THAILAND

TECHNOLOGY NEEDS ASSESSMENTS REPORT FOR CLIMATE CHANGE

MITIGATION

Coordinated by

National Science Technology and Innovation Policy Office

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FOREWORD

The importance of science and technology has been highlighted as tools for mitigation and adaptation for both developed and developing countries. The latter, in particular, has become more pressing to develop and acquire key technologies to cope with climate change, including disaster in various forms and severity. The globalization of environmental protection, in some sense, has increased enormous pressure on developing countries while trying to continue their economic development, making it necessary to identify their own technological priorities.

Thailand is no exception, even though there is a certain level of technological research and development, capabilities and achievement. It is thus an opportune time to assess and prioritize technological needs for climate change. Various technologies in vulnerable sectors –energy, agriculture, water resource and modeling – were identified through extensive analyses of data on current and projected science and technology capabilities, drivers, and barriers in Thailand.

The Ministry of Science and Technology, Thailand, through the National Science Technology and Innovation Policy Office, has analyzed and prioritized the technologies required for nation-wide mitigation and adaptation regimes. The "Technology Needs Assessments and Technology Action Plans Report for Climate Change Mitigation/Adaptation in Thailand" is the first comprehensive report providing the technology requirements and their subsequent action plans in terms of climate change mitigation and adaptation. This report is significant for investors, technology developers, scientists, intelligence communities, analysts and policy makers in facilitating the growth of national prosperity under the impact of climate change leading to the green growth that are sustainable.

(Dr. Plodprasop Suraswadi)
Minister of Science and Technology

PREFACE

Thailand today faces a number of challenges affected by climate change. These include ever-increasing natural and human-made disaster – such as, extreme weather events, land-slide, flood, draught, rising sea level, biodiversity loss, and health damage – ,which if not addressed may lead to catastrophic consequences. Climate change is no longer a mere scientific concept owned by scientists but moved into our daily lives as more and more people become concerned with the complexity of this issue. The latest available data on greenhouse gas emissions from Thailand show that emissions continue to increase, underscoring the need for action while sustaining the economic reinforcement. To cope with the climate situation, it would be reasonable for Thailand to prioritize its technology strategies and identify problem areas in terms of policy objectives on mitigation and adaptation.

As a first step, it is necessary for Thailand to assess whether their current efforts in improving technological capability have been successful in supporting mitigation and adaptation. The review and analysis of Thai technologies could reflect whether the current technology-related policies and national research system support mitigation and adaptation and whether they are in harmony with other related impacts such as social acceptance and economic cost. Appropriate approaches to the technologies that would best-suit the stage of national development would be desirable. These investigations could provide a wide range of strategic options for policy-making both in the short and longer terms.

The National Science Technology and Innovation Policy Office (STI) continues to broaden and deepen its involvements in climate change mitigation and adaptation, particularly, in technology development and technology transfer policy. However, any technological change does not occur in isolation. It can have considerable impact on the people, culture, economy, and society in the overall context. Scientists, investors, economists and policy makers should work together towards developing technology with full awareness of the complex interactions and relationships within the system. STI's aim is, therefore, to bridge the cooperation among government agencies, private sectors, academia and industry in strengthening the policy implementation in a sustainable manner. In responding to the global and local climate concerns, STI conducts the research project entitled "Technology Needs Assessments and Technology Action Plans Report for Climate Change Mitigation/Adaptation in Thailand" among one of the first fifteen countries from Africa, Asia, Latin America, Caribbean, and Europe to conduct the projects funded by the UNEP Division of Technology, Industry and Economics (DTIE) in collaboration with the UNEP Risoe Centre.

I believe the results of the well thought out findings in this report could provide Thailand not only the mitigation and adaptation strategic plan and policy recommendations to the Thai government but also identifying opportunities for capacity building, research collaborations, private and industrial participations, and technologies transfer to enhance socio-economic sustainability in the long-term. It is also our belief that the outcome would benefit not only our own country but the global community as a whole.

(Dr. Pichet Durongkaveroj)
Secretary General
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Abbreviations:

List of Abbreviations could follow the format below.

AAGR	Average annual growth rate
AIT	Asian Institute of Technology
ASEAN	Association of South East Asian Nations
BIOTEC	National Center for Genetic Engineering and Biotechnology
BMA	Bangkok Metropolitan Administration
BOI	Board of Investment
CCS	Carbon Capture and Storage
CCKM	Center of Excellence for Climate Change Knowledge Management
CCOs	Climate Change Officers
CDM	Clean Development Mechanism
CEPA	Committee on Energy Policy Administration
CER	Certified Emission Reduction
CFL	Compact Fluorescent Lamps
CSR	Corporate Social Responsibility
CT	Clean Technology
DEDE	Department of Alternative Energy Development and Efficiency
DEDP	Department of Energy Development and Promotion
DIW	Department of Industrial Works
DMF	Department of Mineral Fuels
DNA-CDM	Designated National Authority for the Clean Development Mechanism
DOEB	Department of Energy Business
DSM	Demand side management
DTIE	Division of Technology, Industry and Economics
EE	Energy Efficiency
EGAT	Electricity Generating Authority of Thailand
ENCON	Energy Conservation Promotion
EOR	Enhanced Oil Recovery
EPPO	Energy Policy and Planning Office
ERC	Energy Regulatory Commission of Thailand
ESCO	Energy service company
EV	Electric Vehicle
GCM	General Circulation Model
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse gas
HAII	Hydro and Agro Informatics Institute
HRSG	Heat Recovery Steam Generator
HTT	Hydrothermal Treatment Technology
KP	Kyoto Protocol
LoA	Letter of Approval
LPG	Liquefied Petroleum Gas
MCA	Multi-Criteria Analysis
MCDA	Multi-criteria decision analysis
MEA	Metropolitan Electricity Authority
MEPS	Minimum Energy Performance Standards
MoA	Ministry of Agriculture and cooperation
MoE	Ministry of Energy
MoEd	Ministry of Education
MoIn	Ministry of Industry
MoNRE	Ministry of Natural Resources and Environment
MOST	Ministry of Science and Technology
MOU	Memorandum of understanding
NAMA	Nationally Appropriate Mitigation Actions

NCCC	National Climate Change Committee
NEEP	National Energy Efficiency Plan
NEPC	National Energy Policy Council
NEPO	National Energy Policy Office
NESDB	National Economic and Social Development Board
NGOs	Non-governmental organizations
NGV	Natural Gas Vehicle
NSTDA	National Science Technology Development Agency
OAE	Office of Agriculture Economics
ONEP	Office of Natural Resources and Environmental Policy and Planning
PoA	Programme of Activities
PEA	Provincial Electricity Authority
PCD	Pollution Control Department
PDP	Power Development Plan
PTT	PTT Public Company Limited
PV	Photovoltaic
RE	Renewable Energy
REDP	Renewable Energy Development Plan
SMEs	Small and medium enterprises
SPP	Small Power Producer
STI	National Science Technology and Innovation Policy Office
TAP	Technology Action Plan
TBCSD	Thailand Business Council for Sustainable Development
TGO	Thailand Greenhouse Gas Management Organization
TISI	Thai Industrial Standards Institute
TNA	Technology Needs Assessment
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
URC	UNEP Risoe Centre
VOC	Volatile organic compound
VSPP	Very Small Power Producer

TNA and TAP Report for Climate Change Mitigation in Thailand

1. Background

Many countries are concerned about global warming and have committed to taking action against the threat. Since 2010, one hundred and ninety three parties have ratified the Kyoto Protocol; however, only 37 countries (Annex I countries) have committed themselves to reducing their greenhouse gas (GHG) emissions to the levels required in the treaty (UNFCCC). Thailand ratified the Kyoto Protocol in August 2002 but has no legal binding target to reduce or to limit its GHG during the first commitment period. Thailand, however, can become involved in the carbon trading market through the Clean Development Mechanism (CDM).

In order to cope with climate change, both mitigation and adaptation measures and technologies are needed. The UN defines mitigation, in the context of climate change, as human intervention to reduce the sources or to enhance the sinks of greenhouse gases. Adaptation technology, on the other hand, is defined as finding and implementing promising approaches for adjusting to adverse effects from climate change. A technology needs assessment (TNA) is an effective tool that provides a country the opportunity to track its need for new equipment, techniques, services, capacities and skills for both climate change mitigation and adaptation.

The United Nations Environment Programme (UNEP), on behalf of the Global Environment Facility (GEF), is implementing a new round of TNAs with objectives that go beyond identifying technology needs narrowly. These TNAs will lead to the development of a national technology action plan (TAP) that prioritizes technologies, recommends an enabling framework for the diffusion of these technologies, and facilitates the identification of good technology transfer projects and their links to relevant financing sources. The TAP will systematically identify the practical actions necessary to reduce or remove political, financial and technological barriers.

The UNEP Division of Technology, Industry and Economics (DTIE) in collaboration with the UNEP Risoe Centre will provide targeted financial, technical, and methodological support to assist 36 countries to conduct TNA projects. Thailand is one of the first fifteen countries from Africa, Asia, Latin America and the Caribbean, and Europe being supported in the first round, which began in 2010.

The overall objectives of the Thai TNA and TAP project discussed in this report are as follows:

- To identify, assess, and prioritize technological needs for GHG mitigation.
- To access information on technology transfers and increase public awareness on climate change issues.
- To evaluate the various social issues relevant to the proposed policy, conduct an analysis on the pros and cons of different control strategy alternatives, and provide estimates of the costs and impacts of legislative mandates.

2. The uses of TNAs and TAPs

This report provides an assessment of the technology needed for nationwide mitigation remedies. The results of the analysis are useful for policy makers to build a roadmap for internal mitigation technologies and to align with the global community. This report helps Thailand to identify technological needs and reinforce its capacity in the area of climate change.

3. Structure of the report

This report is a policy analysis summary and is organized as follows:

- Section I is the TNA report, which focuses on technology prioritization for the energy management sector.
- Section II lays out the TAPs for the specific sectors selected in Section I through a prioritization process.
- Section III elaborates cross-cutting issues for the TNAs and TAPs of the nation’s different sectors.

Section I

Technology Needs Assessment

Executive Summary

In recent years, the changing energy development situation in Thailand and the national policy on energy including its existing infrastructure and management situation were the primary facts used to analyze and summarize the country's top challenges in energy management. Pressure from international panels/agreements also accelerated the importance of energy as the major sector in greenhouse gas (GHG) emissions in the world and also in Thailand after the UNFCCC and the Kyoto Protocol in 90's. Even Thailand is not an Annex I country of the protocol but the mitigation of GHG is a necessary task for every country as is the concept of common but different responsibilities. Hence, the prioritization of energy technology to mitigate the impact of climate change is very important for the country's long-term development.

This Technology Needs Assessment (TNA) focused on identifying and assessing the mitigation effects of climate change technology on the energy management sector by using the Multi-Criteria Approach (MCA). The results of technology prioritization were then selected and reviewed with stakeholder consultation to ensure that all considered technology options contribute to the country's objectives. TNA prioritized procedures to find out the energy technology needs assessment of Thailand are also illustrated in this Fig 1.In this study, there are four main groups of technology in the energy management sector which are related to climate change impact mitigation. The four groups include (i) energy supply and transformation, (ii) renewable energy technology, (iii) energy efficiency improvement on the demand side, and (iv) other energy technologies.

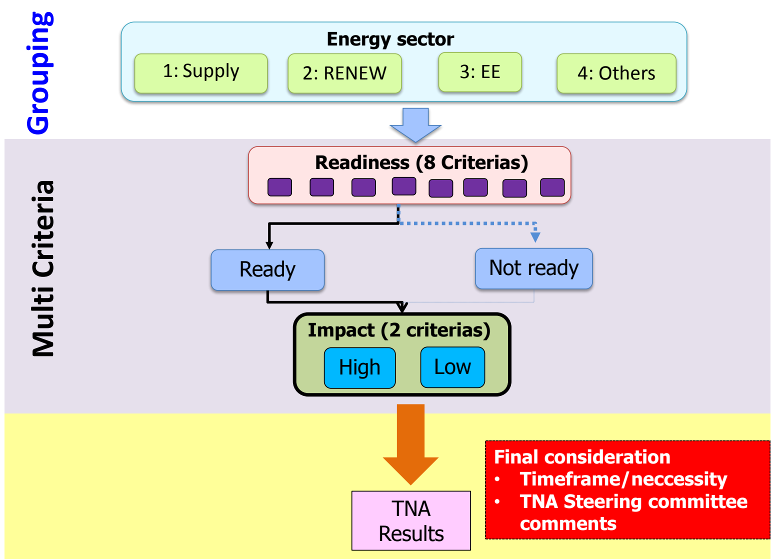


Fig 1 Technology prioritization procedures

The ten main factors consist of eight "readiness" and two "impact" factors with different weights as shown in Table 1 as follows.

Table 1 Criteria factors for prioritize TNA in energy sector

Criteria	(a) Assessment (from 1 to 5)	(b) Weight	(c) = (A)x(B) Point
Readiness			
(1) Policy infrastructure including regulation	5	0.1	0.5
(2) Benefit and cost	5	0.1	0.5
(3) Short-term trend	5	0.1	0.5
(4) Management infrastructure	5	0.1	0.5
(5) Possibility of domestically based production	5	0.2	1
(6) Stakeholder and social acceptance	5	0.2	1
(7) Current technology situation in Thailand	5	0.1	0.5
(8) Current technology situation in developed countries	5	0.1	0.5
Impact			
(9) Other impacts (social, economic and environment)	5	0.5	2.5
(10) Estimated GHG mitigation of technology	5	0.5	2.5
Grand total			10

The results of the technology prioritization are summarized as follows:

- Smart grid
- Waste (to power generation)
- Second and third generation of biofuels
- Energy efficiency in combustion in the industrial sector
- Carbon capture and storage (CCS)

All of the five selected technologies are vital mitigation technologies for increasing the capacity and efficiency of energy development and management in Thailand. For maximum utility, all technologies should also be considered, by both the public and private sector, as appropriate tools for driving the country toward its national policy and strategy in energy which is one of the most important infra-structure to all sectors. However, the development in energy should focus as a whole system that integrates all of the technologies, not only in these selected five areas, to support the climate change and greenhouse gas mitigation which is now is among the most crucial issues at national and international level.

1 Introduction

1.1 Overall Objectives of the TNA

As a developing country in Asia, Thailand experienced a wide range of economic situations ranging from being one of the world's highest economic growth rates (with the average annual growth rate (AAGR) of 8.3% during 1985) to the economic crisis (in 1997). By the end of 2003, Thailand economic situation was the world's second highest in gross domestic product (GDP) growth rate (6.7%), and the GDP has been growing continuously ever since(Office of National Economic and Social Development Board, 2010). Currently, as the region's second largest economy and energy consumer, Thailand alone contributes to nearly 30.2% of ASEAN energy consumption which explains why greenhouse gas (GHG) emissions from the energy sector are the highest proportion in the national GHG inventory (Office of Natural Resources and Environmental Policy and Planning, 2008). Hence, mitigation action of GHG emissions by introducing new energy technology is imperative for the country. However, due to the availability of various technological choices in the energy sector, the technology needs assessment is essential for Thailand to identify and prioritize the most appropriate technology, at this current situation, for maximizing the benefit of the country.

This report focuses only on the mitigation technology by identifying the technology needs for the energy sector in Thailand under the stress from climate change. Here, we review the available technologies and prioritize them using MCDA approach.

1.2 National circumstances on climate change

GHG emissions in Thailand have increased by approximately 4.7% per year from 2000 to 2008. The largest source of emissions is the electricity generation sector (78 million tons, MT), followed by the industrial sector (67 MT) and the transportation sector (51 MT) (**Fig 2**) (International Energy Agency, 2010).

An analysis from the Intergovernmental Panel on Climate Change (IPCC) projected that Thailand will experience an increase in temperature of 1.4 to 5.8 ºC over the period from 1990-2100(IPCC, 2001). The projected climate condition of Thailand under this global warming threat is being studied by various researchers. A few general circulation models (GCMs) have predicted that the current average temperatures in Thailand of 21.5-27.5 °C may increase to 25-32 °C. **Fig 3** illustrates an example of such a simulation, suggesting temperature increases in all regions, especially in the eastern and southern parts of Thailand (Thongtanakul, 2009). Similarly, two studies by Chinvanno (Chinvanno, 2009a, Chinvanno, 2009b) concluded that the hot season, defined as days with a maximum over 33 °C, would be longer by 2-3 weeks.

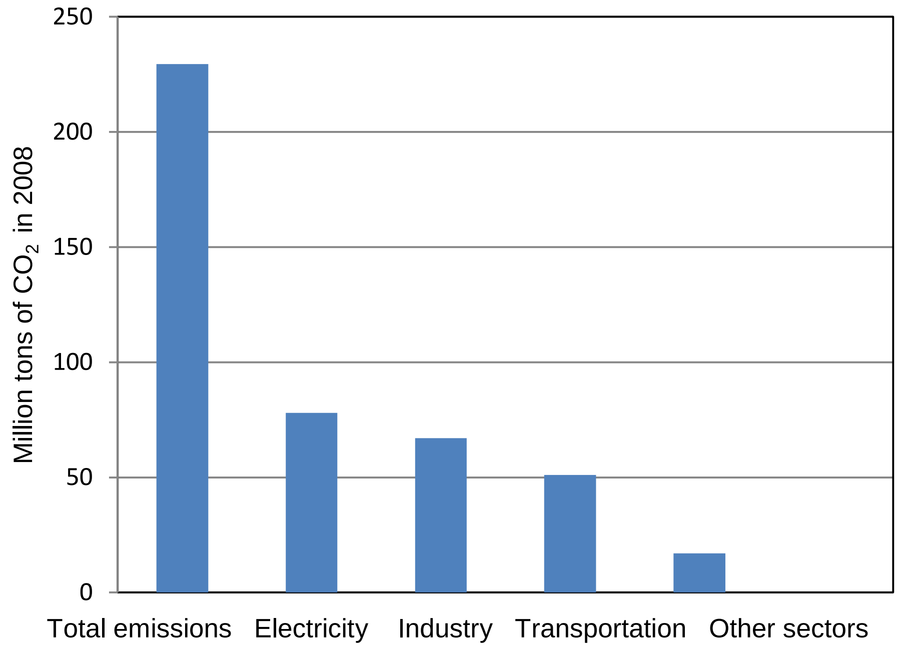


Fig 2 GHG emissions by sector in 2008 (million tons)
Source: (International Energy Agency, 2010)

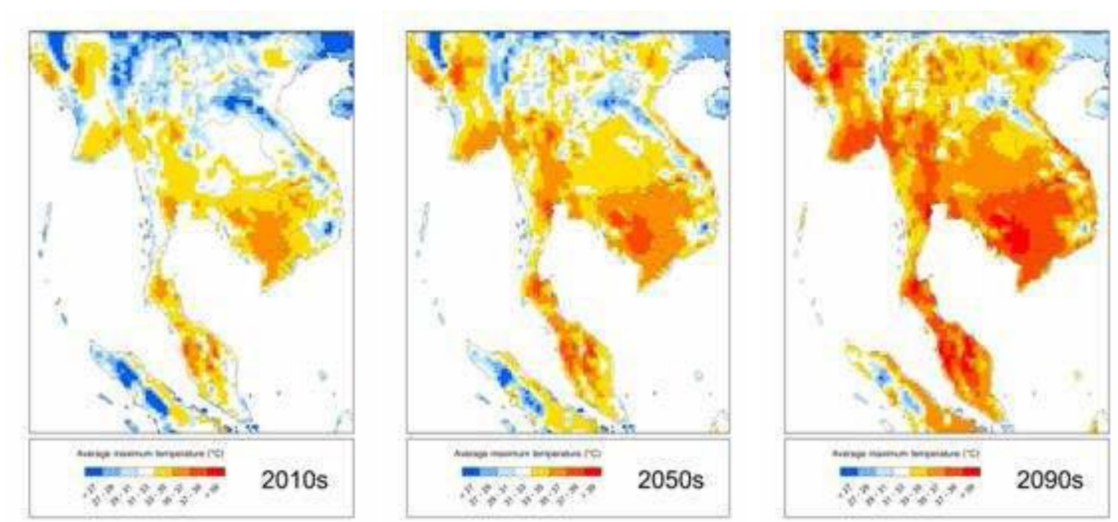


Fig 3 Trend of future changes in average maximum temperature in Southeast Asia

The impacts from climate change are not proportionally distributed among the GHG producers. In other words, the impacts are unavoidable and unpredictable for Thailand even though Thailand is not a major GHG producer. Global warming causes changes to the seasons, such as in the pattern and intensity of rainfall. Moreover, it can increase the intensity of El Nino and La Nina, which typically occur in Thailand every 4-10 years. Temperature changes and rising sea levels threaten to decrease fishery, agriculture, and aquaculture yields. Corals might suffer more severe bleaching due to the continual rising of the ocean temperature. Several sectors—including agriculture, water and coastal resources, and land use—are vulnerable to climate change. The two national priority sectors facing direct impacts are the agricultural and water resource sectors.

Agriculture is still a fundamental part of the Thai economy and social structure. Global climate change could affect agriculture in various ways. The effects of climate change introduce 1) more frequent extreme events likes floods, droughts, and storms, 2) abnormally severe weather, and 3) a rise in temperature (Rerkasem, 2011). The adaptive capacity of farms and farmers in the country is an important element of the country's food and economic security and should be regarded as a national priority. The Office of Agricultural Economics (OAE) regards rice, sugar cane, cassava, and palm oil as major national economic crops and has called for governmental support to acquire sufficient climate change adaptation technology (ONEP and UNDP, 2010).

Thailand has 25 river basins in total and many sub water systems throughout the country. Over the past several decades, Thailand has encountered a variety of water resource management problems, ranging from flooding to droughts; some parts of Thailand experience both flooding and drought in the same year. These water resource management issues severely interrupt the social and economic growth of the country. Due to the nature of Thailand's agricultural-based economy, proper management of its water resources is imperative.

1.3 National sustainable development strategies for climate change

1.3.1 Structure and management of Thailand's climate change sector

National Climate Change Committee: NCCC

In Thailand, the Office of Natural Resources and Environmental Policy and Planning (ONEP), under the Ministry of Natural Resources and Environment (MONRE), is the national main focal point to the UNFCCC. Historically, the National Climate Change Sub-committee was established under the National Environmental Board after the country ratified the UNFCCC. In July 2007, the government upgraded the National Climate Change Sub-committee to the National Climate Change Committee (NCCC), chaired by the Prime Minister. As shown in **Fig 4**, the committees consist of the permanent secretaries from nine economic ministries and national economic authority (the National Economic and Social Development Board: NESDB) with up to nine committees from experts in related fields while the permanent secretary of MoNRE also acts as a committee and committee's secretary. Technical subcommittees are also established under the national committee to support different aspects of climate change issues, including mitigation and vulnerability and adaptation. Thailand has the strategic plan on climate change and is currently developing its ten-year action plan.

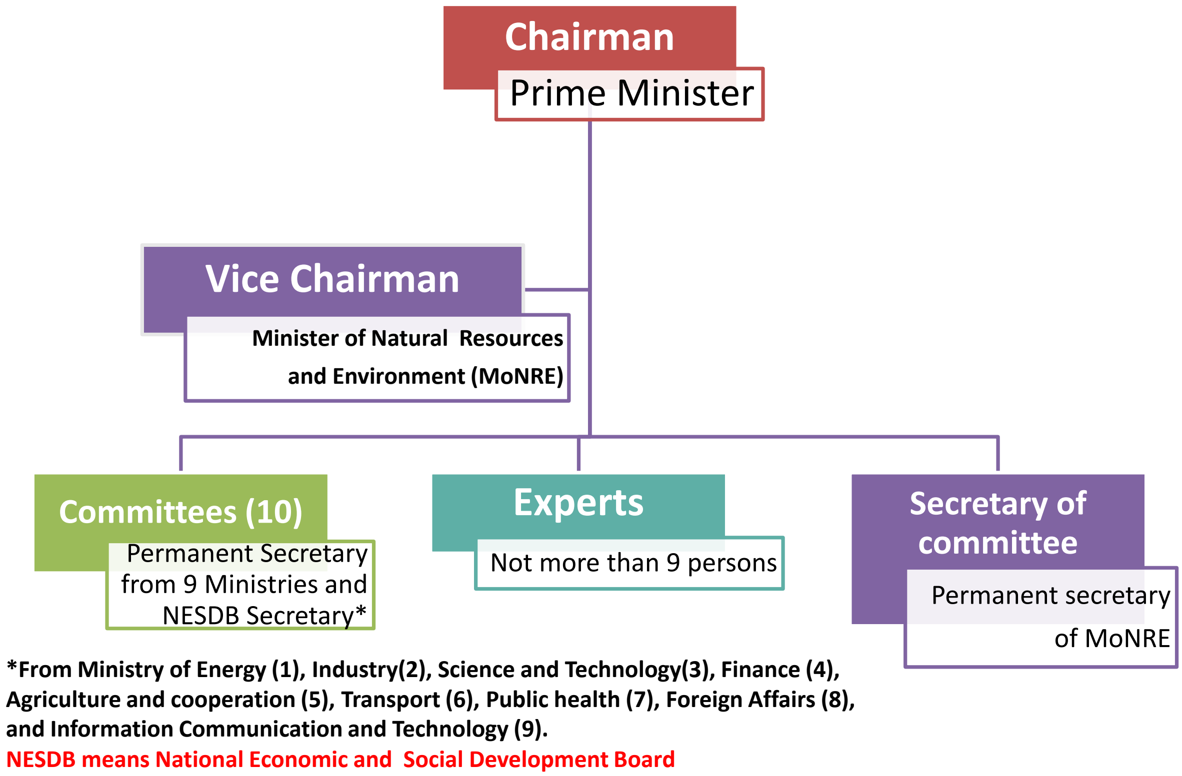


Fig 4: Structure of Thai National Climate Change Committee (NCCC)

Due to the increasing importance of climate change mitigation and adaptation, the establishment of the climate change officers (CCOs) in all nineteen ministries and other eleven related authorities have been set from the cabinet resolution in 8 September 2009. The CCOs will be the coordinator of each ministry or authority for the climate activities in all government organizations.

Thailand Greenhouse Gas Management Organization: TGO

Thailand also founded the Thailand Greenhouse Gas Management Public Organization (TGO) as an autonomous governmental organization in July 2007. While NCCC sets policy, the TGO, as Thai Designated National Authority for CDM (DNA-CDM), aims to exercise all aspects of climate change mitigation projects, including CDM projects. As an implementing agency on GHG emission reduction in Thailand, a key political aim of TGO is to strengthen the links between measures to address sustainable development and those to address the climate change. The important overlapping areas between the sustainable development policy and the climate change policy include improvements of energy efficiency and promotion of carbon sequestration.

Hence the main missions of TGO are as follows: (i) to analyze and screen the CDM projects for the issuance of the Letter of Approval (LoA) and to monitor the projects; (ii) to promote CDM projects and the CER Market; (iii) to be the National Information Clearing House of GHG; (iv) to manage all information regarding the approved CDM projects and CERs' value; (v) to enhance the capacity building of the government and private sectors on GHG management; (vi) to promote public outreach programs on GHG; and (vii) to promote and to support all activities related to climate change mitigation. The organization chart of the TGO is illustrated in **Fig 5**.

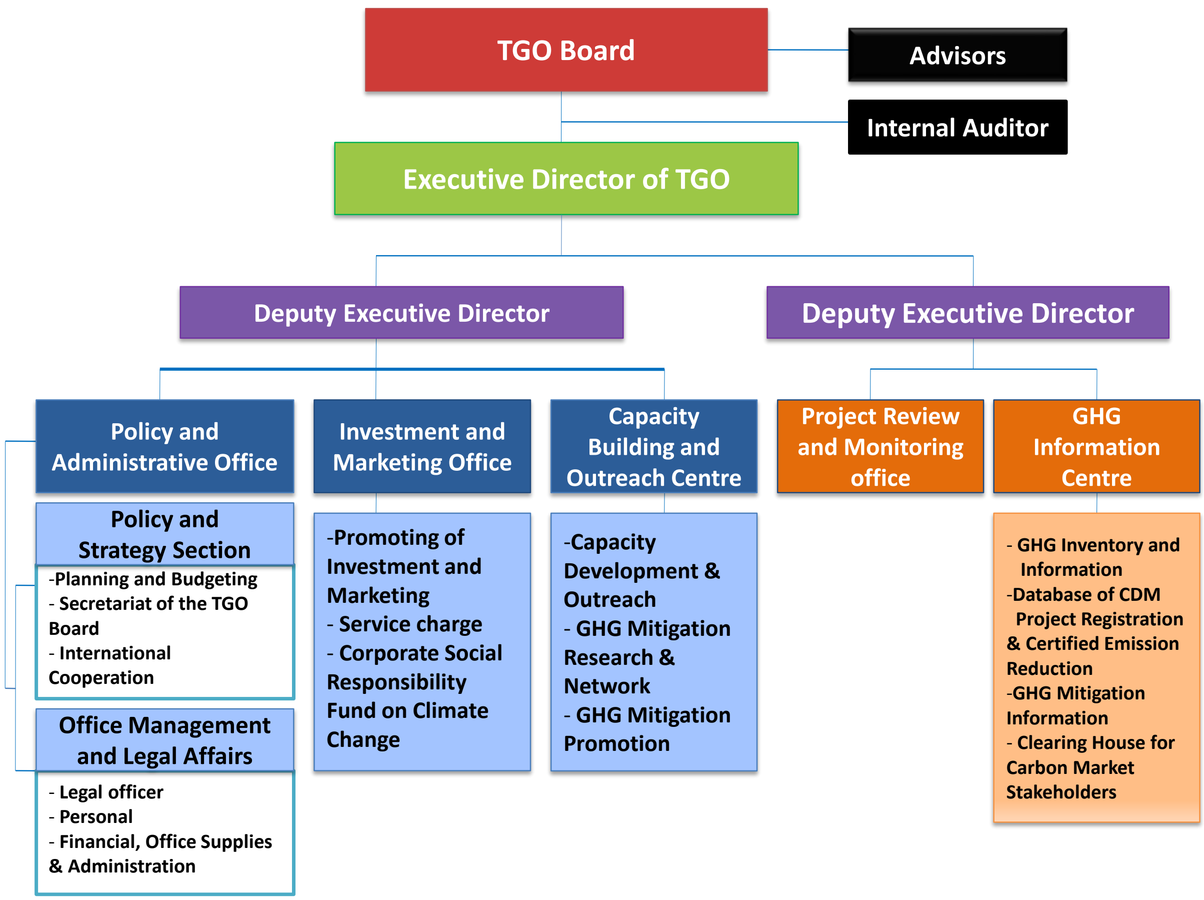


Fig 5 Structure of Thailand Greenhouse Gas Management Public Organization (TGO)

1.3.2 Strategic and action plan on climate change National Strategic Plan on Climate Change Management (2008-2012)

Approved by the cabinet on 22 January 2008 (Office of Natural Resources and Environmental Policy and Planning, 2008), the Ministry of Natural Resources and Environment has launched the strategic responses to climate change covering the year 2008 to 2012 The strategies and corresponding action plans are summarized as follows:.

1) Building capacity to adapt and reduce Thailand's vulnerability to climate change impacts. This strategy aims to protect and conserve natural resources as well as to improve adaptability in the natural resource, agricultural, and industrial sectors. The corresponding action plans include, 1) creating capability to assess climate change impacts, 2) preventing and mitigating damage caused by climate change impacts, and 3) creating adaptation capacity in all sectors such as natural resources, agricultural and industry.

2) Promoting greenhouse gas mitigation activities based on sustainable development: The goal of this strategy is to promote clean technology in the various sectors. Mitigation activities could include, for instance, increasing energy efficiency, promoting the use of renewable energy, minimizing solid waste and chemical use in farms, recycling material, as well as increasing carbon sinks by forest conservation.

3) Supporting R&D to better understand climate change and its impacts as well as adaption and mitigation options: This strategy aims to provide useful information to policy makers via technical and academic support from climate change researchers. It involves supporting R&D and climate change knowledge management Through this strategy, the action plans could involve 1) generating and providing knowledge on climate change, 2) developing database on climate change impacts and adaptation options in all relevant sectors, 3) creating knowledge management on GHG mitigation options, and 4) developing appropriate mechanisms to inform policy makers.

4) Raising awareness and promoting public participation: The objective of this approach is to motivate public awareness and to promote common understanding on the roles of the local community on climate change issues. The corresponding action plans are 1) organizing public awareness campaigns and outreach activities on a regular basis 2) promoting awareness in the educational sector, and 3) developing mechanisms to evaluate the effectiveness of campaigns and outreach activities on a regular basis.

5) Building the capacity of relevant personnel and organizations to establish a framework for knowledge and technology coordination and integration: This strategy aims to promote collaboration between personnel and organizations involved in climate change to transfer and share knowledge, technology, and experience. The corresponding action plans include 1) supporting continuous training and skill development related to climate change and 2) creating mechanisms for knowledge and technology transfer in the organization and across the organizations.

6) Supporting international cooperation to accomplish the common goal of climate change mitigation and sustainable development: This approach promotes international cooperation to transfer and share knowledge, technology, and experience. The action plans include 1) integrating climate change implementation under relevant international frameworks and 2) promoting skill development and knowledge and technology transfer among relevant organizations dealing with climate change in the international level.

National Master Plan on Climate Change 2010-2019

To enable the implementation of the National Strategy for Climate Change, ONEP transformed these strategies into the “National Master Plan on Climate Change 2010-2019.” The ten-year master plan consists of three approaches:

Strategy 1: Creating adaptability to respond and reduce the impacts of climate change.

Strategy 2: Supporting GHG reduction and increasing carbon sinks under sustainable development schemes.

Strategy 3: Integrating knowledge, databases, and tools on climate change management.

1.3.3 Energy Structure and policy

1.3.3.1 Structure and management of the energy sector

The energy sector in Thailand is managed by the National Energy Policy Council (NEPC), established under the National Energy Policy Council Act, B.E. 2535 (or NEPC Act, A.D.1992), with the Energy Policy and Planning Office (EPPO) of the Ministry of Energy (formerly National Energy Policy Office or NEPO) acting as the secretariat for policy development. To enhance the management, the

Committee on Energy Policy Administration (CEPA) was established to assist with the mission of the NEPC. Additionally, the NEPC is responsible for the promotion of energy conservation and the management of the Energy Conservation Promotion Fund (ENCON Fund) pursuant to the Energy Conservation Promotion Act, B.E. 2535 (or ECP Act, A.D. 1992). In October 2002, after the reformation of the Thai bureaucracy, the Ministry of Energy was established. Energy-related agencies or state enterprises that were previously under the auspices of different ministries, such as the Electricity Generating Authority of Thailand (EGAT) or the Petroleum Authority of Thailand (PTT) were grouped under the Ministry of Energy so that energy sector management and the planning and development of national energy programs, including regulation, would be more unified (Lertsuridej, 2004).

As shown in Fig 6, the Ministry of Energy comprises four departments responsible for energy regulation, monitoring and promotional activities in all energy areas including energy security and pricing, energy efficiency improvement, and renewable energy technologies development (MoE, 2003). The Department of Alternative Energy Development and Efficiency (DEDE), formerly the Department of Energy Development and Promotion (DEDP), drives the renewable energy development and compulsory energy conservation programs under the ECP Act, A.D. 1992. The Department of Mineral Fuel (DMF) was established from the Mineral Fuels Division of the Department of Mineral Resources, Ministry of Industry and parts of the Defense Energy Department, Ministry of Defense. The DMF was established to be responsible for the exploration and production of mineral fuels throughout the Kingdom including the development and management of fuel negotiations between Thailand and neighboring countries. The Department of Energy Business (DOEB), which originated from parts of the Ministry of Commerce, acts as a regulator of oil and gas products and services. PTT Public Company Limited conducts exploration and production of oil, petroleum products, and natural gas while Bangchak Petroleum is involved only in activities relating to oil and petroleum products. EGAT, one of the country’s largest state enterprises, is responsible for electricity generation activities, including transmission, distribution and promotion of energy conservation through demand-side management (DSM) programs. The electricity and natural gas business sector in Thailand is regulated by the Energy Regulatory Commission, an independent organization which excluded from Fig 6.

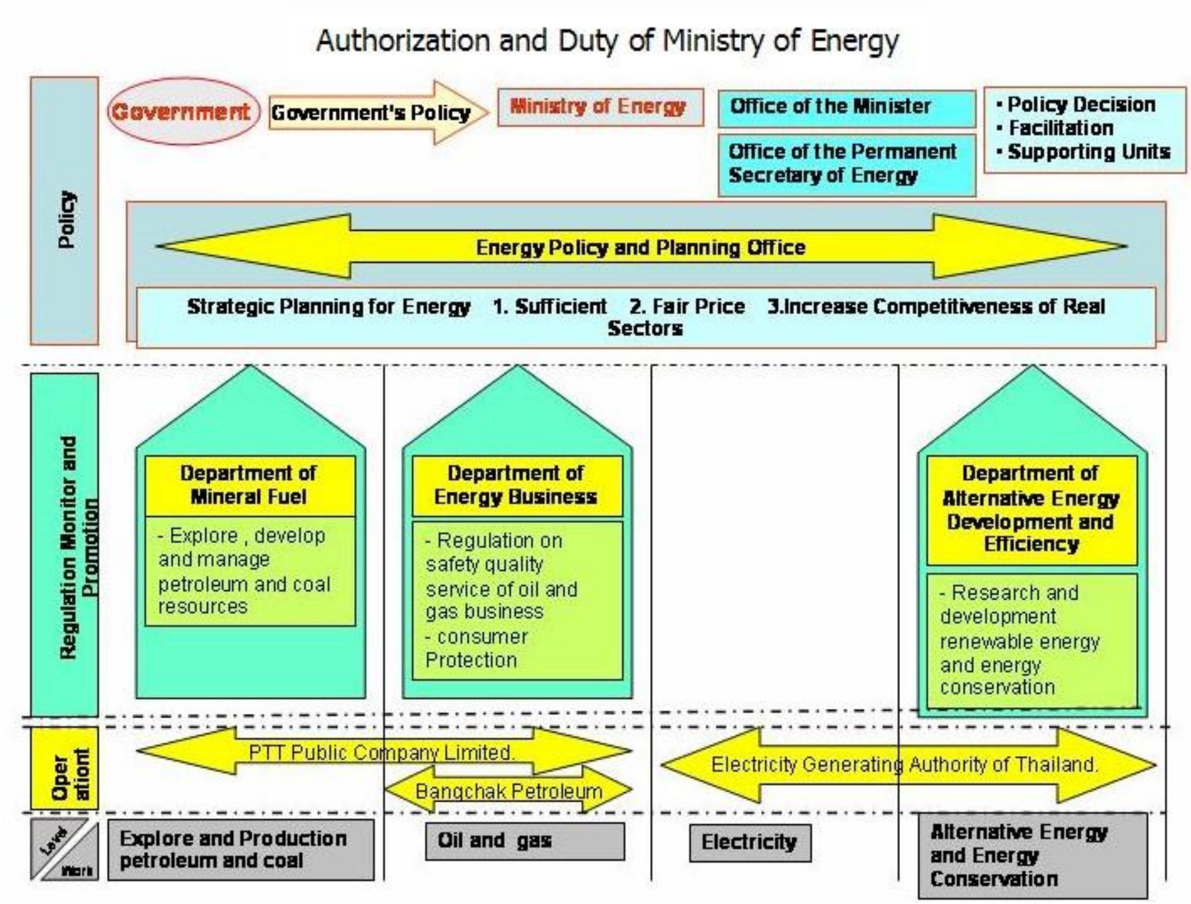


Fig 6 Structure and lines of reporting of the Ministry of Energy

1.3.3.2 Strategic and action plan on energy

(i) Thailand's Energy Policy

Thailand's Prime Minister, Mr. Abhisit Vejjajiva, delegated the Minister of Energy, Dr. Wannarat Channukul, to deliver Thailand's energy policy as follows(MoE, 2011):

- Intensifying energy development: With an aim to achieve sufficient and stable energy supply, this strategy involves 1) expediting exploration and development of energy resources both in and out of Thailand, 2) negotiating with neighboring countries at the government level for joint development of energy resources, 3) creating an energy mix which will reduce risks pertaining to supply, price volatility and production costs, 4) encouraging electricity production from renewable energy, particularly from small or very small scale electricity generating projects, and 5) studying the appropriateness of other alternative energies for electricity generation.

The action strategies in response are:

1. Promoting domestic crude oil production and condensation together with developing related infrastructures.
2. Procuring sufficient natural gas from both domestic and foreign sources together with developing related infrastructures to meet the demand of the country.

3. Developing the electricity supply industry to adequately meet the demand of the country and promoting fuel diversification. Conducting a feasibility study on the development of other fuel options for power generation, such as nuclear, clean coal, and oil shale.
4. Exploring overseas energy resources, with the emphasis on cooperation between the public sectors and Thai's private operators.
5. Promoting and strengthening the development of the energy industry as well as downstream industries.
6. Devising a plan for energy emergency preparedness.

- **Including alternative energy on the national energy policy agenda**:

The strategies in response are:

1. Promoting the production and utilization of biofuels, such as ethanol and biodiesel, for the substitution of conventional oil consumption.
2. Promoting the use of natural gas in the transportation (NGV), industrial, commercial and household sectors.
3. Promoting all forms of renewable energy including wind, solar, hydropower, biomass, biogas and energy from waste.
4. Promoting research and development of alternative energy, renewable energy and other innovative energy technologies on the national level.
5. Placing alternative energy on the national energy agenda and determining appropriate incentive measures.
6. Establishing and strengthening renewable energy networks through a public participation process at the community, district and provincial levels in order to create long-term energy security.

- Monitoring and maintaining energy prices at appropriate, stable and affordable levels

1. The strategies in response are: Regulating energy prices to ensure stability and fairness, while reflecting actual production costs through the market mechanism.
2. Promoting service quality and safety improvement of energy-related businesses, facilities, service stations and equipment.
3. Encouraging competition and investment in the energy business.

- Encouraging energy conservation and efficiency in the household, industrial, service and transportation sectors The corresponding strategies are:

1. Encouraging national energy development and energy conservation programs.
2. Organizing campaigns to raise the awareness of the importance and approach to energy conservation.
3. Devising incentives for energy saving investment..
4. Promoting research and development on energy-saving systems and technologies.
5. Setting standards and regulations for energy-saving equipment, materials, and energy management protocol.
6. Promoting the networks of organizations, particularly SMEs, involved in energy-efficiency and conservation.

- **Encouraging environmentally-friendly energy procurement and consumption** The strategies for implementation are:

1. Monitoring the environmental impact of energy production, conversion and utilization.

2. Promoting the clean development mechanism (CDM) in the energy sector to reduce greenhouse gas emissions.
3. Monitoring and controlling volatile organic compound (VOC) emissions from petrochemical and refining industries to reduce their environmental impact.

(ii) Renewable Energy Development Plan (2008 – 2022)

Given the impact of highly volatile oil prices on economic development in Thailand, a 15-year Renewable Energy Development Plan (DEDE, 2008) was developed by the Department of Alternative Energy Development and Efficiency (DEDE) to reduce dependency on imported oil. The objectives of this plan are 1) to utilize renewable energy as a major energy supply to replace oil imports, 2) to increase energy security, 3) to promote utilization of green energy in communities and enhance development of the renewable energy technology industry, and 4) to research and develop highly efficient renewable energy technologies. This plan targets an increase in the share of renewable energy to be 20% of Thailand's energy supply by 2022.

