Report on
Role of Renewable Energy for Productive Uses in Rural Thailand

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Global Network on Energy for Sustainable Development (GNESD)

By

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0. Executive Summary

Introduction

The objectives of the present study are to identify the major barriers to renewable energy technologies (RETs) diffusion in Thailand and to suggest broad policy outlines to address/overcome them. The study analyses the current energy consumption pattern in the residential, productive and social sectors in rural Thailand, identifies the major energy intensive activities in each sector and discusses the potential for RETs in the country. Case studies on RETs used for productive activities and their associated benefits both at the local and national levels are presented along with the problems facing wider dissemination of RETs in the country. The study also describes the major government programmes and policies to promote RETs in Thailand and presents their major successes and failures.

Energy consumption in rural Thailand

An assessment of the current energy consumption pattern in rural Thailand shows that for the residential and productive sector, the most energy consuming activities require heat. In the residential sector, cooking can represent up to more than 60% of the total energy share whereas for small scale industries, thermal processes such as pasteurising, drying, brick making, etc. can represent, on average, up to more than 50%. For both these sectors, heat is currently produced by the combustion of biomass-fuelwood and charcoal. Energy related expenses represent up to 30% of the total expenses of a household. In the productive sector, the share of energy in the running costs is very variable, but can go up to 70% in the most energy intensive industries. On the other hand, in the social sector (e.g. health centres, schools) mainly modern forms of energy, namely grid electricity and LPG, are used. For the social sector, energy usually represents an almost negligible part of the total running costs (about 3 %).

Renewable resources

At the country level, Thailand is endowed with abundant biomass and solar resources, with good potential for wind and micro-hydro based energy producing technologies in specific regions.

- ***Solar:*** The annual average daily solar radiation in Thailand is about 5.0 to 5.3 kWh/m^2-day corresponding to 18 to19 MJ/m^2-day. High values of about 20-24 MJ/m^2-day, are recorded during April and May. The north eastern and northern regions receive about 2,200 to 2,900 hours of sunshine per year (6-8 sunshine-hours per day).
- ***Biomass:*** Biomass resources, namely, agricultural wastes, wood and plantation, animal dung, garbage and wastewater possess a recoverable energy potential (REP) amounting to about 1,076,567 TJ/yr as fuel for heat production, and about 2,179 Mm^3/year of exploitable biogas.

RETs status

Thailand has extensive experience with RETs. Solar PV technologies have been implemented during the last 25 years for both rural electrification (Battery Charging Stations (BCS) and Solar Home Systems (SHS)), and for water pumping. However, these programmes have not been fully successful, even if the actual capacity installed is high (1.9 MW for BCS, 0.954 MW for water pumping systems and 36 MW of SHS based electricity planned until the end of 2005). More than 60% of the BCS and more than 45% of the water pumping systems failed because of inappropriate operation and maintenance (e.g. due to lack of training of the users), and due to the design not matching the actual energy needs of the communities. All the systems implemented by the government are 100% subsidised. The approach followed by the government to promote PV based RETs has led to misuse and abuse of the technology. The high number of failures also gives a bad name to the technology.

The Government has also promoted biogas digesters for more than 15 years. The total installed capacity in 2004 reached 142,527 m^3 of biogas plants. The programme focuses on in feedstock farms and is based on a partial subsidy basis (up to 38%) and a strong collaboration between implementers-users. The programme is still going on and so far has given mixed results. Biogas digestors installed in large farms have a pay back period of about 5 years. However, more robust and integrated systems have to be designed in order to avoid technical failures, complicated operation and costly maintenance especially for medium size digesters.

Niches for RETs

Based on the identified energy needs for productive uses in rural areas and the renewable energy potential in Thailand, three case studies that have a good replication potential were identified and analysed: solar drying, charcoal production from agricultural residue and biogas production.

In the agro-processing sector, demonstration units of solar dryers have been implemented both in Northern and Southern Thailand for bananas and rubber, respectively. A banana dryer costs about US$ 4,900 for a 100 kg/batch banana model and a community rubber dryer costs about US$ 23,000 for a 15,000 sheets/batch model. The payback period for this technology ranges between 2 to 6 years.

Solar dryers allow the production of higher quantity of goods and a higher quality of the products that can be sold at a higher price. Solar dryers have therefore the potential to bring additional income to dried goods producers. For example, the market price of solar dried bananas dried with solar dryers is 75% higher than traditionally sun dried ones.

The large amount of animal manure produced in livestock farms throughout Thailand could be used to produce around 560 Mm^3 of biogas per year, equivalent to 11,751 TJ. Biogas digesters could be also installed in the increasing number of wastewater treatment plants as well as in factories producing large amount of organic wastes (e.g. tapioca scratch factories). The gas produced by such digesters can be used for heat and/or mechanical energy production. In pig farms where biogas digesters promoted by the government have been installed, reduction of diesel consumption by up to 60% has been recorded. A pay back period of 4 to 6 years is reported for biogas digesters in pig farms.

Production of charcoal from agricultural wastes is also a promising technology, due to the high demand for this fuel and the large potential of residue (about 60 million tons per year for the ten main residues). The potential of bagasse, sugarcane leaves, coconut shelves and rice husk is significant in the poorer regions of Northern, Northeastern and Southern Thailand. The production of charcoal from agricultural residue can be implemented at both small and large scales, depending on the kind of waste. It can help address waste disposal issues and also provide a new source of income for the farmers. The pay back period of a medium scale pilot project of charcoal production from coconut shells has been estimated at about 3 years. The technology of producing charcoal from agricultural wastes is not yet fully mature in Thailand, and thus further research and development efforts are needed to ensure a better efficiency and lower costs. Besides technical barriers, another problem that hampers the development of charcoal production units is the current biomass market, as biomass producers and users are often not well linked together. The former are not aware of the energy potential of their residue while the latter are not aware of its availability. Furthermore, the price of residue is highly fluctuating, leading to its instability.

Current RETs policies

To reduce its dependence on imported fossil fuels and promote sustainable development, the Thai government has undertaken various initiatives to promote energy savings and RETs. Some of the key initiatives are summarised below:

a) ENCON Act: The Royal Thai Government (RTG) adopted the Energy Conservation and Promotion (ENCON) Act in April 1992 and two years later, launched the ENCON Programme to set guidelines, criteria, conditions and priorities for ENCON Fund allocation. One of the main objectives of this programme is the promotion of the development and use of renewable energy sources[1].

b) "Divided by 2" campaign: In 1996, the National Energy Policy Office (NEPO)[2] initiated a project of energy conservation promotion, called "Divided by 2" and funded by the ENCON Fund. The objective of this campaign is to raise awareness on efficient and effective use of energy.

c) EGAT ACT and Net Metering: In 1992, the EGAT Act was amended, allowing private Independent Power Producers (IPPs) and Small Power Producers (SPPs)[3] to sell their electricity to the grid. Ten years later, in May 2002, a policy called net metering was adopted. This policy allows small RETs power producers[4] to sell their excess electricity to the grid.

d) Specific programmes to promote RETs: From the beginning of the 1980s, the RTG has launched different programmes aimed at promoting RETs. Dissemination programmes of PV Battery Charging Stations (BCS), PV pumping stations and solar home systems (SHS) have been implemented, and as a result, more than 3,000 units of both BCS and pumping stations were installed and about 300,000 SHS are planned to be installed by the end of 2005. In the late Eighties, EPPO started a programme to subsidize biogas digesters for pig farms. The programme resulted in the installation of 142,527 m^3 of biogas plants in 2004.

e) Strategic plan promoting new and renewable technology development: The RTG has the objective of raising RETs shares in the final fuel mix of the country from 0.5% in 2002 to 8% in 2011. This target accounts for a total of 6,540 ktoe of renewable energy supply comprising the following: 1,060 ktoe from power producers using RETs[5], 3,910 ktoe mainly from traditional biomass, agricultural wastes and industrial wastes, and 1,570 ktoe from the increase of ethanol blending with gasoline and substitution of the use of diesel oil by biodiesel. As part of this strategic plan, a policy called Renewable Portfolio Standard (RPS), whose implementation details are being discussed in October 2005, is considered by the government. In particular, this policy requires that 5% of new capacity addition in power generation should be based on RETs.

Barrier to RETs

Based on an analysis of case studies, past governmental programmes to promote RETs and current policies on RETs, some barriers to RETs promotion and utilisation were identified:

a) Barriers to RETs promotion

i. Financial barriers: Financial factors constitute the key barrier hampering the diffusion and promotion of RETs in Thailand. The capital cost of RETs is high compared with conventional energy.

ii. Information barriers: There is a lack of awareness about RETs that hinders their development in Thailand. RETs are not an obvious or preferred choice for the users. There is currently no national campaign to sensitize potential users on the benefits of RETs.

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[1] More details on the ENCON programme can be found at http://www.eppo.go.th/encon/encon-fund00.html.
[2] Called now Energy Policy and Planning Office (EPPO)
[3] Including RETs based generation
[4] Of up to 1 MW per power producer
[5] For a total installed capacity of 2400 MW (an addition of 1,840 MW compared to 2002)

iii. Technical barriers: Although many RETs are technically mature, some RETs suffer from a lack of research and development activities that could lead to development of products suited to local needs.
iv. Institutional Barriers: In spite of the efforts of the Thai government to promote RETs over the past 20 years, and the creation of a body dedicated to RETs (Department of Alternative Energy Development and Efficiency (DEDE)) within the Ministry of Energy in 2002, institutional barriers still remain. In particular, there is a lack of coordination between the different organisations involved with RETs in Thailand (government agencies, non governmental organizations (NGOs), multilateral organisations, etc.). Within government agencies, some non-RETs specialists are still involved in RETs projects, especially for PV technologies.

v. Other Barriers
   - Conventional energy sources have been subsidized for many years.
   - Selected RETs promoted by the government: Over the last two decades, the RTG has focussed on diffusion of PV based technologies, even though other promising options (solar thermal for drying, biomass, biogas, etc.) are available.
   - Pricing policies do not consider environmental costs of conventional sources: The social cost of pollution due to conventional energy sources is not taken into account in the current pricing policies of the government.

b) Barriers to proper utilisation and maintenance of RETs
The top-down approach followed by governmental agencies implementing RETs-based projects, and the lack of involvement in the different stages (design, implementation, operation, etc.) are barriers to the proper operation and maintenance of these technologies.

Policy outlines
Policy outlines to address/overcome specific barriers can be associated to an objective representing the desired situation to which a policy should lead. For this study, seven objectives were identified. To attain these objectives a series of policy outlines were identified considering the strengths, weaknesses, opportunities and threats of each objective. The policy outlines are summarised as follows:

a) To make RETs economically competitive to the conventional sources of energy
i. Reflecting the real costs of conventional sources in retail prices
ii. Promoting RETs for creation of income generating activities and reducing energy expenditures in the long run
iii. Making RETs imports financially more attractive
iv. Providing financial incentives for:
   - RETs users
   - RETs electricity producers
   - RETs manufacturers
   - RETs spare parts producers and suppliers

b) To raise awareness on RETs and their applications throughout the country
i. Using existing information diffusion structures to further promote mature RETs
ii. Diffusing success stories of RETs for creation of income generating activities and reducing energy expenditures in the long run
iii. Demonstration of promising RETs
iv. Sharing experiences among the different stakeholders

c) To make mature RETs appropriate to the different local conditions available in the national market
i. Increasing R&D activities to make RETs (including low cost) appropriate to the local conditions

ii. Promoting network of knowledge and technology transfer

d) To implement RETs that match users' needs

i. Encouraging RETs producers to diversify each given model of RETs in terms of size, capacity and types of application.
ii. Scaling up applications from demonstration sites
iii. Encouraging the implementing agencies to assess the potential for RETs before implementation, and to include the users in the design process to assess their needs

e) To properly install, operate and maintain RETs

i. Training users and local staff on maintenance and repair in a manner they can understand (scaling up existing initiatives, local language, etc)
ii. Implementing pay per use services

f) To develop the agricultural residue market to benefit all stakeholders

i. Linking the agricultural residue producers to the potential users
ii. Mitigating perceived risk of agricultural residue based RETs projects
iii. Sharing the benefits of residue based RETs among the different stakeholders
iv. Defining standards for residue

g) Implementation of RETs based projects by qualified government staff

i. Investing in staff capacity building
ii. Diffusing success stories of RETs for creation of income generating activities

Stakeholders' reactions to the policy outlines

Discussions with a number of stakeholders during this study brought out the following points:

a) RETs projects should involve the local communities

It was observed that users should be at the centre of the decision making process, and should be able to choose the most suitable technologies, according to their needs and financial means. For this to happen, awareness campaigns have to be launched at the community level, including demonstration projects for the potential users to judge the potential of each technology. These demonstration projects should be easily accessible to rural communities (they should not be located in big cities or university campuses).

b) Financial benefits should flow to local communities

Regarding biomass power plants, it was felt that local communities did not get any financial benefits from such projects. Some people interviewed suggested that local communities should get some share in the plants. Many stakeholders pointed out that biomass power plants might not be financially feasible because the price of the biomass fuel could rise if the demand was to increase.

c) Promotion of low cost RETs as a priority

Some stakeholders pointed out that low cost technologies should be prioritized. Some examples, such as blending of pure vegetable oil and diesel for agricultural machines, charcoal production residue and solar drying, were quoted as promising technologies.

d) Financing RETs

Financial measures to promote RETs are needed, but stakeholders had various opinions. For some, subsidies should be avoided, whereas for others they should be smart, i.e. with a planned exit strategy. Other financial measures such as internalising environmental costs of non-renewable sources or removing subsidies on conventional sources were suggested, although it was also observed that this was more of a political matter.

e) Contracted RETs based electricity generation

The promotion of centralised RETs-based power plants, through green pricing or power wheeling was seen as a good idea. However, it was pointed out that these measures would require a wider opening of the power market.

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List of Acronyms and Abbreviations

AC	Alternating current
ADB	Asian Development Bank
Ah	Ampere hour
AIT	Asian Institute of Technology
ASEAN	Association of the Southeast Asian Nations
ATA	Appropriate Technology Association
BAU	Biogas Advisory Unit
BETs	Biomass Energy Technologies
BCS	Battery Charging Station
BGET	Border Green Energy Team
BMA	Bangkok Metropolitan Area
BOSCH	Biomass One-Stop Clearing House Information Service
BTC	Biogas Technology Centre
CMU	Chiang Mai University
DC	Direct Current
DEDE	Department of Alternative Energy Development and Efficiency
DEDP	Department of Energy Development and Promotion
DOAE	Department of Agricultural Extension
ECCT	Energy Conservation Centre of Thailand
E for E	Energy for Environment Foundation
EGAT	Electricity Generating Authority of Thailand
ENCON	Energy Conservation and Promotion
EPPO	Energy Policy and Planning Office
ESCO	Energy Service Company
FAO	Food and Agriculture Organisation
GDP	Gross Domestic Product
GNESD	Global Network for Sustainable Development
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
hh	household
kgoe	Kilo Grams of Oil Equivalent
kWh	Kilowatt-hour

NA	Not Available
LPG	Liquefied Petroleum Gas
LU	Livestock Unit
MEA	Metropolitan Electricity Authority
MJ	Mega Joules
Mm^3	Million Cubic Meter
MoE	Ministry of Energy
NEPO	National Energy Policy Office
NESDB	National Economic and Social Development Board
NESDP	National Economic and Social Development Plan
NGO	Non Governmental Organisation
NSO	National Statistical Office
OPD	Outpatient Department
PEA	Provincial Electricity Authority
PEDA	Punjab Energy Development Agency
PV	Photovoltaic
PVPP	Photovoltaic Power Plant
PWD	Public Works Department
R& D	Research and Development
REP	Recovery Energy Potential
RETs	Renewable Energy Technologies
RGPV	Roof-top Grid Connected Photovoltaic
RPS	Renewable Portfolio Standard
RTG	Royal Thai Government
SERT	School of Renewable Energy Technology, Naresuan University
SHS	Solar Home System
SPP	Small Power Producer
TEI	Thailand Environment Institute
TPV	Thai Photovotaics Limited
toe	Tons of Oil Equivalent
UASB	Upflow Anaerobic Sludge Blanket
UNICEF	United Nations Children's fund
US$	United States Dollar
VSPP	Very Small Power Producer
WEC	World Energy Council
WHO	World Health Organisation
W_p	Watt peak
WWF	World Wildlife Fund

1. Background

Energy and development are undeniably interlinked. Developing countries tend to consume more energy to satisfy their growing needs and to increase the standard of living of their population. Socio-economic development, through education, provision of good healthcare or income generating activities cannot be achieved without utilisation of energy (electricity, heat, mechanical, etc). However, the overexploitation of non-renewable sources can result in environmental problems and hazards (local pollution, climate change, etc.). As some of these fossil resources (oil, natural gas) are located in only a limited number of countries, the developing Asian countries are dependent on these countries for their importation.

Thailand, a medium income country ranked 73[6] at the Human Development Index (HDI) consumed a total of 56,289 ktoe of primary commercial energy in 2003. In the same year, the total energy imported represented 55% of the total net primary energy supply. Furthermore, in 2003, the combined cost of the total energy imported represented 6.9% of the GDP and 13% of the commodity import (DEDE, 2004c). Out of the total energy import, crude oil represented 75.5 % in 2003 (DEDE, 2004a).

During 1999 – 2003 the net primary energy supply increased with an average annual growth rate (AAGR) of 5.9%. During the same period, the AAGR of the total energy domestic production and import were 4.9 and 7.1 % respectively. Thailand is, therefore, heavily dependent on energy imports and this dependence is rising and will continue to rise in the future if no alternate measures are taken. Furthermore, during 1987-2003, the ratio of energy consumption growth rate to the GDP growth rate (energy elasticity) has been 1.4:1 (Sutiranatana, 2004).

In the face of the rise of oil prices in the international market[7], the Royal Thai Government (RTG) decided to heavily subsidise fossil fuels (diesel and to lesser extend gasoline) for the users. In particular, diesel has been maintained at a constant price of 0.36 US$/litre[8,9] from 10 January 2004 to 22 February 2005. This decision, motivated by the significant dependence of economic activities on fossil fuels, was meant to stimulate economic growth and limit inflation. The subsidy plan came to an end on Wednesday 13 July 2005. It cost the country more than US$ 2.2 billion[10,11].

On the other hand, in rural Thailand, where the majority of the poor live, the traditional use of biomass (charcoal and fuelwood) for cooking and other needs requiring heat, still appears to be the most used fuel-type. However, the disadvantages of using such cheap conventional sources are well-known and include the adverse health impacts on local people through the inhalation of particulate matters and emission of fumes from the combustion process. Furthermore, inefficient and sustainable use of these local resources can lead to local environmental degradation, such as deforestation.
Renewable energy technologies (RETs) have been increasingly considered as a viable alternative to satisfy energy needs for both domestic and productive uses[12], especially in the remote areas and many

[6] http://hdr.undp.org/statistics/data/countries.cfm?c=THA (17 October 2005)
[7] Oil prices reached a peak in September 2005 of US$ 70/barrel on the West Texas Intermediate http://omrpublic.iea.org/ (22 November 2005)
[8] For 2004 an average rate of 40.8 Baht/US$ is considered
[9] 14.59 baht/litre
[10] Baht 86.555 billion
[11] http://www.eppo.go.th/petro/pricestoday-2547.html (22 November 2005)
[12] Definitions of Productive Uses:

demonstration projects have been implemented in developed and developing countries. However, these RETs promotion programmes suffered setbacks. Concerted research and development is needed to make these technologies more reliable and affordable and therefore, more attractive to the users.

2. Rationale and Motivation

Poverty alleviation is one of the major concerns of the governments of developing countries and is the first of the eight Millennium Development Goals (MDGs). One of the prerequisites to eradicate poverty is the promotion of income-generating activities at the village level, using local traditional knowledge, available resources and raw materials. However, to be sustainable, these activities must be economically profitable and have minimum or no adverse impacts on the environment.

Renewable energy technologies (RETs) can help reduce environmental impacts caused by energy production and utilisation; offer a better quality of service or a decrease in energy related costs in the long run.

For RETs to become widely used in developing countries, there is a need to overcome a wide range of barriers still hampering their development. These barriers can be addressed by adequate and appropriate policies. These can be enacted if decision makers are sensitised to RETs and their associated benefits. A previous research theme the Global Network on Energy for Sustainable Development (GNESD), Energy Access, showed that as far as the power sector reforms are concerned, government policies could have a real, positive or negative impact on the poor. This shows that, if poverty alleviation is sought, policies have to be designed and implemented in a way that can benefit the poor.

