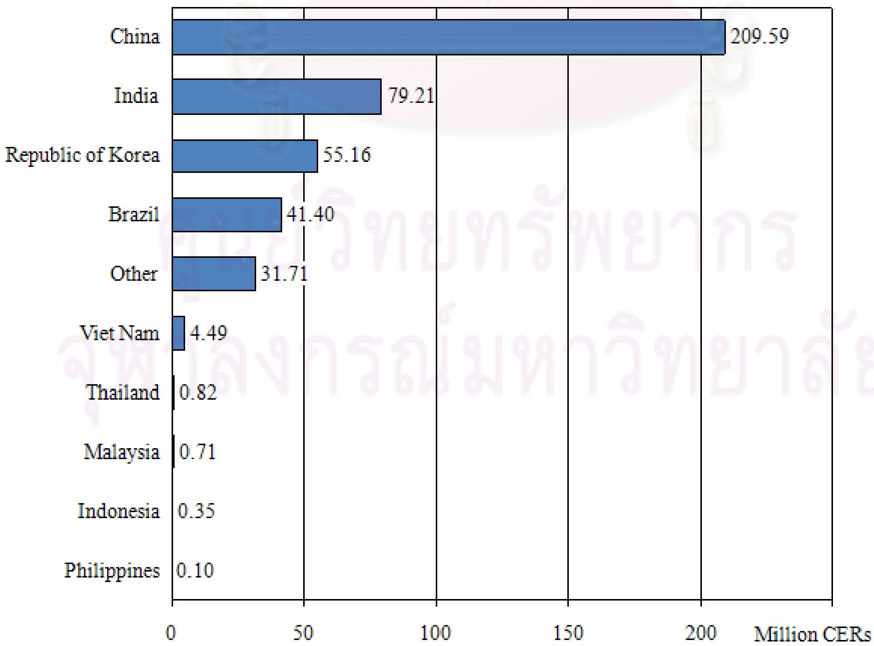

Figure 7 CERs issued by Host Party

Source: Using data from UNFCCC (2010b)

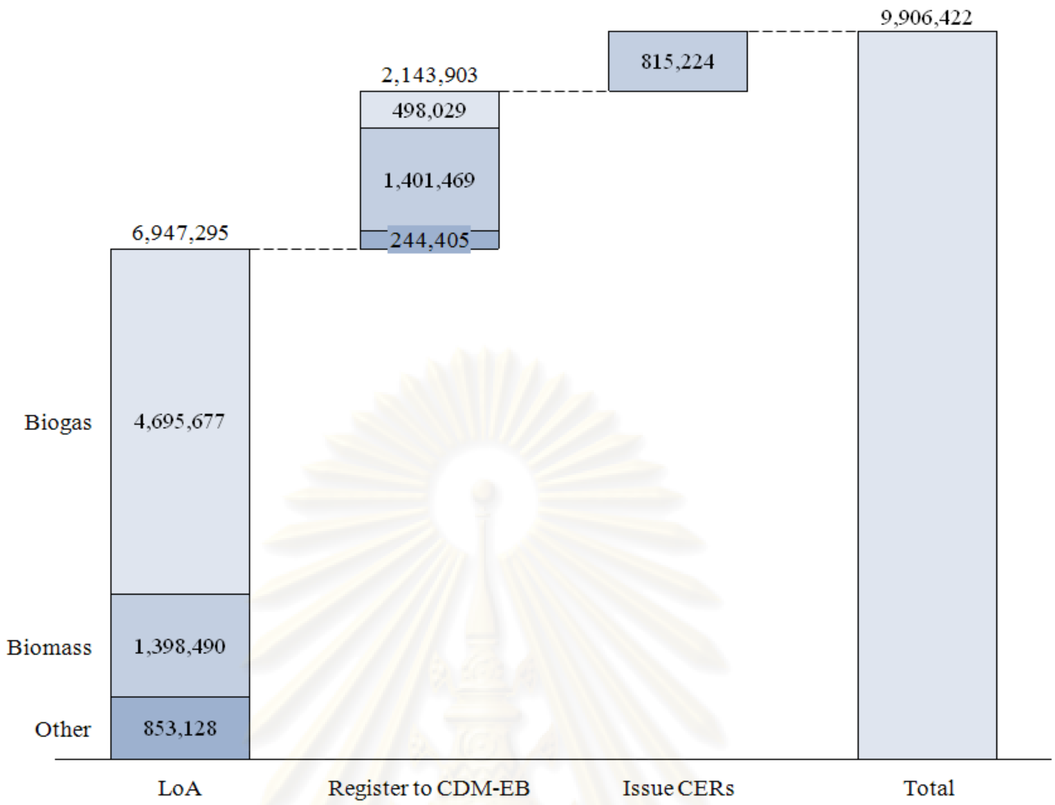

Figure 8 Status of Thailand CDM

Source: Using data from TGO (2010)

2.3.5 Nationally Appropriate Mitigation Actions

While the Bali Action Plan[13] suggests the possibility of linking GHG mitigation action in developing countries with support for such action, in a "measurable, reportable and verifiable (MRV)[14]" manner, it does not specify the relationship between nationally appropriate mitigation actions (NAMAs) in developing countries and support for such actions. In particular it leaves open the question of whether or not the two should be explicitly linked, or whether progress in

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[13] Paragraph 1(b) (ii) of the Bali Action Plan calls for: “Nationally appropriate mitigation actions by developing country Parties in the context of sustainable development, supported and enabled by technology, financing and capacity-building, in a measurable, reportable and verifiable manner”.

[14] In defining a framework for MRV of action and/or support, many issues still remain to be addressed. Still to be defined for the post-2012 regimes are the scope of what needs to be measured (e.g. GHG outcomes, intermediate outcomes, or inputs), how it should be measured, when MRV is required, and who should be responsible for doing it.

one area might be dependent on progress in the other area (e.g. actions are dependent on financing or financing is dependent on actions). It also remains unclear whether the MRV requirements apply to the link between NAMAs in developing countries and mitigation support, or to one or both of the separate elements. However, the Bali Action Plan does not specify the relationship between NAMAs in developing countries and support for such actions. In particular it leaves open the question of whether the two should be linked or whether progress in one area is dependent on progress in the other area (e.g. actions are dependent on financing or financing is dependent on actions). It also remains unclear whether the MRV requirements apply to the link between NAMAs in developing countries and mitigation support, to one or both of the separate elements or to all three dimensions of the linking notion.

In the international climate negotiations preceding Copenhagen in December 2009, nationally appropriate mitigation actions, (NAMAs) were used as the solution of many open issues and with very different interpretations of what the term actually stands for. The negotiations have so far failed to define what NAMAs actually are. Views also differ on the institutional structure needed for providing support to NAMAs as well as ways to measure, report and verify actions. Due to this vague approach, the negotiations surrounding NAMAs are still generalized, making it difficult to work on concrete implementation issues. In many discussions and submissions, NAMAs have been categorized as follows:

– Unilateral NAMAs: mitigation actions undertaken by developing countries on their own

– Supported NAMAs: mitigation actions in developing countries, supported by direct climate finance from Annex I countries (in the following called 'directly supported NAMAs')

– Credited NAMAs: mitigation actions in developing countries, which generate credits to be sold on the carbon market (e.g. sectoral crediting).

2.4 Summary of Findings

Climate change is now a scientifically established fact. The exact impact of greenhouse gas emission is not easy to forecast and there is a lot of uncertainty in the science when it comes to predictive capability. But we now know enough to recognize that there are large risks, potentially catastrophic ones (Watkins, Ugaz et al., 2007). Climate change, and more specifically the carbon emissions from energy production and use, is one of the more vexing problems facing society today. It is not just an environmental issue. It is fast becoming one of the defining facts of economic development in the 21st century. It will shape investment, technology deployment and human development around the world and no sector will be more profoundly affected than energy. Energy is central to sustainable development and poverty reduction efforts. It affects all aspects of development.

Currently, electric power production is largely based on the combustion of fossil fuels, predominantly coal and natural gas, except in countries with abundant hydropower. This inevitably leads to the emission of CO_2, since carbon capture and storage and renewable energy sources are not feasible or available yet on a large scale. Decarbonisation of energy supply is among the key issues facing policymakers in the years ahead. To address the problem requires careful consideration and balance among multiple dimensions, technical, economic, social, and political. Electricity is versatile not only in its applications but also in its energy sources. It is the only practical way that we can currently use coal, nuclear, hydro, wind energy, and solar photovoltaic on a large scale, and we can actually use any other form of energy to produce it, including oil, natural gas, biomass, solar thermal, and geothermal, among others. Although electricity is still our most expensive form of energy, electricity prices have remained relatively stable during the past 30 years when fossil fuels prices have been extremely volatile (Randolph and Masters, 2008).

Electricity price does not truly reflect include externality to the world ecosystem. Energy fuels our economy and quality of life, but it is costly both in monetary terms and in impacts to the natural and human environment. These impacts are part of the "cost of doing business" but to a large extent they are not included in the costs of energy. They are termed externalities. Externalities are social costs borne by users and non-users alike, but not internally by the producer and thus are not reflected in the price of goods or services produced (Randolph and Masters, 2008). To achieve sustainable energy, we must consider these costs over the fuel or system's life cycle. These environmental impacts include air pollution from the combustion of fossil fuels, radioactive materials involved in the nuclear fuel cycle, impacts on lands and waters of fuel extraction, and transport and construction of conversion systems. Before addressing these impacts, the section below discusses what appears to be the major environmental constraint facing fossil energy—global climate change triggered by greenhouse gas emissions, primarily carbon dioxide from fossil fuel combustion.

Looking at the various factors influencing carbon emissions to find an efficient path for reducing carbon emissions, one might expect marginal cost of reducing CO_2 to be about the same for all alternative options. To find the most economically efficient path, it is important to seek and pursue opportunities for carbon reduction that have the lowest costs among all the sectors of the economy. In this context, it is not economically efficient, for example, to pursue high-cost but low-carbon opportunities in the electricity generation sector if electricity conservation can produce the same results at lower costs. By the same token, if low-cost opportunities exist in the transportation sector, these must be pursued before higher-cost opportunities in electricity generation are captured. Renewable energy is considered generally as sustainable energy. Nonetheless, environmental and social issues of renewable energy technologies do arise with increasing significance, increasing project size, and energy-related trade. Guidelines and recommendations for sustainable practices in renewable energy applications are becoming increasingly important.

In next chapter, current situation of Thailand's electricity generation system was presented, followed with evolution, current status, generation capacity, electricity demand, characteristics and fuel mixture in electricity generation.

CHAPTER III
GENERAL SITUATION IN THAILAND'S ELECTRICITY SECTOR

3.1 Evolution of Thailand's electricity development

3.1.1 Before establishment of Ministry of Energy

During the 1970's, approximately 90 percent of Thailand's commercial primary energy consumption (including non-energy use) was imported mostly petroleum products. The discovery of natural gas in the Gulf of Thailand and lignite in the Northern part of the country reduced amount of import dependence to about 60 percent. During early 1990s when high growth in power demand existed, the government developed several initiatives to privatize state electric utilities then firmed up after 1997, and engage independent power producers (IPPs) through the use of long-term power purchase agreements[15] (PPAs) for supply of electrical power into the grid system. Thailand's power system has a single buyer structure that the Electricity Generating Authority of Thailand (EGAT) currently provides 53 percent of the country's electricity supply. EGAT plays not only the main role in generating country's electricity generation but also in operating all high voltage transmission lines, and monopolizing the buying power of the country's electricity (Amranand, 2009).

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)

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[15] Power Purchase Agreement (PPA) is a legal contract between an electricity generator (provider) and a power purchaser (host). The power purchaser purchases energy, and sometimes also capacity and/or ancillary services, from the electricity generator. Such agreements play a key role in the financing of independently owned (i.e. not owned by a utility) electricity generating assets. The seller under the PPA is typically an independent power producer, or "IPP." Energy sales by regulated utilities are typically highly regulated, so that no PPA is required or appropriate.

responsible for electricity sale in the remaining parts of the country. Lastly, private power producers sell electricity to the electric utilities under power purchase agreements or 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 (See also in Figure 9).

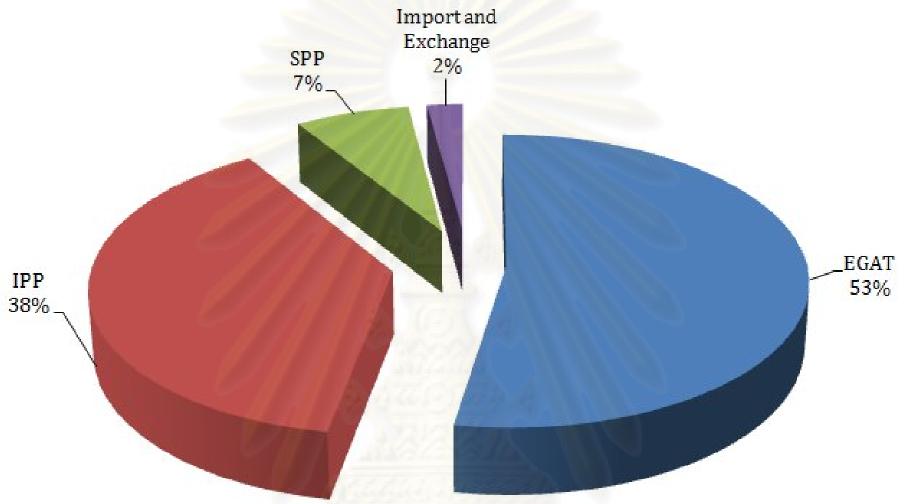

Figure 9 Share of Electricity Supply in 2009

Source: Using data from Ministry of Energy (2010)

Amranand (2009) describe the electricity development in the period before 1991, there was no private power producer supplying electricity into grid. The National Energy Policy Office (NEPO) had been trying to introduce private sector investment since 1989 through implementation of regulation to require the electric utilities to buy power generated by small private power producers, but the policy faced heavy resistance by the electric utilities and their labor unions. In 1992, SPP regulation for purchase power from Small Power Producers was finally approving under the government of Anand Panyarachun and the announcement of IPPs program in 1994 for larger power plants.

The SPP program allowed private investment in the generation of electricity using the cogeneration system and generation of electricity using renewable energy. The criteria for selected SPPs using steam usability, efficiency of the cogeneration system and size of facilities. In 2001, government introduced the Very Small Power Producer Program (VSPP) for allowing SPP with sale into the grid of less than one MW. The VSPPs can also sell to any one of the three electric utilities (EGAT, MEA and PEA) depending on their connectivity to grid transmission system (Figure 10 illustrate distribution of power plant classified by types of producer).

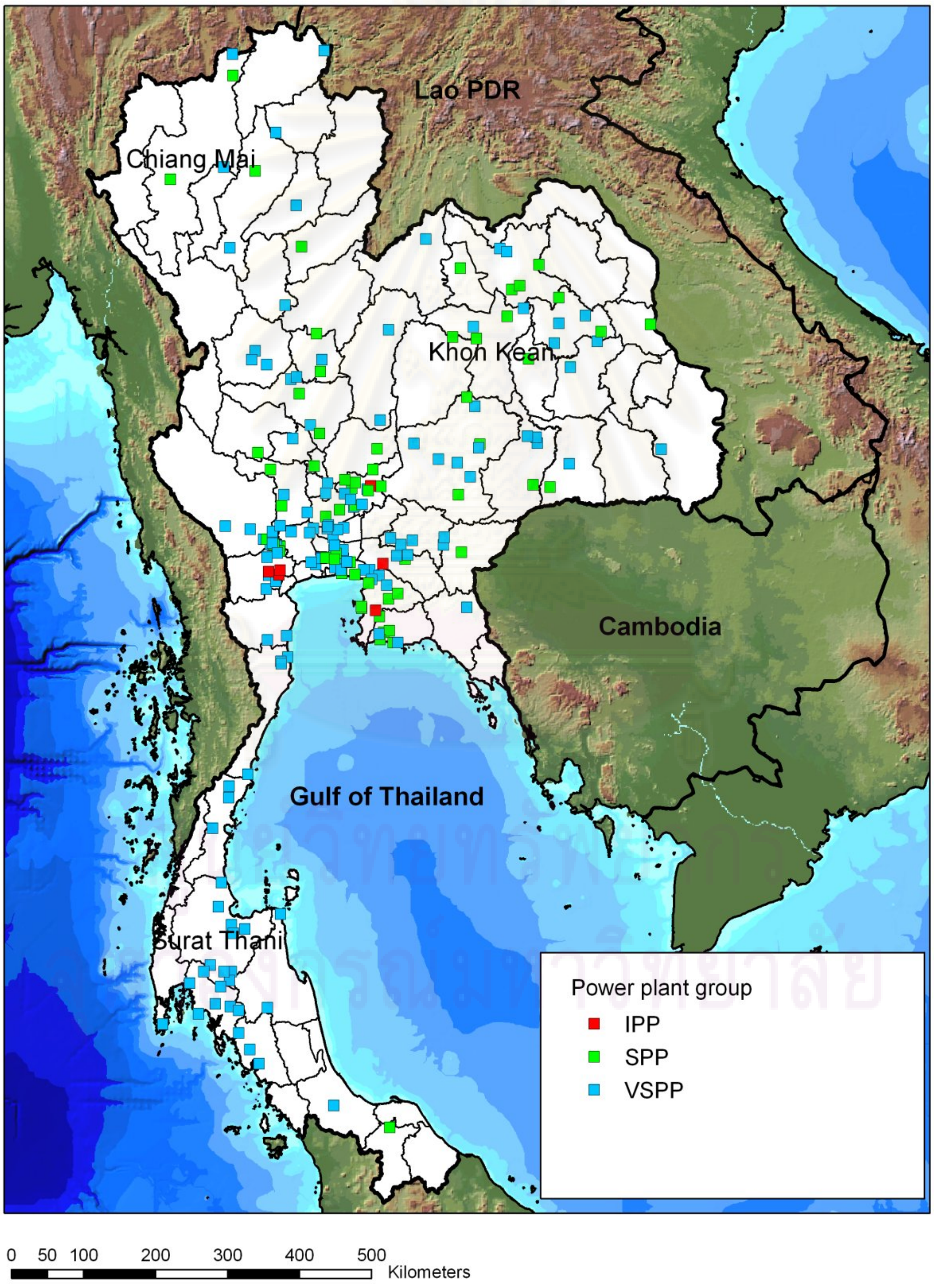

Figure 10 Distribution of Power Plants Classified by Types of Producer

Source: Using data from OERC (2010)

In addition, the government also launched a program to encourage the renewable energy SPPs by providing an additional tariff for a period of 5 years from the Energy Conservation Fund using adder system. The "adder" was determined through a competitive bidding system that resulted in approval of 14 projects with average "adder" of 0.18 baht per kWh (US¢ 0.56), representing approximately 5 percent increase from the normal tariff. With a relatively low level of adder, it is not surprising that all of the 14 projects were using bagasse, paddy husk, or woodchips as fuels. By the end of 2006, there were about one hundred SPP and VSPP projects supplying 2,344 MW of electricity to the grid, but since most of these facilities also sold electricity to users nearby, total generating capacity were around 4,160 MW. Almost all of these projects were those launched before 2002 as very few projects were initiated after the establishment of Ministry of Energy.

3.1.2 The establishment of Energy Regulatory Commissioner (ERC)

The most significant development in the regulation of Thailand's energy sector is the passage of the Energy Act B.E. 2550 since December 11, 2007, an Energy Regulatory Commission was appointed in February 2008 consisting of seven members, to serve as an independent agency responsible for regulating and monitoring power and gas sectors to ensure the reliability and security of the power and gas supplies. However, the Commission works within the policy framework established by the National Energy Policy Council (NEPC), chaired by the Prime Minister.

The Commission is primarily responsible for reviewing a national power development plan for submitting recommendations to the Cabinet. For regulating and approving gas transportation and electricity tariffs including the automatic tariff adjustment mechanism or commonly known as the F_t tariff; issuing licenses; regulating the energy sector in a fair and transparent manner; ensuring the delivery of quality and reliable energy services and protecting the rights and interests of energy consumers, local communities and general public.

Moreover, the Act provides for specific responsibilities and authorities for the Commissioner in fulfilling its mandate are the Power Development Fund[16]. The Fund is to be used as a channel for implementing the subsidy arrangements for underprivileged power consumers; rehabilitating localities; compensating people affected by power plant operations, and the promotion of renewable and environmentally friendly energy. Revenue for the fund is provided by a levy on power generators through the electricity tariffs. All power plants have to pay a levy to the Fund during the plant commissioning at the following rates.

3.2 Current Status

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 (Chirarattananon and Nirukkanaporn, 2006). 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.

3.2.1 Generation capacity

The electricity supply system in Thailand consists of a single tightly interconnected grid that serves the entire country using 'circle-network system' to connect the whole country in an electric ring structure. Energy Policy and Planning Office (2010a) reported at the end of 2008, the country's power system had a total installed generating capacity of 29,891.65 MW, 4.77 percent higher than the prior year, consisting of the generation capacity from EGAT's power plants totaling

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[16] Under section 93 of the Energy Act B.E. 2550 (2007) provide roles and responsibility of commissioner to set up the Power Development Fund to be (1) used as capital to support extensive extension of electricity service provision to various localities so as to decentralize prosperity to provincial areas; (2) to develop the local communities affected by the operation of a power plant; and (3) to promote the use of renewable energy and technologies in the electricity industry operation that have less impact on the environment, with due consideration on the balance on natural resources; and (4) to create fairness for power consumers".

15,020.96 MW, accounting for 50.25 percent of the country's total capacity. Domestic private power producers and neighboring countries totaling 14,870.69 MW or 49.75 percent of the country's total generation capacity, comprising 12,151.59 MW from domestic independent power producers (IPPs), 2,079.10 MW from small power producers (SPPs) under firm energy contracts, and 640 MW power import from Laos and Malaysia.

The deepening world economic crisis and the domestic political unrest have severely affected on country's export, manufacturing, and tourism industries, thus resulting in declining electricity consumption growth. The country's gross energy generation throughout 2008 totaled 148,200.93 million kWh, a mere 0.87 percent increase from the preceding year, comprising energy generation from EGAT's own power plants and electricity purchased from private power sources. EGAT's power plants provided 63,930.68 million kWh of electrical energy, accounting for 43.14 percent of the country's total generation. EGAT's generation was 2.80 percent lower than the previous year. Its generation energy mix included natural gas (accounting for 25.13 percent of the country's total electricity), lignite (12.60 percent), hydropower (4.69 percent), and diesel oil (0.71 percent). Additionally, EGAT's renewable energy power plants including geothermal, solar cells and wind power plants also supplied totally 2.00 million kWh of energy. EGAT has continuously decreased its generation from the high priced oil to keep its production cost to the lowest possible. Compared with the prior year, it's fuel oil-based and diesel oil-based generation was reduced by 68.90 percent and 15.94 percent respectively. Generation from hydropower also decreased 12.69 percent whereas natural gas-based and lignite based generation increased from the previous year by 3.56 percent and 0.97 percent respectively (Electricity Generating Authority of Thailand, 2008).

3.2.2 Electricity demand

Energy Policy and Planning Office (2010a) reported the electricity consumption in Thailand classified into three principal end-user sectors including industrial, commercial and public services, and residential sector. The electricity consumption increased from 56,279 to 134,937 GWh during 1993 to 2008 and peak demand of electricity increased from 9,730 to 22,568.2 MW during 1993 to 2008. The industrial sector is the largest electricity consumer with growing demand at average of 7.5 percent per year. The energy-intensive industries dominated demands are petrochemicals, steel mills, refineries and cement plants. The power sector in Thailand like many other developing countries is heavily dependent on fossil fuels. Much of this capacity based on thermal and combined cycle generation where natural gas alone contributes to over 73.90 percent of total electricity generation, followed by lignite and coal at about 17.40 percent, hydropower at 3.63 percent and fuel oil at 1.38 percent respectively (Figure 11).

Electricity consumption increased 5.52 percent from the prior year to 127,930.30 million kWh. Industrial sector continued to be the biggest consumers accounting for 48.84 percent of the country's total electricity consumption, followed by business or commercial sector (24.77 percent), residential sector (21.04 percent), and other sectors (5.35 percent). In 2006, the consumption in the industrial and business sectors grew at the slower rates of 4.77 percent and 6.76 percent respectively while residential and other sectors saw the consumption growth rates of 5.61 and 6.41 percent (Electricity Generating Authority of Thailand, 2007). EGAT's electric energy sales throughout the year 2008 increased barely 1.40 percent year-on-year to 141,557.89 million kWh.

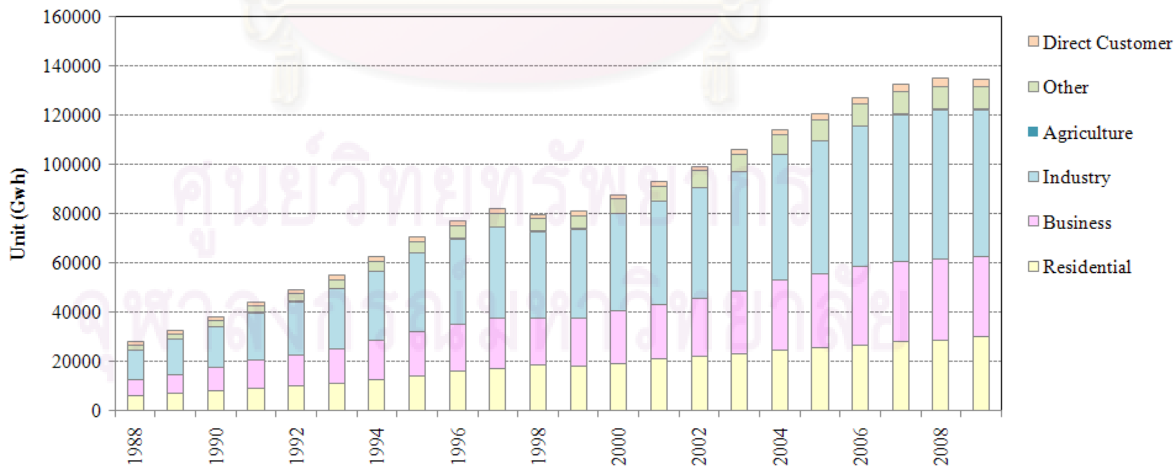

Figure 11 Electricity Consumption by Sector from 1988 - 2009

Source: Using data from Energy Policy and Planning Office (2010a)

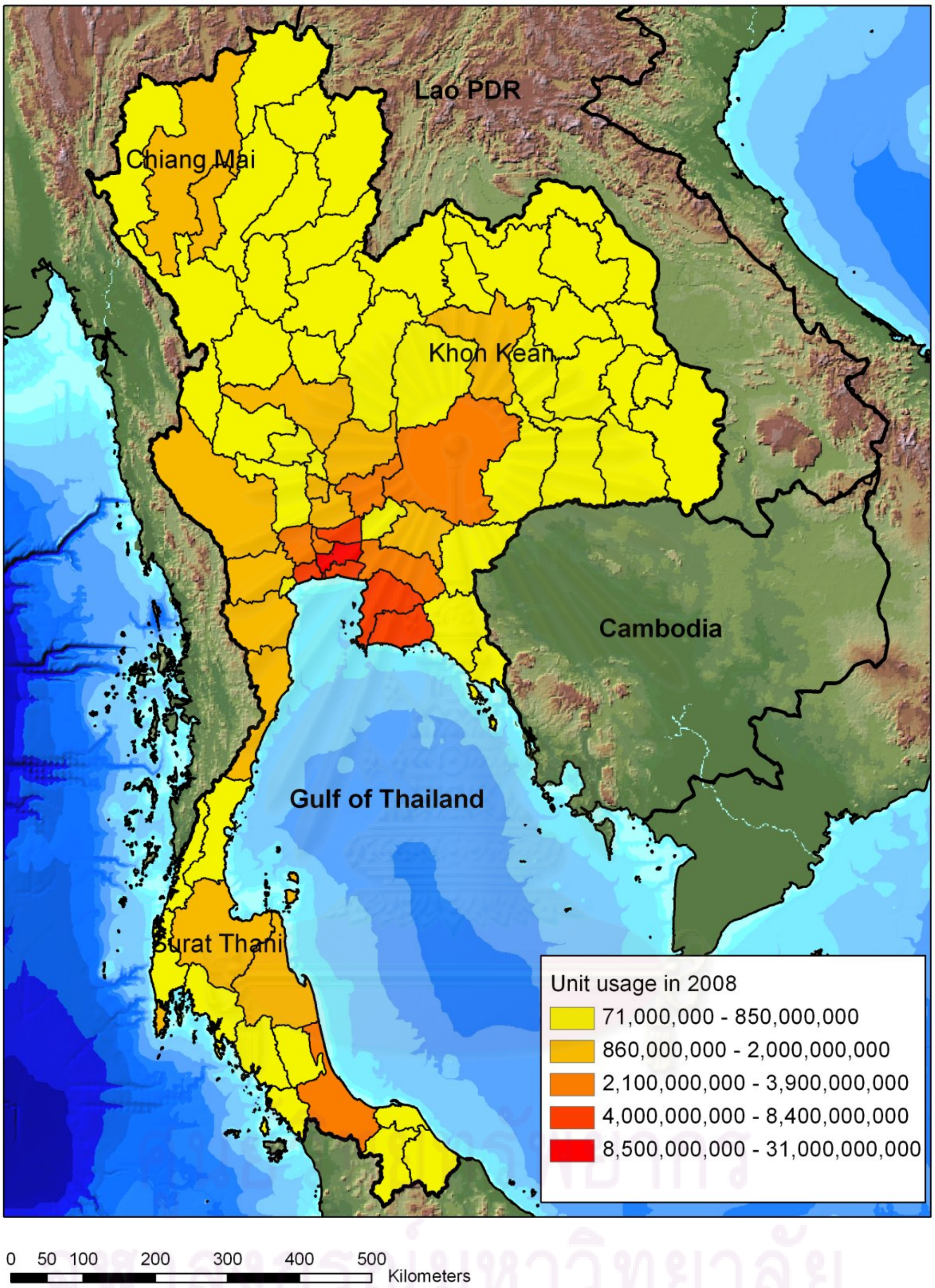

Figure 12 Electricity Consumption in 2008

Source: Using data from OERC (2010)

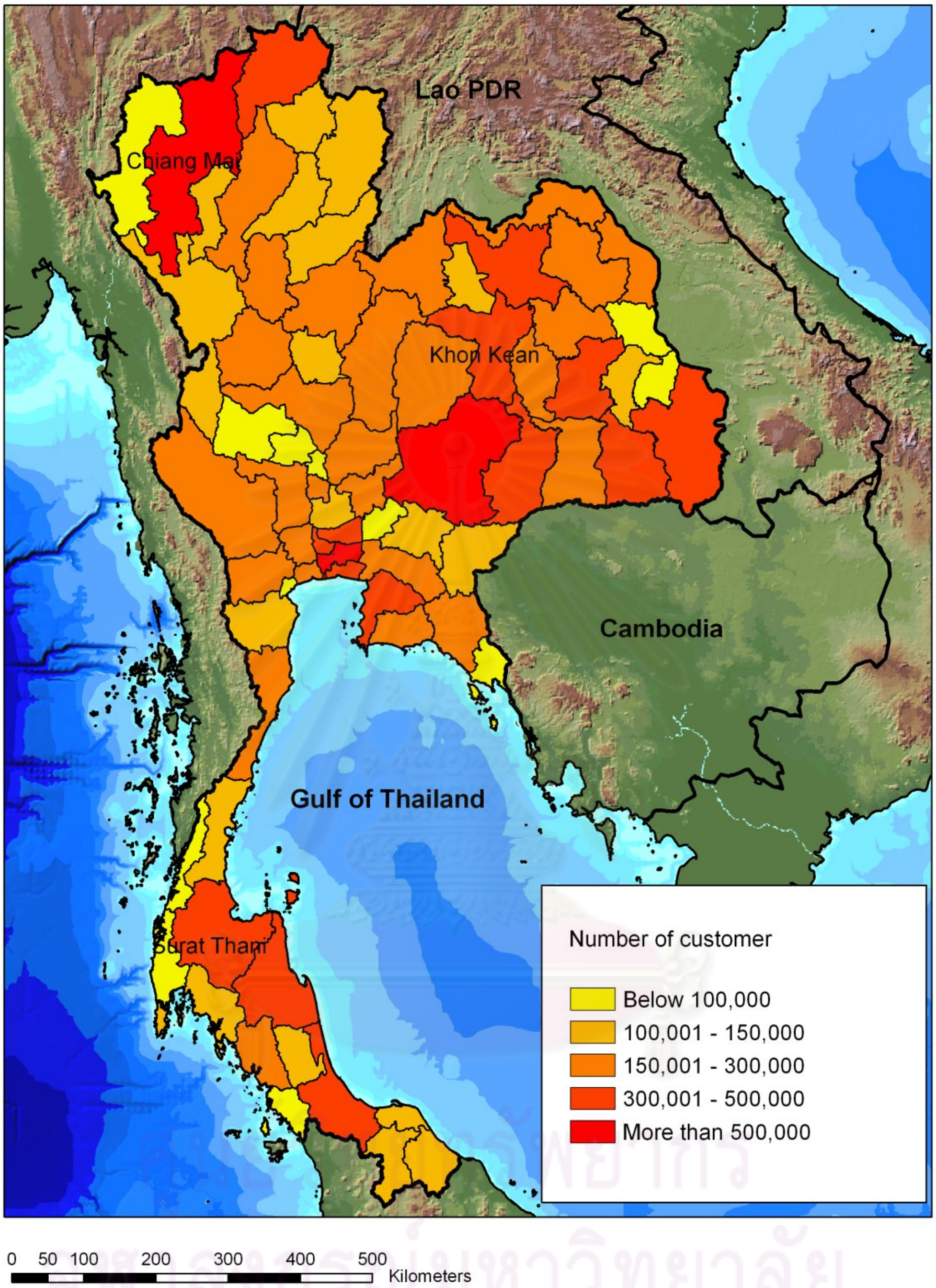

Figure 13 Number of Customers in 2008

Source: Using data from OERC (2010)

The dropping sales growth was attributable to the softening electricity demand caused by decelerating economic expansion. EGAT's sales volumes in 2008 consisted of 94,859.95 million kWh of energy (67.01 percent) sold to the Provincial Electricity Authority (PEA), 43,598.23 million kWh (30.80 percent) to the

Metropolitan Electricity Authority (MEA), 1,622.49 million kWh (1.15 percent) to a small number of direct customers, 961.10 million kWh (0.68 percent) to neighboring utilities, and 516.12 million kWh (0.36 percent) to other minor customers (Electricity Generating Authority of Thailand, 2008).