The renewable energy development plan (REDP) is divided into 3 phases (as in **Fig 7**), including the short-term, the medium term, and the long-term. In the short-term (2008 – 2011), the focus is on the promotion of commercial renewable energy technologies and potential energy sources such as biofuels.

For the medium term (2012 – 2016), the plan will emphasize on the development of renewable energy technology industry and encouragement of new renewable energy R&D, including new technologies for biofuels production, to achieve economic viability . Also, this plan will introduce the Green City model to the communities for sufficient economy and sustainability development.

In the long term (2017 – 2022), the plan aims to continuously promote the utilization of available renewable energy technologies, to extend green city models throughout Thai communities, and to encourage the country to be the hub of biofuels and renewable technology exports in the ASEAN regions.

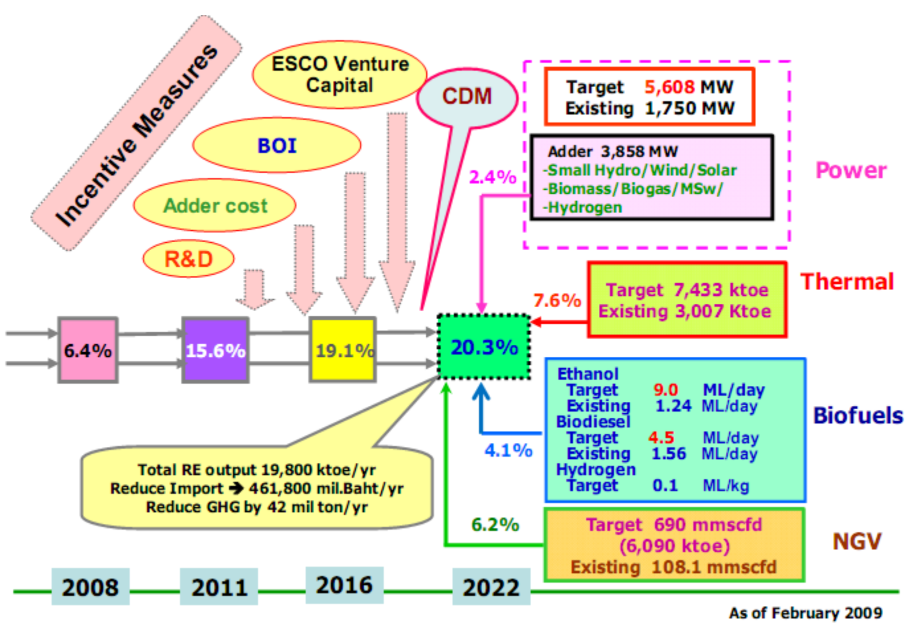


Fig 7 Renewable Energy Development Plan 2008 – 2022

Source: REDP 2008-2022 by Department of Alternative Energy Development and Efficiency (DEDE, 2008)

Table 2 presents the potential, target and existing situation of renewable energy in each phase according to the REDP. It should be noted that a lot of factors affected the renewable energy implementation, e.g. the rising of the palm oil price that affected the biodiesel target, the lack of paddy husk which caused the supply shock in biomass power plant, and the protest of biomass power plant from NGOs. One of the most important mechanisms to drive the renewable energy implementation to meet the target is the added cost subsidization program, as shown in **Table 3**.

The normal power tariff rate from renewable energy technologies will be added with the specified adder rates which range from 0.3 Baht per kWh to 8.0 Baht per kWh. For the solar energy power, the added cost was reduced from 8.00 Baht per kWh to 6.50 kWh in the mid-2010.

Table 2 Potential, target and existing situation of renewable energy in Thailand (as of January 2011)

Type of Energy	Potential	existing	2008 - 2011		2012 - 2016		2017 - 2022	
Electricity	**MW**	**MW**	**MW**	ktoe	**MW**	ktoe	**MW**	ktoe
Solar	50,000	**32**	**55**	6	**95**	11	**500**	56
Wind Energy	1,600	**1**	**115**	13	**375**	42	**800**	89
Hydro Power	700	**56**	**165**	43	**281**	73	**324**	85
Biomass	4,400	**1,610**	**2,800**	1,463	**3,220**	1,682	**3,700**	1,933
Biogas	190	**46**	**60**	27	**90**	40	**120**	54
Municipal Solid Waste	400	**5**	**78**	35	**130**	58	**160**	72
Hydrogen			**0**	0	**0**	0	**3.5**	1
Total		**1,750**	**3,273**	1,587	**4,191**	1,907	**5,608**	2,290
Thermal	**ktoe**	**ktoe**		**ktoe**		**ktoe**		**ktoe**
Solar Thermal	154	**1**		**5**		**17.5**		**38**
Bimass	7,400	**2,781**		**3,660**		**5,000**		**6,760**
Biogas	600	**224**		**470**		**540**		**600**
Municipal Solid Waste		**1**		**15**		**24**		**35**
Total		**3,007**		**4,150**		**5,582**		**7,433**
Biofuel	**m lt/d**	**m lt/d**	**m lt/d**	ktoe	**m lt/d**	ktoe	**m lt/d**	ktoe
Ethanol	3.00	**1.24**	**3.00**	805	**6.20**	1,686	**9.00**	2,447
Biodiesel	4.20	**1.56**	**3.00**	950	**3.64**	1,145	**4.50**	1,415
Hydrogen			**0**	0	**0**	0	01 mill kg	124
Total			**6.00**	1,755	**9.84**	2,831	**13.50**	3,986
Total Energy Consumption (ktoe)		66,248		70,300		81,500		97,300
Total Energy from R E (ktoe)		4,237		7,492		10,319		13,709
Renewable Energy Ratio		**6.4%**		**10.6%**		**12.7%**		**14.1%**
NGV (mmscfd - ktoe)		108.1	393.0	3,469	596	5,260	690	6,090
Total Energy from RE + NGV (ktoe)				10,961		15,579		19,799
Alternative Energy Ratio				**15.6%**		**19.1%**		**20.3%**

Source: (1) Potential and target are taken from REDP 2008-2022 by Department of Alternative Energy Development and Efficiency (DEDE)

(2) Existing situation figures are taken from DEDE's Renewable Energy Situation 2010

Table 3 Added Rate for SPPs and VSPPs Using Renewable Energy

Energy Source	Countrywide Except The 3 Most Southern Provinces (Baht/kWh)	The 3 Most Southern Provinces (Baht/kWh)	Areas Using Diesel Engines (Baht/kWh)	Subsidized Period (Years)
Biomass				
Contract Capacity ≤1 MW	0.5	1.5	1.5	7
Contract Capacity > 1 MW	0.3	1.3	1.3	7
Biogas				
Contract Capacity ≤1 MW	0.5	1.5	1.5	7
Contract Capacity > 1 MW	0.3	1.3	1.3	7
Small, Micro & Mini Hydroelectric				
50 kW ≤Contract Capacity < 200 kW	0.8	1.8	1.8	7
Contract Capacity < 50 kW	1.5	2.5	2.5	7
Waste				
-Anaerobic Digestion/landfill	2.5	3.5	3.5	7
- Thermal Process	3.5	4.5	4.5	7
Wind Energy				
Contract Capacity ≤50 kW	4.5	6.0	6.0	10
Contract Capacity > 50 kW	3.5	5.0	5.0	10
Solar Energy	8.0 and 6.5	9.5	9.5	10

Source: Resolution of the 124th (2/2009) Meeting of NEPC on 9th March 2009

(iii) Energy Conservation Program

Thailand established the energy saving regulations to encourage energy conservation in all sectors through campaigns aiming to build up energy-saving conscience. In addition, Thailand also keeps promoting efficient use of energy by providing incentives to attract the private sectors to use energy-saving appliances and to reduce electricity usage during the peak periods.

Since 1995 with a funding from Energy Conservation Promotion Fund (ENCON Fund), Thailand has launched three phases of energy conservation programs as follows: ((1) Phase I which covered the year 1995-1999 and consisted of 91 supported projects, (2) Phase II which covered the year 2000-2004 and consisted of 195 supported projects, and (3) the current phase III which is covering the year 2005-2011 and consisted of 247 supported projects.

As shown in **Fig 8** (National Energy Policy Office, 2010), the first two phases of the energy conservation program consisted of three main sub-programs, i.e. (i) compulsory program, (ii) voluntary program, and (iii) complimentary program while the current phase consists of (i) renewable energy development program, (ii) energy efficiency program, and (iii) strategic and administration program, as shown in **Fig 9** (EPPO, 2005). However, it should be noted that although this is so called energy conservation program, it, in fact, consists of energy conservation projects, renewable energy research and development projects, and capacity building including public relation projects. All three phases of this program are widely considered as a powerful mechanism to drive the energy conservation activities in Thailand.

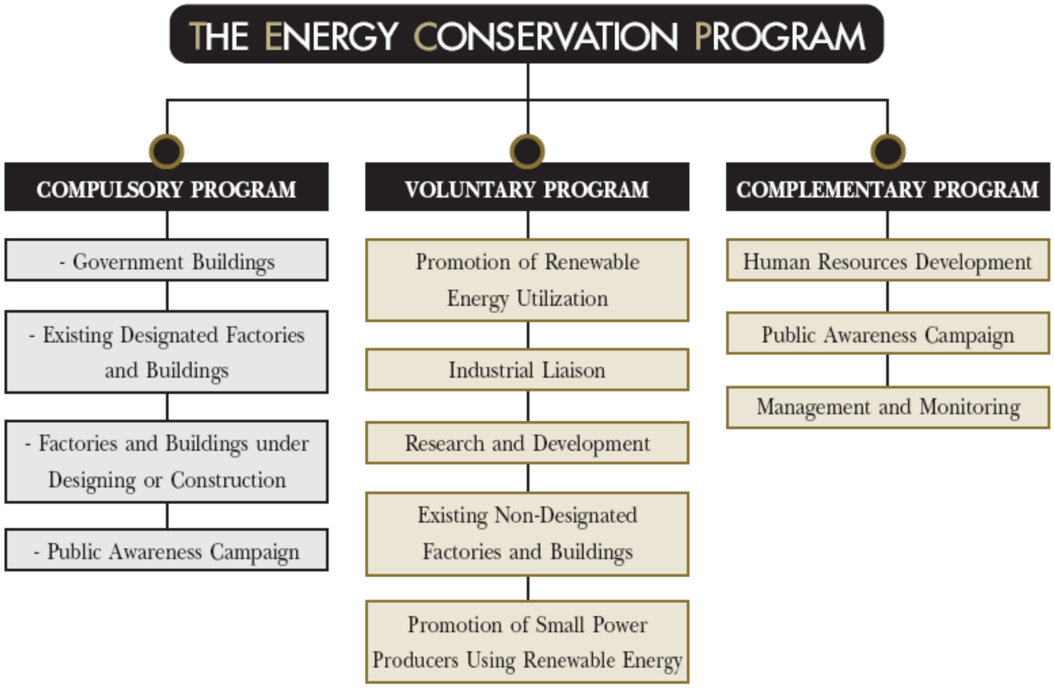


Fig 8 Structure of the Energy Conservation Program on Phase I (1995 to 1999) and II (2000-2004)
Source: Implementation Achievement during the fiscal year 2001 Energy Conservation Promotion Fund (National Energy Policy Office, 2001)

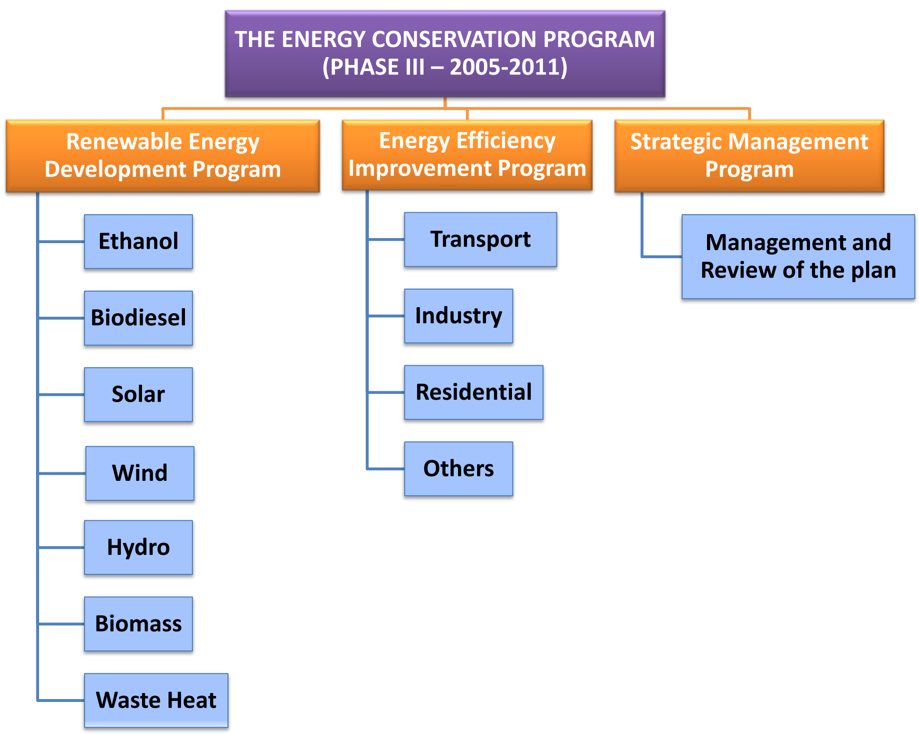


Fig 9 Structure of the Energy Conservation Program on Phase III (2005-2011)
Source: Translated from Implementation Achievement during the fiscal year 2005 of Energy Conservation Promotion Fund (EPPO, 2005)

On the third phase of energy conservation program, four major energy saving initiatives are launched to stimulate entrepreneurs to implement energy efficiency improvement. These four initiatives are revolving fund for energy efficiency (EE) and renewable energy (RE) projects, energy service company or ESCO venture capital fund, tax incentives for energy saving, and DSM bidding. Moreover, Thailand develops the standards for electrical appliances and energy conservation buildings as well as encourages the development of mass public transportation and railway system to promote the usage of efficient energy which will reduce the economy's investment in energy procurement.

(iv) National Energy Efficiency Plan (2011-2030)

Due to the reliance on the energy imports and the energy price rise, Thailand decided to develop the first long-term plan on energy efficiency improvement. This National Energy Efficiency Plan (NEEP) is applicable to four main economic sectors involving (1) transport sector, (2) industry sector which includes construction and mining sector, (3) large-scale commercial sector, and (4) small and medium commercial sector and residential sector.

The main highlights of this plan are:

- Reducing the energy elasticity from 0.98, which is the average value from the last 20 years, to 0.7 in the year 2030,
- Reducing the energy intensity by 25% in 2030,
- Applying five strategies to accelerate the plan;
  - **(1)** Applying compulsory programs with solid regulations and standards, for example, mandatory labeling or minimum energy performance standards (MEPS),
  - **(2)** Applying complimentary programs such as demand side management (DSM) and energy service company (ESCO),
  - **(3)** Campaigning value realization and behavior change in energy consumption, for example, low carbon economy concept or eco-driving,
  - **(4)** Supporting technology development and innovation for more energy efficient devices/appliances,
  - **(5)** Promoting capacity building and institutional arrangement from both public and private entities.

In conclusion, the total cumulative energy saving from this plan is expected to be 290,000 ktoe, and it can reduce carbon dioxide emission from the energy consumption around 980 million tonnes from 2011 to 2030, as shown in Table 4.

Table 4 Expected average energy saving and CO_2 emission reduction from Energy Efficiency Plan

Economic sector	Average energy saving per year (ktoe)		Average CO_2 emission reduction per year)million tonnes(	
	2011-2015	2011-2030	2011-2015	2011-2030
Transport	1,300	6,400	4	20
Industry	1,120	5,500	4	17
Commercial and residential				
- Large scale commercial	220	1,100	1	6
- Small and medium commercial sector and residential sector	320	1,500	1	6
Total	**2,960**	**14,500**	**10**	**49**

Source: Energy Efficiency Plan 2011-2030 (EPPO, 2011)

(v) Power Development Plan (2010-2030)

Since December 2008, the electricity demand has decreased substantially due to the economic suppression. As a result, the Ministry of Energy appointed a subcommittee to prepare a new Thailand power development plan (PDP) for the year 2010 to 2030 which reflects the lower estimated energy demand of 4.3-4.5% (in comparison to the energy demand of 5-5.5% forecasted in the previous PDP (2007)). PDP 2010 was approved by the National Energy Policy and Planning Committee (NEPC) and endorsed by the Cabinet on 12 March 2010 and 23 March 2010, respectively. This PDP is designated as a Green PDP which highlights on the GHG emission reduction and the promotion of efficient energy utilization and electricity production through co-generation system. It cooperates cabinet-approved power purchase projects from domestic producers and neighboring countries and also power generation projects from renewable energy.

The proportion of natural gas usage is also reduced in this plan, from 70% at the present to only 42%. On the other hand, other energy sources as the co-generation system, the renewable energy, and the power purchase from neighboring countries will be used in a greater proportion.

With the aforementioned assumptions about the future electrical supplies, the power imports from neighboring countries, and the load forecasts, EGAT and the Ministry of Energy cooperated in performing the Thailand Power Development Plan which can be summarized as follows;

- **Projects during 2010-2020**
  - EGAT-owned power plants 4,821 MW
  - Independent Power Producers (IPPs) 4,400 MW
  - Small Power Producers (SPPs) 3,539 MW
  - Very Small Power Producers (VSPPs) 2,335 MW
  - New combine cycle power plant supporting LPG production 800 MW
  - Power purchase from neighboring countries 5,669 MW
- **Projects during 2021-2030**
  - New EGAT power plant (Renewable) 97 MW
  - New EGAT power plant (Natural Gas) 13x800 MW
  - New EGAT power plant (Clean Coal) 8x800 MW
  - New EGAT power plant (Nuclear) 5x1,000 MW
  - Power purchase from SPP 3,800 MW
  - Power purchase from VSPP 1,745 MW
  - Power purchase from neighboring countries 6,000 MW

However, due to the Fukushima Daiichi nuclear power plant accident from the great tsunami in Japan on 11 March 2011, the National Energy Policy and Planning Committee (NEPC) has granted the 3-year delay of Thailand's first nuclear power plant construction plan.

2 Institutional arrangement for the TNA and stakeholder involvement

As one of the six countries in Asia supported by the Global Environmental Facility (GEF) through the UNEP to prepare climate change technology needs assessments, the Royal Thai Government assigned the National Science Technology and Innovation Policy Office (STI) as the Thai TNA coordinator. With the Asian Institute of Technology (AIT) as the regional centre for Asia, the present institutional arrangement for the Thai TNA project followed the UNEP RISØ centre-recommended structure is illustrated in Fig **10** with the details discussed below.

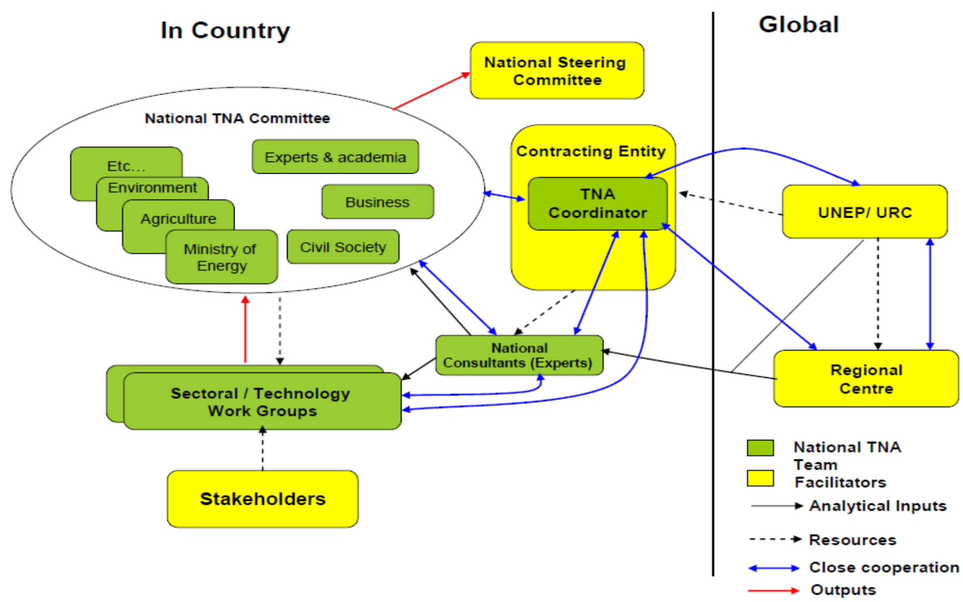


Fig 10 Institutional arrangement for the TNA project as suggested the UNEP RISØ centre

Various stakeholders from government agencies, academic institutes, and private sectors are engaged in the national structure at various levels. The national TNA committee has Naksitte Coovattanachai (Senior Advisor to Secretary-General, STI) as its chairman, and its committee members are representatives from (1) the Department of Industrial Work, the Ministry of Industry; (2) the Health Systems Research Institute, the Ministry of Public Health; (3) the Energy and Environment Cluster, the National Science Technology Development Agency; (4) the Thailand and Environment Institute (an NGO); (5) the Energy Policy and Planning Office, the Ministry of Energy; (6) the Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi; (7) the Joint Standing Committee on Commerce, Industry, and Banking; (8) the Thailand Greenhouse Gas Management Organization (a public organization); (9) the Department of Alternative Energy Development and Efficiency, the Ministry of Energy; (10) the Thailand Research Fund; (11) the Office of Natural Resources and Environmental Policy and Planning; and (12) the National Science Technology and Innovation Policy Office. The National Steering Committee has the permanent secretary of the Ministry of Natural Resources and Environment as its chairman, and the Steering Committee contains representatives from (1) the Ministry of Foreign Affairs, (2) the Ministry of Agriculture and Cooperatives, (3) the Ministry of Transport, (4) the Ministry of Energy, (5) the Ministry of Science and Technology, (6) the Ministry of Public Health, (7) the Ministry of Industry, (8) the National Economic and Social Development Board, (9) the Thai Meteorological Department, (10) the Pollution Control Department, (11) the Royal Forest Department, (12) the Department of Water Resources, (13) the Department of Marine and Coastal Resources, (14) the

Thailand Greenhouse Gas Management Organization (a public organization), (15) the Thailand Research Fund, (16) the Federation of Thai Industries, (17) academia, and (18) the Office of Natural Resources and Environmental Policy and Planning (as the secretariat). The working groups (which also serve as national consultants) for selected sectors (as described next) were appointed by the National Steering Committee as discussed in detail in Section 3.1 (see “Process and criteria of sector selection”). Various stakeholders of each selected sector were engaged during focus group meetings and national public hearings as discussed in detail in Section 4.

3 Sector prioritization

3.1 Process and criteria of sector selection

On July 12, 2010, the Office of National Resources and Environmental Policy and Planning (ONEP), under the Ministry of Natural Resources and Environment, and the National Science Technology and Innovation Policy Office (STI), under the Ministry of Science and Technology, launched the first meeting for the Thailand Technology Needs Assessment project. Fifty-four experts and stakeholders (Annex 3) in climate change technology participated to discuss their viewpoints and to identify the highly impacted sectors. The meeting concluded that mitigation technology is needed for energy efficiency and the renewable energy sector while adaptation technology is needed for the agricultural sector, water resources management, and modeling sector. The four selected sectors are also in line with the National Strategy on Climate Change Management (Office of Natural Resources and Environmental Policy and Planning, 2008) and the 1st National Policy and Plan on Science, Technology, and Innovation (National Science Technology and Innovation Policy Office, 2012). The energy sector and the agricultural sector are the main focus of Pillar 1: building capacity for climate change adaptation, Pillar 2: promoting GHG mitigation, and Pillar 3: promoting research and development on adaptation and mitigation of the national strategy on climate change management. Similarly, the climate change adaptation using the modeling sector and the adaptation of the agricultural sector are incorporated in Strategy 3.1 of the 1st National Policy and Plan on Science, Technology, and Innovation while the GHG mitigation for the energy sector and the adaptation for the water resource management sector are planned in Strategy 3.2 and 3.4 of the same plan.

To develop a TNA for targeted mitigation technology and adaptation technology, the Steering Committee appointed four technology workgroups composed of members from the following institutions: (1) Science and Technology Research Institute, Chiang Mai University for the energy efficiency and renewable energy sector, (2) the National Center for Genetic Engineering and Biotechnology (BIOTEC), the National Science and Technology Development Agency (NSTDA), for the agriculture sector, (3) the Hydro and Agro Informatics Institute (HAII) for the water resource management sector, and (4) the Center of Excellence for Climate Change Knowledge Management for the modeling sector. The members of these workgroups also serve as national consultants.

3.2 An overview of the energy sector

3.2.1 GHG emission from energy sector

Table 5 illustrates the GHG inventory of the energy sector in comparison to the total GHG emissions from 1990 to 2008. Obviously, since 1998 the proportion of GHGs emission from energy sector has substantially increased. Undoubtedly, the energy sector is the largest contributor of GHG emissions.

Table 5 Thailand Greenhouse gas inventory in all sectors and in energy sector

Greenhouse Gas Inventory of the year	CO_2 Net Emission	CH_4	N_2O	Total	Total (%)
1990 (B.E.2533)					
Total Emission & Removals	**163,996**	**57,675**	**3,506**	**225,177**	**100**
Energy Sector	76,731	2,469	459	79,659	35.4
1994 (B.E.2537)					
Total Emission & Removals	**201,929**	**66,586**	**17,317**	**285,831**	**100**
Energy Sector	125,483	4,127	257	129,868	45.4
1998 (B.E.2541)					
Total Emission & Removals	**204,293**	**79,537**	**13,647**	**297,477**	**100**
Energy Sector	143,817	7,880	257	151,954	51.1
2000 (B.E.2543)					
Total Emission & Removals	**157,854**	**58,829**	**12,030**	**228,277**	**100**
Energy Sector	149,915	8,690	775	159,380	69.8
2003 (B.E.2546)					
Total Emission & Removals	**218,359**	**95,340**	**27,900**	**341,599**	**100**
Energy Sector	178,945	11,508	1,240	191,693	56.1
2008 (B.E.2551)					
Total Emission & Removals	**263,282**	**111,013**	**27,070**	**400,077**	**100**
Energy Sector	204,785	11,698	1,237	217,721	54.2

3.2.2 Current Status of Technologies

This section summarizes the current status of technologies in Thailand's energy sector. The four main groups of technologies include:

(a) Energy Supply and Transformation

- Electricity Generation from Commercial energy
- Electricity distribution system
- Oil Refinery plant
- Natural gas separation plant and distribution system
- Smart grid

(b) Renewable Energy technology

- Solar energy
  - Solar photovoltaics (PV) for electricity
  - Solar thermal
- Wind energy for power generation
- Hydro energy for power generation
- Biomass
  - For power generation
  - For thermal use
- Biogas
  - For electricity from Biogas engine
  - For thermal use
- Biofuels
  - Ethanol
  - Biodiesel
- Other renewable energy technologies (If any)

(c) Energy Efficiency improvement in demand side,
- Industry sector
- Transport sector
- Commercial sector and building
- Residential Sector
- Other sectors

(d) **Others**
- Carbon Capture and Storage (CCS)

The details of each group of technologies are as follows:

3.2.2.1 Energy Supply and Transformation

- **Electricity generation from commercial energy and distribution system**

Presently, Thailand's power plants have the total capacity of 30,833 MW while Thailand consumed 149,475 GWh power consumption in 2010 (DEDE, 2011). Most of the electricity generation (~70%) is from natural gas. EGAT developed the power development plan in 2010 (PDP 2010) which proposes the construction of new power plants for future power generation at the capacity of ~65,547 MW in 2030. These new power plant will produce electricity from various technologies and sources such as 16,670 MW from 21 CCGT power plants, 8,400 MW from 11 clean coal technology power plants, 512 MW from new hydro power, 7,137 MW from cogeneration, and 4,617 MW from SPP and VSPP. Even with these new power plants, Thailand still needs to import around 11,669 MW from Laos, Myanmar and China.

As for the transmission and distribution system, most infrastructures of Thailand's national electricity grids have not undergone significant change since 1960s. This power transmission system is a one way communicative system. Electricity transmits from generators to end users via transmission lines and distribution systems. Some weak points and gap found in the system include (i) leakage due to long distance transmission loss, (ii) difficulty to monitor, identify and repair the damage, and (iii) labor intensive in reading electricity meters. To upgrade the transmission and distribution efficiency, smart grid is essential. Smart grid uses advanced devices and software to acquire and manage data from electrical energy generating, control, and monitoring devices. Using real time information, many problems can be detected promptly. The smart system will equip with advanced tools to analyze the data for decision making purposes. Currently, EGAT, MEA and PEA have appointed a team to study the smart grid to further develop the electricity transmission system in Thailand.

- **Oil refinery and natural gas separation plant**

There are seven refineries in Thailand with total capacity of 1.1 million barrel per day. These are owned or partly owned by the state company, PTT. According to the 2011 BP Statistical Energy Survey, Thailand had 1.40% of the world total refinery in 2010 (BP, 2011). Natural gas development in Thailand began in 1973 when the survey found that the Gulf of Thailand has a large reserve of natural gas to be commercially used. The country's capacity of natural gas separation is 1,710 MMscfd from five separation plants. In addition, Thailand owns one small size for LPG plant gas processing the total of 120 MMscfd (i.e., 1.10% of the world total natural gas production in 2010 (BP, 2011). Most of the refineries are located in the Eastern region of Thailand with very high productivity.

- **Natural gas distribution system**

Since the natural gas exploration in the early 80, the natural gas transmission pipelines system have been constructed and developed continuously. By the end of 2007, Thailand has the total natural gas transmission pipelines (both onshore and offshore) of 3,000 km, transporting natural gas at a rate of 3,200 million cubic feet per day. Pipeline system is shown in **Fig 11**. The total number of petroleum concession is 19 production projects (6 on-shore and 13 off-shore projects) and 65 survey projects (38 onshore and 27 offshore projects) in 2010. The latest survey revealed that the reservoir in the gulf of Thailand has the capacity of 22.87 million MMscf (TCF). **Fig 12** illustrates the forecast of natural gas production from the Gulf of Thailand.

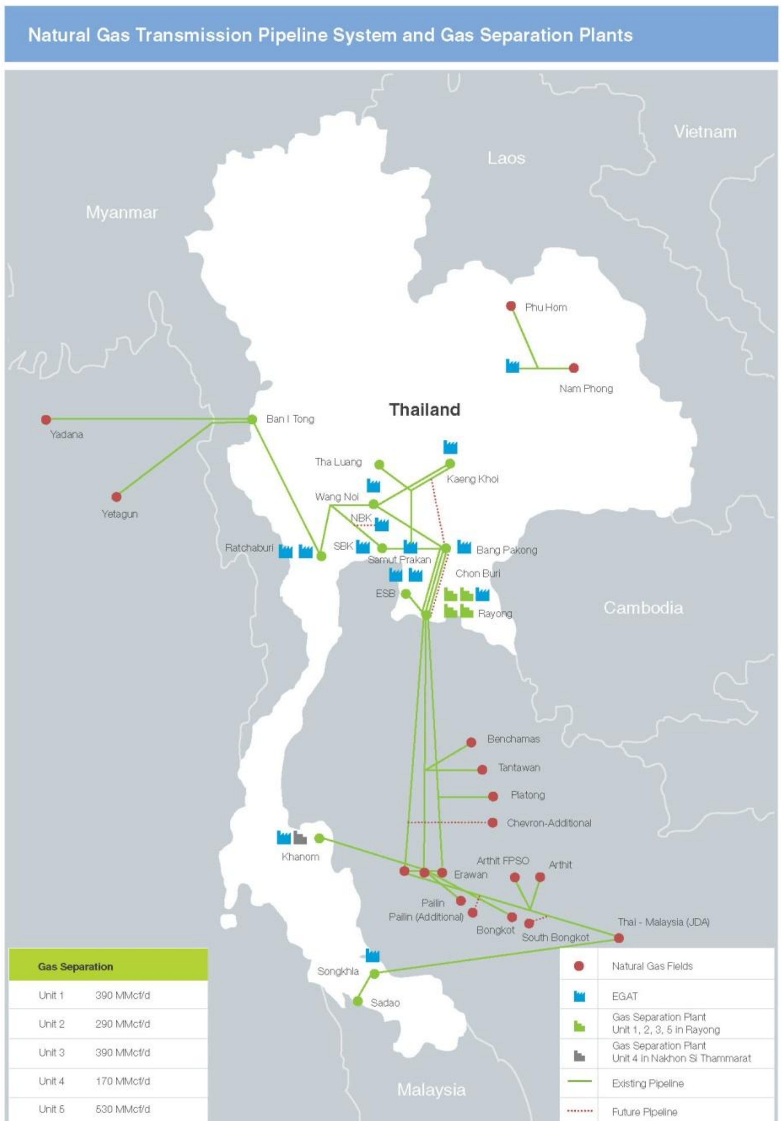


Fig 11 Map of natural gas transmission pipeline system and gas separation in Thailand (MoE, 2010)

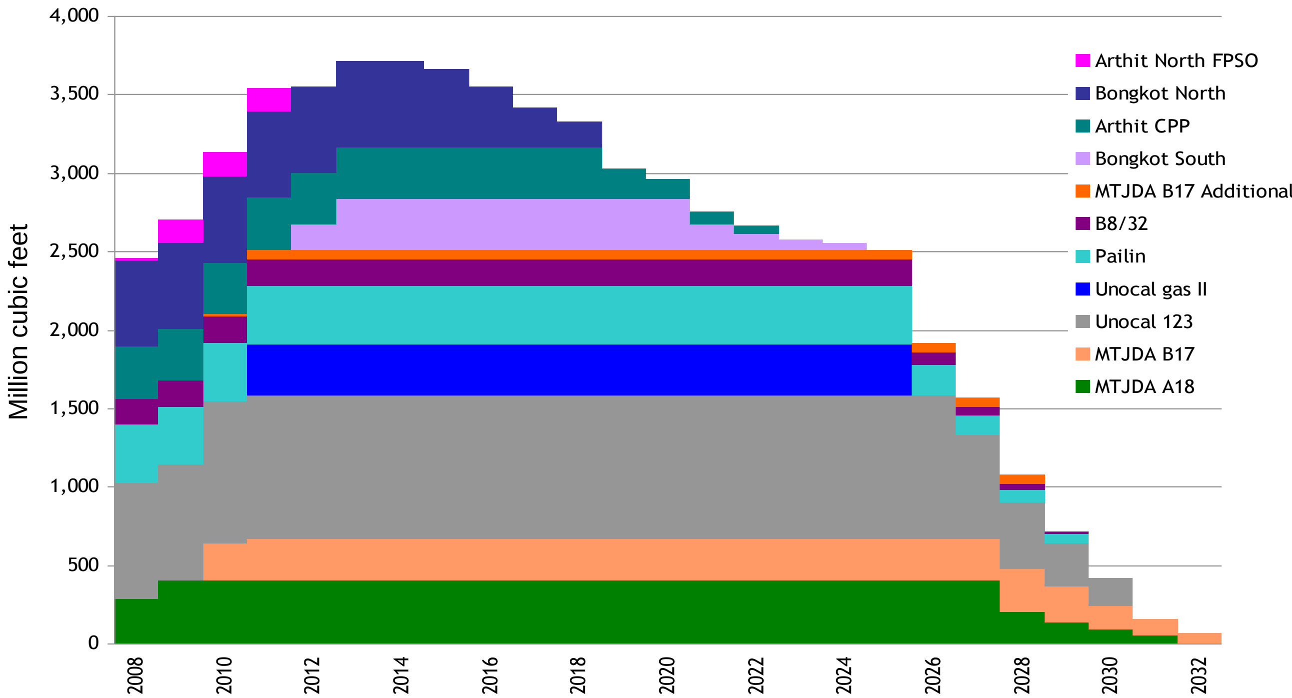


Fig 12 Natural gas production forecast from the Gulf of Thailand: 2008 to 2032 (MoE, 2010)

3.2.2.2 Renewable Energy Technology

The national strategies on alternative energy require the increase of energy efficiency, economic value of energy consumption, and the country's competitiveness. The development of alternative energy supply is urgently needed. The target is set to increase the share of alternative energy to 13.5% by the year 2011. In 2010, this target accounts for 11,311 ktoe of alternative energy supply comprising 1,443 ktoe from electricity generation from alternative sources, 3,851 ktoe from thermal energy, and 6,426 ktoe from transportation fuels (ethanol, biodiesel and NGV).

- **Solar energy**

As evident from Thailand's annual-average daily global radiation of 18.2 MJ/m^2/day, solar energy is an alternative energy option with great potential for Thailand. Thailand's solar map is shown in Fig 13. Even with high potential, rapid progress in harnessing this abundant source of energy is of urgent need. In 2010, the solar PV in Thailand has the capacity of 48.56 MW. The cost of solar PV technology rapidly declines from 25 US$/Watt in early 80s to 2-3 US$/Watt in 2010, mainly because of the advanced solar technologies from China, which cause the solar market boom in Thailand. DEDE evaluates that there would be 55 MWe and 500 MWe installed capacity by the year 2011 and 2022, respectively, with 10 years incentives of adder cost for solar power generation developer at 6.50 Baht/kWh (the new adder cost rate reduced from 8.50 Baht/kWh since June 2010). This adder cost is proven as the main incentive to the investor since 2009.

The challenge of solar PV energy is the demand of the crystalline wafer or amorphous cell production to support the rising demand of solar PV in the future. Thailand also needs the parabolic through and Sterling engine solar power generation technology which is still not considered as a proven technology in the country due to the lack of financial support from domestic financial institutes.

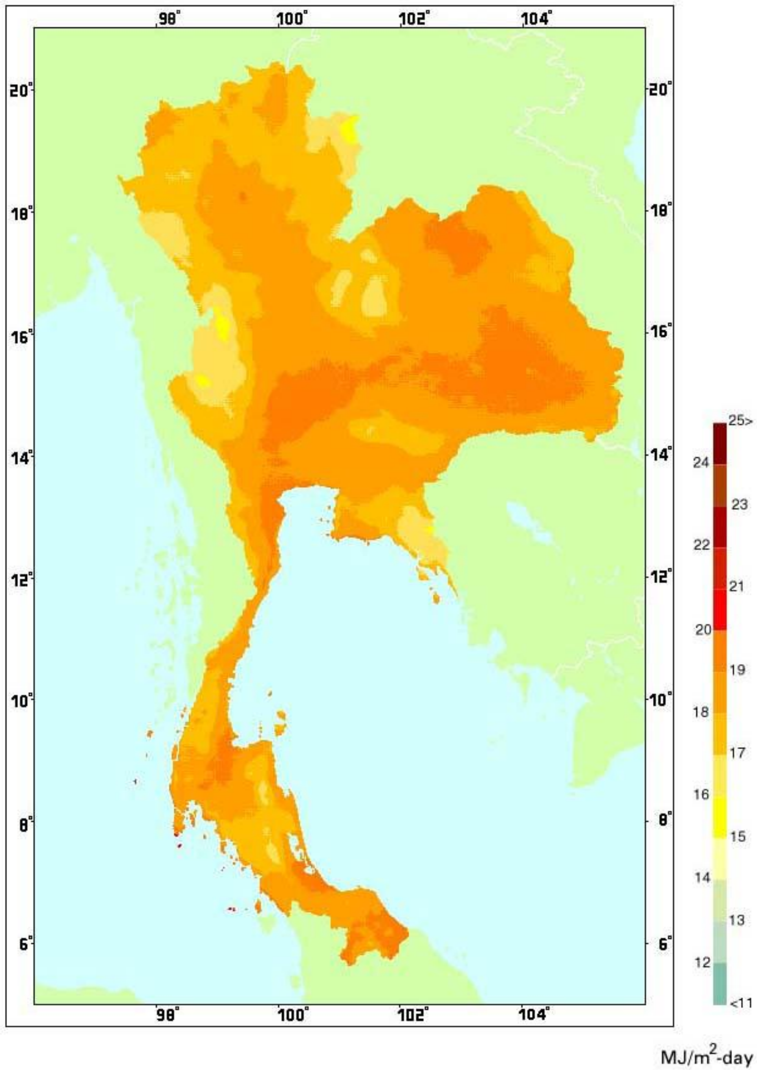


Fig 13 Thailand solar map (DEDE, 2010)

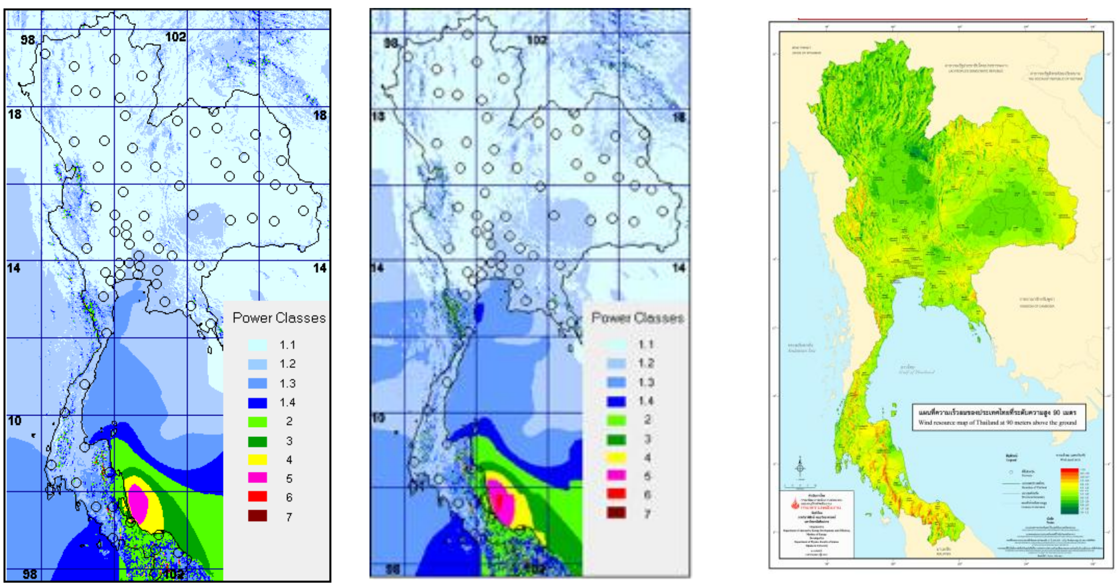
On the other hand, solar thermal offers a small output and is not widely used due to the high initial investment cost, compared to electric water heaters. In 2006, more than 50,000 m^2 of flat plate collectors were installed on commercial buildings, hotels, hospitals and private residences. Solar thermal capacity ranged from 3,000 to 3,500 m^2 of solar water heaters per year in 2006. Most solar panels were made for export, but private firms are now beginning to market solar roofing and smaller-scale systems for residential and commercial use in the domestic market. However, due to the decrease of the equipment price for solar PV and the 30% direct subsidy by DEDE, thermal energy production by solar thermal is increased to be approximately 5 ktoe of in 2010 and expected to be 38 ktoe by 2022.

The opportunity of solar thermal is the rising demand due to DEDE's 30% direct subsidy scheme for household and commercial sector (especially in hotel, department store and school). In addition, due to the relative simplicity of the solar thermal technology compared with solar PV, Thai manufacturers under government support can domestically handle this demand.

- **Wind energy**

By the end of 2010, around 5.13 MW installed capacity of wind power, mostly onshore, is fully operated in Thailand. Due to the inconsistency and the low wind speed at an average of 4 m/s at the height of 50 m, the potential of the wind power in Thailand is rather limited, as shown on the wind maps in **Fig 14**.