Studying RETs and their potential applications in Thailand is particularly interesting for three main reasons: First, the country is endowed with abundant renewable energy resources, solar and biomass in particular. These resources could be exploited in a systematic manner to satisfy the growing energy needs of the kingdom. Second, since the late 1970s, the Royal Thai Government (RTG) has embarked on promoting RETs, mainly focusing on PV based technologies for remote areas, for both water pumping and electrification purposes. The experience gathered and the lessons learned during these last 25 years could be useful for decision makers in other countries. Third, the level of electrification in Thailand is high (98.5% of the total villages and 83.9% of the household have access to electricity (DEDE, 2004e)). RETs have therefore to find niche applications different from decentralised power generation for rural electrification. This is unusual in developing countries.

Focussing on rural Thailand, where the majority of the poor live, this report aims at identifying the role RETs can play to address poverty alleviation. The main barriers to RETs promotion and use, and policy options that could help to overcome them are discussed.

As a first step, an initial assessment presents the energy needs in rural Thailand. This is followed by an evaluation of the potential and status of the different RETs. Based on this analysis, some promising RETs for productive use in rural Thailand are described along with their respective benefits and drawbacks, and the role of various stakeholders involved in promoting RETs in Thailand. Finally,

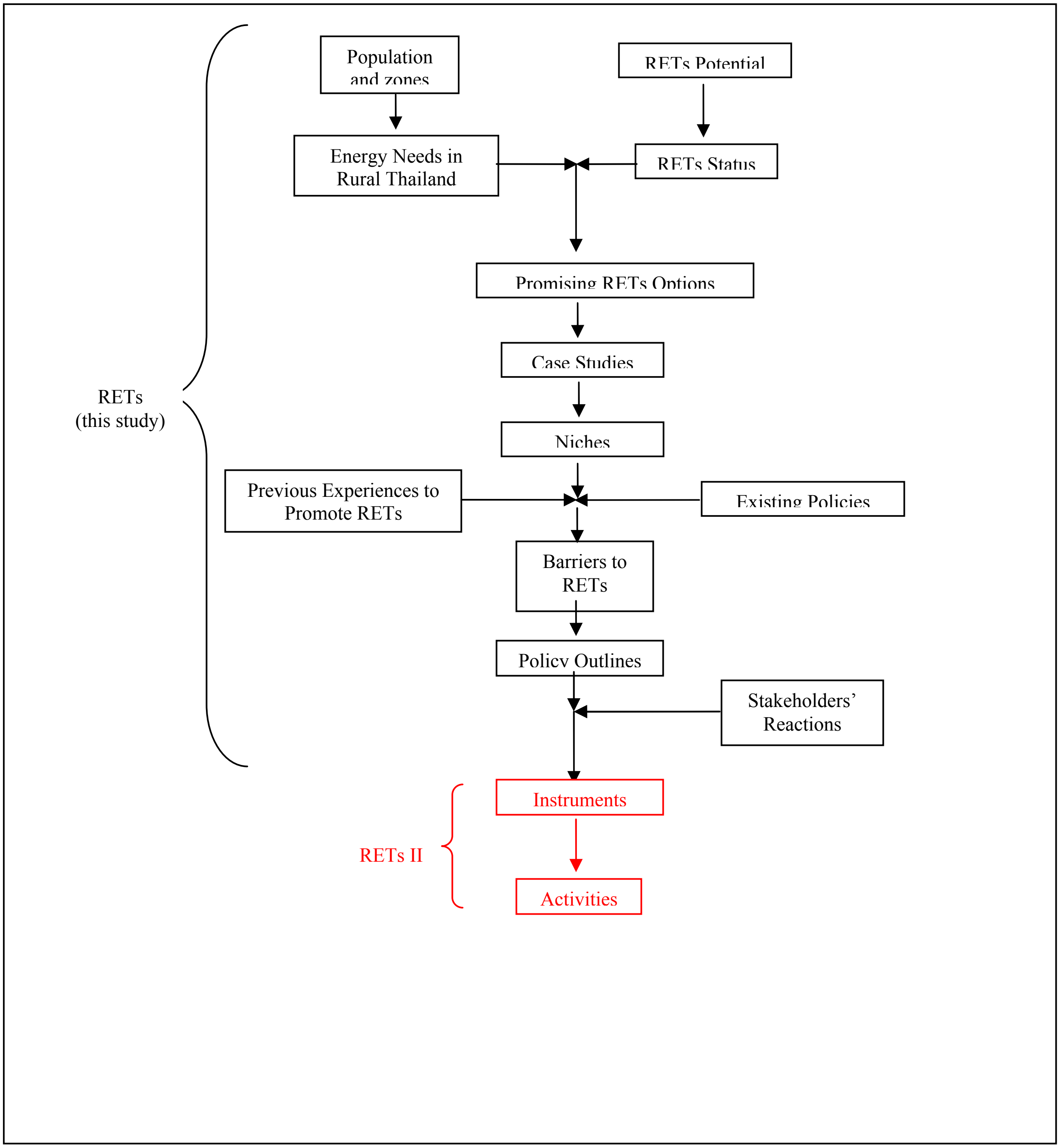
- In the context of providing modern energy services in rural areas, a productive use of energy is one that involves the application of energy derived mainly from renewable resources to create goods and/or services either directly or indirectly for the production of income or value. (GEF/FAO Workshop, 2002)

The term ‘productive uses’ refers broadly to enhancing income generation opportunities and productivity in rural areas, e.g. small industry, agriculture, commercial activities, telecommunications, education and health facilities, clean water, refrigeration, to improve quality of life and increase local resilience and self-reliance. (Etcheverry, 2003) descriptions of some past RETs promotion programmes give a broader perspective of the problems still remaining to be overcome.

This initial assessment leads to the identification of the main barriers to RETs promotion and utilisation. These are analysed to define policy outlines to overcome them. These outlines were presented to key stakeholders for comments and feedback.

The overall methodology is presented in figure 1. The two last steps noted, namely characterisation of instruments and definition of activities will be studied in detail in the next research theme in the framework of GNESD, RETs II.

Figure 1: Schematic representation of the methodology for RETs theme



3. Initial Assessment

The objective of this chapter is to identify the main barriers to renewable energy technology (RETs) promotion and development for poverty alleviation. The two first sections briefly present the socio-economic background of Thailand and highlight the energy needs in rural Thailand. The needs for alternatives as well as the different RETs options to satisfy the identified needs are also presented. The status of RETS and their potential in Thailand, are then shown. Three cases studies of RETs for productive uses in rural Thailand and potential niches for RETs in Thailand are also presented. The main stakeholders are introduced and a section is dedicated to the description of past governmental programmes promoting RETs. This chapter ends with a summary of the identified problems related to RETs utilization and promotion.

3.1 Characterization of population and zones

In Thailand, the poor are defined as the population with a monthly average income below the poverty line defined by the National Economic and Social Development Board (NESDB). In 2002, the national poverty line was set to 922 Baht/person/month[13]. Based on this amount, approximately 10% of the total population were considered as poor in 2002. Countrywide, about 86.5% of the population living below the poverty line reside in rural areas while the remaining live in urban areas[14]. At the regional level, Table 1 shows that the north-eastern part of Thailand is the poorest region in the country, both in actual as well as relative numbers NESDB (2001, 2002). For 2002, the average monthly income per household in rural Thailand is US$ 222 (9,500 Baht) (NSO, 2003a).

Table 1: Distribution of the population below poverty line by region in Thailand in 2002

Type	Greater Bangkok[15]	Central	Northern	North-eastern	Southern	Total, (%)
Urban	64,819	108,515	133,887	408,987	121,242	837,450 (4.04)
Rural communities	9,278	406,785	980,442	3,361,698	619,761	5,377,964 (12.58)
Total	74,097	515,300	1,114,329	3,770,685	741,003	6,215,414
Proportion of the total population (%)	0.96	4.34	9.84	17.68	8.71	9.79
Growth rate (%)[16]	-43.00	-4.57	-7.14	-27.35	-35.00	-24.20

Sources: NESDB (2001, 2002)

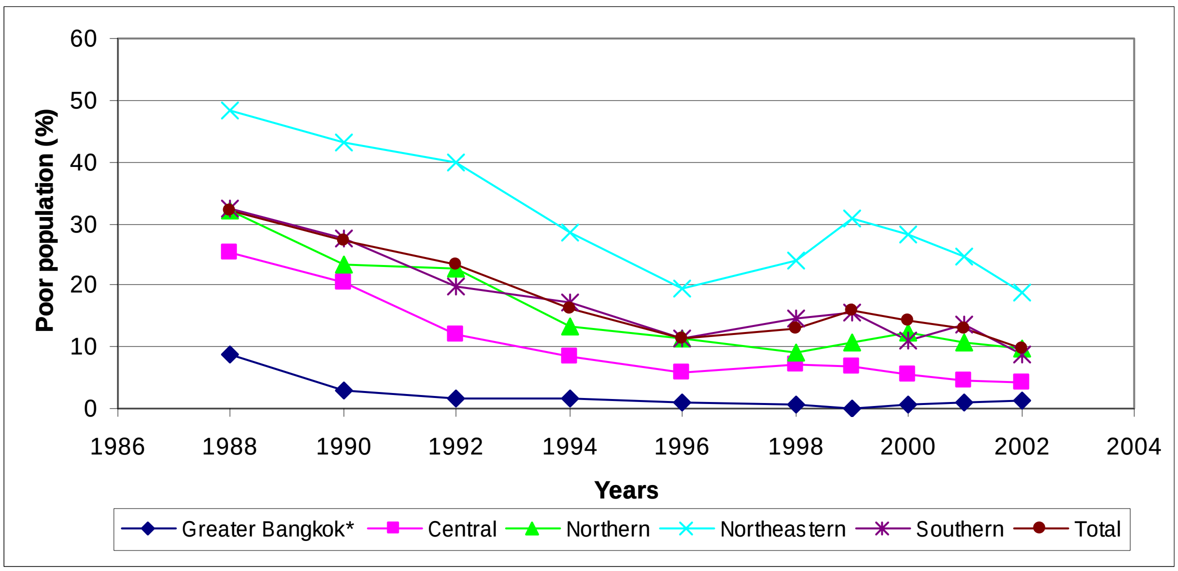
Figure 2 shows the variation and proportion of the poor population in Thailand from 1988-2002. At the country level, the total number of poor has decreased significantly from 1988 to 1996, from more than 32% to less than 12%. However, due to the economic crisis during 1996-1999, the number of poor had increased to almost 16% in 1999. From 1999 onwards, as the Thai economy recovered, and the annual GDP growth rate rose from -10.5% in 1998 to +5.3% in 2002 (NSO, 2003a), the population below the poverty line continuously decreased during this period and was less than 10% by 2002.

The same trends were observed at the regional level during 1988 to 1996, where the relative number of poor decreased significantly. However, as the economy slowed down at the end of 1996, the percentage of deprived people in rural areas increased. Figure 1 shows that during the peak of the economic crisis (1998-1999) although there was a rise in the percentage of poor population in all other regions in the

[13] In this report, an average exchange rate of 43 Baht/US$ is considered for the year 2002.
[14] Urban and rural areas are considered to be municipal and non-municipal areas, respectively.
[15] Greater Bangkok (Bangkok metropolis, Nonthaburi, Pathumthani and Samutprakan).
[16] Compared with data of year 2001.

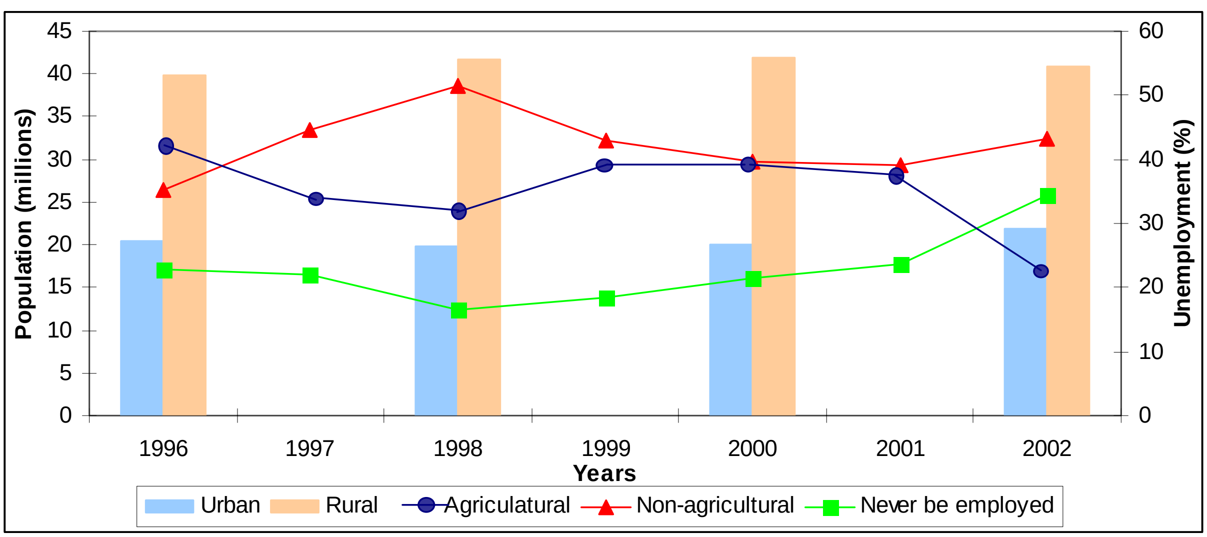
country, the opposite was experienced in the metropolitan centre of Greater Bangkok. This can be explained by the fact that during this period, a great number of people probably left the municipalities and went back to their home villages in the rural areas. Indeed, as shown in Figure 2, during this period, the population of rural areas increased while it decreased in urban areas. Moreover, the unemployment rate in the industrial sector (non-agricultural) increased. In rural areas however, the unemployment rate in the agricultural sector decreased in spite of the increase in rural population. This shows that people came back to work in the fields during the economic crisis. However, during this time, the average income of the people working in rural Thailand dropped thereby increasing the ratio of the poor population in the agricultural areas. On the other hand, after the economic recovery, more jobs became available in the industrial sector and thus there were migrations to the urban centres.

Figure 2: Proportion of poor in Thailand according to region and national level



Source: NESDB (1992-2002)

Figure 3: Trends of population and unemployment rate in Thailand



Source: NESDB (2003b) and Limjeerajarus et al. (2004a)

Hence, it can be concluded that the decrease of the unemployment rate in rural Thailand in the beginning of the 21st century is probably due more to the decrease in population than to an increase in job opportunities. Creation of jobs in rural areas is required to alleviate poverty and reverse the phenomenon of rural to urban migration.

3.2 Needs and energy requirements

A great majority of the poor in Thailand live in rural areas, mainly in the Northern and Northeastern regions (Table 1). To evaluate the potential role of RETs for poverty alleviation, the current energy consumption patterns in rural Thailand have to be assessed. This section aims at identifying the main energy consuming activities in three different sectors (residential, productive and social), their related costs and their share in the total running costs. These identified activities could be targeted in priority for the implementation of measures aimed at increasing efficiency of energy use and provision of reliable energy.

The main source for this section is the survey on the energy consumption in rural Thailand, carried out every five years by the Department of Alternative Energy Development and Efficiency (DEDE). To complete and complement some of the observations by DEDE, a field survey was carried out in three villages in three different regions of Thailand (see Appendix 1 for details).

The next 3 sub-sections present an analysis of the current energy patterns and their related expenses in the residential, productive and social sectors. The need for alternatives is then emphasized followed by renewable energy options to satisfy the main energy needs.

3.2.1 Residential uses

Consumption

The annual average energy consumption of Thai rural households, excluding transport, is summarised in Table 2 below.

Table 2: Yearly average energy consumption per household in rural Thailand

Type of energy service	Consumption (kgoe/hh)	Share (%)	Main fuels used
Cooking	518.71	60.1	Charcoal, Wood
Agriculture	224.57[17]	26.0	Diesel, Gasoline
Lighting, Entertainment and Convenience[18]	87.36	10.1	Electricity, Diesel
Industry & Handicraft	14.92	1.7	Wood, Electricity
Others	17.85	2.1	NA
Total	**863.41**	**100**	

Source: DEDE (2003c)

The two most energy consuming activities are cooking (60%) and self-subsistence agriculture, respectively. Biomass (charcoal and fuelwood) used in a traditional way is the most used option to cook. Pumping water for domestic uses is not a need that requires a lot of energy. Along with other uses (lighting, cooling down the space, preserving goods, etc) it does not represent more than 10% of the total consumption of an average household. This is explained by the fact that in many places, villagers collect rain water.

[17] Agriculture for self-subsistence
[18] Convenience: water pump, fan, Air-Conditioning (AC), refrigerator, water heater, washing machine, hair dryer.

Regarding transportation needs, the limited survey carried out for this study shows that motorbikes are very popular in rural Thailand. About two-thirds of the households surveyed had at least one motorbike. The transportation energy needs allotment comprises, on an average, about 20% of the total energy share of a household, and in some cases, it even exceeds 30% (AIT, 2004a).

Expenses

A summary of the yearly energy expenditures per activity is given in Table 3 below. It shows that activities requiring the highest amount of energy are also the most expensive to satisfy. However, differences in costs between the different requirements are less pronounced than energy consumption. This is explained by the fact that, per kilogram of oil equivalent (kgoe), electricity is about 2 and 3.5 times more expensive than diesel and wood respectively (DEDE, 2003c).

Table 3: Yearly average energy expenditures per household in rural Thailand

Type of energy service	Cooking	Agriculture	Lighting, Entertainment and Convenience	Industry & Handicraft
Cost (US$/hh)	132.9	104.9	71.6	5.3

Source: DEDE (2003a, 2003b, and 2003c)

The average expense per rural household[19] for energy is over US$ 310 per year. As a comparison, the average annual income in rural Thailand is US$ 3,314.4[20] per household and the average annual expenditure is US$ 1967.6[21] per household (DEDE, 2003c). On a yearly basis, the energy related expenses then effectively corresponds to about 9.5% of household income and represents more than 15.5% of the total household expenditures. AIT (2004a) shows similar trends, with average energy expenses representing between 19 and 28% of the total monthly expenditures of the household, as shown in Appendix 1. However, a more recent and comprehensive survey from DEDE, not yet published, suggests that energy corresponds to more than 30% of the total expenses of a rural household (AIT, 2004c).

Summary

For rural Thailand, the different types of energy uses can be detailed and prioritised as shown in Table 4 (excluding transport).

Table 4: Prioritisation of energy use in the residential sector in rural Thailand

Type of energy service	**Energy Consumption** (kgoe/hh/yr)	**Main fuel used**	**Cost** (US$/hh/yr)	**Impact**
Cooking	518.08	Charcoal	132.7	Basic need
Field ploughing	174.64	Diesel	80.6	Increases production, Increases income
Convenience	51.67	Electricity	41.6	Basic need, Increases standard of living,
Water pumping for crop irrigation	39.65	Diesel	20	Increases production, increases income
Entertainment	18.03	Electricity	15.46	Increases standard of living
Lighting	17.65	Electricity	14.56	Enables working during night time

Source: DEDE (2003a, 2003b, and 2003c)

[19] The exact total is not possible to calculate due to a lack of data on the fuels used to satisfy "other" needs
[20] 142,520.03 Baht/year/household
[21] 84,606.11Baht/year/household

Energy services such as cooking and field ploughing require heat and mechanical energy, respectively and exhibits the highest annual energy consumption as well as costs for rural households. These are therefore the two activities for which finding alternatives should be prioritized. The third one, convenience, implies the use of electricity for cooling space, preserving food and heating and pumping water.

The alternative or renewable options for satisfying the energy service needs as presented in Table 4 are discussed in section 3.2.4.

3.2.2 Productive uses

Consumption

A particularity of rural Thailand is that it is difficult to distinguish productive uses from residential uses. The same energy requiring devices are often shared for both professional and personal activities. In this section, two different categories related to the productive sector are being considered, namely, Residential and Business (restaurants, shops, etc.) and Residential and Industry (production units: e.g. cottage industries, foodstock production, workshops, etc.), following the terminology used in DEDE (2003c). For these two categories, the different types of energy uses, the average consumptions as well as the two main fuels used are shown in Table 5.

Table 5: Yearly average energy consumption of the productive sector in rural Thailand

Type of energy service	Residential + Business			Residential + Industry		
	Consumption (kgoe/hh)	Share (%)	Main fuels used	Consumption (kgoe/hh)	Share (%)	Main fuels used
Cooking	340.75	39.56	Charcoal, LPG	409.05	25.49	Wood, Charcoal
Agriculture	236.22	27.43	Diesel, Electricity	187.33	11.66	Diesel, Gasoline
Industry & Handicraft	145.74	16.92	Electricity, LPG	830.97	51.73	Wood, Electricity
Lighting, Entertainment and Convenience	129.30	15.01	Electricity, Diesel	127.61	7.94	Electricity, Diesel
Others	9.32	1.08	NA	51.39	3.20	NA
Total	**861.32**	**100**		**1,606.35**	**100**	

Source: DEDE (2003c)

In rural Thailand, the highest energy consumption activities in the productive sector (industry and businesses) are cooking, agriculture and industry/handicraft. In the business sector, cooking represents almost 40% of the total energy consumption. Charcoal is the most widely used fuel followed by LPG and fuelwood. In the industrial sector, wood and charcoal are used more than LPG. Similar to the residential sector, pumping water does not represent an important part of the total energy consumption in the productive sector.