Compared to the year 2007, the sale volumes to PEA increased only 1.83 percent whereas the sales to MEA increased marginally from last year. The energy sales to neighboring utilities grew 29.06 percent due mainly to the increased portion of electric energy sold to the Cambodia via Electricite du Cambodge (EDC)[17] since November 2007. On the other hand, the energy sales to EGAT's direct customers dropped by 1.90 per cent because of sluggish economy. The sales portion to other minor customers increased 13.68 percent from the preceding year (Electricity Generating Authority of Thailand, 2008). As of October 2009, peak generation of electric power system was recorded at 22,045 MW and peak demand of electricity was 123,857 GWh with 77 percent of Load factor (Energy Policy and Planning Office, 2010a).

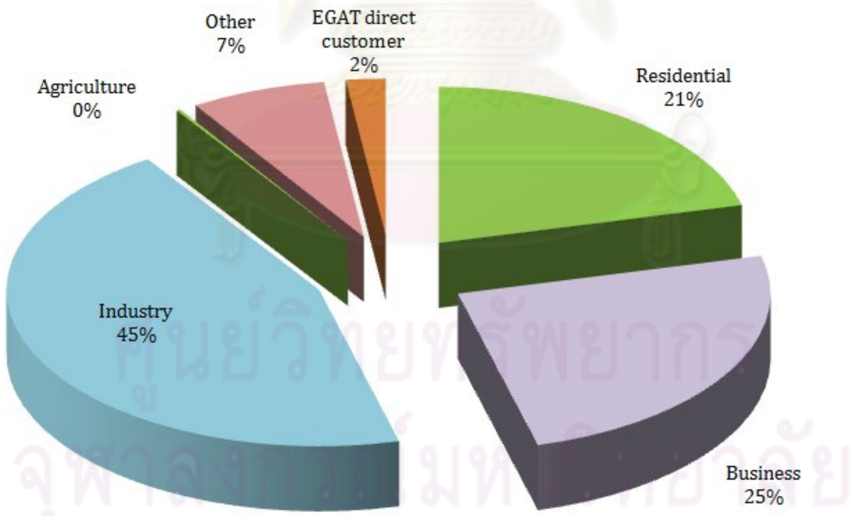

Figure 14 Electricity Consumption in 2009

Source: Using data from Ministry of Energy (2010)

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[17] Cambodian electricity company

3.2.3 Fuel consumption

Electricity production by the utilities correspondingly increased from 4,400 GWh in 1970 to about 44,000 GWh in 1990 because of the start using natural from the Gulf of Thailand. This amount obtains around 12.78 percent of total energy consumption. In 1990, the total installed capacities in the power sector amounted to 8,500 MW this amount are six fold increase from about 1,300 MW in 1970.

Electricity Generating Authority of Thailand (2009) reported total of Thailand's capacity can be classified as hydro power plants of 3,764.2 MW (13.6%), thermal power plants of 9,666.6 MW (34.8%), combined cycle power plants of 12,806.0 MW (46.0%), gas turbine and diesel power plants of 972.4 MW (3.5%), and renewable power plants of 279.3 MW (1.0%) including the Thailand-Malaysia interconnection (1.1%).

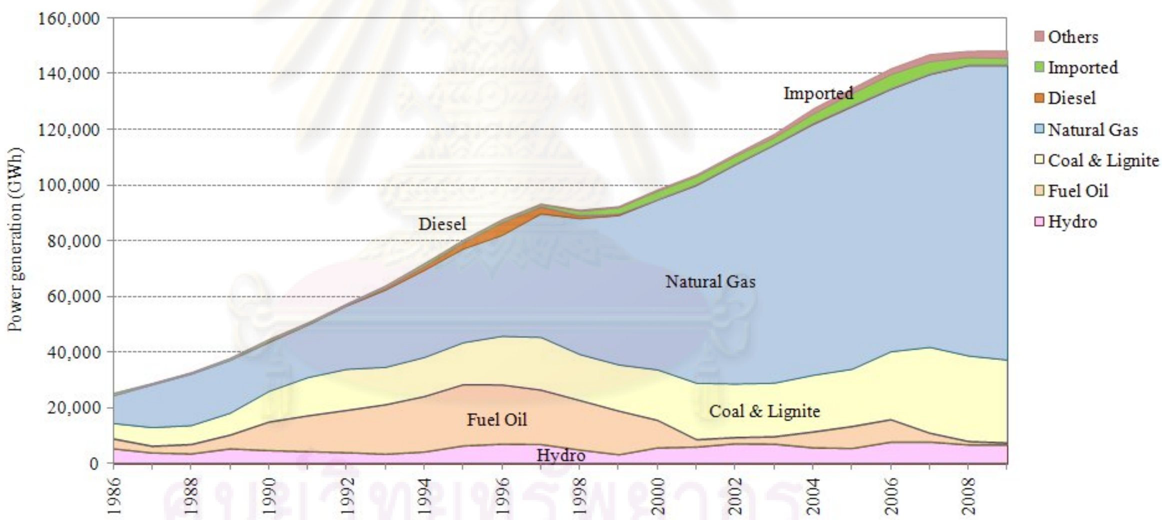

Figure 15 Capacity and Fuel Share of Thailand's Electricity Generation

Source: Using data from Ministry of Energy (2010)

3.2.3.1 Natural gas utilization

For natural gas utilization in electricity generation, Thailand uses 74 percent of its natural gas supply for power generation and 70 percent of its power comes from gas-based technology and the rest based on coal, hydropower and renewable energy (Energy Policy and Planning Office, 2010a). Nakawiro (2007) express high dependence on natural gas in power generation raises concerns about security of electricity supply that could affect competitiveness of Thai manufacturing and other industries at the global level (Figure 16). Although natural gas supply of Thailand is from domestic resources, the country could be vulnerable from high gas dependence in its power generation (Energy Policy and Planning Office, 2010a).

In 2008, natural gas utilization at EGAT's own generation facilities amounted to 339,786 million cubic feet or 302,471 billion Btu equivalents. The gas supplies came from various gas fields including the Gulf of Thailand, Nam Phong, Phu Hom, Sirikit, the A-18 field of the Thai-Malaysian joint development area (JDA) in the Gulf of Thailand, Arthit, and Myanmar's Yadana and Yetakun gas fields. EGAT's gas utilization decreased 0.74 percent from the prior year but produced electric energy 3.56 percent more (Energy Policy and Planning Office, 2010d).

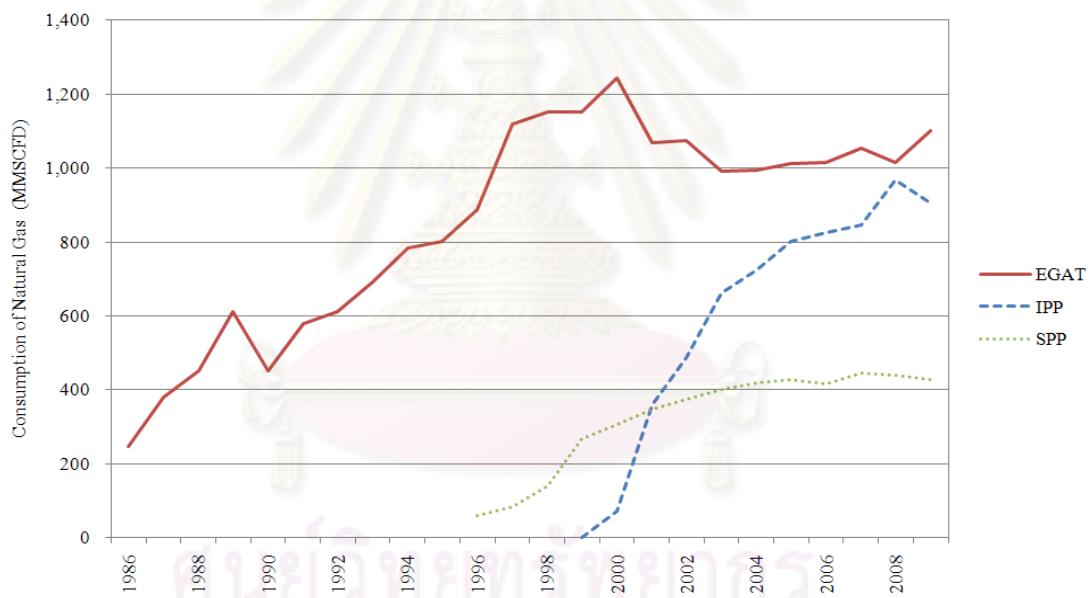

Figure 16 Natural Gas Consumption for Electricity Generation

Source: Using data from Ministry of Energy (2010)

Nakawiro and Bhattacharyya (2007) indicated natural gas has played its crucial role for electricity generation in Thailand for years. Although the country obtains various benefits from gas-based generation technology, it has been recently revealed that high gas dependence in power generation makes the Thai economy vulnerable over time. In the near future, continued growth in electricity demand is likely to make the country vulnerable from gas dependence in power generation. The

Office of the Energy Regulatory Commissioner (OERC) (2010) reported the installed capacity of natural gas based power plant in Thailand reached 26,216 MW. Of this, the power capacity from 9,036 MW from EGAT, 12,832 MW from IPP, 4,307 MW from SPP and 39.94 MW from VSPP power plant.

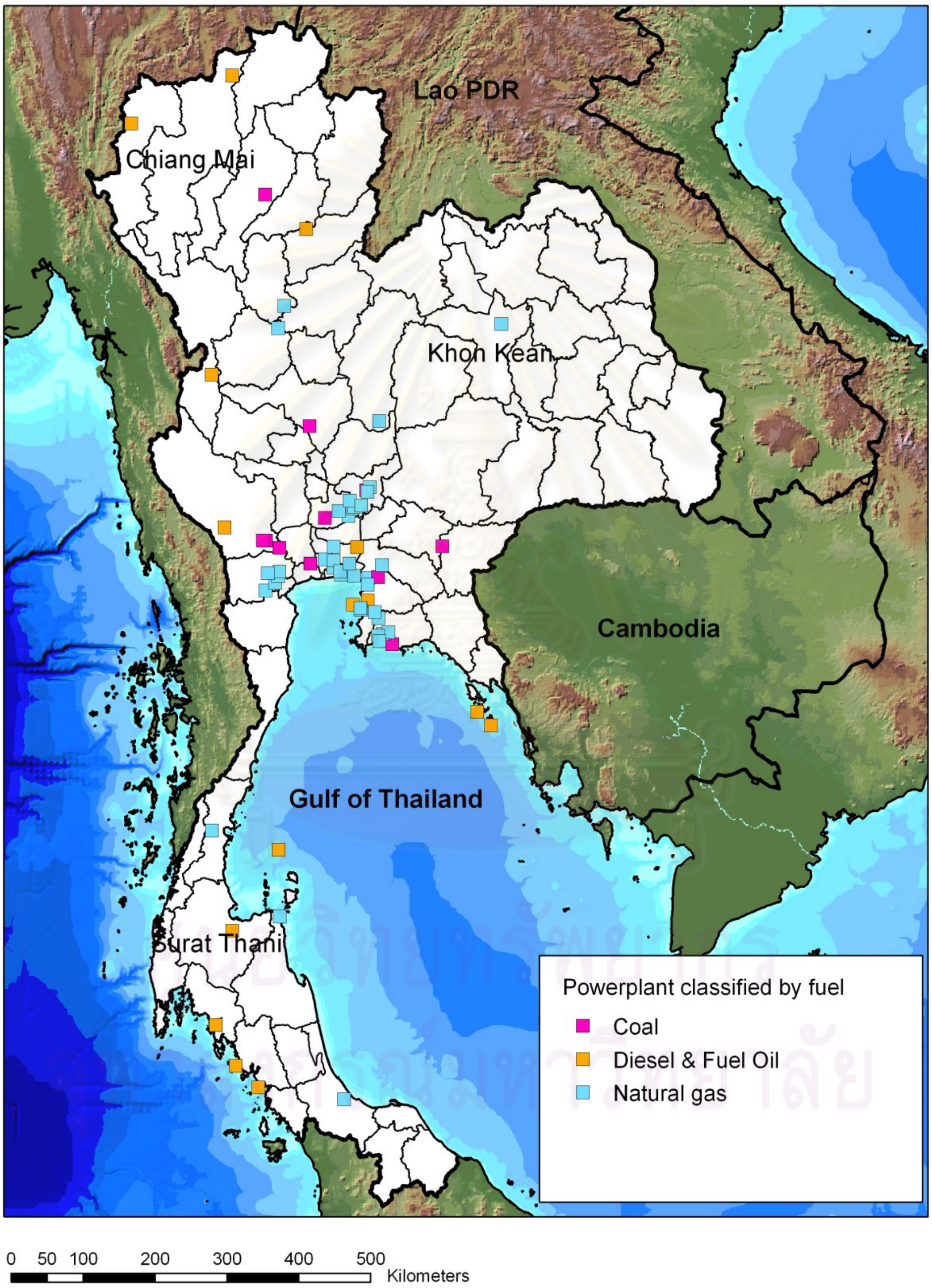

Figure 17 Distribution of Major Power Plant Classified by Fuel

Source: Using data from OERC (2010)

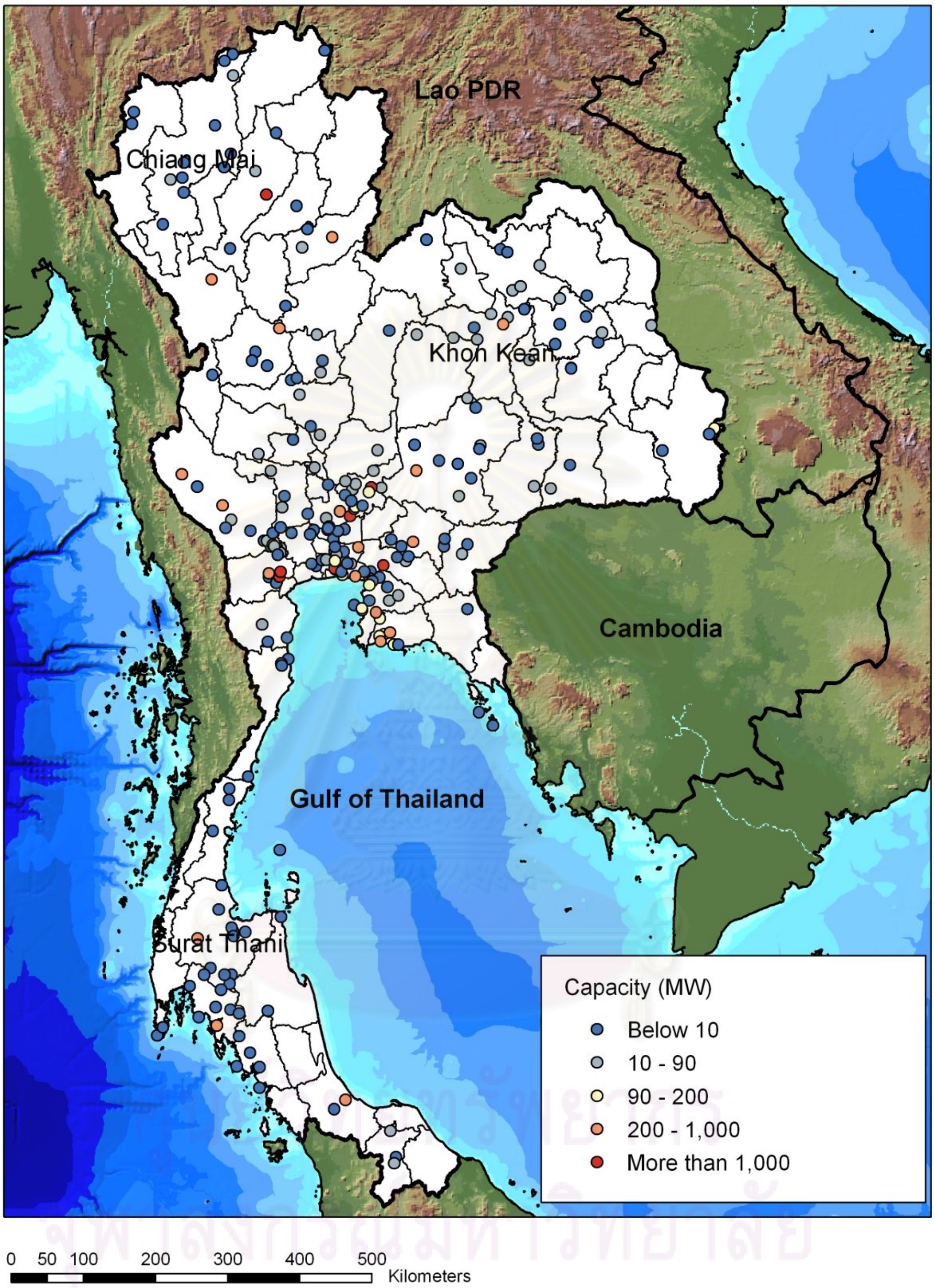

Figure 18 Distribution of Power Plant Classified by Capacity

Source: Using data from OERC (2010)

3.2.3.2 Diesel and Oil utilization

For diesel and fuel oil utilization in electricity generation, shares of oil in Thailand's Total Primary Energy Supply (TPES) have been relatively stable in the range between roughly 40 percent and 50 percent in the last 35 years. Oil represented 42 percent of TPES in 2006 while natural gas accounted for 28 percent of TPES in the same year. EGAT has continuously reduced its dependence on the high-priced oil for its own power generation. Oil procurement management was aimed at substituting for other types of fuel only in emergency. As a result, fuel oil consumption at EGAT's power plants was reduced by 68.52 percent from 786 million liters in the previous year to 247 million liters.

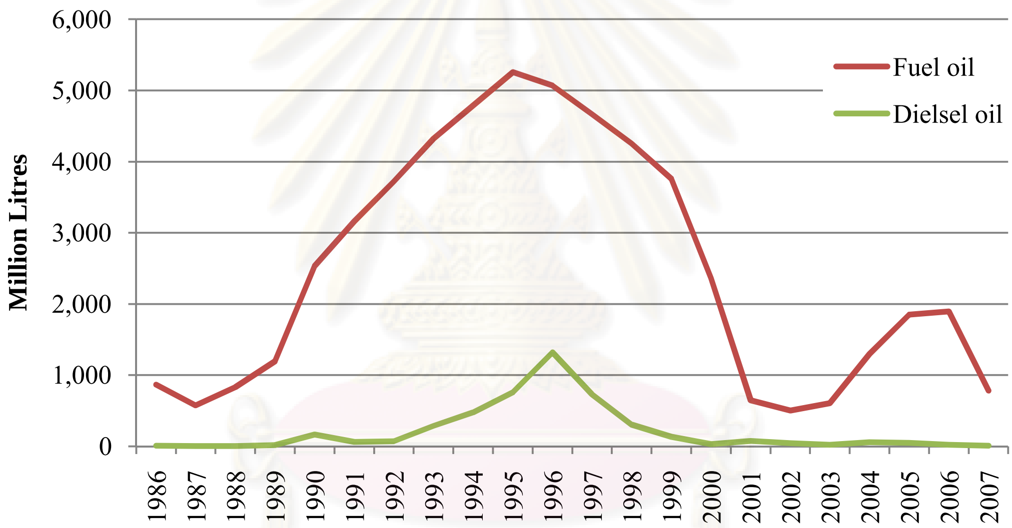

Figure 19 Fuel Oil and Diesel Oil Consumption in Electric Generation from 1986-2007

Source: Using data from Energy Policy and Planning Office (2008)

Electricity Generating Authority of Thailand (2008) reported the utilization of diesel oil also decreased 16.46 percent to 7.26 million liters in 2008. This utilization used for primary combustion of the fossil fuel-fired boilers of Mae Moh, South Bangkok, and Krabi thermal power plants; as standby fuel for running peak load power plants; and used in fuel swapping tests of gas-fired power plants. However, the consumption of diesel oil for the country's electricity generation increased considerably from 8 million liters in 2007 to 50 million liters in 2008 as

IPPs' power plants had to use diesel oil as natural gas substitute during the period of gas short supply caused by damage on Myanmar's Yetagun pipeline system and the production delay of PTT's Arthit gas field. The Office of the Energy Regulatory Commissioner (OERC) (2010) reported the installed capacity of oil based power plant (diesel and fuel oil) in Thailand reached 26,216 MW. Of this, the power capacity from 954.9 MW from EGAT (grid connected), 19.92 MW from EGAT (isolated), 12.14 MW from SPP and 8.37 MW from VSPP power plant.

3.2.3.3 Coal and Lignite

Lignite is another major domestic energy source for power generation and industry. In 2008, the average production of lignite was 49,468 tons per day. For coal and lignite utilization in electricity generation, EGAT's Mae Moh Lignite Mine produced and supplied totally 16.41 million tons of lignite to Mae Moh power plants in 2008, an increase of 2.18 percent from the prior year. Figure 20 illustrate pattern of coal and lignite consumption in electricity generation.

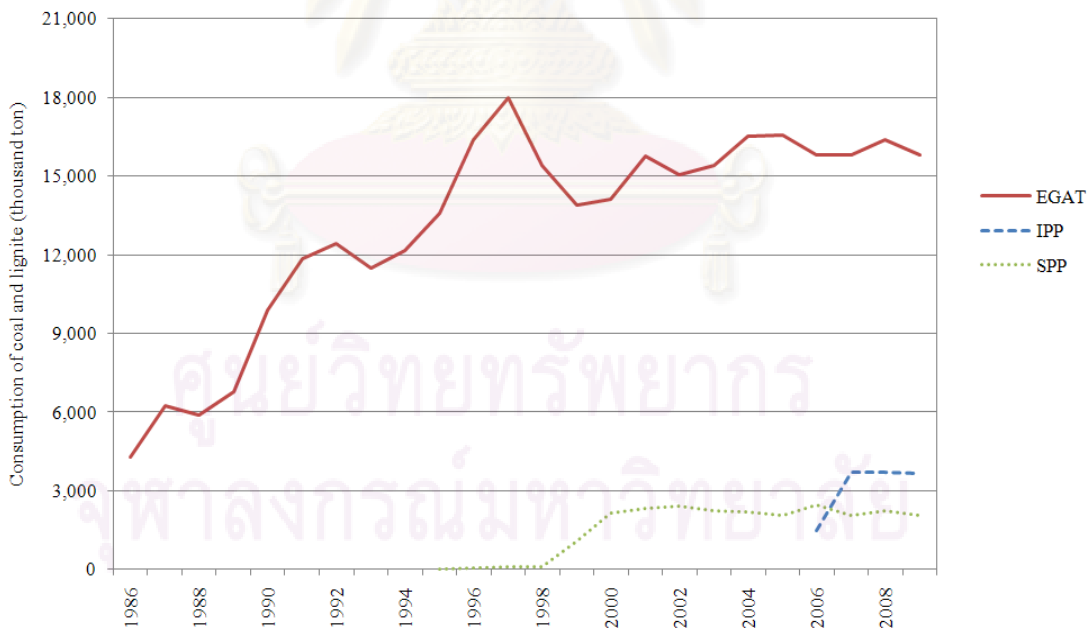

Figure 20 Coal and Lignite Consumption for Electricity Generation

Source: Using data from Ministry of Energy (2010)

The Office of the Energy Regulatory Commissioner (OERC) (2010) reported the installed capacity of coal fired power plant (lignite and bituminous) in

Thailand was 4,766.37 MW. Of this, the power capacity from 2,400 MW from EGAT (lignite), 1,436.96 MW from IPP (bituminous), 899.17 MW from SPP and 30.20 MW from VSPP power plant.

3.2.4 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 (Figure 21). 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.

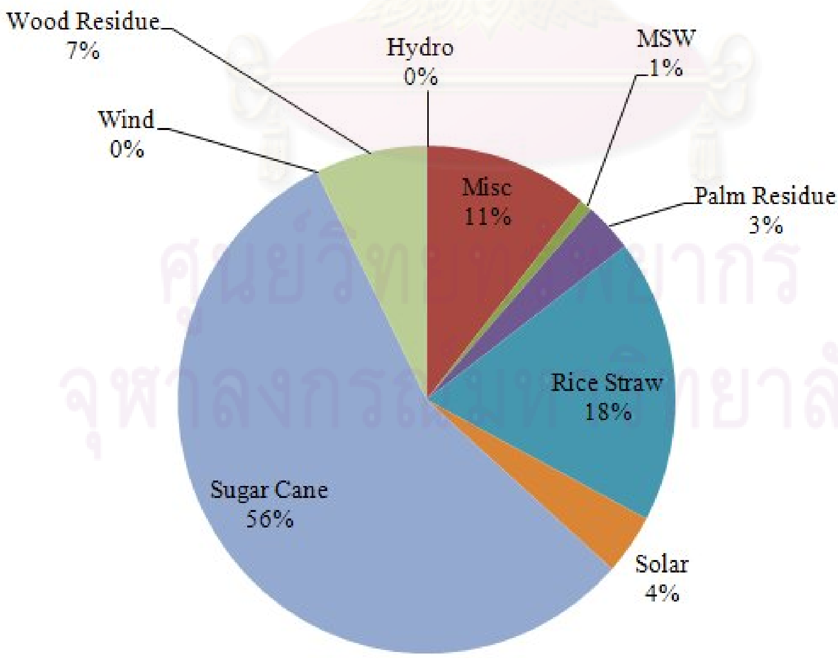

Figure 21 Renewable Energy in Electricity Generation in 2009

Source: Using data from Ministry of Energy (2009)

3.2.4.1 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 currently covered approximately 4 percent of the country low carbon electricity.

Ministry of Energy (2008) indicated three main biomass sources in Thailand are from agricultural residues, forest industry and residential sector. 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 (See also in Figure 23). 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 (Suramaythangkoor and Gheewala, 2010). 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 (Figure 24).

The Office of the Energy Regulatory Commissioner (OERC) (2010) 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. EPPO (2010b) 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 (Energy Policy and Planning Office, 2010c). 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.

3.2.4.2 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 (Prasertsan and Sajjakulnukit, 2006). 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 (Figure 25).

The OERC (2010) 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. EPPO (2010c) 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.