Table 6 estimates the wind energy potential available for power generation in the country. The wind energy potential is along the coasts of the Southern Thailand. Even though the technology for electricity generation from wind energy is readily available, it is relatively new to Thailand. Implementation is rather limited due to the local wind condition and the high cost of producing energy from a wind turbine. The government also sets up the adder cost for 10 years incentives for wind power developers at 4.50 Baht/kWh (for less than 50 kW installed capacity) and 3.50 Baht/kWh (for more than 50 kW). From the adder cost incentives, the low-cost wind technology from China can compete in Thailand's wind market from its low investment cost in the forthcoming 200 to 300 MWe installation from eight wind farms in Thailand in 2011.



(a) Including calm *(b) Excluding calm* *(c) New wind energy map*

Fig 14 Annual average Thailand wind map by wind power classes (DEDE, 2010) (Department of Alternative Energy Development and Efficiency, 2010b)

The opportunity of the wind energy relies on the large offshore wind farms in the Southern region of Thailand, but the investment and overall cost must be competitive with technologies from China.

Table 6: Wind energy potential in Thailand

Characteristic	Poor (< 6 m/s)	Fair (6-7 m/s)	Good (7-8 m/s)	Very Good (8-9 m/s)	Excellent (> 9 m/s)
Land Area (sq. km)	477,157	37,337	748	13	0
% of Total Land Area	92.60%	7.20%	0.20%	0.00%	0.00%
MW Potential	NA	149,348	2,992	52	0

Note: For large wind turbines only. Potential MW assumes an average wind turbine density of 4 MW per square kilometer and no exclusions for parks, urban, or inaccessible areas. Wind speeds are for 65 m height in the predominant land cover with no obstructions. Source: Wind Energy Resource Atlas of Southeast Asia

- **Hydropower**

Hydropower has been utilized to generate electricity since 1964. However, hydropower resources are limited due to the environmental impact upon surrounding areas of the possible hydropower projects. Future development of hydropower will likely be limited to small-scale projects which are considered most economical and environmentally friendly. It should be noted, however, that a thorough feasibility study of a small hydropower project tends to indicate that the cost of electricity generated from a suitable hydropower site can be more economical than electricity generated from a set of photovoltaic plants.

In 2009, the existing small hydropower plants generate 67 MW. Most are located in the Northern region of the country as shown in **Fig 15**. The 2012 target of energy generation from small-scaled hydropower plants according to REDP is 324 MW consisting of three main potential sources, i.e.; (i) small hydro power (200 kW to 6 MW) development with 95.6 MW potential from 42 sites by DEDE, (ii) village-size mini hydro power (20 to 200 kW) development with 9.112 MW potential from 155 villages by municipality, and (iii) the power generation from existing downstream dam. This energy generation will be combined with the 78.7 MW installed capacity from 6 dams by EGAT and the remaining 155.5 MW from 48 dams by DEDE and EGAT. These small hydro power plants are expected to have zero or nearly zero environmental impact. The ministry of energy also sets up the adder cost for raising the 7-years incentives for hydropower developers at 0.80 Baht/kWh (for 50-200 kW installed capacity) and 1.50 Baht/kWh (for less than 50 kW).

It is unlikely to construct a large scale dam in Thailand; however, Thailand plans to construct a dam and large hydropower plant in Myanmar, despite of opposition from civic and environmental groups. EGAT is planning to develop a 1.35 GW plant along the Salween River and expects to start commercial operations and export power to Thailand around 2015.

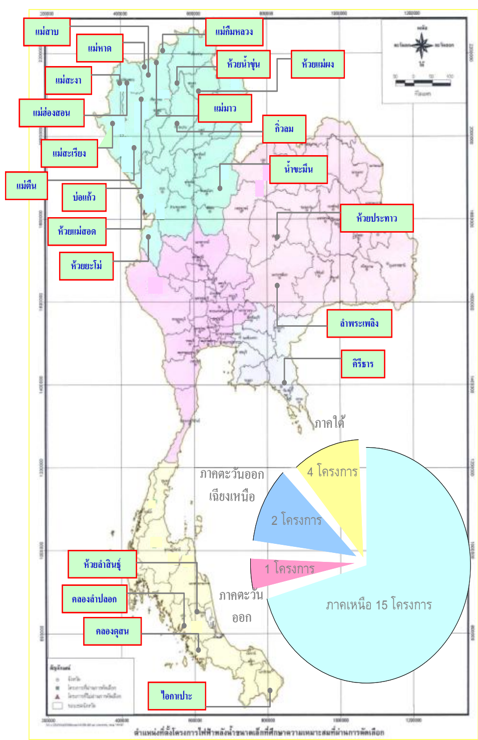


Fig 15 Small and Mini-hydro power in Thailand (DEDE, 2008)

- **Biomass**

Renewable energy derived from biomass sources has the potential for development to meet Thailand's future energy demands. Over the past few decades, domestic biomass resources such as fuel wood and bagasse were the most important alternative sources of energy, amounted to about 4.54 Mtoe per year (DEDE, 2008). In the past five years, bagasse and rice husk were among the most widely available biomass materials. However, surprisingly, during the boom of biomass power generation from the seven-year 0.5 Baht/kWh (for less than 1 MW biomass power plant) and 0.3 Baht/kWh (for more than 1 MW biomass power plant) adder cost subsidy, rice husk and bagasse were not considered the potential energy sources. Other agricultural products having high potential for energy production are cassava roots, coconut, and palm products. From the REDP, biomass is considered the main potential renewable energy with the existing 1,644 MW electricity generation. Approximately 2,749 MW installed capacity has been planned for the year 2011. This capacity comprises 1,520 MW from rice husk, 395 MW from bagasse, 624 MW from fuel woods, and the rest 210 MW from other agricultural wastes.

- **Biogas**

The use of biogas is recognized as an environmental friendly and sustainable solution. Biogas is produced from anaerobic biodegradation of organic matters in the absence of oxygen and the presence of anaerobic microorganisms. Anaerobic digestion is a consequence of a series of metabolic interactions among various groups of microorganisms. These organic matters are from various agricultural and industrial processes as well as from municipal solid waste. These energy sources offer opportunities for small-scale producers.

From a 2007 survey, 10,000 food factories and 20 million heads of livestock in Thailand generated wastes and wastewater suitable for biogas production. According to the REDP, the existing power generation from biogas is 66.15 MW and 243 ktoe for thermal use. Most is from wastewater treatment of cassava and crude palm oil industry and swine manure. Ministry of Energy plans to increase the power generation to 60 MW and the thermal/heat generation to 470 ktoe from the remaining swine manure, cassava and palm oil wastewater. This expands to include new industries such as ethanol, food and rubber by the year 2011.

The total biogas production potential is around 2,064 million m^3 per year (equivalent to 1,011 ktoe). This amount of biogas potential can generate 289 MW of electric energy or substitute approximately 939 million liters of fuel oil. Hence, the REDP plans to expand the biogas production to 120 MW power generation (with 103.4 MW installed capacity in December 2010) and 600 ktoe heat generation. The new top sources of feedstock for biogas production in the future are cow/chicken manure, cassava pulp and wastewater from paper industry, and other agro-industries such as beverage.

The remaining challenge of biogas technology is the new biomass-to-biogas technology such as grass, corn cob and cassava roots, which requires academic research and high investment cost.

- **Waste**

Another important renewable energy source is waste, including the fresh waste and municipal solid waste (MSW). The REDP classifies two possible uses of the waste-to-energy potential; (i) power generation and (ii) thermal use. For the power generation, a minimum of 100 tons of waste per day is required as the main source of biogas production while the municipality of less than100 tons of waste per day should consider thermal energy production from biogas as LPG substitution. Currently, Thailand installed 13.13 MW power generations and 1.09 ktoe thermal energy generations from waste.

Bangkok generates approximately 8,800 tons of waste per day and 25 municipalities around Thailand produce more than 100 tons of waste per day. At the early stage, 78 MW of power generation would be implemented by 2011. Most of the waste would managed by using landfill gas (LFG) technology and incineration.

Many municipalities have high potential on power generation but lack of financial support and LFG technology including the waste separation system and waste management technology. The milestone of REDP is 160 MW power generation installed capacity from waste by the year 2022.

As for the thermal energy production from waste, implementation in small or medium municipalities or other types of communities such as college and fresh market, which are at risk of long-term reliability on waste supply, may not be a cost effective investment for a private sector.

- **Biofuels**

Having plentiful agricultural resources, Thailand is in the position of effectively deploying biofuels, ethanol and biodiesel, as an alternative energy source. The sufficient and stable supply of feedstock (sugarcane, and molasses, cassava) for ethanol manufacture is of critical importance to the success of the gasohol program. Thailand is by far the largest producer of sugarcane in South-East Asia and is also Asia's largest producer of cassava, with an average output of 20 million tons a year (Gonsalves, 2006). In addition, Thailand is among the major world palm oil plantation for biodiesel production.

For gasohol production and utilization, the average of 1.3 million liters of ethanol was produced daily in 2010(MoE, 2011). The goal is to produce up to 9.0 million liters per day in 2022 according the REDP. The mixing proportion of ethanol with conventional gasoline is mostly 10:90 (so called, gasohol E10) while gasohol E20 (with proportion ethanol 20% and gasoline 80%) and gasohol E85 are also available in the retail market but in the limit number.

For biodiesel production and utilization, the average of 1.9 million liters of biodiesel was produced daily in 2010(MoE, 2011), mainly from palm oil. The goal is to produce up to 4.5 million liters per day. The mixing proportion of biodiesel with conventional high speed diesel in Thailand varies from 3 to 5 percent; e.g., biodiesel 5% with diesel 95%, due to the limitation of domestic palm oil production.

In terms of second and third generation biofuels, Thailand still lacks both research and production even though the country has full capacity of employing the technology from the full of agricultural wastes and plantation.

- **Other renewable energy technologies**

Geothermal, wave and tidal energy were considered in the past researches. However, their feasibility study concluded that these sources of energy did not have significant potential in Thailand.

3.2.2.3 Energy Efficiency Improvement Analysis

The Energy Conservation Promotion Act has been in effect since April, 1992 with the objective of promoting the energy conservation discipline and investment in factories and buildings. Under this Act, the Energy Conservation Promotion Fund (ENCON fund) provides financial support to government agencies, state enterprises, non-government organizations, and private sectors that wish to implement measures to increase energy efficiency utilization. At the same time, a punishment clause is stipulated in the Act for the participants who fail to comply with the ENCON standards, criteria, and procedures required by ministerial regulations. In addition to the ENCON fund, the Ministry of Energy also establishes two additional funds, including ESCO Fund and Energy Efficiency Revolving Fund to promote private investments in renewable and energy efficiency projects with the initial capitals from the ENCON fund. The structure of the energy efficiency concepts and funds is shown in Fig 16.

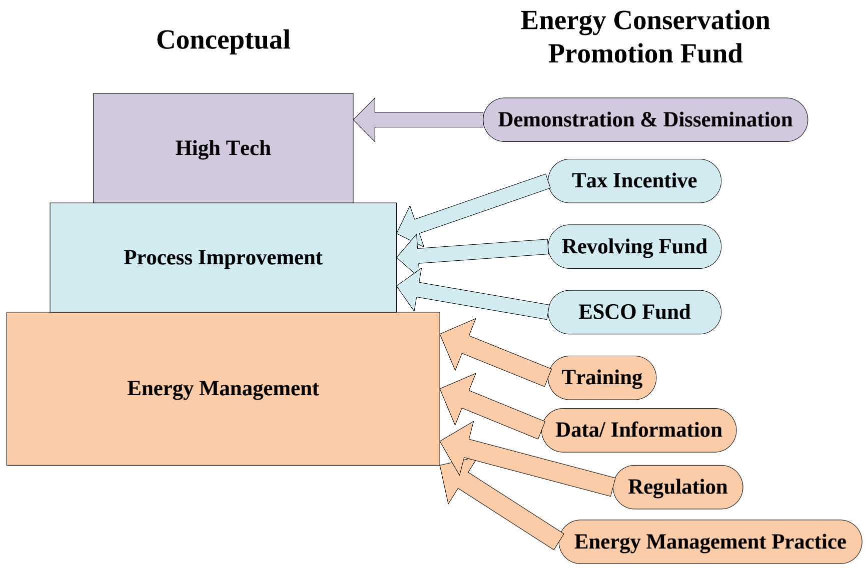


Fig 16 The structures of the energy efficiency concept and funds

With the characteristics of a "rolling plan," the projects under the Energy Conservation Program and their estimated budgets are reviewed and revised annually. This is to address possible change of the influential factors such as new policies/strategies determined by the government, economic and social conditions which can substantially affect the outcome. The use of the ENCON fund is monitored under the framework of the Energy Conservation Program. The first two phases of the ENCON program covered the periods from 1995 to 1999 and from 2000 to 2004, respectively. Currently, the implementation is under Phase 3 (2005-2011) with the aim to increase energy efficiency by reducing commercial energy use by the year 2011. Under this plan, alternative energy development is encouraged with a target of increasing its share to 15.6% of the total final energy consumption, replacing about 10,961 ktoe of commercial energy demand.

Sectorial Energy Efficiency Improvement Goals

- **Industrial Sector**

Various measures are implemented to encourage energy efficiency improvement in the industrial sector. The details of the measures are:

- Revolving Funds or Soft loans

  Soft loans are provided to stimulate and expedite energy efficiency investment in large-scale buildings and factories.

- ESCO Venture Capital

  The ESCO fund is a source of venture capital for ESCOs to jointly invest with private operators in energy efficiency and renewable energy projects. It is implemented through various channels – venture capital, equity investment, equipment leasing, carbon market, technical assistance, and credit guarantee facility. The fund provides equity capital up to 50% of the total equity. In addition, in the case of very small projects, it provides the support via equipment leasing. The fund has outsourced the identification and appraisal of projects to two entities as follows:

- Tax incentives

  - Cost-based incentive: about 1.25 times of the actual investment capital on energy saving project is allowed for tax deduction by phasing the deduction over a period of 5 years. As of now, 94 facilities have received the tax benefits. The government lost 135 million baht of tax revenue, but saved energy expenses by around 360 million baht.

  - Performance-based incentive: 30% of saving value (less than 2 million baht) is returned to the project owners through income tax reduction. After two years of implementation, 174 facilities have joined the program, investing over 1,280 million baht in energy efficiency projects and reduced the energy consumption by 825 million baht.

  - Board of Investment (BOI) Thailand: income tax is waived for 8 years for ESCO or renewable energy projects.

- DSM by Bidding Mechanism

- Financial support is provided to encourage business operators to invest in higher energy efficiency machines and equipment;

- Subsidy is granted based on the actual annual energy saving from such investment (subsidy = annual energy saving x subsidy rate [as bid by each company])

- The maximum subsidy rate is set for each energy type as shown in the Table 7.

With bidding mechanism, proposals with lower weighted subsidy rate will be subsidized first, and this scheme is expected to reduce energy consumption by 149 ktoe in 2011.

Table 7 Subsidy Rates of Thailand's Bidding Mechanism under the DSM

Energy Type	Maximum Subsidy Rate
Electricity	1 Baht/kWh
Heat from liquid and gas fuels e.g. fuel oil, LPG, natural gas, etc.	75 Baht/MMBtu
Heat from solid fuels e.g. coal, wood, rice husks, sawdust, bagasse and other agricultural waste	15 Baht/MMBtu

- Other Supportive Measures for SMEs

Provision of grants to small and medium enterprises (SMEs) is available for the replacement of existing production processes and technologies with proven high-efficiency for example, energy efficiency improvement of tobacco curing process, ceramic shuttle kilns, and Chinese sausage dryers.

- **Household and commercial sector**
  - Promotion of high-efficiency equipment:

Various measures and campaigns based on both compulsory and voluntary basis in demand side management programs are as follows:

- Minimum Energy Performance Standards (MEPS) for appliance such as air-conditioners, refrigerators, ballast, fluorescent lamps and compact fluorescent lamps, water heating appliances, etc.;
- Energy efficiency labeling;
- Establishment of the standards of LPG-fired cooking stoves;
- Promotion of high-efficiency charcoal cooking stoves;
- Establishment of building codes & building material standards;
- Promotion of high efficiency compact fluorescent lamps (CFL)
- Promotion of high efficiency T5 fluorescent lamps which encourage replacement of T8 (36 Watt) fluorescent lamps with T5 (28 Watt) fluorescent lamps, targeting a savings of 408 ktoe in 2011.

  - Public awareness campaigns such as TV spots, booklets, youth activities, etc.

3.2.2.4 Other energy sector

- **Carbon capture and storage**

Carbon capture and storage (CCS) is a range of technologies that can cut CO_2 emissions up to 90%. It is considered as the technical breakthrough that provides a rapid and practical way the world can cut overall CO_2 emissions (ERDI, 2011). A distinction is usually made between two methods for CCS, as follows;

(i) Pre-combustion, where the CO_2 is captured on location, during the extraction of natural gas or oil before it is burned, as shown in Fig 17.

(ii) Post-combustion, where the CO_2 is captured during the process of burning coal or gas for electricity production as shown in Fig 17. More research is needed into this area, which is promising for climate change mitigation as it allows countries that rely heavily on coal to continue using this source of energy without putting the world's climate at risk. Post-combustion techniques can also be applied to other energy-consuming industries, such as paper, steel, cement and refinery.

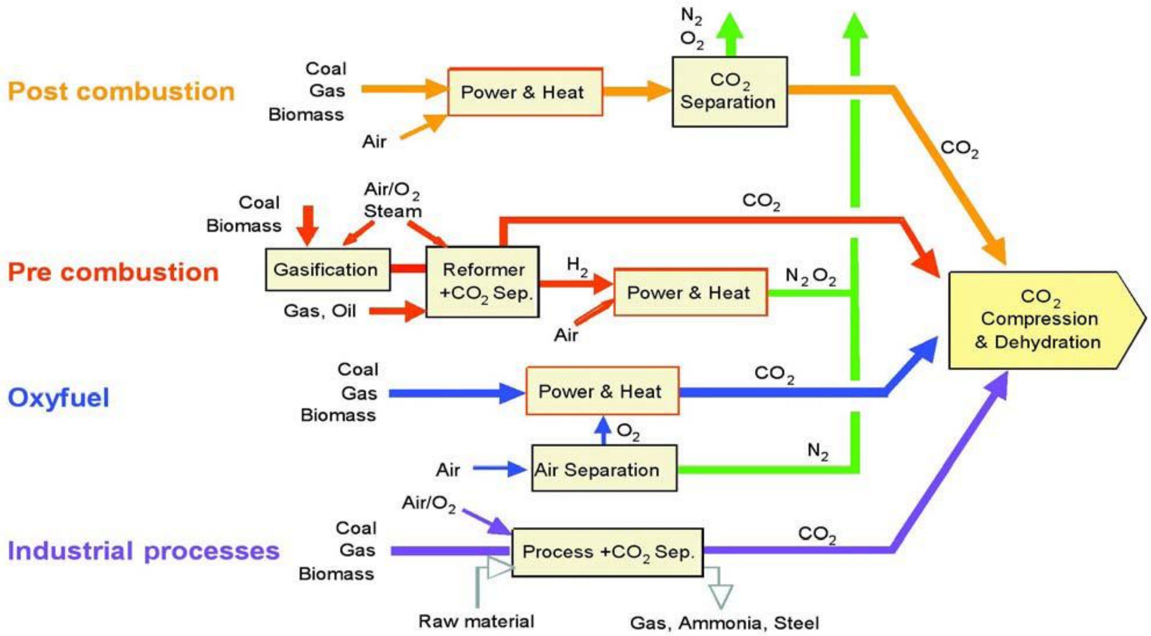


Fig 17 Carbon capture and storage diagram

Source: IPCC CCS

CCS usually involves a series of steps including carbon dioxide separated from large power plants which is subsequently compressed into liquid form. The liquid CO_2 is then transported to a designated location (usually via existing pipeline networks or shipped by trucks or tankers). It is injected into geological formations deep underground or under the ocean bed (often in depleted gas fields). Depending on the plant's location, CO_2 can sometimes be injected directly underground, without having to compress and transport the gas to other locations. The CO_2 can be pumped straight underground, where it is trapped under high pressure in liquid form. Since this technology is new for Thailand, education and training would be of wide interest.

There remain several drawbacks of CCS technology. These include high energy requirement, environmental impact, requirement for large equipment sizing, and its cost effectiveness. So far, Thailand has no implementation of CCS technology. Nevertheless, the petrochemical and power generation sectors are interested in investing in this technology in the future. In the government sector, the Department of Mineral Fuels under the Ministry of Energy will start the first project to find out the country's potential on CCS which would focus on the total investment, operation cost, and reliability of the technology in 2011. It can be concluded that Thailand is quite new to CCS, and government policy on CCS is still unclear and need to be addressed.

4 Technology Prioritization

4.1 An overview of possible mitigation technology options in energy sector and their mitigation benefits

Prior to identifying possible mitigation technology options in the energy sector, the goals of energy management in Thailand are defined according to the national energy plans and strategies. As shown in Table 8, the energy sector in Thailand focuses on five main strategies including the GHG emission management through clean development mechanism (CDM). However, the energy security is still the top priority of the sector while the alternative energy development and energy conservation and efficiency improvement strategies are also beneficial for the climate change mitigation.

Table 8 Strategies of Thailand's energy development

Strategy	Methodology
(1) Intensify energy development	Achieving sufficient and stable energy supply and expediting exploration and development of energy resources
(2) Include alternative energy on the national energy policy agenda	Encouraging production and use of alternative energy, particularly bio-fuel and bio-mass, to enhance energy security, reduce pollution, and benefit farmers
(3) Monitor and maintain energy prices at appropriate, stable and affordable levels	Setting an appropriate fuel price structure which supports the development of energy crops but also reflects actual production costs
(4) Encourage energy conservation and efficiency in the household, industrial, service, and transport sectors	Fostering and consciousness-raising, energy-saving and effective energy use; providing incentives to induce private sector investment in energy-saving appliances and household sector to reduce electricity consumption during peak periods; supporting research and setting standards for buildings and electrical appliances; and supporting the development of mass public transportation.
(5) Encourage environmentally-friendly energy procurement and consumption	Setting relevant standards and promoting CDM projects which reduce social and environmental impacts as well as GHG emissions

According to the goals of the energy management in Thailand discussed above, four groups of technology options capable of fulfilling the goals are 1) energy supply and transformation, 2) renewable energy technology, 3) energy efficiency improvement in demand side, and 4) other energy sector.

Table 9 summarizes technology options in each group and their competitiveness with energy management strategies. The details of these technology options are available in the Annex.

Table 9 Technology options in each group and their competitiveness with energy management strategies

Technology	***Strategy***					***Details***
	Intensify energy development	Include alternative energy	Monitor and maintain energy prices	Encourage energy conservation and efficienc	Encourage environmentally-friendly energy and consumption	
Energy Supply						
· Power Generation						Energy supply is the delivery of fuels or transformed fuels to point of consumption from production through transmission and distribution.
- Efficiency	•		•	•	•	
- Smart grid (cross cutting issue)	•	•		•	•	
· Oil refineries and Natural gas separation	•		•	•	•	
· District cooling	•		•		•	
Renewable Energy						
Solar Energy						Renewable energy technology is technology which comes from natural resources, which are renewable or naturally replenished. In this study, the low potential of renewable energy in Thailand such as tidal, wave, hydrogen and geothermal energy are neglected.
· Solar thermal		•			•	
· Solar PV		•			•	
Waste and MSW						
· Thermal		•			•	
· Electricity	•	•	•		•	
· For Fuel	•	•			•	
Biomass						
· Electricity	•	•	•		•	
· Thermal		•			•	
Biogas						
· BGC		•			•	
· Electricity	•	•	•		•	
· Thermal		•			•	
Biofuels						
· Biodiesel	•	•	•		•	
· Ethanol	•	•	•		•	
· 2nd generation biofuels	•	•	•	•	•	
· NGV	•	•	•		•	
Energy Efficiency Improvement						
Commercial sector and Residential sector						Energy efficiency improvement is the goal of efforts to reduce the amount of energy required to provide products and services in all economic sectors. Improvements in energy efficiency are most often achieved by adopting a more efficient technology or production process.
· Lighting				•	•	
· Building Envelope				•	•	
Industry sector						
· Motor and drives				•	•	
· Combustion		•		•	•	
· Chiller				•	•	
· Air Compressor				•	•	
Transport sector						
· passenger (Mass)				•	•	
· passenger (Private)				•	•	
· Logistic (IT and planning)				•	•	
Other energy sector						
· CCS	•			•	•	

4.2 Criteria and process of technology prioritization

The multi-criteria analysis (MCA) was applied to prioritize the energy technology options in **Table 9**. By using the background data and comments from energy experts, the prioritization was exercised based upon the two main groups of criteria, the readiness of the country and the impacts to the country **Fig 18**.

The criteria of the technology prioritization were initially developed by the national consultant of the energy sector. Then, the criteria were revised based on the comments from the general public hearing and from the focus expert group meetings (see Annex 3). The technologies with the highest points from the MCA would be set as the technology for the further development of the technology action plan (TAP).

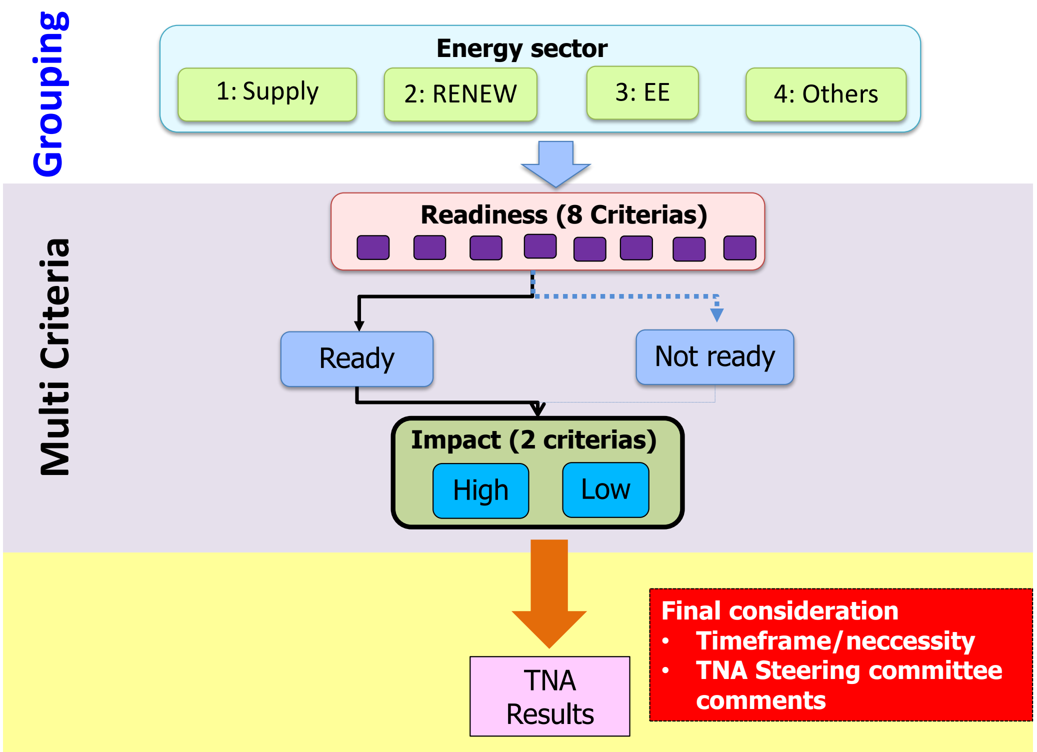


Fig 18 Technology prioritization procedures

The two criteria, readiness and impact, can be further elaborated as follows:

a) The Readiness
The readiness consists of eight criteria with the total of 5 points as presented in Table 10. Each criterion has different weighting factors as also shown in Table 10. First, the readiness criteria were applied to all technology options, and the technology options obtained more than 3.5 out of 5 were chosen to score based on the "Impact" criteria.

b) The Impact
The impact consists of two criteria with the total of 5 points also presented in Table 10. Each criterion has the weighting factor of 0.5. The technology options which obtain more than 8.5 point out of 10 point are regarded as the high priority technologies in the energy management sector.

Table 10 Criteria and weighting system

Criteria	***(a) Assessment (from 1 to 5)***	***(b) Weight***	***(c) = (A)x(B) Point***
Readiness			
(1) Policy infrastructure including regulatory	5	0.1	0.5
(2) Benefit and cost	5	0.1	0.5
(3) Short-term trend	5	0.1	0.5
(4) Management infrastructure	5	0.1	0.5
(5) Possibility of domestically based production	5	0.2	1
(6) Stakeholder and social acceptance	5	0.2	1
(7) Current technology situation in Thailand	5	0.1	0.5
(8) Current technology situation in developed countries	5	0.1	0.5
Impact			
(9) Other impacts (social, economic and environment)	5	0.5	2.5
(10) Estimated GHG mitigation of technology	5	0.5	2.5
Grand total			*10*

Table 11 Meaning of score in each criterion

	Criteria
(1) Policy infrastructure and regulatory	
5	Have policy, financial, and regulatory support
4	Have policy and financial or regulatory support.
3	Have direct policy support but no financial support.
2	Have policy support indirectly.
1	No related policy supported.
(2) Benefit and cost	
5	Technology is very high return in investment without any mechanisms
4	Technology is very high return in investment with some mechanisms
3	Technology is return in investment in all levels with some mechanisms.
2	Technology is not cost effective in some levels
1	Technology is not cost effective in all levels
(3) Short-term trend	
5	Very high possibility/trend of implementing this technology in Thailand within five years
4	High possibility/trend of implementing this technology in Thailand within five years
3	Possibility/trend of implementing this technology in Thailand within five years
2	Low possibility/trend of implementing this technology in Thailand within five years
1	No possibility/trend of implementing this technology in Thailand within five years
(4) Management infrastructure	
5	Have a very good management infrastructure systematically supporting this technology.
4	Have a good management infrastructure supporting this technology
3	Have a fine management infrastructure supporting this technology
2	Have a some management infrastructure supporting this technology
1	No management infrastructure supporting this technology

	Criteria
(5) Possibility of domestically based production	
5	Very high possibility of domestically based production of this technology.
4	High possibility of domestically based production of this technology.
3	Possibility of domestically based production of this technology.
2	Low possibility of domestically based production of this technology.
1	No possibility of domestically based production of this technology.
(6) Social and stakeholder acceptance	
5	Stakeholders in all sectors accept this technology.
4	Government and local stakeholder accept this technology.
3	Government and public stakeholder accept this technology.
2	Only government accepts this technology.
1	Stakeholders in all sectors not accept this technology.
Criteria	
(7) Current technology situation in Thailand	
5	Situation of the technology in Thailand is in the beginning stage.
4	Situation of the technology in Thailand is diffused in limited areas with problem(s)
3	Situation of the technology in Thailand is diffused in limited areas.
2	Situation of the technology in Thailand is diffused in all related sector
1	Situation of the technology in Thailand is fully diffused in all related sector
(8) Current technology situation in developed countries	
5	Situation of the technology is fully diffused in all related sector in all developed countries
4	Situation of the technology is diffused in all related sector in some developed countries
3	Situation of the technology is diffused in limited areas in some developed countries
2	Situation of the technology is diffused in limited areas with problem(s) in some countries
1	Situation of the technology in developed countries is in the beginning stage.
(9) Other impacts (social, economic and environment)	
5	Increase economic impact immensely with no environmental impact
4	Increase economic impact with no environmental impact
3	Increase economic impact with slightly negative environmental impact
2	Without any impact to the economic and environment
1	Have a negative impact to the economic or environment
(10) Estimated GHG reduction	
5	This technology can dramatically reduce GHGs
4	This technology can significantly reduce GHGs
3	This technology can reduce GHGs
2	This technology can reduce GHGs in low figure
1	This technology can reduce GHGs in very low figure

4.3 Results of Technology Prioritization

The results of technology prioritization are summarized in this chapter (see Table 12). Here, we separately discuss the results of the two prioritization steps, the readiness step and the impact step, based on the two criteria mentioned above.

1st Step: Prioritization according to the readiness

From the first prioritization step which focused mainly on the "Readiness" factor, the energy management technologies, which have more than 3.5 point out of 5 point, consist of 14 technologies in four groups of technology (Table 12) as follows:

(a) Energy supply

- Smart grid
- District cooling

(b) Renewable energy technology

- Solar thermal
- Solar photo-voltaics (PV)
- Waste (power generation)
- Biomass (power generation)
- Biomass (Thermal utilization)
- Second and third generation of biofuels

(c) Energy efficiency improvement

- Lighting system
- Building envelope
- Motor and drives in industry sector
- Fuel Combustion in industry sector
- Mass Transport (rail-based system)

(d) Other energy sector

- Carbon capture and storage (CCS)

Notably, in some emerging technologies such as the carbon capture and storage (CCS) and the waste-to-fuel have relatively low scores due to the lack of readiness in the country while the more conventional technologies such as the fuel combustion in industry sector have very high scores due to the readiness of the technology including the financial capability.

2nd Step: Prioritization according to the impact

The 14 technologies were further prioritized according to the "impact" factor. Considering both the readiness and the impact, the final five technology options from the four groups of technology needed in the energy sector (which have the score greater than 8.5 out of 10) (**Table 12**) are as follows:

(a) Energy supply

- Smart grid

(b) Renewable energy technology

- Waste (power generation)
- Second and third generation of biofuels

(c) Energy efficiency improvement

- Fuel Combustion in industry sector

(d) Other energy sector

- Carbon capture and storage (CCS)

All of the five selected technologies are vital mitigation technologies for increasing the capacity and efficiency of energy development and management in Thailand. For maximum benefit, all technologies should also be considered, by both public and private sectors, as important tools for driving the country toward the national policies and strategies in energy management. However, the development in the energy sector should focus on the integrated technologies addressing the whole system rather than only these five selected technologies, to support the climate change and GHG mitigation.

Table 12 Results of technology prioritization according to the two factors, readiness and impact

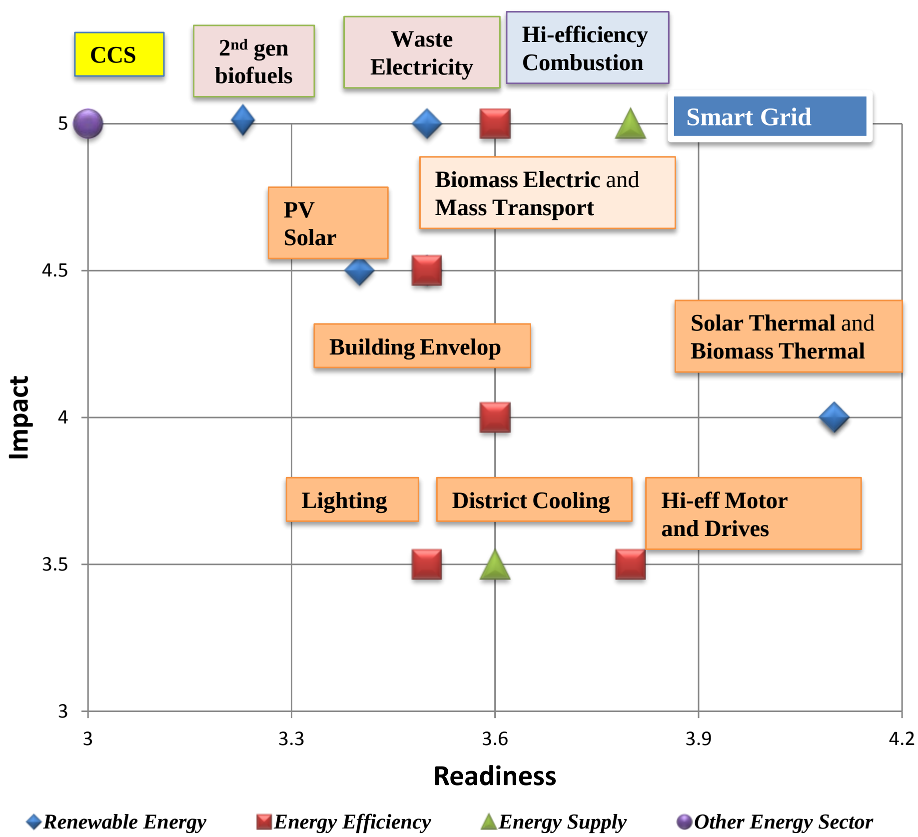
Technology	Readiness									Impact			Total
	Policy and plan including regulatory	Benefit and cost	Short-term trend	Management infrastructure	Possibility of domestically based production	Stakeholder and social acceptance	Current technology situation in Thailand	Current technology situation in developed countries	Sub-total point	Other impacts (social, economic and environment)	Estimated GHG mitigation of technology	Sub-total point	
Weighted of criteria	5%	5%	5%	5%	10%	10%	5%	5%	50%	25%	25%	50%	100%
Energy Supply													
· Power Generation													
- Efficiency improvement	3	4	2	4	1	3	2	4	2.7				
- Smart grid (cross cutting issue)	4	3	4	4	2	5	5	4	3.8	5	5	5	8.8
· Oil refineries and Natural gas separation	2	2	1	5	1	2	2	4	2.2				
· District cooling	3	3	4	3	2	5	5	4	3.6	3	4	3.5	7.1
Renewable Energy													
Solar Energy													
· Solar thermal	4	3	5	4	4	5	3	4	4.1	5	3	4	8.1
· Solar PV	4	1	5	4	2	5	3	3	3.4	5	4	4.5	7.9
Wind Energy													
· Electricity	4	1	3	3	2	5	3	4	3.2				
Waste and MSW													
· Thermal	4	2	3	3	2	3	4	4	3				
· Electricity	4	4	3	3	3	3	5	4	3.5	5	5	5	8.5
· For Fuel	1	2	2	1	1	3	5	2	2.1				
Biomass													
· Electricity	4	3	5	4	4	2	3	4	3.5	4	5	4.5	8
· Thermal	4	4	5	3	5	4	3	4	4.1	4	4	4	8.1
Biogas													
· CBG (Compressed Biogas)	3	2	3	2	2	4	5	3	3				
· Electricity	5	3	4	4	3	4	2	2	3.4				
· Thermal	5	3	3	3	3	4	2	2	3.2				
Biofuels													
· Biodiesel	4	3	5	3	3	4	2	3	3.4				
· Ethanol	4	3	5	4	3	3	2	4	3.4				
· 2nd generation biofuels	3	1	2	3	4	4	5	2	3.2	5	5	5	8.2
· NGV	5	3	5	2	2	3	4	4	3.3				
Energy Efficiency Improvement													
Commercial sector and Residential sector													
· Lighting	4	2	4	3	4	4	2	4	3.5	4	3	3.5	7
· Building Envelope	3	3	4	3	5	3	3	4	3.6	4	4	4	7.6
Industry sector													
· Motor and drives	2	5	4	3	3	5	3	5	3.8	4	3	3.5	7.3
· Combustion	3	4	4	3	2	5	3	5	3.6	5	5	5	8.6
· Chiller	2	3	3	2	2	5	2	5	3.1				
· Air Compressor	1	3	3	2	2	5	2	5	3				
Transport sector													
· passenger (Mass)	5	3	5	3	1	5	2	5	3.5	5	4	4.5	8
· passenger (Private)	3	3	3	2	2	4	5	5	3.3				
· Logistic (IT and planning)	3	3	3	2	3	4	4	3	3.2				
Other energy sector													
· CCS	3	1	2	2	2	5	5	3	3	5	5	5	8

5 Conclusions

The present TNA report for climate change mitigation in Thailand is supported by the Global Environmental Facility (GEF) through the UNEP. The National Science Technology and Innovation Policy Office (STI) is assigned as the Thai TNA coordinator. The first step of the TNA is to identify highly impacted sectors in urgent need of mitigation technology. Thus, the first meeting for the Thailand Technology Needs Assessment project was launched on July 12, 2010 and could identify the energy sector as the most important sector for climate change mitigation. Subsequently, to develop a TNA for targeted sectors, the Steering Committee appointed Science and Technology Research Institute, Chiang Mai University as the national consultant for the energy efficiency and renewable energy sector.

In the development of the TNA, mitigation technology in four areas were initially proposed and discussed as they addressed the national goals of the energy management plans and strategies. These four groups of technologies include energy supply, Renewable energy technology, Energy efficiency improvement, and other energy technologies. Each group of technology has technology options. The technology options were ranked according to the readiness of the country and the impact to the country.

Fig 19 illustrates the results of technology prioritization based on the two criteria. The technologies selected for Technology Action Plans include smart grid, high efficiency combustion, waste to power, the second and third generation biofuels, and CCS.



Note: Selected technologies consist of smart grid, high efficiency combustion, waste to power, the second and third generation biofuels, and CCS.

Fig 19 Results of technology prioritization

Section II

Technology Action Plans

Executive summary

In this section, the TAPs for each technology were developed to achieve technology implantation. In this process, barriers to the transfer and diffusion of the prioritized technologies were identified. The barriers related to technology implementation have been identified in four aspects; i.e. (i) financial, (ii) policy and regulatory, (iii) technology, and (iv) capacity building. All barriers are summarized as follow.

Table 13 Summary of the barriers

	Smart grid	Waste (to power generation)	Efficient Fuel combustion	CCS	Second generation biofuels
Financial	- High investment costs on technology and infrastructure	-High investment costs on technology and energy infrastructure	- Low to medium investment costs	- Very high investment costs on technology and infrastructure	-High investment costs
Policy and regulation	- No clear roadmap policy for EGAT and MEA -Require safety standard and measurement - Lack of collaboration with international institutes in term of technology or researcher or expert exchange	- REDP has developed the roadmap on this issue - Unclear policy covering all stakeholders' benefit e.g. scavenger - Unclear policy on waste separation policy	-Require the national action plan	- No policy and regulation related to CCS, especially on operating and monitoring	- Require clear policy that encourages and supports both researchers and private sectors to invest on the technology
Technology	- Technology must be imported - Research and Development is still at the initial state and very limited to certain institutes - Lack of information on climate change issue and the smart grid - System must be maintained by power utility	- Technology must be imported, especially the HTT technology	- Certain technology must be imported	- Research and Development is still at the initial state and very limited to certain institutes - Lack of supporting funds for research on feasibility study, technology impact both inshore and offshore	- This technology has been well developed in certain countries. - Require both fundamental and advance research, especially on technology development and life-cycle assessment

	Smart grid	Waste (to power generation)	Efficient Fuel combustion	CCS	Second generation biofuels
Capacity building	- Lack of fundamental knowledge on technology, infrastructure design, and maintaining system	- Lack of fundamental knowledge on technology - Lack of waste separation management - May raise conflicting issue with the community	- Lack of fundamental knowledge on technology - Lack of good practice, especially on small to medium industry	- Lack of fundamental knowledge on technology, infrastructure design, and maintaining system - May raise conflicting issue with the community	- Lack of fundamental knowledge on technology

The technology action plan of each selected technology is summarized in Table 14 -18.

The technology implementation activities are divided into 3 phrases: short, medium, and long term. Moreover, the activity prioritization is also summarized in the tables.