The share of the different energy end-uses is very context specific (activity, location, etc.). Two examples (a coconut factory and a restaurant) are given in Appendix 1 (Figure 1-2).

Expenses

The share of energy costs to the total running costs of a production unit (business or industry) depends on the type of activity. It can be as high as 70% for agricultural activities requiring large quantities of water (e.g. rose apple or lemon plantations) or foodstuff production units requiring large cold storage capacities (AIT, 2004a). For small scale and more traditional activities, such as traditional fruit drying, small pig farms or paddy cultivation using rainwater, the share of energy is less significant and sometimes negligible. Low energy intensive industries have often low production rates and produce low quality goods. In restaurants, the main expenses are for food ingredients, and the energy expenditures represent only about 3% of the monthly running costs (AIT, 2004a).

Table 6 gives the yearly average energy related expenses in the productive sector in rural Thailand. The yearly energy expenses, excluding transportation costs, exceed US$ 430 for businesses, and it is more than US$ 530 for industries[22].

Table 6: Yearly average energy expenditure in the productive sector in rural Thailand (in US$/unit/year)

Type of energy service	Cooking	Agriculture	Lighting, Entertainment and Convenience	Industry and Handicraft
Residential and Business	98.7	120.8	109.2	96.7
Residential and Industry	113.2	87.1	106.7	223

Source: DEDE (2003a, 2003b, and 2003c)

Summary

The different needs for the industrial sector in rural Thailand are summarised and presented in Table 7. As shown in the table, the most energy consuming activities (drying, baking, pasteurising, brick making, pottery, cooking, etc.) require heat. Currently, this is provided by fuelwood.

Table 7: Prioritisation of energy use in the industrial sector in rural Thailand

Type of energy service	Energy Consumption (kgoe/hh/yr)	Main fuel used	Cost (US$/hh/yr)	Impact
Heat for thermal processes[23]	796.58	Wood	191.4	Increases production, Increases quality, increases income
Cooking[24]	404.05	Wood	112	Increases production, Increases income
Field ploughing	145.7[25]	Diesel	67.2	Increases production, Increases income
Water pumping for crop irrigation	33.1[26]	Diesel	16.4	Increases production, Increases income
Cold Storage for production conservation	7.82	Electricity	6.9	Preserves production, Increases income

Source: DEDE (2003a, 2003b, and 2003c)

As shown in Table 7, agriculture related energy needs are of lesser importance both in terms of consumption and cost.

[22] The exact total is not possible to calculate due to a lack of data on the fuels used to satisfy “other” needs
[23] Drying, backing, brick making, pottery, and pasteurising
[24] Cooking food for the staff
[25] This data is not available as such in the Rural Energy Consumption Survey. It has been deducted from the values obtained for the residential sector.
[26] Idem 25

3.2.3 Social Services

Consumption

The most common social services provided at the village level are related to health and education. Several villages usually share health centres and school facilities. Table 8 summarises the average energy consumption in surveyed schools and health centres.

Table 8: Yearly energy consumption of the social sector in two surveyed villages

Type of energy service	Health centre		
	Consumption (kgoe/hc/year)	Share (%)	2 main fuels used
Patients Transportation	658.3	49.5	Diesel Gasoline
Office Work	247	18.6	Electricity
Lighting, Entertainment and Convenience	197.94	14.9	Electricity
Sterilisation	134.61	10.1	LPG Electricity
Vaccine Storage	90.78	6.8	Electricity
Total	**1328.63**	**100**	

Type of energy service	School		
	Consumption (kgoe/s/year)	Share (%)	2 main fuels used
Lighting, Entertainment and Convenience	891.0	52.0	Electricity
Cooking	631.6	36.9	LPG
Office Work	171.8	10.0	Electricity
Others	18.7	1.1	Electricity
Total	**1713.2**	100	

Source: AIT (2004a)

For health centres, the three most energy consuming activities (patients transportation, office work, and lighting entertainment and convenience) are not directly related to the provision of health care. Transporting patients to the nearest hospital represents almost half the total energy consumption. In addition, patients are not fed (only OPD services are provided) in the surveyed health centres. There are, therefore, no cooking needs to be satisfied (the staff buys its food in nearby restaurants) (AIT, 2004a).

For schools, more than 50% of the energy consumption is dedicated to the provision of an atmosphere suitable for education (lighting, air conditioning, etc.).

It is important to point out that the surveyed schools and health centres used only modern forms of energy (grid electricity and fossil fuels).

Expenses

The energy related expenses of the surveyed schools and health centres are summarised in Table 9. These expenditures amount to more than US$ 800 and US$ 1,000 per year for health centres and schools respectively. Details of energy related expenses with respect to the total running costs are given in Appendix 1 (Figure 1-3).

Table 9: Yearly Energy Expenditures in the social sector in rural Thailand (in US$/service/year)

Type of energy service	Health centre[27] Cost (US$/hc/year)
Patients Transportation	375
Office Works	175.3
Lighting, Entertainment and Convenience	150
Vaccine Storage	64.4
Sterilisation	62.4
Total	**827.1**

Type of energy service	School Cost (US$/ s/year)
Cooking	268.0
Lighting, Entertainment and Convenience	620.1
Office Works	119.6
Others	13.0
Total	**1020.7**

Source: AIT (2004a)

Salaries represent the largest share of running costs in the surveyed schools and health centres. In schools, other running costs, including energy, are almost negligible. In the health centres, the share of energy expenses does not represent more than 5% of the running costs as compared to the costs of medicines, which represents an important share (about 25%). Hence, the impact of RETS in terms of providing additional income in the social sector in rural areas or improving working conditions will be rather limited.

Summary

The different services consuming the highest amount of energy in schools and health centres are presented in Table 10 below. The fuels used are either fossil based or grid electricity.

Table 10: Prioritisation of energy use in the surveyed school and health centres in rural Thailand

Category	Type of energy services	Energy Consumption (kgoe/hh/yr)	Main fuel used	Cost (US$/hh/yr)	Group	Impact
Health Centre	Patients Transportation	658.3	Gasoline	375	Rural Communities	Decreases running costs
	Vaccine Storage	90.78	Electricity	64.4	Rural Communities	Decreases running costs
School	Lighting Entertainment and Convenience	891	Diesel	620.1	Rural Communities	Decreases Running costs Improves studying conditions

Source: AIT (2004a)

3.2.4 Need for alternative forms of energy and renewable energy options

The analysis of the current energy consumption patterns in rural areas as well as the current energy scenario in Thailand shows that:

- In rural Thailand, energy related costs can be an important part of the total expenditures of a household or small-scale businesses and industries. Any reduction of these costs can provide an additional income or create employment opportunities.
- The majority of the people living in rural areas in Thailand still rely on traditional biomass to satisfy their cooking needs. Cooking is currently the most energy consuming activity for both

[27] Average of two rural health centres

the domestic and business sectors. It is now well known worldwide that the traditional use of wood and charcoal for cooking leads to indoor air pollution that in turn badly affects the users' health. Time spent by women and children to collect the wood and deforestation issues are other major concerns linked with the traditional use of biomass.

- While in rural areas, traditional biomass (wood and charcoal) is the most preferred fuel, Thailand remains nevertheless a net energy importer, with a share of energy import amounting to 55 % of the total net energy supply. Crude oil representing more than 75% of the total energy import. The recent rise of oil prices and the increase of consumption of fossil fuel is an economic burden for the country. Indeed, in January 2004, the Thai government launched a plan to subsidise fossil fuels that cost the country more than US$ 2.2 billion in one year and a half.

- Some small-scale traditional enterprises are not very energy intensive, but their production remains low, both in terms of quantity and quality. The low energy consumption can be due to several factors: lack of availability of modern forms of energy, non-affordability of modern forms of energy, lack of affordability of appliances using modern forms of energy, etc.

RETs can provide viable alternatives to conventional sources of energy and play a major role in alleviating poverty in a sustainable manner while tackling the above-mentioned issues. The link between lack of modern energy consumption and low development indices has been widely reported and highlighted. In particular, new income generating activities are more likely to develop if modern and reliable sources of energy (e.g. electricity) are available. RETs usually provide energy at a decentralised level, where it is needed; therefore avoiding energy distribution costs and losses. RETs can bring a modern form of energy to remote areas unlikely to get linked to national grids in the near future.

The reliability of RETs is usually better than conventional energy sources. For example, electricity grids in developing countries are often under-designed and power cuts are frequent during peak hours. RETs producing electricity, if well designed and used in an appropriate way, can overcome this problem. A reliable source of energy is a necessary condition for enterprises and therefore for economic development. Biomass-based RETs allow a much more efficient use of biomass resources than traditional technologies. Replacing traditional use of biomass by RETs allows a reduction in fuel costs as well as a reduction in the environmental impacts (at both the global and local level) of biomass use. The more efficient use of biomass also has direct positive impacts for human development, as it reduces indoor air pollution that is responsible for more than two and a half million deaths every year (IEA, 2002), and saves time for women and children to engage in productive or other activities[28].

In the industrial sector, RETs can increase the production quantity and quality. This, in turn can provide additional income. In some cases, RETs can also reduce energy related expenses, especially in the long run.

At the country level, a more systematic use of RETs can help to reduce the dependency on imported energy and its related economic burden. From the environmental point of view, RETs help to decrease the pressure on both the local and global environment. In particular, they mitigate CO_2 emissions and therefore reduce global warming, which affect the impoverished societies more than any other class of the population.

[28] By reducing the time needed to gather fuelwood.

RETs are available in various sizes and configurations, and theoretically, they can satisfy all the energy requirements in rural Thailand. However, different parameters (energy needs, availability of renewable resources, national policies, local and global market, etc.) will influence the choice of the most appropriate RETs for each situation. The selection of a particular RET is, therefore, very context specific.

In the case of rural Thailand, activities consuming the highest amount of energy for the residential, industrial and social sectors are presented in Table 11. For each activity, the possible RETs and their competing non renewable sources are given[29].

Table 11: Main energy use and potential renewable energy technologies

Category	Type of energy service	Renewable Technologies	Competing non-renewable
Residential	Cooking	Biomass and Biogas Solar cooker	LPG, Grid
	Lighting, Entertainment and Convenience	Solar PV Micro hydro Wind Geothermal Biodiesel Bioethanol	Grid, diesel, kerosene
	Transportation	Biodiesel Bioethanol	Diesel, gasoline, CNG
Industrial	Heat for drying units, bakeries, etc.	Solar dryer Biomass Biogas Geothermal	Grid, LPG, Kerosene
	Water pumping for crop irrigation	Solar PV Biodiesel Biogas Biomass gasification Wind	Grid, diesel, gasoline
	Field ploughing	Biofuel	Diesel, gasoline
Social/Community Services	Refrigeration for vaccine conservation	Solar PV	Grid, Kerosene, LPG

3.3 Technologies

Renewable energy is energy from a source that can be managed so that it is not subject to depletion in a human timescale. Sources include the sun's rays, wind, waves, rivers, tides, biomass, and geothermal. The different technologies using renewable resources currently available are described in different references, among which (Boyle, 2004) and (Sørensen, 2004), and are not detailed here. The different RETs currently used in Thailand as well as their status are discussed in this section. Their respective potentials are presented in section 3.4. The current status in Thailand is discussed technology wise in this section.

3.3.1 Solar Photovoltaic

In Thailand, the Ministry of Public Health and the Medical Volunteers Foundation launched the first national programme for solar PV in 1976. The solar modules were then used to power communication equipment in rural health centres.

[29] For a better understanding, each requirement is given only once, i.e., if cooking is needed both in the residential and industrial sector, the same RETs can be applied.

As of November 2005, there are no manufacturers of PV modules in Thailand. Two main companies, joint ventures launched with technological back up from foreigners, import solar cells and assemble them locally into PV modules. The current importation tax for solar cells is 35% (Wongsapai, 2004b). The total annual production capacity is about 3 MW, which exceeds the local demand [30]. The current market price of PV crystalline modules is about 7.5 US$/$W_p$ [31].

To reduce production costs an American managed company planned in 2002 to implement a production unit of low cost PV cells using local raw materials. The production cost of such amorphous silicon cells was estimated at about 1.38 US$/$W_p$ (Mogg, 2002). However, due to administrative complications, the company decided to pull out of Thailand [32].

A Thai PV manufacturer is planning to build a factory to produce solar cells. This production plant will have a capacity to produce 20MW_p of solar cells per year. It could start its production in 2007. Locally made solar cells are expected to be 20 to 30% cheaper than the imported ones (Jaimsin, 2005).

The different uses of PV based technology in Thailand can be summarised as follows:

Water Pumping

The Thai government launched several programmes to disseminate water pumps in the mid eighties. The technical failures (more than 45% according to a survey) faced by the installed systems are in most cases due to designs mismatching needs as well as misuse and abuse of the technology (see Section 3.8 for details).

In the government programmes, imported AC pumps and inverters are used. The prevailing cost of pump sets used (AC pump and AC/DC inverter) is about US$ 1,750. The equivalent cost of pumped water is about 0.17 US$/$m^3$ [33] (Sriuthaisiriwong, 2000). The programmes were implemented on a fully subsidised basis. By the end of 2003, the total installed capacity reached 954 kW_p, 6.4% higher than in 2002 (Wongsapai, 2004c).

Battery Charging Stations (BCS)

In off grid areas, solar modules can be used to charge batteries that the users take home to power appliances providing different services (lighting, entertainment, etc). As is the case for water pumping, PV BCS have been implemented in Thailand in the framework of governmental programmes (described in detail in Section 3.8). About 1,660 fully subsidised stations with a total capacity of 1.9 MW_p have been implemented since 1988 (Green, 2004). The total installed capacity rose by 19.56% during the year 2003 (Wongsapai, 2004c). PV BCS faced many technical failures linked to lack of proper operation and maintenance. According to one survey, more than 60% of the installed systems have failed (see Section 3.8 for details).

The cost of a PV BCS of 3 kW intended to serve fifty to eighty households have been estimated at US$ 18,400 (Green, 2004), i.e. from US$ 230 to 370 per household.

The production cost of electricity of PV BCS was estimated at 1.13 US$/kWh (Sriuthaisiriwong 2000).

[30] ASEAN centre for energy: http://www.aseanenergy.org/pressea/thailand/solar/solar_thermal/background.htm (July 5, 2004)
[31] 300 baht/Wp. Personal communication with Solartron (January 9, 2006)
[32] Personal communication with the manager (October 26, 2004)
[33] For 770 Wp installation pumping 9,772 m3 of water/year

Solar Home Systems (SHS)
Solar Home Systems have been implemented in Thailand since the beginning of 2004. At that time, the government launched a two-year programme for rural electrification using SHS. The objective of this campaign is to provide electricity to the 290,716 households still out off the grid and to reach a national electrification level of 100% of registered household by 2005[34].

The SHS standard kit, which is provided free of cost to the rural households is composed of a crystalline PV module of 120 W_p and a 12V/125Ah battery, both locally produced. Private companies contracted by the Provincial Electricity Authority (PEA) are implementing the systems (Boonoon, 2004), (Wongsapai, 2004a and 2004b). According to PEA, the first phase (installation of 150,000 systems) is 90% completed. The second phase (installation of the remaining systems) is about to start[35]. If the objective of the project is reached, Thailand will have 36 MW_p of installed capacity of SHS.

The 120W_p SHS currently used in Thailand cost about US$ 610 per system including the implementation cost[36]. A preliminary study estimated the cost of electricity produced by SHS to be between 0.34 and 0.5 US$/kWh (Limjeerajarus et al., 2004b).

Grid connected PV systems
As of June 2005, the agreement for the connection of 577 kW_p of roof top grid connected PV modules (RGPV) has been signed between individuals and power utilities and 544.2 kW_p has already been installed, mainly in Bangkok metropolitan (EPPO, 2005)[37]. The systems installed include 400 kW_p implemented on the roof of a shopping centre in Bangkok (Kositchotethana, 2004). Furthermore, the Electricity Generating Authority of Thailand (EGAT), owns four solar power plants with a total capacity of 544 kW_p in Northern, Eastern and Southern Thailand. The largest is a 500 kW_p solar power plant, in the province of Mae Hong Sorn (North). It was completed in April 2004 and is the largest PV power plant in South East Asia (Wongsapai, 2004b).

3.3.2 Solar thermal

Solar thermal technologies include the following applications: solar water heating for residential and industrial uses, steam generation for electricity production (large or small scale) and hot air production for drying goods.

At the end of 1999, 50,000m^2 of flat-plate collectors have been installed on commercial buildings, hospitals and private residences for hot water production. This solar thermal capacity is said to be expanding at a rate of some 3,000 – 3,500 m^2 per year[38], especially in hotels, hospitals, and other hot water consumer services. The available solar water heaters, sold by 9 trading companies, are both locally produced and imported, mainly from Australia. Currently, solar water heaters represent 15% of the total (small) market of water heaters. These devices are currently not subsidised by the government and there are no plans to do so in the near future[39].

Solar dryers have been implemented at a demonstration scale since the end of the nineties. The main applications are for drying bananas in Northern Thailand and rubber drying in the Southern part of the country. As of today, 10 solar drying units for bananas and 2 for rubber have been implemented.

[34] PEA: www.pea.co.th/project/project_solar.htm (in Thai) (27 January 2005)
[35] Personal communication with PEA officials (15 November 2005)
[36] PEA: www.pea.co.th/project/project_solar.htm (in Thai) (27 January 2005)
[37] Via http://www.eppo.go.th/power/data/data-website.xls
[38] World Energy Council: http://www.worldenergy.org/wec-geis/edc/countries/Thailand.asp (August 17, 2004)
[39] ASEAN Centre for Energy: http://www.aseanenergy.org/pressea/thailand/solar/solar_thermal/background.htm (August 17, 2004)

A banana solar dryer costs approximately US$ 4,900[40], whereas a traditional dryer costs not more than US$ 50. As such even if the solar dryer produces higher quality products, with a pay back period between two to six years; the initial investment cost is high for Thai farmers considering the average income mentioned above.

3.3.3 Biomass Gasification

Two large-scale pilot power plants are currently using biomass gasification in Thailand. These include a 9.8 MW rice husk fired power plant completed in 2003 and a 23 MW power plant powered by parawood wastes and oil shells is still under construction. These power plants being new, reliable data on the cost of electricity produced is not available.

As of November 2005, there are no small-scale gasification power plants in the country. This absence of this technology is probably due to the high level of electricity access through the grid in Thailand. In other Asian countries (India and China in particular), small-scale applications for cooking, water pumping or electricity generation have been successfully implemented in rural communities.

3.3.4 Biogas

Biogas technologies have been implemented in Thailand since the mid-eighties. As of mid-2004, the total volume of installed digesters amounts to 142,527 m^3. The biogas produced in the digesters is used to produce heat (burner, boiler) or mechanical energy (gas engine). In Thailand, the main use of biogas is for electricity generation.

Two main sources of organic wastes exist in Thailand: feedstock farms and large waste water producing factories (e.g. tapioca scratch factories).

The technology used is both locally produced and imported. In the mid-nineties, the Thai government launched a programme to promote local technology in pig farms. The technology promoted, locally designed and manufactured, it is not yet fully mature and further development is needed to overcome some operation and maintenance problems (see Section 3.8 for details). At the beginning of the 21st century, foreign biogas companies have started to work with industries producing large quantities of wastewater. Nine of such plants are running in Thailand as of October 2005[41].

3.3.5 Biofuels

In Thailand, the technology to produce both biofuels already exists. Biodiesel production in the country started in 1980. The current production is 30,000 litres/ day for biodiesel and 640,000 litres/day for bioethanol (DEDE, 2004a).

Economically, to be accepted, biofuels have to be cheaper than conventional fossil fuels. In the case of biodiesel, however, because of the high demand (especially in the food manufacturing industry) but limited availability of the raw materials (used vegetable oil, palm oil and coconut oil), production costs are high and therefore biodiesel, if not subsidised cannot be sold below the diesel price. Therefore, the Thai government has a policy to sell biofuels 0.5 Baht cheaper than fossil fuels (DEDE, 2004a).

Even if the reliability of biofuels has been proved, the car industry does not guarantee that its cars can run with biodiesel or gasohol without damages (Wongsapai, 2004c). But the experience in Brazil

[40] Banana Solar Dryer with capacity of 100 kg per batch (AIT, 2004a), personal communication with SERT
[41] Personal communication with one biogas implementer (25 October 2005)

proved that imported cars could be easily adapted to the local gasohol containing about 25% of ethanol (Szwarc, 2004).