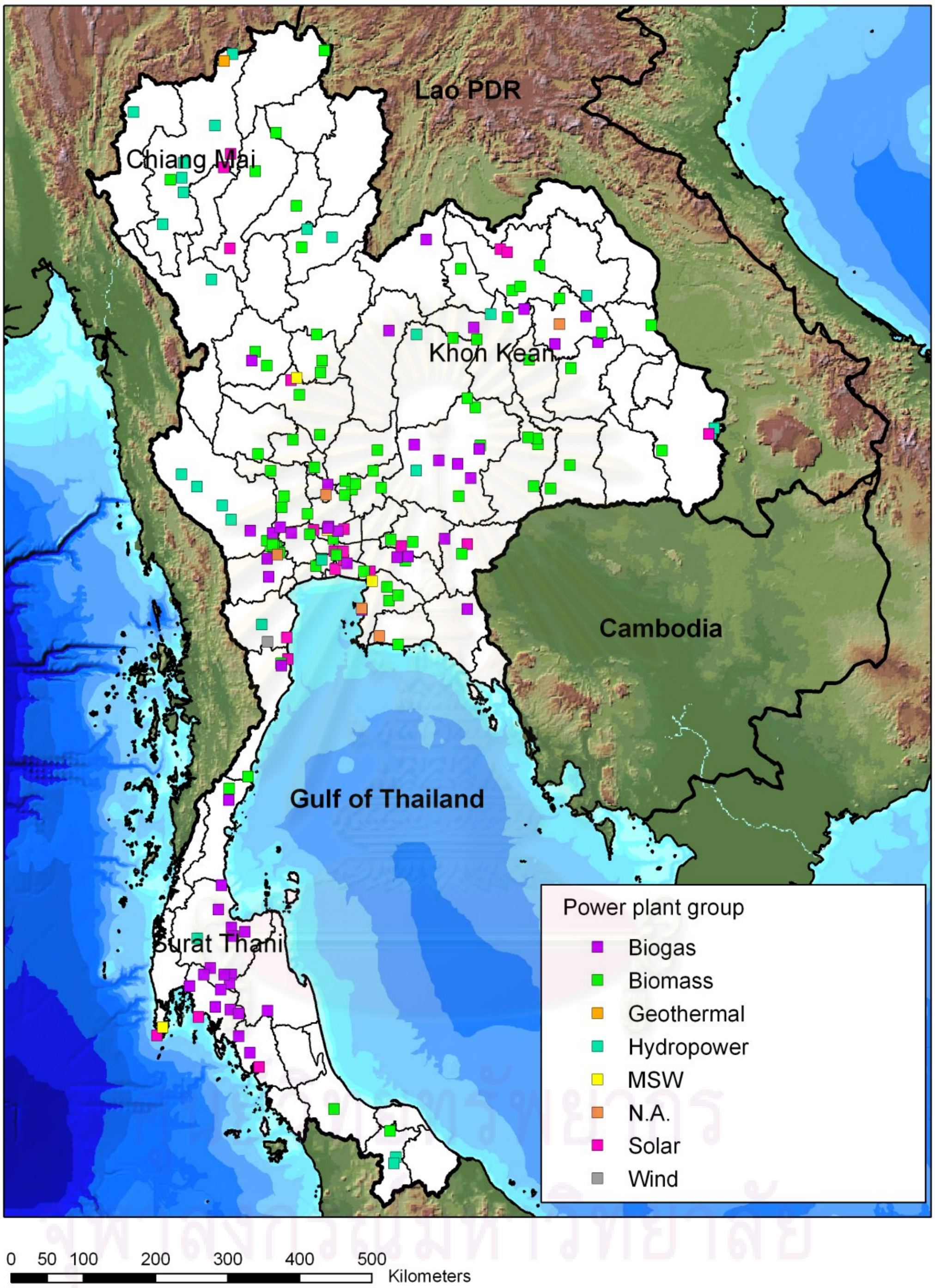

Figure 22 Distribution of Renewable Power Plants in 2010

Source: Using data from OERC (2010)

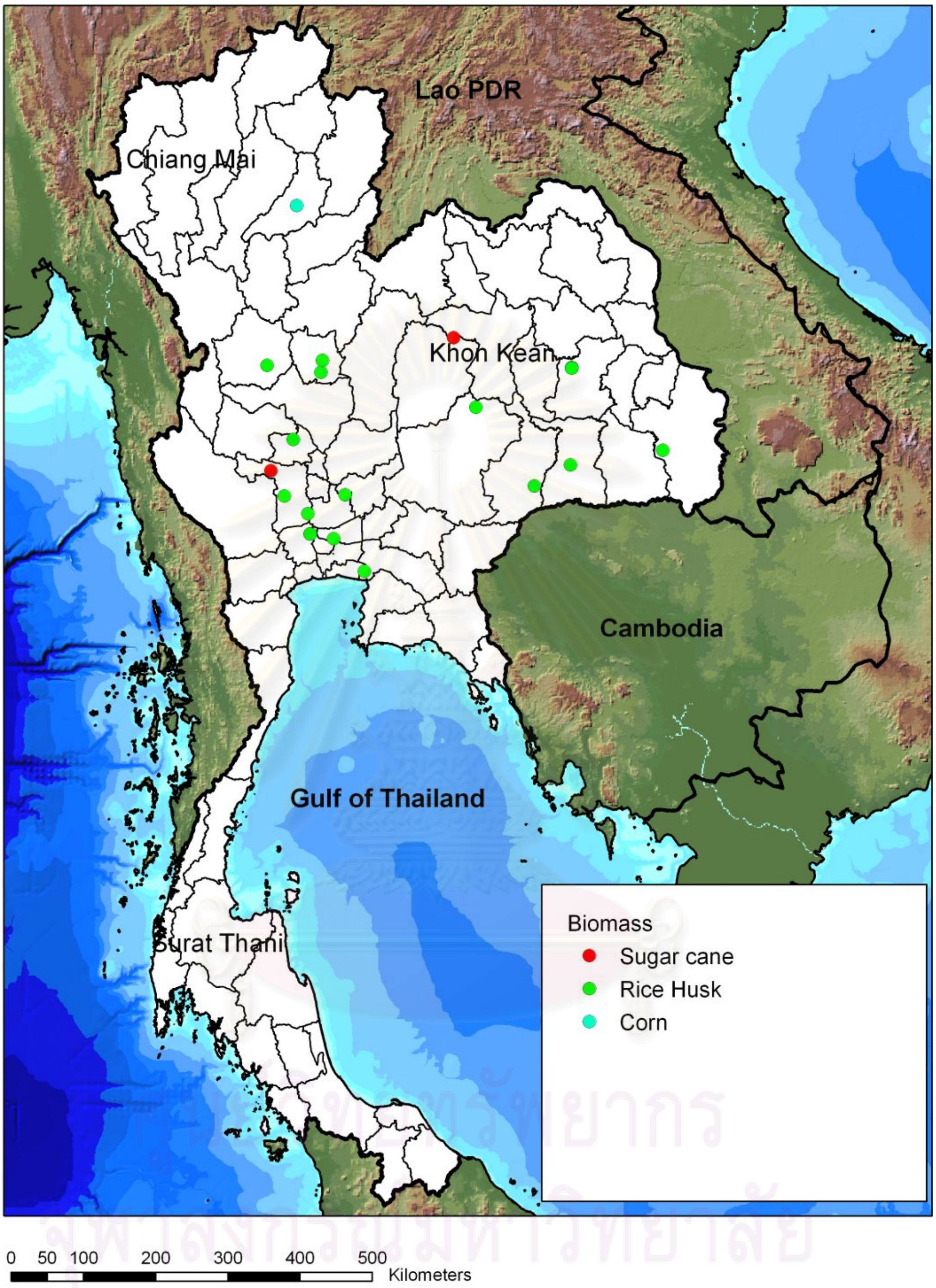

Figure 23 Distribution of Major Biomass Power Plant in 2010

Source: Using data from OERC (2010)

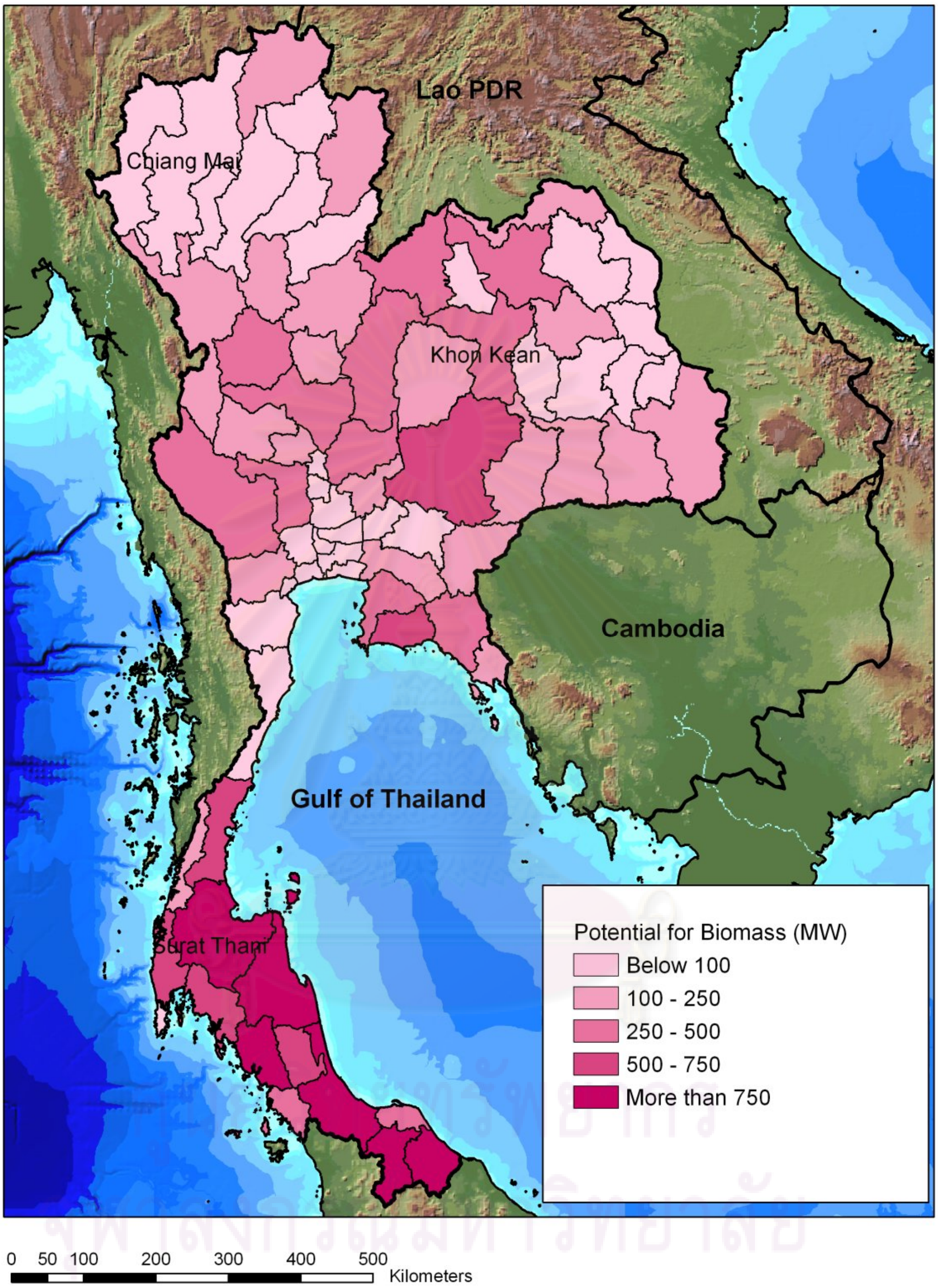

Figure 24 Estimated Potential of Biomass for Electricity Generation in 2009

Source: Using data from OERC (2010), Department of Alternative Energy Development and Efficiency (2009) and Office of Agricultural Economics (2009)

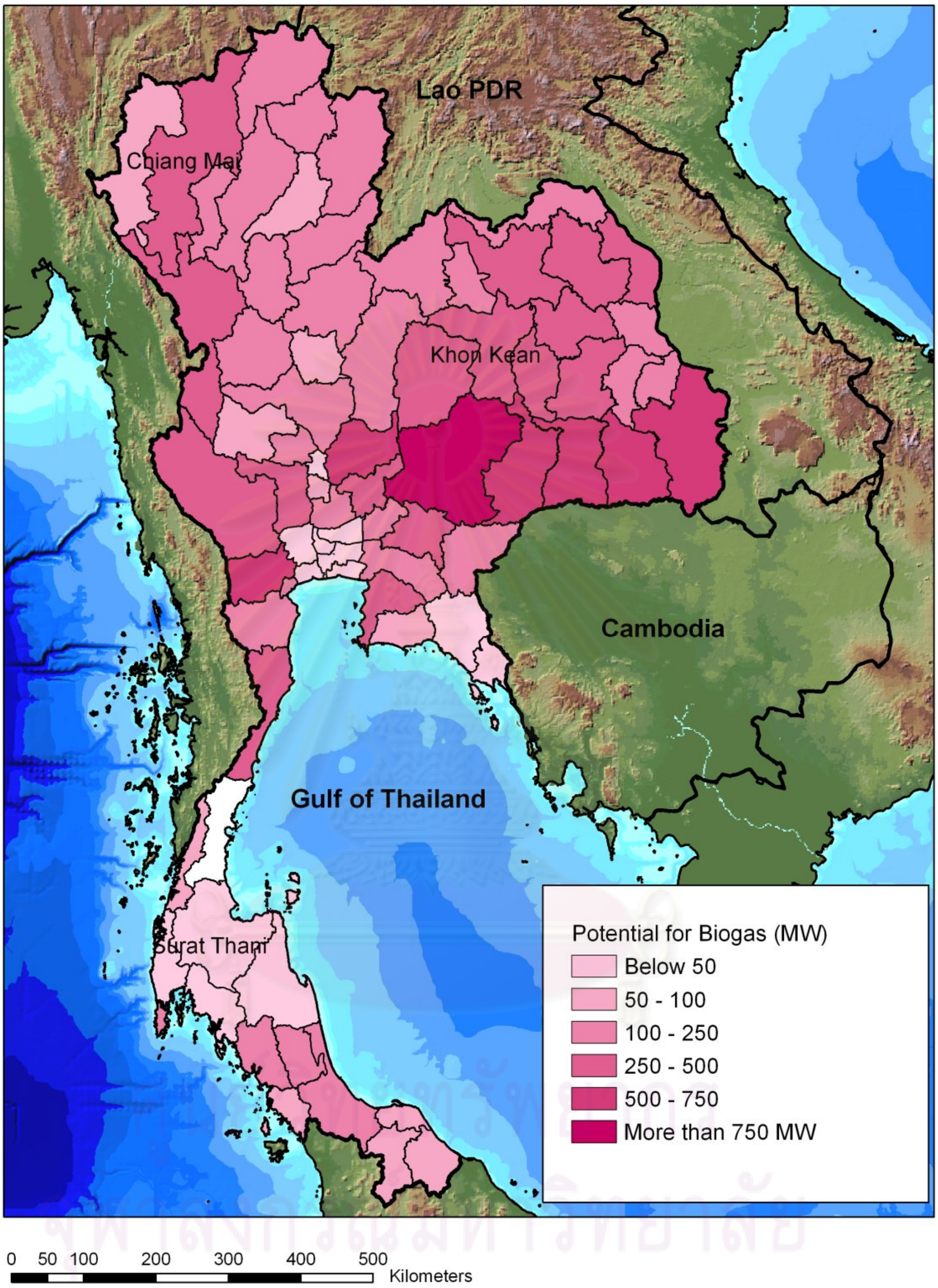

Figure 25 Estimated Potential of Biogas for Electricity Generation in 2009

Source: Using data from OERC (2010), Department of Alternative Energy Development and Efficiency (2009), Office of Agricultural Economics (2009) and Department of Livestock Development (2010)

3.2.4.3 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 (Liamsanguan and Gheewala, 2008). 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. (2007) 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 (2010) reported the installed capacity of electricity from municipal solid waste in Thailand reached 13 MW. 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 (Energy Policy and Planning Office, 2010c).

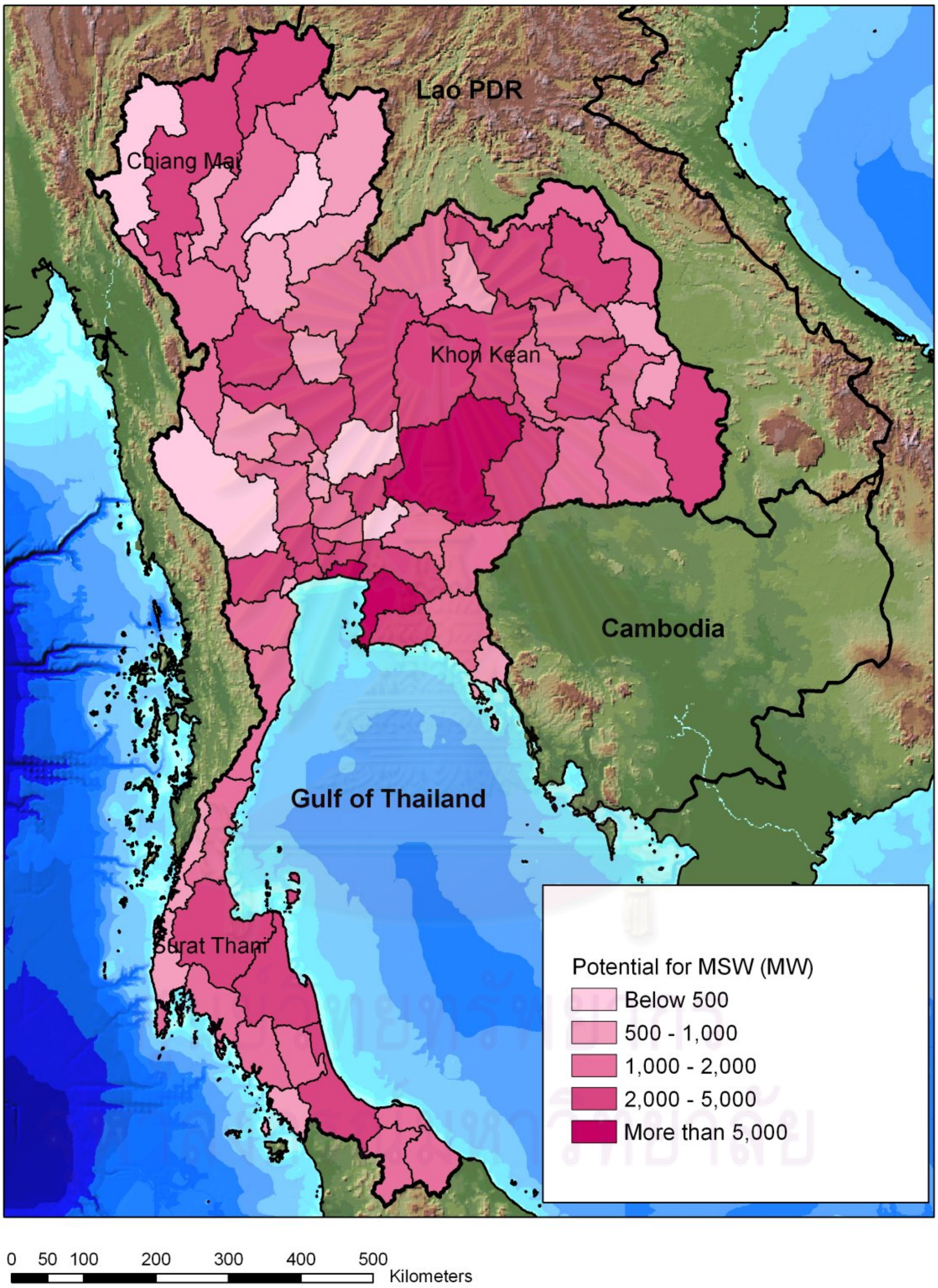

Figure 26 Potential of Municipal Solid Waste for Electricity Generation in 2009

Source: Using data from OERC (2010) and Department of Alternative Energy Development and Efficiency (2009)

3.2.4.4 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 (Ministry of Energy, 2009). 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 (Electricity Generating Authority of Thailand, 2010b; Pienpucta and Pongtepupathum, 2009).

EPPO (2010e) indicated hydropower existing potentials for development is at 15,155 MW. By the end of December 2009, the OERC (2010) reported the installed capacity of hydropower in Thailand reached 3,438 MW. 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.

3.2.4.5 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 (Energy Policy and Planning Office, 2010e; True Wind Solutions, 2001).

The study of Prabamroong et al, (2009) 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 (2010) reported the installed capacity of wind power in Thailand are in very small amount about 0.38 MW. As of March 2010, EPPO (2010c) 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). 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.

3.2.4.6 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 (Jivacate, 1994). 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 (Green, 2004).

By the end of December 2009, the OERC (2010) reported the installed capacity of solar power in Thailand are 7.8 MW. EPPO (2010c) 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.

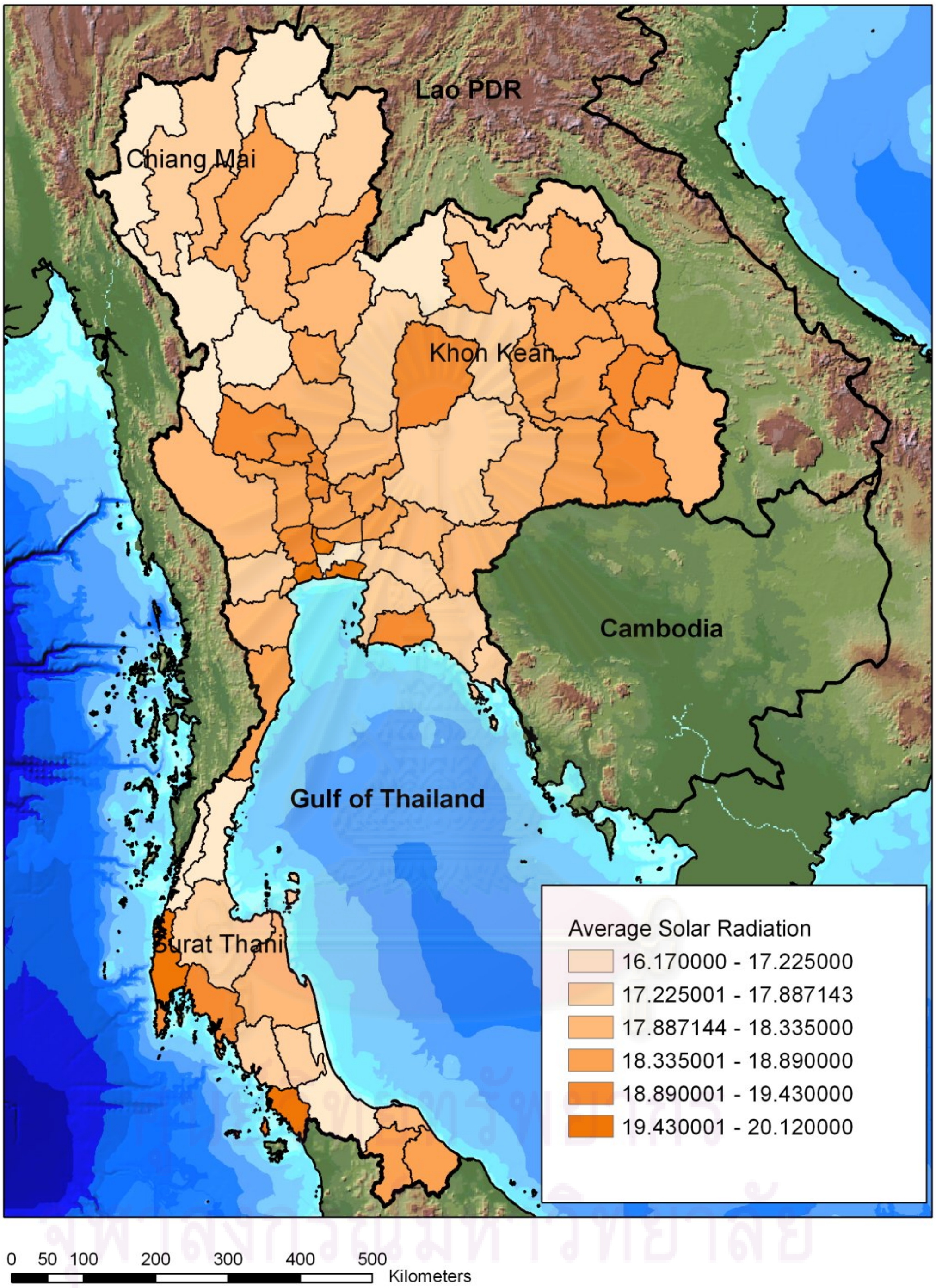

Figure 27 Average Solar Radiation

Source: Using data from OERC (2010) and Department of Alternative Energy Development and Efficiency (2009)

3.2.4.7 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 (Figure 28).

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 (Energy Policy and Planning Office, 2010e). Due to limited geothermal resources in the country, Thailand has small potential to produce more renewable energy from this area.

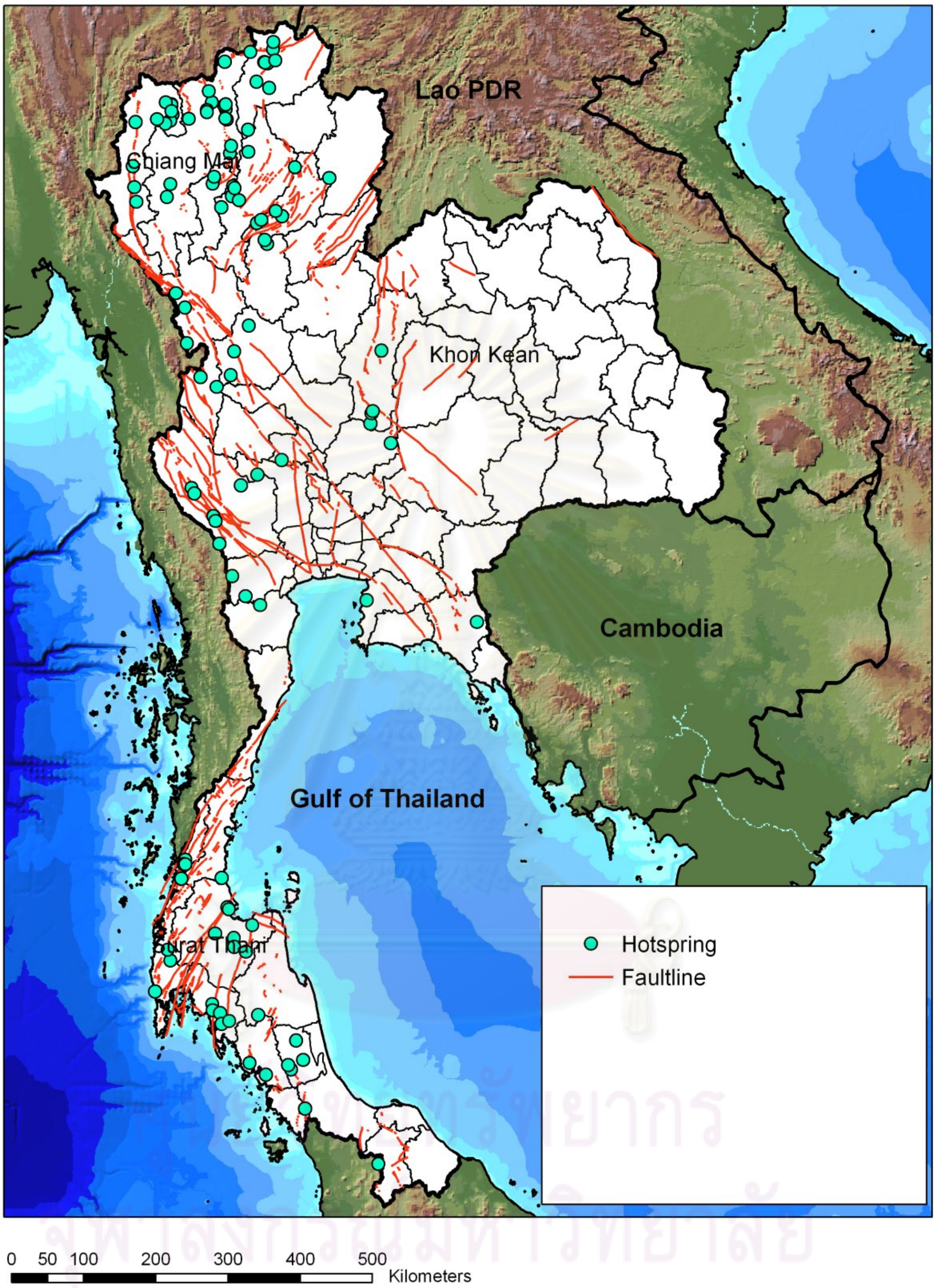

Figure 28 Location of Hot Spring in Thailand

Source: Using data from OERC (2010) and Department of Mineral Resources (2010)

3.2.5 Transmission and distribution

Electric power is brought from the power generating plant to the end user through a complex system of high-voltage, medium-voltage, and low-voltage power lines that are collectively known as the grid. The grid was never "designed" in the sense that a group of sophisticated engineers looked over the entire county's collection of power plants and load centers and laid out an optimized system of wires to connect them all (Figure 29). On the contrary, it mainly just grew from what we had years ago by adding a patchwork of transmission lines to get the power to load centers that changed over time. Generating plants used to be near cities and the grid was mainly local. Power plants were then moved away from cities as real estate values went up, and the grid began to stretch out (Richter, 2010).

Most grid-management systems aim to transport electricity over as short a distance as possible. In many large countries, the overall system consists of a number of separate grids, sometimes with quite different characteristics, that can be linked together (Chi-Jen, 2009; Hammerschlag, Pratt et al., 2007; The International Energy Agency, 2005; 2009b). The International Energy Agency (2009b) reported much more electricity is produced than is ever used. Transmission and distribution (T&D) losses and direct use in power plants equates to 14.3 percent of the electricity produced worldwide (8.8% is lost through T&D, which includes commercial and technical losses). While losses are significantly higher in developing countries, in absolute terms, the United States and Europe lose the most electricity – because of the sheer size of their electricity markets. The two most efficient countries are Canada and Japan, with losses of only 9 to 11 percent. For Thailand, EGAT (2010a) reported T&D loss in EGAT, MEA and PEA transmission line only 2.5, 3.6 and 5.1 percent respectively.

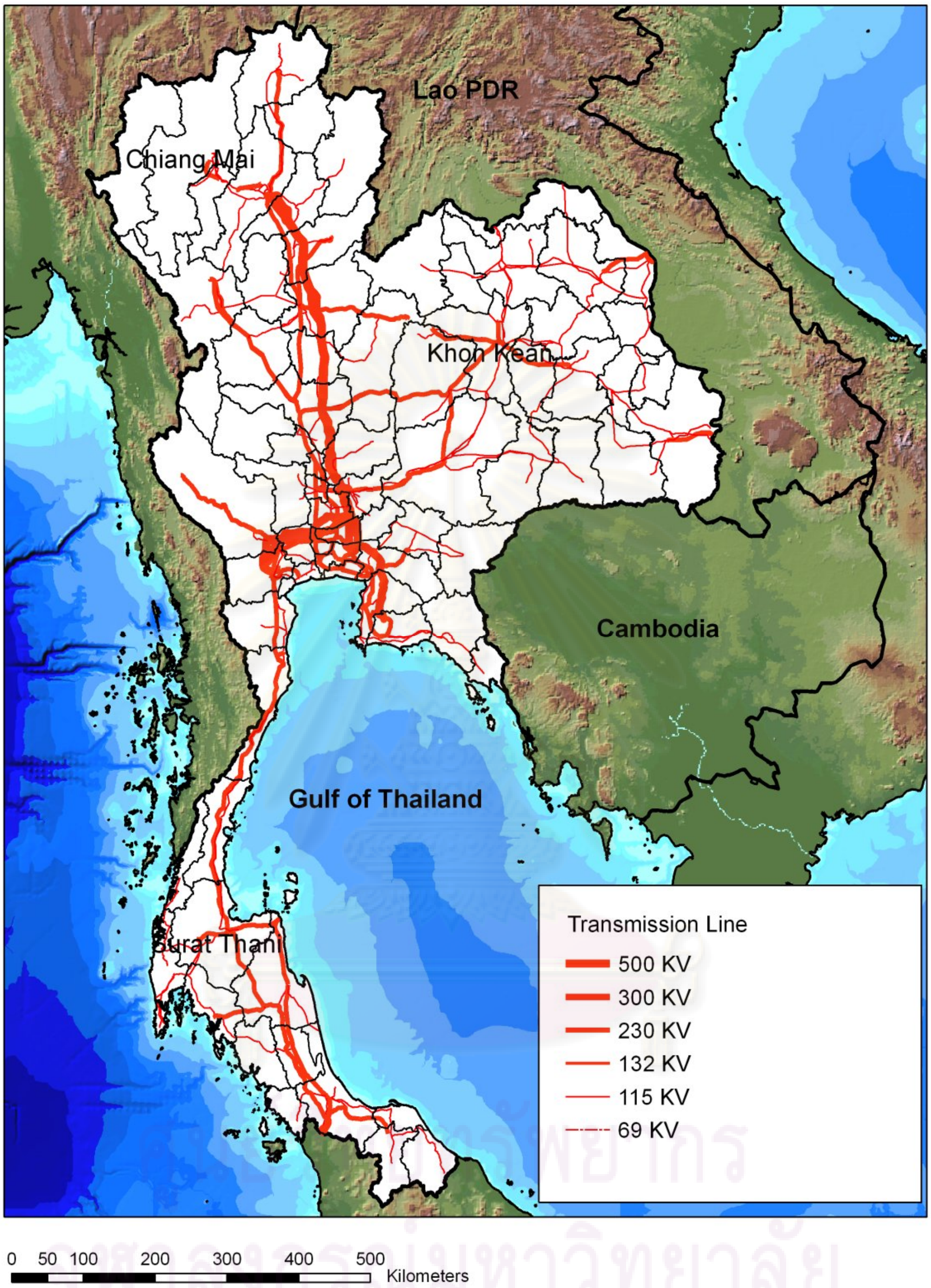

Figure 29 Distribution of Transmission Line

Source: Using data from Office of the Energy Regulatory Commissioner (2010) and Electricity Generating Authority of Thailand (2010a)

3.3 Summary of Findings

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).