Table 14 Technology action plans of smart grid

No./ Priority	Activities	Period			No./ Priority	Activities	Period		
		S	M	L			S	M	L
Financial					***Technology***				
A1/High	Control system and battery storage: Apply for international fund	✓			A13/ Very high	Prioritize the needs for developing smart grid devices such as smart meter and storage	✓		
A2/High	Smart metering : request financial support government	✓			A14/ Very high	Technology feasibility analysis at the country level	✓		
A3/ Normal	Smart grid device: Financial support from government through special projects, tax incentive		✓		A15/High	Demonstrate the full pilot smart grid project operation		✓	✓
A4/ Normal	Encourage education and/or research works		✓		A16/High	Study the impact of the smart device market to climate, social, and environment	✓		
A5/High	Encourage PEA, MEA and EGAT to invest and develop main control system	✓	✓						
A6/High	Feasibility study on CDM-PoA in smart grid	✓							
A7/ Normal	Study on the potential of internationally supported NAMA concept		✓						
Policy and Regulatory					***Capacity Building***				
A8/ very high	Develop smart grid national plan along with the roadmap	✓			A17/ High	Expand network among academic and research institutes	✓		
A9/ very high	Develop clear policies and regulations with framework and timeline to internalize smart grid to REDP and NEEP	✓			A18/ High	Strengthen international research network/ programme		✓	
A10/ Normal	Study international standard for smart grid device (e.g. IEEE, IEC and ISO)		✓		A19/ High	Scholarships or grants from agencies e.g. Energy Conservation Promotion fund or Power plant fund	✓	✓	
A11/ Normal	Establish institute that can certify activities associated with smart grid			✓					
A12/ Normal	Set the policy to test both security and stability of smart grid by both system and each device		✓						

Table 15 Technology action plans of waste (to power generation)

No./ Priority	Activities	Period			No./ Priority	Activities	Period		
		S	M	L			S	M	L
Financial					**Technology**				
B1/ Very high	Apply for international fund, especially on technology e.g. HTT and other waste technology (RDF)	✓	✓		B9/ Very high	Develop technology transfer mechanism, especially the HTT	✓	✓	
B2/ High	Budget allocation for technology development e.g. incineration, landfill	✓			B10/ High	Promote technology investment to Thai entrepreneurs		✓	
B3/ High	Government supports for waste to power through the special projects/mechanisms (e.g. tax incentive, soft loan, feed-in-tariff)	✓	✓		B11/ Normal	Study the impact of the waste market to power or energy generation	✓		
B4/ Very high	Study on the potential of CDM-PoA in waste to power from national level or provincial level	✓			B12/ Normal	Study management and economics aspects including the LCA for waste to energy	✓		
B5/ Normal	Study on the potential of domestic/international supported NAMA concept	✓			B13/ Normal	Analyze the climate change impact from all waste to energy technology	✓		
Policy and Regulatory					**Capacity Building**				
B6/ High	Enact policy or regulation that enhance ability to implement the waste to power	✓			B14/ Very high	Strengthen research network among academic institutes, especially on HTT	✓		
B7/ Very high	Create the waste separation system	✓	✓		B15/ High	Capacity building in local community and NGO and public promotion in waste separation system and motivation by training, seminar or exhibition	✓	✓	
B8/ Very high	Set up policy to alleviate the non-technical issue including the long term support policy	✓	✓		B16/ Normal	Develop community network in waste management to energy	✓		

Table 16 Technology action plans of energy efficiency in boiler

No./ Priority	***Activities***	***Period***			***No./ Priority***	***Activities***	***Period***		
		S	***M***	***L***			***S***	***M***	***L***
Financial					***Technology***				
C1/ High	Apply for international supports for expensive devices	✓			C11/ Very high	Sector or industry prioritization to be implemented the selected technologies (i.e. modulating burner and once-through boiler)	✓		
C2/ High	Budget allocation for implementing energy efficiency in boiler project	✓			C12/ Very high	Feasibility study of possible technologies	✓		
C3/ Normal	Government supports private company investment for domestic based production e.g. soft loan, tax incentive, DSM bidding	✓	✓		C13/ High	Develop technology transfer mechanism both domestic and international level		✓	✓
C4/ Normal	Investigate GHG reduction potential of CDM-PoA	✓			C14/ High	Support domestic based production	✓	✓	
C5/ Normal	Feasibility study for developing NAMA concept		✓		C15/ Normal	Monitoring the results of implementing the project, especially in boiler equipment market		✓	
					C16/ Normal	Study the GHG emissions reduction		✓	
Policy and Regulatory					***Capacity Building***				
C6/ Very high	Develop the roadmap and action plan for energy efficient in boiler burner	✓			C17/ High	Develop research network among academic institutes	✓		
C7/ Very high	Develop policies/regulations to support the NEEP (Northeast Energy Efficiency Partnerships) with a clear framework and timeline	✓			C18/ Very high	Technology transfer and approach in modulating burner and once-through boiler	✓	✓	✓
C8/ High	Study international standard and safety issues of energy consumption in burner		✓		C19/ Very high	Develop the technician and operator training programs in burner/boiler operation	✓	✓	
C9/ Very high	Establish research institute or encourage research works in this area	✓			C20/ High	Maintenance training and development by applying the Best practices case studies		✓	
C10/High	Regulatory/guideline/standard on fuel use per ton of steam production in each fuel type		✓						

Table 17 Technology action plans of CCS

No./ Priority	Activities	Period			No./ Priority	Activities	Period		
		S	M	L			S	M	L
Financial					**Technology**				
D1/ Very high	Apply for international funding on CCS	✓	✓		D11/ Very high	Feasibility study on location of CCS in both off-shore and on-shore	✓		
D2 /Normal	Research funding for CCS			✓	D12/ Very high	Study and research the geology and related data in both off-shore and on-shore	✓	✓	
D3/ High	Develop a long-term policy to support CCS	✓	✓		D13/ High	Study on CCS for storage, site assessment, geology, hydrogeology, EOR potential, technology selection, risk management, and best practices study		✓	✓
D4/ High	Encourage government agencies (PTT, EGAT, SCG) or research institute to study and/or invest on CCS pilot projects	✓	✓		D14/ High	Study the impact analysis of CCS to climate change from main technology	✓	✓	
D5/ Very high	Feasibility study on CCS-CDM	✓	✓						
D6/ High	Study the potential of internationally supported NAMA concept		✓						
Policy and Regulatory					**Capacity Building**				
D7/ Very high	Assign responsible parties for CCS	✓			D15/ High	Inform stakeholders about the issue related to CCS, especially on environmental impacts	✓	✓	
D8/ Very high	Develop policy that supports CCS technology e.g. design, construction, operation, injection, and monitoring post-injection	✓	✓		D16/ High	Establish CCS training programs	✓	✓	✓
D9/ Normal	Study the international standards and regulations in both the international covenant and sea borders, especially in natural gas and oil field		✓		D17/ High	Create CCS international cooperation development		✓	✓
D10/ High	Identify the needs for appropriate regulation or guideline or standard or licenses on CCS including safety guideline which should be along with international context		✓	✓	D18/ Normal	Public understanding of CCS role in GHG mitigation and enhanced oil recovery			✓
					D19/ Normal	Establish the CCS research network from public agency and academic institute		✓	

Table 18 Technology action plans of second generation biofuels

No./ Priority	***Activities***	***Period***			***No. /Priority***	***Activities***	***Period***		
		S	***M***	***L***			***S***	***M***	***L***
Financial					***Technology***				
E1/ Very high	Apply for international fund, especially on advance technology	✓	✓		E12/ Very high	Identify the most appropriate technology for second and third generation biofuels	✓		
E2/ Very high	Allocate budget for research and pilot scale projects	✓	✓	✓	E13/ High	Conduct fundamental researches on second and third generation fuels	✓	✓	
E3/ High	Promote private company/industry investment on the 2nd market	✓	✓		E14/ High	Set up demonstration plants		✓	✓
E4/ Very high	Encourage national energy agency to study and/or research on bioethanol and biodiesel		✓	✓	E15/ Normal	Manage collecting system of agricultural residue e.g. equipment and post-harvest machines		✓	
E5/ Normal	Study on the potential of CDM in biofuel		✓		E16/ High	Impact analysis of the technology to the market, agricultural or food sectors	✓	✓	
E6/ Normal	Study on the potential of domestic and international supported NAMA concept		✓		E17/ Normal	Investigate the GHG reduction from second and third generation biofuels	✓		
Policy and Regulatory					***Capacity Building***				
E7/ Very high	Develop national plan/roadmap for second and third generation biofuels	✓			E18/ High	Establish research institutes focusing on second and third generation biofuels	✓	✓	
E8/ Very high	Identify the government agency responsible for second and third generation biofuels development	✓			E19/ Normal	Capacity building in main issues to stakeholders focus mainly in the domestic production potential, understanding of GHG mitigation and other environmental impact		✓	✓
E9/ High	Study the international standards/regulations related to biofuels		✓		E20/ High	Prepare scholarship or grant to increase experts/ researchers in this area	✓	✓	
E10/ Normal	Establish research institutes particularly focus on second and third generation biofuels			✓	E21/ High	Organize training programs (exchange experts among world class institute) for related agencies both public and private sectors	✓	✓	
E11/ Normal	Identify the needs for appropriate regulation, guideline, or standard, including safety guideline		✓		E22/ Normal	Inform publics about the technology to have correct understanding		✓	✓

1 TAPs for the prioritized technologies in Energy sector

1. Preliminary targets for technology transfer and diffusion based on Section I

According to technology needs assessment discussed in Part 1, the action plans to achieve technology implantations are described in this part.

1.1 Targets for Technology Transfer and Diffusion

The objectives of Thailand's energy management technology transfer and diffusion have been set to respond to the policy and strategy in creating stability and sustainability in the national energy development. The prioritized technologies must be able to alleviate problems or increase efficiency of the infrastructure management system, as well as develop the competency of the domestic human resources. There following are the selecting criteria for energy sector.

1) Support adequate energy supply for energy security
2) Support energy development including environmental consideration
3) Renewable energy development (RE)
4) Energy efficiency improvement (EE)
5) Clean and new energy technology (CT)
6) Support energy business
7) Capacity building and knowledge management

Therefore in identifying action plans for each technology, consideration must be given to every step of the selection, the transfer process and diffusion, as well as the implementation of the technology to ensure achievement according to national targets, policy, and strategy.

1.2 Framework for Technology Action Plans

From TNA and TAP concepts developed by UNEP and Risoe center, there are five major steps in identifying the technology action plan.

(1) Identify and prioritize technology
The criteria and the selection process were described in Part I

(2) Analyze the main barriers of the selected technology
There are four aspects related to the barriers (i) economic, (ii) regulatory, (iii) institutional, and (iv) capacity building

(3) Solution finding
Investigating possible solutions to address the barriers for the transfer and diffusion of technology

(4) Identify the energy technology action plans

Fig 20 presents the technology needs for the energy sector which are smart grid, waste-to-power, efficient burner, CCS, and second generation biofuels. Those technologies cover from the energy supply, transformation, distribution and end-use consumption.

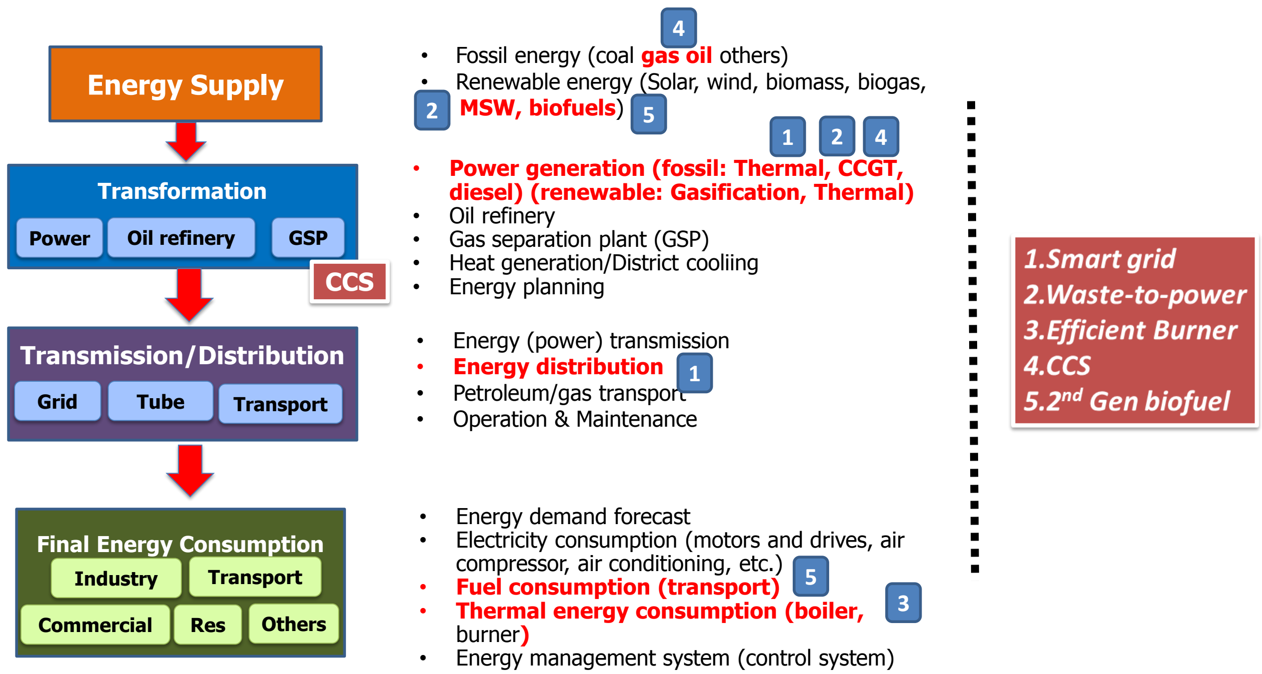


Fig 20 Technology needs assessment

1.3 Technology description and Mapping

In this section, all five prioritized technologies were introduced, briefly reviews and mapped in details of demand development, important issue for implement, and existing situation in the country. For more information on technology description, more details are provided in Annex 1.

1.3.1 Smart Grids

The term "smart grid" refers to a modernization of an electricity delivery system in which it includes monitoring, protection, and automatically optimizing the operation of interconnected electrical elements - from the central and distributed generator through the high-voltage network and distribution system, to industrial users and building automation systems, to energy storage installations and to end-use consumers (Electric Power Research Institute, 2009).

The smart grid, as illustrated the concept in **Fig 21** responses to the power demand with quality of supply. The grid consists of elements that can self-heal from any events of power disturbance. Furthermore, it can accommodate any types of power generation and storage, and optimize power operation efficiently. The technologies involve in the smart grid are smart metering, storage system, and control system. A smart metering is an electrical meter that responds to both producer and user. The producer receives the information of the power consumption, and the user can acquire the electric expenses. The storage system stores excess power from power generation and keeps balancing power voltage. The importance of the storage system is demonstrated in **Fig 22**. Lastly, the control system manages the power generate connection and electrical distribution in a whole power network.

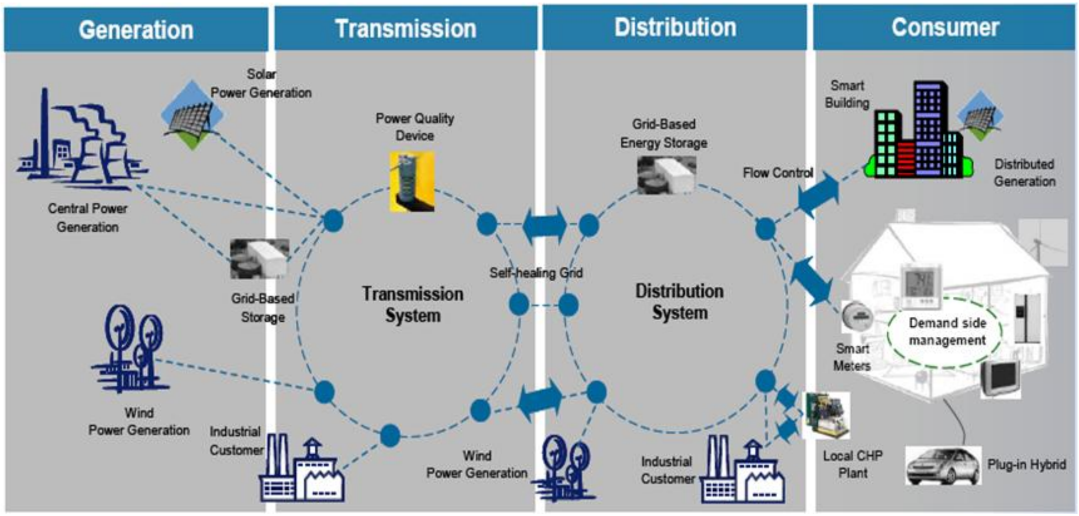


Fig 21 The concept of smart grid system
Source: (Major Economic Forum, 2009)

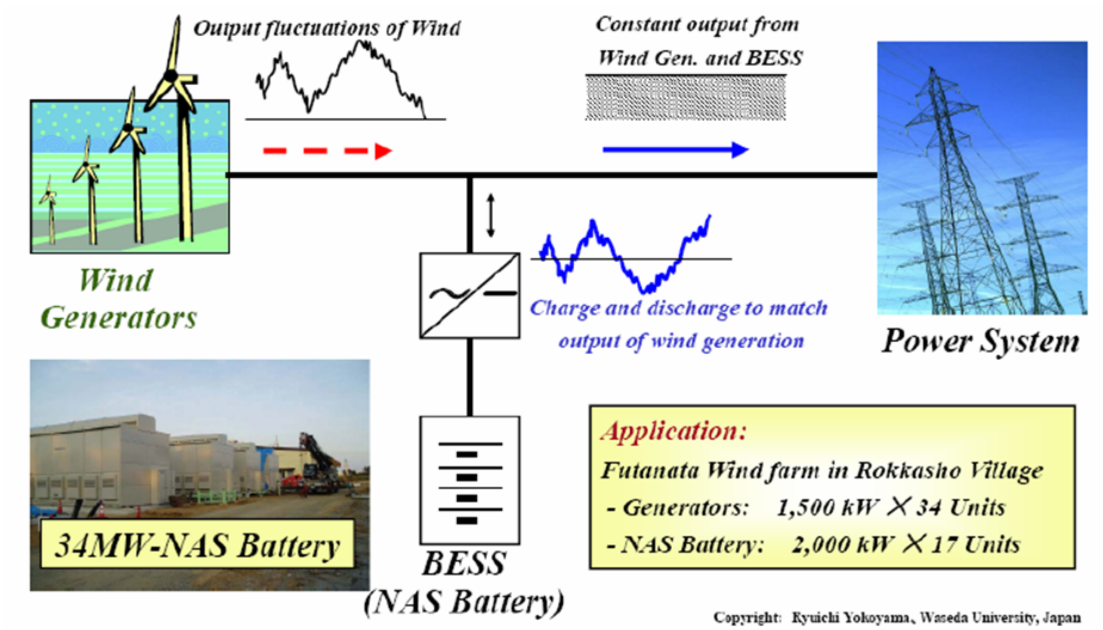


Fig 22 The storage system
Source: Kyuichi Yokohama, Waseda University, Japan(Yokoyama Ryuichi, 2011)

The Thai Provincial Electricity Authority (PEA) has initiated the smart grid plan since 2011. The project will be completed in the next 15 years. **Table 19** presents the technology mapping results and evaluates the status of the technologies.

Table 19 Technology map for smart grid

Technology Mapping: Smart Grid				
Sub-technology	**Details**	**Requirements for development**	**Important issues**	**Status/ accessibility**
1.1 Smart Metering	• An electric meter that responds to both producers and users • Real-time information of power consumption • Users can choose power supply sources and also monitor their electric expenses	• Advance technology • High investment • New power system • National policy that both enhance energy security and renewable energy • Actual electricity cost	• System risk • Plant and infrastructure location and technology • Cost per unit (including both fix and variable costs) • Laws and regulations • Privacy control for user)security(• Social and community acceptance	Early stage of research and development, rarely installed /limited
1.2 Storage system	• Stores power from power generation and balance power voltage for stable and reliable electricity • Support power to all sectors e.g. supply-side (the electricity from power generation or other substation), demand-side (all sectors) and mobile-side (hybrid or EV charger)			Early stage of research and development / very limited
1.3 Control system	• An information system to control the power generate connection and electrical distribution in complete network			Early stage of research and development / very limited

1.3.2 Waste to Power Generation

Dumped and burned on open field is still the most common waste management methods in Thailand. The Pollution Control Department (PCD) reported 65% of waste management is dumped and burned open field, 35% land filled, and 1% incineration (Pollution Control Department).

The dumped and burned open field leads to various consequence problems, for example, not enough land to dispose the waste, protest from community near dispose site, lack of man power, and etc. Alternatively, the PCD have been encouraging community to separate waste and convert to fertilizer (PCD, 2004).

A large percentage of waste is found in Bangkok in which it produces approximately 9,000 tons per day (Bangkok Metropolitan Administration, 2010). In other large size municipalities (around 25 municipalities) also produce more than 100 tons per day each. Therefore, it is a very high potential to convert those waste to useful energy. There are two appropriate technologies to convert the waste to energy: hydrothermal treatment and incineration. The hydrothermal treatment process, depicted in Fig 23, is a new technology that developed by the Tokyo Institute of Technology (Prawisudha, 2009).

The process converts raw waste to dry powder ready to use as fuel. The advantage of this technology is that the condensate from system can capture a pollutant such as Dioxin into liquid that can be treated easily. Moreover, the technology is compatible with all types of waste without separation prior. The commercial scale was used in Hokkaido, Japan as shown in Fig 24.

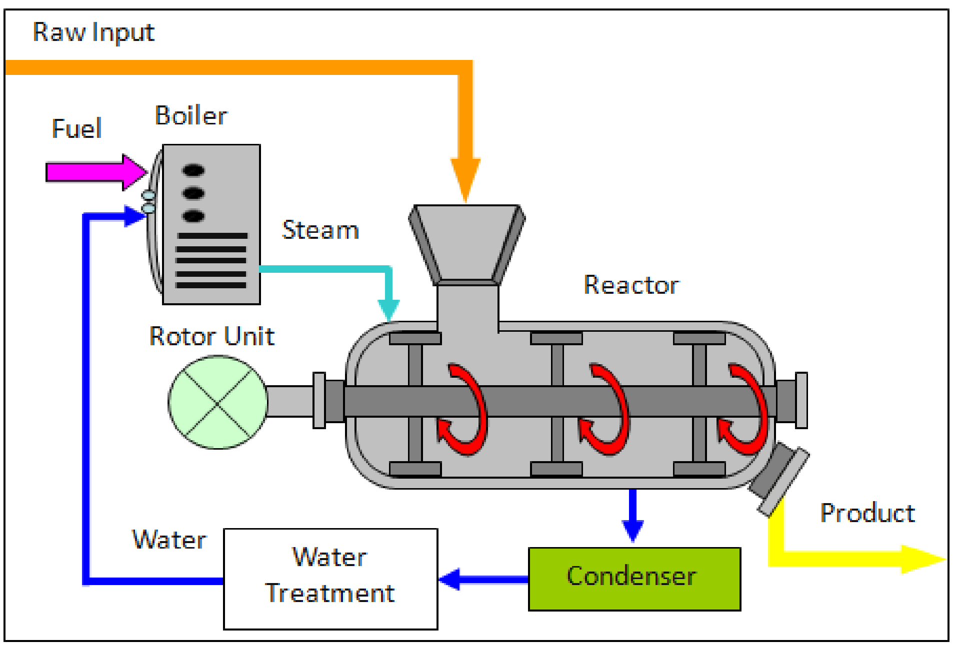


Fig 23 The Hydrothermal process converts raw waste to combustible product
Source: (Tokyo Institute of Technology, 2010)

Fig 24 Commercial hydrothermal plant in Hokkaido, Japan
Source: Tokyo Institute of Technology, 2010

The models proposed by Chaisawadi et al. (Chaisawadi, 2011) provides tentative solutions for small to large scale community. All models demonstrate the same basic key point, which is waste separation. The non-organic waste can be used as fuel source in incinerator that can generate both heat and electricity. Note that hazardous waste can be eliminated during this process. Table 20 presents the technology mapping results and the status of the technologies.

Table 20 Technology map for waste to power generation

Technology Mapping: Waste to power generation				
Sub-technology	**Details**	**Requirement for development**	**Important issues for implement**	**Status/ accessibility**
2.1 Hydrothermal Treatment Technology	• Transformation of waste to power. The pollutants such as dioxins can be released in liquid. (No need for waste separation)	• Advance technology e.g. Hydrothermal • High investment	• Information disclosure from owner technology, • Domestic based production is acceptable • Cost consideration in both fixed and variable cost • Stakeholder knowledge and confidence in technology	Early stage of research and development / very limit accessibility
2.2 Incinerator	• Waste to energy in form of heat and electricity		• Technology extension from technology owner • Domestic based production • Cost consideration • Stakeholder knowledge and confidence in technology	Beginning development / limit access

1.3.3 Efficient Fuel Combustion in Industry Sector

There are approximately 8,800 steam boilers in Thailand, in which they produce steam in total at about 110,000 ton per hour. To increase boiler efficiency, modulating burner and once through boiler are needed.

The modulating burner could vary and control water temperature as fixed. A computer acts as a brain of the system that controls fire intensity accounting for use load and external temperature. Fig 25 illustrates external parameters affect the building temperature e.g. occupancy levels, equipment, and weather. The capacity of modulated burner is rated by its “turn down ratio”, which is the ratio between the maximum and minimum power output of the burner (Sabien Technology Ltd.). When the power demand is within the range of the power output, the burner can continue operation without completely turning off. Fig 26 demonstrates the cost-saving from adopting the Sabien’s burner.

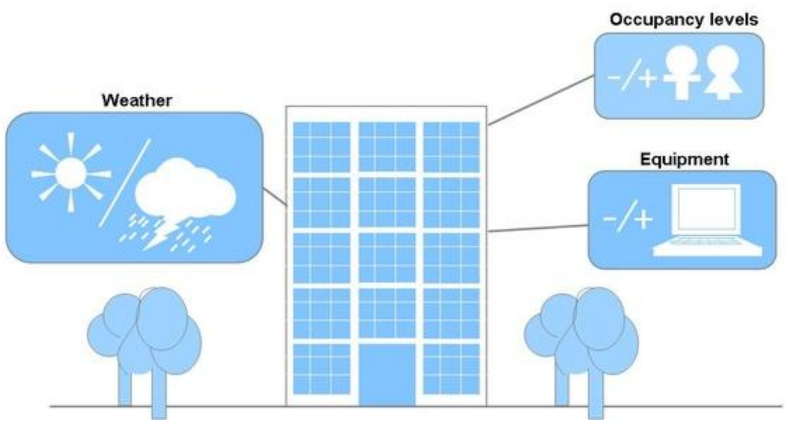


Fig 25 Parameters that affect building temperature

Client	Average Saving	Payback	£ per CO2t saved
O2	22%	< 2 years	£3.78
Marriott Hotels	22%	< 1 year	£2.48
Bradford Council	20%	< 1 year	£4.60
Newcastle City Council	16%	< 2 years	£24.67
Land Registry	15%	< 1 years	£4.87
Serco	13%	< 2 years	£10.28
Communities & Local Govt.	12%	< 2 years	£7.66
Royal Mail	11%	< 1 year	£4.20

Fig 26 The company cost saving after installed modulated burner

Research works have showed energy saving through a modulated burner. Christopher and Pat reported the used of modulated burner with biogas generated from wastewater treatment process (Snider, 2006) could save energy.

Moroz et al. reported the use of modulated burner in heat treatment process (Moroz, 1991). In this process, the burner is used in coupled with the solar heating) Citherlet, (2007. The control scheme of modulated burner in domestic heating system is discussed in (Rijckaert, 1999).

Another alternative technology is the once through steam generator (OSTG). OSTG produces steam from water inlet in one direction as depicted in Fig 27. This system can generate steam in comply with the demand that typically fluctuates throughout the operation. The OTSG offers smaller greenhouse gas footprint than typical boiler. Moreover, it is intrinsically explosion safe since only little amount of water content inside the boiler at a time. It also can be used with the combined cycle power plant as shown in **Fig 28**.

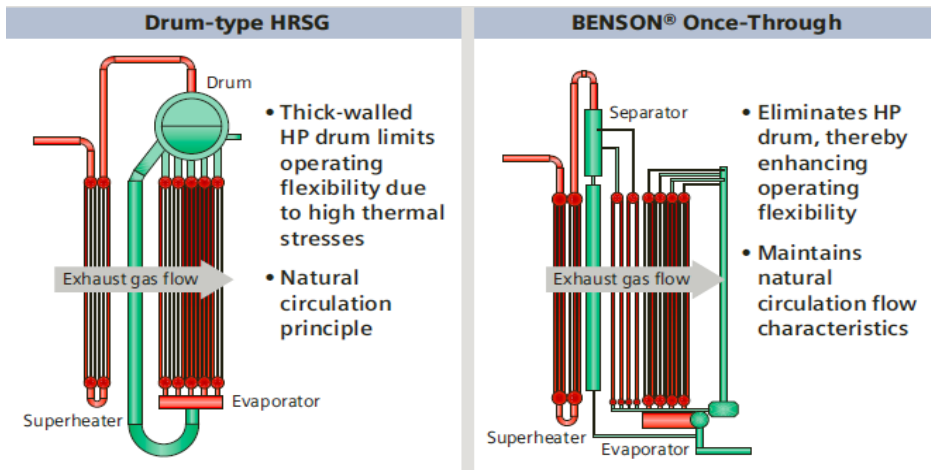


Fig 27 A comparison between the drum boiler and OSTG

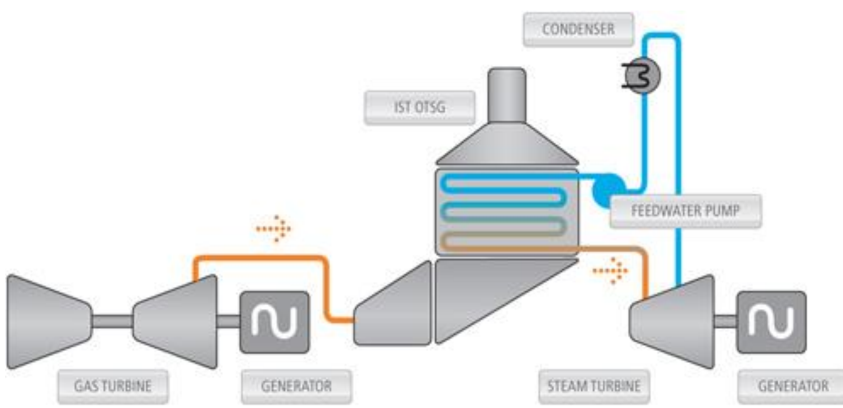


Fig 28 Combined cycle power plant with OSTG

The OSTG technology is mature because it has been developed since 1965 (Fanaritis, 1965). Many research works have conducted mathematical models and simulations to justify appropriate operations and designs. For example, Ray and Bowman developed a nonlinear model of the OSTG (Ray, 1976) and Zhao et al. study the heat transfer characteristics (Zhao, 2003). Dumont and Heyen proposed mathematic model of the once-through heat recovery steam generator (HRSG) (Dumont, 2004). The OSTG was first adopted in Thailand by the Ratchaburi Power Plant(Ando, 2002). It reported to be the first OSTG system in South-East Asia.

BENEFITS	OTSG	DRUM
COMPETITIVE CAPITAL COSTS		
Small footprint for reduced real estate needs	Yes	No
No diversion stack required	Yes	No
No blow-down equipment required	Yes	No
REDUCED INSTALLATION COSTS		
4-6 week installation time	Yes	No – 14-18 weeks for average installation
REDUCED OPERATIONAL COSTS		
No steam loss due to blow-down	Yes	No
Fast start-up and flexibility	Yes – OTSG can produce usable superheated steam in 15 minutes	No
Dry running capability	Yes – Only OTSG has dry running capability	No
Less make-up water required	Yes	No
Fewer operators required with simplified maintenance	Yes – OTSG has fewer components and 50 fewer I/O points	No
Increased electrical output and steam with same amt of fuel	Yes	No
No nitrogen blanketing or chemical cleaning	Yes	No
Remote operations capability	Yes	No

Fig 29 A comparison between OSTG versus drum boiler

Table 21 Technology maps in efficient fuel combustion

Technology Mapping: Efficient Fuel combustion				
Sub-technology	**Details**	**Requirement for development**	**Important issues for implement**	**Status/ accessibility**
Efficient boiler				
3.1 Modulating burner	• Ability to control and vary the fire so that water temperature stays precisely • The outdoor temperature is measured and adjusted accordingly	• Understand technology including processes and control system • Represent the actual fuel price	• Technology transfer from manufacturers and technology owner • Readiness of domestic manufacturer • Knowledge and reliable of technology in industry	Imported technology/ limit
3.2 Once Through Boiler	• Water is fed at the bottom, and steam is generated at the top of the stack • Compact design • Low accidental rate	• Demand of steam utilization is fluctuated • Keep the steam quality stability • Knowledge in material design • Increase in fuel price	• Technology transfer from manufacturers and technology owner • Readiness of domestic manufacturer • Knowledge and reliable of technology in Thai industry	Imported technology/ limit

1.3.4 Carbon Capture and Storage (CCS)

Carbon capture and storage (CCS) is relatively new technology that could directly capture CO_2 from the source and store in places that the green-house gas does not enter to the atmosphere. The integrated pilot-scale of CCS power plant was started in 2008 by German company. It reported that the power plant equipped with CCS could reduce 90% of CO_2 emissions (Metz, 2005). The CCS technology comprises of three major steps. **Fig 30** demonstrates capturing, transporting, and storage of CO_2 in all routes. The CCS can be categorized into 3 types. The first type of CCS is called post-combustion CCS. This CCS technology captures CO_2 from the exhaust gas. It targets to install mainly in energy industry such as power plant. Instead of capturing CO2 from post combustion, alternatively, pre-combustion CCS removes CO_2 before the combustion process. This process converts hydrocarbon fuel into carbon monoxide (CO) and hydrogen gas (H_2). The next step is to convert CO into CO_2 by reacting it with water, known as shift conversion. Finally, the CO_2 is separated from the hydrogen which can then be combusted cleanly. The CO_2 can then be compressed into liquid and transported to a storage site. The hydrogen gas can be used as fuel directly (Scottish Carbon Capture and Storage, 2012).

The last CCS technology is called the O_2/CO_2 recycle (oxyfuel). This technique extracts pure oxygen from ambient air and then used in combustion process. The exhaust gas product, in which it contains CO_2 and H_2O, is partially recycled back to the plant. The remaining gas is sent to CO_2 capture and storage. The three primary methods for CO_2 capture today are pre-combustion capture, post-combustion capture, and oxyfuel firing for CO_2 capture.

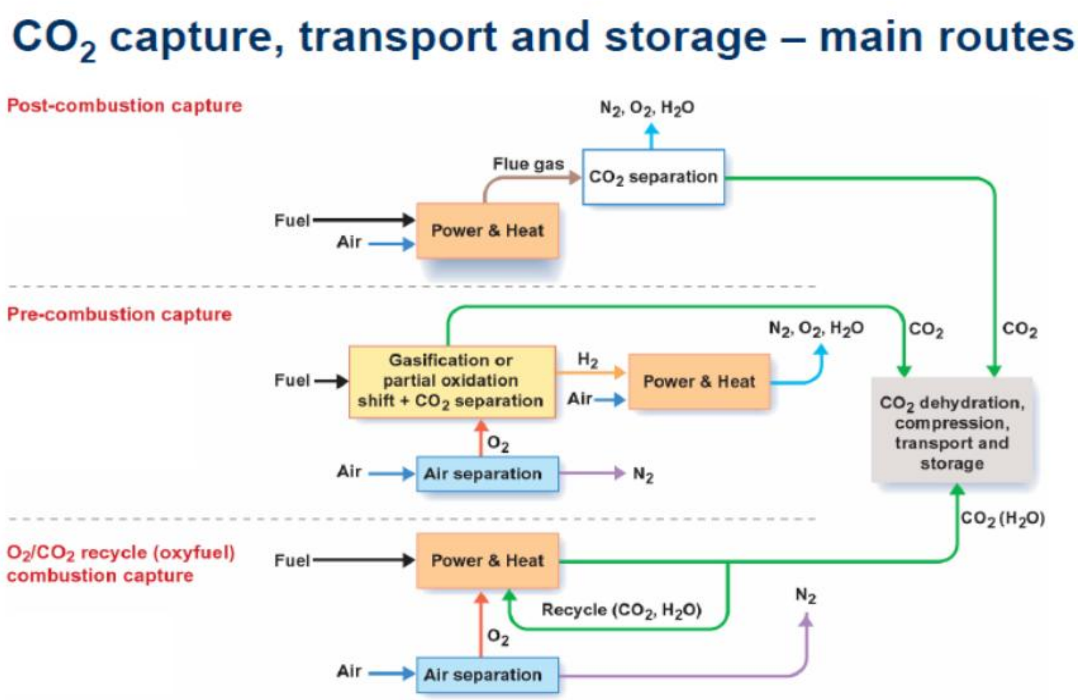


Fig 30 CO_2 capturing, transporting and storage routes
Source: (VGB, 2011)

It is said that CCS is one of the lowest-cost in green-house gas mitigation(International Energy Agency, 2009). The roadmap from IEA provides 40 years (2010-2050) perspectives of CCS in term of investment cost, number of CCS projects, and etc. **Fig 31** shows storage capacity of each region and usage in 2050.

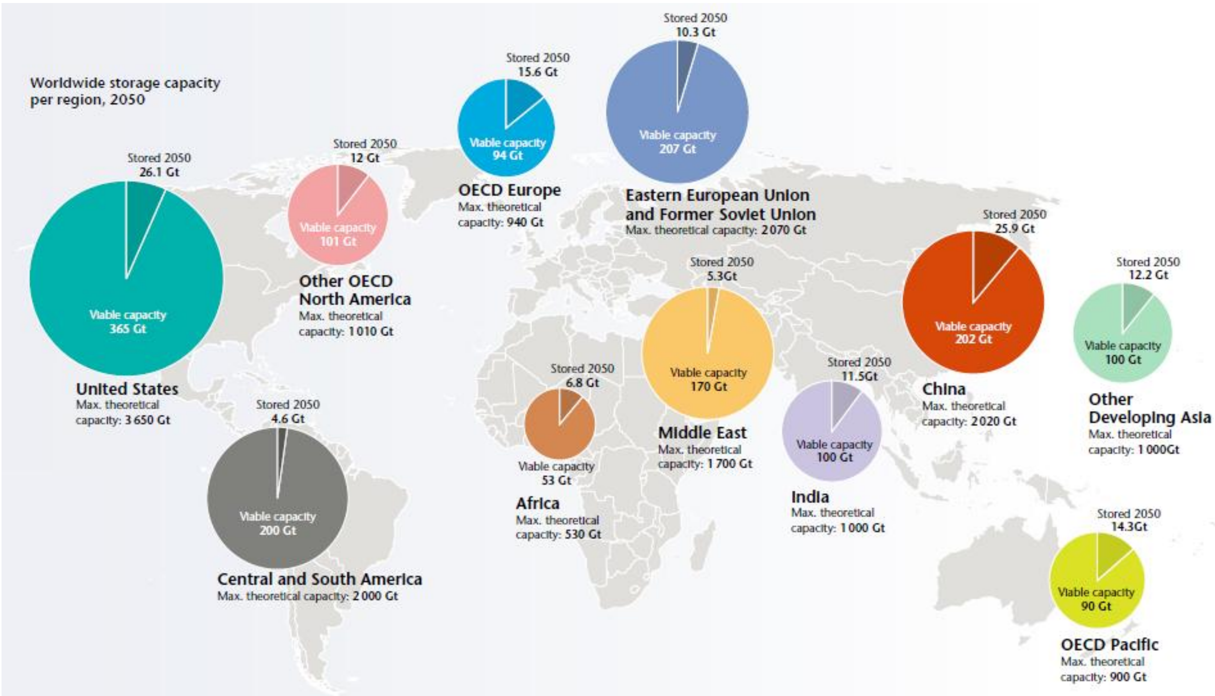


Fig 31 Theoretical viable CO_2 storage capacity in each region in 2050 (IEA, 2009)

The Shell is one of the private companies to sponsor CCS project in Canada (Shell, 2011). In Thailand, Pattanapongchai and Limmeechokchai (Pattanapongchai, 2010) proposed CO_2 mitigation model for future power plant. The Thailand Environment Institute (TEI) and the Thailand Business Council for Sustainable Development (TBCSD) (Viboonchart, 2011) was also launched a pilot project that utilized mangroves to capture and store CO_2 although it does not perfectly align with the CCS technology. Furthermore, Sritong et al.(Sritong, 2011) studied the microalgae as CO_2 storage.

For the government agency, the Department of Mineral Fuels (DMF) also studied on CCS roadmap for Thailand which includes the capacity building, government roles, regulatory framework and technical survey. The CCS roadmap in this study comprises three phases covering capacity building, project development, regulatory issues, incentives and stakeholder engagement issues from 2011 to 2030. **Table 22** showed the technology mapping results and status of the technologies.

Table 22 Technology maps in CCS

Technology Mapping: CCS				
Sub-technology	**Details**	**Demand for development**	**Important issues for implement**	**Status/ accessibility**
1.1 Post combustion capture	The CCS basic concept Mainly applicable to energy sector e.g. power plant CO_2 from exhaust gas will be captured and stored	• Require imported technology • High investment cost • Knowledge of CCS technology • Regional and stratum in-depth analysis • Investment and technology risk assessment • Cooperate system design or feasibility study (currently, PTT studied in 1 site; i.e. CCS South Bongkot NG Producing area with potential at 1 Mt-CO_2 annually). The study also reported not cost effective even with CDM.	• Technology transfer (know-how) • Fixed and variable cost • Require law and regulations mandate, Currently only EOR: Enhanced Oil recovery can do through Petroleum Act • Social and community acceptance • Appropriate CCS site and technology decision • Technology and experience transfer to operator via capacity building	Beginning / Very limited
1.2 Pre-combustion capture	• Applicable to some chemical industries or gas productions (hydrogen and methane) • Fuel will be transformed to CO and burned by gasification CO will be transformed to CO_2 and stored Hydrogen will be used as fuel			None / Very limited
1.3 O_2/CO_2 Recycle (Oxyfuel)	Separate O_2 from air to burn fuel in power/heat plant • CO_2 from combustion and steam will be recovered to the system			None / Very limited

1.3.5 Second and Third Generation Biofuels

Since Thailand is one of the largest agriculture producers, the country has large amount of agricultural residue that is potentially be converted into energy. The residue is normally disposed by either land filled or burn and could lead to other problems e.g. NIMBY or air pollution. The second generation biofuel (e.g. agricultural residual or cellulosic ethanol) could potentially address those residues and attain fuel. In addition, cellulosic ethanol could reduce emissions of greenhouse gas significantly. For example, lignocellulosic biofuels can reduce greenhouse gas emissions by 90%, comparing to fossil petroleum, while first generation biofuels could cut emissions by 20-70%. **Fig 32** indicates theoretical production price for the biofuels in some selected countries.