3.3.6 Wind

In Thailand, the two main applications of wind power are electricity generation and water pumping. These applications have been implemented since 1983 and 1980, respectively (DEDE, 2004b). As of 2003, a total capacity of 1.5 MW of water pumps and wind turbines delivering a total capacity of 0.388 MW have been installed mostly by EGAT and DEDE (DEDE, 2004b). Currently, the production cost of electricity for wind turbines is estimated to be between 0.11 and 0.13 US$/kWh (Limjeerajarus et al. 2004b).

3.3.7 Micro-Hydro

In Thailand, micro-hydro power plants (less than 200 kW) have been mainly implemented for rural electrification in off grid areas. Since 1979, 59 projects with a total capacity of 2 MW have been promoted mostly by DEDE in Northern Thailand (CMU, 2004), (Pacudan, 2003). However, by the end of 2003, only 25 sites remained, with a total installed capacity of 599 kW. The failures are due to the grid extension, the lack of involvement of the communities, lack proper maintenance of the systems and deliberate political choices (Greacen, 2004).

Despite the low level of implementation, the electricity production cost of micro-hydro plants, between 0.030 US$/kWh and 0.038 US$/kWh, is lower than the current retail price of grid electricity (Limjeerajarus et al., 2004b).

3.3.8 Geothermal

There is currently, in Thailand, only one geothermal power plant with an installed capacity of 300 kW. It was established in 1989 in the northern province of Chiang Mai. This installation extracts geothermal energy to produce electricity as well as heat for drying. The production cost of electricity has been estimated at 0.06 $/kWh to 0.12 $/kWh (Ramingwong et al, 2000).

3.3.9 Status of grid connected RETs

RETs producing electricity presented earlier in this section can be divided between grid connected and stand alone installations. The status of grid connected RETs is presented in table 12.

Table 12: Status of grid connected RETs as of June 2005 (agreement signed with utilities)

Resource	No. of projects	Total Power installed (MW)	Total Power supplied to the grid
Solar PV	70	1.1	0.6
Bagasse	31	605.4	183.3
Wood and other residues[1]	21	438.9	291.8
Paddy Husk	13	103.1	80.3
Biogas	13	3.2	3
Landfill gas	4	24.7	15
Micro Hydro[2]	25	0.6	0.6
Geothermal	1	0.3	0.3
Total	**177**	**1,177.3**	**574.3**

Source: EPPO (2005)[42], expect for micro hydro (CMU, 2004)
[1] Excluding bagasse and paddy husk
[2] Micro hydro in Thailand is considered under 200 kW

[42] Via http://www.eppo.go.th/power/data/data-website.xls

In May 2005, the total installed capacity of RETs actually producing electricity was 903.25 MW[43]. Out of this total, 391 MW[44] were connected to the grid and the rest was used to satisfy the needs of the producers (EPPO, 2005). The majority of RETs based grid connected power generation is within inefficient cogeneration systems (Amatayakul et al., 2002). After biomass based RETs, solar PV technologies present the second largest power installed, with 1.14 MW_p of power installed. These comprise of privately owned rooftop grid connected PV modules, and of four centrals owned by EGAT (EPPO, 2005).

At the country level, the share of RETs in the total energy consumption was 0.5 % in 2002 (Lertsuridej, 2004b).

3.3.10 Summary

Table 13 summarises the main advantages and disadvantages of some particular RETs as well as the installed capacity and the means of dissemination. The prospective installed capacities for the different technologies in 2011 are given in section 3.6.

As an indication the prices of conventional sources in rural areas is: electricity (residential)[45] 0.059 US$/kWh, electricity (industrial) 0.058 US$/kWh, Diesel 0.55 US$/l, Gasoline 0.61 US$/l [46]. Furthermore, small electricity customers in rural areas get electricity at a subsidised rate of 0.039US$/kWh (Greacen, 2004).

One of the main drawbacks of all the technologies presented in this section is their high upfront costs. As shown in the previous sections, PV pumping systems, PV BCS, solar dryers, etc. are not affordable as such by individuals and/or communities.

For RETs producing electricity micro-hydro and large-scale combustion of biomass appear to have lesser production costs than the market price. This shows that the investment cost is not the only factor to be considered and RETs can be cheaper in the long run.

In case of rural electrification, it is important to point out that the government and the public utilities involved have substantially invested to extend the grid. Yet, money could also have been invested in RETs if they had appeared to be the most feasible solution to electrify the rural/remote areas. Greacen (2004) calculates the cost of grid extension versus micro hydro for remote villages. It concludes that for a village of 50 households, micro-hydro becomes cost effective when the grid is 4 km away or more. In a village of 300 households is micro-hydro becomes cost effective when the grid is 8 km away or more .Therefore, for electricity producing RETs, the argument that they are not feasible because they are not affordable as such by the local communities should not be used. The agency (government, NGOs, etc…) responsible for rural electrification should select the most appropriate technology (assessing the needs, the locally available natural resources and the distance to the grid) and make the initial investment. Users, on the other hand should pay for their monthly consumption.

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[43] 4.4 MW for very small power producers (<1MW)
[44] 2.7 MW for very small power producers (<1MW)
[45] Baht 2.46 and 2.41 per kWh on average in 2003 (DEDE, 2004e)
[46] http://www.eppo.go.th/retail_prices.html (24 November 2005). During most of 2004, diesel price was US$ 0.36/liter

Table 13 : Status of different RETs in Thailand

Technologies	Installed Capacity	Means of dissemination	Advantages	Disadvantages	Cost
Solar water pumping	954 kWp	100% subsidy governmental programmes	Provide running water to people used to get water from wells	Initial investment Risks of water shortage during rainy season	0.17 US$ / m^3 [1]
Solar battery charging	1900 kWp	100% subsidy governmental programmes	Provide electricity to out off the grid areas	Initial Investment Users need to carry batteries to the stations Need of a supply and disposal network for batteries	1.13 US$ / kWh [1]
Solar Home System	18000 kWp	100% subsidy governmental programmes	Provide electricity to out off the grid areas	Initial Investment Need of a supply and disposal network for batteries	0.34 US$/kWh to 0.50 US$/kWh[2]
Solar Drying	12 units[47]	Demonstration units 100% subsidised by research institute and government	Low O&M Cost, easy maintenance, local manufacture	Initial Investment compared to traditional drying	4,900 US$ / Dryer[3]
Direct combustion of biomass for electricity production (Rankine Cycle)	480.6 MW	Large agro manufactures (rice mills, etc.)	Using Waste to produce energy	Raw material availability and price	0.047 US$/kWh to 0.051 US$/kWh [2]
Biogas for heat production	142,527m^3	Partial subsidy government programme	Fuel Availability	Initial investment Technology sensitiveness	0.04 US$ / Nm^3 [4]
Micro-Hydro	599 kW	Government rural electrification programmes and local initiatives (NGOs, etc)	Provide electricity to out of the grid areas	Initial investment	0.030 US$/kWh 0.038 US$/kWh[2]
Wind turbine	388 kW	Public Utilities	Provide electricity to out of the grid areas	Initial investment Wind availability	0.105 US$/kWh to 0.130 US$/kWh[2]
Biodiesel	30,000 l/d	Private Companies	Can be used with standard CI engines	Raw material availability and price Use of "food" to produce energy	0.61 US$/liter[5]
Bioethanol	640,000 l/d	Private Companies	Can be mixed with gasoline up to 25% with minor modification to the engine	Raw material availability and price Use of "food" to produce energy	0.29 US$ /lifter of pure ethanol[6]
Geothermal	300 kW	Public Utilities	Provide electricity to out off the grid areas	Geothermal Resources Availability	0.06 $/kWh to 0.12 $/kWh [7]

Source: [1]Sriuthaisiriwong (2000)[48], [2] Limjeerajarus et al. (2004b), [3]AIT (2004a)[49], [4] GEMIS (2004), [5] Raja Biodiesel, [6] DEDE (2004a), [7] Ramingwong et al. (2000).

[47] 10 banana dryers (100 kg/batch) and 2 rubber dryers (15,000 sheets/batch)
[48] For 770 Wp installation pumping 9,772 m^3/year and a 825 Wp battery charging station producing 2.66 kWh/day respectively
[49] For a banana dryer with 100 kg capacity

3.4 Renewable resources

The potential of renewable energy resources in Thailand is detailed below:

3.4.1 Solar

The annual average daily solar radiation in Thailand is about 18 to 19 MJ/m2 per day[50] (DEDE, 1999). The highest solar radiations are recorded in April and May with 20-24 MJ/m^2-day. Furthermore, the northeastern and northern regions receive about 2,200 to 2,900 hours of sunshine per year (6-8 sunshine-hours per day). The overall potential for PV power generation has been estimated at more than 5,000 MW (DEDE, 2003e). The potential for solar energy in Thailand is therefore very good. For the regional potential of solar energy, a solar map of the country made by DEDE, is given in Appendix 2, Figure 2-1.

3.4.2 Biomass

Biomass resources can be classified into four main categories, namely, agricultural wastes, wood and plantation, animal dung, garbage and wastewater. The recoverable energy potential (REP) of each of these different categories is shown in Table 14. In total, the energy potential from biomass as fuel amounts to about 1,076,567 TJ/yr to be used for heat production and about 2,179 Mm^3/year for exploitable biogas (Limjeerajarus et al., 2004).

Table 14: The energy potential from biomass in Thailand in 2000

Types	Biomass (kton)	Exploitable Biogas (Mm^3/year)	Recoverable Energy Potential (REP) (TJ/year)
Agricultural residue	42,494	-	604,821
Animal Dung	-	560	11,751
Municipal solid waste	7,324	1,184	112,047
Waste water	-	435	10,448
Feasible wood production from plantation	22,500	-	337,500
Total	**72,318**	**2,179**	**1,076,567**

Source: Limjeerajarus et al (2004)

More than half of the total REP, about 56.2%, could be recovered from agricultural residue. The potential for the ten main residues is shown in table 2-1 in appendix 2. The total potential for biomass power generation is estimated at 7,000MW (DEDE, 2003e).

3.4.3 Biodiesel

The total potential for biodiesel production in Thailand has not been reported. The main sources for biodiesel in Thailand are used vegetable oil, palm oil, coconut oil physic nut oil. The production of palm oil reached 4 million tons per year in 2003, whereas the production of coconut oil was of 1.4 million tons per year in 2003 (DEDE, 2004c). Physic nut, is seen as having a big potential for biodiesel production in the future. However, it is currently not widely cultivated in Thailand, but the government plans to promote its cultivation in the future[51]. This nut is seen as strategic to reduce Thailand's dependency towards fossil fuels.

3.4.4 Bioethanol

Four main sources of carbohydrate feed stocks, namely, sugarcane, sugar molasses, corn, and cassava root are technically suitable resources in Thailand for bioethanol production. However, the annual production of sugarcane (60 million tons) as compared to the sugar mill capacity (75 million tons/ year)

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[50] 5.0 to 5.3 kWh/m^2 per day

[51] thailand.prd.go.th/the_focus_view.php?id=900 (17 October 2005)

makes these resources inadequate. It is estimated that in the coming year the surplus of cassava could be used to generate two million litres of bioethanol per day (DEDE, 2004c). An average of 800,000 litres per day of ethanol could be produced from molasses in spite of the high demand for this material, both internationally and nationally, and of the seasonal production (three to four months per year) (Keawsompong et al. 2002).

3.4.5 Wind

Wind resources in Thailand are promising along the coasts of both the Andaman Sea and the Gulf of Thailand, but, are very low inland, especially in the northern region. In the two coastal areas, the lower and upper wind velocities vary within 6 to 10 km/hr and 9 to 17 km/hr, respectively. In contrast, in northern Thailand, the lower and upper wind velocities normally lie within 2-7 km/hr and 6-10 km/hr[52], respectively (DEDE, 1999).

At the country level, only 0.2 % of the total land area experiences good to excellent wind conditions[53]. Opportunities for village wind power are considerably more widespread than large wind turbines because small wind turbines or wind pumps are able to operate satisfactorily at lower wind speeds. Area of good to excellent wind sources for village power is in central Thailand (World Bank, 2001). The overall potential for power generation is estimated at 1,600 MW (DEDE, 2003e). The regional potential of wind energy is shown, in Appendix 2, Figure 2-2.

3.4.6 Small Hydro

The potential for power generation with small-hydro based technologies has been estimated at 700 MW, mainly in the northern part of the country (DEDE, 2003e).

3.4.7 Geothermal

More than 90 hot springs with surface temperatures ranging from 40°C to 100°C are scattered throughout the country as shown in Appendix 2, Figure 2-3 (Ramingwong et al., 2000). Most of them are located in northern and southern Thailand. However, these hot springs have low geothermal potentials due to low hot water flow rate and low water pressure. They have, therefore, been promoted as tourists attractions.

[52] Wind velocity given by DEDE was measured at 40 meters above ground in the predominant land cover with no obstructions.
[53] Defined as: wind velocity about 7-8 m/s at 65 m above ground level.

3.4.8 Summary

Table 15 summarises the renewable energy resources available in Thailand.

Table 15: Potential of renewable energy in Thailand

Resource	Unit	Country Average	
Solar			
Global radiation	MJ/m²-day	18-19[1]	18-19[1]
Sunshine-hours	hrs/year	2,200-2,900[1]	2,200-2,900[1]
Estimated potential for power generation	MW		> 5,000[7]
Biomass and Biogas			
Feasible wood production from plantation	TJ/year	337,500[4]	337,500[4]
Agricultural wastes	TJ/year	604,821[2]	604,821[2]
Animal manure	TJ/year	11,751[2]	11,751[2]
Municipal solid wastes	TJ/year	112,047[2]	112,047[2]
Waste water	TJ/year	10,448[2]	10,448[2]
Estimated potential for power generation	MW		7,000[7]
Biodiesel			
Palm Oil	Million tons/ year	3.256[3]	3.256[3]
Coconut Oil	Million tons/ year	1.400[3]	1.400[3]
Others	Million tons/ year	0.507[3]	0.507[3]
Bioethanol			
Sugarcane	Million tons/ year	60[5]	60[5]
Sugar molasses	Million tons/ year	3[5]	3[5]
Cassava roots	Million tons/ year	20[5]	20[5]
Wind			
lower wind velocity	km/hr	6-10[1]	6-10[1]
Upper wind velocity	km/hr	9-17[1]	9-17[1]
Estimated potential for power generation	MW		1,600[7]
Small Hydro			
Estimated potential for power generation	MW		700[7]
Geothermal			
Surface temperature	°C	40-100[6]	40-100[6]

Source: [1]DEDE (1999), [2]DEDE (2003d), [3]DEDE (2004c), [4]Sajjakulnukit et al. (2003) [5]Keawsompong et al (2002), [6]Ramingwong et al. (2000), [7] DEDE (2003e).

3.5 Case Studies

About 86.5% of the poor in Thailand live in rural areas. More specifically, the north-eastern part of the country has the highest number of poor people in both actual and relative value (3,770,685, i.e. 18.94% of the total population), and this exceeds half of the total number of the entire country. High numbers of impoverished people are also found in northern and southern Thailand. Based on the studies done by NSO (2003a), the average income per household in Thailand's rural areas in 2002 is about 222 US$/month.

The tables in section 3.2.3 show that the energy consumption as well as the monthly energy expenditures are much higher in the productive sector than in the other sectors in rural Thailand. The most energy consuming activities in the productive sector require heat for thermal processes (drying, backing, producing bricks, pottery, cooking, etc). The use of renewable energies in the productive sector can help to promote new income generating activities, to reduce monthly energy related costs or to produce higher quality goods which in the long run would assist in the alleviation of poverty throughout the country.

As briefly described in section 3.2.5, the possible RETs for productive uses in rural Thailand include: solar PV, solar thermal, biomass, biogas, geothermal, biofuel, wind and small or micro-hydro.

At the country level, the largest renewable resources are solar and biomass. Based on these two resources, three different RETs in three different regions have been selected as case studies:

- Solar Banana Drying in Northern Thailand
- Charcoal production with coconut shells in Central Thailand
- Biogas production in a pig farm in Northern Thailand.

These case studies have been chosen for their potential in alleviating poverty in the poorest region of Thailand, their replicability at the country level (see section 3.7) and the wide range of energy services they provide. As shown earlier, in the productive sector in rural Thailand, the most energy consuming activities require heat. The two first case studies (solar drying and charcoal production) are related to heat production. These two case studies are examples of RETs used to generate an extra-income. The solar banana-drying case study is an example of production quality improvement through RETs. The charcoal case study is an example of a new income generating activities developed thanks to RETs. The third case study, biogas generation from pig dung for electricity generation, illustrates an example of RETs used to reduce monthly energy expenditures.

Availability of data and accessibility of the sites where these technologies have been implemented were also important factors in the choice. Also, all the selected RETs are currently in use in Thailand.

3.5.1 Solar Banana Drying in Northern Thailand

The traditional method of drying bananas is by simply placing the fruits on a shelf under the sun. The advantage of this technology is its simplicity and low cost (not more than US$ 50 per dryer). The drying period is approximately seven days. The main drawbacks are that the fruits are not protected from insects or dust and production is impossible in case of rain. Furthermore, if rain starts when the bananas are still on the shelf, it is not uncommon that part of the production is damaged before the fruits can be removed (AIT, 2004a).

To improve the quality of the product and reduce losses during the production process, fruits must be covered and protected from the outside environment. To allow a continuous production during the rainy season, heat should be provided by an additional source[54].

Improved solar dryers are available in different sizes but the general concept remains the same for all the models. Air is heated up in solar collectors and is blown (either sucked by a fan or by natural convection) through the drying chamber where the bananas are placed. In case of absence of sun, air can be heated with biomass.

The solar collector is typically made from a black iron plate covered by a glass. The surveyed model[55] is about 50 cm X 150 cm X 300 cm. The hot air blows through the drying chamber sucked by a fan run

[54] For a good quality of the final product, hot air has to be supplied to the fruit without interruption.
[55] Developed by the School of Renewable Energy Technology (SERT), Naresuan University, Phitsanulok 65000, Thailand

by a 35 W_p solar PV panel. The drying chamber is about 180cm X 250cm X 136 cm and can contain up to 100 kg of bananas per batch. This solar dryer can dry the bananas in 5 days even during the rainy season. The School of Renewable Energy Technology (SERT) from Naresuan University in Phitsanulok, Northern Thailand, is currently testing 10 such banana solar dryers in the field (AIT, 2004a).

Because they are protected from insects and dust, the solar dried bananas are of better quality and can fetch a price up to 75% higher than the traditionally dried ones, i.e. at a price of 35 Baht/kg instead of 20 Baht/kg. Interestingly, there is a local market for this high quality production and even some interests from England to import it. The current production level is however too low to satisfy the foreign market (AIT, 2004a).

All the systems implemented by SERT have been given to the local people for free. The real cost of the system is about US$ 4,900[56] A building next to the dryer is needed to peel the bananas before drying and for the packaging once dried. Traditionally, these preliminary steps are made outside without any protection against dust and insects. If such building has to be built, it costs about US$ 20,000. Taking into consideration the cost of the dryer and the building and assuming a non-stop production throughout the year as well as the same cost of operation and maintenance for the two technologies (solar dryers and traditional ones), the payback period of banana solar dryers comes to about 6.5 years. However, assuming that the building already exists, the pay back period drops to less than 2 years[57].

3.5.2 Charcoal production with coconut shells in central Thailand

Charcoal is a very important fuel in rural Thailand. For the residential and business sectors, it is by far the most used fuel for cooking. The charcoal consumption in Thailand was estimated to be around 6.7 Mega tons in 1997 (Bhattarai, 1998).

Traditionally, charcoal in Thailand is made from mangrove and rubber trees. It is not uncommon that fresh wood is used for this purpose. The use of agricultural wastes to produce charcoal has therefore the double advantage of reducing cutting of fresh wood, as well as providing an alternative use of wastes thus avoiding transportation for their disposal[58] and preventing local pollution from their decomposition. Furthermore, charcoal production is an activity that generates income. Besides charcoal, different products can be made from coconut shells - fibres for blankets, natural fertilisers or boxes.

Thailand is among the largest producers of coconut in the world, with a total yearly production of 1,420 kilo tons in 2003 (FAO, 2004). This activity is extremely developed in central Thailand, where more than 93% of the production is concentrated (DOAE, 2003). The general method to produce charcoal from coconut is by burning shells of fully matured nuts in limited supply of air, sufficient for carbonisation only but not for complete combustion.
In the case of a demonstration project implemented by DEDE in Ratchaburi, Central Thailand, a 200 litre oil drum is used as kiln. The operating temperature is between 300-400°C and the yield is estimated at 20-22%. For the combustion to take place, 400 litres of diesel are consumed monthly (DEDE, 2004d). This particular production unit is linked to a coconut mill factory producing about 1,080 tons of shells per year. The production can be broken down as follows: about 5% of the total amount of shells is produced as charcoal, about 14% as fibres, about 13% as fertiliser and about 5% as boxes. The rest is either used as fuel for the different production processes requiring heat or is simply lost.