Next chapter, I reviewed the electricity expansion policy that include Power Development Plan (PDP), Alternative Energy Development plan (AEDP), the concept of low carbon electricity abatement and emission scenario to understand Thailand's characteristics under different assumption.

CHAPTER IV
ELECTRICITY EXPANSION POLICY AND PROSPECT FOR LOW CARBON ELECTRICITY DEVELOPMENT

4.1 Thailand's electricity expansion policy

This section reviewed the electricity expansion policy that include Power Development Plan (PDP), Alternative Energy Development plan (AEDP), the concept of low carbon electricity abatement and emission scenario to understand Thailand's characteristics under different assumption.

4.1.1 Power Development Plan (PDP)

The choice of electricity generation technologies not only directly affects the amount of CO_2 emission from the power sector, but also indirectly affects the economy-wide CO_2 emission. It is because electricity is the basic requirement of economic sectors and final consumptions within the economy. In Thailand, although the power development plan (PDP) has been planned for the committed capacity to meet the future electricity demand, there are some undecided electricity generation technologies that will be studied for technological options. Thailand Power Development Plan 2010 – 2030 (PDP 2010) was formulated by the Electricity Generating Authority of Thailand (EGAT) under the policy framework of the Ministry of Energy, in terms of reliability of power supply, fuel diversification, power purchase from neighboring countries, and power demand forecast, etc.

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 to 5.3 percent (Electricity Generating Authority of Thailand, 2009).

At the same time, the use of lignite will be cut from 9.0 percent to only 6.3 percent. If the plan remained unchanged, the power system would reflect with high reserved margin. Furthermore, the power development projects in Lao PDR, which tariff MOU have expired or were terminated, are required to review and re-negotiate their proposed tariff. Under PDP-2010, the total install capacity is 36,335 MW and the total capacity of retirement of old power plants is 19,973.7 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 (Electricity Generating Authority of Thailand, 2010b). For more details on PDP 2010 see also in Appendix D.

4.1.2 Alternative Energy Development plan (AEDP)

Renewable energy systems already reduce greenhouse gas emissions from the energy sector, although on a modest scale. As an agricultural country, Thailand is full of agricultural products, high potential for all types of renewable energies exists in the country and strengthen the national energy security. The Ministry of Energy has launched an ambitious program to increase investments in renewable energy e.g. wind, solar, biomass, and other clean renewable energy sources. Ministry has also initiated the 15-Year Alternative Energy Development plan (AEDP) from 2008 to 2022 to speed up the important of renewable energy usage. These policies will promote energy security of the kingdom by reducing energy imports and increasing energy resources, building competitive energy market for sustainable economic growth, and help reducing the emission of greenhouse gases in the long-run (Ministry of Energy, 2009).

The Energy Industry Act, BE 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 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 (Ministry of Energy, 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 AEDP detailed target for electricity generation from renewable sources is summarized in Table 7. 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 boost 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 7 Target for Electricity Generation of Renewable Energy from 2008 to 2022

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

Source: Ministry of Energy (2009) and EGAT (2010b)

4.2 Abatement opportunities for low carbon electricity development

Energy modeling is a popular and widely used approach to identify the energy consumption, pollution 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 (Ko, Huang et al., 2010; Mulugetta, Mantajit et al., 2007). Randolph and Masters (2008) discuss on three complicating factors for implement low carbon emission policies. First, progress is slow toward alternatives to conventional fuel and reduces demand growth. We are nearly as dependent on fossil fuels now as we were in the 1970s. Although demand growth in developed countries has slowed, it offset by the increasing demand in the developing world. World energy usage nearly doubled from 1975 to 2005, and we remain dependent on fossil fuels, especially oil. Second, transition to sustainable energy faces barriers to change, including uncertainty about supply options and their impacts, economic and political interests that fight to protect their status quo, and consumers' resistant to change their behavior. Consumers continue to desire bigger cars and houses and more energy-consuming products. Lastly, time is short.

Over the past three decades, the economy and environment have provided clear signals that our energy patterns are not sustainable. Despite these warnings, we have done little to alter our patterns of use. The international community has begun to assess a range of possible options for strengthening the international climate change effort after 2012. Thailand also does its best to help reduce global GHG targets while (minimizing impact on) maintaining economic growth. This study analyzed the realistic implementation potential for GHG emissions reduction from electricity sector in Thailand. Comparison mitigation options are crucial to identify cost-effective alternatives for the country.

4.2.1 Framework for identification of emission abatement opportunities

Emissions abatement in the Power sector is achieved by reducing demand for electricity, or by replacing fossil-fuel power generation with low-carbon alternatives. To identify the contributions and the challenges of establishing a sustainable energy supply system, three scenarios are prepared in this research, which includes Business as usual (BAU), with nuclear scenario (WNC) and without nuclear (NNC) electricity development options. Appendix B explained detailed assumptions in the study. This study presents three scenarios for Thailand's energy consumption and related carbon dioxide emissions up to 2030. It explains the crucial technologies for Thailand as it leaves a business-as-usual trajectory and joins a low carbon pathway.

The energy modeling techniques was employed to quantitatively analysis all three scenarios and compare among each scenario. Each scenario is linked to frame particular policies and defines the supply side characteristics and assumptions used. 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. However, scenario analysis is not a prediction of the future; it is a valuable tool for exploring the impact of particular sets of policies on energy and emissions. The scope of the modeling exercise was restricted to energy and energy-related greenhouse gas (GHG) emissions (predominantly CO_2). The major sources of energy consumption and emissions in Thailand – industry, buildings and transport – are captured in the analysis.

For cost estimation from power generation, cost data were collected from 43 power plants. This comprises 4 coal-fired power plants, 19 gas-fired power plants, and 20 plants based on other fuels or technologies. The cost estimates presented in the study were calculated based on the International Energy Agency

(IEA) (2010) methodology, using input parameters provided by literature reviews, site visiting, and interviewing. 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 (More details of cost calculation described in Appendix C).

4.2.1.1 Reference scenario (BAU)

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 (Mulugetta, Mantajit et al., 2007). 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). 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 (Electricity Generating Authority of Thailand, 2010b). 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 (Electricity Generating Authority of Thailand, 2010a). As illustrated in Table 8, it is assumed that final energy demand continues to rise in the long run.

4.2.1.2 The With-nuclear scenario (WNC)

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.

Early this year, EGAT in cooperation with a research institute, conducted an opinion poll asking about 40,000 citizens their feelings towards nuclear power plants. Most respondents supported the construction of the plants, with a few disagreeing out of safety concerns. EGAT has to speed up the delivery of a clear message to people - especially those in the 16 places listed for establishing a nuclear plant - that nuclear power is a clean energy and does not pollute the environment (Thongrung, 2010). However, 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.

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 8). 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 AEDP 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).

The WNC scenario differs from BAU scenario in that it incorporates the following aspect (Table 8). 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 AEDP 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 (Electricity Generating Authority of Thailand, 2010b). 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.

Table 8 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 Alternative 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.

4.2.1.3 The Without-nuclear scenario (NNC)

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 (Electricity Generating Authority of Thailand, 2010b). 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.

4.3 Results from energy modeling

4.3.1 Impact on energy consumption

Over the study period, the electricity generation is projected to 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 (Table 9). 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 retirement of 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 30.

Table 9 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

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 30.

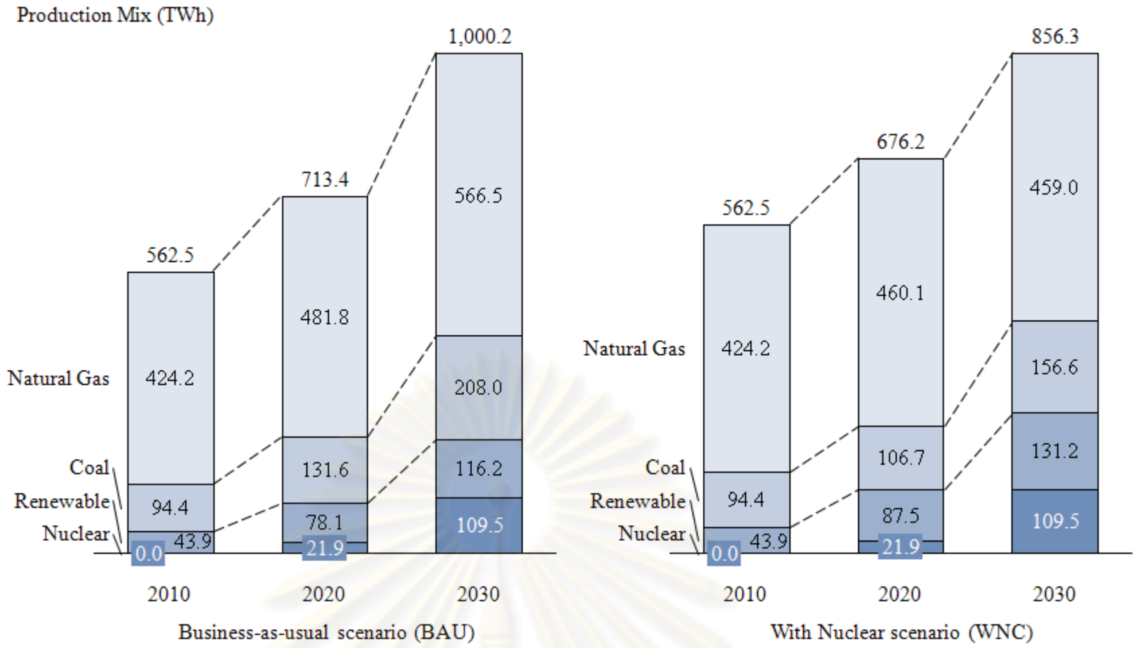

Figure 30 Comparison of production mix between BAU and WNC scenario

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 31.

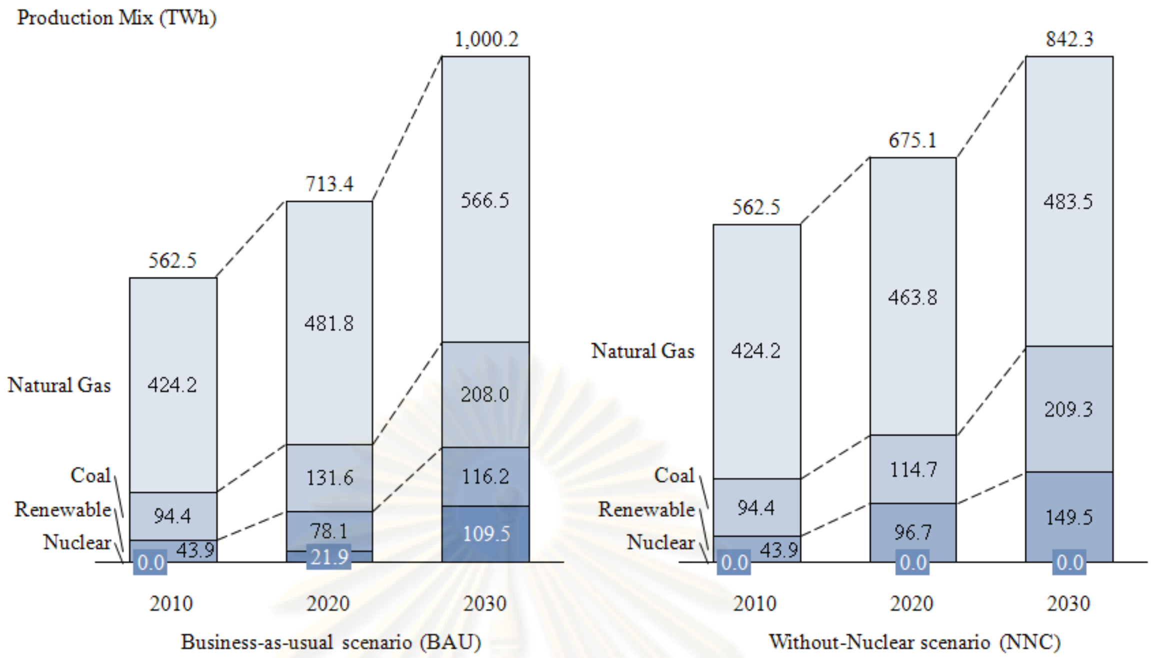

Figure 31 Comparison of production mix between BAU and NNC scenario

4.3.2 Impact on energy-related greenhouse gas emissions

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 10 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 $MtCO_2$-eq or 6.33 percent from lignite), and 1.38 percent from oil based, as shown in Figure 32 and Figure 33.

Table 10 Carbon dioxide Emission Comparison Summary

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

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 10). 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.

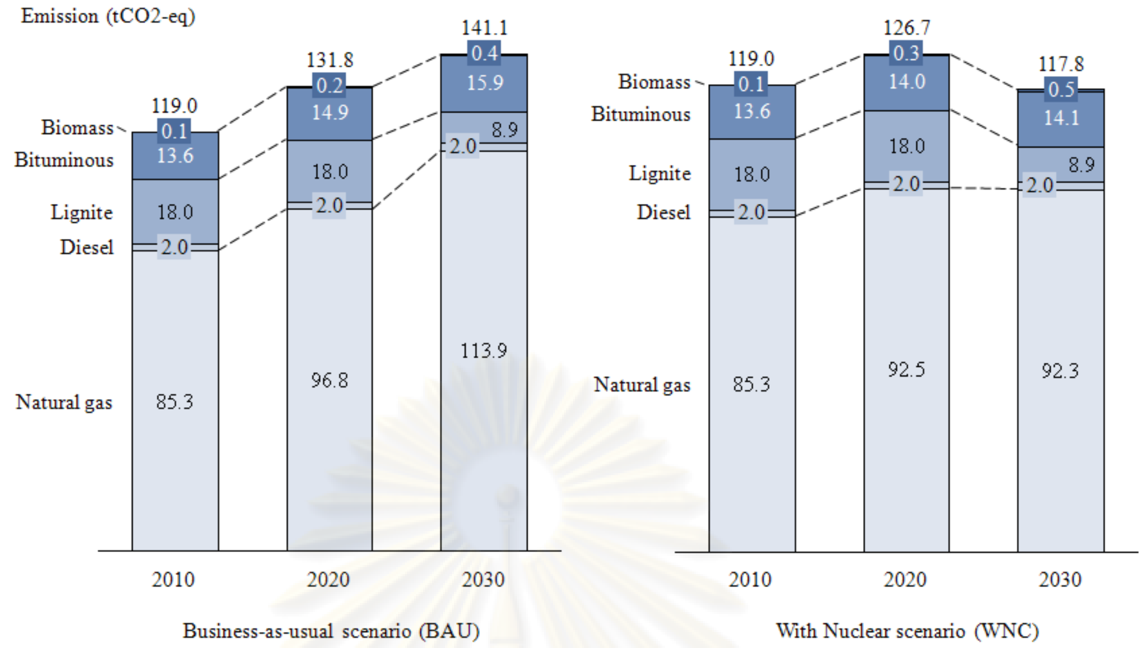

Figure 32 Comparison of GHGs emission between BAU and WNC scenario

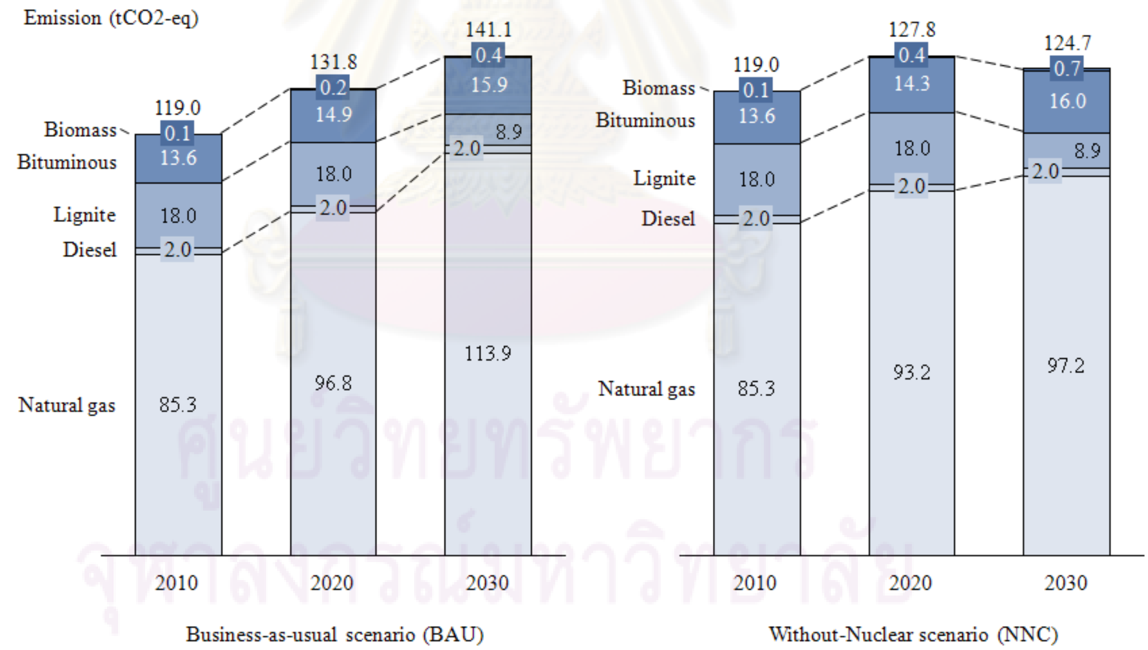

Figure 33 Comparison of GHGs emission between BAU and NNC scenario

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 Figure 34). 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.

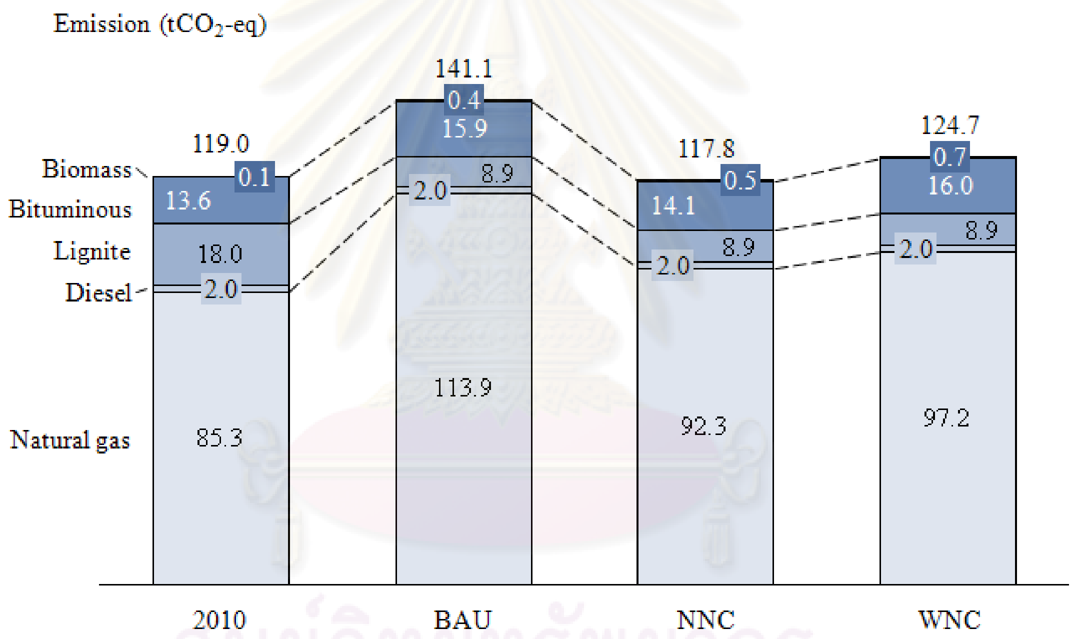

Figure 34 Comparison of GHGs emission of three scenarios in 2030

4.4 Abatement cost comparison

The question of how much tackling climate change is going to cost is a recurrent issue in today's global discussion about how to transition to a low-carbon economy. How large will capital investments need to be? Which sectors offer the highest returns on those capital outlays? Answering such questions is one of the main objectives of our research and our analysis allows us to assess not only the cost but also the opportunity of investing in carbon abatement. Many of the measures we have identified can be captured at a relatively low cost and many would even produce a positive net return. In aggregate, our research indicates that future energy savings compensate for a huge share of the initial investments of an ambitious abatement drive, if the most cost-effective abatement options are pursued. It also demonstrates how much can be saved through policy that incentivizes the lowest cost alternatives.

As mentioned in previous chapters, this is not to say that the implementation of such an abatement program will be easy. On the contrary, as described in Chapter 3, it will require a significant mobilization challenge to capture the opportunities that we have identified. It is also likely that shortfalls in realizing the low cost options will mean that higher cost alternatives will have to be pursued. There will also be transaction and program costs as well as dynamic macro-economic effects that we have not included in our analysis. 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 (The International Energy Agency, 2009c) 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 (Bloomberg New Energy Finance, 2010; Ellerman and Decaux, 1998).

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 11 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.

Table 11 Cost Comparison between Three Scenarios

Scenario	Year					Total (2010-2030)
	2010	2015	2020	2025	2030	
Cost per kWh (USD/kWh)						
BAU	-	202.252	104.964	49.438	37.615	73.873
With-nuclear (WNC)	-	194.091	115.225	49.431	38.043	78.691
Without-nuclear (NNC)	-	196.691	135.104	62.967	47.063	91.933
Emission per MWh (tCO_2/MWh)						
BAU	0.456	0.425	0.391	0.333	0.301	
With-nuclear (WNC)	0.456	0.424	0.406	0.323	0.296	
Without-nuclear (NNC)	0.456	0.423	0.410	0.339	0.313	
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
$NPC_{WNC} – NPC_{BAU}$ (Billion USD)						0.36
Abatement cost (USD/tCO_2-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
$NPC_{NNC} – NPC_{BAU}$ (Billion USD)						0.09
Abatement cost (USD/tCO_2-eq)						7.89

4.5 Summary of Findings

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. 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.

Next chapter, the abatement opportunities and identify barrier and constrains for low carbon electricity development in Thailand were presented.

CHAPTER V
CONSTRAINS FOR LOW CARBON ELECTRICITY DEVELOMENT

5.1 Important constrains hindering the low carbon electricity development

The power industry plays a unique role in climate change, being by far the largest sector both in emissions and opportunities to reduce them. However, power sector has many characteristics that make implementation of greenhouse gases mitigation less challenging than in most other sectors. First, this sector consists of a relatively small number of large companies, which are used to regulation and to take regulatory incentives into account when prioritizing investments. Second, consumer implications are relatively limited (except for a potentially higher electricity price) and third, compliance is comparatively easy to measure and monitor (Blyth, 2010; McKinsey and Company, 2009). Reducing the GHG intensity of energy will require development and deployment of major breakthroughs in energy efficiency, demand reduction, fuel diversify to lower emission such as renewable energy, nuclear, clean coal, capturing GHGs emission with carbon capture and storage (CCS). This chapter aims to present important and potential roles of low carbon electricity development based on current GHG emission abatement opportunities and options for promoting low carbon electricity in Thailand.

This section examined why low carbon electricity development are not fully implemented. Constrains related to regulation, nature of electricity development, technical and economic issues are identified. Understanding these constrains are very important parts led to future improvement of the functions and success of low carbon electricity development. Major number of obstacles inhibiting the expansion of low carbon electricity development can be divided into three categories: regulatory-related barriers; technical and environmental-related barriers and economic-related barriers. The following sections describe each category in more detail.

5.2 Institutional Constrains

Politics and regulatory on energy and environment are key factors that could accelerate or delay the development. The most obvious barriers relate to the inconsistent political support for renewable energy development. Unlike subsidies and incentive for conventional fuel technologies, policies aimed at encouraging renewable energy have changed frequently; despite of high potentials to generate electricity from renewable sources in Thailand, these policy uncertainties prolong the speed of development and wide adoption of renewable energy. To be a force for change, governments must help to reduce uncertainty for investments in higher cost. By supporting in the following areas will remove barriers and uncertainty, facilitate the establishment of efficient markets, and drive technological innovation and investment.

To reducing the policy inconsistency between government organizations (in numbers) and policies that promote clean energy expansion in regulation (siting and licensing), generation (typically fueled by renewable energy); financial support (e.g. fuel subsidize, soft loans, etc.) and expansion policies. For example, to obtain licenses for power plants construction and operation required a lot of processes before obtained the license. Power plants shall obtain (1) license for the energy industry operation[18], (2) licensed from Department of Industrial Work for Industrial Operation, (3) Environmental Mitigation Measures of Environmental Impact Assessment (EIA), under section 46 of the Enhancement and Conservation of National Environmental Quality Act 1992 (B.E. 2535) required an EIA report before submitting for license, (4) permission from local administration and (5) Health Impact Assessment (HIA) report.

Mendonça, Jacobs et al. (2010) expressed renewable energy investor, manufacturer or operator already knows, the variability of policy relating to renewable energy technologies serves as a serious impediment. Entrepreneurs seeking investment from individuals and institutions often require consistent conditions upon

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[18] Section 47 of the Energy Industry Act B.E. 2550 (2007) define roles of power industry shall obtained license from the commissioner before starting operation. The ERC has issued 5 types of licenses in the electricity and 4 types of licenses in the natural gas.

which to make decisions. Forecasts of profitability (usually require data concerning tax credits, depreciation schedules, cash flows and the like, well into the future) introduce an extra level of uncertainty into the decision-making process when policy makers frequently change the factors that go into these financial calculations. Most (if not) all technologies for generating electricity will require multiple permits. These permits are intended to consider the local impacts on the land, water, and air that occur during the installation and operation of these technologies. Depending on the size and location of the generating facility, permits from local zoning boards, state agencies, and federal agencies may be required. In the case of traditional electricity-generating facilities, such as those that use coal and natural gas, there is a long and evolving licensing process that has been applied across the country.

Social opposition or NIMBY[19] effects for new power plant development has delayed the construction of several major renewable energy projects. While proponents cite the environmental, economic, and energy security benefits to be gained from these projects, opponents cite the negative impacts, which often include potential damage to local ecosystems, loss of aesthetic value to the natural landscape, and the opportunity cost of land use. For example, biomass and biofuels require large amounts of land that could instead be used for agricultural purposes. Hydropower is becoming increasingly difficult to locate potential site; most major potential sites are already being used, and ecological considerations are preventing the exploitation of remaining ones. Siting renewable energy projects can also lead environmentalists against one another. Although an exhaustive review of local impacts and permitting issues is beyond the scope of this study.

Permitting issues for biomass, wind, geothermal, and photovoltaics is discussed; most of the areas that have high potential for alternatives energy development in Thailand e.g. wind, small hydropower and geothermal are belonging to government and inaccessible by the project investor. The government has been promoting biomass power plants among the private sector. At the present time,

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[19] Not in My Backyard or NIMBY refer to someone who objects to siting something in their own neighborhood but does not object to it being sited elsewhere.

biomass power plants - most of which fall into the category of Very Small Power Producer (VSPP), referring to a generating capacity of not more than 10MW - using bagasse, cornstalks, woodchips, rice husk, and waste from palm trees sell electricity to EGAT. However, government should reduce gap between different organization in roles and activities collaborating on similar documentation requirement for shortening complex process and long period of licensing. For biomass, geothermal, and solar, the guidance for permitting is less well developed. Most of the opposition against biomass power plants is based on the air pollution that results in burning the organic matter to create energy. As well, many locals are angry that they have been left out of the decision-making process.

Article 67 of the Constitution[20] says that individuals and communities have the right to conserve, protect and to benefit from local natural resources and biodiversity, and prohibits any projects or activities which can cause serious negative impacts to the environment, natural resources and public health. The Constitution further states that if the authorities want to pursue a project with the potential to cause these negative impacts a comprehensive EIA must be conducted. This must include a public hearing process with the participation of locals and independent environmental and public health organizations. Local communities can file a lawsuit against government agencies, local authorities or state enterprises if they do not follow the rules. Table 12 summarizes some of the most important regulations that apply to all large electricity generating facilities. Local communities feel the rules are being manipulated to deny them participation in the process and they are distrustful of assurances from the government and the companies involved that environmental impacts will be minimal. They feel a thorough study is essential to ensuring the protection of their lifestyle and environment.

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[20] Under Thai Constitution 2007 (B.E. 2550), section 67 paragraph 2, states that project or activity which may seriously affect the quality of environment, natural resources or health shall not be permitted, unless its impacts on the quality of environment and on health of people in affected communities has been studied and evaluated, and consultation with the public and interested parties has been organized.