		Feedstock price*	**USD/lge**	
oil price: USD 60/bbl		USD/GJ	**Btl-diesel**	**lc-Ethanol**
Woody energy crops	global (IEA analysis)	5.4	0.84	0.91
Straw/stalks	China	1.9 - 3.7	0.66 - 0.79	0.68 - 0.85
	India	1.2 - 4.3	0.62 - 0.80	0.63 - 0.86
	Mexico	3.1	0.74	0.79
	South Africa	0.8 - 3.1	0.6 - 0.74	0.6 - 0.79
	Thailand	2.0 - 2.8	0.67 - 0.72	0.67 - 0.77

*Note that feedstock prices reflect assumptions by local experts and might vary regionally
Assumed cost factors are: capital costs: 50% of the total production costs; feedstock is 35%; operation and maintenance (O&M), energy supply for the plant and others between 1-4% each.
Source: Based on IEA analysis presented in ***Transport, Energy and CO_2*** (IEA, 2009c)

Fig 32 Theoretical production prices for second-generation biofuels in selected

Fig 33 shows raw material for the first, second and third generation biofuels. It indicates that Thailand is ready to move to second generation biofuels, if technology is developed. More research works are required to emphasize on conversion process that converts biomass cellulose to liquid fuel. The conversion process technologies include biochemical, thermo-chemical, and biodiesel from algae. On the other hand, the value chain products and technology must also be developed and promoted. This includes a quality supply of conversion process enhancer such as enzyme, catalyst and bio organism as well as the equipments or process involve in the process such as gasification.

First, Second and Third Generation Biofuels

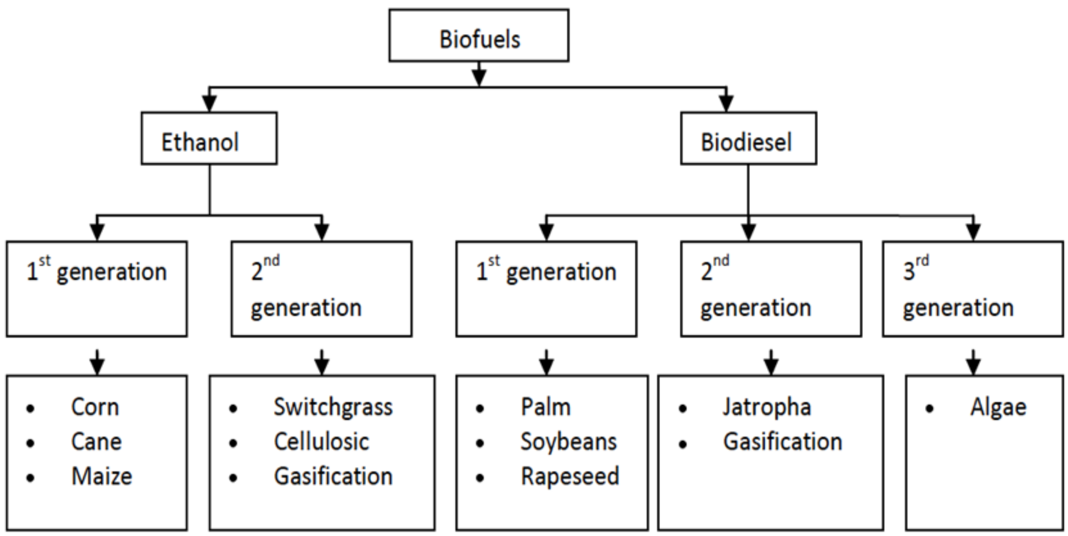


Fig 33 The first, second and third generation biofuels routes

Source: Altprofits, 2009
Note: In some documents (e.g. National Non-food crops center, USA), algae also considers as second generation biodiesel.

The petroleum authority of Thailand (PTT) initiates the support for second generation biofuels as its corporate social responsibility (CSR) activities since 2007. The research networks consist of PTT, BIOTEC (NSTDA) and server universities were form in the name of Thailand collaborative research network on micro-algal energy/fuel (THINK ALGAE). They target to produce energy/fuels from algae with competitive price by 2017. The biofuel was highlighted in financial outlook report in (KPMG LLP, 2009). While the biofuels gain popularities as sustainable alternative to fossil fuels, more research needs to carry out to bring the production cost more attractive. Li and Liu (Li, 2008) provide perspective of microbial oils production. Sun and Cheng (Sun, 2000) gave a review of lignocellulosic conversion process to ethanol. **Table 23** shows the technology mapping and the status of the technologies.

Table 23 Results of technology maps in second and third generation biofuels

Technology Mapping: 2nd and 3rd Generation Biofuels				
Sub-technology	**Details**	**Requirements for development**	**Important issues for implement**	**Status/ accessibility**
1.1 Conversion Process	• Technology for converting cellulose to liquid fuel • Type of technology: 1. Biochemical conversion process 2. Thermochemical conversion process 3. Biodiesel from algae • High potential of biomass from agricultural waste	• Fundamental research works for second-generation biofuels • Research funding • Understanding in technology including processes and equipment • Technology suitable for specific raw material • Risk management analysis on investment and technology selection • Preliminary design and feasibility study	• Separation of food and energy chains • Own technology, reduce imported technology • Knowledge related to equipment and machines for collecting and harvesting agricultural waste • Investment feasibility • Policies and regulations • National institute • Databases • Human development in the areas of research techniques and management	Early stage of research and development/ Limited
1.2 Value chain products & technology	• Products needed in the production such as enzyme, catalyst and others • Process or equipment that uses in the process such as gasification			

2 Barrier Analysis

The barriers to the transfer and diffusion of forecasting and warning systems can be summarized into four aspects: policy, technology, financial, and capacity building barriers. The details of these barriers are discussed in this section. The overall technology barrier involves inefficient budget for fundamental research and project investment. In addition, research essential for the technology application are still in a nascent stage of development. Besides, the lack of data integration and collaboration among research institutes is one of the key challenges for technology development.

2.1 Barrier identification and analysis for the transfer and diffusion of smart grid

Policy Barriers

For the initial start of smart grid system, technologies must be imported since those technologies are still in early stage of research and development.

This introduces high investment to deploy such system in Thailand. Although successful implementation increase efficiency of overall power supply system substantially, the policy does not appear in every organization involve in electric power supply. There is information appear in the roadmap for Provincial Electricity Authority (PEA)(Provincial Electricity Authority, 2011). However, neither the Electricity Generating Authority of Thailand (EGAT) nor Metropolitan Electricity Authority (MEA) has clearly defined plans. Furthermore, there is no law/regulation that allows the integration or cooperation among those electricity generating authorities, i.e. EGAT, MEA and PEA.

The lack of information on impact of smart grid to the climate change could slow down the smart grid action plan. Thus, the benefits of the technology to climate change should be more emphasized.

Technological Barriers

The fundamental problem of technology barrier is the lack of scientists or engineers to developed modeling tools. For this reason, most of the advanced tools are imported. Moreover, the lack of collaboration among researchers/institutes also leads to incomplete analyses.

Financial Barriers

Advanced technologies needed for research in this field are pretty costly and require the help of the government. There is no clear cut that which organization will absorb those costs; for example, the smart meter that can send usage data back to the utility provider.

Capacity Building Barriers

The lack of fundamental knowledge from design to system maintenance sets researchers apart into tiny groups that cannot create any impactful results.

Smart grid requires real-time interaction between energy providers and users. This means that the network system must be reliable and nationwide. Some remote areas still do not have electricity for usage. The electricity and data network in Thailand are only congested at urban area. Therefore, the implementation of the smart grid can initially be achieve in urban area and may not be fully completed.

All barriers identification and analysis for the transfer and diffusion of smart grid are summarized in Table 24.

Table 24 Barriers identification and analysis for the transfer and diffusion of smart grid

Barriers and solutions - Smart Grid			
Sub-technology	**Barriers**	**Solution**	**Stakeholders**
1.1 Smart Metering 1.2 Storage system 1.3 Control system	**Financial:** • High investment cost and require high energy potential **Policy and Regulatory:** • Roadmap policy appear in PEA's plan but no clear policy or action plan for EGAT and MEA • No equipment standard and IT Security system • No cooperation with international organization.	**Financial:** Plan to get more supports from abroad in high technology equipment **[Short term]** Government support the financial for smart device though the projects/measures (e.g. Tax incentive, ESCO fund) **[Medium term]** Implement and deploy energy authorities for education and/or research **[Short term]** CDM-PoA/Credited NAMA concept **[Short term]** **Policy and Regulatory:** • Put smart grid in the national action plan along and clearly assign the related authorities responsibility **[Short term]** • Study and push the clear policies/regulations for support in appropriate period and internalize smart grid to REDP and EEP with clear success framework and time duration **[Medium term]** • Study the international standard (IEEE, IEC, ISO) of the smart equipment and may establish the National Smart Grid • Certification center. **[Short to Medium term]** • Set the policy to test both security and stability of smart grid by both system and each device **[Short term]**	*MoE* *DEDE and EPPO* (policy, regulatory and promotion, capacity building) *ERC* (policy and regulatory) *EGAT, PEA, MEA and end-users* (implement, finance, capacity building) *MOST and MoEd* (research and development, capacity building)

Barriers and solutions - Smart Grid			
Sub-technology	**Barriers**	**Solution**	**Stakeholders**
	Technology: • All technology need to import and the equipment has various types. However, it should be start developing from the most importance and high potential, • The research and develop in Thailand is at beginning in institute or university level but not in wide-spread, • No information of smart grid in climate change impact, • System must be maintained by power utility. **Capacity Building:** • Lack of technology knowledge from technology design to maintaining	**Technology:** • Prioritize the smart grid devices and start plan to developing that device such as start metering and storage **[Short term]** • Potential and feasibility analysis in country level and beginning area and demonstrate the full pilot project operation. **[Short to Medium term]** • Study the impact of the smart device market **[Short term]** • Analyze the climate change impact of smart grid **[Short term]** • Suggest and push for Utility to invest and develop the main control system **[Short term]** **Capacity Building:** • Develop a research network from academic institutes with best practices case-study **[Short term]** • Develop international smart grid network. **[Medium Term]**	

2.2 Barrier identification and analysis for the transfer and diffusion of waste to power generation

Policy Barriers

Converting waste to energy has always attracted attentions from many organizations. However, high investment cost is required to meet economy of scale. The policy that encourages cooperation mechanism between private and government sectors should be deployed.

Technology Barriers

The fundamental problem of technology barrier is the lack of scientists or engineers to developed modeling tools. For this reason, most of the advanced tools are imported and they have license. The expensive technology license prohibits the ability to import the full option technology. Moreover, the lack of collaboration among researchers/institutes also leads to incomplete analysis.

Financial Barriers

The plant to transform waste to energy requires new setup. As a result, initial investment is very high. The skyrocketing cost may not attract many investors. The aid from the government may require.

Capacity Building Barriers

Currently, there is no mandate for waste separation. Since the waste is not wanted from any community, establish the waste treatment plant may cause conflict with community and/or non government organization (NGO) or even from existing scavenging business. All barriers identification and analysis for the transfer and diffusion of waste to power generation are presented in Table 25.

Table 25 Barriers identification and analysis for the transfer and diffusion of waste to power generation

Barriers and solutions - Waste to power			
Sub-technology	**Barriers**	**Solution**	**Stakeholders**
2.1 Hydrothermal Treatment Technology 2.2 Incinerator	**Economic:** • High investment cost • Seasonal fluctuations in the quantity of waste being collected **Policy and Regulatory:** • REDP has Roadmap and clear policy • Require policy to cover all stakeholders e.g. scavenger etc. **Technology:** • Main equipment need to import, • This technology belongs to Japanese license (HTT)	**Economic:** • Plan to get external support for expensive device **[Short term]** • Government support the financial for smart device though the projects/ measures (e.g. Tax incentive, ESCO fund) **[Medium term]** • CDM-PoA/Domestic or Credited NAMA concept **[Short term]** **Policy and Regulatory:** • Law or regulation that promotes waste separation **[Short term]** **Technology:** • Plan for technology transfer and promote for Thai entrepreneurs to domestic production **[Short term]** • Study of the impact of the waste/trash market. **[Short term]** • Analyze the climate change impact from waste to energy technology **[Short term]**	*MoE* *DEDE and EPPO* (policy, finance, regulatory and promotion, capacity building) *MoIn (DIW)* (policy and regulatory) *MNRE (PCD, ONEP)* (regulatory on emission waste, and EIA, capacity building) *MOST and MoE* (research and development, capacity building)

Barriers and solutions - Waste to power			
Sub-technology	**Barriers**	**Solution**	**Stakeholders**
	Capacity Building: • Lack of knowledge management in the long-term, • Protest from community, Lack of waste separation management.	**Capacity Building:** • Advance technology transfer of HTT **[Short term]** • Capacity building in local community and NGO and public promotion in waste separation system **[Short term]**	

2.3 Barrier identification and analysis for the transfer and diffusion of Efficient Fuel Combustion in Industrial Sector

Policy Barriers

The roadmap policy in national energy efficiency plan also does not encourage enterprise to have efficient practice in boiler management. The steam boilers are known for high rate of fuel consumption. Proper managements of boilers are definitely creating real impact not only the operating cost but also the climate change. The investment cost is only partially preventing the implementation, the lack of better understanding of boiler operation in SME is also playing important role.

Technology Barriers

Due to the lack of scientists or engineers expert in this area, technologies that can be applied to achieve efficient fuel combustion need to be imported.

Financial Barriers

As usual for new technology, the high investment cost especially for the small and medium enterprise (SMEs) deflects immediate adoption of the technique.

Capacity Building Barriers

There is very little research on key technologies in Thailand. This is because those technologies may be already well developed. Furthermore, there is very little progress in material science that is the important knowledge to achieve practical equipment design and development.

All barriers identification and analysis for the transfer and diffusion of energy efficient in boiler are presented in Table 26.

Table 26 Barriers identification and analysis for the transfer and diffusion of energy efficient in boiler

<table>
<tr><th colspan="4">Barriers and solutions - Efficient Fuel combustion</th></tr>
<tr><th>Sub-technology</th><th>Barriers</th><th>Solution</th><th>Stakeholders</th></tr>
<tr><td>3.1 Modulating burner</td><td rowspan="2">Finance:
• High investment cost)especially in SMEs(
• Potential depends on steam demand pattern of each industry

Policy and regulatory
• Develop National energy efficiency plan

Technology:
• Need to import technology,
• Property right for domestic production.

Capacity building:
• Lack of knowledge in operation and maintenance in long-term
• Lack of good practice in boiler operation, especially in SME level.</td><td rowspan="2">Finance:
• Government support in financial measures (e.g. tax incentive or ESCO fund [Medium term]
• CDM-PoA/Domestic NAMA [Short Term]

Policy and regulatory
• Action and implement plan including loan incentive [Short term]
• Regulatory/guideline/standard on fuel use per ton of steam production in each fuel type [Long-term]

Technology:
• Technology transfer
• Support domestic based production
• Study the impact of implementing especially in boiler equipment market [Short term]
• Study on impact to climate change [Short term]

Capacity building:
• Technology transfer and approach [Short term]
Technician/operator training/development by using the Best practices case [Short term]</td><td rowspan="2">MoE
DEDE and EPPO
(policy, regulatory and promotion, finance, capacity building)

MoIn
DIW
(regulatory, finance, capacity building)

MOST and MoEd
(research and development)</td></tr>
<tr><td>3.2 Once Through Boiler</td></tr>
</table>

2.4 Barrier identification and analysis for the transfer and diffusion of CCS

The CCS is a new concept that is not wide spread among audiences. Implementation of this technology could introduce conflict to the local community. Moreover, long-term operation and maintenance have not confirmed the safety and sustainability of the system. Also, the CCS system has high investment cost and requires large area site to operate.

Policy Barriers

There is no policy aimed to address or implement CCS in term of monitoring, operating and leakage reporting. Thus, the CCS roadmap and policy should be developed in the national energy plan which clearly identifies responsibility of governmental agency. Thailand should prepare for CCS regulation matrix covering the capture, transport and storage including the licenses, permission, and safety control in all processes.

Technology Barriers

Since CCS is relatively new technology, not many research studies has analyzed the impact of climate change, geological storage atlas, and the effect of storage to neighbors.

Financial Barriers

Government funding in pilot scale CCS or enhanced oil recovery incentives should be considered.

Capacity Building Barriers

There is very limited research on CCS technology in Thailand. CCS experts and training programs must be transferred from developed country. Funding for research and development in CCS especially for enhance oil/gas recovery from natural gas processing should also set as top priority. All barriers identification and analysis for the transfer and diffusion of CCS are summarized in Table 27.

Table 27 Barriers identification and analysis for the transfer and diffusion of CCS

Barriers and solutions - CCS			
Sub-technology	**Barriers**	**Solution/TAP**	**Stakeholders**
1.1 Post-combustion capture	**Financial:** • High investment cost and require large area site • CCS to CDM is now in process	**Financial:** • Require international support **[Short term]** • Promote the study and/or research in pilot scale. **[Short term]** • Support CCS to CCS-CDM and Credited NAMA concept **[Short term]**	*MoE* *(DMF)* (policy, finance, regulatory, capacity building)

1.2 Pre-combustion capture	**Policy and Regulatory:**
	• Policy and regulation are not clear in CCS, especially in monitoring, operating, and reporting leakage
	• International Law
		Policy and Regulatory:
		• Study and deploy policies and regulations support in the appropriate time **[Short to Medium term]**
		  • 10 years → Design approval and construction
		  • 20-30 years → CCS Operate and Injection
		  • after 20 years → Monitoring site and post-injection
		• Study International std/regulations in both the international covenant and sea borders **[Medium term]**
			EGAT, PTT, IPP
			(implement, finance, capacity building)
			
			MOST and MoE
			(research and development, capacity building)

1.3 O_2/CO_2 Recycle (Oxyfuel)	**Technology:** • Thailand NG contains 15-35% CO_2 but still lack of research and develop in institute or university in CCS potential • Lack of deep stratum analysis both on- and off-shore • Lack of impact information in off-shore case that may impact to other country • Lack of study in CCS impact to climate change	**Technology:** • Potential and site (area) analysis of CCS **[Short to Medium term]** • Study and research the geology and related data **[Short term]** • Impact analysis of CCS to climate change **[Short Term]**	
	Capacity Building: • Lack of all technology knowledge from design to maintenance • May encounter protest against CCS in long term • Long-term safety operation and maintenance.	**Capacity Building:** • Establish the CCS research network from academic institute **[Medium term]** • Capacity building in CCS main issues to stakeholders including the understanding of environmental impact. **[Medium term]**	

2.5 Barrier identification and analysis for the transfer and diffusion of Second Generation Biofuels

Policy Barriers

Thailand has potential in creating the second and third generation biofuel. However, unclear government's policy has slowed the growing progress of the biofuel, even for the first generation. For example, there is no law or regulation that allows ethanol producers to sell the product other industries but petroleum industry under Section 7 according to Fuel Trade Act. Additionally, ethanol is still classified as liquor thus it is under Liquor Act. Lastly, there is no enough incentive e.g. tax exception for new cars that can use higher ethanol content. The second generation biofuels involve not only the raw materials but also the related equipment and chemicals.

Technology Barriers

The R&D for second generation biofuel is limited to certain countries. For Thailand researchers have been developed for a while, but still at early stage.

Financial Barriers

Implementation the second generation biofuels production plant requires high investment, especially for the new technology and infrastructure. The production cost may higher than typical fossil fuel or first generation biofuels.

Capacity Building Barriers

Since technology and process to produce the second generation biofuels are very new, more research are need to carry out in domestic to eliminate technology dependent from oversea. Furthermore, there is no central institute to manage directions in developing key components to produce the second generation biofuels.

All barriers identification and analysis for the transfer and diffusion of second generation biofuel are presented in Table 28.

2.6 Linkages of the barriers

The previous section described the barriers related to the implementation of technologies for the country. To implement those technologies, there are common barriers among technologies which are summarized as follows:

- The lack of fundamental knowledge from the technology design to maintenance
- High investment cost of the technology, especially in CCS, smart grid, and second generation biofuels
- Require technology transfer
- Require training program, as well as research collaboration in all prioritized technologies
- Supportive and clear policy

Table 28 Barriers identification and analysis for the transfer and diffusion of second generation biofuels

Barriers and solutions - 2nd Generation Biofuels			
Sub-technology	**Barriers**	**Solution/TAP**	**Stakeholders**
1.1 Conversion Process	**Technical:** • 2nd generation biofuel technology has been developed in certain countries • Technology development in Thailand is still in the early stage • Limited number of experts in this area **Finance:** • High investment cost **Policy:** • Require clear policy that encourages and supports both researchers and private sectors to invest on the technology **Capacity building:** • Lack of national research institute	**Technical:** • Require fundamental research on the production **[Short to Medium term]** • Fiscal support in pilot scale and Demonstration plant **[Short term]** • Develop post-harvest separation and collection system including equipment and post-harvest machines **[Medium term]** **Finance:** • Investment fiscal support **[Short to Medium term]** • Focus on credited NAMA **[Medium term]** **Policy:** • Develop national plan the encourage the production and the use of biofuel **[Short term]** **Capacity building:** • Set up national institute to response all R&D **[Short term]**	*MoE* *(DEDE, DOEB and EPPO)* (policy, finance, regulatory and promotion, capacity building) *MoIn* *(DIW and BOI)* (regulatory and investment support) *MoA and MNRE* (long term supply, capacity building) *MOST and MoE* (research and development, capacity building)

Barriers and solutions - 2nd Generation Biofuels			
Sub-technology	**Barriers**	**Solution/TAP**	**Stakeholders**
1.2 Value chain products and technology	**Technical:** • Lack of research and development thus those advance technology must be imported **Finance:** • High investment cost **Policy:** • Lack of national plan **Capacity building:** • Lack of national research institute setting and value chain study for all details.	**Technical:** • Support fundamental and applied research **[Short to Medium term]** **Finance:** • Investment support for local usage and export **[Short to Medium term]** **Policy:** • Development national plan for 2nd-gen biofuel supporting industry **[Short term]** **Capacity building:** • Set up the study in value chain **[Short term]** • Prepare for the promotion to all sector **[Medium term]**	*MoE (DEDE, DOEB and EPPO)* (policy, finance, regulatory and promotion, capacity building) *MoIn* *(DIW and BOI)* (regulatory & investment support) *MoA and MNRE* (long term supply, capacity building) *MOST and MoE* (research and development capacity building)

3 Enabling Framework to Overcome the Barriers

Various dimensions of the barriers of each technology have been identified in the previous section. In this section, to overcome those barriers, an overview of an enabling framework is discussed. The aim is to illustrate the barriers and possible frameworks, as well as related stakeholders.

3.1 Possible solutions to address the barriers for the transfer and diffusion of Smart grid

Smart grid is one of the most advance technologies of which there is still no country has fully implemented this approach. To address the capability barriers, possible solutions are listed as follows:

Technology selection

Smart grid requires advance technology both from supplier and consumer. According to the first and second public hearing with many experts in electrical engineers, they selected the top three smart grid technologies that should first be developed; they are smart metering, power storage system, and smart control system. Besides, more research works on these following topics should be conducted in the meantime.

- Conduct a cost-benefit analysis/project feasibility study at the national level and initial pilot project
- Study the impact of the smart device market
- Analyze the climate change impact of smart grid

Policy and regulation

- Embrace the smart grid technology in the national plan
- Enact policies/regulations for support in appropriate period and internalize smart grid to REDP and EEP with a clear success framework and milestone
- Review international standard (e.g. IEEE, IEC, ISO) of the smart grid equipment and launch the National Smart Grid Certification center
- Relevant policy on monitoring, safety, and stability issues of the smart grid

Financial:

- Applying for financial support from both domestic and foreign funding agencies
- The Government could support the smart grid device though the projects/measures (e.g. tax incentive and ESCO fund)
- Applying for research budgets on the potential of CDM-PoA/ internationally supported for NAMA concept in smart grid

Capacity Building:

- Encourage research network/ practitioners/ experts in related fields both domestically and internationally

3.2 Possible solutions to address the barriers for the transfer and diffusion of Waste to power generation

Technology selection

There are various technologies in waste to energy (power, heat, or fuel). Waste to power seems to have high potential to be implemented in Thailand. According to the public hearing, survey, and literatures, the hydrothermal treatment (HTT) is the most attractive technology. Thus, the government agencies should plan for technology transfer, especially the HTT and, in the meantime, prepare to develop own technology domestically. In addition, more research studies emphasizing on the impacts of waste market as well as the climate change are in need. Note that HTT has already been licensed to establish pilot plants so that it can be commercialized in Thailand in the near future.

Policy and regulation

- Create the waste separation and system with laws or regulation revisions
- Set up the policy to alleviate the non-technical issue including long term supporting policy

Capacity Building:

- Technology transfer of HTT
- Capacity building in local community and NGO and public promotion in waste separation system and motivation by training, seminar, or exhibition
- Develop community, national network in waste management to energy

Financial:

- Apply for external funding for the initial project set up
- Government supports the financial for technology through the projects/ measures (e.g. tax incentive, ESCO fund)
- Study on the potential of CDM-PoA/ internationally supported NAMA concept in waste to energy

3.3 Possible solutions to address the barriers for the transfer and diffusion of Efficient Fuel combustion

The improvement of energy efficiency in boiler heating system requires less advance technology than smart grid or second generation biofuels. If the improvement of energy efficiency is successfully applied in steam boilers nationwide, this would result in huge GHG reduction for the country. The possible solutions to achieve energy efficiency improvement in boiler in Thailand can be listed as follows:

Technology selection

Among various technologies for energy efficiency in boiler, the modulating burner and once-through boiler were chosen from the experts in this area. Since this technology can be developed within the country, the government may prepare for technology transfer from large scale factory to SMEs. Moreover, more study on the impact of this technology to climate change is needed.

Regulations and policy

Action plan for implementing this technology must be developed. The government could stimulate implementing mechanism through loan incentive, tax reduction, and etc. In addition, the country may require more stringent standard on fuel use per ton of steam production for each fuel types.

Financial

Government could support the financial for energy efficiency projects, especially on energy intensive industries (e.g. Tax incentive, ESCO fund). In addition, government or private sectors should seek to apply for the CDM-PoA or NAMA concept from domestic or international supporting agencies.

Capacity Building:

Encourage technology transfer and approach in modulating burner and once-through boiler in appropriate manufacturing sub-sector. Moreover, training programs for technician and operator should be developed. The best practices case studies could be referred to have a better understanding and clear vision on technology implementation.

3.4 Possible solutions to address the barriers for the transfer and diffusion of CCS

CCS is very capital intensive GHG mitigation technology. One of the benefits of CCS is the enhancement of oil recovery from the field. According to the barriers listed in the previous chapter, the solutions to overcome those barriers are summarized as follows:

Technology selection

- Potential and site (area) analysis of CCS in both off-shore and on-shore
- Study and research on geology and related data in both off-shore and on-shore
- The interesting issues of CCS in Thailand are comprehensive mapping for storage, site assessment (geology, hydrogeology, EOR potential), technology selection, risk management and best practices study
- Impact analysis of CCS to climate change from main technology including the power generation sector

Policy and regulation

- Assign responsible parties for CCS development
    - Develop action plan with timeframe for the CCS. This project requires long-term policy support; for the first 10 years, the design approval and construction could be developed; After 20-30 years of preparation, CCS could be fully operated; and after 20 years, the site monitoring and post-injection measure should be planed
- Study the international standard and regulation in both the international covenant and sea borders, especially in natural gas and oil field
- Identify the needs for appropriate regulation, standard, or license on CCS, including safety guideline which should be along with international context

Financial:

- Apply for international supports
- Encourage national energy agency for study and/or research in pilot scale CCS
- Clear long-term domestic policy in CCS support
- Support CCS to CCS-CDM and internationally supported NAMA concept from international fund

Capacity Building:

- Capacity building in CCS main issues to stakeholders including the understanding of environmental impact
- Identify the CCS skill and training requirement in related domestic agencies
- International cooperation development
- Public understanding of CCS role in GHG mitigation and enhanced oil recovery
- Establish the CCS research network from public agency and academic institute

3.5 Possible solutions to address the barriers for the transfer and diffusion of Second generation biofuels

Technology selection

- Identify the needs for appropriate technology on second and third generation biofuels which are the most appropriate to the country
- Conduct fundamental research on the second and third generation fuel
- Fiscal support in pilot scale and demonstration plant and related applied researches
- Develop waste management system including equipment and post-harvest machines

Regulations and policy

- Development national plan for second and third generation biofuels supporting industry
- Identify the government agency responsible for second and third generation biofuels development
- Study the international standard and regulations in all high potential biofuels field
- Identify the needs for appropriate regulation or guideline or standard or licenses including safety guideline which should be along with international context covering large and medium scale biofuels production

Financial:

- Investment fiscal support for local consumption and export
- Plan to seek for international support or collaboration in second and third generation biofuels
- Encourage national energy agency for study and/or research in pilot scale in both bioethanol and biodiesel
- Clear long-term domestic policy and support
- Study on the potential of CDM/domestically or internationally supported NAMA concept from international fund in both second and third generation biofuels

Capacity Building:

- Set up national institute to response all activities in second and third generation biofuels
- Capacity building in main issues to stakeholders focus mainly on the domestic production potential, understanding of GHG mitigation and other environmental impact
- Identify the skill and training requirements for both public and private sector
- International cooperation development especially on research and development
- Inform public understanding in GHG mitigation and food sector relationship
- Establish research network from public agency and academic institute

4 Technology Action Plans

Solutions to overcome the barriers were listed in the previous chapter. Subsequently, the Technology Action Plans (TAPs) for each technology were developed. In this process, barriers to the transfer and diffusion of the three prioritized technologies were identified. Eventually, the TAPs were developed and could be divided into 3 phases: short-term (1-3 years), medium term (3-5 years) and long term (5-10 years) as shown in Table 29 - 33.

Activity A is the activity under the technology action plan for smart grids
Activity B is the activity under the technology action plan for waste to power generation
Activity C is the activity under the technology action plan for energy efficient in boiler
Activity D is the activity under the technology action plan for CCS
Activity E is the activity under the technology action plan for second generation biofuels

Table 29 Technology action plans for smart grid

No.	Activities	Period			Related stakeholders	Key indicators	Priority	Fund sources
		Short	Medium	Long				
Financial								
A1	Control system and battery storage: Apply for international fund	✓			(i) Foreign agencies, (ii) Central agencies (MoE)	(i) Number of system implemented, (ii) the increasing rate of implementation	High	International level
A2	Smart metering : request financial support government	✓			(i) Central agencies (MoE)	(i) Number of system implemented, (ii) the increasing rate of implementation	High	National level
A3	Smart grid device: Financial support from government through special projects, tax incentive		✓		(i) Central agencies (MoE, PEA, MEA, DEDE, EPPO)	(i) Number of system implemented, (ii) the increasing rate of implementation	Normal	National level
A4	Encourage education and/or research works		✓		(i) Foreign agencies (ii) central agencies (MoE, MOST, research agency, education institute)	(i) Number of research studies (ii) Publications (iii) Seminars/participants	Normal	International level and national level
A5	Encourage PEA, MEA and EGAT to invest and develop main control system	✓	✓		(i) Central agencies (MEA, PEA, EGAT)	(i) Number of system implemented, (ii) the increasing rate of implementation	High	National level
A6	Feasibility study on CDM-PoA in smart grid	✓			(i) Foreign agencies (ii) Central agencies (MoE, MOST, research agency, education institute)	(i) The number of CDM-PoA project, (ii) The GHG mitigation potential	High	International level and national level

No.	Activities	Period			Related stakeholders	Key indicators	Priority	Fund sources
		Short	Medium	Long				
A7	Study on the potential of internationally supported NAMA concept		✓		(i) Central agencies (TGO, MoE, education institute)	(i) The number of NAMA project, (ii) The GHG mitigation potential	Normal	International level and National level
Policy and Regulatory								
A8	Develop smart grid national plan along with the roadmap	✓			(i) Central agencies (MoE, MEA, PEA, EGAT)	(i) the national plan	Very high	National level
A9	Develop clear policies and regulations with framework and timeline to internalize smart grid to REDP and NEEP	✓			(i) Central agencies (DEDE, EPPO)	(i) the national plan	Very high	National level
A10	Study international standard for smart grid device (e.g. IEEE, IEC and ISO)		✓		(i) Central agencies (MEA, PEA, TISI) (ii) Foreign certification center/institute	(i) Number of standard published/implemented	Normal	International level and national level
A11	Establish institute that can certify activities associated with smart grid			✓	(i) Central agencies (MEA, PEA, TISI) (ii) Foreign certification center/institute	(i) National Smart Grid Certification center	Low	International level and national level
A12	Set the policy to test both security and stability of smart grid by both system and each device		✓		(i) Central agencies (MEA, PEA, EGAT, MOST) (ii) Foreign agency	(i) The system security indicators implemented and tested (ii) The device security indicators implemented and tested	Normal	International level and national level

No.	Activities	Period			Related stakeholders	Key indicators	Priority	Fund sources
		Short	Medium	Long				
Technology								
A13	Prioritize the needs for developing smart grid devices such as smart meter and storage	✓			(i) Central agencies (MEA, PEA, EGAT)	(i) Prioritized technology (ii) timeline	Very high	National level
A14	Technology feasibility analysis at the country level	✓			(i) Central agencies (MEA, PEA, EGAT), (ii) Foreign agencies/fund	(i) Study reports	Very high	International level and national level
A15	Demonstrate the full pilot smart grid project operation		✓	✓	(i) Foreign agencies, (ii) Central agencies (MoE, MOST, research agency, research institute)	(i) Number of pilots project of smart grid (ii) Expand from pilot project to full scale operation	High	International level
A16	Study the impact of the smart device market	✓			(i) Central agencies (MEA, PEA, EGAT), (ii) National Industry institute	(i) The market impact from smart grid report, (ii) the SWOT analysis of smart grid in Thailand	High	National level
A17	Analyze the climate change impact guideline of smart grid	✓			(i) Central agencies (TGO, education institute)	(i) The guideline of GHG mitigation from smart grid system	Normal	International level and national level
Capacity Building								
A17	Expand network among academic and research institutes	✓			(i) Education and research institute, (ii) foreign education institute/center/ fund	(i) Number of participants in smart grid network, (ii) number of research papers, (iii) number of case study reports	High	International level and national level

No.	Activities	Period			Related stakeholders	Key indicators	Priority	Fund sources
		Short	Medium	Long				
A18	Strengthen international research network/programme		✓		(i) Education and research institute, (ii) foreign education institute/center/ fund	(i) Number of participants in smart grid network/programme, (ii) MOU with international agencies	Normal	International level and national level
A19	Scholarships or grants from agencies e.g. Energy Conservation Promotion fund or Power plant fund	✓	✓		(i) Education institutes, (ii) Research institutes	(i) Number of scholarships or grants , (ii) Budget ratio	High	National level
A20	Increase number of experts/researchers in the smart grid field	✓	✓		(i) Central agencies (MoE, MEA, PEA, EGAT), (ii) Education institutes	(i) Number of experts	High	National level
A21	Develop public relations program to promote the smart grid technology			✓	(i) central agencies (MoE, MEA, PEA, EGAT)	(i) the percentage increasing in understanding of the people in smart grid	Low	National level

Table 30 Technology action plans for waste to power generation

No.	Activities	Period			Related stakeholders	Key indicators	Priority	Fund sources
		Short	Medium	Long				
Financial								
B1	Apply for international fund, especially on technology e.g. HTT and other waste technology (RDF)	✓	✓		(i) Foreign agencies, (ii) central agencies (MoE), (iii) Education and research institute	(i) Number of technology transferred, (ii)The number of system implemented, (iii) The increasing rate of implementation	Very High	International level
B2	Budget allocation for technology e.g. incineration, landfill	✓			(i) Central agencies (MoE, MoIn)	(i) Number of system implemented, (ii) the increasing rate of implementation	High	National level
B3	Government supports for waste to power through the special projects/mechanisms (e.g. tax incentive, soft loan, feed-in-tariff)	✓	✓		(i) Central agencies (MoE, DEDE, EPPO, MNRE)	(i) Number of implemented system, (ii) the increasing rate of implementation	High	National level
B4	Study on the potential of CDM-PoA in waste to power from national level or provincial level	✓			(i) Foreign agencies, (ii) central agencies (MoE, research agency, education institute)	(i) Number of CDM-PoA project, (ii) GHG mitigation potential	Very High	International level and national level
B5	Study on the potential of domestic/international supported NAMA concept	✓			(i) Central agencies (TGO, MoE, education institute)	(i) The number of NAMA project, (ii) The GHG mitigation potential	Normal	International level and national level

No.	Activities	Period			Related stakeholders	Key indicators	Priority	Fund sources
		Short	Medium	Long				
Policy and Regulatory								
B6	Enact policy or regulation that enhance ability to implement the waste to power	✓			(i) Central agencies (MoCommerce, MNRE, PCD, ONEP, BMA)	(i) The new or revised regulation	High	National level
B7	Create the waste separation system	✓	✓		(i) Central agencies (MNRE, PCD, ONEP, BMA), (ii) Selected municipality level	(i) The prototype of waste management system, (ii) The proportion of waste management in cities	Very High	National level and Municipality level
B8	Set up policy to alleviate the non-technical issue including the long term support policy	✓	✓		(i) Central agencies (MNRE, MoInterior) (ii) Municipality level	(i) Internalized smart grid in the national plan	Very high	National level and Municipality level
Technology								
B9	Develop technology transfer mechanism, especially the HTT	✓	✓		(i) Foreign agencies, (ii) central agencies (MoE, research agency, education institute)	(i) HTT technology transfer results, (ii) the report on potential of HTT in Thailand	Very high	International level and national level
B10	Promote technology investment to Thai entrepreneurs		✓		(i) Central agencies (MoE, research agency, education institute)	(i) Number of pilots project of new technology(s) (ii) Expansion plan from pilot project to full scale operation	High	National level
B11	Study the impact of the waste market to power or energy generation	✓			(i) Central agencies (MoE, MOST, research	(i) The market impact report	Normal	National level

No.	Activities	Period			Related stakeholders	Key indicators	Priority	Fund sources
		Short	Medium	Long				
					agency, education institute)	(ii) The SWOT analysis of new waste technology in Thailand		
B12	Study management and economics aspects including the LCA for waste to energy	✓			(i) Central agencies (MNRE, MoE, MOST, research agency, education institute)	(i) The supply chain impact from waste report	Normal	National level
B13	Analyze the climate change impact from all waste to energy technology	✓			(i) Central agencies (TGO, education institute)	(i) GHG reduction from waste to energy project in Thailand	Normal	International level and national level
Capacity Building								
B14	Strengthen research network among academic institutes, especially on HTT	✓			(i) Education and research institute (ii) exchange researchers with well known institute/center/ fund	(i) Number of participants /researchers/experts in this area (ii) number of research paper, (iii) number of case study reports	Very high	International level
B15	Capacity building in local community and NGO and public promotion in waste separation system and motivation by training, seminar or exhibition	✓	✓		(i) Education and research institute, (ii) foreign education institute/center/fund	(i) Number of participants in seminar/training	High	National level and Municipality level
B16	Develop community network in waste management to energy	✓			(i) Education institutes, (ii) Research institutes	(i) Number of network community	Normal	National level and Municipality level

Table 31 Technology action plans for energy efficient in boiler

No.	Activities	Period			Related stakeholders	Key indicators	Priority	Fund sources
		Short	Medium	Long				
Financial								
C1	Apply for international supports for expensive devices	✓			(i) foreign agencies, (ii) central agencies (MoE, MoIn)	(i) number of system implemented, (ii) the increasing rate of implementation	High	International level
C2	Budget allocation for implementing energy efficiency in boiler project	✓			(i) central agencies (MoE, DEDE, EPPO, MoIn, DIW)	(i) number of implemented projects	High	National level
C3	Government supports private company investment for domestic based production e.g. soft loan, tax incentive, DSM bidding		✓		(i) central agencies (MoE, DEDE, EPPO, DIW)	(i) number of implemented projects	Normal	National level
C4	Investigate GHG reduction potential of CDM-PoA	✓			(i) central agencies (MoE, MOST, research agency, education institute)	(i) number of CDM-PoA projects (ii) reduction of GHG emissions	Normal	International level and national level
C5	Feasibility study for developing NAMA concept		✓		(i) central agencies (TGO, MoE, education institute)	(i) number of NAMA project, (ii) The GHG mitigation potential	Normal	National level
Policy and Regulatory								
C6	Develop the roadmap and action plan for energy efficient in boiler burner	✓			(i) central agencies (MoE, DEDE)	(i) the roadmap for energy efficient boiler	Very high	National level

No.	Activities	Period			Related stakeholders	Key indicators	Priority	Fund sources
		Short	Medium	Long				
C7	Develop policies/regulations to support the NEEP (Northeast Energy Efficiency Partnerships) with a clear framework and timeline	✓			(i) central agencies (MoE, DEDE, EPPO)	(i) the roadmap or action plan	Very high	National level
C8	Study international standard and safety issues of energy consumption in burner		✓		(i) central agencies (DIW, DEDE), (ii) foreign standard	(i) the new regulation in safety (if required)	High	International level and national level
C9	Establish research institute or encourage research works in this area	✓			(i) central agencies (DIW, DEDE)	(i) established institute	Very high	International level and national level
C10	Regulatory/guideline/standard on fuel use per ton of steam production in each fuel type		✓		(i) central agencies (DIW, DEDE), (ii) foreign standard	(i) the new guideline/regulation in consumption (if required)	High	International level and national level
Technology								
C11	Sector or industry prioritization to be implemented the selected technologies (i.e. modulating burner and once-through boiler)	✓			(i) central agencies (DIW, DEDE)	(i) the study report (ii) the timeline	Very high	National level
C12	Feasibility study of possible technologies	✓			(i) central agencies (DIW, DEDE), (ii) education/research institute	(i) reports or publications	Very high	National level
C13	Develop technology transfer mechanism both domestic and international level		✓	✓	(i) central agencies (DIW, DEDE), (ii) National Industry institute	(i) number of pilot projects	High	National level

No.	Activities	Period			Related stakeholders	Key indicators	Priority	Fund sources
		Short	Medium	Long				
C14	Support domestic based production	✓	✓		(i) central agencies (DIW, DEDE), (ii) National Industry institute	(i) number/unit of domestic based production (ii) the market penetration of new efficient boiler	High	National level
C15	Monitoring the results of implementing the project, especially in boiler equipment market		✓		(i) central agencies (DIW, DEDE), (ii) National Industry institute	(i) the impact from new energy efficient burning system report (ii) the SWOT analysis	Normal	National level
C16	Study the GHG emissions reduction		✓		(i) central agencies (TGO, education institute)	(i) the guideline of GHG mitigation from smart grid system	Normal	International level and national level
Capacity Building								
C17	Develop research network among academic institutes	✓			(i) education and research institute, (ii) foreign education institute/center/fund, (iii) industrial sector	(i) number of participants in network (ii) number of research papers	High	International level and national level
C18	Technology transfer and approach in modulating burner and once-through boiler	✓	✓	✓	(i) central agencies (DEDE, DIW) (ii) industrial institutes, (iii) industrial sector	(i) number/unit of technology transfer in industry (ii) the market penetration of new efficient boiler	Very High	International level and national level
C19	Develop the technician and operator training programs in burner/boiler operation	✓	✓		(i) central agencies (DEDE, DIW) (ii) industrial institutes (iii) industry sector	(i) number of participants in smart grid network/programme, (ii) MOU with international agencies	Very high	National level

No.	Activities	Period			Related stakeholders	Key indicators	Priority	Fund sources
		Short	Medium	Long				
C20	Training programs for developing and maintaining, applying best practices case studies		✓		(i) central agencies (DEDE, DIW) (ii) industrial institutes (iii) industry sector	(i) The number of scholarship granted, (ii) Budget ratio	High	National level