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[56] 200,000 Baht.
[57] (AIT, 2004a) and personal communication with SERT (August 3, 2004)
[58] If not used to produce charcoal, coconut shells would have to be shipped away for disposal. For a coconut factory dealing with 1000 tons of coconut per year this cost can be as much as US$ 1700 per year (AIT, 2004a)

The current market price of coconut shell by-products is given in table 16. Charcoal price is the highest of all by products at 5 Baht/kg.

Table 16: The costs of coconut shell by-products

Types of by-product	Charcoal	Fibers	Fertilizer	Boxes
Unit price (Baht/kg of by-product)	5	2	1.5	3.3
Production (tons/year)	54	151.2	140.4	54
Income Generation (Baht/year)	270,000	302,400	210,600	180,000

Source: DEDE (2004f)

The investment cost for the surveyed unit is US$ 12,000[59]. The operation and maintenance cost is around US$ 21,100 per year[60] whereas the annual income amounts to approximately US$ 25,250[61]. The amount saved yearly on waste disposal is about US$ 1,660. Based on the above figures, the payback period is estimated at about 3 years (DEDE, 2004d), (AIT, 2004a).

From a technological point of view, it seems that this demonstration unit can be improved. In India, a similar production process shows a yield of up to 30%[62]. In Sri Lanka, a brick kiln is reported to have a yield of 40% (SMIs in Asia, 2002) as compared to the surveyed unit in Thailand that has a yield of about 20-22%.

3.5.3 Biogas production in a pig farm in Northern Thailand

In Thailand, pig farms are the second most important livestock with about 7.761 million heads in 2002 (DEDE, 2003d). These farms generate around 879.95 million kg of dry dung per year, which can be used to produce 134.67 Mm^3 of biogas, corresponding to about 2,828 TJ of recoverable energy (DEDE, 2003d).

A pig farm located in Praves in the northern province of Chiang Rai provides an interesting case study. This medium scale farm has 805 pig heads. The farm possesses a biogas production unit: a channel digester with an Upflow Anaerobic Sludge Blanket (UASB) designed for 170 LU (Livestock Units) (BTC, 2004). The volume of the dome is 300 m^3 and the whole system costs about US$ 30,900[63]. The users benefited from a partial subsidy of 23% provided by EPPO and so paid US$ 23,800 for the system. The project benefited from technical support of the Biogas Technology Centre (BTC) of Chiang Mai University.

The biogas generated in the digester is mixed with diesel oil and this blend is used to fuel five modified diesel engines serving two main purposes. Three 11 hp engines are used to run the fans of the pig farm. The remaining two engines, with a capacity of 5 kW each, are used for power generation to satisfy the electric needs of the farm. Electricity is mainly needed to warm up the piglets, to run the water pumps, etc.

[59] 480,000 Baht.
[60] 862,000 Baht per year.
[61] 1,030,500 Baht per year.
[62] http://coconutboard.nic.in/charcoal.htm#source (July 15, 2004)
[63] 1.26 million Baht

Because of the use of biogas as fuel, the diesel oil consumption of the farm dropped by 62%, allowing savings of about 938 litres /month (BTC, 2004). During the time of the survey, the payback period was of about 6 years due to the low (subsidized) diesel price. However, considering the higher diesel in November 2005, the pay back period drops to less than 4 years[64].

Utilization of pig dung as energy source also provides some environmental benefits for both the local (land and water) and global (methane emissions) environment (Cohen, 2004), (Intarangsi and Kiatpakdee, 2000).

A summary of the three different case studies is presented in Table 17.

Table 17: Summary of the different case studies chosen

Case Studies	Solar Banana Drying	Charcoal from Coconut Shells	Biogas in a Pig Farm
Description			
Location	Phitsanulok, North	Rachaburi, Centre	Chang Rai, North
Requirement	Drying bananas	Production of Charcoal	Operating fans water pumps, etc
Technology	Solar Dryer	Drum Kiln	Channel Digester + UASB
Capacity/Scale	2.25 m^2 of solar collector 100 kg banana per batch	150 kg of charcoal/day	300 m^3 of biogas system
Investment Cost	US$ 4,900 with a capacity of 100 kg of bananas	US$ 12,000	US$ 30,900 (23,800 with subsidies)
% Covered with RETs	100%	100% of the heating needs	62% of diesel oil
Target Population	Small scale dry banana producers	Rural communities producing coconut shell	Pig farms
Advantages	Drying time reduced Quality of the product and market price increased All year around production Income generated at the village level	Usage of wastes to produce energy Income generated at the village level Local and global pollution reduced	Fossil fuel consumption reduced Energy related expenditures reduced Local and global pollution reduced
Disadvantages	High Investment cost	High Investment cost Production linked to the coconut factory Further technical development needed	High Investment cost Need of skilled operator
Representativeness			
Replicability	High	High	High
Potential population benefited	Rural areas with production of dried goods and a good solar potential	Rural areas with agricultural residue	Rural areas with livestock activity
Complexity	Medium Production of dried good	High Fuel for heat production	High Fuel heat and mechanical energy production

[64] These figures are calculated with the subsidized price of the digester.

3.6 Assessment of Capacities

The promotion of RETs in Thailand involves various stakeholders. Their respective roles and activities are presented below.

3.6.1 Government

The Royal Thai Government (RTG) is the key stakeholder in the field of RETs. Government energy related activities were reorganised in 2002 with the creation of a Ministry of Energy (MoE). Within this new ministry, two governmental agencies, Energy Policy and Planning Office (EPPO) and Department of Alternative Energy Development and Efficiency (DEDE) are involved with RETs. EPPO responds to the planning, enforcement and promotion of energy policies. On the other hand, implementation and evaluation of RETs based projects are under the responsibility of DEDE. As it is often put, EPPO works as the head and DEDE as the hands. The RTG has undertaken different national initiatives to promote sustainable energy. These are summarised below.

ENCON Act

The RTG adopted the Energy Conservation and Promotion (ENCON) Act and the subsequent ENCON Fund in April 1992. The capital and assets of this Fund are derived from the Petroleum Fund, levies imposed on petroleum product producers and importers and additional sources such as surcharges on power consumption, government subsidies, remittances from the private sector, etc. The ENCON Programme was launched in August 1994 to set guidelines, criteria, conditions and priorities for ENCON Fund allocation. This programme, whose main objective programme is the promotion of energy savings and use of renewable energy sources, comprised of 3 sub-programmes, namely compulsory sub-programme, voluntary sub-programme and complimentary sub-programme (Sajjakulnukit, 2002)[65].

Divided by 2 campaign

In 1996, EPPO[66] initiated a project of energy conservation promotion, "Divided by 2". This project, funded by the ENCON fund is still on going. Its main objective is to raise awareness on, and promote efficient and effective use of energy[67].

EGAT ACT and Net Metering

In 1992, the EGAT Act was amended, allowing private Independent Power Producers (IPPs) and Small Power Producers (SPPs) to sell their electricity to the grid (Shrestha et al., 2004). As of June 2005, 62 RETs based SPPs have been commissioned[68]. The total power installed amounts to 1,169.3 MW, out of which a total of 571 MW will be sold to the grid. Furthermore, 43 of these RETs based SPPs, representing a total capacity installed of 898.9 MW (388.30 MW sold to the grid) are currently producing power (EPPO, 2005).

In May 2002, Thailand's Cabinet passed a legislation requiring the country's electric utilities to allow small RETs producers (up to 1 MW per installation) to connect to the grid. Under this arrangement, generators that produce less than they consume in a monthly period pay the remaining balance at the retail tariff rate. For net excess production, producers are compensated at the "bulk supply tariff" which is about 80% of the retail rate (Greacen et al., 2003). As of June 2005, a total capacity of 9,157.5 kW[69]

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[65] More details on the ENCON programme can be found at http://www.eppo.go.th/encon/ (25 November 2005)
[66] At that time National Energy Policy Office (NEPO)
[67] http://www.eppo.go.th/e_saving/index.php (June 15, 2004)
[68] Excluding very small power producers (VSPPs)
[69] This capacity corresponds to the capacity actually connected to the grid. The overall total capacity of the very small power producers is more than 12,510.7 (the exact total is unknown, because not all the producers registered their total capacity with EPPO).

was registered under this agreement[70]. It has been acknowledged that policies like opening the grid to independent (small) power producers and net metering are a prerequisite for RETs development (Martinot, 2002).

Programmes to promote RETs

From the beginning of the eighties, the RTG has launched different programmes aiming at promoting RETs. PV Battery Charging Stations (BCS) and PV pumping systems have been implemented through two programmes handled by the Public Works Department (PWD, till 2002) and DEDE (DEDP till 2002). As a result, more than 3000 units of both BSC and PV pumping systems have been installed (see Sections 3.3 and 3.8 for details) (Green, 2004), (Sriuthaisiriwong, 2000). In the late eighties EPPO started a programme to subsidize biogas digesters for pig farms (see section 3.8 for details), (Intarangsi and Kiatpakdee, 2000). This programme is now part of the ENCON, programme voluntary sub-programme and will run till 2008. Other individual RETs projects are funded by EPPO under the voluntary sub-programme. Finally, improved cooking stoves (ICS) have also been promoted since the early eighties but ICS currently account for only 0.17% of the total stove usage in the domestic sector (Limmeechokchai and Chawana, 2005).

Strategic plan to promote new and renewable technology development

The RTG has the objective to raise RETs shares in the final fuel mix of the country from 0.5% in 2002 to 8% in 2011. This target corresponds to a total of 6,540 ktoe/year of renewable energy supply comprising of 1,060 ktoe/year from power producers using RETs[71], 3910 ktoe/year mainly from traditional biomass, agriculture wastes and industrial wastes and 1,570 ktoe/year from the increase of ethanol blending with gasoline and substitution of diesel by biodiesel. To reach this objective, the government is planning to implement several measures such as RPS (see below), support for R&D in the field of RETs, etc. (Lertsuridej 2004a).

Renewable Portfolio Standard (RPS)

To increase the share of renewable energy in power production, the RTG approved a policy called Renewable Portfolio Standard (RPS). In particular, this policy requires that 5% of new capacity addition in power generation should be based on RETs (Hongladarom, 2005), (Lertsuridej 2004b). As of November 2005, the government is still discussing the implementation measures of this policy

Table 18: Expected total installed capacity of RETs in year 2011

Types	Total Installed Capacity (MW)	Expected installed capacity (MW)[2]
Solar	5.5[3]	250
Wind	0.19[1]	100
Biomass and Biogas	480.6[3]	840
Biodiesel	22.43 (thousand litres/day)[4]	2,400 (thousand litres/day)[6, 72]
Bioethanol	640 (thousand litres/day)[6]	3,000 (thousand litres/day)[6, 73]
Micro hydro	2[3]	350 (Small hydro)
Geothermal	0.3[1]	-
IPP and SPP	374.5[5, 74]	860
Total	**863.09**	**2,400**

Source: [1]Limjeerajarus et al. (2004b), [2]Lertsuridej (2004a), [3]Pacudan (2003), [4]Bangchak (2004), [5]DEDE (2003a) and[6]DEDE (2004c).

[70] http://www.eppo.go.th/power/data/data-website.xls (31.10.2005)
[71] For a total installed capacity of 2400 MW (an addition of 1,840 MW compared to 2002)
[72] i.e. 3% of the total Diesel consumption or 720 million litres of biodiesel equivalent per year in 2011.
[73] To blend 10% with standard gasoline, in both gasoline 91 and 95, in 2011.
[74] Rice mill and sugar industries. However, the actual generated capacity is only 93.7 MW (DEDE, 2003a).

3.6.2 Public Utilities

Three government owned companies are responsible for the generation, transmission and distribution of electricity, namely Electricity Generating Authority of Thailand (EGAT), Metropolitan Electricity Authority (MEA) and Provincial Electricity Authority (PEA). PEA was established to standardize electricity distribution in all areas of Thailand except Bangkok metropolis and its suburbs (Samutprakan and Nonthaburi), which are under the responsibility of MEA. Furthermore, PEA and MEA are in charge of the distribution and the retail service functions in their respective areas. EGAT owns 59.1% (15,351 MW) of the total power generation installed capacity and is the only one responsible for transmission (Hongladarom, 2005). There is, as of October 2005, no regulatory agency for the power sector.

EGAT still remains a government owned company as of November 2005, but its status is subject to intensive discussions and debates. The privatisation plan of the government is currently strongly opposed by EGAT employees and consumers protection groups. The opponents fear a rise of electricity tariffs and a decrease of services once the utility is privatised in the absence of a strong regulatory body.

EGAT and PEA have implemented dozens of RETs based projects, especially in rural Thailand. Two examples of their joint efforts to promote RETs are the 300 kW geothermal power plant in Northern Thailand (Chiang Mai Province) and PV-wind hybrid power plant in Southern Thailand (Phuket Province). On different occasions, EGAT has also cooperated with EPPO to invest in RETs based power plants. 500 kW_p-PV power plant in Northern Thailand is one example of their fruitful collaboration. Furthermore, PEA is currently funding a programme to install solar home systems (SHS) in off-grid areas. MEA has not yet played a significant role on RETs promotion and dissemination in Thailand.

3.6.3 Research and Development (R&D)

Thailand has several high-level research institutes very active in the field of energy in general and RETs in particular. One university has one RETs dedicated department, the School of Renewable Energy Technology, Naresuan University, in Phitsanulok (Northern Thailand). The Asian Institute of Technology carries out research on RETs, both from the technical and policy perspective within its Energy Field of Study part of the School of Environment, Resources and Development. Other universities carry out research on RETs in their different engineering departments.

Technology wise, R&D on RETs in Thailand can be summarised as follows[75]:

- Four main research centres are currently working on solar energy and according to the main actors involved in this field and their collaboration is good. The collaboration between Thai and overseas research institutes is also considered as good.
- The research on solar thermal technologies is carried out in three main research institutes. The collaboration between them is said to be excellent as is the collaboration with overseas research centres.
- Five research institutes are leading the research on biomass gasification. One NGO, Biomass One-Stop Clearing House Information Service (BOSCH), part of the Energy for Environment Foundation is very active in advocating the use of biomass and implementing biomass based projects.
- Two research centres carry out research on biogas.

[75] Personal communication with SERT director (August 24, 2004)

One objective of the ENCON programme is to promote R&D in the field of RETS and the ENCON Fund is available for R&D purposes. However, according to different stakeholders met during this study, R&D is an important barrier hindering the promotion of RETs in Thailand.

In 2001, Thailand dedicated 0.22% of its GDP to research and development. This is much less than the most of the developed countries (Sweden, Finland, Japan, Korea, United States all are above 2.5%) and less than half of the figure for the neighbouring Malaysia (0.48%). In the same year, 22.6% of the Thai budget for research and development was used for engineering and technologies[76]. The exact figure for RETs is not available.

3.6.4 Private Sector

According to Prasertsan and Sajjakulnukit (2005) and Green (2004), the lack of collaboration between the government and the private sector is a major barrier to RETs development in Thailand. However, it has to be pointed out that the government programmes to promote solar PV technologies (BCS, SHS, etc.) have been implemented in collaboration with private contractors. Technology wise, the status of the private sector is given in Section 3.3.

3.6.5 NGOs

Besides international organisations (Greenpeace, WWF, etc.), there are five Thai NGOs, which are active in the field of energy conservation and promotion of RETs in Thailand, namely Energy Conservation Center of Thailand (ECCT), Energy for Environment Foundation (E for E), Thailand Environment Institute (TEI) and Appropriate Technology Association (ATA), and Palang Thai.

Some initiatives from Thai NGOs, even if limited are noteworthy. For example, Palang Thai, in collaboration with international partners, launched the Border Green Energy Team (BGET). This project, among other activities, provides, on a regular basis, training on operation and maintenance of SHS in remote areas[77].

All the NGOs working in the field of energy conservation and RETs promotion are networking with each other. In addition, NGOs sometimes work as government's consultants on energy conservation and RET promotion matters. EPPO occasionally hires these NGOs to draft policies and do some research on particular topics. However, NGOs' influence in the decision-making process is said to be rather limited.

3.6.6 Users

As pointed out by Prasertsan and Sajjakulnukit (2005) and reported by the different stakeholders met during this study, there is a serious lack of awareness about RETs by the potential users in Thailand. RETs are poorly advertised and are not an obvious choice for customers using conventional energy sources. Also, there is no national campaign to sensitize potential users to the benefits of RETs (Sajjakulnukit, 2002). The current campaign, "Divided by two", promotes energy conservation, and is not focused on RETs.

Various studies[78] have shown that in Thailand potential users are more sensitive to financial issues than to environmental ones. Examples of increased income generation resulting from RETs utilisation have to be well documented and advertised, it is unlikely that they will be widely accepted and used.

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[76] http://www.nrct.net/eng/ (4 November 2004)
[77] http://www.palangthai.org/en/bget (11 November 2005)
[78] In particular (Intarangsi et al., 2000)

Moreover, users sometimes see RETs as old-fashioned, especially when the grid is available. Several micro-hydro power plants have stopped being used when the grid became available in their area (AIT 2004a and 2004c), (Greacen, 2004).

In some cases, errors made by RETs project implementers have contributed to give a bad name to these technologies. They are now sometimes mistrusted (Green, 2004).

3.7 Renewable Energies Niches

The case studies of RETs for productive uses described in the section 3.5 can be extrapolated to other activities and to other regions in Thailand. The concept of promising technologies for a specific region is called a niche. This section presents three niches of RETs for productive uses. The main problems relative to each technology are also discussed. The three niches are summarised in Table 22 at the end of the section.

3.7.1 Solar Drying

Solar dryers can be used to dry different agricultural products: rubber, rice, chillies, etc. International experiences with solar dryers are widely reported in the literature[79]. Table 19 presents examples of agricultural products that could be dried in Thailand, as well as the market value of the dried products, with both traditional and solar dryers (when available).

From a regional point of view, most of the rice production comes from the poor region of North-Eastern (38.4%) and Northern Thailand (29.3%). 88.4% of rubber comes from the South of the country, while the remaining comes from Central Thailand. The variety of banana that is usually dried, called "Nam Wa", is produced mainly in Western and Northern Thailand (54.6% and 31.1% respectively) (DoAE, 2003). Farmers from the poorest regions of Thailand (North-East and North) could therefore directly benefit from the additional income brought by the solar drying technology.

Table 19: Potential agricultural production for solar dryers

Types	Production (kTons/year)	Original Price	Price with Conventional Drying	Price with Solar Drying	Increased Value with Solar Drying[80]
Rice	35,.800[1]	4,526 Baht/Kwien[81] (25% of moisture content)[1]	5,243 Baht/Kwien (5% of moisture content)[1]	-	-
Rubber	2.,900[1]	46.90 Baht/kg[3]	48.67 Baht/kg[3]	49.67-50.17 Baht/kg[3]	71-107 Million US$/year
Banana	9.6[1,82]	4.09 Baht/kg[1]	8.62 Baht/kg[2]	15.08 Baht/kg[2]	1.5 Million US$/year

Source: [1]DOAE (2003), [2]AIT (2004a) and [3,83]

The investment required for improved solar dryers is high for farmers. For example, an individual 100 kg/batch banana dryer costs about US$ 4,900 while a community 15,000 sheets/batch rubber dryer is about US$ 23,000. An example of the latter is currently used by a community of 119

[79] In particular, (Soponronnarit, 1995) and http://www5.gtz.de/gate/techinfo/techbriefs/E014E_2002.pdf (December 9, 2004)
[80] As compared with traditional drying
[81] 1 Kwien is equal to 1,600 kg approximately. This price is price of normal-quality rice.
[82] For "Nam Wa" bananas
[83] And personal contacts with a responsible of a rubber solar dryer project (July 29, 2004)

households in the South of Thailand, making the investment at about US$ 195 per household. This is high compared to the average monthly income per household in rural Thailand (US$ 222). However, the payback period is between 2 and 5 years for banana dryers, and about 4 years for rubber.

AIT developed a series of hybrid solar-biomass dryers. These dryers are being implemented on a commercial basis in the Philippines and diffused in Nepal and Cambodia. The commercial applications in the Philippines gave promising results especially for pineapples and mangoes. The quality of the dried products suits the export market and the pay-back periods for the different types of dryers are reported to be between 1 and 2.5 years (RERIC, 2002). The current project does not include diffusion of this technology in Thailand, but the designs of these different dryers have been distributed to Thai stakeholders during an international workshop held at AIT in October 2004.

The improved dryers can be built with locally available material and technologies. The construction of the solar collectors requires certain skills that can help to develop the capacity of the local labour. The utilisation of solar dryers is a technical improvement compared to the traditional method and it can be assumed that it will not be seen as obsolete in the coming years. The size of the dryer can be easily adapted to the needs, therefore insuring that this technology can satisfy future needs.