Table 12 Some of the important regulations that apply to all electricity generating facilities

Criteria	Statutory Citation	Law and Regulations
Siting and Licensing	Defines qualifications, procedures and conditions of the application for license	Notification of Energy Regulatory Commissioner (B.E. 2552) issued Pursuant to the Energy Industry Act B.E. 2550 issue on 12 October 2552
	Define qualifications, procedure and condition for licensing	The Ministerial Regulation, No. 19 (B.E. 2549) issued Pursuant to the Factory Act B.E. 2535 issue on 10 May 2549
	Prescribed types of industries, rules, procedure and criteria for Environmental Impact Assessment Report Preparation	Notification of the Ministry of Natural Resources and Environment (B.E. 2552) issued on 31 August 2552
	Prescribed qualification and condition for apply industrial permit	Notification of Ministry of Industry No. 22 (B.E.2551), issued on 22 July 2551
	Type and period of Energy Industry License	Notification of Energy Regulatory Commissioner (B.E. 2551) issued Pursuant to the Energy Industry Act B.E. 2550 issue on 4 December 2551
	Procedure for applied the Energy Industrial License	Notification of Energy Regulatory Commissioner (B.E. 2551) issued Pursuant to the Energy Industry Act B.E. 2550 issue on 4 December 2551
	Defines qualifications, procedures and conditions for COD	Notification of Energy Regulatory Commissioner (B.E. 2552) issued Pursuant to the Energy Industry Act B.E. 2550 issue on 12 October 2552
	Prescribe rule, Procedure, Method and Guideline for Preparation of the Environmental Impact Assessment	Notification of the Ministry of Natural Resources and Environment (B.E. 2552) issued on 29 December 2552

105

Criteria	Statutory Citation	Law and Regulations
	Report for Project or Activity which may Seriously Affect Community with respect to Quality of Environment, Natural Resources and Health	
	Rules and Procedures for the Health Impact Assessment of Public Policies	Declaration of the National Health Commission (B.E. 2552)
Emission standard	Prescribed type, level and concentration of air pollution emission from power plant	Notification of Ministry of Science and Technology (B.E.2538), issued on 25 December 2538
	Prescribed type, level and concentration of air pollution emission from power plant	Notification of Ministry of Science and Technology (B.E.2549), issued on 5 April 2549
	Control emission standard from power plant, measurement, report and verification methodology	Notification of Ministry of Industry (B.E.2547), issued on 28 September 2547
	Control emission standard from power plant, measurement, report and verification methodology	Notification of Ministry of Science and Technology (B.E.2538), issued on 25 December 2538
	Emission control from MSW power plant	Notification of Ministry of Science and Technology (B.E.2550), issued on 17 June 2550
	Prescribe power plant with capacity higher than 29 MW in must install Continuous Emission Monitoring (CEMs)	Notification of Ministry of Industry (B.E.2544), issued issue on 11 December 2544
	Prescribed type, period and methodology for information transfer from CEMs	Notification of Department of Industrial Works (B.E.2550), issued on 11 December 2550
	Prescribe emission control of Mae Moh power plant	Notification of Ministry of Science and Technology No. 3 (B.E.2545), issued on 27 January 2545
	Prescribe emission standard from old power plants	Notification of Ministry of Science and Technology No. 2

Criteria	Statutory Citation	Law and Regulations
		(B.E.2542), issued issue on 2 December 2542
Emission standard	Prescribe emission standard from power plants	Notification of Industrial Estate Authority of Thailand No. 79 (B.E.2549), issued on 4 September 2549
	Emission control from cement and co-firing in power generator	The Ministry of Industry Notice (B.E. 2548), issued on 8 November 2549
	Control emission from MSW power plant	Notification of Ministry of Science and Technology (B.E.2540), issued on 17 June 2540
Emission monitoring	Environmental monitoring and reporting	Notification of Department of Industrial Work (B.E.2528), issued on 16 December 2528
	Environmental monitoring and reporting	Notification of Ministry of Industry No. 11 (B.E. 2544), issued on 11 December 2544
	Prescribe roles and responsibility of pollution control officer in power plant operation	The Ministerial Regulation, No. 2 (B.E. 2535) issued Pursuant to the Factory Act B.E. 2535 issue on 24 September 2535
	Prescribe the monitoring and reporting methodology of pollution monitoring	Notification of Department of Industrial Work (B.E.2551), issued on 21 March 2551
	Prescribe the environment and safety report of power plant	The Ministerial Regulation, No. 3 (B.E. 2535) issued Pursuant to the Factory Act B.E. 2535 issue on 24 September 2535
	Prescribe qualification of environmental staff in power plant with capacity higher than 10 MW	Notification of Department of Industrial Works (B.E.2547), issued on 24 December 2547

Renewable energy tends to be strongly supported by public opinion, while activities such as the use of nuclear and fossil energy, the burning of waste, chemical factories and the construction of roads are often met with resistance. This has implications for the nature of local siting conflicts. However, the opposition against a specific project is often connected to local residents having a negative perception of the developer and of the limited opportunity they have to influence the planning process. Moreover, renewable energy, notably the readily available biomass, is good for Thailand but the government has to ensure investors carry out their projects responsibly. However, many small power plants avoid the EIA process because regulations state that plants with less than a 10 MW capacity don't need to conduct an EIA. For example, biomass power plant which will use coconut waste as its energy source in Tap Sakae district of Prachuab Khiri Khan Province has faced a strong protest from the locals, even though many will earn extra income from selling coconut waste to the plant. The community's skepticism looms when investors consistently build 9.9-megawatt plants to avoid the environmental impacts assessments required by law for any power plant exceeding 10 megawatts in capacity, initially the plan was for a 5 MW capacity plant but this was changed to 9.6 MW.

5.3 Technical and Environmental Related Barriers

As discussed in previous chapter, renewable energy can potentially play an important role in stabilizing greenhouse gas emissions and mitigating climate change. Renewable energy has many environmental benefits as well as some negative attributes. To secure broad public and policy support to promote renewable energy development, it is essential to include not only the climatic aspects, but also other broader economic, environmental, and social benefits in any analysis. It is therefore not possible to link the global scenario analysis directly to requirements for specific policies at a national level. The fact that a project is concerned with renewable energy does not mean that it will be automatically welcomed by everybody. The lessons concerning inclusive planning processes are as important here as in the siting of other facilities. People who oppose a facility are not usually negative towards renewable energy per se, even if they are critical of the location chosen and the way in which it has been selected.

5.3.1 Environment opposition for renewable energy development

Most potential impact of renewable are hydropower, wind, biomass projects have been increasingly associated with negative ecological and socio-economic impacts. Various techniques implemented to minimize the ecological impacts: e.g., fish ladders, careful operation of reservoirs, and integration of powerhouses into the landscape, and noise reduction. Since most impacts are site-specific, each plant design requires individually appropriate environmental safeguards. Generally small hydropower projects have a higher level of public acceptance, as these sites can frequently be adapted to remediate local environmental concerns. On the positive side of other renewable energy technology, e.g. wind turbines generate electricity without air pollutants that conventional power plants emit in great quantities. However, much of the negative impact of wind turbines has been associated with avian collisions especially with birds and potential noise pollution.

Perhaps the most vociferous environmental concern relates to the death of birds (“avian mortality”) and bats (“chiropteran mortality”) resulting from collisions with wind turbine blades (Mendonça, Jacobs et al., 2010). Randolph and Masters (2008) show evidence of avian collision in the northern California wind farms cause unacceptably high mortality rate of birds the public cares most about raptors. Moreover, renewable energy facilities have many characteristics in common that distinguish them from the siting of other facilities, and it is useful to discuss them in general terms.

Centralized and large-scale utility renewable power plants can require large amounts of land, and when these systems are built in densely forested areas or ecosystems rich in flora and fauna, they can fragment large tracts of habitat. For example, the enormous tracts of land requirement for construction wind turbine have seen extensive technical development during recent years. If located in a pristine area, more development of road and another facility will certainly impact the native environment. Although most renewable technologies use only a fraction of the water used by thermoelectric plants, some renewables, such as geothermal, hydroelectric, and solar thermal, can be water intensive. Energy technologies that withdraw and consume less water will have both public benefit and economic advantages in the marketplace moving forward. One option is to develop electricity from sources that use very little water, such as wind and PV. Other options include developing technologies that limit the use of water with fossil-fuel electricity sources or use alternate sources of water, such as reclaimed or saline water.

5.3.2 High variability of renewable energy cause unstable of grid security

Ensuring power supply security requires a deeper understanding of grid- related issues than those related to energy supply availability. Naturally varying renewable energy sources certainly provide secure quantities of energy when considered over a specific duration but do not necessarily guarantee the secure delivery of power as and when needed. The significance of the separation of requirements for energy delivery and power delivery gives rise to separate power supply-related questions, such as those concerning plant capacity, generation load factors, system capacity planning margins, probabilistic measures of system power supply security, and backup plant requirements. From the viewpoint of a power system operator, some of the difficulties associated with renewable source variability affecting the delivery of electrical power are as follows: (1) uncertainties in predictions of power available at any given time, leading to scheduling difficulties, although obviously the degrees of uncertainty vary with the length of forecasting horizon; (2) magnitude of fluctuations in power output, where small fluctuations can be accommodated easily, but larger fluctuations require special countermeasures; and (3) speed of fluctuations, where slow changes in resource availability and, hence, power output are usually predictable, but fast changes are less so.

In all national electricity supply systems, the power demand varies over the course of a day; there is a rise and fall every 24 hours, with usually a night-time minimum and a daily maximum. To assess the contribution that renewable or other sources of energy can make to electricity supply, the distinction between energy and power has to be kept clearly in mind. Whereas the commercial operation of each generation plant is measured against total energy delivered, in Thailand the EGAT acting in its roles as Thailand System Operator (SO) under Energy Industry Act

2007[21], has to ensure that the power generated (the rate of delivery of energy) balances the power demand at all times, otherwise the system fails. The related issues are indentified as following;

5.3.2.1 Plant availability

In addition, there are generating plant performance abilities to be considered, such as power conversion limits where generating plant can operate efficiently only within certain limits of energy availability. This is an important concern because even a brief power outage can cause millions of dollars in damage. Two of the most talked about forms of renewable energy, solar and wind power, suffer from intermittency, which means they cannot produce power 24 hours a day, seven days a week. For example, wind farms generate power only when the wind is blowing within a certain range of speed. Wind and hydropower are site specific; excellent locations can produce very high power densities. When there is too little wind, the towers do not generate power; but when the wind is too strong, they must be shut down for fear of being blown down. And even when they function properly, wind farms' average output is less than 30 percent of their theoretical capacity.

Wind farms unfavorably impact grid related power system operations. However, this is an inherent consequence of the application of wind power but not attributable to an individual turbine. With the expansion of wind power and the increase of wind power ratio in a local grid, such unfavorable impact will likely become the technical bottle neck for wind power integration. Wind power decreases accuracy of load forecast and therefore affects power grid dispatching and operation. Moreover, wind power impacts frequency control of power grid, voltage regulation, power supply quality, fault level and stability of power grid. At present, it is hard to say whether building wind farms and running a grid will be possible without fossil

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[21] Under section 87 of Energy Industry Act 2007 (B.E. 2550) describe roles and responsibility of EGAT System Operator (SO) to control, management and overseeing of the energy system for ensure the overall system balance, security, stability, efficiency and reliability. However, the system operator shall fairly instruct licensee operating the electricity industry to generate electricity and shall not exert unjust discrimination.

fuels, especially because no viable renewable fuel in 'liquid' form is evident (Laughton, 2007; Moomaw, 2008; Tzimas, A.Georgakaki et al., 2009; Verbruggen, Fischedick et al., 2010).

5.3.2.2 Variation of raw material supply

Theoretically, the earth can feed all the people alive today, yet even now 800 million people are affected by hunger. They suffer from hunger because they are too poor to buy food, not because too little food is available or insufficient land on which to grow it, however, vast areas are taken up with the production of feed crops for the livestock industries in industrialized countries (Solino, Prada et al., 2009). Government currently has launched ambitious programs to enhance investments in renewable energy e.g. wind, solar, biomass, and other clean renewable energy sources. Biomass power plants are believed to have less environmental impacts, which is not really true. Fossil fuels like coal, oil, and gas are good and convenient sources of energy, and they meet the energy demands of society very effectively. Fossil fuel resources are finite and not renewable. Biomass, on the other hand, grows and is renewable. A crop cut this year will grow again next year; a tree cut today may grow up within a decade. 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.

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, moreover, the quantity and quality of renewable resources has become the prominent barrier. 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, Most of biomass resources can only produced during harvesting season; for example, period of sugar harvesting is limited (5 months from December to April, see also in Figure 35). Thus, electricity from the sugar factory is mostly seasonal (Baguant, 1984; Krewitt, 2008)

The potential from biomass supply is widely distributed throughout the country depending on seasons. Particularly, rice is main agricultural product. The rough estimate of rice statistics data in Thailand were represented as major harvest and second harvest. Major harvest would be from May-June until November-December. Second harvest is from December-January until May-June. Accordingly the data are represented as wet season (major harvest) and dry season (second harvest). Table 13 present variation of some agricultural product in year 2008 to 2009, according to major harvest and second harvest. Ubon Ratchathani, Nakon Ratchasima, Burirum, Surin and Roi-Et province covered 75 percent of total yield (capacity), however, major harvest would be from May/June until November/December and second harvest is from December/January until May/June (see example of seasonal variation of rice production of Thailand in Figure 35 and Table 13). Figure 36 (left) indicates the rice production data (both seasonal variation and spatial distribution) in the year 2009 and while Figure 36 (right) gives the information on density of rice straw produced, i.e. tones of rice straw produced with respect to the provincial area in Thailand. Figure 36 to Figure 42 presented potential area for biomass energy development in Thailand.

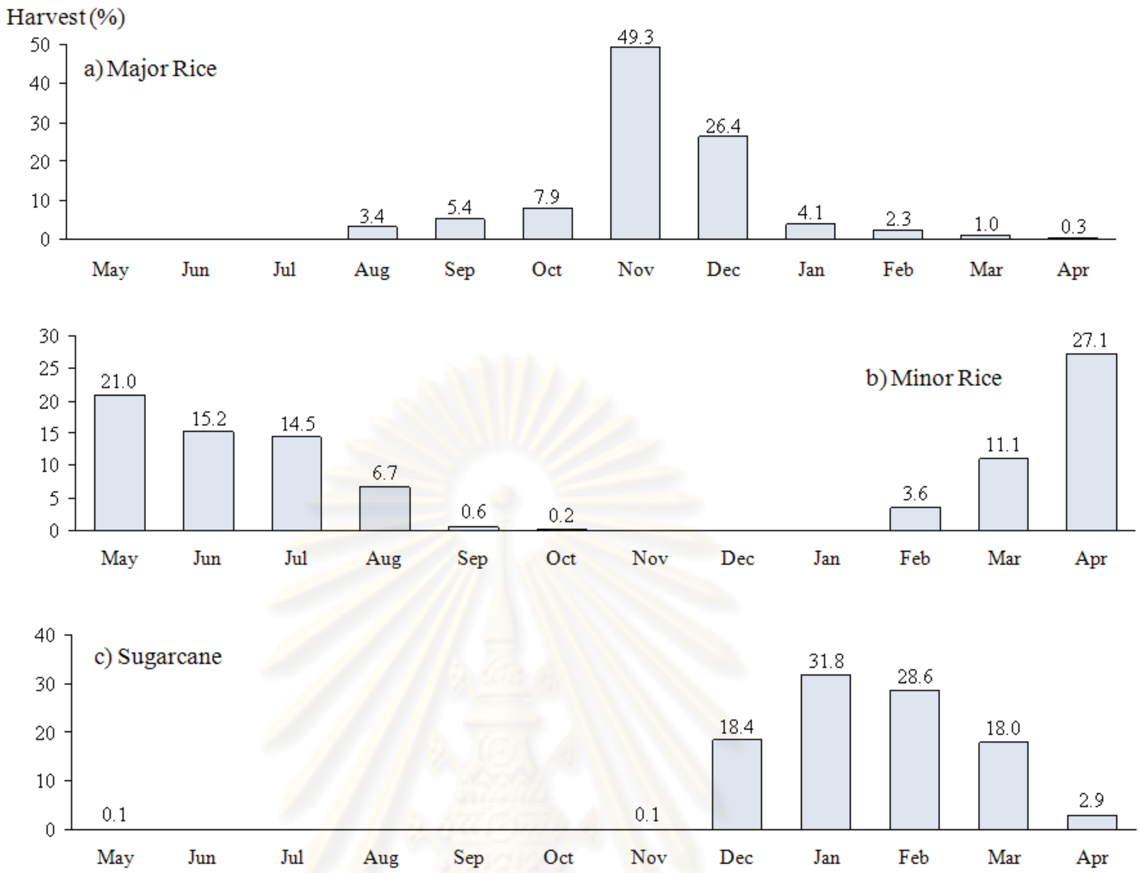

Figure 35 Seasonal Variation of Major Agricultural Products in 2008-2009

Source: Using data from Office of Agricultural Economics (2009)

Table 13 Seasonal Variation of Major Agriculture Products

Products	Production (%)																			Harvest period
	2008							2009												
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Major Rice			3.37	5.40	7.93	49.30	26.37	4.06	2.31	0.98	0.28									Nov-Dec
Second Rice								3.58	11.10	27.14	20.99	15.23	14.50	6.68	0.62	0.16				Apr-May
Corn Maize			13.76	27.70	18.01	17.32	12.39	6.14	2.96	0.95	0.64	0.10	0.03							Sep-Nov
Millet						5.09	42.22	33.85	18.07	9.77										Dec-Jan
Cassava					5.41	10.99	15.16	20.91	15.21	12.08	9.36	2.41	0.85	1.85	2.41	3.36				Dec-Feb
Sugarcane						0.11	18.41	31.84	28.64	18.01	2.93	0.06								Jan-Feb
Pineapple								8.30	9.21	8.84	7.96	13.95	11.69	3.66	2.30	5.29	8.30	10.46	10.04	May-Jun
Soybean		0.52	11.00	9.11	2.14	3.72	1.31		4.73	38.65	27.43	1.39								Mar-Apr
Green bean		6.87	1.62	0.82	7.91	33.04	29.11	0.33	0.92	9.08	9.20	1.10								Nov-Dec
Peanut		2.57	21.34	18.01	9.89	9.33	6.59	1.18	2.03	9.76	15.18	3.53	0.59							Aug-Sep
Rubber								11.62	8.04	3.83	2.49	6.75	8.00	8.78	9.55	10.36	10.92	8.35	11.31	Sep-Oct
Palm oil								6.37	6.84	9.83	8.54	8.34	7.52	7.30	7.72	8.41	9.44	9.96	8.73	Oct-Nov

Source: Using data from Office of Agricultural Economics (2009)

115

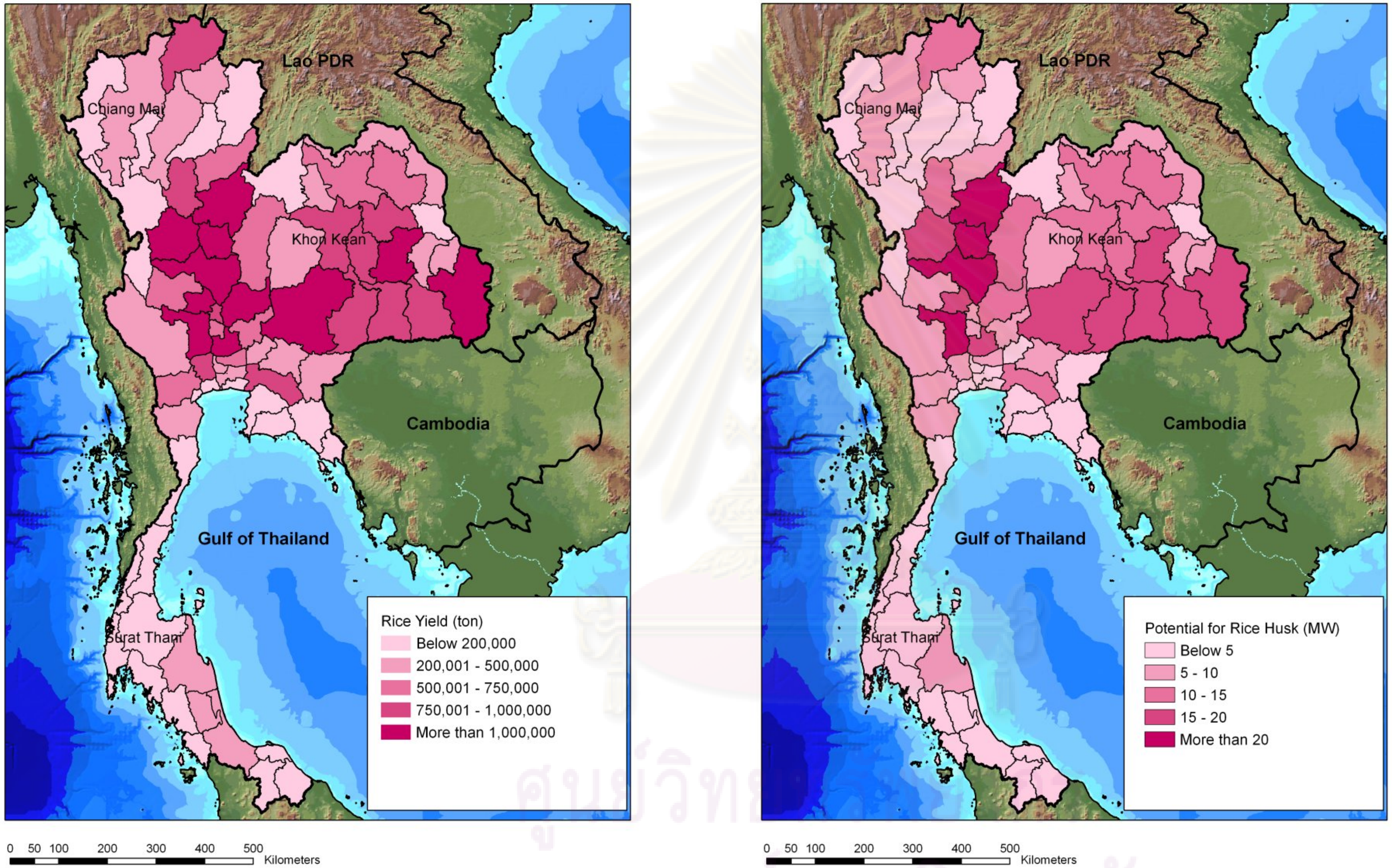

Figure 36 Yield and Potential of Rice Husk for Electricity Generation in 2009

Source: Using data from OERC (2010), DEDE (2009) and OAE (2009)

116

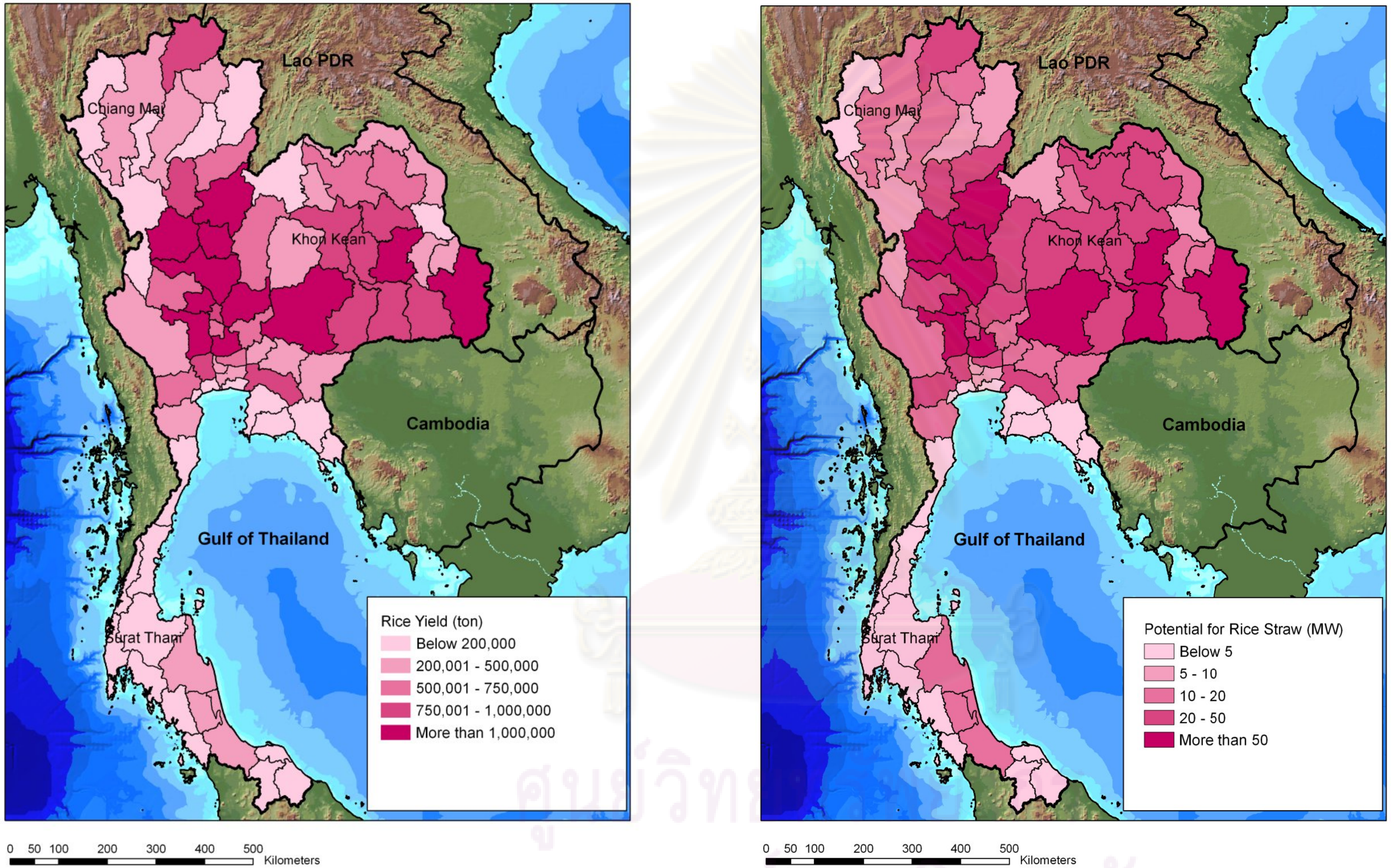

Figure 37 Yield and Potential of Rice Straw Residue for Electricity Generation in 2009

Source: Using data from OERC (2010), DEDE (2009) and OAE (2009)

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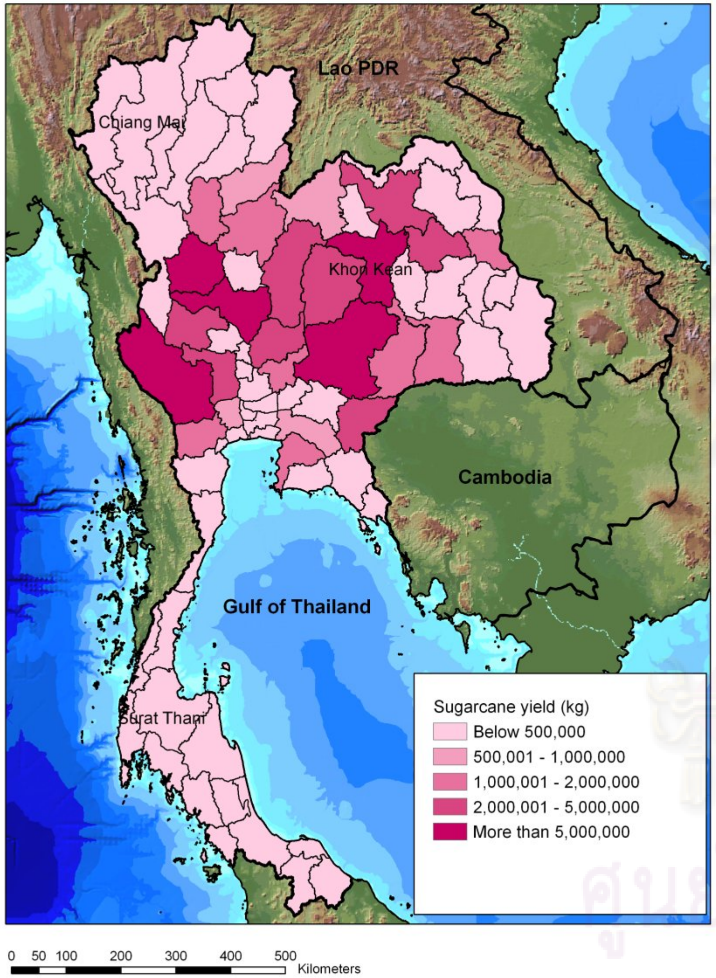

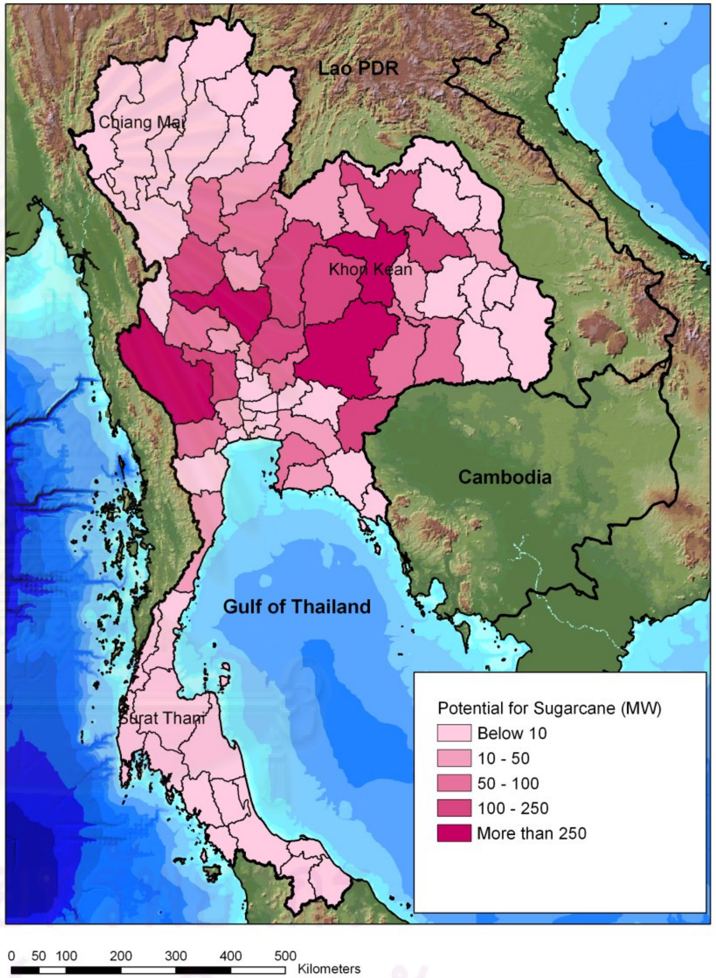

Figure 38 Yield and Potential of Sugarcane for Electricity Generation in 2009

Source: Using data from OERC (2010), DEDE (2009) and OAE (2009)

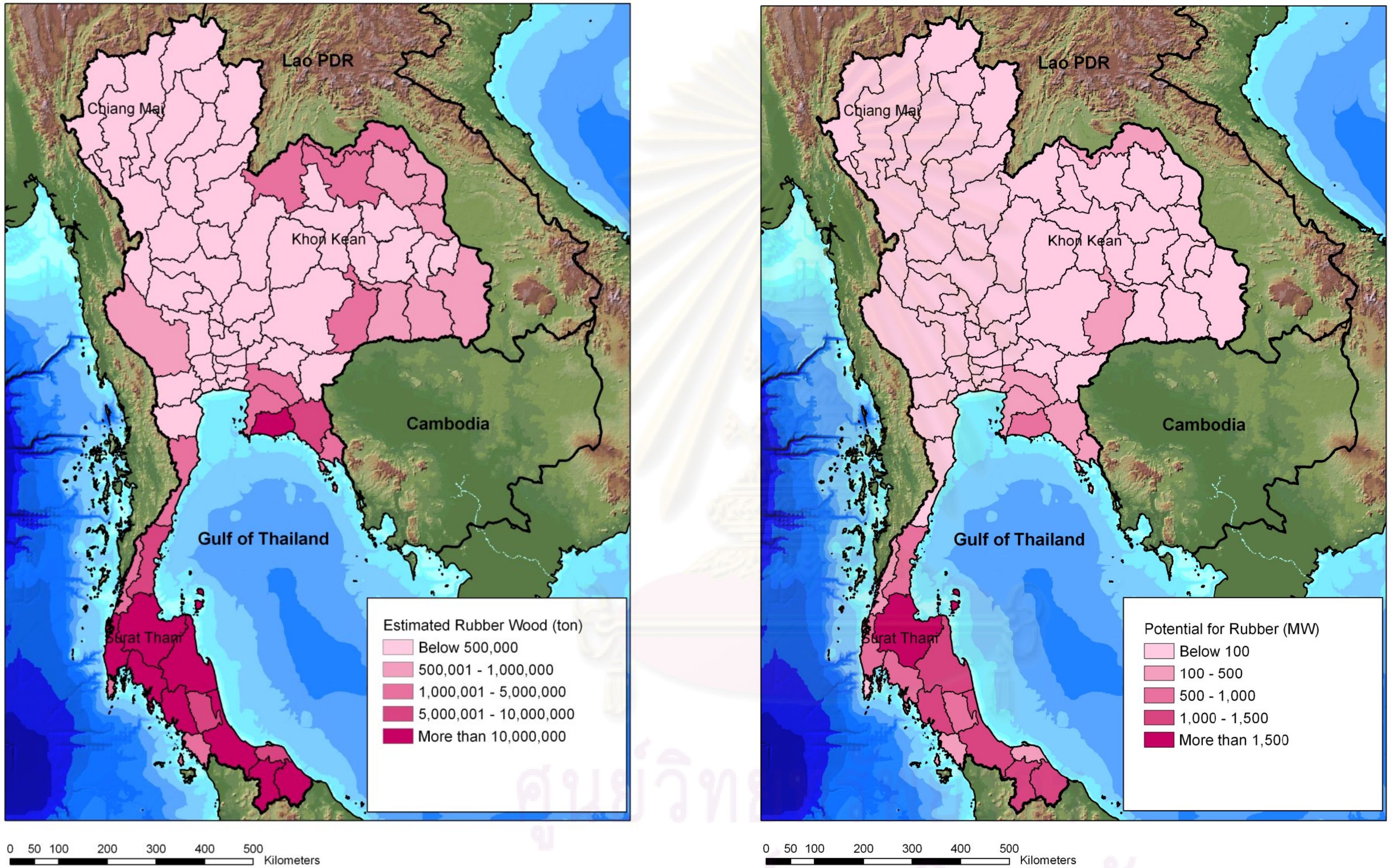

Figure 39 Yield and Potential of Rubber for Electricity Generation in 2009

Source: Using data from from OERC (2010), DEDE (2009) and OAE (2009)