Table 32 Technology action plans for CCS

No.	Activities	Period			Related stakeholders	Key indicators	Priority	Fund sources
		Short	Medium	Long				
Financial								
D1	Apply for international funding on CCS	✓	✓		(i) foreign agencies, (ii) central agencies (MoE, DMF, PTT)	(i) supporting projects and grants	Very High	International level
D2	Research funding for CCS			✓	(i) central agencies (MoE, DMF, PTT, EGAT)	(i) research works on CCS (ii) feasibility study report	Normal	National level
D3	Develop a long-term policy to support CCS	✓	✓		(i) central agencies (MoE, DMF, PTT, EGAT)	(i) policy in CCS	High	National level
D4	Encourage government agencies (PTT, EGAT, SCG) or research institute to study and/or invest on CCS pilot projects	✓	✓		(i) central agencies (MoE, DMF, PTT, EGAT)	(i) number of CCS fiscal (ii) the increasing rate of study in CCS	High	National level
D5	Feasibility study on CCS-CDM	✓	✓		(i) foreign agencies (ii) central agencies (MoE, DMF, PTT, EGAT, research institute)	(i) number of CCS-CDM projects (ii) The GHG mitigation potential	Very High	International level and national level
D6	Study the potential of internationally supported NAMA concept		✓		(i) central agencies (TGO, MoE, education institute)	(i) number of NAMA project (ii) The GHG mitigation potential	High	International level and national level

No.	Activities	Period			Related stakeholders	Key indicators	Priority	Fund sources
		Short	Medium	Long				
Policy and Regulatory								
D7	Assign responsible parties for CCS	✓			(i) central agencies (MoE, DMF)	(i) responsible agency on CCS	Very high	National level
D8	Develop policy that supports CCS technology e.g. design, construction, operation, injection, and monitoring post-injection	✓	✓		(i) central agencies (MoE, DMF, PTT, EGAT), (ii) MOST, research agency, education institute	(i) report study on CCS potential in Thailand	Very high	National level
D9	Study the international standards and regulations in both the international covenant and sea borders, especially in natural gas and oil field		✓		(i) central agencies (MoE, DMF, PTT, EGAT), (ii) MOST, research agency, education institute	(i) report study on international standards	Normal	International level and national level
D10	Identify the needs for appropriate regulation or guideline or standard or licenses on CCS including safety guideline which should be along with international context		✓	✓	(i) central agencies (MoE, DMF), (ii) MOST, research agency, education institute	(i) CCS needs assessment	Normal	International level and national level
Technology								
D11	Feasibility study on location of CCS in both off-shore and on-shore	✓			(i) central agencies (MoE, DMF, PTT, EGAT) (ii) research agency, education institute (iii) foreign	(i) feasibility study report (ii) timeline	Very high	International level and national level

No.	Activities	Period			Related stakeholders	Key indicators	Priority	Fund sources
		Short	Medium	Long				
					agencies/fund			
D12	Study and research the geology and related data in both off-shore and on-shore	✓	✓		(i) central agencies (PTT, EGAT), (ii) research agency, education institute, (iii) foreign agencies/fund	(i) the study report	Very High	International level and national level
D13	Study on CCS for storage, site assessment, geology, hydrogeology, EOR potential, technology selection, risk management, and best practices study		✓	✓	(i) central agencies (PTT, EGAT) (ii) research agency, education institute (iii) foreign agencies/fund	(i) the study report	High	International level and national level
D14	Study the impact analysis of CCS to climate change from main technology	✓	✓		(i) central agencies (TGO, MoE, DMF) (ii) research agency, education institute, (iii) foreign agencies/fund	(i) the impact from CCS report (ii) the SWOT analysis	High	International level and national level
Capacity Building								
D15	Inform stakeholders about the issue related to CCS, especially on environmental impacts	✓	✓		(i) central agencies (MoE, DMF, PTT, EGAT) (ii) research agency,	(i) number of participant in CCS (ii) number of case study documents	High	International level and national level

No.	Activities	Period			Related stakeholders	Key indicators	Priority	Fund sources
		Short	Medium	Long				
					education institute (iii) foreign agencies/fund			
D16	Establish CCS training programs	✓	✓	✓	(i) central agencies (MoE, DMF, PTT, EGAT)	(i) participants in CCS training program (ii) experts and researchers	High	National level
D17	Create CCS international cooperation development		✓	✓	(i) central agencies (MoE, DMF, PTT, EGAT) (ii) foreign agencies/fund	(i) The number of linkages/cooperation, (ii) the number of joint development activity	High	International level
D18	Public understanding of CCS role in GHG mitigation and enhanced oil recovery			✓	(i) central agencies (PTT, EGAT, TGO) (ii) foreign agencies/fund	(i) the percentage increasing in understanding of the people in CCS, (ii) the number of seminars/workshops	Low	National level
D19	Establish the CCS research network from public agency and academic institute		✓	✓	(i) research agency, education institute, (ii) foreign research network	(i) CCS research network established	Normal	International level and national level

Table 33 Technology action plans for second generation biofuels

No.	Activities	Period			Related stakeholders	Key indicators	Priority	Fund sources
		Short	Medium	Long				
Financial								
E1	Apply for international fund, especially on advance technology	✓	✓		(i) foreign agencies (ii) central agencies (MoE)	(i) number of supporting projects	Very high	International level
E2	Allocate budget for research and pilot scale projects	✓	✓	✓	(i) central agencies (MoE, MOST, PTT, DEDE) (ii) research or education institutes	(i) number of supporting projects (ii) increasing rate of pilot projects	Very high	National level
E3	Promote private company/industry investment on the 2nd market	✓	✓		(i) central agencies (MoE, PTT, DEDE, Bangchak)	(i) number of implemented system (ii) increasing rate of implementation	High	National level
E4	Encourage national energy agency to study and/or research on bioethanol and biodiesel		✓	✓	(i) central agencies (MoE, PTT, DEDE, MOST) (ii) research agency, education institute (iii) foreign fund	(i) number of research study (ii) published papers (iii) seminars/participants	Very high	National level
E5	Study on the potential of CDM in biofuel		✓		(i) foreign agencies (ii) central agencies (MoE, MOST, research agency, education institute)	(i) number of CDM project (ii) GHG mitigation potential	Normal	International level and national level

No.	Activities	Period			Related stakeholders	Key indicators	Priority	Fund sources
		Short	Medium	Long				
E6	Study on the potential of domestic and international supported NAMA concept		✓		(i) central agencies (TGO, MoE, education institute)	(i) number of NAMA project (ii) GHG mitigation potential	Normal	International level and national level
Policy and Regulatory								
E7	Develop national plan/roadmap for second and third generation biofuels	✓			(i) central agencies (MoE, DEDE)	(i) the national plan/roadmap in biofuels (ii) timeline	Very high	National level
E8	Identify the government agency responsible for second and third generation biofuels development	✓			(i) central agencies (MoE, DEDE)	(i) government agency(s) identified	Very high	National level
E9	Study the international standards/regulations related to biofuels		✓		(i) central agencies (DOEB)	(i) summary reports of standards or regulations related to biofuels	High	National level
E10	Establish research institutes particularly focus on second and third generation biofuels			✓	(i) central agencies (DEDE, PTT, Bangchak), (ii) foreign center/institute	(i) research works	Normal	International level and national level
E11	Identify the needs for appropriate regulation, guideline, or standard, including safety guideline		✓		(i) central agencies (DOEB)	(i) biofuels regulation/guidelines	Normal	International level and national level
Technology								
E12	Identify the most appropriate technology for second and third generation biofuels	✓			(i) central agencies (MoE, MOST, PTT, DEDE) (ii) research or education institute	(i) identified the technology needs (ii) timeline	Very high	National level

No.	Activities	Period			Related stakeholders	Key indicators	Priority	Fund sources
		Short	Medium	Long				
E13	Conduct fundamental researches on second and third generation fuels	✓	✓		(i) central agencies (MoE, MOST, PTT, DEDE) (ii) research or education institutes (iii) international funding	(i) number of study reports	High	International level and national level
E14	Set up demonstration plants		✓	✓	(i) foreign agencies (ii) central agencies (MoE, MOST, research agency, education institute) (iii) foreign funds	(i) pilot projects (ii) number of applied researches (iii) expansion plan from pilot scale to full biofuel scale	High	International level and national level
E15	Manage collecting system of agricultural residue e.g. equipment and post-harvest machines		✓		(i) central agencies (MoE, MoA, DEDE)	(i) market impact from smart grid report (ii) the SWOT analysis	Normal	National level
E16	Impact analysis of the technology to the market, agricultural or food sectors	✓	✓		(i) central agencies (MoE, MOST, PTT, DEDE) (ii) research or education institute	(i) the study report (ii) the SWOT analysis	High	National level
E17	Investigate the GHG reduction from second and third generation biofuels	✓			(i) central agencies (TGO, education institute) (ii) foreign funds	(i) the study report	Normal	International level and national level

No.	Activities	Period			Related stakeholders	Key indicators	Priority	Fund sources
		Short	Medium	Long				
Capacity Building								
E18	Establish research institutes focusing on second and third generation biofuels	✓	✓		(i) education and research institute (ii) foreign education institute/center/fund	(i) research institute	High	International level and national level
E19	Capacity building in main issues to stakeholders focus mainly in the domestic production potential, understanding of GHG mitigation and other environmental impact		✓	✓	(i) education and research institute (ii) foreign education institute/center/fund	(i) the number of participant, (ii) number of certificate issued	Normal	National level
E20	Prepare scholarship or grant to increase experts/ researchers in this area	✓	✓		(i) Research institutes	(i) scholarships/ grants	High	National level
E21	Organize training programs (exchange experts among world class institute) for related agencies both public and private sectors	✓	✓		(i) central agencies (MoE, DEDE), (ii) private sector, (iii) education institute	(i) number of experts or researchers	High	National level
E22	Inform publics about the technology to have correct understanding		✓	✓	(i) central agencies (MoE, PTT, Bangchak)	(i) informed community	Low	National level

5 Conclusions

Section II develops the Technology Action Plans (TAPs) for selected technologies. In general, the development process consists of 1) setting up preliminary targets for technology transfer and diffusion of each technology option, 2) identifying barriers, 3) investigating possible solutions to address those barriers for the transfer and diffusion of technology, 4) and eventually developing a technology action plan for each technology option by considering legislation and regulation, financial incentives, institutional arrangement, infrastructure, R&D support, and human resource development.

According to the TNA the selected technologies include 1) Smart grid 2) Waste to power generation 3) Second and third generation of biofuels 4) Fuel Combustion in industrial sector and 5) Carbon capture and storage (CCS). The TAPs of all five prioritized technologies have been developed following the UNEP-RISOE TAP procedure.

Then, the barriers have been identified and grouped into four aspects (i) financial issue (ii) policy and regulatory (iii) technology and (iv) capacity building. Subsequently, the TAPs for each technology were developed. In this process, barriers to the transfer and diffusion of the prioritized technologies were identified. The TAPs were established and divided into 3 phases, short-term (3 years), medium term (5 years) and long term (5-10 years) as shown in Table 29 - 33.

In conclusion, Thailand needs an international support on technology knowledge transfer. One is a training course through a consortium of leading international universities, local universities, research centers and private companies. Linking with international organizations and experts is also desirable to ensure the portable application with the state of the art technologies. Moreover, sufficient funding from international agencies is the key to successes since most technologies, e.g. smart grid, CCS, second and third generation biofuel, which requires tremendous amount of investment on technologies and infrastructure. For the domestic development, the priority must be placed on adjusting the national energy policy with conceptually clear, simple, and theoretically sound. Importantly, the government should consistently support the policy throughout the implementation stage.

Section III

Cross-cutting issues for the National TNA and TAPs

Executive summary

The aims of this section are to identify common barriers of technology implementation across selected technologies in energy sector and to analyze technology action plans. This starts with identifying common needs and possible synergies of the selected technologies that could be achieved by addressing some key elements influencing multiple technologies. As a result, the following four major common barriers across sectors are identified: 1) technology capability, 2) capacity building, 3) policy and regulation, and 4) economy. Knowing these barriers and their relationships will better enable decision makers to implement technologies in a manner that strategically copes with unseparatable technical, financial, ethical, and regulatory obstacles. The cross-cutting analysis also investigates possible capacity development actions that could refine the proposed technology action plan (TAP).

These further refinements are to overcome or lessen the cross-technology barriers and are summarized in Table 34.

Table 34 grouped into two parts: domestic actions and international actions (technology transfer from outside of the country). In brief, the lack of financial support and knowledge/expert seems to be fundamental barrier for technology development and implementation of the country. Both issues entail robust international supports, especially during the initial phase.

On the other hand, for the domestic actions, most of the common barriers require a clear cut policy or supporting mechanism among responsible parties. Such policies in principle can be listed as follow: policy on enhancing 1) multi-agency partnership 2) research collaboration, 3) R&D budget, and 4) MOU with developed countries on technology transfer or research collaboration.

Table 34 The further proposed actions to overcome or lessen cross-technology barriers

	Barrier	Short term
Require international actions	Technology capacity	- Providing guidance/sharing knowledge on standardizing data format, data collection procedure, and data interpretation -Providing training courses or multidisciplinary exchanged researchers
	Capacity building	- Providing guidance/sharing knowledge on technology e.g. smart grid, CCS
	Policy and regulation	- Collaboration with international institutes in term of technology or researcher or expert exchange
	Economy	- Providing financial aids for an initial phase such as, researcher exchange program and training course
Domestic actions	Technology capacity	- Providing guidance/sharing knowledge on standardizing data format, data collection procedure, and data interpretation -Regional collaboration on sharing data and research works
	Capacity building	- Allocating budget for development and maintenance infrastructure
	Policy and regulation	- Promoting policy on enhancing research collaboration, R&D budget, MOU with developed country on technology transfer or research collaboration - The same direction policy among electricity generating authority e.g. EGAT, MEA and PEA
	Economy	- Increasing R&D budget

1. Identified common barriers across the sectors

According to the barriers described in TAPs (Section II) for the selected technologies of the energy sector, the four major common barriers across technology options can be identified as follows; 1) technology capability, 2) capacity building, 3) policy and regulation, and 4) economy.

We can conclude that lack of experts and researchers appears to be the most critical hurdle for all selected technologies for energy sector. The smart grid, CCS, second generation biofuels, and waste to power require state of the art technology while the improvement of energy efficiency in boiler heating system requires unsophisticated technology which could potentially be developed domestically with the government supporting mechanism.

Similarly, lack of budget for technology development is also a serious barrier for most of the technology development. These two barriers, as a matter of fact, are interrelated and tied to the barriers of political and regulatory origins. For example, due to the lack of R&D budget, the number of research work as well as human resource development in sciences and technology for climate change cannot be prolonged. Consequently, we could not develop necessary technologies ourselves, and most of the advanced technologies must be imported. Unsurprisingly, the imported technologies are, most of the time, costly and not suitable for local contexts making Thailand unable to exploit their full potential. This issue might be solved by the right political initiation. R&D supporting policy and policy enhancement on research collaboration are key catalysts to stimulate collaboration among agencies and would promote more advanced research while avoid duplication of effort.

The barriers on capacity building have a close tie to the national policy, budget, and know-how barriers. For example, the smart grid technology appears in the roadmap for Provincial Electricity Authority (PEA). However, neither the Electricity Generating Authority of Thailand (EGAT) nor Metropolitan Electricity Authority (MEA) has any plan on this issue. The unclear directives and organizational structures definitely prohibit the capacity building of the technology. Furthermore, there is no law/regulation that allows the integration or cooperation among those electricity generating authorities.

	Smart grid	Waste (to power generation)	Efficient Fuel combustion	CCS	Second generation biofuels
Financial	- High investment costs on technology and infrastructure	-High investment costs on technology and energy infrastructure	- Low to medium investment costs	- Very high investment costs on technology and infrastructure	-High investment costs
Policy and regulation	- No clear roadmap policy for EGAT and MEA -Require safety standard and measurement - Lack of collaboration with international institutes in term of technology or researcher or expert exchange	- REDP has developed the roadmap on this issue - Unclear policy covering all stakeholders' benefit e.g. scavengers - Unclear policy on waste separation	-Require the national action plans	- No policy and regulation related to CCS, especially on operating and monitoring	- Require clear policy that encourages and supports both researchers and private sectors to invest on the technology
Technology	- Technology must be imported - Research and development is still at the initial state and very limited to certain institutes - Lack of information on climate change issue and the smart grid - System must be maintained by power utility	- Technology must be imported, especially the HTT technology	- Certain technology must be imported	- Research and development is still at the initial state and very limited to certain institutes - Lack of supporting funds for research on feasibility study, technology impact both inshore and offshore	- This technology has been well developed in certain countries. - Require both fundamental and advance research, especially on technology development and life-cycle assessment
Capacity building	- Lack of fundamental knowledge on technology, infrastructure design, and maintaining system	- Lack of fundamental knowledge on technology - Lack of waste separation management - May raise conflicting issue with the community	- Lack of fundamental knowledge on technology - Lack of good practice, especially on small to medium industry	- Lack of fundamental knowledge on technology, infrastructure design, and maintaining system - May raise conflicting issue with the community	- Lack of fundamental knowledge on technology

1. 1. Technology

1.1.1. Expert and know-how

Limited skillful human resources are major constraint in developing and implementing technology. To ensure effective implementation, human resource development programs and continuous technical trainings to maintain the quality of staff members must be implemented. Due to the lack of experts and budget for research and development, most of the advanced technology is imported. Those imported technologies are not only expensive but also cannot capture local contexts, resulting in substandard outcomes. Thus, apparently, if neither Thailand can develop technology by itself, nor could it manage to keep purchasing a full-option (costly) technology from other developed countries, it could not reach the full potential of climate change adaptation technology.

The root of these obstacles is evident when considering several important figures of the country. For example, the number of researchers per capita in Thailand is lower than the world average. On top of that, the budget allocation for R&D from both public and private sectors is also lower than the world average. According to statistic in 2008, there were 6.8 researchers per 10,000 citizens while the world average researcher was 24.9 per 10,000 citizens. The R&D budget was accounting for 0.22 % of GDP while the world average was 1.01 % of GDP. The private sector allocated R&D budget 0.08 % of GDP while the world average was 0.63% of GDP. This reveals an important evidence of the major barrier for science and technology development in Thailand.

Another supporting fact that shows the lack of experts and R&D budgets in Thailand is number of registered patents. The overall registered patents in 2008 were 1,685,037 with an average of 29,052 patents for each country. Thailand has registered 6,741 patents worldwide, increasing 1.13 percent from 2007.

To overcome this barrier, the government should put a serious concern and be sincerely aware of this issue. The help from the outside of country is very important and could drive a major push to success as well.

1.1.2. Research/Institutional collaboration

Promoting a collaboration atmosphere between public and private sectors is an urgent need for the country. Collaborative effort between institutes could help avoid over expenses and duplication of the effort among governmental agencies and research institutes. It could also reduce fragmented analysis and incomplete results. The level of collaboration could extensively be done domestically, regionally, and internationally.

For Thailand, the collaboration is still limited even among governmental agencies itself. If there is a clear policy or high level coordination mechanism for cooperation, it could open up to more channels for conducting advanced research. To enable the implementation, it is necessary for the national focal points to cooperate. The objective of information exchange and stakeholder collaboration is to formulate appropriate actions which would ensure greater mobilization of resources/data and further enhance the efforts from implementation agencies and stakeholders in fulfilling their support from the government and attracting international support.

1.2 Capacity building

Lack of technology know-how is the main barrier of the technology capacity building. Since, the lack of know-how, most of the developing countries to spend their budget for imported technology, the more important task is to utilize the full potential of the infrastructure, which requires maintenance and continuous upgrade. In many developing countries, the absence of funding and expertise to maintain infrastructure has jeopardized the sustainability of technology utilization. Furthermore, infrastructure for example massive infrastructure for smart grid and CCS sometimes comes with a complex web of social and regulatory issues (e.g., the “not-in-my-backyard” syndrome), which is often an enduring subject for public debate.

1.3 Policy and Regulation

The solutions of some cross-cutting barriers are only at policy level, for example, policy frameworks on enhancing fundamental research, policy framework on implementing technologies, and public perception and education on new technologies. Absence of appropriate national legal and policy frameworks on enhancing fundamental research prohibits technology development as well as its implementation. Effective technology implementation requires a solid national plan, ensuring sufficient budgets, manpower, and resources. In addition, various activities to promote public awareness in science and regulation, e.g. CCS, should be organized.

Public perception and education on climate change technology is another issue that requires national policy support. Tradition and public perspective can affect how technology is perceived, and compatibility of a new technology with the values and beliefs of a society can affect technology adoption. Such perspective can shape public opinion and the politics behind debates to define problems and acceptable technological solutions. For example, CCS and smart grid are quite new technology. They may worry about unknown human health and environmental effects. For this reason, an emphasis should be placed on education curriculum to create public awareness and understanding on climate change and its technology implementation.

1.4 Low investment on R&D Budget

An obvious barrier to the application of any technology is lack of budget sufficient for capital investment, technology operation and maintenance, and human resource capacity development to implement the technology at its full potential. Technology implementation requires know-how and capacity of technological adaptation and dissemination. Building science and technology capacity requires investment in R&D. Funding for 1) the education and training of scientists and engineers, 2) scientific research and technology development activities, 3) promotion of technology transfer to commercial applications, and 4) dissemination of technology into the marketplace should come from both public or private sources. For Thailand, the level of R&D capacity is extremely low and not an attractive place for private investors. R&D is a cumulative process that requires not only financial investment but also the support from government and private sectors. Private investors can look for opportunities with high return on investment while the government agencies look for opportunities to collaborate with private sectors to push forward technology options suitable for the needs of the country.

2. Technical capability, public participation, and public awareness of each technology

Besides evaluating technology implementation by considering the cross-cutting barriers, it is also important to examine technical capability, public participation, and public awareness of each technology.

Due to the limitation of the resources including time, budget, and know-how, technologies should be prioritized based on their capability, public participation, and public awareness. Technical capability of the country for a technology is defined as the ability of the country to implement the technology of interest with its current resources (e.g. technical expertise, human resources, and infrastructure). By evaluating all the technologies together based on their capability, the improvement of boiler efficiency requires unsophisticated technology and could be developed domestically. On the other hand, smart grid, CCS, second and third biofuels generation, and waste to power require stage of the art technology of which their R&D in Thailand are still in an early stage. Those technologies, however, have a great potential to impact various groups of stakeholders across the sectors. Fortunately, a Thai company has just received the license to establish the hydrothermal treatment (HTT) pilot facility, one of the most attractive technologies for waste to power, from Japanese company. For this reason, the company can in the future commercialize this technology in Thailand.

Besides the perspective of technology accessibility, the second and third biofuels generation and waste to power were ranked as the first priority for future development in Thailand. They could result in win-win solutions by enhancing energy security while reducing waste. Moreover, as an agricultural country, the input for those technologies, e.g. agricultural residual and municipal waste, are plentiful and fully accessible.

For public participation and involvement, certain technologies involve certain groups of stakeholders and may not require much public participation. For example, CCS and boiler efficiency improvement involve managers or technicians in the industry. On the other hand, smart grid, waste to power, and second and third generation biofuels require public involvements in many ways e.g. to grow energy plants for biofuels, separate/collect waste for energy generation, learn to utilize smart gird. The different levels of public involvement result in different degrees of policy enforcement. For example, the government could impose the industry on policy/ regulation on implementing CCS and improving boiler efficient. On the contrary, the national policy enforcement is required for implementing smart grid, waste to power, second and third generation biofuels. Nonetheless, all technologies require public understanding and agreement.

CCS may raise public concern; even though, this technology reveals highest potential GHG reduction. The CCS system requires a large area site to operate which may be adjacent to communities. The lack of technological knowledge is also clouding the potential benefits. Moreover, long-term operation and maintenance has not yet guaranteed the sustainability of the system. Similar to the waste to power, establishing a waste treatment plant will definitely conflict with the community and/or non government organizations (NGO).

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Annex 1 Technology Description

A.1 Smart grids

1. Introduction

The US Department of Energy (DOE) defines smart grids as follows:

"Smart grid generally refers to a class of technology people are using to bring utility electricity delivery systems into the 21st century, using computer-based remote control and automation. These systems are made possible by two-way communication technology and computer processing that has been used for decades in other industries. They are beginning to be used on electricity networks, from the power plants and wind farms all the way to the consumers of electricity in homes and businesses. They offer many benefits to utilities and consumers -- mostly seen in big improvements in energy efficiency on the electricity grid and in the energy users' homes and offices."

For a century, utility companies have had to send workers out to gather much of the data needed to provide electricity. The workers read meters, looked for broken equipment, and measured voltage, for example. Most of the devices to deliver electricity have yet to be automated and computerized. Now, many options and products are being made available to modernize the electricity industry.

The "grid" represents the entire network that carries electricity from the plants to consumers. The grid includes wires, substations, transformers, switches and much more. Smart grid means "computerizing" the electric utility grid. It includes adding two-way digital communication technology to devices associated with the grid. Each device on the network can be equipped with sensors to gather data (power meters, voltage sensors, fault detectors, etc.) plus two-way digital communication between the device in the field and the utility's network operation center. A key feature of the smart grid is automation technology that lets the utility adjust and control each individual device or millions of devices from a central location.

The number of applications on the smart grid is growing as fast as the innovative companies that can construct and supply the smart grid. The benefits of the smart grid include enhancing cyber-security, handling sources of electricity like wind and solar power, and even integrating electric vehicles onto the grid. The companies making the smart grid technology or offering such services include well-established communication firms, and brand new technology companies (DOE, 2011).

While EPRI defines a smart grid as the modernization of the electricity delivery system to monitor, protect, and automatically optimize the operation of its interconnected elements from the central and distributed generator through the high-voltage network and distribution system to all kinds of uses ranging from industrial users, building automation systems, electric vehicles, appliances, and other household devices(EPRI, 2009).

Fig A1 illustrates the smart gird systems from the supply to demand side which reflects the concept of safety operation, high efficiency, sustainability, reliability, economic incentives, security and environmental friendly (Provincial Authority of Thailand, 2011).

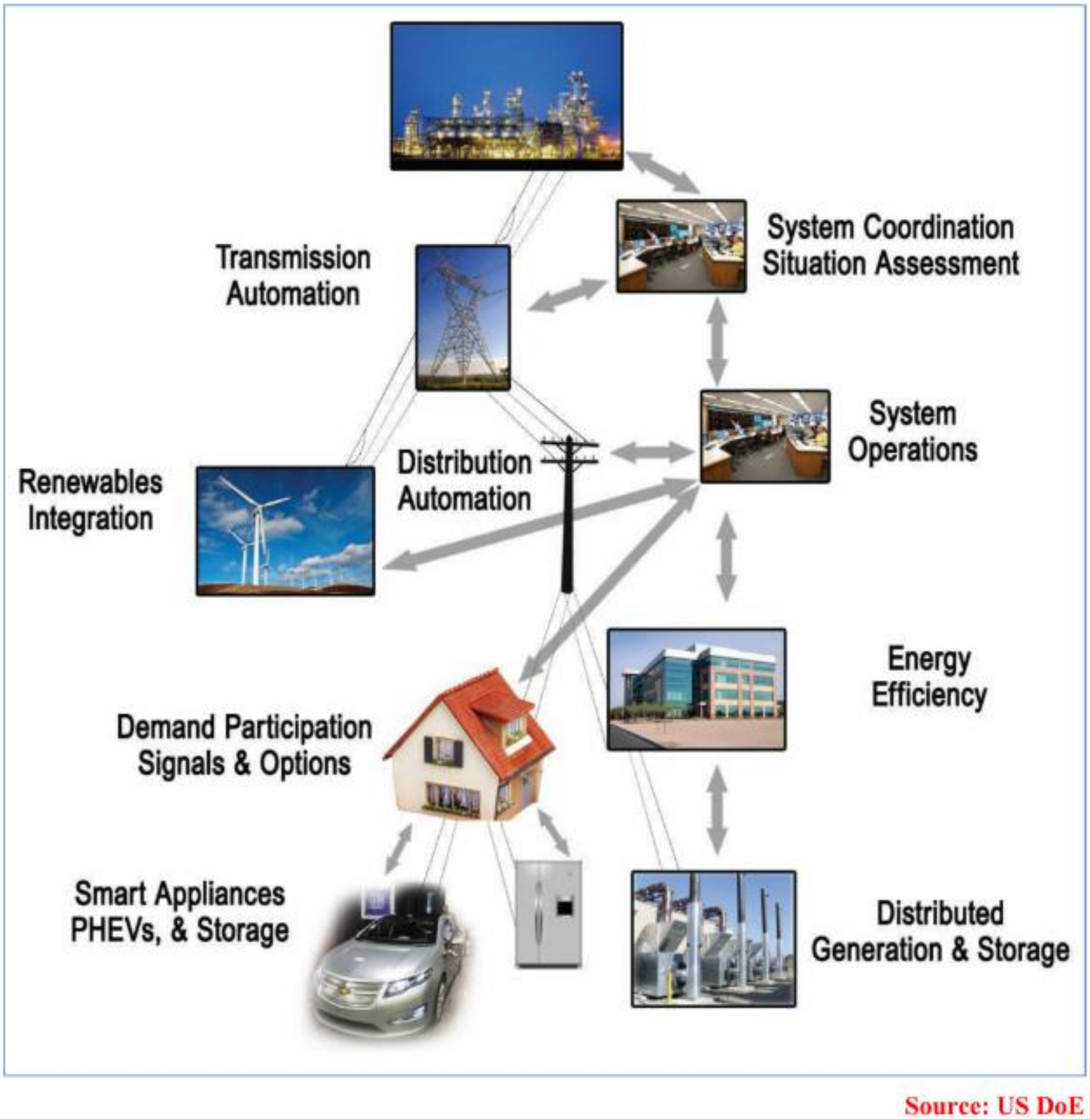

Fig A 1: Smart grid

The NDTL of DOE defines the seven key elements of smart grids as follows (National Energy Technology Laboratory of United States, 2008);

1. Active consumer participation
2. Accommodates generation and storage options
3. Enables products, services and markets
4. Provides power quality
5. Optimizes assets and operates efficiently
6. Resist attacks (response to disturbances)
7. Self-healing from operations. Resilient against attack and natural disaster

The main characteristics of smart grids are explained in Table A 1 (International Energy Agency, 2011).

Table A 1 Main characteristics of smart grids

Characteristic	Description
Enables informed participation by customers	Consumers help balance supply and demand and ensure reliability by modifying the way they use and purchase electricity. These modifications come as a result of consumers having choices that motivate different purchasing patterns and behaviors. These choices involve new technologies, new information about their electricity use, and new forms of electricity pricing and incentives.
Accommodates all generation and storage options	A smart grid accommodates not only large, centralized power plants, but also the growing array of customer-sited distributed energy resources. Integration of these resources – including renewable, small-scale combined heat and power, and energy storage – will increase rapidly all along the value chain, from suppliers to marketers to customers.
Enables new products, services and markets	Correctly designed and operated markets efficiently create an opportunity for consumers to choose among competing services. Some of the independent grid variables that must be explicitly managed are energy, capacity, location, time, rate of change and quality. Markets can play a major role in the management of these variables. Regulators, owners/operators and consumers need the flexibility to modify the rules of business to suit operating and market conditions.
Provides the power quality for the range of needs	Not all commercial enterprises, and certainly not all residential customers, need the same quality of power. A smart grid supplies varying grades (and prices) of power. The cost of premium power-quality features can be included in the electrical service contract. Advanced control methods monitor essential components, enabling rapid diagnosis and solutions to events that impact power quality, such as lightning, switching surges, line faults and harmonic sources.
Optimizes asset utilization and operating efficiency	A smart grid applies the latest technologies to optimize the use of its assets. For example, optimized capacity can be attainable with dynamic ratings, which allow assets to be used at greater loads by continuously sensing and rating their capacities. Maintenance efficiency can be optimized with condition-based maintenance, which signals the need for equipment maintenance at precisely the right time. System-control devices can be adjusted to reduce losses and eliminate congestion. Operating efficiency increases when selecting the least-cost energy-delivery system available through these types of system-control devices.
Provides resiliency to disturbances, attacks and natural disasters	Resiliency refers to the ability of a system to react to unexpected events by isolating problematic elements while the rest of the system is restored to normal operation. These self-healing actions result in reduced interruption of service to consumers and help service providers better manage the delivery infrastructure.

2. Smart grid technologies (IEA, 2011)

Smart grid technology areas govern the entire grid, from generation through transmission and distribution to various types of electricity consumers. Some of the technologies are actively being deployed and are considered mature in both their development and application, while others require further development and demonstration. A fully optimized electricity system will deploy all the technology areas in Fig A 2. However, not all technology areas need to be installed to increase the "smartness" of the grid (International Energy Agency, 2011).

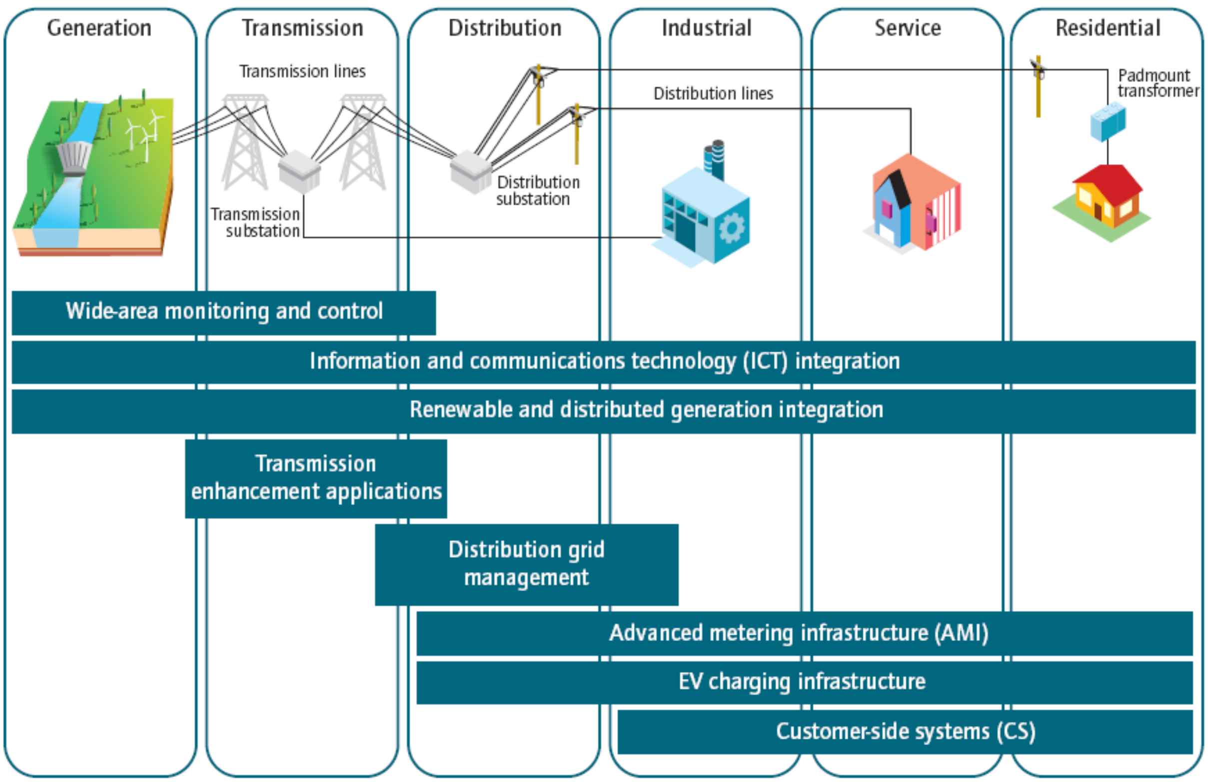

Fig A 2 Smart grid technology areas
Source: IEA (2011)(International Energy Agency, 2011)

2.1 Wide-area monitoring and control

Real-time monitoring and display of power system component and performance across interconnections and over large geographic areas help system operators to understand and optimize power system component, behavior, and performance. Advanced system operation tools avoid blackouts and facilitate the integration of variable renewable energy resources. Monitoring and control technologies along with advanced system analytics – including wide-area situational awareness (WASA), wide-area monitoring systems (WAMS), and wide-area adaptive protection, control and automation (WAAPCA) – generate data to inform decision making, mitigate wide-area disturbances, and improve transmission capacity and reliability.

2.2 Information and communication technology integration

Underlying communication infrastructure, whether using private utility communication networks (radio networks, meter mesh networks) or public carriers and networks (Internet, cellular, cable or telephone), supports data transmission for deferred and real-time operation during outages. Along with communication devices, significant computing, system control software, and enterprise resource planning software support the two-way exchange of information between stakeholders which enable more efficient use and management of the grid.

2.3 Renewable and distributed generation integration

Integration of renewable and distributed energy resources – encompassing large scale at the transmission level, medium scale at the distribution level, and small scale on commercial or residential building – can present challenges for the dispatchability and controllability of these resources and for operation of the electricity system. Energy storage systems, both electrically and thermally based, can alleviate such problems by decoupling the production and delivery of energy. Smart grids can help through automation of control of generation and demand (in addition to other forms of demand response) to ensure balancing of supply and demand.

2.4 Transmission enhancement applications

There are a number of technologies and applications for the transmission system. Flexible AC transmission systems (FACTS) are used to enhance the controllability of transmission networks and to maximize power transfer capability. The deployment of this technology on existing lines can improve efficiency and defer the need of additional investment. High voltage DC (HVDC) technologies are used to connect offshore wind and solar farms to large power areas, with decreased system losses and enhanced system controllability, allowing efficient use of energy sources remote from load centers. Dynamic line rating (DLR), which uses sensors to identify the current carrying capability of a section of network in real time, can optimize utilization of existing transmission assets, without the risk of causing overloads. High-temperature superconductors (HTS) can significantly reduce transmission losses and enable economical fault-current limiting with higher performance, though there is a debate over the market readiness of the technology.

2.5 Distribution grid management

Distribution and sub-station sensing and automation can reduce outage and repair time, maintain voltage level and improve asset management. Advanced distribution automation processes real-time information from sensors and meters for fault location, automatic reconfiguration of feeders, voltage and reactive power optimization, or to control distributed generation. Sensor technologies can enable condition- and performance-based maintenance of network components, optimizing equipment performance and hence effective utilization of assets.

2.6 Advanced metering infrastructure

Advanced metering infrastructure (AMI) involves the deployment of a number of technologies – in addition to advanced or smart meters that enable two-way flow of information, providing customers and utilities with data on electricity price and consumption, including the time and amount of electricity consumed. AMI will provide a wide range of functionalities:

- Remote consumer price signals, which can provide time-of-use pricing information.
- Ability to collect, store, and report customer energy consumption data for any required time intervals or near real time.
- Improved energy diagnostics from more detailed load profiles.

- Ability to identify location and extent of outages remotely via a metering function that sends a signal when the meter goes out and when power is restored.
- Remote connection and disconnection.
- Losses and theft detection.
- Ability for a retail energy service provider to manage its revenues through more effective cash collection and debt management.

2.7 Electric vehicle charging infrastructure

Electric vehicle charging infrastructure handles billing, scheduling, and other intelligent features for smart charging (grid-to-vehicle) during low energy demand. In the long run, it is envisioned that large charging installation will provide power system ancillary services such as capacity reserve, peak load shaving, and vehicle-to-grid regulation. This will include interaction with both AMI and customer-side systems.

2.8 Customer-side systems

Customer-side systems, which are used to help manage electricity consumption at the industrial, service and residential levels, include energy management systems, energy storage devices, smart appliances and distributed generation. Energy efficiency gains and peak demand reduction can be accelerated with in-home displays/energy dashboards, smart appliances, and local storage. Demand response includes both manual customer response and automated, price-responsive appliances and thermostats that are connected to an energy management system or controlled with a signal from the utility or system operator.

Table A2 highlights a number of hardware and systems and software associated with each technology area. Within the smart grid technology landscape, a broad range of hardware and software applications and communication technologies are at various levels of maturity.

It should be noted here that some technologies have proven themselves over time, but many have yet to be demonstrated or deployed on a large scale. Existing projects give an indication of the maturity levels and development trends of smart grid technologies which presented in Table A3.

Table A 2 Smart grid technology in both hardware and software

Technology area	Hardware	Systems and software
Wide-area monitoring and control	Phasor measurement units (PMU) and other sensor equipment	Supervisory control and data acquisition (SCADA), wide-area monitoring systems (WAMS), wide-area adaptive protection, control and automation (WAAPCA), wide area situational awareness (WASA)
Information and communication technology integration	Communication equipment (Power line carrier, WIMAX, LTE, RF mesh network, cellular), routers, relays, switches, gateway, computers (servers)	Enterprise resource planning software (ERP), customer information system (CIS)
Renewable and distributed generation integration	Power conditioning equipment for bulk power and grid support, communication and control hardware for generation and enabling storage technology	Energy management system (EMS), distribution management system (DMS), SCADA, geographic Information system (GIS)
Transmission enhancement	Superconductors, FACTS, HVDC	Network stability analysis, automatic recovery systems
Distribution grid management	Automated re-closers, switches and capacitors, remote controlled distributed generation and storage, transformer sensors, wire and cable sensors	Geographic information system (GIS), distribution management system (DMS), outage management system (OMS), workforce management system (WMS)
Advanced metering infrastructure	Smart meter, in-home displays, servers, relays	Meter data management system (MDMS)
Electric vehicle charging infrastructure	Charging infrastructure, batteries, inverters	Energy billing, smart grid-to-vehicle charging (G2V) and discharging vehicle-to-grid (V2G) methodologies
Customer-side systems	Smart appliances, routers, in-home display, building automation systems, thermal accumulators, smart thermostat	Energy dashboards, energy management systems, energy applications for smart phones and tablets.

Source: IEA (2011)(International Energy Agency, 2011)

Table A 3 Maturity levels and development trends of smart grid technologies

Technology area	Maturity level	Development trend
Wide-area monitoring and control	Developing	Fast
Information and communications technology integration	Mature	Fast
Renewable and distributed generation integration	Developing	Fast
Transmission enhancement applications	Mature	Moderate
Distribution management	Developing	Moderate
Advanced metering infrastructure	Mature	Fast
Electric vehicle charging infrastructure	Developing	Fast
Customer-side systems	Developing	Fast

Smart grids include technology areas, such as renewable energy resources and demand response, which are not exclusively associated with, but are related to smart grids. Some of these technology areas were being studied long before the term smart grid was developed and therefore may offer solutions to problems that smart grids hope to address.

Smart grids consist of four main areas including (i) power generation, (ii) transmission, (iii) distribution, and (iv) end-use. The collaboration with these electricity system technology areas has the opportunity to accelerate the useful deployment of smart grids and avoid repeating past development work. An ideal way to collaborate across these electricity system technology areas is through the IEA Implementing Agreements (IAs) 29 of the 43 IAs and 11 focus on electricity system issues as shown in Table A3, these are coordinated under the electricity co-ordination. It should be noted here that this evaluation results in Fig A3 were taken from the US point of view.

3. Main Equipment

Smart grid technologies are already used in other applications such as manufacturing and telecommunications and are being adapted for use in grid operations. In general, smart grid technology can be grouped into five key areas (DOE, 2010).