Solar dryers do not satisfy a basic need as such, but provide increased income and produce better quality goods. From a technical point of view, this technology is very effective as it allows addressing the main drawbacks of the traditional way of drying (protection against insect and dust and possibility of production during the rainy season, etc.). Users have greater freedom of action with these improved dryers, since it allows production throughout the year with an additional fuel (biomass). Improved solar dryers allow a diversification of the activity since different products can be dried. Furthermore, once put in the dryer the production does not require much attention, and so frees the owner for other activities while goods are being dried. From the environmental point of view, the impact can be slightly negative due to the combustion of biomass in the rainy season. However, quantities used are usually very small and dead wood can be burned to limit pressure on local forests.

The social acceptance of this technology seems good. All the users interviewed were satisfied[84]. Only the price is prohibitive for individual farmers if they do not have access to financing schemes. Technologically speaking, the improved solar banana dryers are very simple and local producers have no problems with them. However, new models have to be developed to be suitable for a variety of products. Aspects related to commercialisation, training and maintenance also need to be further studied.

3.7.2 Charcoal production with biomass residue

The agriculture sector is the base of the Thai economy and it accounts for about 60% of the labour force (Srisovanna, 2004). This activity generates a lot of residue, which can be used as a renewable resource for energy production. Biomass from agriculture wastes has therefore a high potential to be used as renewable energy sources. This potential has been estimated for the 10 main residues at about 60.933 million tons per year (Sajjakulnukit and Verapong, 2003). Details on the kinds and quantities of residue available in Thailand are given in table 2-3 in Appendix 2. The main agricultural residue consists of paddy husk and straw, bagasse from sugarcane, palm oil waste, wood waste etc. To some extent, these residues are currently already used as fuel. For example, 17 million tons of rice husk and sugar cane bagasse are combusted for steam generation in rice mills and sugar factories respectively (Amatayakul and Greacen, 2002). This steam is then used for electricity production as well as a heat source in the production process. Other residue is used as raw material for other purposes but their

[84] AIT (2004a), and personal contacts with a rubber solar dryer user (July 29, 2004).

proportion is marginal. After deduction of the current usage, the available potential of biomass from agriculture residue was more than 40 million tons in 2002 (Sajjakulnukit and Verapong, 2003).

The charcoal consumption in Thailand has been estimated at 6.7 Mega tons in 1997 (Bhattarai, 1998). Residue that can be used in charcoal production include paddy husks, bagasse, sugar cane leaves and coconut shells. Examples of projects using agricultural wastes to produce charcoal are widespread around the world and include bagasse (Kenya)[85], sugarcane leaves (India)[86], coconut shells (Thailand, India)[87]. Furthermore, several examples of rice husk charcoal utilisation as organic fertilisers are also found in the literature[88]. The availability of these four residues in Thailand is shown by region in Table 20.

Table 20: Potential for charcoal production by region (1998)

	Paddy Husk (kton/year)	Bagasse (kton/year)	Sugar cane leaves (ktons/year)	Coconut Shell (kton/year)
Northern	683	715	4,112	0
Central	599	1,020	5,872	81
North-Eastern	903	1,136	6,538	0
Southern	101	0	0	5
Greater Bangkok	122	47	271	0
Total	**2,409**	**2,918**	**16,793**	**86**

Source: Sajjakulnukit (2003) and DOAE (2003)

The potential of agricultural wastes for charcoal production is therefore very important, especially in the poor region of Northern and North-Eastern Thailand.

In Thailand, the charcoal yield production varies from 19 to 36 % depending on the kiln used[89].

Depending on the size of the charcoal production unit, the investment might be not affordable for farmers. The example given in section 3.5 is US$ 12,000 for a unit producing 135 kg of charcoal per day. However, this unit was designed to produce other by-products from coconut shells (fibres, blankets, etc). The payback period for this example is about 3 years, making such a project attractive for investors. In India, a brick kiln to carbonise sugar cane leaves is reported to cost about US$ 470 for a daily production of 100kg of charcoal[90].

As described in section 3.2, charcoal in rural Thailand remains the most preferred fuel in the residential and business sector for cooking. In the industrial sector, it is also widely used to provide heat for different production processes. Producing charcoal is therefore a flexible activity as the fuel will be used to satisfy different needs. There will be a market for charcoal from residue if it can be sold at a lower price than traditional charcoal from wood.

The resilience of rural livelihoods is not affected by this technology, because the raw material used is a waste that would not be utilised otherwise. In addition, local production of charcoal offers a good

[85] 5 tons/day commercial plant (Karstad, 2000).
[86] 15 tons/year demonstration units http://members.tripod.com/ARTI_India/ (July 22, 2004).
[87] 1 ton/day commercial plant http://coconutboard.nic.in/charcoal.htm (July 15, 2004)
[88] Among which, FADINAP (2004) and FFTC (2001).
[89] Personal communication with Thai biomass specialist (July 27, 2004)
[90] http://www.ashdenawards.org/winners_02_01.html (July 22, 2004)

opportunity for employment in rural areas. Furthermore, it gives a chance to the local communities to diversify their livelihood strategies.

Producing charcoal from agricultural wastes has a good overall impact on the local environment and allows addressing deforestation issues. However, special care has to be taken during the carbonization process, as the volatile substances are harmful to humans.

The technology of producing charcoal from all different agricultural wastes, especially rice husk and sugarcane leaves is not yet fully mature in Thailand. Further research and development efforts are also needed to ensure higher efficiency and lower costs. As explained in section 3.5, the yield of the demonstration unit is lower than other similar units in other contexts (20% against 30% in India).

Another problem that can hamper the development of charcoal from residue production units is the current biomass market. As pointed out by Prasertsan and Sajjakulnukit (2005) and Sajjakulnukit and Verapong, (2003) biomass producers and users are often not well linked together. The former is not aware of the energetic potential of their residue while the latter are not aware of residue availability. Furthermore, as pointed by different stakeholders[91], prices highly fluctuate, depending on seasons, demand, etc. Examples show that once residue starts to be used for energy purposes, their price drastically increases, thus hindering the long- term financial viability of the residue based projects.

3.7.3 Biogas production in livestock farms

Livestock farms are distributed throughout Thailand and they generate about 2.89 million tons of dry animal manure each year (DEDE, 2003d). This amount could be used to produce around 560 Mm^3/yr of biogas, equivalent to 11,751 TJ of recovery energy potential (REP). Table 21 presents the theoretical biogas yield and REP from different livestock activities.

Table 21: Potential of biogas production from different livestock activities

Animal Dung	Total (thousand heads)	Manure Production (kg/head/day)	Biogas yield (Mm^3/yr)	REP (TJ)
Cattle	5,208	5.6	239	5,018
Pig	7,761	1.1	135	2,828
Buffalo	1,702	8.0	97	2,036
Chicken	172,247	0.03	82	1,713
Others	N/A	N/A	7	156
Total	**N/A**	**N/A**	**560**	**11,751**

Source: DEDE (2003d)

The main barrier to diffusion of biogas digesters in feedstock farms in rural Thailand is the high upfront cost. For example, as presented in section 3.5, a 300 m^3 dome gasifier designed for 170 livestock units in a pig farm costs about US$ 30,000 (DEDE, 2004b). However, biogas digesters are meant for medium to large scale farms that have to be seen as enterprises with higher investment capacities than small-scale farmers. Furthermore, this technology is partly subsidised by EPPO (between 20 and 30%) in the framework of the ENCON Programme. This subsidy will be available till 2008. For medium scale farms using the gas in diesel engines, the pay back period varies from 4 to 6 years, depending on the retail price of the substitute diesel and the load of the engines.

The gas produced can be used for different purposes, such as providing heat for cooking or drying or it can be used as fuel for an engine that can run a water pump or a generator. This technology can

[91] AIT (2004c) and personal interviews

therefore help the development of income generating activities. In Thailand, in at least one site, biogas is used to fire pottery and to pasteurize mushrooms (AIT, 2004a).

From an environmental point of view, the impact of this technology is very positive; If not used, the dung would contribute to both local pollution (land and water) and global warming (methane emissions) (Cohen, 2004), (Intarangsi and Kiatpakdee, 2000).

The technological capability of this niche is good because the fuel (animal dung) is readily available on site and does not require a specific distribution network. However, (Intarangsi et al. 2000) points out that trained technicians have to be on site to ensure a proper use of the technology. This is still one drawback of the technology.

A comparative assessment of the three selected niches according to different indicators is presented in Table 22.

Table 22: Assessment of the niches for the three selected RETs

Criteria / Potential Niches	Solar Drying	Agriculture residue for Charcoal production	Biogas from livestock farms
Representativeness			
Replicability	High	Very High	High
Potential population benefited	Rural areas with production of dried goods (Rice (North-East and North), Banana (Central and North), Rubber (South)	Rural areas with agricultural wastes (North, North-East, Central)	Rural areas with livestock activity and animal dung
Complexity	Medium Drying goods	Good Fuel for cooking and drying both in the industrial and residential sector and raw material for industries	Good Fuel for cooking and drying both in the industrial and residential sector and raw material for industries
Suitability/Viability/Sustainability			
Affordability	Medium	Medium	Medium
Effectiveness	High	High	High
Risk of obsolescence	Low	Medium	Low
Flexibility	Medium	High	High
Technological capability	High	Medium	High
Suitability and urgency	Medium	High	Medium
Resilience	High	High	High
Adaptability	High	Medium	Medium
Environmental impacts	Low	Low	Low
Social acceptance	Very High	Very High	Medium
CD requirements	Medium	High	High
Income generation	High	High	Medium

3.8 Assessment of other experiences

During the last 25 years, the Thai government, through several agencies, implemented different programmes to promote RETs. For example, in the eighties, one PV water pumping programme in north-eastern Thailand and a rural electrification programme using Battery Charging Stations (BCS) in northern Thailand started. Both programmes were implemented by two agencies namely, Public Works Department (PWD) and Department of Energy Development and Promotion (DEDP) till 2002. From 2002 onwards, these two programmes were shifted under the supervision of the Department of Alternative Energy Development and Efficiency (DEDE), part of the newly created Ministry of Energy.

In the beginning of the 90s, The National Energy Policy Office (NEPO) started to fund the Biogas Advisory Unit (BAU) of Chiang Mai University (CMU), to disseminate biogas reactors (Intarangsi et al., 2000). BAU was initiated during an earlier project supported by the German Technical Cooperation (GTZ) in 1987.

This section details these three RETs programmes. The two programmes to diffuse and implement PV technologies are unique in the developing world, in the sense that they are completely state-funded (Green, 2004). As Lew (1998) points out: "As a result of three government programmes, Thailand now has more photovoltaic battery charging stations (over 1,000 installations) and probably more PV water pumping stations than any other country." The biogas digester diffusion programme is more recent and was developed on a partial subsidy basis, thus offering another perspective for the analysis.

3.8.1 Photovoltaic Battery Charging Stations in Northern Thailand

Photovoltaic Battery Charging Stations (PV BCS) are small power plants run by PV modules designed to charge batteries. The recharged batteries are mainly used by villagers for residential purposes such as lighting, entertainment (radio, TV), convenience (fans), etc. They can also be used for productive uses, extending working hours of shops and workshops, for example.

In Thailand PV BCS have been implemented since 1982 in remote villages located in grid-inaccessible areas. The national programme was initiated through the country's fifth Five-Year Plan (1982-1986). At the end of 2003, 1,660 installations with a total capacity of 1.9 MW_p were installed by PWD[92] and DEDP[93] (Green, 2004). From 2002, the programme is managed by DEDE. The overall cost of this programme over the last 15 years is estimated at US$ 11 million (Green, 2004).

Field surveys realised between 1988 and 2001 in a total of 60 villages in Northern Thailand[94] and reported in Green (2004) and Sriuthaisiriwong and Kumar (2001) allow analysing the main successes and failures of this government programme.

The most positive outcome of the BCS mentioned by the villagers is:

- The majority of the people interviewed (68.3%) rated their quality of life as "better" or "much better" than before the PV BCS. The main advantages quoted are the better quality of lighting and the access to new services such as radio or television (Sriuthaisiriwong and Kumar, 2001).

Similarly, Green (2004) reports that the improvements in the villagers' standard of living include improved light quality for performing household tasks, convenience of the electricity supply and an increase of household safety.

On the other hand, the main problems noticed during the survey can be summarised as follows:

- More than 60% of all systems surveyed showed some technical problems (mainly due to lack of appropriate maintenance and improper use of the technology). In more than 10% of the

[92] 1,400 systems for a total installed capacity of 1.1 MW_p (Green, 2004).
[93] 260 systems for a total installed capacity of 0.8 MW_p (Green, 2004).
[94] 50 villages have been surveyed in (Green, 2004) and ten in (Sriuthaisiriwong and Kumar, 2001).

surveyed villages, the systems were completely broken whereas in more than 50% of the villages the system had some damage affecting the overall efficiency of the system. In addition, more than 30% of the surveyed solar panels were shaded (Green, 2004).

- Despite claims of bi-yearly maintenance visits, villagers reported that government staff rarely, if ever, came to check the stations (Green, 2004).
- Monthly fees collected for a central fund to maintain the installations have been implemented only in DEDP installed BCS. In all the villages surveyed, none of this money had been completely paid (Green, 2004).
- The users have a very low knowledge about their systems (only 10% of the villagers in PWD BCS reported that they had a good knowledge). Lack of proper training by the implementing agencies and communication problems[95] were reported as the main barrier to proper utilisation (Green, 2004).
- All the surveyed villages had the same installed capacity of PV BCS (825 W_p for DEDE and 3 kW_p for PWD). This does not match the population's needs. This leads to either over or under-use of the system, resulting in inefficiencies (Sriuthaisiriwong and Kumar, 2001).
- Although deep-cycle batteries are the most appropriate for PV systems, shallow-discharge batteries such as car/truck or motorcycle batteries are preferred by the users, for reasons of cost and availability in rural areas. These kinds of batteries have a lower storage capacity (Green, 2004), (Sriuthaisiriwong and Kumar, 2001).
- It was observed that batteries (5-15 kg) were often transported over distances of about 5 km (Sriuthaisiriwong and Kumar, 2001).

3.8.2 Photovoltaic Water Pumping Systems

Since 1988, PV water pumping systems have been installed throughout Thailand and the current total capacity installed is about 954 kW_p (Wongsapai, 2004c). Out of this total power installed, 740.5 kW_p have been implemented mainly in North-eastern Thailand by PWD through the 7^{th} and 8^{th} Five Year plans (1992-2001). These systems are mainly used to provide sanitary water. The general model followed for this installation is a pump powered by PV modules pumping water from a pond to a tank from where villagers get their water. In some cases, a piping system has been installed to deliver the water directly to the users.

Sriuthaisiriwong (2000) presents the results of a survey of seventeen systems (all installed between 1988 and 1998) in North-eastern and central Thailand in 2000. Out of these seventeen systems, eleven were in working condition. However, in two sites the systems were still in working condition but were not used because of social conflicts in the village.

The most positive points highlighted are:

- 83 % of the users are highly satisfied or satisfied by the PV water pump. It turns out that the main reason for the satisfaction is the fact that the service is free.
- In all of the surveyed sites, solar modules themselves are always working, and so they are never the reason of the technical failure.

On the other hand, the main problems are reported as follows:

- Almost 45% of all the systems installed in Thailand between 1990 and 1997 failed.
- The weak parts of the surveyed systems are the pump and the inverter. The failures are often due to a lack of maintenance (dead insects in the inverter, pump's filters clogged). Moreover, these elements are imported and spare parts are often not readily available.

[95] Most of the villages where the BCS have been implemented are composed of ethnic minorities having their own languages

- The system as a whole seems badly designed, with the pump generally oversized, leading to a low efficiency of the installation (1.8 to 2.9%).
- The lack of organization of the water supply is a major drawback leading to abuse of the people living near the tank and to the discontentment of the people living far from it. This can lead to significant social tensions within the community.

3.8.3 Biogas

The Thai Biogas Programme initiated in 1988 by Chiang Mai University (CMU) and the Department of Agricultural Extension (DoAE) with financial and technical help from the German Technical Cooperation, pursued 2 main objectives: promoting the use of locally available energy resources and addressing environmental problems caused by livestock farms. This first programme lasted seven years and was considered a success (Intarangsi and Kiatpakdee, 2000). After the end of the programme in 1995, facing public confidence in the technology, CMU sought support from EPPO[96]. A new programme was then launched, “The Biogas Dissemination Programme in Livestock Farms: Medium and Large Size Farms.” This project was divided into 3 phases:

Phase I (Pilot Phase) 1995-1997: 10,000 m^3 of digesters implemented.
Phase II (Demonstration Phase) 1997-2002: 40,000 m^3 of digesters implemented.
Phase III (Full Scale Expansion Phase) 2001-2008: 150,000 m^3 of digesters implemented.

After Phase 3, it is expected that biogas plants will be implemented in about 48 % of the large farms in the country, treating wastes from about one million pigs.

The gas produced in the digester is mainly used to generate electricity (via generator sets) and heat to satisfy the needs of the farm. (Intarangsi and Kiatpakdee, 2000) notes three key success factors of this programme:

- Subsidy from EPPO for part of the construction cost (up to 38 % of the biogas production part) and promotion of low cost loan as well as loan facilitation.
- Linking the subsidy to the condition of complete construction according to CMU design and specification.
- Securing a guarantee from the owners of the plants for proper operation and maintenance and monitoring the system for a full year after implementation.

The main lessons learned from this programme are:

- The technology that permits conversion of animal dung into useful energy is available and economically profitable. For large farms, the payback period is about 5 years, as long as the gas is fully utilised.
- Economic return of the project is a better attraction to farmers than treatment of wastes.
- Some form of incentive is necessary to help quicker and wider adoption of the system.
- Enforcement of pollution laws alone is not enough to promote biogas technology.
- The system should be delivered in a complete package instead of separate modules.
- The system needs proper operation and maintenance, as all past failures indicated. It is important that the owner knows how the system works.
- Moving parts or mechanical equipment should be avoided or minimized to reduce operation and maintenance costs and to ensure easier operation of the plant.
- A more tolerant system needs to be developed. It is possible for a large farm to hire a trained technician to operate and maintain the system, but not for medium size farms, which form the

[96] NEPO at that time.

largest part of the livestock population. The technology should be developed towards a cheaper and tolerant system rather than a sophisticated and sensitive one.

Amatayakul and Greacen (2002) observe that most of the pig farms use modified diesel engines for electricity generation. The technology has low upfront costs but requires frequent maintenance and a major overhaul every 3-5 years due to corrosion caused by the presence of hydrogen sulphide in the biogas. Although more efficient and longer-lasting gas turbine technologies are available they have to be imported and cost 3-5 times more, and so their adoption in Thailand is still limited. Furthermore, the technical problems faced by small scale biogas had not yet been solved by October 2005[97].

3.9 Overall assessment and identification of barriers

The assessment of different RETs options for productive uses shows that economically viable and technically feasible options exist. In addition, the potential for RETs in Thailand is also very high.

However, a number of barriers that hinder the use of RETs in rural Thailand for productive uses need to be addressed by adequate policies. This section summarises the key barriers that exist to RETs promotion and utilisation. The scope of this section is voluntarily broad. Indeed, RETs have to be promoted by general policies that cannot be restricted to one sector of activity or one group of population.

A systematic analysis of these barriers and suggested policies to overcome them is presented in the next chapter.

3.9.1 Barriers to RETs promotion

Barriers affecting the promotion of RETs can be classified into four main categories: financial, informational, technical, and institutional. These are summarised in the sub-sections below. The barriers are discussed technology wise.

Financial barriers

Like in most other countries, financial factors constitute one of the key barriers hampering the diffusion and promotion of RETs in Thailand. Compared to other fossil fuel based technologies, the capital cost of RETs is high. Furthermore, Thailand, unlike many other developing countries, has very few off-grid areas, for the grid has been thoroughly extended during the last decades of the 20th century.

a) Solar PV

Distributors of solar modules exist in Thailand, though PV cells themselves are imported and taxed at a rate of 35% (Wongsapai, 2004b), (Green, 2004).

The production cost of electricity has been estimated at 1.13 US$/kWh (Sriuthaisiriwong 2000) for PV BCS and between 0.34 to 0.50 US$/kWh for SHS (Limjeerajarus et al. 2004b). On the other hand, the average price of grid based electricity in rural areas was about 0.058US$/kWh for the industrial sector and 0.059 US$/kWh for the residential sector in 2003 (DEDE, 2004e).