119

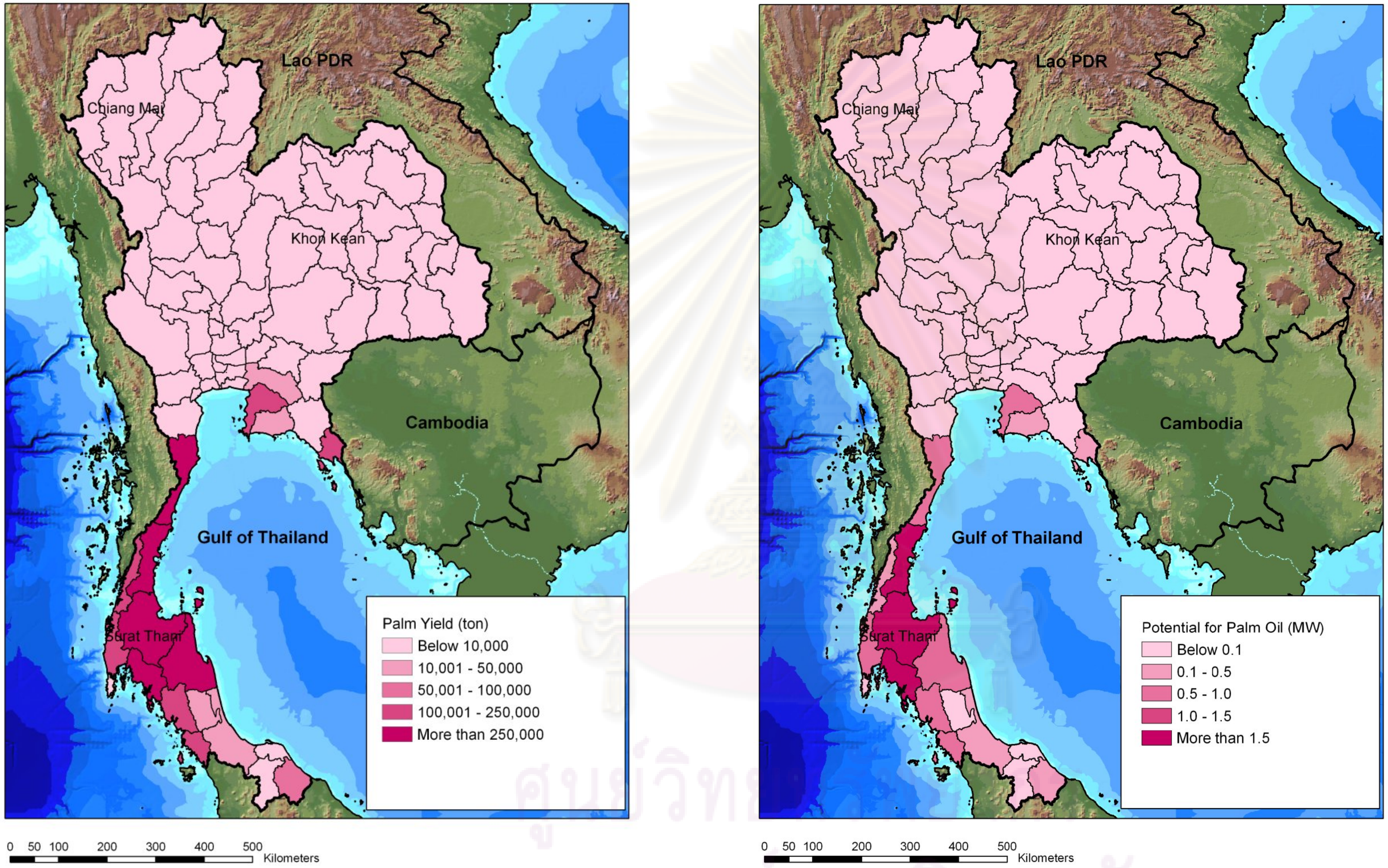

Figure 40 Yield and Potential of Palm Oil Residue for Electricity Generation in 2009

Source: Using data from from OERC (2010), DEDE (2009) and OAE (2009)

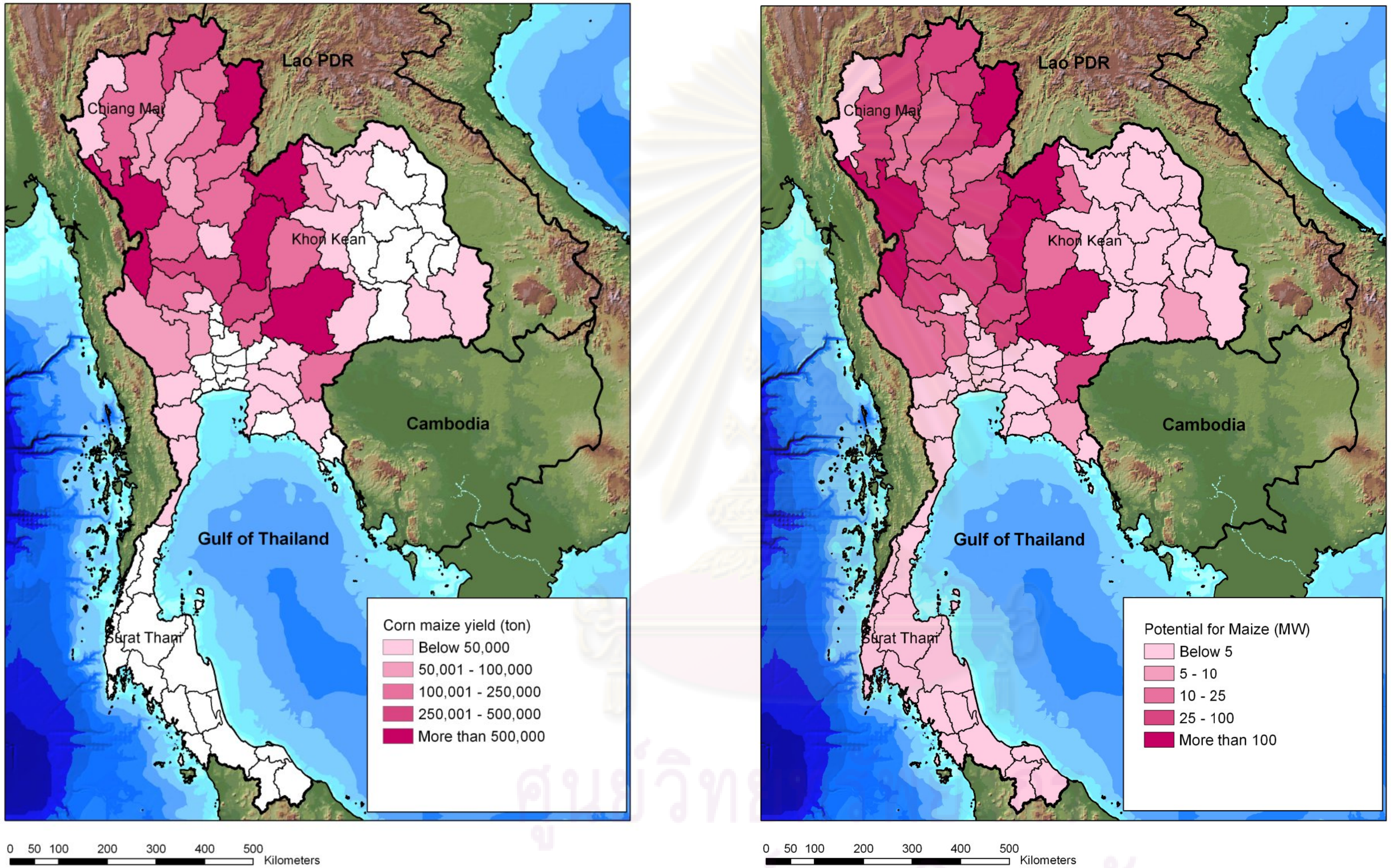

Figure 41 Yield and Potential of Corn Maize for Electricity Generation in 2009

Source: Using data from OERC (2010), DEDE (2009) and OAE (2009)

121

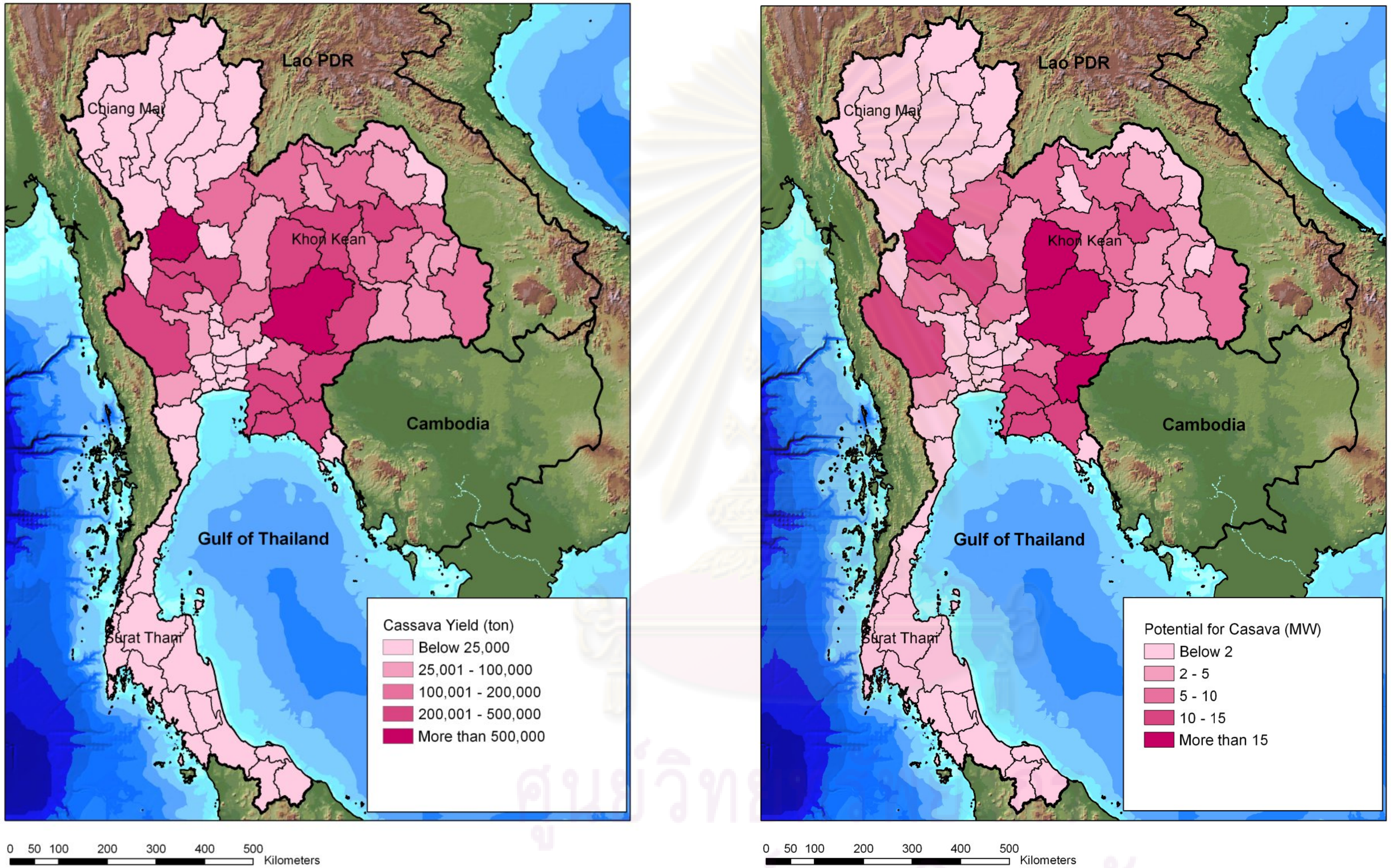

Figure 42 Yield and Potential of Cassava Residues for Electricity Generation in 2009

Source: Using data from OERC (2010), DEDE (2009) and OAE (2009)

122

5.4 Economic Related Barriers

5.4.1 Lack of available start-up finance for renewable

Thailand has much potential to generate power from renewable energy. Nevertheless, systematic support and promotional policy guidelines of the government is currently necessary to help alleviate the investment cost for renewable energy-fueled power generation development so as to eventually enhance its commercially competitiveness, which will be a key mechanism to further promote the development of appropriate power generation technology from each domestic renewable energy sources. Renewable energy project developers face financial barriers of a long payback time, lack of bank confidence and a shortage of money for feasibility studies. Specific country situations, such as policies that restrict PPA length and political instability, further complicate the prospects of attracting foreign investors and earning loans.

Renewable energy projects are unique in their demands on project financing because the necessary of feasibility studies, the long payback period due to the high initial project costs, and the perception of high risk for some technologies. Expensive feasibility studies must be undertaken to identify the proper site for development. The resource assessment and initial environmental impact reports are considered pre-investment and may or may not be repaid, depending on whether or not the project is developed. It is usually taken on by the company interested in development with the expectation that capital invested during this time will be recovered through the operation of the plant. However, in countries with significant political risk, this investment is lacking and prevents projects from even being considered (Lokey, 2009).

The project developers can struggle to secure financing since renewable energy projects tend to have a long payback time before the high capital costs will be recovered. Table 14 summarized an overview of the levelized and investment costs of renewable energy versus the levelized cost of conventional energy and Appendix C presented more detailed on levelized cost of Thai’s power industry.

Table 14 Investment and Average Generation Costs for Various Energy Technologies

Technology	From Literature Review		This study (Appendix C)	
	Average generation costs (US ¢/kWh)	Investment costs (US $/Watt)	Average generation costs (US ¢/kWh)	Investment costs (US $/Watt)
Natural gas combined cycle	3.5	0.6	4.50	1.725
Coal	4.8	1.2	4.76	1.52
Nuclear	4.8	1.8	-	-
Wind	5.5	1.4	-	-
Biomass	6.5	2	7.20	2.03
Geothermal	6.5	1.5	-	-
Small hydropower	7.5	1	-	-
Photovoltaics	55	7	-	-

Source: Using data from The IEA (2010) and Lokey (2009)

Generation costs include the initial cost of investment and fuel; whereas the investment costs only take into account the construction costs of the system. Typically, an acceptable internal rate of return on a power plant project is 25 percent; however, investment funds will occasionally not accept lower than a 30 percent return on investment. This translates into approximately a four to five year payback. Hydro projects will sometimes have up to a ten year payback. In many countries, power utilities still control a monopoly on electricity production and distribution. In these restrictions in the absence of a legal framework, independent power producers may not be able to invest in renewable energy facilities and sell power to the utility or to third parties under Power Purchase Agreements (PPA). The reason these projects are still pursued is that they can operate for over 100 years and recover the costs of investment over a long period of time. Because of these special circumstances, renewable energy projects will often need a long-term PPA of up to 20 years to get financing. This agreement will ensure to the bank that the project owners have off-takers, will purchase the electricity for a set price or utilities, and may negotiate power purchase agreements on an individual ad-hoc basis. This making it difficult for project developers to plan and finance projects on the basis of known and consistent rules.

Ministry of Energy defines a Small Power Producer (SPP) as either a private or state enterprise that generates electricity either (1) from non-conventional sources such as wind, solar and mini-hydro energy or fuels such as waste, residues or biomass, or (2) from conventional sources (natural gas, coal, oil) and using cogeneration (combined cycle units capable of producing power and steam). Both IPPs and SPPs have long-term power purchase agreements with EGAT as the single buyer. The PPAs allocate market risk to EGAT (and its captive ratepayers) leaving SPPs and IPPs to manage the operating and fuel price risks. SPP contracts are between 5 and 25 years with terms and specifications set by EGAT, the national power monopoly.

EGAT has defined two types of purchasing rates for buying SPP power, non-firm and firm power. The value of non-firm power is determined by EGAT's short- run avoided energy cost. Firm power means the SPP can guarantee availability of electricity supply during the system peak months. Payment to firm SPPs is determined by EGAT's long-run avoided capacity and energy costs. Indeed, the barrier to greater renewable energy penetration is the lack of enabling policy and regulatory frameworks, policy for what purpose or to promote which subject usually favor traditional energy sources. SPPs to date are not very cost effective but investors still do it because it is the policies from the government to promote SPPs by provide adder, for example, some of the benefits derived could be the sale of steam to industries. SPPs incentives come from several sources to make the business cost-effective.

As for other sources of renewable energy, especially the biomass, this is the time for biomass in Thailand. Usually power producers are free to make these PPAs with large consumers, but some countries do not permit it. Lokey (2009) give an example on PPA arrangement, the Power producers in Mexico are free to arrange PPAs, but they must be structured so that the off-taker has at least a 1 percent share in the power producers' operations. Also in Nicaragua (Lokey, 2009), the power producer must pay from 15 to 30 percent of the price negotiated in the PPA to the state utility as a transmission tariff and there is currently no wholesale electricity market. Regarding to CDM project development, the multilateral development banks, that understand the risks of renewable energy CDM projects, can offer project financing, but often do so in exchange for taking most of the CERs revenues by offering low CERs prices or a small percentage of CERs for the project owner. CDM-specific financial barriers like penalties for not producing the CERs promised, difficulty choosing the legal rules to follow for enforcement of the ERPA[22]. However, language barriers and asymmetric CERs price information create complex and confusing financial negotiations for project developers (The United Nations Framework Convention on Climate Change, 2010c).

If a project begins producing energy before it is registered, it cannot qualify for CDM. The project started CDM process in 2002. The first PDD which was prepared by Mitsubishi Securities was finished in May 2003. In October 2003, EB 11 approved the proposed baseline and monitoring methodology of Pichit Project. Unfortunately, Thailand, as a host country, is still in the process of adopting CDM framework and regulations. Once this process is done, expected sometime in March-April 2006, the application and approval process of CDM project in Thailand will be started. Such a time-consuming process prevented the Company from being able to proceed for the EB registration with the Approved Methodology 0004 (AM0004) within 2005. The Company has to revise the PDD by changing from AM0004 to ACM0006 instead. However, the Company is expecting to complete the registration process by the end of 2006.

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

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[22] Emissions Reduction Purchase Agreement (ERPA) means transaction that transfers carbon credits between two parties under the Kyoto Protocol. The buyer pays the seller cash in exchange for carbon credits, thereby allowing the purchaser to emit more carbon dioxide into the atmosphere. The standards for this agreement are outlined by the International Emissions Trading Association.

This agreement usually involves two countries; however, it may occur between a country and a large corporation. Buyers expect their carbon emissions to be above the level allocated to them by the Kyoto Protocol, while the seller expects to produce less. Often, the seller has implemented new technology or is developing a new project that is expected to lower its greenhouse gas emissions.

generation. Mallon (2006) 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. (2008) expressed investments of renewable energy companies not only generate 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 (Amranand, 2009).

5.4.2 Renewable energy is more expensive than conventional fuel when the externalities are not priced

Fossil fuel always subsidized by government, 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 more favorable or more attractive driven by energy security motivation (2008).

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. 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. For example, Tester et al. (2005) 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.

Mallon (2006) expressed current renewable energy is only more expensive than thermal (nuclear and fossil) generation if the environmental and social impacts, the 'externalities[23]', are not priced. Failure to acknowledge this in some way leads to distorting policy frameworks. Furthermore, renewable prices are declining and even in the most hostile markets they will continue to converge in price with conventional energy sources without externality pricing. The prices of goods bought and sold in markets prior to this form of intervention tend not to include the environmental cost of production, consumption and disposal, this costs are known as 'externalities' (Connelly and Smith, 2006; Goodstein, 2005; Prindle, Zarnikau et al., 2010). The use of economic instruments is not only concerned with providing internal incentives to polluters and resource users to reduce their emissions or to reduce their inputs. It also seeks to internalize the external costs of pollution and resource depletion. 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

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[23] Economists define "pollution" as a negative externality described as a cost of a transaction not borne by the buyer or seller. Pollution is termed an externality because it imposes cost on people who are "external" to the producer and consumer of the polluting product.

competition between renewable energy and traditional fuels and bring the country to a sustainable future. 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 (Sookkumnerd, Ito et al., 2005).

5.4.3 Lack of Research and Development to reduced cost on imported technology

Photovoltaics are already an economically competitive technology in several niche applications. Small applications are often supplied with small batteries or button cells, compared to household electricity prices of around 20 cents/kWh in Germany. For example, the costs with photovoltaics can quickly explode to several hundred Euros per kWh. It takes about 280 mignon cells[24] to store one kilowatt hour using high-quality alkaline manganese batteries (Quaschning, 2010). Now, no one would ever think about buying 280 mignon cells to run a washing machine just once. However, with small applications we often tend to be willing to pay whatever it costs to buy batteries. It is often the infrequent use of these small applications that even makes using electricity affordable. Photovoltaics can compete with this type of high energy cost even under the cloudiest conditions. It is often an economic alter- native even to large battery systems. However, photovoltaics will have to relinquish its niche role if it is to become effective in protecting the climate. This will only happen if it becomes a grid-connected system and replaces conventional power plants.

Whereas small-scale photovoltaic island systems[25] are already competitive today, the energy production costs for grid-connected photovoltaic systems are in most cases still higher than normal market prices. It currently only makes sense to install large numbers of grid-connected photovoltaic systems if state incentive schemes are available. Even if the quantity of solar power is still relatively small, in the medium term photovoltaics will be able to provide the largest share of environmentally compatible electricity supply. From a purely mathematical standpoint, it could be used to supply the world's entire energy needs. This would

[24] Mignon cell or AA battery is a standard size of battery

[25] Isolated system or non grid connected system

only take a fraction of the surface of the Sahara Desert to accomplish. Even countries like Great Britain, Germany and France would be able to cover all their electricity requirements through photovoltaics. On the other hand, from a technical perspective it is not a good idea to rely solely on one technology for the future supply of energy. Photovoltaic systems work well in combination with other renewable energy systems, such as wind power, hydropower and biomass systems. A well-planned combination of systems will increase supply reliability and avoid the building of large storage systems to ensure sufficient supplies are available at night and during the winter.

Costs will have to drop further before large numbers of countries start using photovoltaics on a considerably larger scale than at present. Past experience has shown that major cost reductions are possible. Whereas the price of photovoltaic modules was still around 60 inflation-adjusted US dollars per watt in 1976, by 2007 it had already dropped to around 3 dollars per watt (Quaschning, 2010). What is crucial for cutting costs is an increase in production. If production quantities rise, then costs will drop noticeably due to the effects of streamlined production and also because of technical advances. During the past 30 years cost savings of around 20% have been achieved due to a doubling in the total quantities of photovoltaic modules produced. There is nothing to indicate that this development will not continue. It is possible that the prices of photovoltaic modules could fall below US$ 1 per watt by 2020. As a result, the current cost to generate electricity using photo- voltaic systems would have shrunk to about one fourth (See also in Figure 43).

This would then make photovoltaic systems very interesting to end users in Central Europe, even without the need for any government subsidy schemes. A photovoltaic system would be able to produce electricity more cost-effectively for household use than an energy supply company could deliver to the household. In the sunniest parts of the world photovoltaics could produce energy more cost-effectively than any conventional alternatives. For that reason, the main markets for solar energy in the long term will be in places other than Western Europe. The absence of efficient renewable energy generation technologies and supports of skilled manpower and spare parts is one of the prime technical barriers (Quaschning, 2010).

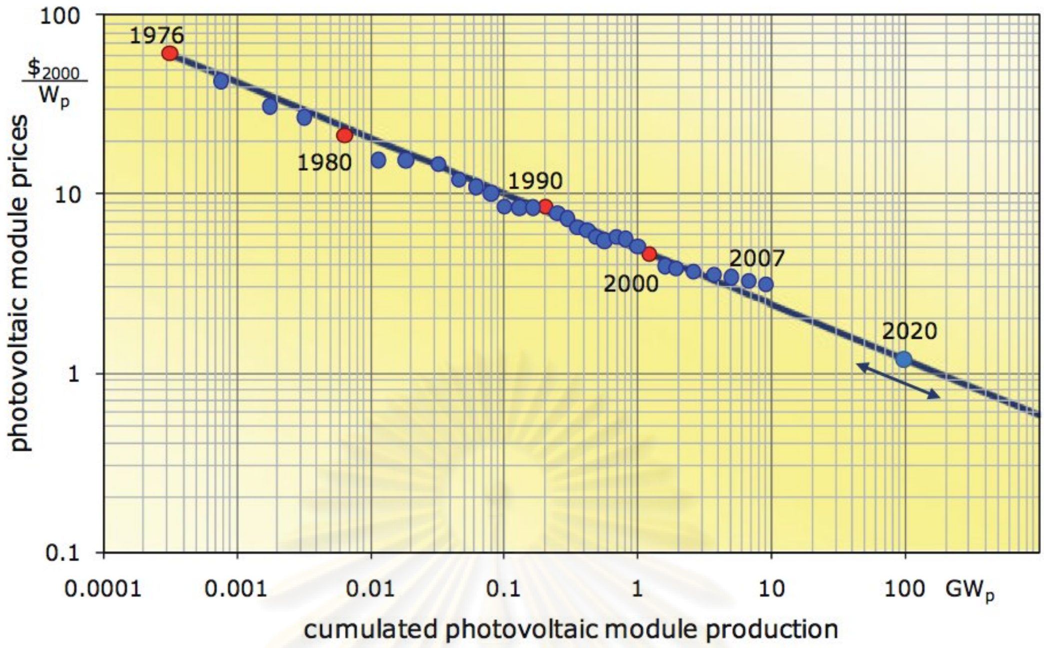

Figure 43 Development of inflation-adjusted photovoltaic module prices on the basis of total quantity of modules produced worldwide

Source: Quaschning (2010)

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 (Tchobanoglous, Theisen et al., 1993). Increase efficiency of waste separation can help increasing the yield of biogas generation but it also requires public education on waste management.

Proven, cost-effective technologies may still be perceived as risky if there is little experience with them in a new application or region. The lack of visible installations and familiarity with renewable energy technologies can lead to perceptions of greater technical risk than for conventional energy sources. These perceptions may increase required rates of return, result in less capital availability, or place more stringent requirements on technology selection and resource assessment. “Lack of utility acceptance” is a phrase used to describe the historical biases and prejudices on the part of traditional electric power utilities. Utilities may be hesitant to develop, acquire, and maintain unfamiliar technologies, or give them proper attention in planning frameworks. Finally, prejudice may exist because of poor past performance that is out of step with current performance norms. In next chapter, policy suggestion for low carbon electricity development will be presented.

CHAPTER VI
CONCLUSION

6.1 Challenges Faced by Low Carbon Electricity Systems

Thailand faces energy and environmental challenges as being both a contributor and victim of the effects from climate change. Renewable energy was identified as having great potentials for greenhouse gases emission reduction, due mainly to ample physical supply of the agricultural and industrial by-product such as rice husk, wood chips, bagasse, and other available biomass on fields. Based on potential installment of energy technology, the major proportion of renewable energy will mainly derive from biomass to fulfill target of 3,700 MW in 2022, Thailand need to increase about 230 percents from current capacity 1,610 MW in 2009. The expected goal under AEDP is not too hard to achieve, 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 cause disruptions to power supply include droughts reducing hydropower availability and withering field crops and other food supplies. The effects of climate change may affect the trade-off between food supplies in term of food plantation areas and purposed uses for biomass energy supplies.

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. Government released many tools for motivate utilization of electricity generation from renewable energy in many different ways. For example 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. 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 should strongly subsidy research to develop low cost solar cell by encouraging the co-operation of research and development.

Moreover, government may urgently set up a policy to promote the roof-top solar energy system to reduce energy demand 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 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. Another excuse to sit by and do nothing, maybe it is already too late, or perhaps the debate has already been shaped by various political agendas to polarize the right and the left to a point where one must pick a side, despite the amazing ability of humans to rationalize, and create this as an either/or discussion about our economic model and its future. It seems asinine to believe that the human civilization has not held any impact upon the global weather/climate system in the last four hundred years since the Industrial Revolution. Effective policy and regulation will be at the core of the response to global warming. In fact, the transition to a low-carbon economy might be the first global economic transition of this scale to be driven largely by policy.

Designing the low carbon electricity policy is a huge challenge to political leaders and regulators: it needs to achieve aggressive emission reductions, incorporate many sectors of the economy, be acceptable by many countries, be cost effective, and be equitable among the many stakeholder groups that are concerned. However, this study does not take a view of what regulation should be put in place and how aggressively targets should be set. These are political decisions that need to be made considering all the aspects above, and also considering many non-climate related political priorities.

6.2 Policy Recommendation for Low Carbon Electricity Development

Thailand's Electricity demand is rising and there are no indications that this demand will be curbed significantly in the short and medium term, despite the energy savings and improved efficiency measures that have been implemented. At the same time, the electricity generation infrastructure is aging and a large number of power plants are scheduled for retirement. Unless new electricity generation capacity is developed to fill the emerging gap between electricity demand and supply, Thailand's power generation sector will be under severe constrain in the coming years, with negative consequences for the economy and the standard of living of citizens. Specific strategies may be required to be developed for a low carbon electricity development as follows.

6.2.1 Promotion of energy efficiency and demand reduction

Conventional or fossil fuels are highly polluting and non-renewable. Reducing use has both environmental and health benefits. Those on fixed incomes such as the elderly are vulnerable to fuel poverty and higher efficiencies can reduce the amount spent on fuel. Energy efficiency and renewable energy are tending to be the "twin pillars" of a sustainable energy policy. Both strategies must be developed concurrently in order to stabilize and reduce carbon dioxide emissions. Efficient energy use is essential to slowing the energy demand growth so that rising clean energy supplies can make deep cuts in fossil fuel use. If energy use grows faster than, renewable energy development, this will chase a receding carbon emission target. Likewise, unless clean energy supplies come online rapidly, slowing demand growth will only begin to reduce total carbon emissions; a reduction in the carbon content of energy sources is also needed. A sustainable energy economy thus requires major commitments to both efficiency and renewable.