3.1 Integrated communications

Some communications are up to date, but are not uniform because they have been developed in an incremental fashion and not fully integrated. In most cases, data is being collected via a modem rather than a direct network connection. Areas for improvement include: substation automation, demand response, distribution automation, supervisory control and data acquisition (SCADA), energy management systems, wireless mesh networks and other technologies, power-line carrier communications, and fiber-optics. Integrated communications will allow for real-time control, information and data exchange to optimize system reliability, asset utilization, and security

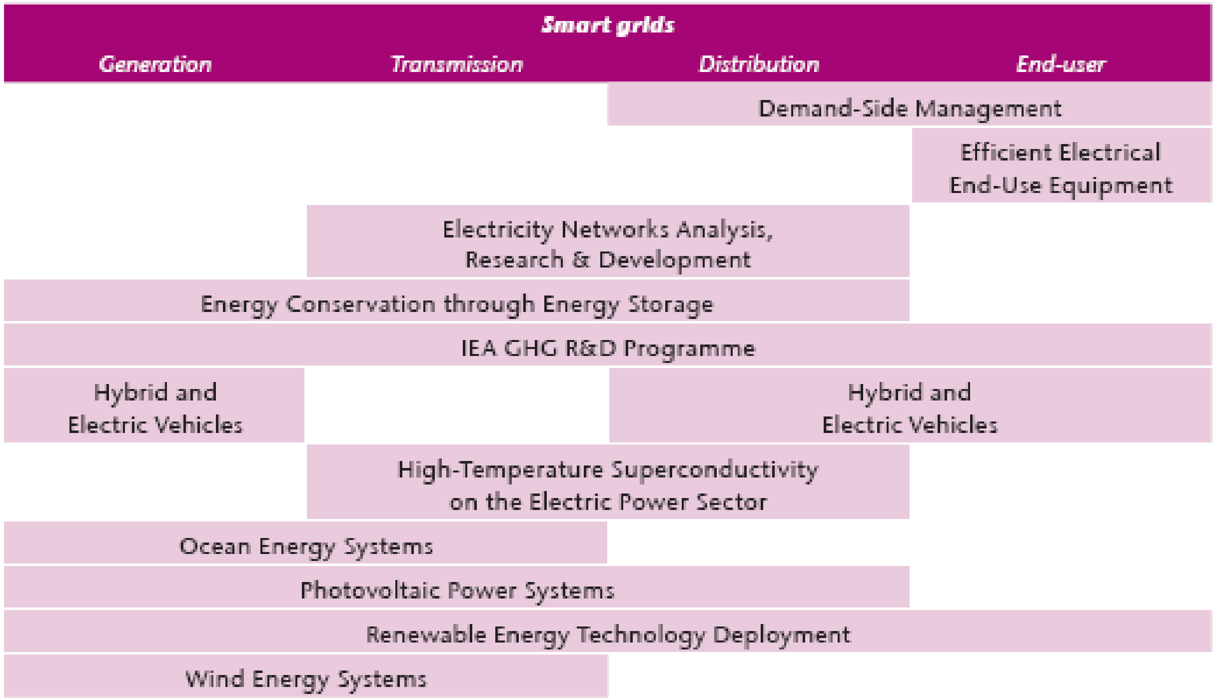

Fig A 3 Electricity sector focus for IEA ECG Implementing Agreements
Source: IEA (2011)(International Energy Agency, 2011)

3.2 Sensing and measurement

Core duties are evaluating congestion and grid stability, monitoring equipment health, energy theft prevention, and control strategies support. Technologies include: advanced microprocessor meters (smart meter) and meter reading equipment, wide-area monitoring systems, dynamic line rating (typically based on online readings by Distributed temperature sensing combined with Real time thermal rating (RTTR) systems), electromagnetic signature measurement/analysis, time-of-use and real-time pricing tools, advanced switches and cables, backscatter radio technology, and digital protective relays.

3.3 Smart meters

A smart grid replaces analog mechanical meters with digital meters that record usage in real time. Smart meters are similar to Advanced Metering Infrastructure meters and provide a communication path extending from generation plants to electrical outlets (smart socket) and other smart grid-enabled devices. By customer option, such devices can shut down during times of peak demand

3.4 Phasor measurement units

High speed sensors called PMUs distributed throughout their network can be used to monitor power quality and in some cases respond automatically to them. Phasors are representations of the waveforms of alternating current, which ideally in real-time, are identical everywhere on the network and conform to the most desirable shape. In the 1980s, it was realized that the clock pulses from global positioning system (GPS) satellites could be used for very precise time measurements in the grid. With large numbers of PMUs and the ability to compare shapes from alternating current readings everywhere on the grid, research suggests that automated systems will be able to revolutionize the management of power systems by responding to system conditions in a rapid, dynamic fashion.

A wide-area measurement system (WAMS) is a network of PMUS that can provide real-time monitoring on a regional and national scale. Many in the power systems engineering community believe that the Northeast blackout of 2003 would have been contained to a much smaller area if a wide area phasor measurement network was in place.

3.5 Advanced components

Innovations in superconductivity, fault tolerance, storage, power electronics, and diagnostics components are changing fundamental abilities and characteristics of grids. Technologies within these broad R&D categories include: flexible alternating current transmission system devices, high voltage direct current, first and second generation superconducting wire, high temperature superconducting cable, distributed energy generation and storage devices, composite conductors, and “intelligent” appliances

3.6 Advanced control

Power system automation enables rapid diagnosis of and precise solutions to specific grid disruptions or outages. These technologies rely on and contribute to each of the other four key areas. Three technology categories for advanced control methods are: distributed intelligent agents (control systems), analytical tools (software algorithms and high-speed computers), and operational applications (SCADA, substation automation, demand response, etc.). Using artificial intelligence programming techniques, Fujian power grid in China created a wide area protection system that is rapidly able to accurately calculate a control strategy and execute it. (http://en.wikipedia.org/wiki/Smart_grid - cite_note-37). The Voltage Stability Monitoring & Control (VSMC) software uses a sensitivity-based successive linear programming method to reliably determine the optimal control solution

3.7 Smart power generation

Smart power generation is a concept of matching electricity production with demand using multiple identical generators which can start, stop and operate efficiently at chosen load, independently of the others, making them suitable for base load and peaking power generation. Matching supply and demand, called load balancing, is essential for a stable and reliable supply of electricity. Short-term deviations in the balance lead to frequency variations and a prolonged mismatch results in blackouts. Operators of power transmission systems are charged with the balancing task, matching the power output of the all the generators to the load of their electrical grid. The load balancing task has become much more challenging as increasingly intermittent and variable generators such as wind turbines and solar cells are added to the grid, forcing other producers to adapt their output much more frequently than has been required in the past.

Conclusions

In conclusion, the smart energy demand mechanisms and tactics include

- smart meters,
- dynamic pricing,
- smart thermostats and smart appliances including the storage,
- automated control of equipment,
- real-time and next-day energy information feedback to electricity users, usage by appliance data
- Scheduling and controlling loads such as electric vehicle chargers, home area networks (HANs), and others.

A.2 Waste (power generation)

1. Introduction

Electricity or thermal energy production from renewable energy waste is an alternative to help reduce the problem of the environment. However, presently, Thailand has an electricity generation capacity from solid waste disposal of only around 5 MW. While the goal of waste renewable energy promotion is 160 MW by 2022. Several barriers including as unclear laws and regulations are the main obstacles to investors of waste-to-energy technology. There is also a lack of management and campaign of waste separation at the community level including a lack of confidence in the existing technology.

To achieve waste electricity generation, cooperation from all relevant sectors is required. Guidelines are needed from the government to assist, support and stimulate the investment in the waste energy production. In the past, the policy was not clear because most of the waste energy production was derived from government operations or financially supported by the government for construction and project implementation.

To materialize the goal of waste-to-energy promotion, it is necessary for all the stakeholders throughout the supply chain to cooperate (as shown in Fig A 4). As a result, the ministry of energy collaborated with government institutes, private sectors and local administrative organizations to integrate waste-to-energy technology in the master plan of Bangkok. In addition, the Pollution Control Department (PCD) issued the guideline to produce energy from solid waste while the Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy established the waste energy production promote plan to set targets and goals for waste-to-energy development.

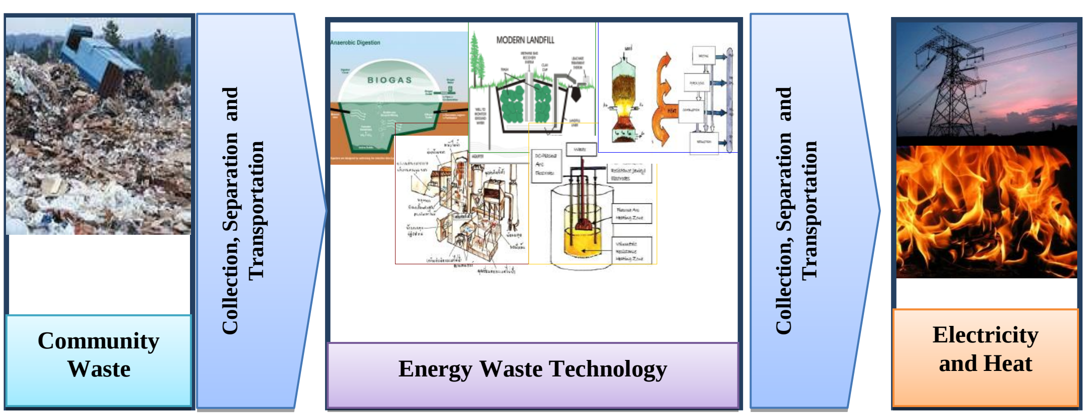

Fig A 4 Waste to energy supply chain
Source: DEDE, 2008 (DEDE, 2008)

2. Technology characteristics

Currently, there have several principle waste energy technologies which have different advantages and limitations as shown in Table A4.

Table A 4 Waste energy technology characteristics

Technology	Advantages	limitations
1. Incineration	• Highly flexible waste type; various waste can be burnt at the same time • Reduce a lot of mass and volume • Short treatment time • High energy yield • Require small space for the system.	• High investment, operation, and maintenance cost. • The facility should have the capacity greater than 250 tons per day to be cost effective. • Advanced and emerging technology; cannot be developed in Thailand yet. .
2. Anaerobic Digestion, AD	• Clean technology • Large amount of biodegradable waste in Thailand • Simple technology; can be developed easily in Thailand.	• Have to campaign the organic waste separation from the beginning. • Require the development of microbial species enable to digest waste at various environmental conditions and produce high gas yield. • Require soil conditioner marketing to increase the revenues of the system.
3. Landfill Gas to Energy	• Decrease the release of methane (GHG) to the atmosphere • Decrease risk of explosion or fire hazard from landfill • Simple technology; can be developed easily in the country	• The volume of waste in landfill must be greater than 1 million ton for cost effectiveness • Hard to predict the gas generation rate due to complex phenomena governed by various factors.
4. Refuse Derived Fuel	• Clean technology • Capable of using with pyrolysis / gasification • The RDF can be stored and used when needed • Require small space for the system • Simple technology; can be developed easily in the country.	• Unable to complete the waste destruction; need a further waste treatment to complete the treatment/destruction process. • No market for the RDF in Thailand just yet.

Technology	Advantages	limitations
5. Gasification	• Clean technology • Reduce a lot of mass and volume • Short treatment time • High energy yield • Require small space for the system	• Must be used with a basis waste destruction process such as RDF. • Require high investment, operation and maintenance cost. • Advanced technology; cannot be developed in the country
6. Plasma Arc	• High heating temperature increases waste destruction efficiency. • Residual of the high temperature process is slag, which stabilizes hazardous substances generally found in the residual of low temperature such as ash.	• High investment, operation, and maintenance cost. •
7. Plastic waste into fuel processing technology.	• Liquid fuel can be transported easily and economically. • The fuel can be stored to use when needed. • Require small space for the system • Simple technology; can be handled by the country	• Require the effective plastic waste separation process. • Require cleaning process for the plastic waste.

3. Country specific / applicability

Thailand has implemented many technologies mentioned above. Some examples are as follows:

(1) Phuket municipal waste burner: started in January 2003, the system uses of burner technology from Japan. The system can receive 250 tons of waste per day, and the waste heat is brought to produce steam to generate electricity capacity of 2.5MW.

(2) Rayong municipal organic fertilizer and energy factory: started in December 2004, the system uses of anaerobic digestion technology from Finland. The system can receive the organic waste about 60 tons per day which generates the energy at the capacity of 625 kW .

(3) Samutprakan, waste landfill power generation project : the system uses piping technology to collect biogas from the landfill by domestic expert. The electricity is generated by a gas engine at the capacity of 950kW.

(4) Nakhonpathom, waste landfill power generation project: started in May 2008, the same technology as at Samutprakan. The electricity is generated by a gas engine at the capacity of 1 MW.

4. Status of technology in country

The status of Thailand waste-to-energy source is as follows:

(1) The composition and quantity of waste.

Waste composition changes according to the season and climate conditions, socio-economic behavior, lifestyle, habit and consumption behavior. The average waste composition in 30 municipalities, are summarized in Table A 5.

Table A 5 Average waste composition in municipalities with more than 100 tons/day and 50-100 tons/day

Component	Quantity > 100 tons/day	Quantity 50-100 tons/day
Food / vegetables / fruits	53.49 %	57.18 %
Plastic	20.12 %	19.40 %
Paper	8.95 %	8.38 %
Grass	5.02 %	3.47 %
Metal	1.80 %	1.52 %
Other	10.62 %	10.05 %

Source: Department of Alternative Energy Development and Efficiency, 2012(Department of Alternative Energy Development and Efficiency, 2012)

Table A6 summarizes the amount of waste generated and treated in Bangkok, the municipality and Pataya, and outside the municipality. The details can be described as follows:

Table A 6 The amount of waste handled correctly by the principles in 2007

Area	Amount (Tons/Days)	
	Occurred	Eliminated
Bangkok	8,532	8,532
Municipality and Pataya (6,500 location)	13,600	4,810
Outside the municipality (6,500 location)	18,200	1,090
Total	**40,332**	**14,432**

(i) Bangkok. The amount of waste generated is 8,532 tons/day, 21 % of the total waste of the country. All the waste is treated or disposed. 87% is disposed in landfills while 13% is used as fertilizer. Bangkok has 3 waste transfer stations. The On-Nut waste transfer station can receive 3, 336 tons / day (39%) and is disposed in a landfill at the Phanom Sarakham, Chachoengsao around 2, 229 tons / day (26%) while 13% (1, 107tons / day) of the waste was composted and used as fertilizer. The Nongkhaem waste station can receive 3, 113tons / day (37 % (while the Tharang waste Station can received 2, 083tons / day (24%). All of the waste from these two stations is disposed in the landfill at Kamphaeng Saen, Nakhon Pathom.

(ii) The Pataya municipality: the total waste is 13, 600tons / day , 34% of the country. Only, 35% (4810tons / day) is disposed per day.

(iii) Outside the municipal waste: the total waste is 18,200 tons / day , 45 % of the country. Only, 6% (1, 090tons / day) is disposed per day.

The details of waste quantity in 2005 to 2007 are shown in Table A7 and Fig A5.

Table A 7 The amount community waste in 2005-2007

Area	Amount of Community Waste(Tons/Day)		
	2005	2006	2007
1. Bangkok	8,291	8,379	
2. Municipality and Pataya	12,635	12,912	13,600
2.1 Central and East	5,499	5,619	
2.2 North	2,148	2,195	
2.3 Northeast.	2,906	2,971	
2.4 South	2,082	2,128	
3. Outside the municipal	18,295	18,295	18,200
Total	**39,221**	**39,988**	**40,322**

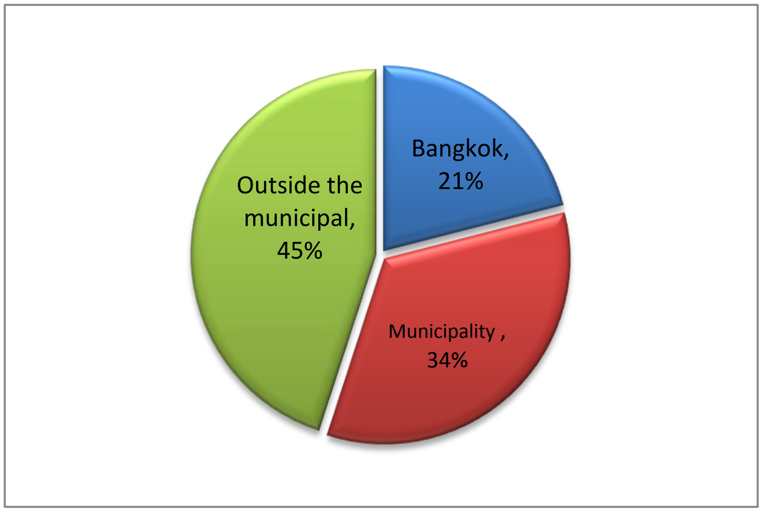

Fig A 5 The amount of waste classified by area condition in 2007 (40,322 tons/day)

The linear regression analysis of the waste data (Table A7) reveals that in 2022, Thailand will reach 45,855 tonnes of waste per day (Fig A6). By using the assumption that 100 tons of waste can generate electricity 1 MW and that 70% of waste is capable of energy production, the energy generation potential from waste is 320 MW.

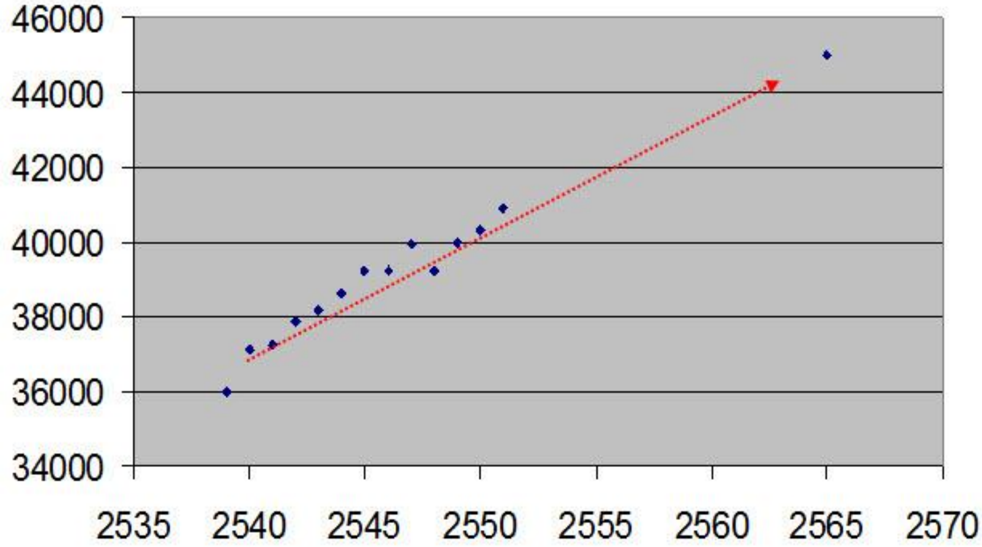

Fig A 6 Estimate the amount of waste in 2022

Thailand has the target to promote waste-to-energy generation only 50% (160 MW, or 72 ktoe (Plant Factor = 60%) of the full potential by considering the possibility of management and waste collection.

(2) Hydrothermal treatment of waste

Hydrothermal treatment technology is a new technology developed by the Tokyo Institute of Technology. The advantage of this technology is that the toxic from typical thermal treatment techniques such as dioxin can be transferred into liquid and subsequently treated. Moreover, the technology is applicable for all types of waste without waste separation (excluding hazardous waste and flammable waste). It is suitable for a country with limited appropriate waste separation like Thailand.

Fig A7 illustrates the hydrothermal. Waste is fed into the reactor and undergoes the hydrothermal reaction with saturated steam supplied from the oil-fired boiler as the heating source. At the same time, the waste is stirred by a rotor unit to obtain homogeneous mixture. After reaching intended temperature, the reactor is set to maintain the temperature for a certain holding period. The hydrothermal treatment finishes by releasing the pressurized steam to the condenser until the reactor reaches atmospheric pressure. The products can then be pushed outside by rotating the stirrer acting as a screw conveyor. The water condensed in the condenser is sent to the water treatment facility to be fed back to the boiler as feed water for steam generation, constituting a closed-loop of water flow.

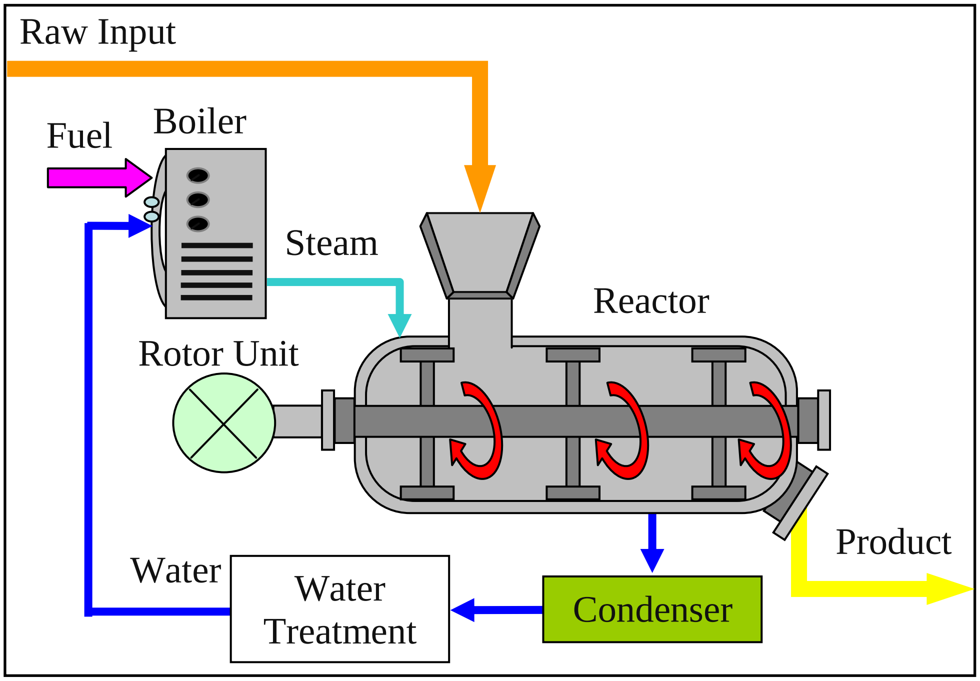

Fig A 7 Developed commercial hydrothermal treatment system diagram

The waste residual through the hydrothermal process will have high moisture content (~, 40-70% moisture); then, the residuals dried by natural means. The final product (dry, 10% moisture) can used as fuel to produce energy in system as shown in Fig A8.

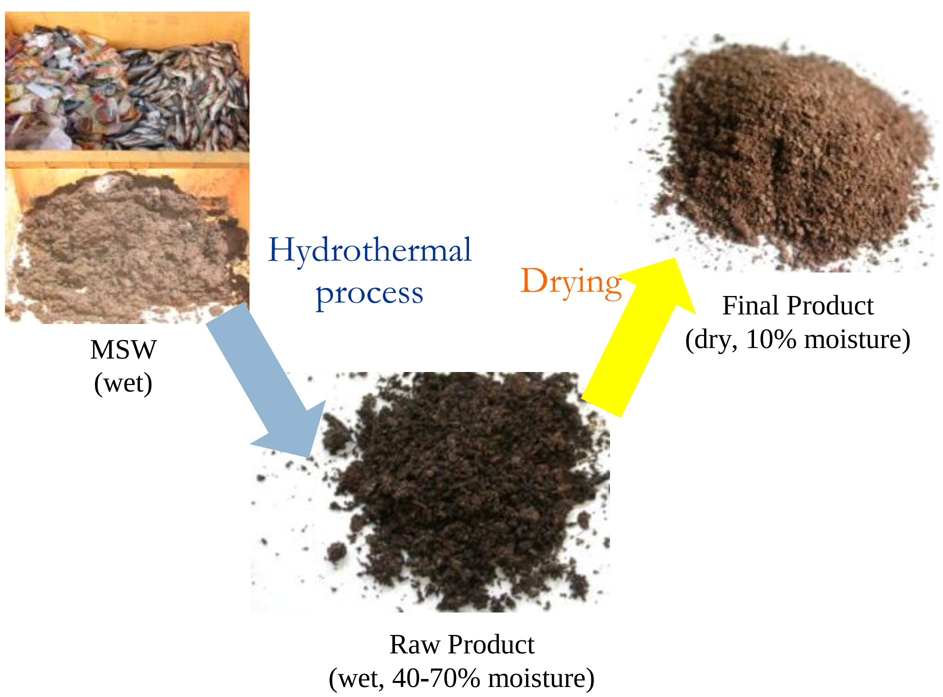

Fig A 8 Raw MSW conversion by employing the hydrothermal treatment.

A.3 Second and third generation of biofuels

1. Introduction

Biofuels can be classified into 3 generations: First, second and third generation The 2nd generation biodiesel includes liquid fuels derived from Jatrapha seed oil and from a catalytic conversion process of synthetic gas from the gasification of biomass. The 2nd generation ethanol is a liquid fuel from non-food bio-materials such as biomass and bio-waste having high cellulose. Fig A 9 summarizes the benefits of biofuels compared to conventional fuel. It was found that the GHG performance of biofuels is the key to achieving a low-carbon transportation sector and meeting this roadmap's vision. However, given the extensive nature of the potential supply and use of biofuels and their interaction with the agricultural and forestry sectors, all three pillars of sustainability; i.e. (i) environment, (ii) economic and (iii) social, need to be fully considered and appropriately addressed on policy level.

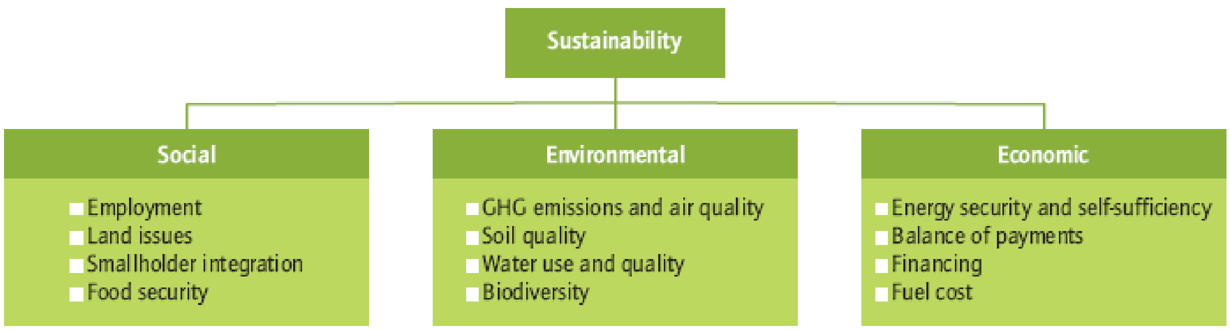

Fig A 9 Environmental, social and economic aspect from biofuels production
Source: IEA (2011)(International Energy Agency, 2011)

2. Second Generation Biodiesel Technology

Biodiesel is fuel derived from biological materials such as vegetable oils, animal fats or oil from algae. Biodiesel usually refers to the products from a chemical reaction of vegetable or waste oil and ethanol and methanol called a Transesterification process. Properties of biodiesel are similar to fossil diesel fuel, which can be used in a standard diesel engine without modification. Biodiesel contains 10% oxygen and zero sulfur, which results in the vehicle engine burning more completely and efficiently. It is credited with reducing 40% of the smog problem and a large percentage of carbon monoxide reduction. Biodiesel can be used 100% or mixed with petro-diesel, called the "B" ratio. B5 to B20 are acceptable levels in several countries.

First generation biodiesel was derived from food bio-feedstocks such as soybeans, palm, canola and rapeseed. Promotion of the first generation biodiesel caused interaction problems with human food-chains, including supply and demand balancing, land use, water management.

Several processes under development aim to produce fuels with properties very similar to diesel and kerosene. These fuels blendable with fossil fuels in any proportion can use the same infrastructure and should be fully compatible with engines in heavy duty vehicles. Advanced biodiesel and bio-kerosene will become increasingly important to reach this roadmap's targets since demand for low-carbon fuels with high energy density is expected to increase significantly in the long term.

Advanced biodiesel includes:

Second generation biodiesel come from non-food bio-feedstocks such as jatropha or the use of technologies such as biomass to liquid (BTL). These feedstocks have the advantage of not affecting the human food chain.

Hydrotreated vegetable oil (HVO) is produced by hydrogenating vegetable oils or animal fats. The first large-scale plants have been opened in Finland and Singapore, but the process has not yet been fully commercialized. Biomass-to-liquid diesel, also referred to as Fischer-Tropsch diesel, is produced by a two-step process in which biomass is converted to a syngas rich in hydrogen and carbon monoxide. After cleaning, the syngas is catalytically converted through the Fischer-Tropsch (FT) synthesis into a broad range of hydrocarbon liquids, including synthetic diesel and bio-kerosene.

Advanced biodiesel is not widely available at present, but could become fully commercialized in the near future, since a number of producers have pilot and demonstration projects underway (IEA, 2011).

3. Second Generation Bio-ethanol Technology

The first generation ethanol feedstocks are corn, sugarcane, maize etc. These feedstocks present the problem of affecting the food price structure. Available land areas for cultivation are also a concerning factor.

Second generation ethanol feedstocks are mainly from agricultural wastes such as corn stover, sugarcane baggase and also from wood, grasses or the non-edible parts of plants. It is produced from lignocelluloses, a structural material that comprises much of the mass of plants. The ethanol is derived not from the starch component like the first generation ethanol, but from the lignocellulosic component of the feedstock. Large sources of lignocellulose are available including non-food wild plants that grow in non-cultivated and non-arable lands. The second generation ethanol feedstocks overcome the two main bottlenecks for the first generation feedstock: adverse effects on food prices and inability to scale.

Cellulosic ethanol is a biofuel produced from wood, grasses or the nonedible parts of plants. It is a type of biofuel produced from lignocellulose, a structural material that comprises much of the mass of plants. Lignocellulose is composed mainly of cellulose, hemicellulose and lignin. Corn stover, switchgrass, miscanthus, woodchips and the byproducts of lawn and tree maintenance are some of the more popular cellulosic materials for ethanol production. Production of ethanol from lignocellulose has the advantage of abundant and diverse raw material compared to sources like corn and cane sugars but requires a greater amount of processing to make the sugar monomers available to the microorganisms that are typically used to produce ethanol by fermentation.

Lignocellulosic materials, which provide structure to plants, are found in the stems, stalks, and leaves of plants and in the trunks of trees. The abundance of lignocellulosic materials – roughly 60 to 90 percent of terrestrial biomass by weight – along with the fact that they are not used for food and feed (unlike corn and sugarcane), are key reasons why lignocellulosic ethanol and other lignocellulosebased biofuels have attracted scientific and political interest. Lignocellulose and hemicellulose, which are referred to collectively as lignocellulosic materials, can be broken down into sugars, which can then be fermented into ethanol. Lignocellulosic materials being examined for the production of biofuels include those derived from switchgrass, prairie grasses, short rotation woody crops, agricultural residues, and forestry materials and residues.

Ethanol is chemically the same whether it is produced from corn, sugarcane or cellulose. However, the production processes are different and the necessary production technologies are in different stages of development. Corn and sugar based ethanol production technologies have been used at a commercial scale for decades. In contrast, some of the technologies needed to produce cellulosic ethanol, an “advanced biofuel” (broadly defined as a biofuel derived from organic materials other than simple sugars, starches, or oils) are quite new.

The advantage of the use of ethanol as fuel especially in the transportation sector is that ethanol/gasoline mix is an "oxygenate" fuel. It adds oxygen to the fuel mixture so that it burns more completely and reduces polluting emissions such as carbon monoxide.

Any amount of ethanol can be combined with gasoline, but the most common blends are:

- E10 - 10% ethanol and 90% unleaded gasoline.
- Ethanol is a clean-burning, high-octane fuel. Ethanol can be produced domestically in most countries. When ethanol is blended with gasoline, the octane rating of the petrol goes up by three full points, without using harmful additives. The higher the octane rating, the slower the fuel burns and the less likely the engine will knock.

Comparing with corn, cellulosic feedstocks have better energy conversion ratios, reduce CO2 emissions, and create less damaging land and water impact as shown in Table A 8.

Table A 8 Comparison of various ethanol types and gasoline

	Corn ethanol	Cane ethanol	Gasoline	Cellulosic ethanol
Energy output	8	1.3	1	236
CO2 emission	1.94 kg/lit	1.07 kg/lit	2.49 kg/lit	0.22 kg/lit
Ignition temperature	High	High	Lower	High
Water use in production	Growth of corn, refining diesel for tractors	Growth of cane	Refining of crude	Varies greatly
Production per acre	1512 liter	2305 liter	N/A	2780 liter

Source: Worldwatch Institute, US DOE–EIA, US EPA

All existing gasoline-engine vehicles can use E10 with no modifications to the engine. The use of higher mixing percentage needs to tune up and modify the engine, such as E85 is for use in a flexible fuel vehicle.

In terms of the environment and GHG mitigation, cellulosic ethanol has the potential to provide significant lifecycle GHG reductions compared to petroleum based gasoline. In addition, the use of cellulosic materials to produce ethanol may yield a variety of other environmental benefits relative to corn based ethanol. Researchers at the University of California at Berkeley estimated that on a lifecycle basis as shown in Table A 9, cellulosic ethanol could lower GHG emissions by 90 percent relative to petroleum based gasoline. Other analyses have shown that cellulosic ethanol produced using certain feedstocks could be carbon negative, which means that more carbon dioxide (CO_2) is removed from the atmosphere than is emitted into the atmosphere over the entire lifecycle of the product. However, these studies do not include estimates of emissions due to indirect land use change. An analysis undertaken by the California Air Resources Board as it developed the California Low Carbon Fuel Standard found significant lifecycle GHG emission reductions from cellulosic ethanol relative to gasoline.

Table A 9 Lifecycle GHG Intensity for Cellulosic Ethanol, based on the California GREET Model

Fuel	Feedstock	CA GREET GHG (g CO2e/MJ)	GHG reduction compared to gasoline
Cellulosic Ethanol	Farmed trees	1.60	98.3%
Cellulosic Ethanol	Forest residues	21.40	77.7%
California Gasoline (incl. 10% ethanol)		95.9	

A Comparison of first and second generation biofuels shown in Table A 10.
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Table A 10 A Comparison of first and second generation biofuels

First- Vs. Second-Generation Biofuels		
Parameters	1st gen.	2nd gen.
Direct food vs. fuel competition	Yes	No
Feedstock cost per unit of production	High	Low
Land-use efficiency	Low	High
Feasibility of using marginal lands for feedstock production	Poor	Good
Ability to optimize feedstock choice for local conditions	Limited	High
Potential for net reduction in fossil fuel use	Medium	Medium-High
Potential for net reduction in greenhouse gas emissions	Medium	Medium-High
Readiness for use in existing petroleum infrastructure	Yes	Yes
Proven commercial technology available today	Yes	No
Simplicity of processes	Yes	No
Capital costs per unit of production	Low	High
Total cost of production	High	High
Minimum scale for economical production	Medium	High
Direct food vs. fuel competition	Yes	No
Feedstock cost per unit of production	High	Low
Land-use efficiency	Low	High
Feasibility of using marginal lands for feedstock production	Poor	Good
Ability to optimize feedstock choice for local conditions	Limited	High

4. Current situation

A wide variety of conventional and advanced biofuel conversion technologies exists today. The current status of the various technologies and approaches to biofuel production is summarized in Fig A 10 below (IEA, 2011).

Cellulosic Ethanol Production - Current Status

As of March 2010, there are no large-scale commercial cellulosic ethanol refineries producing cellulosic ethanol. There are nearly ten commercial cellulosic ethanol plants worldwide that are either planned or under construction.

Cellulosic Ethanol Production – Future Projections

A study of the future of next-generation biofuels in Europe, by Bloomberg New Energy Finance, estimated that cellulosic ethanol supply could grow from 63bn litres in 2015 to 75bn litres in 2020 (under the base case scenario) and from 73bn litres in 2015 to 90bn litres in 2020 (bull case scenario). The top EU countries for next-generation ethanol supply are identified in order as France, Germany, Spain, United Kingdom, Italy and Poland. Conservatively, France was identified as having the potential to produce 15 billion liters of ethanol from biomass by 2020.

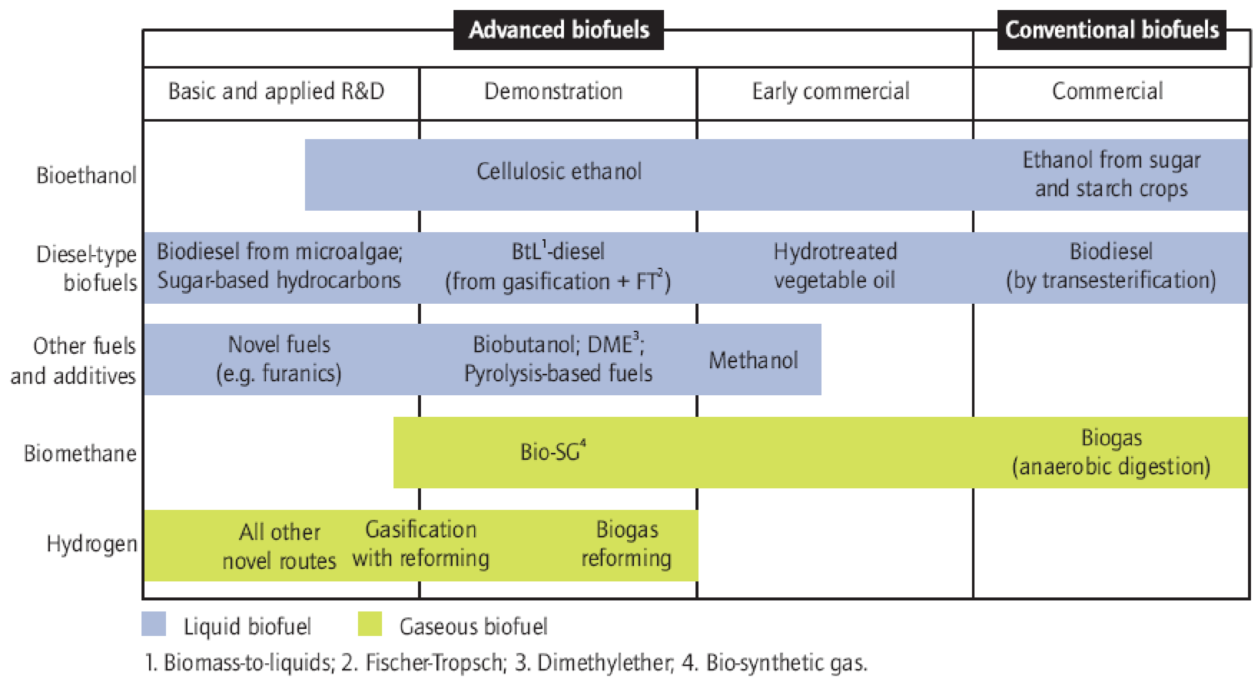


Fig A 10 Current status of the various technologies in biofuels
Source: IEA (2011)(IEA, 2011)

The United States estimated that the cellulosic ethanol production will increase from 3 billion gallons from 2015 to 10.5 billion gallons in 2020. Brazil and China will represent great production and marketable areas for biofuels from nonfood raw materials. India and South Africa are starting to look into ethanol as an option to reduce their energy dependence.

2. Key issues for development

Several advanced biofuels currently in a critical phase of technology development need to reach commercial scale and be widely deployed. As with conventional biofuels, improvements in conversion efficiency are needed, as well as strategies for reducing capital requirements. These strategies have to include integrating the different process steps along the whole supply chain (i.e. from biomass feedstock to the transportation of biofuels) to demonstrate the effective performance and reliability of the process. This should include the use of core technology components such as tar-free syngas production or (hemi-) cellulose to sugar conversion in other industries (*e.g.* the chemical industry).

Specific research and development (R&D) needs will need to be addressed to prove the industrial reliability as well as the technical performance and operability of the conversion routes in order to achieve economically sound production processes, as presented in Table A11. Detailed scientific support, modeling and monitoring of the above fields are required to obtain maximum learning and progress from the current pilot and demonstration activities (IEA, 2011).

Table A 11 Advanced biofuels key research and development issues

Technology	***Key R&D issues***
Cellulosic-ethanol	• Improvement of micro-organisms and enzymes • Use of C5 sugars, either for fermentation or upgrading to valuable co-products • Use of lignin as value-adding energy carrier or material feedstock
HVO	• Feedstock flexibility • Use of renewable hydrogen to improve GHG balance
BTL-diesel	• Catalyst longevity and robustness • Cost reductions for syngas clean-up • Efficient use of low-temperature heat
Other biomass-based diesel/kerosene fuel	• Reliable and robust conversion process in pilot and demonstration plants
Algae-biofuels	• Energy- and cost-efficient cultivation, harvesting and oil extraction • Nutrient and water recycling • Value-adding co-product streams

Source: IEA (2011)(IEA, 2011)

A.4 Fuel combustion in the industrial sector

1. Introduction

Boiler and kiln are the main boiler types in industry. They are a major energy consumer in both factory (especially food factory) and buildings (especially in hotels). In Thailand, based on the Department of Industrial Works (DIW) under Ministry of Industry database, there are 8,816 boilers in the country. Their capacity is 110,000 ton/hr. 6,306 of them are fire tube boilers with the capacity of 31,000 ton/hr., while the other 2,510 boilers are water tube boilers with the capacity of 79,000 ton/hr. Most of the fire tube boilers are used in small- and medium-sized factories which require low technology level and yield low energy efficiency as well. Improving burner technology can lead to significant energy efficiency yield for Thailand.

2. Technology characteristics

There are various types of burners with unique characteristics as follows:

2.1 On / off control system

This is the simplest control system. It means that the burner is either firing at full rate or turned off. The major disadvantage of this system is that the boiler is subjected to large and often frequent thermal shocks every time the boiler fires.

2.2 High / low / off control system

This is a slightly more complex system where the burner has two firing rates. The burner operates first at the lower firing rate and then switches to full firing as needed, thereby overcoming the severe impact of the thermal shock. The burner can also revert to the low fire position at reduced loads, again limiting thermal stresses within the boiler.

2.3 Modulating control system

A modulating burner controller will alter the firing rate to match the boiler load over the whole turndown ratio. Every time the burner is shut down and restarted, the system must be purged by blowing cold air through the boiler passages. This wastes energy and reduces efficiency. Full modulation, however, means that the boiler keeps firing over the whole range to maximize the thermal efficiency and minimize the thermal stress.

The pros and cons of each type are shown in Table A12.

Table A 12 Pros and cons of burner technology

Technology	Advantages	Disadvantages
On / off control system	• Simple • Inexpensive	• Low energy efficiency • If a large load comes on to the boiler just after the burner has switched off, the amount of steam available is reduced. In the worst cases this may lead to the boiler priming and locking out • Fluctuating output of steam
High / low / off control system	• The boiler can respond to large loads better as the 'low fire' position will ensure that there is additional excessive energy stored in the boiler • If the large load is applied when the burner is on the 'low fire' position, it can immediately respond by increasing the firing rate to 'high fire'. Thus, the purge cycle can be omitted	• More complex than on-off control • More expensive than on-off control
Modulating control system	• The boiler is very effective in tolerating large and fluctuating loads • Should more energy be required at short notice, the control system can immediately respond by increasing the firing rate, without pausing for a purge cycle	• Most expensive • Most complex • Burners with a high turndown capability are required

Modulating Burner

Boilers are often the principal steam or hot-water generators in industrial plants. Consequently, they must be designed to operate efficiently and safely while respond promptly to the demanded changes. Fig A 11 represents an adaptive burner-management system. Control techniques are capable of reducing operating costs while providing greater flexibility in plant management and control. Tools for burner combustion controller generally include regulation of excess air, oxygen trim, burner modulation, air/fuel cross-limiting, and total heal control.