The cost of a PV BCS of 3 kW intended to serve fifty to eighty households have been estimated at US$ 18,400 (Green, 2004), i.e. from US$ 230 to 370 per household. This figure when compared with the average income per household in rural areas, US$ 222 (NSO, 2003a) is high. However, the government has invested extensively in the past decades to extend the grid to rural areas. It therefore could be assumed that the cost of electrification of the remaining off-grid areas could be borne by the

[97] Personal communication with Chang Mai University (31 October 2005).

government and not the communities. Furthermore, the cost of grid extension should be compared with possible alternative decentralised options. For example, in the case of a 50 household village, with a potential for micro-hydro, located four kilometres or more from the grid, it is cheaper to build a micro hydro power plant than to extend the grid.

b) Solar Thermal-Drying

A solar dryer costs approximately US$ 4,900[98], whereas a traditional dryer costs not more than US$ 50. As such, even if the solar dryer produces higher quality products, with a pay back period between two to six years, the initial investment cost is high for Thai farmers considering the average income in rural areas mentioned above.

c) Biomass

The large number of different biomass based technologies and the fluctuating price of the fuel used, makes it difficult to give realistic numbers for their investment and production costs. However, as pointed out by Sajjakulnukit (2002): “Most RETs, including biomass have high capital investment compared with conventional energy technologies. This is the main reason that most biomass energy technologies are not financially feasible in the existing competitive market.” Furthermore, biomass based projects, as many RETs projects, are considered as highly risky by financers. Biomass project developers therefore face difficulties to get access to finance (Prasertsan and Sajjakulnukit 2005).

c) Wind

The production cost of electricity from wind sources has been estimated in the range of 0.105 and 0.130 US$/kWh (Limjeerajarus et al. 2004b).

Information barriers

As pointed out by Prasertsan and Sajjakulnukit (2005) and observed by different stakeholders, there is a serious lack of awareness about RETs that hinders their development in Thailand. RETs are not well advertised and are not an obvious choice for users. As compared to energy conservation, there is currently no national campaign to sensitize potential users to the benefits of RETs (Sajjakulnukit, 2002).

Thailand Energy and Environment Network (TEENET)[99] and Regional Energy Resources and Information Centre (RERIC)[100] at AIT, are active in diffusing information and reports in the field of energy and environment, RETs in particular, but their publications are intended for experts and do not reach the average public.

Various studies[101] have shown that potential users are more sensitive to financial issues than to environmental ones, so unless examples of income generation or cost reduction with the use of RETs are well documented and diffused; it is unlikely that they will be widely accepted and used.

a) Solar PV

Although national programmes to diffuse RETs have been implemented for more than 15 years, these have been focused on residential uses with no particular emphasis on income generating activities. For solar PV technologies, there is a lack of “success stories” that may help to give a good name to these technologies (Green, 2004).

[98] Banana Solar Dryer with capacity of 100 kg per batch (AIT, 2004a), personal communication with SERT.
[99] http://www.teenet.info/
[100] http://www.serd.ait.ac.th/reric/
[101] In particular Intarangsi et al. (2000)

b) Solar Drying
The fact that only few research centres work on this topic might hamper the diffusion of information, and, in turn, the promotion of this promising technology. Furthermore, only a limited number of solar dryers are currently used in the field. This makes it difficult for farmers to get to know about this technology.

c) Biomass
For biomass based technologies, Prasertsan and Sajjakulnukit (2005) and Amatayakul and Greacen (2002) point out that there is a lack of data and information on biomass availability and characteristics. To be used as a fuel, biomass should be classified according to its properties.

Furthermore, despite the large biomass potential in Thailand, the different actors (producers and users) are not well linked. It appears that, on the one hand producers do not know what to do with their residue and very often transport them away to dump them away, while on the other, potential biomass users are not aware of its availability (Sajjakulnukit and Verapong, 2003), (AIT, 2004a).

As it is the case for solar drying, there are currently a limited number of biomass based RETs projects. The absence of successful example of such project does not build the confidence of the users and the investors Prasertsan and Sajjakulnukit (2005).

d) Micro-Hydro
RETs are also seen as old-fashioned by users who prefer to get power from the grid (when available) rather than decentralized power plants. In many cases, micro-hydro systems stopped to be used when the grid electricity became available (Greacen, 2004).

e) Biofuels
Car manufacturers in Thailand do not guarantee that biofuels can be used without harm to engines, even if mixed with conventional fossil fuels. It is unlikely that a potential user will buy a product without specifications or performance insurance (Wongsapai, 2004c).

Technical barriers
Though some RETs are locally produced and technically mature (solar water heaters, micro-hydro turbines, wind turbines, etc.), other RETs suffer from lack of research and development that hampers their diffusion.

In India, the fact that all the different components of PV water pumping systems are locally produced is one of the key factor of success of the large PV water pumping programmes in different states (Punjab, Haryana, Rajasthan and Uttar Pradesh) (van den Akker and Lamba, 2002).

a) Biogas digesters
Existing biogas digesters remain overly sensitive to the quality of organic matter utilised (Intarangsi and Kiatpakdee, 2000). Furthermore, the gas is generally used in modified diesel engines for electricity generation. The technology requires frequent maintenance and a major overhaul every 3-5 years due to corrosion problems that are caused by the presence of hydrogen sulphide in the biogas (Amatayakul and Greacen, 2002).

b) Biomass
For biomass-based technologies, there is lack of standards for assessment of performance that hinders their development and commercialisation (Prasertsan and Sajjakulnukit 2005). Moreover, charcoal production from different kinds of residue (rice husk, straw, etc.) is not yet fully mature. Other

technologies, such as small-scale biomass gasification for example, do not exist in Thailand. To make the best use of Thailand's considerable biomass resources, this technology could be transferred from other countries (India, China, etc.).

Furthermore, the fact that biomass based technologies do not have a long history in the market and, that it is, in general difficult to make a profit out of it is pointed out to explain the lack of adequate experts in this field (Prasertsan and Sajjakulnukit 2005).

Institutional Barriers

The Thai government has put a lot of effort to promote RETs over the past 15 years, especially PV based technologies. Furthermore, it has reorganised its energy ministry in 2002 and created an agency dedicated to RETs, DEDE. At the country level, the necessity of having one only agency centralising RETs promotion and implementation has been acknowledged as a key factor to insure RETs project successes[102] (Bhattacharya, 2002). However, institutional barriers still remain.

There are different government agencies working with RETs and the coordination among them is often poor. There is also a lack of incentive from the government to work with the power sector (Prasertsan and Sajjakulnukit 2005).

a) Solar PV

Until 2002, PV BCS and PV pumping systems were implemented by two agencies, namely, the Development and Promotion (DEDP) and the Ministry of Interior's Public Work Department (PWD). The latter agency was responsible for rural infrastructure, and was comprised mainly of civil engineers without an appropriate background in solar energy (Green, 2004). DEDE has now taken over the implementation work related to RETs in Thailand, and many former PWD employees have joined in this effort (Wongsapai, 2004b).

b) Biomass

For biomass based technologies, the Ministry of Agriculture is involved. The coordination between different organisations working under different ministries is poor (Prasertsan and Sajjakulnukit, 2005).

Current RETs policies

The Thai government has put considerable funds and effort into the promotion and diffusion of RETs in rural Thailand, PV technologies in particular.

For example, over the last 15 years, more than US$ 11 million have been spent for the promotion of solar battery stations. The programme of promotion of PV BCS has not fully reached its goals and has led to some failures that have not contributed to giving a good name to RETs, PV based in particular. More precisely, there is no evidence of the development of income-generating activities (water pumps are used for sanitarian water and batteries do not allow the powering tools contributing to the development of income generating activities), and only little new understanding or information was generated from the systems due to the lack of feedback. Furthermore, the improvement of standards of living was not found to be significant especially when balanced with the total cost of the programmes (Green, 2004).

On the other hand, the initial assessment carried out for the present report, shows that heat[103] is the major energy end use for both residential and productive uses in rural Thailand. Heat producing RETs

[102] In India, for example, the Ministry for None-Conventional Energy Sources (MNES), energy exists since 1992.
[103] To cook, dry, produce bricks, pottery, bake, pasteurise, etc.

have not been promoted by the government only to some very limited extent (subsidies for biogas digesters).

Furthermore, when the ENCON fund has been used by the government to subsidise RETs based SPPs, it appears that large scale and low power generating costs biomass based RETs power producers were favoured (Prasertsan and Sajjakulnukit 2005).

Pricing Policies

a) Conventional energy sources are subsidized

In Thailand, as in many other countries, conventional sources of energy such as electricity from the grid and fossil fuels are subsidized to maintain a high level of economic growth. Diesel prices in Thailand have been maintained at a constant 0.36 US$/litre from January 2004 to February 2005, despite worldwide prices hikes. Low electricity consumers pay a tariff of 0.039US$/kWh (Greacen, 2004).

b) Pricing policies do not consider environmental costs of conventional sources

In Thailand, like in many other countries, polluting energy sources are not taxed at a higher rate than non-polluting ones, and therefore their real cost for the society is not reflected. On the other hand, as noted above, they receive a subsidy.

c) Rice producers do not get any profits from rice husk utilisation for energy production

In the current legislative framework, in Thailand, rice husk belongs to rice mills and not to farmers. If rice husk was about to become widely used for energy purposes, rice farmers would not get any benefits from it.

3.9.2 Barriers to proper utilisation and maintenance of RETs

The approach followed by the government to develop some RETs based projects acted as barriers to the proper operation and maintenance of these technologies. This, in turn, has lead to numerous technical failures and has contributed to give RETs a bad name. More troublesome is that the same approach is still followed for the new SHS programme started in 2004.

PV based technologies have been the most promoted RETS by the government. Most of the problems described in this subsection are therefore focussed on PV. However, the same problems could occur with other RETs too.

Solar PV

The PV systems implemented in Thailand (BCS, water pumps) have many imported components: solar cells, water pumps, inverters, etc. One consequence of this has been a mismatch of different parts used in installation, and consequently poor overall efficiency of the system. Furthermore, spare parts are often expensive and not readily available. In the field, this means that when a component is broken and should be replaced, it is not repaired and instead the system simply stops being used (Sriuthaisiriwong, 2000).

The PV pumping, BCS and Home Systems promoted by governmental agencies are 100% subsidized. In the case of pumps and battery charging stations, the community owns the technology. In most of the cases, no fees are collected for the use of the technology leading to abuse and misuse (Green, 2004) and (Sriuthaisiriwong and Kumar, 2001).

The PV pumping systems and Battery Charging Stations are all of the same capacity and do not take into account the size of the community and its particular needs. This mismatch of technology with the local needs also contributes to inefficient utilisation and rapid failures (Green, 2004) and (Sriuthaisiriwong and Kumar, 2001).

Many PV systems have been implemented in remote areas where ethnic minorities live. These communities have their own language that is generally not spoken by implementing agency staff. This communication gap caused misunderstandings about the systems' use, which frequently resulted in the decline of the system hardware (Green, 2004).

Finally, there is a general lack of maintenance of the PV BCS that result in rapid failures of the system (Green, 2004). In the Indian state of Punjab for example, the local energy agency (Punjab Energy Development Agency, (PEDA)) launched, in 2000, a large programme of PV water pumping. PEDA included a 5-year maintenance obligation in the tender specifications. The first results of this programme are promising (van den Akker and Lamba, 2002).

Biogas digesters

The biogas digesters designed by the University of Chiang Mai and promoted on a subsidized basis, are sensitive to the quality of the organic matter used. A fully trained operator has to be employed to ensure the proper use of the technology. This is not affordable for small and medium scale livestock farms.

4. Policy Outlines

The objective of this section is to present some policy outlines to address/overcome the identified barriers to RETs utilisation and promotion and to report the reaction of the key stakeholders to the suggested policy outlines. These policies were identified based on Strengths-Weaknesses-Opportunities-Threats (SWOT) analysis. Stakeholders' reactions regarding these outlines were gathered in a workshop and through interviews.

4.1 Objectives and policy outlines

The different barriers to RETs promotion and utilisation in Thailand, presented in Section 3.9, are synthesised into seven problems as shown in Table 23. Each problem is then associated to an objective representing the desired situation to which the policy outlines should lead. Each objective answers the question: what is intended with the implementation of the noted policy?

Table 23: Problems and objectives related to RETs promotion and utilisation in Thailand

Problem	Objective
RETs are not always economically competitive compared to conventional sources (e.g. biofuels, PV power generation, etc.); especially they have a high upfront cost (e.g. Solar dryer, biogas digesters, etc.)	To make RETs economically competitive compared to conventional sources of energy
Diffusion of RETs in Thailand is hampered by lack of awareness of potential users (e.g. no awareness campaign, lack of success stories for PV technologies, etc.).	To raise awareness on RETs and their applications throughout the country
Mature RETs are not available for major applications/uses (e.g. biogas digesters, charcoal from residue, biomass gasification)	To make mature RETs appropriate to local conditions available in the national market
There is a mismatch of the technologies promoted and actual needs (e.g. focus of the government on PV technologies whereas most energy consuming activities require heat, only one design of the PV system irrespective of the size and needs of the communities)	To implement RETs that match users' needs
RETs are not well operated and maintained leading to a short life of the RETs systems (e.g. PV system implemented by the government)	To properly install, operate and maintain RETs
The agricultural residue market is not fully developed (e.g. price of residue highly fluctuating, rice farmers not getting benefits from rice husk based RETs).	To develop the agricultural residue market to benefit all stakeholders
There is a lack of qualified experts in the implementing government agencies (e.g. RETs implemented by non specialist agency (PWD))	Implementation of RETs based projects by qualified government staff

In the following subsections, the objectives described in Table 22 are analysed according to their strengths, weaknesses, opportunities and threats (SWOT). This analysis leads to the identification of possible policy outlines to reach the objective. Details regarding the SWOT analysis for each objective are shown in Appendix 3 (Tables 3-1 to 3-7).

4.1.1 To make RETs economically competitive compared to the conventional sources of energy

RETs must be economically competitive compared to conventional technologies to become widely used. The strengths, weaknesses, threats and opportunities linked to this objective at present in Thailand can be expressed as follows:

Strengths

- ***The Thai government is already inclined to promote RETs:*** During the last two decades, the government has promoted RETs through various programmes, and is now considering implementing a RPS to increase the share of renewable energy in the energy mix (see Sections 3.3 and 3.8 for details).
- ***Funds available for RETs promotion initiative (ENCON Fund):*** Since 1992 ENCON fund is available to promote energy savings and use of renewable energy sources (see Section 3.6 for details).

Weakness

- ***Conflicting priorities:*** In spite of its interest to promote RETs, the government, has in the past subsidised fossil fuels and kept energy prices low to stimulate economic growth (see Sections 1 and 3.9 for details).

Threats

- ***High upfront cost of some RETs components:*** A PV water pump costs US$ 1900, a banana solar dryer costs US$ 4900, etc (other examples can be found in Sections 3.3 and 3.9).
- ***Potential public opposition to removal of subsidies to fossil fuels:*** If fossil fuel prices rise due to removal of subsidies the general public might react unfavourably.
- ***Potential public opposition to high cost of RETs electricity generation:*** If RETs start to be used more for power generation, the current electricity retail price is likely to rise. The general public might oppose such actions.

Opportunities

- ***Availability of international examples of pricing policies favourable to RETs:*** There exists several successful examples of pricing policies and financial schemes favourable to RETs elsewhere (Barua, 2005), (Martinot, 2004b) and (Ibrahim et al., 2002). Thailand could adapt some of these examples to its local context.
- ***Rising and unstable international prices of oil and gas:*** Prices of oil peaked in September 2005 and have been unstable and high since early 2004 (see Section 1 for details).

Policy Outlines

Table 3-1 in Appendix 3 shows the suggested policy outlines to achieve the objective of RETs economic competitiveness in the context of the identified strengths, weaknesses, opportunities and threats. These policy outlines are:

- Assessing the long term economic impact of the subsidy plans.
- Reflecting the real costs of conventional sources in retail prices.
- Promoting RETs for creation of income generating activities and reducing energy expenditures in the long run.
- Promoting electricity producing RETs, reducing energy expenditures in the long run.
- Making RETs imports financially more attractive.
- Providing financial incentives for RETs users.
- Providing financial incentives for RETs electricity producers.

- Providing financial incentives for RETs manufacturers.

4.1.2 To raise awareness on RETs and their applications throughout the country

General awareness on RETs is low in Thailand and needs to be raised. Linked to this objective, the strengths, weaknesses, threats and opportunities under the current situation can be expressed as follows:

Strengths

- ***Campaign for energy efficiency has already being implemented ('Divided by 2'):*** A national campaign on energy savings has been in place since 1996 (see Section 3.6 for details) and the country can use this experience for developing similar campaigns for RETs promotion.

Weaknesses

- ***Lack of RETs lobby:*** The lack of collaboration between public and private sectors, as well as the lack of coordination between the different NGOs working in the field of RETs results in there being no strong lobby to advocate for RETs (see Section 3.6 for details).
- ***Lack of targeted campaign and information available on RETs:*** No campaign to promote RETs currently exists in Thailand (see Section 3.9 for details).

Threats

- ***Familiarity of the users with conventional energy sources:*** In rural Thailand, where about two thirds of the population live, traditional fuels (fuelwood and charcoal) are the preferred fuels for most energy requiring activities. Fossil fuels are used extensively for transportation (that can exceed 30% of the total energy share in the residential sector) and agriculture. Furthermore, the electricity grid reaches 98.5% of the villages (see Sections 3.2 and 3.3 for details).
- ***There is a low level of understanding of energy issues and communication in the remote areas is difficult:*** The general public is more sensitive to economic aspects than environmental issues (see Section 3.8 for details). There was a lack of communication with some ethnic minorities[104] who live in very remote areas that can lead to improper utilisation of RETs (3.8 for details).

Opportunities

- ***Strong/good availability of media and network:*** In Thailand, there is a variety of mediums available throughout the country
- ***Good physical infrastructures (roads, electricity grid) available:*** Electricity grid reaches 98.5% of the villages and an extensive road network reaches almost every Thai village.

Policy Outlines

Table 3-2 in Appendix 3 shows the suggested policy outlines to achieve the objective of raising awareness on RETs in Thailand in the context of the identified strengths, weaknesses, opportunities and threats. These policy outlines are:

- Using existing structures to further promote mature RETs and ensure accessibility of the campaign to the most remote communities as well as to less educated and ethnic minorities.
- Diffusing success stories of RETs for creation of income generating activities and reducing energy expenditures in the long run.
- Encouraging the creation of a RETs lobby.

[104] Ethnic minorities account for about 1.22 percent of the total population, and their concentration is large in a number of North and Northeastern provinces (20 to 49 percent of provincial populations in some cases) (ADB, 2001).

4.1.3 To make mature RETs appropriate to the different local conditions available in the national market

A range of mature RETs that are appropriate to the local conditions (temperature, physical properties of the resources (biomass), etc.) have to be available in the local market for wider use of RETs. The strengths, weaknesses, threats and opportunities of the current situation regarding this objective can be presented as follows:

Strengths

- ***Infrastructure for local production of RETs exists:*** Some RETs are already available on the local market to meet certain needs and good manufacturing possibilities exist (see Section 3.3 for details).

Weaknesses

- ***Lack of adequate mechanisms of transfer of technology:*** Some promising technologies, which have shown good results in other developing countries, are either not mature (biogas, charcoal from agricultural wastes, etc.) or not available at all (small scale biomass gasification, etc.) in Thailand (see Sections 3.3 and 3.9 for details).
- ***Insufficient R&D for RETs:*** Compared to some of its neighbour countries, Thailand has a low budget for R&D (see Sections 3.6 and 3.9 for details).
- ***Lack of initiatives locally to produce appropriate RETs:*** Low cost technology adapted to the local conditions can be developed at the village level. However, this kind of initiatives are lacking in Thailand.

Threats

- ***High cost of developing mature RETs:*** Developing new technologies and building production lines for new products is expensive.
- ***Familiarity of the users with conventional energy sources:*** In rural Thailand, where about two third of the population live, traditional fuels (fuelwood and charcoal) are the preferred fuels for most energy requiring activities. Fossil fuels are used extensively for transportation (that can exceed 30% of the total energy share in the residential sector) and agriculture. Furthermore, the electricity grid reaches 98.5% of the population (see Section 3.2 for details).

Opportunities

- ***Large potential for RETs exists throughout the country:*** See Section 3.4 for details.

Policy Outlines

Table 3-3 in Appendix 3 shows the suggested policy outlines to achieve the objective of making mature RETs appropriate to the different local conditions available in the national market in the context of the identified strengths, weaknesses, opportunities and threats. These policy outlines are:

- Increasing R&D activities to make RETs appropriate to the local conditions.
- Promoting international network of knowledge and technology transfer.
- Using existing structures to commercialize newly mature RETs.
- Encouraging development of low cost locally produced RETs.
- Providing financial incentives to RETs manufacturers.

4.1.4 To implement RETs that match users' needs

To be successful, RETs implemented in the field have to match users' needs. The strengths, weaknesses, threats and opportunities of the current situation regarding this objective can be expressed as follows:

Strengths

- ***Existence of implementing agencies:*** For PV technologies, PEA and some private contractors are implementing SHS, whereas DEDE has been implementing different kind of RETs for more than 15 years (see Sections 3.3 and 3.6 for details).
- ***Some universities are already active in the field and working with communities:*** SERT in Naresuan University is working with local farmers to develop banana dryers (see Section 3.5 and 3.6 for details).
- ***Examples of successful applications of RETs:*** Some RETs based projects (solar dryers, SWH, etc.) have been successfully implemented matching the needs of the users and giving satisfaction (see Section 3.3 and 3.5 and 3.7 for details).