Energy efficiency is the lowest cost and most immediately accessible way to reduce carbon emissions and it reduces the extent to which abatement must be delivered through other means. Improving efficiency is both a technological and social challenge. Energy efficiency is a low-cost, rapidly deployable, and large-scale energy resource. Reducing growth in energy demand is essential to any clean energy strategy: without efficiency advances, clean energy supplies might not keep up with demand and carbon emissions could continue to grow. Policy makers are now focusing on ways in which different policy instruments can influence technological developments and users' behavioral changes with respect to energy efficiency. End-use energy efficiency improvements mean that fewer resources are consumed and emissions are avoided. The use of such resources is expensive, and at such times there is marked upwards pressure on electricity prices. Measures on the demand side, the electricity consumer offer important opportunities to reduce system costs.

6.2.2 Strengthening collaborative efforts and coordination among all governmental agencies

Government should strengthen collaborative efforts and coordination among all governmental agencies will create the great momentum to speed up the process toward low carbon society. However, it is essential to reduce the policy inconsistency between government organizations as well as policies that promote clean energy expansion in regulation, generation, financial support and expansion policies. Making progress on energy and climate will require greater public understanding of the challenges we face, the sacrifices that must be made, and the opportunities that lie ahead. Any new policy initiatives must be accompanied by a coordinated effort to communicate directly with the public about the role they will play in helping to reach these goals. It is recommended to set a national agenda for becoming a low carbon society in year 2030 by establishes a vision for the future. Articulate a long-term vision for addressing energy security and climate change against which all policies will be measured. Integrate energy security and climate change priorities into all aspects of domestic and international policymaking. Governments can take a number of steps to reduce uncertainty, including:

- Removing non-economic barriers, such as legal obstacles to grid access and financial rules that foster inefficient electricity market

- Improving worker training;

– Sponsoring education campaigns that promote acceptance of renewable technologies;

– Creating a predictable and transparent investment framework; and

– Offering incentives that are tied to a technology's maturity and promise.

6.2.3 Providing incentives for fuel diversification into low carbon emission

6.2.3.1 Identification of new kind of renewable energy

The world is not running out of energy. But it is becoming more difficult to access, produce, and convert energy resources and deliver them to the people who need them. For instance, supplies of oil, natural gas, and coal are increasingly located far from demand centers. Moving these products requires an increasingly complex delivery infrastructure that increases vulnerability to disruptions. The adequacy and security of this infrastructure, which is already transporting large volumes of oil and gas over long distances through increasingly crowded transit points, is a critical concern. For improving grid securities and decreasing emission from power generation, government should strengthen energy security through greater effort in increasing access to further utilize renewable energy and other alternative energy as future energy choices is essential.

However, government should concern and promote the 'small and distributed' mode of energy production and consumption at the rural community levels where several hundred units of community biodiesel, biogas, biomass electricity and PV-solar units have been installed in the past decades. Some of such community is a classic showcase that 'small can be beautiful and competitive'. In this regards, the small farm holders and SME energy producers can be part of the development process of the country and can in fact energize the revival of rural community developments into the new modes of knowledge bio-based economy.

6.2.3.2 Revised the potential area for renewable energy development

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 such as the transportation of rice husk for biomass power plant, is averagely farther than 200 km to the plant location. If the policy is to minimize the use of petroleum fuels, biomass resources should be utilized by nearby facility. 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, therefore, carbon emission from renewable energy are not nil, as is generally assumed while evaluating carbon credits. Also the more promotion of biomass to generate electricity could also lead to further forest destruction and encroachment.

6.2.3.3 Applied various policies for renewable energy expansion

Provides private-sector energy incentives to promote low-carbon fuels and technologies, and remove barriers to their deployment. The current mix of regulatory regimes and incentive structures favor conventional fuels and have created significant barriers to new forms of energy that require different production and delivery infrastructure. In addition, the current system of frequently expiring incentives, such as the tax credits offered for energy efficient appliances, inhibits technology progress. The new administration should evaluate the effectiveness of these current regulations and incentives in promoting efficiency, fuel diversity, new technologies and fuels, and reducing greenhouse gas emissions. Successful programs should be extended for a longer period.

The government controls just a subset of clean technology incentives and regulatory barriers. Many of these entities are far ahead of government and would welcome greater action and leadership. For long-term policy, government should align private-sector economic and financial incentives and remove barriers to promote investments in low-carbon energy technologies and also implementation of financial incentives such as loans guarantees and grants (See also in Appendix F for more information of renewable promotion policies in many countries).

6.2.4 Introduction of Clean Coal Technology (CCTs)

Coal used worldwide is projected to increase significantly and is expected to be the fastest growing primary energy source in the next 20 years primarily due to the increasing demand for fuel for electricity generation and in the industrial sector. At present, there are already substantial capacities of coal-fired power plants and coal resources remain largely untapped (The Energy Data and Modelling Center, The Institute of Energy Economics et al., 2009; The International Energy Agency, 2006).

In Thailand, its energy plans indicate the rapid growth of coal utilization for power generation and this presents itself an opportunity to promote and increase cleaner coal use and clean coal technology that could bring in benefits towards national energy security. Despite growing environmental controls, more coal power projects are moving forward, with increasing preference to use clean coal technologies. The importance of collective action to strengthen cooperative partnerships, promotion and utilization of coal and clean coal technologies among government, private sector and NGOs are strongly required. For the sake of national energy security in the long term, Thailand strongly encourages the use of clean coal technologies and promotes collaborative image-building for coal and CCTs in the light of global environmental concerns.

Government should promote CCTs by conducting studies, among others, on upgraded brown coal, coal liquefaction and integrated coal gasification and looking into the potential of carbon capture and storage (CCS) technology as well as encouraging private sector investment and participation. While enhancing environmental planning and assessment of coal projects, harmonizing emission standards and minimum efficiency requirements for coal-fired power plants is also important. To support future CCTs, it is essential to establish coal laboratory and standards, development strategy and action towards harmonization of local practices to encourage coal utilization, resources and facilities. Moreover, education, positive perception and public understanding are key success factor for implement CCT technology today.

6.2.5 Encouraging and Promotional of Local Research and Development

Government could support researchers for carry out their research to extend country potential, and create in-house technology to promote industrial start-up. It should be note that accelerating the pace of technology improvement and deployment could significantly reduce cost of achieving emission reduction goals. 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. Energy research is facing tremendous challenges to enhance knowledge and develop new technologies for cleaner and more efficient energy production, transport, conversion and final use. Therefore, measuring the best state of the art of given technologies against a set of relevant parameters, identifying ambitious but realistic objectives to be attained over various time lines, and assessing the progress made over time are major issues for program managers, researchers or decision-makers. 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.

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. The international political frameworks must be aligned with the long-range business investment cycle so that investments in GHG abatement technologies can be justified commercially. Many technology projects require government policies on issues such as R&D, risk management and large demonstration projects. The utilization of possible instruments, price signals should be created to promote innovative product and technological design. Policies that promote GHG emissions reductions will send the required signals to capital markets.

Moreover, policies must include education programs encouraging consumers toward low-GHG products and services. Strong financial commitments by multilaterals will encourage development and transfer of leapfrog technologies to developing countries. Good governance must accompany additional financing and technical support for energy and technology markets. Most of the technologies needed to achieve dramatic reductions in energy use and a significantly increased use of renewable energy already exist and have been used successfully in at least some jurisdictions. There is, nevertheless, a role for continued technological development in reducing the cost and increasing the market penetration and technical performance of many technologies. However, government support for research and development in the areas of energy efficiency and renewable energy has been stagnant for the past decade, in spite of increasing awareness of the urgency of dealing with the global warming problem. Governments can provide incentives and promotion for research such as; Biomass cogeneration, electricity generation from biogas, Capturing CO_2 emission using algae, Battery for energy storage, etc.

6.2.6 Gaining More Benefits from CDM

The CDM was designed to be flexible since new types of carbon reductions are being devised every day. This flexibility allows new methodologies to be proposed. In Thailand, the project developers of Rice Husk Power Plant (A.T. Biopower) decided to propose a new methodology called New Methodology 0006 (ACM0006: Consolidated methodology for electricity generation from biomass residues). The logic behind proposing this methodology was that it would allow more reduction credits to be earned from renewable energy CDM projects in the country. The rice husk power plant was originated under Thai Government policy, which was to encourage private sector to develop and invest in renewable energy under the Small Power Producers (SPPs) scheme. This energy policy has major objectives to promote alternative energy to complement and strengthen Thai Electricity system by using own resources from biomass such as rice husk, sugar cane-bagasse, corn leaves, tapioca, palm shell and woodchip, to reduce the import of fossil fuels and to replace Thai's supply of fossil fuels which is forecasted to run short in the next 30 years.

Project developers have had difficulty timing the start of their projects with CDM registration because of all of the complicated steps and unforeseen delays that can occur in the process. Having uncertainty about the methodology one is using and the timing of when the project will be registered adds a layer of complexity to the

CDM process that has discouraged project developers. Significant CDM-specific procedural and methodological barriers have discouraged the development of some projects. However, each complex procedure in the CDM project cycle has a purpose that attempts to filter out the non-additional projects. As the process of CDM rule refinement continues and new versions of methodologies are released, the process gets more complicated. Sometimes these changes further discourage development, but they can also stimulate it as is the case with the methodology. The flexible nature of the CDM process allows project developers and consultants to propose changes to the operating and build margin ratios and existing methodologies, but sometimes these changes can have unexpected consequences that do not generate more CERs. Future adjustments to CDM renewable energy methodologies to account for countries with low emission factors and high levels of imported energy could help level the playing field for all countries.

As the CDM develops, issues of regulatory additionality[26] will continue to be clarified and hopefully will be modified to clearly allow state-run utilities to register CDM projects even if they are planned capacity additions. Also, the EB will hopefully make a ruling to clarify issues of financial and regulatory additionality for host countries that have legislation that mitigates greenhouse gases so as to prevent these countries from having a perverse incentive to do nothing about climate change. The necessity for more, local carbon consultants and DOEs obvious as the cost of hiring foreign firms is often prohibitively expensive for developers. These consultants and DOEs need to be more careful in their evaluation of projects to pass the Executive Board's new stringent requirements.

[26] Additionality of CDM is defined as follows: "A CDM project activity is additional if anthropogenic emissions of greenhouse gases by sources are reduced below those that would have occurred in the absence of the registered CDM project activity".

Table 15 Summary of solution for gain more benefit from CDM

Barrier	Segment	Solution
Technical Barrier	Project developer	Train local experts; create system for ordering parts; include a budget for replacement parts; create strict quality control; and include technical best practices in monitoring plan
Social Barrier	Project developer	Follow documented best practices of groups experienced from IPCC
	Government	Provide incentives for municipalities to develop projects; mandate that communities be part owners of projects in exchange for water or land permit; offer income tax exemptions if some CERs are reinvested in community; have companies comply with international standards for environmental responsibility; create incentives to stimulate a culture of paying for electricity; and make a policy for how developers should handle land and water permit disputes
Financial Barrier	Project developer	Utilize a CER insurance product to ensure delivery
	Government	Have DNA office explain value of CERs to local banks; provide money for feasibility studies; create incentives for the same developer or DOE to engage in more than one CDM project; reduce excessive paperwork for renewable energy interconnection in grid; require power wheelers to charge uniform transmission and distribution rates; eliminate the import tax on system requirements and annual income tax; require CDM revenues to be included in future state-run least-cost planning processes; and incorporate CDM in the long-term energy policy strategy
International Barrier	Government	Have DNA offices take a small percentage of CERs and use it for advertising, assisting project developers in the early CDM stages, and the creation of clear registration guides in the host country language, CDM workshops, CDM website, CDM databases and CER price guides. Host countries could also pressure CDM capacity building organizations for equal access to information.

Source: Modified from Lokey (2009)

6.2.7 Preparing for Post-Kyoto

The Bali Action Plan (BAP) highlighted the importance of "Measurable, Reportable and Verifiable[27]" (MRV) greenhouse gas mitigation actions and commitments, as well as support for GHG mitigation actions, in the post-2012 climate framework. This language on MRV was introduced to apply both to developed countries' commitments and actions, as well as to "nationally appropriate mitigation actions by developing country Parties in the context of sustainable development, supported and enabled by technology, financing and capacity-building". However, extending MRV provisions to actions undertaken in developing countries (as well as in developed countries) could have many benefits, including more comprehensive information on global GHG mitigation actions, more information available to assess the effectiveness of such actions, and greater recognition of GHG mitigation actions undertaken in developing countries. Developing a reporting and/or recording framework that collects information on GHG mitigation actions and commitments in a single place, and that is flexible enough to evolve over time, could also help the international community better keep track of global mitigation efforts, and to enhance them as needed.

At present, information on greenhouse gas mitigation (GHG) actions, and the support for such actions, is reported internationally in countries' National Communications.[28] This information is patchy, particularly from non-Annex I countries, as current requirements allow for very irregular reports. There is thus growing interest in having a more comprehensive, and timelier, picture of GHG mitigation actions particularly in developing countries where information is scarcest.

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[27] Measurable, Reportable and Verifiable (MRV) was introduced to apply both to developed countries' commitments and actions, as well as to "Nationally Appropriate Mitigation Actions by developing country Parties in the context of sustainable development, supported and enabled by technology, financing and capacity-building"

[28] As well as including information on GHG mitigation actions, countries' National Communications also contain information on several other issues, including a country's adaptation measures; national circumstances; activities in research and systematic observation; education and public awareness; and technology transfer. Non-Annex I countries also need to include a national GHG emissions inventory.

A reporting or recording mechanism could thus identify enhanced GHG mitigation actions, and also support for these actions, in a measurable, reportable and verifiable (MRV) manner, as per the Bali Action Plan. Suggestions for a "registry" and for "National Schedules", both of which could perform the function of recording and reporting GHG mitigation actions in developing and developed countries, have been made in UNFCCC negotiations for a post-2012 framework (Ellis, Moarif et al., 2009).

Table 16 presents list of activities for greenhouse gas emission reduction from Ministry of Energy in 2010-2012. It should be noted that the developing countries are also likely to need to provide more information than at present. This could include a more comprehensive and timely picture of GHG mitigation actions (implemented and planned, as well as those contingent on provision of support), as well as information on support received. Information may also be needed on the expected/actual GHG impacts of mitigation actions. Moreover, in a post-2012 agreement, developed countries may need to expand reporting to strengthen information in two areas: on GHG actions, and also on support provided, where the latter includes financing and other support for capacity building and technology development and/or transfer. The frequency and detail of reports may also need to be increased, particularly regarding how much support (and of what type) is provided. This may, in turn, require increased co-ordination, within governments and the various divisions and agencies dealing with provision of support, as well as between governments, multilateral development banks and other international institutions (such as the OECD, IEA) involved in the provision and/or monitoring of support. Increased reporting on support received for climate-specific and climate-relevant support by developing countries would be a useful step forward in improving the effectiveness of support.

Currently, the internationally agreed guidance on quantifying the effects of GHG mitigation actions focuses on projects or programmes undertaken via the CDM. Extending such guidance to methodologies, approaches and/or tools to quantify the effects of GHG mitigation actions while not straightforward, this would facilitate countries' MRV-related efforts, and could thus help in developing a more comprehensive and timely system for measuring, reporting and verifying enhanced action on GHG mitigation in the post-2012 climate framework.

Table 16 List of GHGs emission reduction activities in 2010-2015

Activities	Organization	Amount of emission reduction (tCO_2-eq)	CDM Methodology
Fuel switching from fuel oil to natural gas	Bangchak Plc.	60,000	ACM0011 – Consolidated baseline methodology for fuel switching from coal and/or petroleum fuels to natural gas in existing power plants for electricity generation (version 2.2)
Install new co-generation for electricity generation	Bangchak Plc.	100,000	ACM0048 – New cogeneration facilities supplying electricity and/or steam to multiple customers and displacing grid/off-grid steam and electricity generation with more carbon-intensive fuels (version 2)
Boiler efficiency improvement	Bangchak Plc.	75,000	AM0054 – Energy efficiency improvement of a boiler by introducing oil/water
Install new PV system for electricity generation	Bangchak Plc.	25,000	AM0019 – Renewable energy project activities replacing part of the electricity production of one single fossil-fuel-fired power plants that stands alone or supplies electricity to a grid, excluding biomass projects (version 2)
Utilization of waste gas in refinery	Department of Mineral Fuels		AM0055 – Baseline and monitoring methodology for the recovery and utilization of waste gas in refinery facilities (version 1.2)
Replacement of high efficient light bulb in residential sector	EGAT	3,208,722	AM0046 – Distribution of efficient light bulbs to households (version 2)
Improvement of boiler efficiency in electricity generation	EGAT		AM0054 – Energy efficiency improvement of a boiler by introducing oil/water
Energy efficiency improvement in existing EGAT power plants	EGAT		AM0061 – Methodology for rehabilitation and/or energy efficiency improvement in existing power plants
Electricity generation from wind	EGAT		ACM0002 – Consolidated methodology for grid-connected electricity generation from renewable resources (version 10)
Flare gas utilization	PTT Plc.		AM0055 – Baseline and monitoring methodology for the recovery and utilization of waste gas in refinery facilities (version 1.2)
Fuel switching from fuel oil	PTT Plc.		ACM0011 – Consolidated baseline methodology for fuel switching from coal and/or

Activities	Organization	Amount of emission reduction (tCO_2-eq)	CDM Methodology
to natural gas in PTT power plant			petroleum fuels to natural gas in existing power plants for electricity generation (version 2.2)
Electricity generation from biogas	Energy Policy and Planning Office		ACM0002 – Consolidated baseline methodology for grid-connected electricity generation from renewable sources (version 10)
Electricity generation from biomass	Energy Policy and Planning Office		ACM0002 – Consolidated baseline methodology for grid-connected electricity generation from renewable sources (version 10) ACM0006 – Consolidated methodology for electricity generation from biomass residues (version 9)
Waste heat utilization	Department of Alternative Energy Development		AM0036 – Fuel switch from fossil fuels to biomass residues in heat generation equipment (version 3) AM0029 – Methodology for Grid connected electricity generation plans using natural gas (version 3)

Source: Using data from Cheif of Climate Change Officer in Energy Sector (2010)

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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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[1] Accepted by Renewable and Sustainable Energy Reviews and in press.

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

[3] Department of Environmental Engineering, Faculty of Engineering, Chulalongkorn University, Thailand

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).

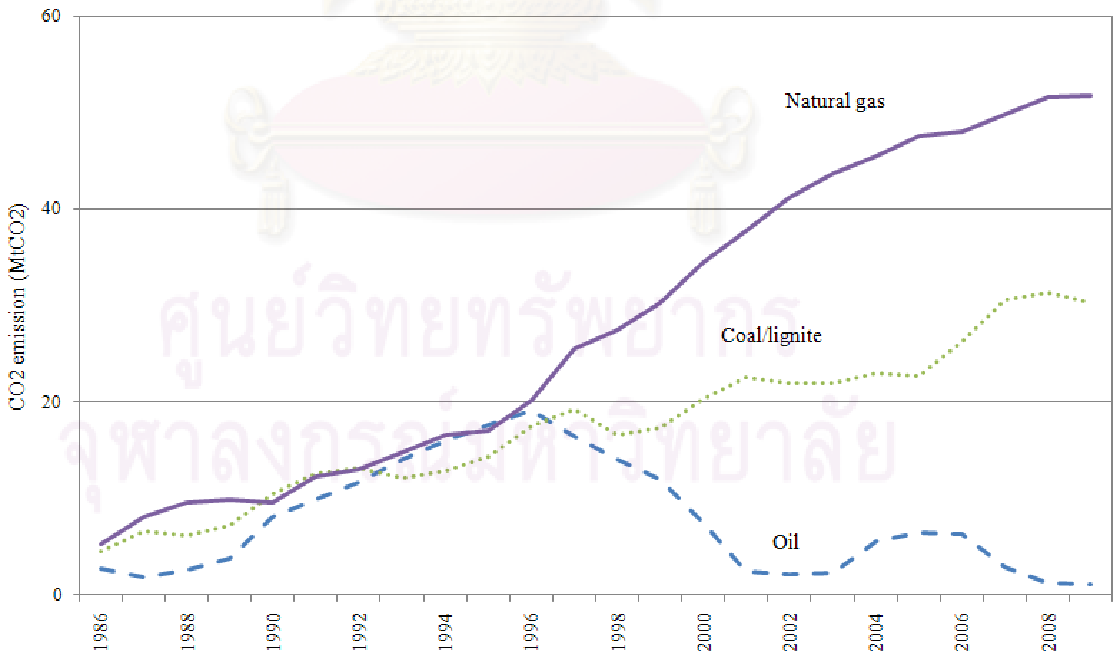


Figure 1 Carbon dioxide emissions from electricity generation in Thailand

Source: Ministry of Energy [8]

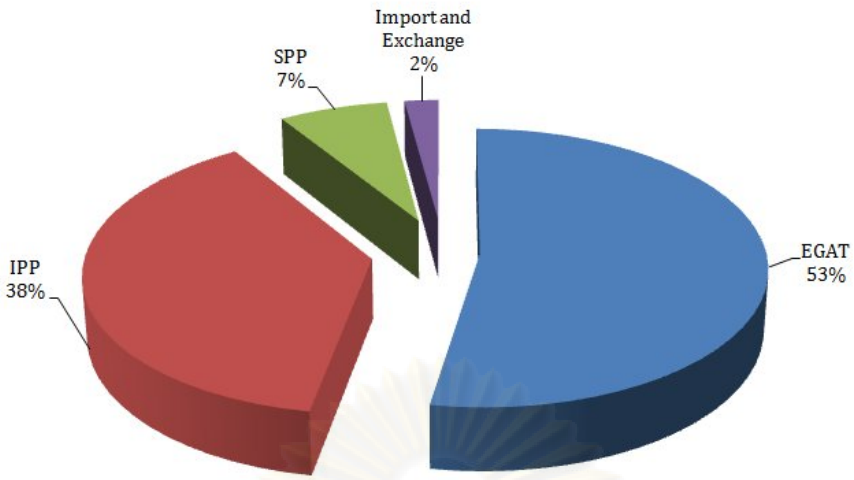


Figure 2 Share of electricity supply in 2009

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.

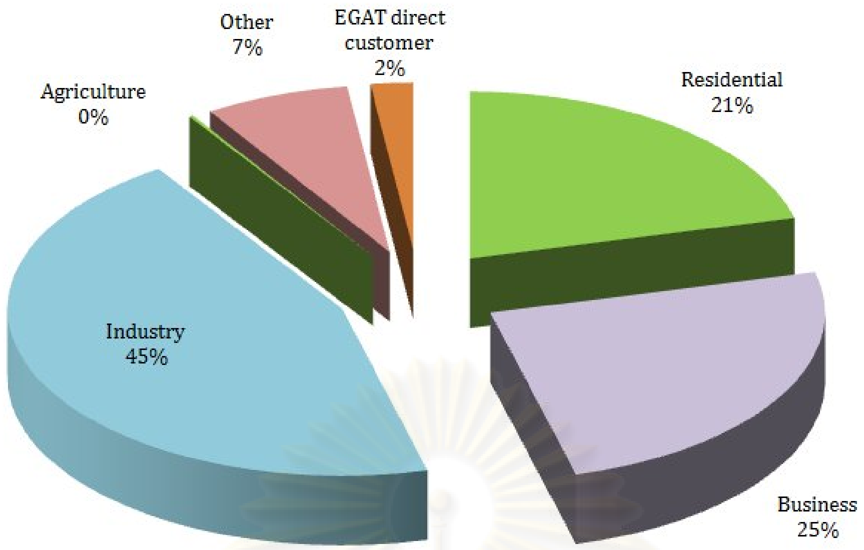


Figure 3 Electricity consumption in 2009

Source: Ministry of Energy [8]

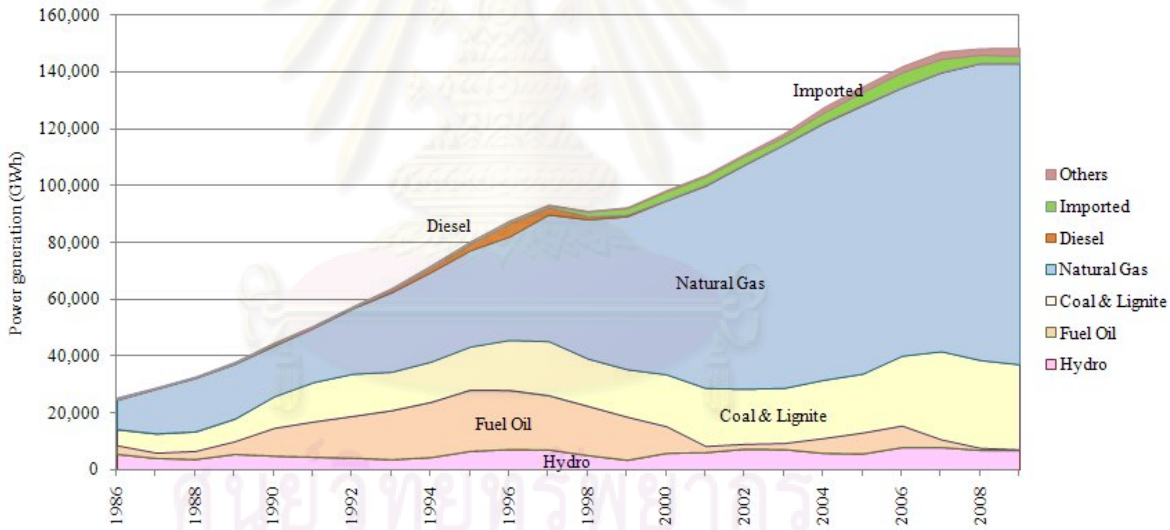
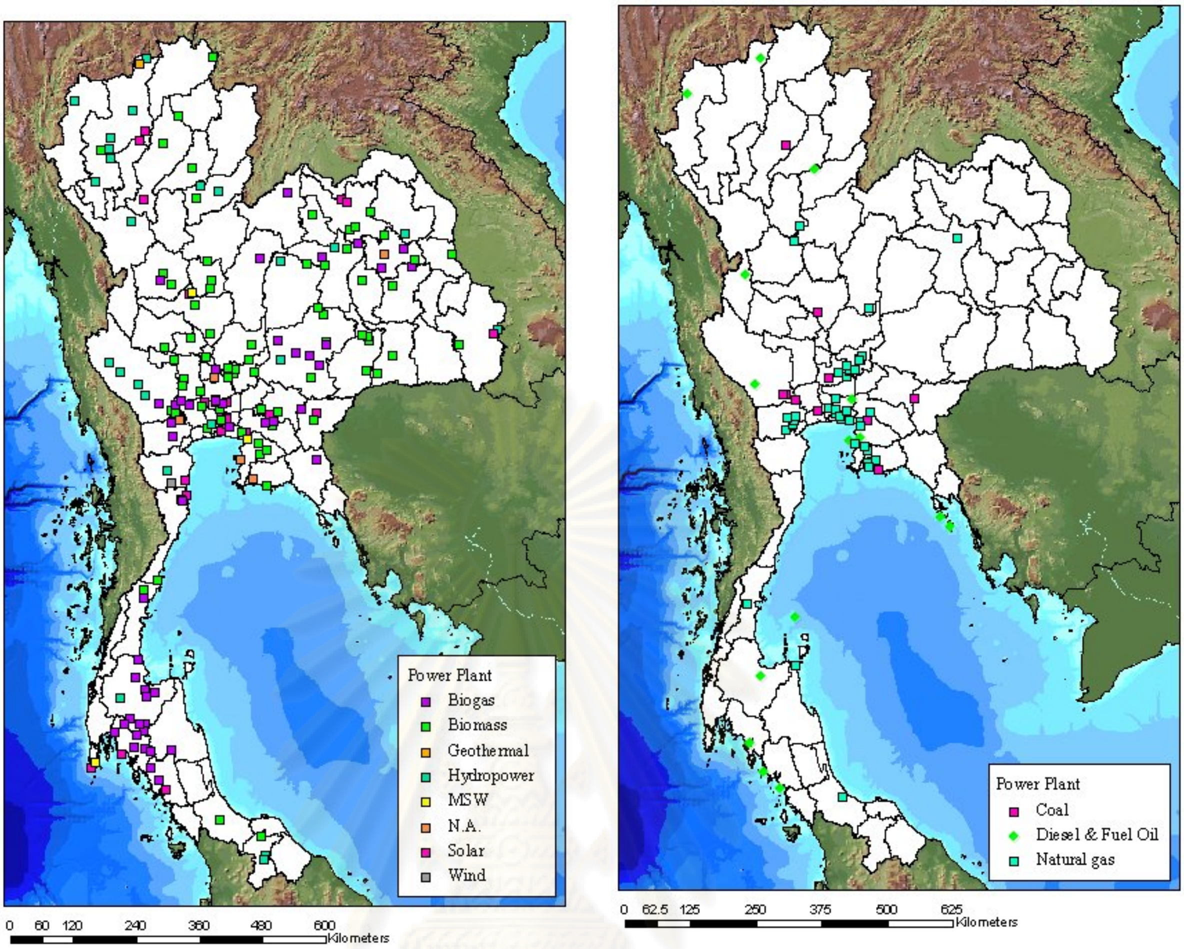


Figure 4 Capacity and fuel share of Thailand's electricity generation

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 m³ 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] Already submitted to Energy Policy and in revising period

[2] International Postgraduate Program in Environmental Management, Graduate School, Chulalongkorn University

[3] Center of Excellence for Environmental and Hazardous Waste Management (EHWM), Chulalongkorn University

[4] Department of Environmental Engineering, Faculty of Engineering, Chulalongkorn University

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.

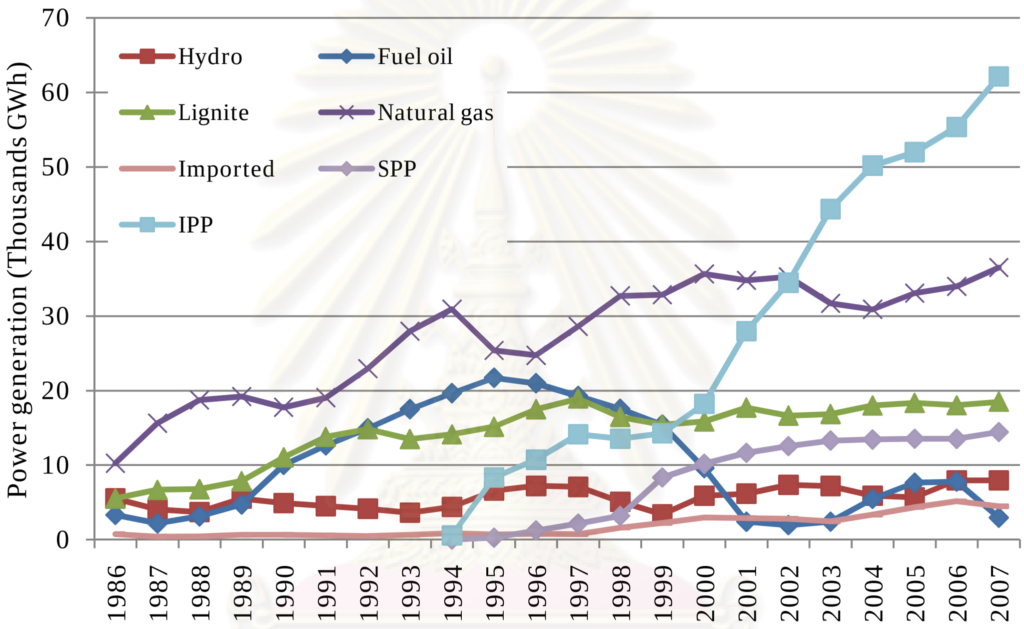

Figure 1 Capacity and fuel share of Thailand's electricity generation

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.