Fig A 11 Modulating burners

Modulating burners are designed to control the burner output (size of flame) to match the boiler variables and load requirements. During this process, the burner is designed to stay at the correct fuel-to-air ratio across the complete firing range to ensure the maximum combustion and boiler efficiency.

There are three basic types of modulating burner control:

Fully Electronic:

- This will independently control the fuel and air volume to the burner via separate fuel and air valves; normally this type of control will have an integral PID load control to ensure that the boiler's set point is being maintained to the boiler's load requirements. This type of system offers high level of combustion control and consistency.

Fully Mechanical:

- This controls the non linear relationship between the fuel and air ratios. A characterization cam is used (sometimes called a compound control). This is linked directly to the fuel valve and the air damper of the burner. This has limited control resolution due to the hysteresis and lost motion of mechanical systems i.e. inertia, friction, wear and tear.

Fully Pneumatic:

- This type of system is commonly used by burner manufacturers as a low cost solution for gas fired burners only. The burner has a gas control valve that is operated by a diaphragm and an impulse line from the burner's air supply. The burner will have a PID load control. This directly controls the burner air damper to give the required air volume. The gas valve will operate to give a directly proportional gas volume according to the correct fuel/air ratio.
- Modulating burners are designed to constantly match the firing rate according to the boiler load demands. In a perfect case, the burner would remain firing constantly whilst heat is required. This, is, however, rarely achieved for the following reasons:

(i) Limited turn down ratio:

- The "turn down ratio" is a function of the burner's capacity to match the current base load of the boiler. For example, the burner, at high fire rate, will give anoutput of 400 kW (100%) and, at low fire rate, will give an output of 100 kW (25%). This would be referred to a "turn down ratio" of 4:1.
- According to the previous example, if the base load remains at above 100 kW, the burner will modulate without turning off and "dry cycling" will not occur. However, if the base load is below 100 kW, the burner will reach and exceed the set point. and the burner will turn off and "dry cycle".

(ii) Other factors that will cause the burner not to modulate:

- Boiler manufacturers do not normally manufacture the burner to be fitted to the boiler. This is left to the application and the customer's requirements to remain flexible and is not limited to the boiler market. In this case, the specified burner and type of burner will be deemed suitably.
- The burner manufacturers offer a range of burner types and capacities. In most cases, the burners output is not perfectly matched to the boiler output and as a consequence the burner is not able to fire below the minimal base load. This will cause the burner/boiler to cycle on and off, i.e. wasting energy.
- Modulating burners with poor "turn down ratios" i.e. 2:1 will act as a high / low or on/off burner again causing excessive boiler cycling, i.e. wasting energy.
- Incorrectly sized boilers for their applications will also cause modulating burners to operate as on/off burners.
- Incorrectly commissioned modulating burners with poor combustion and/or incorrectly commissioned PID load controllers will also cause the burner not to modulate.

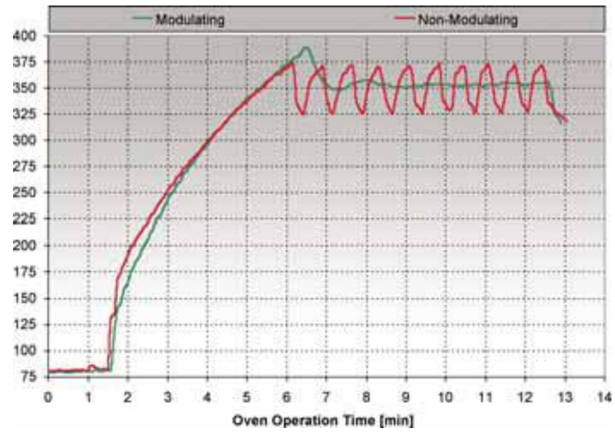


Fig A 12 Results for modulating vs. non-modulating burner in a conveyor oven.

Once-through Boilers

The term "once-through boiler" refers to a special type of water-tube boiler composed of tubes, in which water is input at the bottom, and steam is produced from the top.

This panel shows a typical structure for such a boiler, comprising a drum, a burner, pumps, other accessories, and a control section. Since the drum is composed of tubes, there is little water in the drum, and the boiler thus offers little risk of damaging the surrounding area in the unlikely event of a rupture. The compact design saves installation space. It is safe and no fear of an explosion because of the small water content. A typical structure and its properties are shown in **Fig A 13** and **Fig A 14**, respectively**.**

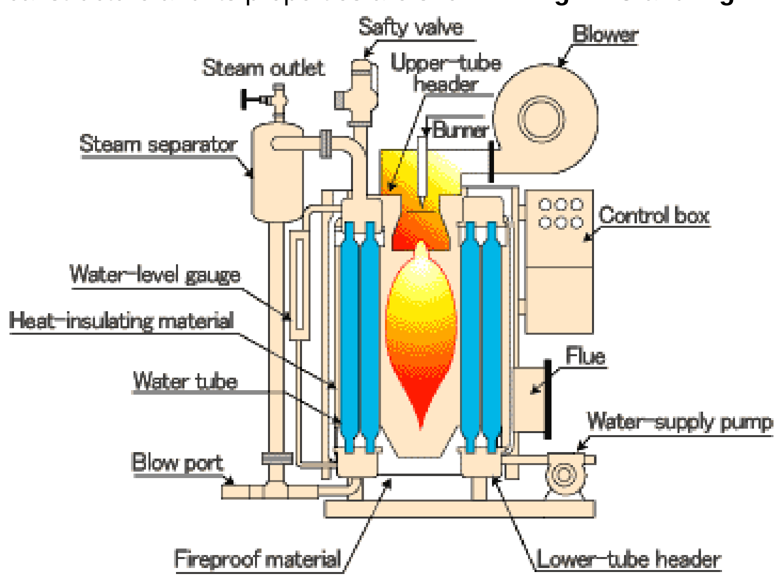


Fig A 13 A Typical Structure of a Once Through Boiler

Fig A 14 An Example of a Once Through Boiler

A.5 Carbon capture and storage (CCS)

1. Introduction

The capture of CO_2 is only economically feasible from large point sources of emissions. Power plants, which account for around one third of global CO_2 emissions, offer the most likely sources. Other sources include gas processing, liquefied natural gas (LNG) and synfuel production facilities, oil refineries and other industrial processes such as cement, iron and steel and chemical production. A brief synopsis of each is provided below (IEA, 2007).

1.1 Power generation

The principal technologies used to generate power from fossil fuels worldwide are, currently pulverized coal-fired steam cycles and natural gas combined cycles. Integrated Gasification Combined Cycle (IGCC) is an emerging option for power generation, although they are not widely deployed due to the complexity of plant operation. CO_2 capture could be incorporated into all of these types of plant.

- Pulverised coal-fired generation
- Gas boilers and turbines
- Integrated gasification technology
- Biomass power generation

1.2 Natural gas processing

Depending on its source, raw natural gas extracted from reservoirs often contains varying concentrations of CO_2along with hydrogen sulphide (H_2S), which must be reduced for technical and safety reasons. Pipeline specifications often require that the CO_2 concentration be lowered to around 2% by volume to prevent pipeline corrosion, to avoid excess energy use in transport, and to increase the heating value of the gas. As such, CO_2 removal is sometimes an integral part of natural gas field development engineering. Appropriate incentives such as the CDM could provide a trigger to mitigate significant portion of CO_2 emissions form this source.

There are now two operational natural gas plants which store CO_2; BP's In Salah plant in Algeria and Statoil's plant at the Sleipner field in the North Sea, both of which store around 1 $MtCO_2$ per year.

1.3 Liquefied natural gas production

Liquefied natural gas (LNG) is natural gas that has been processed to remove impurities and heavy hydrocarbons and then condensed into a liquid, i.e. 'liquefied' at almost atmospheric pressure by cooling it to approximately -163 degrees Celsius. LNG is around 1/600th of the volume of natural gas at the standard temperature and pressure making it much more cost-efficient to transport over long distances where pipelines do not exist.

Two planned LNG projects, the Snohvit gas field in Norway and the Gorgon field in Australia propose to re-inject the stripped reservoir CO_2 into geological formations.

1.4 Refineries

Refineries process crude oil, natural gas liquids, and synthetic crude oils to produce final refined products (primarily fuels and lubricants). For this transformation to occur, part of the energy content of the products obtained from the crude oil is used in the refinery. Refineries produce large amounts of CO_2 emissions, of which about two thirds of the CO_2 emissions are from combustion of oil in fired heaters. The flue gas from these heaters is similar to the flue gas in power stations, so CO_2 could be captured using the same techniques and at broadly similar costs. Where refineries are integrated with other facilities (for example, upgraders or cogeneration plants) significant potential could exist for process optimization to create more concentrated point sources suitable for CO_2 capture.

1.5 Synthetic fuel production

Synfuel plants produce synthetic petroleum products from coal, condensates or natural gas. Coal-to-liquids (CTL) and Gas-to-liquids (GTL) technologies are not yet widely deployed. These processes are expected to become increasingly used over the coming decades, especially if high oil prices (if more than US$70 barrel) are sustained over the medium term.

The first stage of synfuel production in CTL and GTL technologies involves the forming of a syngas from the hydrocarbon input fuel to yield a mixture of hydrogen and CO_2. There are four main processes for producing the syngas:

i) Steam reforming
ii) Partial oxidation (POX)
iii) Autothermal reforming
iv) Combined or two-step reforming

The choice of syngas former is usually dependent on the scale, ease of operation, cost of fuel. It will have an impact on the overall thermal efficiency of the process, as well as the quality of the syngas input into the next step. Optimization with the second step is also a major challenge.

The second step involves the reaction of the produced syngas with a catalyst in a process known as the Fischer Tropsch synthesis, from which a range hydrocarbon products are produced (including gasoline, diesel, solvents, waxes and tars).

There are two main categories of natural gas-based Fischer-Tropsch process technology: the high and the low temperature versions (Royal Dutch Shell web site).

- The high-temperature, iron catalyst-based Fischer-Tropsch GTL process produces fuels such as petrol (gasoline) and gasoil that are closer to those produced from conventional crude oil refining. The resultant GTL products are virtually free of sulphur, but contain aromatics.
- The low-temperature, cobalt catalyst-based Fischer-Tropsch GTL process, however, produces an extremely clean synthetic fraction of gasoil called GTL Fuel that is virtually free of sulphur and aromatics.

1.6 Cement production

CO_2 emitted in the flue gases from cement production also represents a potential source of emissions for capture. Emissions from this sector account for 6% of the total emissions of CO_2 from stationary sources worldwide.

In cement manufacture, CO_2 is produced during the production of clinker, an intermediate product that is ground to produce cement. During the production of clinker, limestone is heated and ‘calcinated’ to produce lime, with CO_2 as a by-product. The lime then reacts with silica, alumina, and iron oxide in the raw materials to make the clinker. Cement production requires large quantities of fuel to drive the high temperature, energy-intensive reactions associated with the calcination of the limestone. CO_2 emissions are directly related to clinker production rates and the fuel combusted. Process CO_2 emissions are determined from the weights and compositions of all carbonate inputs from all raw material and fuel sources, the emission factors for the carbonates and the percentage of calcination achieved.

1.7 Other industries

- Chemical manufacture
- Iron and steel production

2. Technology Characteristic

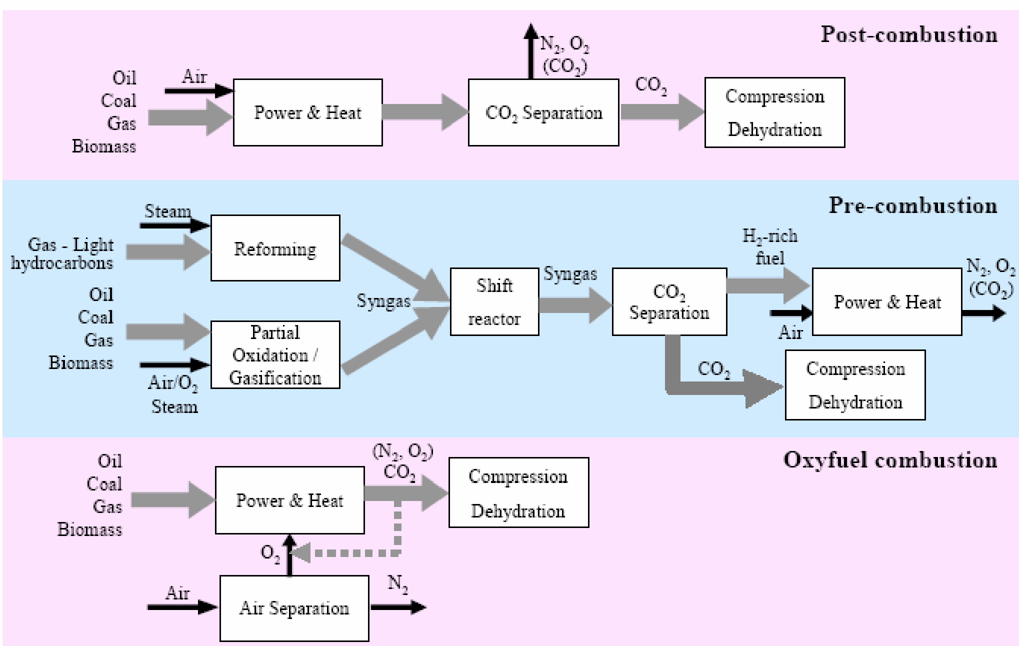
In this paper, there are three main parts of CCS as follows:

2.1 Capture technologies

Carbon capture technologies have long been used for high-concentration, high-pressure CO_2 sources. The three primary methods, as shown in Fig A 15 and compared in Table A 13, for CO_2 capture today are pre-combustion capture, post-combustion capture, and oxyfuel firing for CO_2 capture (IEA, 2009).

- **Pre-combustion capture**

Pre combustion is the process in which the fuel gases resulting from gasification are "shifted" to produce CO_2 and hydrogen, after which the CO_2 is separated. Pre-combustion CO_2 capture from an integrated gasification combined cycle power plant has yet to be demonstrated. However, elements of the technology are already well proven in other industrial processes.



Source: (IPCC, 2005)

Fig A 15 Capture technologies

- **Post-combustion capture**

Post combustion involves scrubbing CO_2 out of the flue gases from the combustion process. Post-combustion capture using solvent scrubbing is one of the most established methods for CO_2 capture, and several facilities use amine solvents to capture significant flows of CO_2 from flue gas streams today.

- **Oxyfuel firing,**

In principle, this technology involves combusting the fuel in high concentrations of oxygen to get a high CO_2 concentration in the flue gas. Oxy-coal combustion is currently being demonstrated at pilot scale in Germany, Australia, and the UK, and oxyfuel combustion has been demonstrated in the steel manufacturing industry with commercially operating plants of up to 250 MW in capacity.

2.2. CO_2 Transport

In principle, CO_2 can be transported using pipelines, marine tankers, trains, trucks, compressed gas cylinders, as a CO_2 hydrate, or as solid dry ice. However, given the quantities of CO_2 that need to be transported to achieve abatement goals, pipelines appear to be the only realistic and viable option for the large volumes associated with deployment. Trains and trucks are currently used in some small-scale pilot projects and may be appropriate for transporting small volumes of CO_2 over short distances. Transport of CO_2 through pipelines is not new; for instance, there are several decades of experience in North America, with more than 30 million short tons of CO_2 /year transported through 3,500 miles of CO_2 pipelines in the United States and Canada. Eventually, CO_2 pipeline grids, similar to those used for natural gas transmission, will be built as CCS becomes more widely deployed (CSLF, 2009).

Table A 13 CO_2 Capture concepts and technologies

Capture Concept	Post combustion	Pre combustion
Separation task	CO_2/N_2	CO_2/H_2
Capture Process		
Absorption	Chemical solvents	Physical solvents
		Chemical solvents
Adsorption	Zeolites	Zeolites
	Activated carbon	Activated carbon
Membranes	Polymeric	Polymeric
Cryogenic	Liquefaction	Liquefaction

Source: (Isaenko Anastasia, 2012)

2.3 CO_2 Storage

A number of projects currently inject CO_2 into oil reservoirs, primarily in the United States and Canada. A majority of these projects focus on enhanced oil recovery (EOR), but some also intentionally store and monitor CO_2 concurrently with EOR operations. The main options for geological CO_2 storage are saline formations, depleted or partially depleted oil and gas reservoirs, and deep, unminable coal seams (IEA, 2009). Of the three options, saline formations are expected to be able to store the greatest quantities of CO_2, followed by oil and gas reservoirs. In addition, our practical knowledge of how CO_2 moves through a variety of geologic formations when permanently stored is limited to a small number of projects, the longest of which has been injecting for more than a decade. However, there is considerable experience in monitoring and modeling of "CO_2 analogues" (such as aquifer water movement, volcanic activity, and fault lines), which will assist in fast tracking global capabilities in both these areas. While monitoring data at existing injection sites has shown that the CO_2 has performed as anticipated after injection and no leakage has been observed at any of the sites where injection is occurring (IPCC, 2005), the CCS industry and governments need to put in place responses to community concern about "learning by doing."

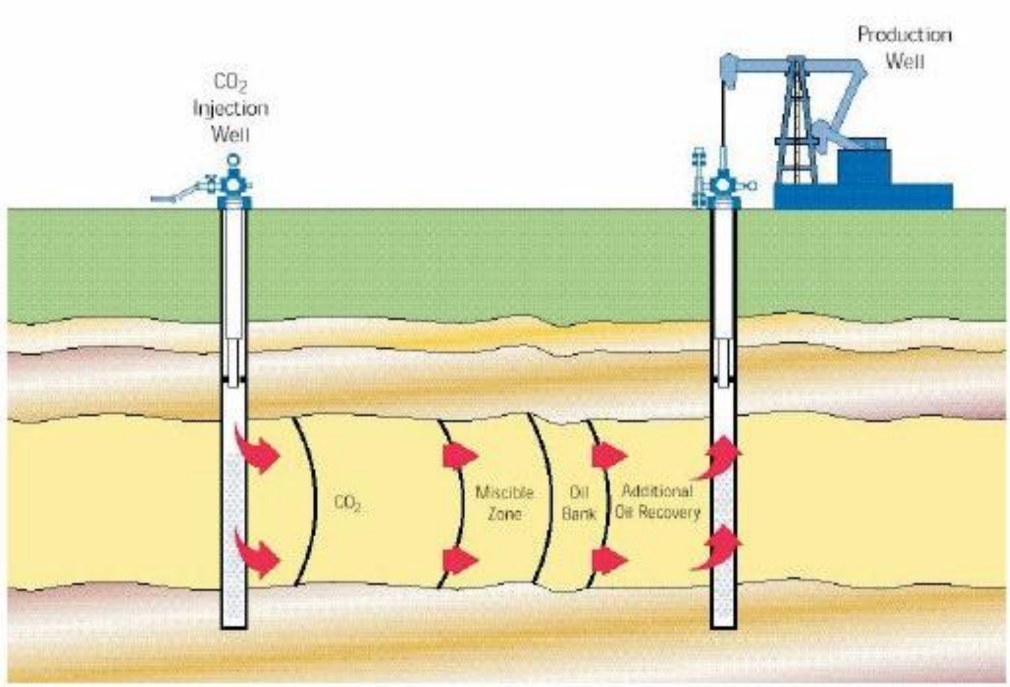
Typical geological target formations comprise three key features including (i) must have sufficient volume (capacity),(ii) must have sufficient permeability for injection (injectivity) and (iii) must overlain by a gas tight sealing formation (caprock) which keeps the buoyant CO_2 from migrating upwards (containment)(Isaenko Anastasia, 2012).

2.4 CO_2 Use

In addition to EOR, CO_2 can be used in certain industrial processes such as mineralization (or carbonation), pharmaceutical and chemical processing and agricultural and biological applications. None of the current uses consumes large amounts of CO_2. Emerging technologies that could absorb larger amounts tend to be in the research or pilot stage. Some CO_2 uses do not represent a permanent storage solution, but could be used to offset the costs of capture while technologies are refined, suitable storage sites are identified and costs of CCS are reduced (CSLF, 2009).

- **Enhanced Oil and Gas Recovery**

Conventional oil production techniques may only recover a small fraction of oil in reservoirs, typically 5%–15%, although initial recovery from some reservoirs may exceed 50%. For the majority of reservoirs, secondary recovery techniques such as water flooding can increase recovery to 30%–50%. Tertiary recovery techniques such as CO_2 injection, as shown in Fig A 16, which is already used in several parts of the world (particularly in the United States), push recovery even further. Currently, most of the CO_2 used for enhanced oil recovery is obtained from naturally occurring CO_2 fields or recovered from natural gas production. Buying CO_2 for this purpose introduces another cost and the CO_2 is recycled as much as possible throughout the EOR process. Nevertheless, the CO_2 left in the reservoir at the end of recovery is regarded as being permanently stored.



Source: (IEA, 2007)

Fig A 16 CO_2 enhanced oil recovery

- **Mineralization**

Nature's way of geologically storing CO_2 is the very slow reaction between CO_2 and naturally occurring minerals, such as magnesium silicate, to form the corresponding mineral carbonate. Among all forms of carbon, carbonates possess the lowest energy, and are therefore the most stable. Carbon dioxide stored as a mineral carbonate would be permanently removed from the atmosphere, and research is under way to increase the speed of carbonation. However, the mass of mineral that would have to be quarried would be many times the mass of CO_2 captured. A novel example of a pilot-scale mineralization project involves the chemical conversion of refining wastes, such as bauxite residue (red mud), by combining them with CO_2. While ideally suited to lower CO_2 volumes, the process addresses CO_2 storage needs while reducing the environmental issues associated with the caustic form of the residue.

- **Biofixation**

Biofixation is a technique for producing biomass using CO_2 and solar energy, typically employing microalgae or cyanobacteria. Horticulture (in glass houses) often uses CO_2 to enhance the growth rates of plants by artificially raising CO_2 concentrations.

- **Industrial Products**

CO_2 captured from ammonia reformer flue gas is now used as a raw material for manufacturing urea in the fertilizer industry, and purified CO_2 is used in the food industry. Possible new industrial uses of CO_2 include catalytic reduction of light alkanes to aromatics, formation of alkylene polycarbonates in the electronics industry and production of dimethyl carbonate as a gasoline additive. CO_2 is thermodynamically stable. Significant energy is needed to convert it for use as a chemical raw material. The additional energy requirement and cost means that its use as a chemical raw material is limited to a few niche markets.

Annex 2 Project Ideas

Project idea 1: Smart grid

Introduction

The smart grid is the new technology that can reduce the transmission losses and lead to the overall reduction of GHG from power generation sector. The smart grid utilizes information technology to manage generation, transmission and distribution of the electricity. It incorporates three technologies: 1) Electronics and embedded systems 2) System control and automation 3) Information and communication. The technologies involve in the smart grid are smart metering, storage system, and control system. A smart metering is an electrical meter that responds to both producer and user. The producer receives the information of the power consumption, and the user can acquire the electric expenses. The examples of upcoming technologies that have been designed to fit the smart grids system are information and communication technology (ICT), automatic meter reading (AMR), advanced metering infrastructure (AMI), demand side management (DSM), plug-in electric vehicle (PEV), energy storage, and distributed generation (DG).

Objectives

1. To prepare all smart grid supporting technologies and infrastructure
2. To inform or equip the government officers with smart grid background knowledge
3. To inform the public about the technology
4. To encourage the private power generation companies to invest in the smart grid system for renewable power generation.

Expected Output and Outcome

1. Reliable power generation system
2. Reduce transmission losses which lead to a cheaper electricity prices
3. Reduce GHG emissions
4. Real-time monitoring system and quickly response to power outage. For the home user, the meter will send status to the utility providers. The status could assist identifying the failure causes.
5. Create a flexible and dynamic communication network
6. Users can monitor their electricity usage; therefore, they are able to manage monthly electricity expenses.
7. Environmentally friendly electricity generation
8. The transmission lines are all connected to stabilize overall demand and supply. This helps to reduce production costs at the peak load.
9. More reliable system

The estimated reduction of GHG from transmission loses is summarized in Table A 14 and depicted in Fig A17. The assumptions for the estimated GHG reduction can be listed as follow:

- The estimated greenhouse gas mitigation can be calculated based on the power demand reported by the PEA.
- The current GHG emissions from the power plants are 0.5812 ton of CO_2 per watt-hour (Thailand Greenhouse Gas Management Organization, 2011)
- The current transmission losses is 5 - 6 percent (Department of Alternative Energy Development and Efficiency, 2010a)
- The smart grid could reduce the loss approximately 1% of the electric loss in the system

Table A 14 Estimated GHG reduction from the smart grid system (2022-2030)

	2022	2023	2024	2025	2026	2027	2028	2029	2030
Expected Consumption (GWh)	174,803	181,479	188,440	194,799	201,772	208,722	215,837	222,938	230,190
Power Demand (GWh)	184,003	191,030	198,358	205,052	212,392	219,708	227,197	234,671	242,305
Lossed in System(GWh)	9,200	9,551	9,918	10,253	10,620	10,986	11,360	11,733	12,115
Percent of Loss (%)	5%	5%	5%	5%	5%	5%	5%	5%	5%
Losses Reductional from smart grid (GWh)	92	96	99	103	106	110	114	117	121
GHG Mitigation from reduce the losses (tCO_2)	53,470	55,510	57,643	59,590	61,723	63,851	66,024	68,192	70,412

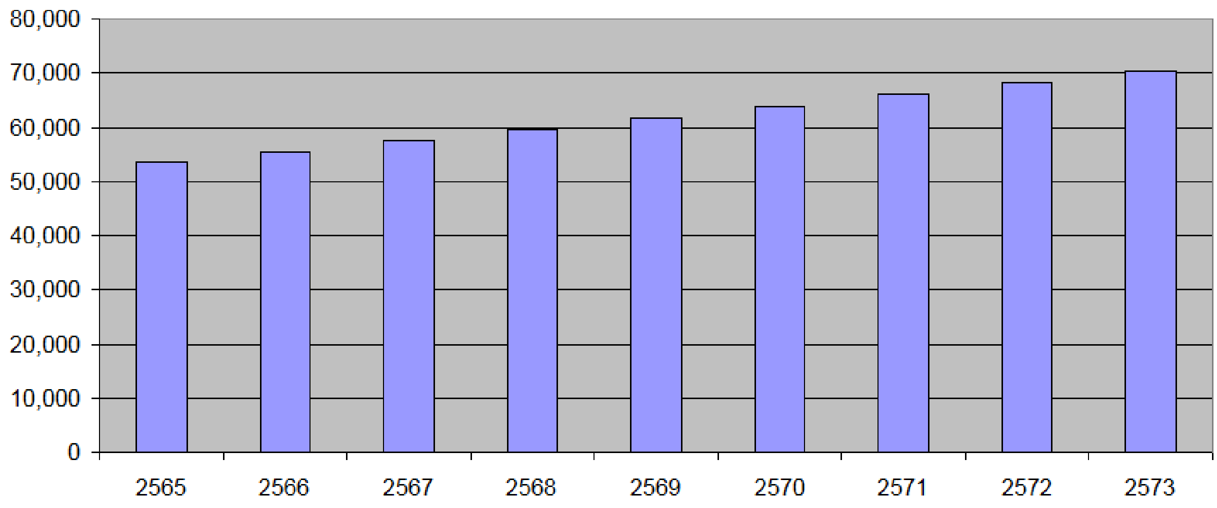


Fig A 17 Estimated tons of GHG reduction when applying the smart grid system from 2022 (B.E.2565) to 2030 (B.E. 2573)

Timelines

- 2012 – 2014 (3 years) Building capacity to ready for the smart grid
    - Technology: conduct fundamental research on technologies to support the smart grid
    - Capacity building: Training programs for staffs, technicians in EGAT, MEA and PEA
    - Consumer: Inform technical information and promote usage benefits
    - Private power producers: Develop a consensus with the companies to encourage the private power generation companies to invest in the smart grid system for renewable power generation.
- From 2014
    - Establish the smart grid system and fully implement at the year 2022
    - Continuously conduct research works to improve/maintenance the technology and the system

Estimated budget

2012-2014	30 Million Baht (or approximately $1 million USD) for R&D in smart grid 100 Million Baht (or approximately $ 3.5 million USD) for promotion and capacity building

Project idea 2: Energy efficiency improvement in industrial sector

Introduction

Fossil-fuel combustion represents the largest portion of GHG released from industry sector. Since all production processes require energy, with old fashioned technology, fuel consumption is inevitably high. Thus, improving fuel use efficiency would significantly cut unnecessary fuel consumption and consequently reduce the overall GHG emissions.

Objectives

1. To support technology upgrades and improve energy efficiency in the industrial sector.
2. Promote a quality manufacturing practice with low energy and GHG footprint.

Expected Output and Outcome

1. Increase overall production efficiency
2. Reduce fuel consumption in the manufacturing processes and consequently reduce GHG emissions

Timeline

- 2012 – 2017 (5 years)
    - Encourage manufacturers to develop the action plans for replacing or modifying their old-fashioned technologies
    - Provide the lists of technologies that are certified energy efficiency, require less installation space, and has high safety e.g. modulated burners etc.

- 2013 – 2022 (10 years)
    - Encourage efficient manufacturing process to produce higher quality products with low energy footprint

Budget

2012-2013	10 Million Thai Baht (approximately $0.3million USD) for conducting research and setting up the pilot project
From 2014	500 million Thai Baht ($16 million USD) for establishing incentive mechanism/program for substitution from old-type conventional boiler to new modulated boiler or once-through boiler. They are 8,800 manufactories, if 500 units participate in the program and the government subsidizes 1 million Baht per unit ($ 33,000 USD). The total costs for the government are 500 million baht.

Project idea 3: CCS Project

Introduction

Carbon capture and storage (CCS) refers to technologies that capture CO_2 from large point source e.g. power generation plant and store in secure place away from the atmosphere. CCS implementation is highly capital intensive and requires many supporting factors e.g. manpower, budget, back-up research and etc.

Objective

1. Survey CCS technical aspects e.g. site location, capturing method, transporting CO_2, and capturing details
2. Feasibility study of CCS system in energy exploration and production industry in Thailand.
3. Financial study of potential onshore and offshore CCS project in Thailand
4. Develop long-term planning for capacity building in CCS
5. Feasibility study on CCS-CDM

Expected Output and Outcome

1. The CCS potential for oil and gas industry which includes
    - Feasibility study on the CCS from pilot CCS project to full scale CCS project in oil and gas field
    - Expected enhanced oil recovery (EOR) rate
    - Technology which most appropriate for the country
    - Regulation requirement
    - International financial incentives

2. Long-term capacity building plan in CCS, which includes
    - Training programs for staffs and technicians
    - Public relations

3. Study the CCS-CDM on these following aspects: certified CDM, manpower, timeframe, and cost-benefit analysis

According to the previous study by PTT, the full scale CCS project size is 1 million tons of CO_2 capture and storage per year in natural gas filed

Timelines

- 2012 – 2014 (3 years)
  - Technology:
    - Review CCS technology and identify the most appropriate CCS technology in capturing, transport and storage in oil and gas industry
    - Study the EOR potential from CCS
  - Regulations;
    - Review international regulations related to CCS
    - Draft CCS principles for Thailand
  - Capacity building:
    - Establish CCS network programs at local and international levels
    - Develop human resource development plan
- 2015 onwards
  - Prepare budget for establishing pilot projects and full scale implementation after 2020
  - Develop CCS standards and regulations in Thailand
  - Inform public about CCS project

Project scenario

1. Greenhouse gas emission reduction from CCS is estimated at 1.0 M-tCO_2e per year
2. Require approximately 100 technicians

Project idea 4: Second generation biofuel

Introduction

Since Thailand is one of the largest agriculture producers, the country has large amount of agricultural residue that is potentially be converted into energy. The residue is normally disposed by either land filled or burn and could lead to other problems e.g. NIMBY or air pollution. The second generation biofuels (e.g. agricultural residual or cellulosic ethanol) could potentially address those residues and attain fuel. In addition, cellulosic ethanol could reduce emissions of greenhouse gas significantly. Moreover, the biofuels would cut oil import and, at the same time, enhance energy security. The ultimate goals of second and third generation biofuels projects are 1) To reduce oil imports 2) To promote the use of biofuels 3) To develop biofuels technology suitable for local context

Objectives:

1. Enact the national policy that promotes the production and the use of second and third generation biofuels. The policy should cover all issues and levels such as feedstock collection, fundamental research, technology development, market analysis, and PR.
2. Develop incentive mechanism that induces private sector investments
3. Develop second and third generation biofuels standards/regulations in Thailand aligning with the international standards/regulations

Expected Output and Outcome

1. The national policy and roadmap on second and third generation biofuels
2. Knowledge and technology transfer
3. Feasibility study on the second and third generation biofuels
4. Self developed technology, appropriate for the country situation
5. Regulation requirement covering from the supply to demand side of biofuels
6. Financial incentives in investment of second and third generation biofuels
7. Long-term capacity building plans e.g. training programs, increasing numbers of experts, and PR

Timeline:

Activities	2012	2013	2014	2015	2016 onwards
Development national plan/roadmap	■				
Do basic research covering all areas	■	■	■		
- Fiscal support in pilot scale & Demonstration plant - Develop waste management system - Pilot scale					
Fiscal support for demonstration plant			■	■	
Promotes large scale production to investors					■

Budget/Resource Requirements:

Tentative budget 346 million Baht (~ $ 11.5 million USD)

Expense details		**Cost (baht)**	**Total (baht)**
Policy formulation			16,000,000
	The national plan development	3,000,000	
	Develop KM programs in 2nd biofuels	3,000,000	
	Seminars/conferences	3,000,000	
	International travel costs and expenses (30 people)	4,000,000	
	Domestic travel costs and expenses (50 people)	2,000,000	
	PR, document, and administration	3,000,000	
Research works:			130,000,000
	Fundamental research funding	10,000,000	
	Apply research funding (lab & pilot scale)	50,000,000	
	Demonstration plant	70,000,000	
Fiscal support for commercial:			200,000,000
	Financial intensive (1-2 plants)	200,000,000	
		Total	**346,000,000**

Project idea 5: Hydrothermal Technology Research Laboratory (Waste to energy)

Introduction

The most recent waste to power and management technologies are hydrothermal treatment and incineration. These technologies can alleviate waste management problems in Thailand and also reduce the climate change impacts.

The hydrothermal treatment (HTT) process was developed by the Tokyo Institute of Technology. This technology can convert raw waste to dry powders which are ready to be used as fuel sources. The one of the advantages of this technology is that the pollutants e.g. dioxin can be captured and converted to liquid. If the pollutants are in liquid form, they can be treated easier than the gas form. Moreover, the technology is compatible in all types of waste and requires no retreatment (or prior waste separation).

In the beginning stage of transfer the HTT to Thailand, the research laboratories and prototype units should be prepared and set under the universities or research institutes.

Objective

To establish the HTT laboratory unit in academic institutes:

1. Technology transfer
2. Develop pilot project on sewage sludge treatment (from high moisture waste at 80-85% water content to low moisture waste with 10-15% water content) by using the superheated steam with 20-25 MPa as a main input.
3. Develop an experimental project by applying HTT by-products with coal and use as fuel source in cement industry clinker process (as shown in Fig A 18).

Expected Output and Outcome

1. The HTT technology transfer
2. Alternative energy sources
3. Reduce the waste problem in Thailand.

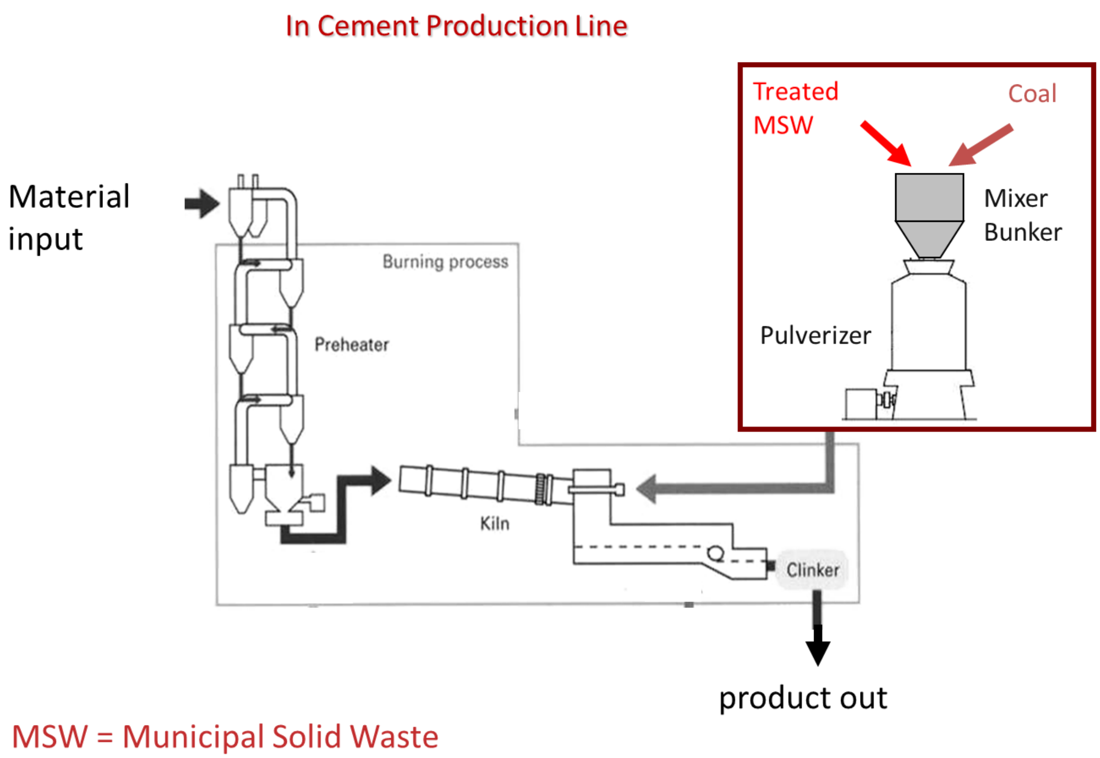


Fig A 18 The Applications of using treated MSW from HTT with coal as fuel sources in cement industry
Source: (Tokyo Institute of Technology, 2010)

Timelines

- 2012 – 2015 (4 years) Technology transfer including:
    - Technology: Research and review technologies, suitable for Thai waste management
    - Capacity building: Academic collaboration between Japanese and Thai University/research institutes. Sign MOU.
    - Laboratory scale setting by using Thai waste (municipal solid waste) and generate heat by gasification process
- 2015 onwards
    - Establish collaboration between Thai university and industrial sectors for HTT transfer especially in cement industry
    - Mix HTT by-product with coal and use as fuel source in clinker process

Budget/Resource Requirements:

The tentative budget 5 years plan is 94 million Baht that can be categorized and summarized in Table A 15.

Table A 15 Budget for Hydrothermal technology

Expense details		Cost (baht)	Total (baht)
Policy works:			4,000,000
	Seminars/conferences	1,000,000	
	International traveling costs and expenses (5 persons)	1,000,000	
	Domestic traveling and expenses (10 persons)	1,000,000	
	PR, documents and handouts	1,000,000	
Research works:			50,000,000
	Basic research supports	10,000,000	
	Applied research supports (lab and pilot scale) and demonstration plant	40,000,000	
Fiscal support for commercial with industry sector:			40,000,000
	Financial incentive (1-2 plants)	40,000,000	
		Total	**94,000,000**

Measurement and evaluation process

Technology indicators

1. Feasibility study on HTT potential from municipal solid waste in Thailand
2. Pilot scale implementation
3. Number of skilled and trained persons
4. Number of full scale implemented (after 2015)

Climate change indicators

5. Apply Measurable, Reportable, Verifiable (MRV) process to verify the carbon credits resulting from Clean Development Mechanism (CDM) from waste-to-energy. Thailand is now developing the draft MRV guidelines.

Annex 3 List of Stakeholders Involved

In this study, focus group and national workshops/seminars were held in Bangkok. Two small focus group meetings were held to prepare energy technology list for prioritization before the 1st nation public hearing. The criteria and report outline were discussed in the meeting. Energy experts, Department of Industrial Works (DIW) representatives, Department of Mineral Fuels (DMF) representatives, Department of Alternative Energy Development and Efficiency (DEDE) representatives were participated in the meeting.

The two national public hearing workshops for Energy Management Sector were held together with the workshops for adaptation sectors. Before attending the workshops, energy management experts were asked to arrange to exchange ideas and review the preliminary draft or outlines of TNA and TAP reports. The main discussion on the first workshop was about the technology assessment. The technology action plan was brought to the table on the second workshop.

The First National Public Hearing Workshops/seminars

The 1st National Public Hearing Workshops on technology needs assessment for energy management were held on 24 June, 2011 at Boardroom 3, Queen Sirikit National Convention Center, Bangkok in Thailand. The 29 stakeholders from the public sector, the private sector, and specialists met to brainstorm on the list of technology groups and technologies, discussing criteria and processes for technology prioritization and to prioritize technology groups and technologies.

List of attended stakeholders.

- Ministry of Energy (MoE)
- Department of Alternative Energy Development and Efficiency (DEDE)
- Energy Policy and Planning Office (EPPO)
- Electricity Generating Authority of Thailand (EGAT)
- The Federation of Thai Industries (FTI)
- National Science and Technology Development Agency (NSTDA)
- National Center for Genetic Engineering and Biotechnology (Biotech)
- Thailand Greenhouse Gas Management Organization (TGO)
- Thailand Environment Institute (TEI)
- King Mongkut's University of Technology, Thonburi (KMUTT)
- Energy Research Institute, Chulalongkorn University (ERI-CU)
- Faculty of Science, Silpakorn University (SU)
- The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology, Thonburi (JGSEE)

Fig A 19 The 1st national public hearing workshop

The Second National Public Hearing Workshops/seminars

The 2nd National Public Hearing Workshops on technology needs assessment for energy management were held on 24 August, 2011 at Twin Towers Hotel, Bangkok in Thailand. The 30 stakeholders from the government, research and education, state enterprises, and public-private sector, and specialists met to brainstorm on technology action plan and on barriers and solutions.
List of attended stakeholders.

- Ministry of Energy (MoE)
- Department of Alternative Energy Development and Efficiency (DEDE)
- Department of Mineral Fuels (DMF)
- Department of Energy Business (DOEB)
- Energy Policy and Planning Office (EPPO)
- Energy Regulatory Commission of Thailand (ERC)
- PTT Public Limited Company (PTT)
- Electricity Generating Authority of Thailand (EGAT)
- Metropolitan Electricity Authority (MEA)
- The Energy Conservation Center of Thailand (ECCT)
- Department of Land Transport (DLT)
- Department of International Economic Affairs (DIEA)
- Department of Marine and Coastal Resources (DMCR)
- Industrial Estate Authority of Thailand (IEAT)
- Thai Airways International Public Company Limited (TG)
- State Railway of Thailand (SRT)
- The Federation of Thai Industries (FTI)
- Management System Certification Institute (MASCI)
- Geo-Informatics and Space Technology Development Agency (GISTDA)
- National Metal and Materials Technology Center,Thailand (MTEC)
- Faculty of Political Science, Ramkhamhaeng University (RU)
- Thailand Environment Institute (TEI)
- King Mongkut's University of Technology Thonburi (KMUTT)
- School of Renewable Energy Technology, Naresuan University (NU)
- Emegant Ventures International Pte Ltd (EVI)
- The Siam Cement Public Company Limited (SCG)
- The Golden Line Business Company Limited
- Team Energy Management Company Limited (TEM)
- Thai Trade Company Limited (TTC)
- Charnin Energy Company Limited
- PVK Island Company Limited


Fig A 20 The 2nd national public hearing workshop

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