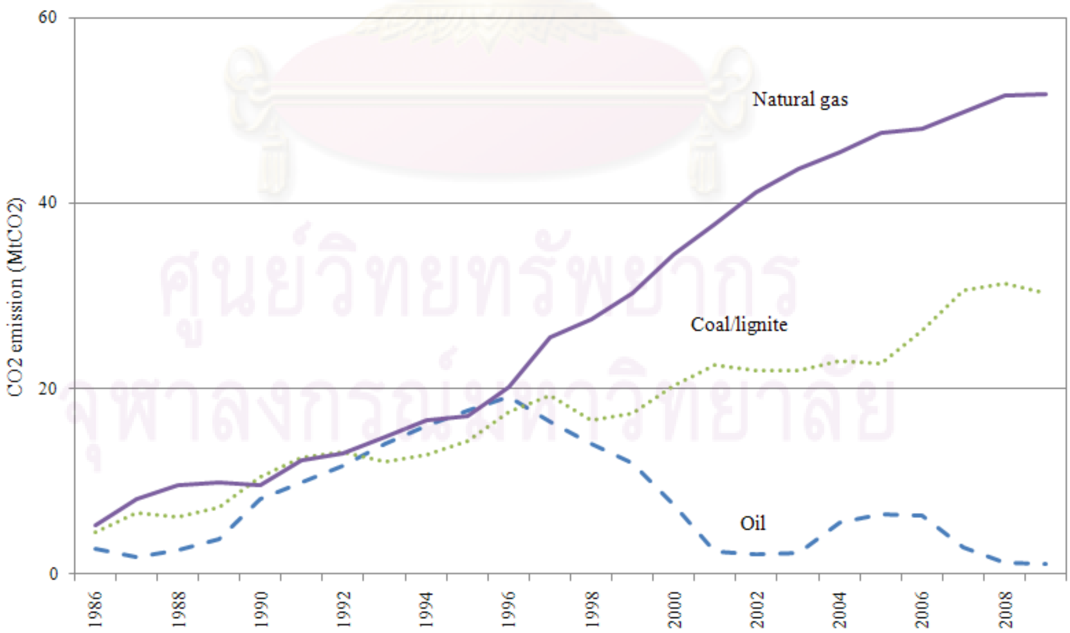

Figure 2 Carbon dioxide emissions from electricity generation in Thailand
Source of data: Ministry of Energy [6]

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.

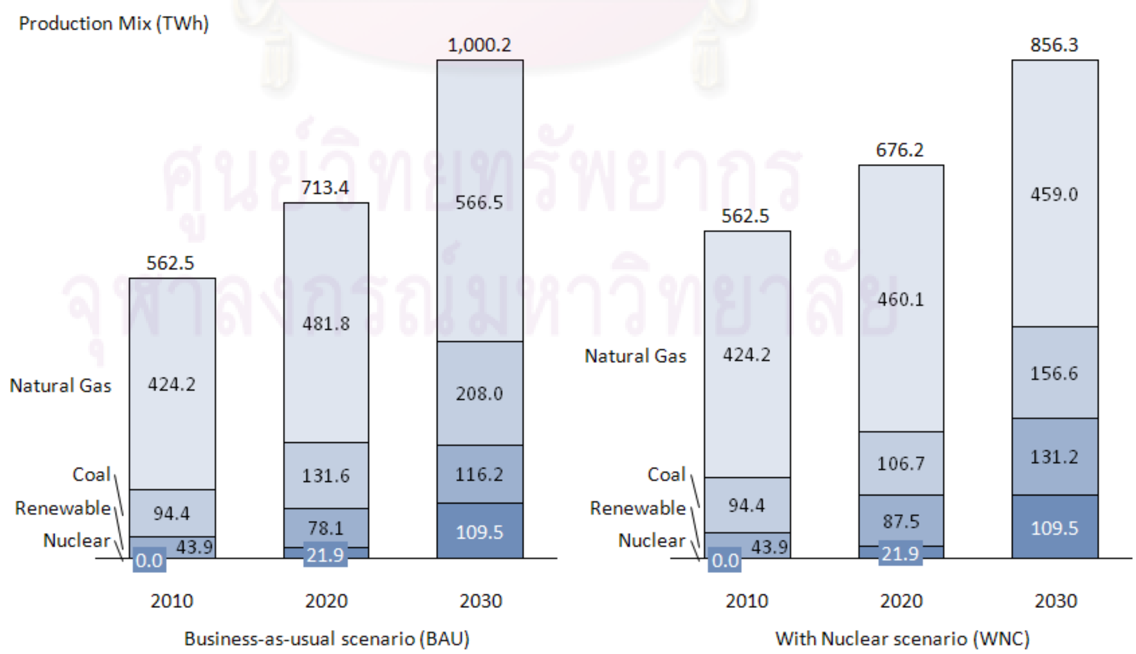

Figure 3 Comparison of production mix between BAU and WNC scenario

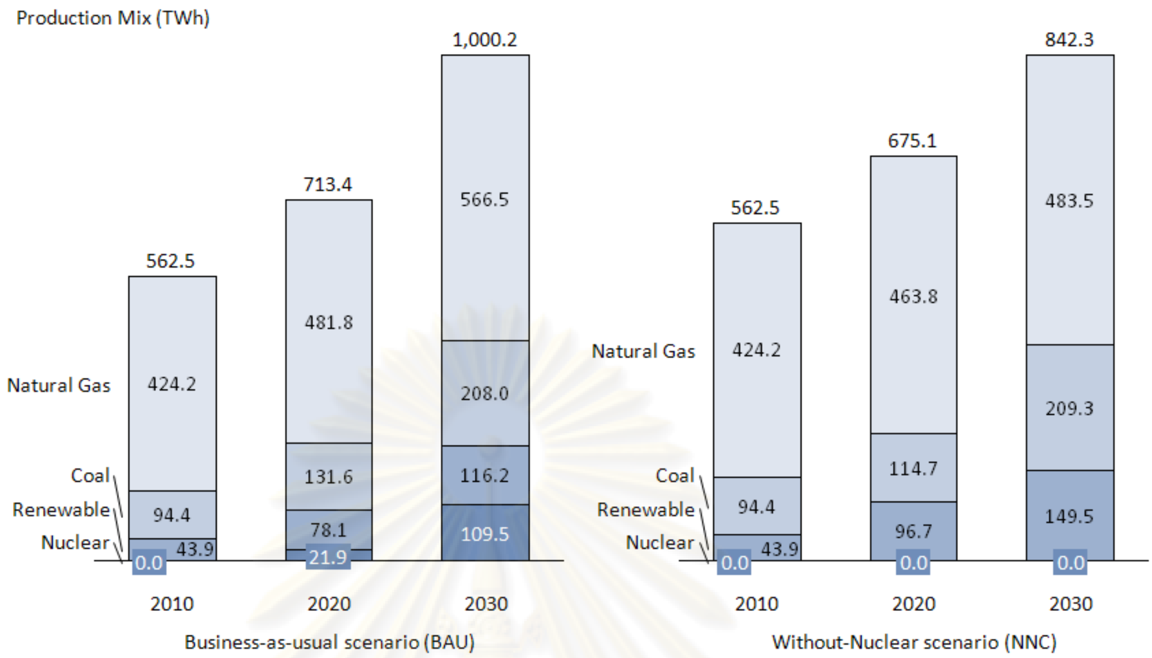

Figure 4 Comparison of production mix between BAU and NNC scenario

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.

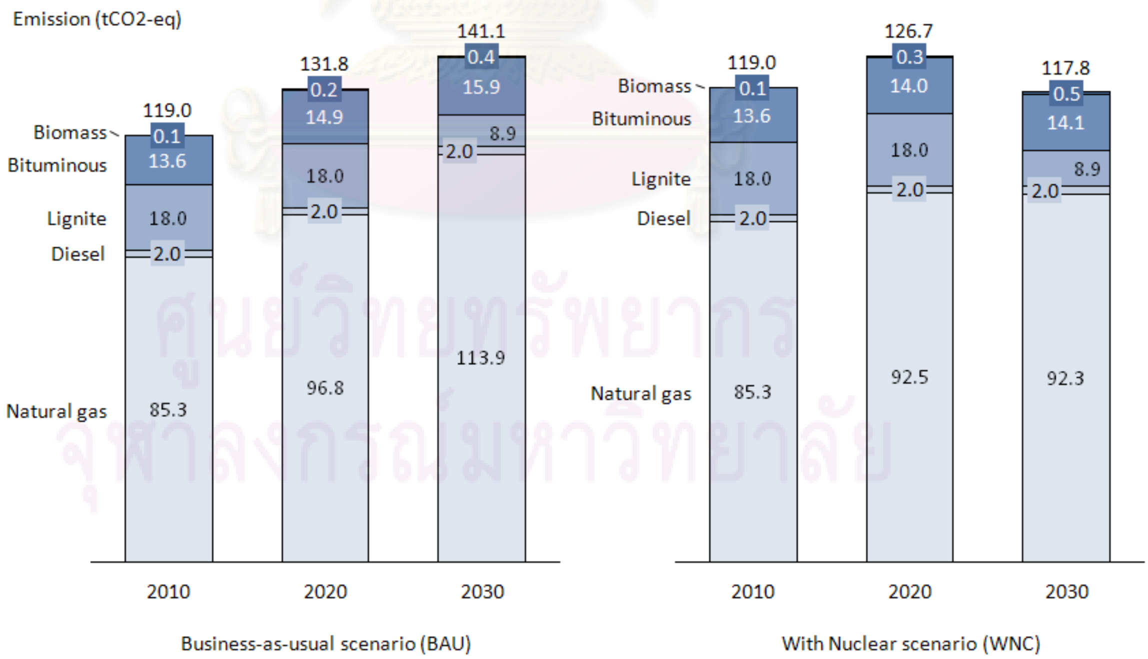

Figure 5 Comparison of GHGs emission between BAU and WNC scenario

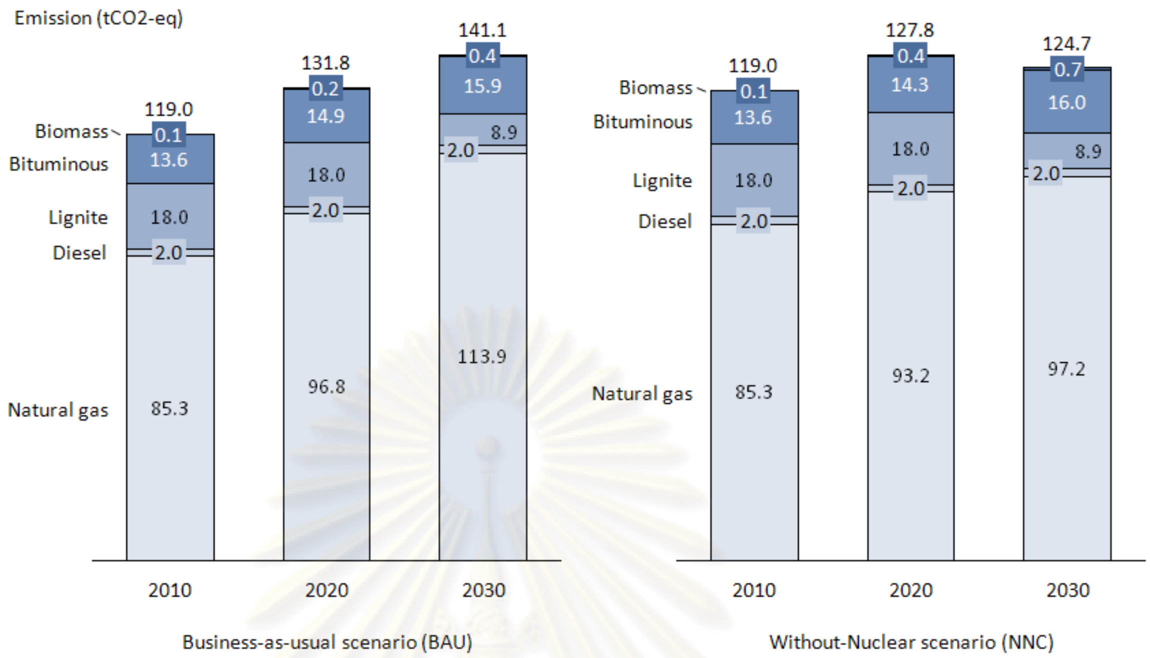

Figure 6 Comparison of GHGs emission between BAU and NNC scenario

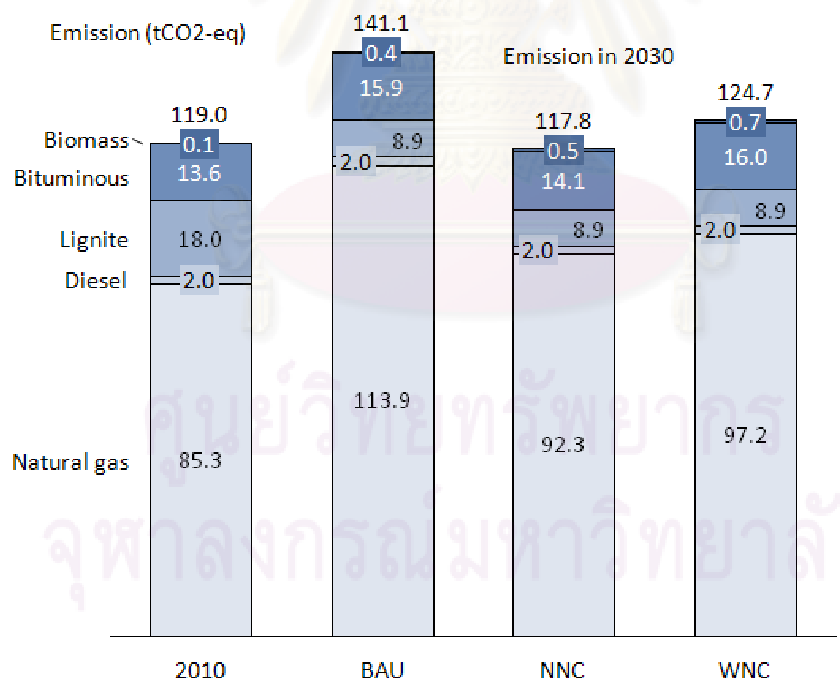

Figure 7 Comparison of GHGs emission of three scenarios in 2030

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.

6 Acknowledgement

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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 < 1 MW > 1 MW	 0.50 0.30	 1.43 0.86	3,700
Biogas < 1 MW > 1 MW	 0.50 0.30	 1.43 0.86	120
Waste Fertilization/ Landfill Thermal process	 2.50 3.50	 7.14 10	160
Wind < 50 kW > 50 kW	 4.50 3.50	 12.86 10	800
Hydropower 50 kW to <200 kW < 50 kW	 0.80 1.50	 2.29 4.29	324
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.

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:

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

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.

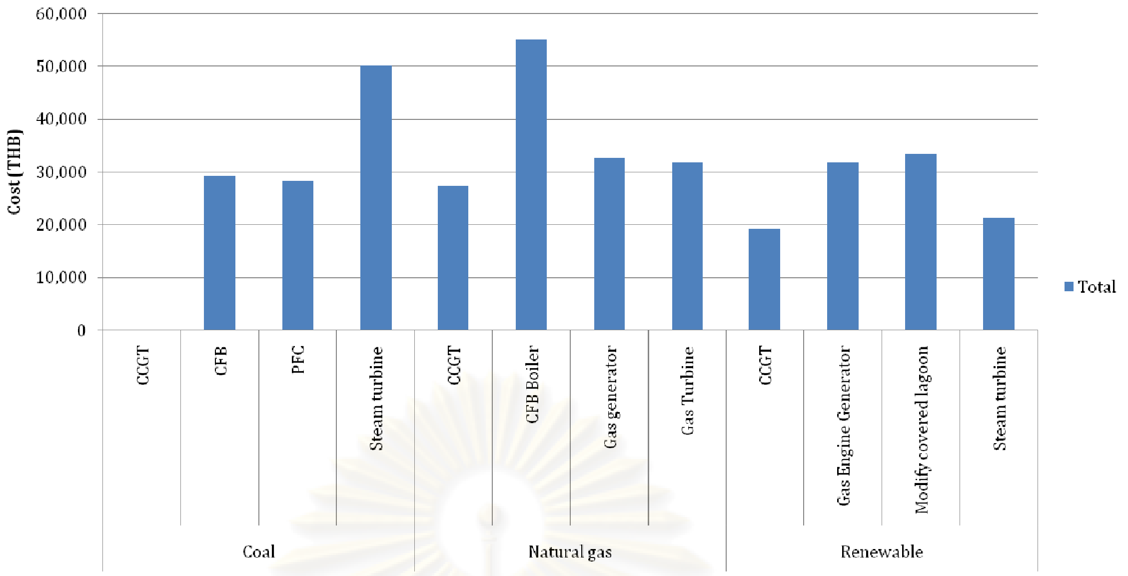

Figure 1 Overnight construction cost (THB/kW) of coal fired power plant

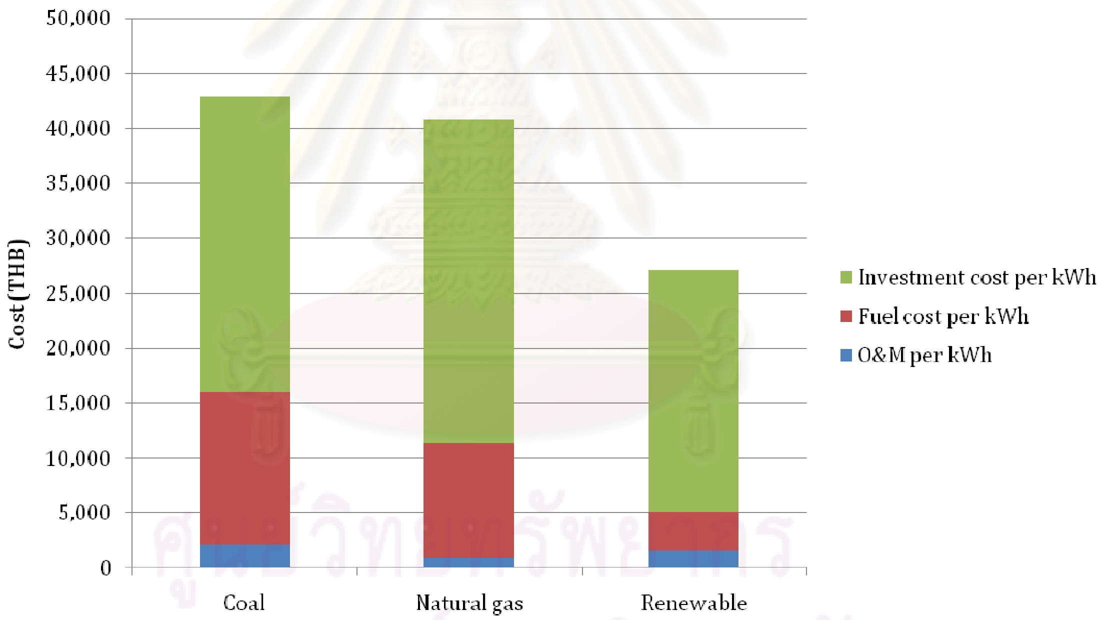

Figure 2 Cost of electricity classified by fuel type

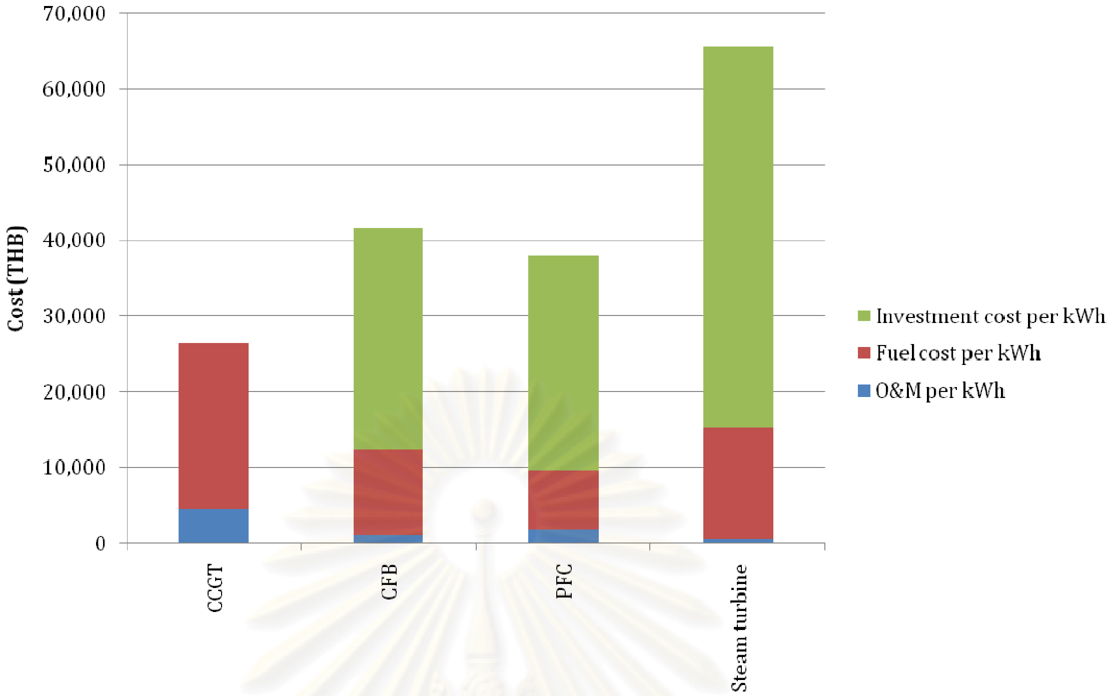

Figure 3 Cost of coal generation electricity classified by technology

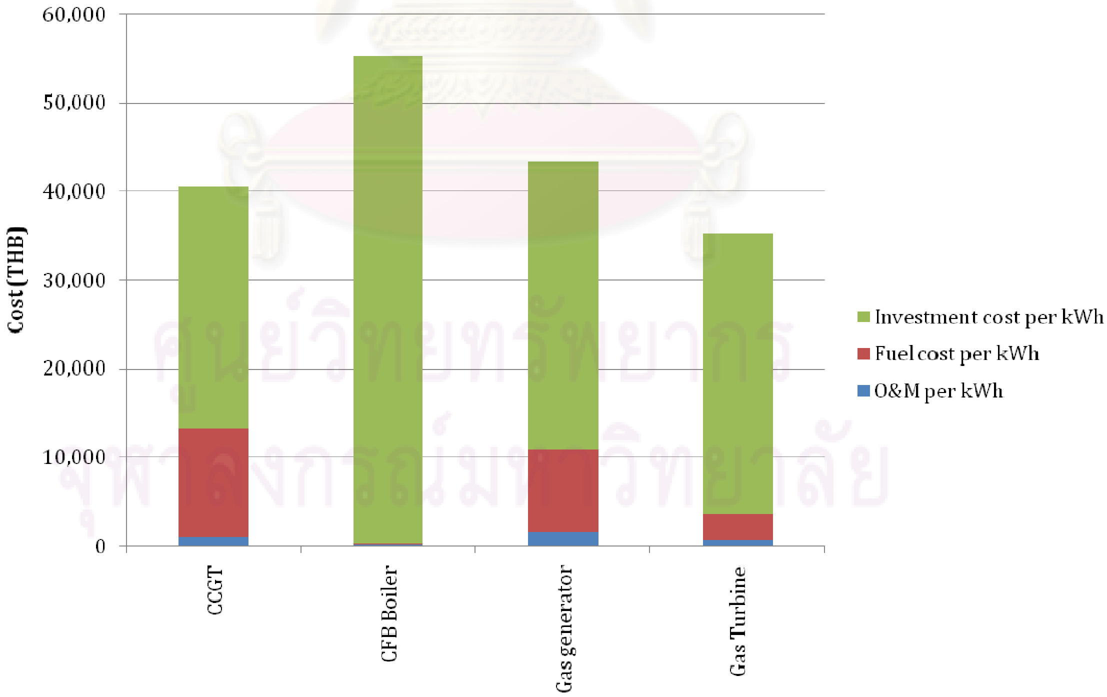

Figure 4 Cost of natural gas generation electricity classified by technology

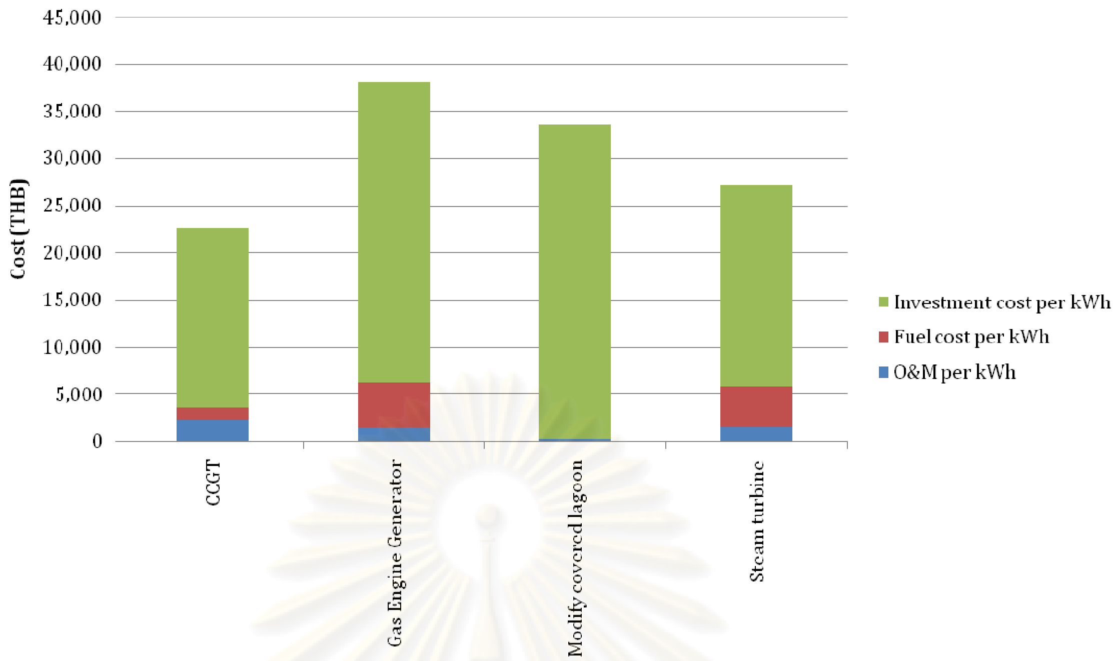

Figure 5 Cost of renewable generation electricity classified by technology

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.

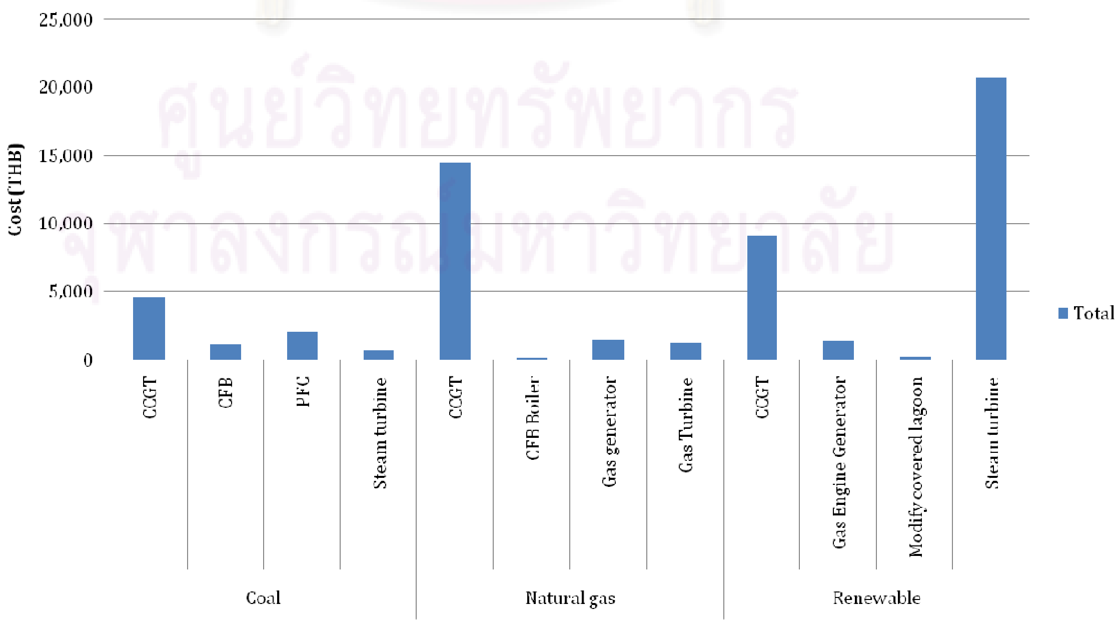

Figure 6 Specific annual O&M cost (per kW) of different types of fuel

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.

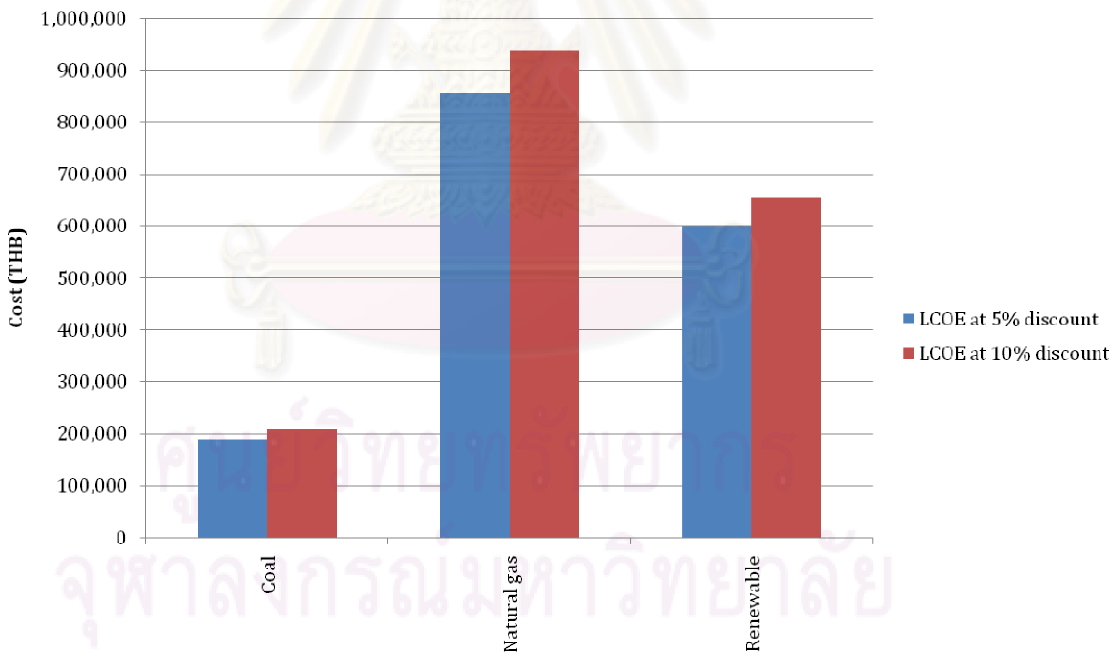

Figure 7 Levelized cost of coal generation electricity at different discount rate

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

244

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.