Weaknesses

- ***Lack of users' participation in RETs programme design:*** The previous RETs diffusion programmes in Thailand were implemented without involvement of the users in the process (see section 3.8 for details).
- ***Lack of technical capability to adapt RETs to users needs.***

Threats

- ***Preference of RETs manufacturers and suppliers to build/produce standard units:*** For reasons of economy of scale, all the PV BCS and PV pumping systems implemented in Thailand were all of the same capacity (see Section 3.3 and 3.8 for details).

Opportunities

- ***Large resource potential exists throughout the country:*** See Section 3.4 for details.

Policy Outlines

Table 3-4 in Appendix 3 shows the suggested policy outlines to reach the objective of making RETs match with users needs in the context of the identified strengths, weaknesses, opportunities and threats. These policy outlines are:

- Encouraging RETs producers to diversify each given model of RETs in terms of size, capacity and types of application.
- Encouraging the implementing agencies to include the users in the design process to assess their needs.
- Encouraging the implementing agencies to assess the potential for RETs before implementation.
- Scaling up applications from demonstration sites.
- Training the users and some local staff for maintenance and repair in a language they can understand.
- Making RETs imports financially more attractive.

4.1.5 To properly install, operate and maintain RETs

In order to minimise failures, RETs have to be properly operated and maintained. The strengths, weaknesses, threats and opportunities of the current situation regarding this objective can be expressed as follows:

Strengths

- ***Existence of some local initiatives of users training:*** An NGO is organising training for SHS users on a small scale (see Section 3.6 for details).

Weaknesses

- ***Lack of staff for regular maintenance (for certain RETs):*** The current programmes promoting PV technologies lack qualified staff to provide regular maintenance and repair services (see Section 3.8 for details).
- ***Lack of investment in building capacity of users (for certain RETs):*** Current programmes promoting PV technologies lack training components for the users who do not know how to maintain their systems (see Section 3.3 and 3.8 for details).
- ***Some RETs are made available free of cost to users:*** Most of the RETs currently implemented in Thailand are fully subsidised and no fees are collected for the use of the technology (see Section 3.8 and 3.9 for details).
- ***Spare parts are not readily available:*** For some RETs implemented in Thailand, especially PV based, some spare parts are not readily available and they are imported (see Section 3.8 and 3.9 for details).

Threats

- ***Remoteness of some areas and language barriers faced by some users:*** Most non-electrified households are located in remote areas and some ethnic minorities do not speak Thai (see Section 3.8 for details).

Opportunities

- ***Training facilities and other infrastructure for proper maintenance and operation exist:*** Different academic institutions such as SERT in Naresuan University or Asian Institute of Technology in Bangkok have RETs demonstration centres that could be used for training (see Section 3.6 for details).

Policy Outlines

Table 3-5 in Appendix 3 shows the suggested policy outlines to attain the objective of making RETs properly operated and maintained in Thailand in the context of the identified strengths, weaknesses, opportunities and threats. These policy outlines are:

- Training the users and some local staff for maintenance and repair in a language they can understand.
- Implementing a pay per use service.
- Implementing financial mechanisms for spare part producers and suppliers.
- Encouraging RETs spare parts suppliers to use existing infrastructure.
- Scaling up and extending support to local initiatives for users training.

4.1.6 To develop the agricultural residue market to benefit all the stakeholders

In spite of the large availability of agriculture residue, their market needs to be further developed. Linked to this objective, the strengths, weaknesses, threats and opportunities at present can be expressed as follows:

Strengths

- ***Existence of capacity for biomass based RETs:*** BOSCH is an NGO focusing its work on biomass. It has already implemented two large-scale projects (see Section 3.3 and 3.6 for details).

Weaknesses

- ***Residue does not belong to the farmers but to the actual residue producers (e.g. rice husk belongs to rice mills):*** In the current policy framework, the residue belongs to the wastes producers and not to the farmers. Therefore, the farmers do not benefit from the profits of the use of residue in the RETs based project (see Section 3.9 for details).
- ***Lack of standards for residue:*** Currently there are no chemical or physical standards for residue making it difficult to assess the recoverable energy for a biomass based project (see Section 3.9 for details).
- ***Lack of awareness among residue producers and users:*** The potential users of RETs are not aware of the availability of residue (quantity, characteristics, etc.) and the producers do not know where the potential users are (see Section 3.9 for details).

Threats

- ***Opportunity cost of residue is highly fluctuating:*** The current market price of some residue is very low, but as soon as the demand rises, e.g. with the development of large scale residue based RETs, the price increases drastically. There are also some fluctuations in residue prices due to seasonal changes in the residue availability (see Section 3.5 and 3.9 for details).

Opportunities

- ***Environmental improvement and avoidance of disposal cost through use of residue as fuel:*** The improper disposal of residue sometimes leads to land and water pollution. Furthermore, these residue have to be sometimes transported in order to be disposed and the cost of transportation can be high (see Section 3.5 et 3.9 for details)
- ***Large quantity of residue available (see Section 3.4 for details).***

Policy Outlines

Table 3-6 in Appendix 3 shows the suggested policy outlines to reach the objective of developing the agricultural residue market in a way that could be beneficial to all the stakeholders in the context of the identified strengths, weaknesses, opportunities and threats. These policy outlines are:

- Linking the residue producers to the potential users.
- Implementing financial mechanisms to reduce the financial risk of residue based RETs projects.
- Sharing the benefits of residue based RETs among the different stakeholders.
- Defining standards for residue.
- Promoting biomass based technologies as a way to reduce / avoid disposal cost and to reduce local pollution.

4.1.7 Implementation of RETs based projects by qualified staff

In the past, inadequately trained staff implemented some RETs projects. In the future, this situation should change and qualified staff should implement RETs projects. The strengths, weaknesses, threats and opportunities of the current situation regarding this objective can be expressed as follows:

Strengths

- ***Creation of a government entity to implement RETs:*** Since 2002 with the creation of the Ministry of Energy, only one governmental agency (DEDE) is implementing RETs projects (see Section 3.6 and 3.9 for details).

Weaknesses

- ***Non-specialist staff still implementing RETs within DEDE:*** Staff involved in the promotion of RETs do not always have adequate knowledge and training in RETs (see Section 3.9 for details).

Threats

- ***More beneficial package for qualified staff in the private sector:*** It is difficult to motivate qualified people to work with RETs, because RETs are not well established in the market and are difficult to make a profit from (see Section 3.9 for details).

Opportunities

- ***Existence of good education/training facilities in Thailand:*** There are several good academic institutions dealing with RETs (see Section 3.6 for details).
- ***Government policies and programmes to promote RETs:*** The RTG has implemented RETs for more than two decades and is currently implementing policies to increase the total share of RETs (see Section 3.6 for details).

Policy Outlines

Table 3-7 in Appendix 3 shows the suggested policy outlines to reach the objective of training the staff or RETs implementing agencies in the context of the identified strengths, weaknesses, opportunities and threats.

These policy outlines are:

- Investing in staff capacity building.
- Diffusing success stories of RETs for creation of income generating activities.
- Sharing experiences among the different stakeholders, including government agencies and academic institutes.

4.2 Stakeholders reactions

To assess the relevance and the feasibility of the policy outlines presented in the section 4.1, stakeholders' inputs and comments were obtained through workshops and interviews:

a) A workshop on the barriers to RETs and the required policies was organised in Bangkok on 19 October 2004. It was attended by 24 Thai stakeholders and policy-makers from ten national organizations (universities, utilities, governmental and non-governmental organisations) and two United-Nations agencies. The presentation prepared for this workshop as well as a summary of the discussions are available in (AIT, 2004c).

b) Seven stakeholders from government, research organisations and international agencies were interviewed. The questionnaire on which the interviews were based is given in Appendix 4. Their views regarding the suggested policy outlines and some specific comments on these outlines are presented in Table 5-1 in appendix 5. These reactions, however, cannot be taken as the official position of their respective organisation/agency.

The main comments/observations gathered during the interviews and the workshops are summarised below:

- Most of the stakeholders underlined the fact that RETs projects should involve the local communities. They were also of the view that users should be at the centre of the decision making process, and should be able to choose the most suitable technologies, according to their energy needs and financial means. Top-down approaches have shown many failures in the past. The implementing agencies should give due consideration to communities' choices and should not focus only on one or two technologies even if such an approach is easier to manage.

- Awareness campaigns have to be launched at the community level, including demonstration projects for RETs promotion. This will enable the potential users to judge for themselves the potential of each technology. These demonstration projects should be easily accessible to rural communities and not be located in big cities or university campuses. They should also emphasise the benefits (especially economic) brought by RETs.

- The financial contribution of communities to a RETs project would reduce abuse and misuse, but this should take into account the financial means of the users. However, it was observed that this measure was not feasible for the poorest of the poor and therefore the other members of the communities may refuse to pay if some do not have to.

- Financial measures to promote RETs are needed. For some stakeholders, subsidies are currently a painful necessity, while for others they are necessary but should be smart, i.e. implemented with a planned exit strategy. For a last group of people however, they should be avoided. The question is also to know where to apply the subsidies: should they target users or manufacturers? On this question as well, the different opinions were heard. All stakeholders agreed on the necessity of other financial measures such as internalising environmental costs of non-renewable sources or removing subsidies on conventional sources, but it was also said that it was more of a political matter. One representative of a government agency argued that the current low price of fossil fuels did not affect RETs competitively since they provide different services (as compared to PV for example).

- Local communities currently do not get any financial benefits from biomass-based projects. It was suggested that local communities should get a share in the plants. Furthermore, since in Thailand, rice husk belongs to rice mills and not to the farmers, who actually grow the rice; it was felt that the farmers should get some benefit if the husk is sold as a fuel for power plants. It was pointed out that biomass power plants might not be economically feasible if the price of the biomass fuel rises due to demand increase. Long-term contracts between agricultural waste suppliers and users could be arranged with an agreed fixed price. It was also suggested that a certain share of the residue produced in the country could be dedicated to energy purposes.

- Low cost technologies should be promoted as a priority. Some promising technologies stated included blend of pure vegetable oil and diesel for agricultural machines, charcoal from locally produced residue and solar drying. For these technologies, it was observed that, there are very little or no financial barriers.

- Local manufacture of RETs should be promoted. However the future demand should be analysed carefully to avoid too many suppliers in the market.

- Network of RETs stakeholders to better share information was agreed on by the majority of the stakeholders who saw the lack of communication between the main actors as a major barrier.

- On the other hand, energy service companies (ESCOs) specialised in RETs was not seen as a priority by the majority of the stakeholders to promote RETs.

- The promotion of centralised RETs based power plant, through green pricing or power wheeling was seen as a good idea. However, it was pointed out that these measures would require privatisation of EGAT and a wider opening of the electricity market.

Having policies to promote RETs is an important step, but there should also be a clear strategy on how to implement them.

5. Summary of key findings and recommendations

Promising RETs options

In rural Thailand, in both the residential and productive sector, most energy consuming activities require heat. In the residential sector, cooking can represent up to more than 60% of the total energy share, whereas in small scale industries, thermal processes such as pasteurising, drying, brick making, etc. can represent, on an average, up to more than 50%. To satisfy these needs and considering the available renewable resources (biomass and solar), three options were identified:

- Solar Drying
- Charcoal production from agricultural residue
- Biogas production

A solar dryer costs about US$ 4900 for a 100 kg/batch banana model with a payback period of 2 to 6 years. Its main advantages include production of better quality product and reduction of drying time. As a result, dried bananas produced with solar drying are sold at a price 75% higher than the traditionally dried ones. Besides, rubber, rice, chillies, and different types of other fruits can also be dried in solar dryers. This technology has therefore a good potential for poverty alleviation, since these are grown in the poor regions of Northeast, North and South of Thailand.

Biogas can be used to produce heat, mechanical energy or electricity. Additionally, this technology allows decreasing the local land and water pollution due to industrial wastes and high concentration of animal manure. Pay back period of 4 to 6 years is reported for biogas digesters in pig farms. However, the technology needs further development if it is to become more reliable and less sensitive to the variations in organic matter properties.

The potential of biomass in the country has not been fully exploited yet and the large amount of agricultural wastes produced could be used to produce useful energy. Production of charcoal from agricultural wastes is therefore a promising technology. In Thailand, the potential of bagasse, sugar cane leaves, coconut shells and rice husk is big in the poorer regions of Northern, Northeastern and Southern Thailand. Charcoal production using agriculture residue is a simple technology that can be implemented at both small and large scale, depending on the kind of waste. It also helps to address waste disposal issues and could provide a new source of income. The pay back period of a medium scale pilot project of charcoal production from coconut shells has been estimated at about 3 years. However, this technology is not yet fully mature in Thailand. Thus further research and development efforts are needed in order to improve production efficiency and lower costs. Besides technical barriers, another problem that hampers the production of charcoal from residue is the current biomass market: Biomass producers and users are often not well linked together, the former are not aware of the energy potential of their residue while the latter are not aware of its availability. Furthermore, prices highly fluctuate according to the seasons, demand, etc.

Based on the analysis of some promising RETs, existing policies to promote RETs and some governmental RETs programmes the following barriers were identified.

Barriers to RETs promotion

a) Financial barriers: Financial factors constitute the key barrier hampering the diffusion and promotion of RETs. Compared with other conventional energy sources, the capital cost of RETs is high.
b) Information barriers: There is a lack of awareness about RETs that hinders their development in Thailand. RETs are not well advertised and are not an obvious choice for users. As compared to energy

conservation, there is currently no national campaign to sensitize potential users to the benefits of RETs.

c) Technical barriers: Though some RETs are locally produced and technically mature (e.g. solar water heaters, micro-hydro turbines, wind turbines, etc.), other RETs suffer from a lack of research and development.

d) Institutional barriers: Although the Thai government has reorganised its energy ministry in 2002 and created a specialised agency (i.e. DEDE) for the implementation of RETs, institutional barriers still remain and coordination between different RETs stakeholders is weak.

e) Current RETs policies: RETs are promoted by the government. Over the last two decades, the RTG has focussed on diffusion of PV based technologies, whereas the most energy consuming activities require heat. Other promising RETs options (e.g. solar thermal for drying, biomass, biogas, etc.) could also be promoted.

f) Pricing policies: Conventional energy sources are subsidized and the social cost of pollution due to conventional energy sources is not taken into account in the current pricing policies.

Barriers to proper utilisation and maintenance of RETs

Furthermore, the top-down approach used led to numerous technical failures. This, in turn, has contributed to give the RETs a bad name.

Policy Outlines

Barriers to RETs promotion could be overcome by appropriate policies. The main policy outlines identified during this study can be summarised as follows:

a) Reflecting the real costs of conventional sources in retail prices.
b) Promoting RETs for creation of income generating activities and reducing energy expenditures in the long run.
c) Making RETs imports financially more attractive.
d) Providing financial incentives for:

- RETs users.
- RETs electricity producers.
- RETs manufacturers.
- RETs spare parts producers and suppliers.

e) Promoting national and international networks of experts for knowledge sharing and technology transfer.
f) Encouraging the implementing agencies to

- Assess the local resources and the needs before implementation.
- Include the users in the design process.
- Train the users and local staff for maintenance and repair in a language they can understand (scaling up existing initiatives).

g) Linking the residue producers to the potential users (for biomass based RETs).

6. Suggestions for future actions

As pointed out by (Martinot et al., 2003), experience with "productive uses" of renewable energy is still in its infancy and deserves much greater attention from donors, development agencies, and governments. The following suggestions can be made for further work:

- In the present study, some data are based on a limited field survey carried out in three villages in Thailand. It is desirable to conduct more comprehensive field surveys for more reliable and general results.
- RETs should be seen as tools to help develop income generating activities and should not be seen as an end in themselves. It is, therefore, necessary to first identify the activities that most benefit the development of local communities (considering their traditions, know-how and the locally available resources). The most suitable RETs for the satisfaction of the energy needs of these activities should then be identified. In the present study, due to the above-mentioned constraints, only a few case studies have been presented.
- Local communities should be directly involved in the process of identifying their needs in terms of services. For future actions, it is therefore recommended to initiate dialogue with the users to identify the income generating activities and the appropriate RETs to satisfy their needs.
- The present study focuses on rural areas in Thailand, where the majority of the poor live. However, not all the inhabitants of rural areas are poor and the poor also inhabit municipalities and urban areas. Unfortunately, data on energy needs for the poor, in rural and urban areas alike, are not available. It is therefore recommended that an effort be made to establish such a database.
- The key findings of this study, if not the whole report, should be available in Thai, in order to make its dissemination to local stakeholders more effective.
- Actual implementation of RETs in the field should be carried out in partnership with key stakeholders.

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Bibliography

1. Asian Development Bank (ADB), 2001. **Health and Education Needs of Ethnic Minorities in the Greater Mekong Subregion**, ADB, 2001, via <URL: http://www.adb.org/Documents/Studies/Health_Education_GMS/#contents> (January 31, 2005).
2. Asian Institute of Technology (AIT), 2004a. **Field Survey for GNESD RETs theme report**, AIT, Thailand, July 2004.
3. Asian Institute of Technology (AIT), 2004b. **Selected Environmentally Innovative Technologies and Programmes in Thailand**, AIT, Thailand, May 2004.
4. Asian Institute of Technology (AIT), 2004c. **Workshop Report,** *Workshop on renewable energy for productive uses in rural Thailand,* Bangkok, Thailand, 19 October 2004.
5. van den Akker, J. and Lamba H., 2002. **Thinking big: Solar water pumping in the Punjab,** *Refocus,* Volume 3, Issue 6, pp. 40-43, November-December 2002.
6. Amatayakul, W. and Greacen C.S., 2002, **Thailand's Experiences with Clean Energy Technologies: Power Purchase Programs,** *paper prepared for UNDP's International Seminar on Energy for Sustainable Development and Regional Cooperation*, NEPO, Bangkok, Thailand, 2002, via <URL: http://www.palangthai.org/en/docs/ThailandsCaseStudyJuly22.pdf > (November 7, 2004).
7. Barua, D.C., 2005. **Rural Electrification with Solar Home Systems: Lessons Learned from Grameen Shakti,** *paper presented at the Asian Regional Workshop on Electricity and Development,* Bangkok, Thailand, April 2005.
8. **Strategy for promotions and development of renewable technologies in Bangladesh: experience from Grameen Shakti,** *Renewable Energy,* Volume 22, Issues 1-3, pp. 205-210 January-March 2001.
9. Bhattacharya, S.C., 2002. **Biomass energy in Asia: a review of status, technologies and policies in Asia,** *Energy for Sustainable Development***,** Volume VI No. 3, pp 5-10, September 2002.
10. Bhattarai, T, 1998. **Charcoal and its Socio-Economic Importance in Asia: Prospects for Promotion**, *Paper prepared at the Regional Training on Charcoal Production*, Pontianak, Indonesia, February 1998, via <URL: http://www.rwedp.org/acrobat/p_charcsocio.pdf> (July 22, 2004).
11. Biogas Technology Center (BTC), 2004. **Report on Operation of Biogas System in Praves Farm,** BTC, Chiang Mai University, September 2004.
12. Boonnoon, J., 2004. **Solar cells to power up rural life,** The Nation, Bangkok, Thailand, 19 April 2004. Via <URL: http://www.nationmultimedia.com/search/page.arcview.php?clid=20&id=97623&usrsess> (10 November 2005)
13. Boyle G. (Editor), 2004. *Renewable Energy: Power for Sustainable Development,* Second Edition, Oxford University Press, 2004.
14. de Carvalho, E, 2004. **The Brazilian Experience with Fuel Ethanol: An Historical and Market Perspective**, *presentation at the Conference on Biofuels: Challenges for Asia Future*, Bangkok, August 30, 2004.
15. Chaiyospol, C., 2000. **PWD PV Water Pumping System and Battery charging Station Projects in Thailand**, Public Work Division, Ministry of Interior, Bangkok, Thailand.
16. Chiang Mai University (CMU), 2004. **Self-Service Village Micro-Hydro Project**, Department of Industrial Engineering, CMU, via <URL: http://doi.eng.cmu.ac.th/microhydro/index.php> (November 11, 2004).
17. Cohen, T., 2004. **Waste to energy: A waste solutions success in Thailand,** *Refocus,* Volume 5, Issue 5, pp 26-28, September-October, 2004.

18. Dennis ,Y. C., Leung, X. L. Yin and C. Z. Wu, 2004. **A review on the development and commercialization of biomass gasification technologies in China,** *Renewable and Sustainable Energy Reviews*, Volume 8, Issue 6, pp. 565-580, December 2004.
19. Department of Agricultural Extension (DOAE), 2003. **Information on fruits and farmers in Thailand in 2001**, Information, System Analysis and Planning Division, DOAE, Ministry of Agriculture and Cooperatives, Thailand, June 2003, via <URL: http://www.doae.go.th/baseinfor/MIS/kpt/index.htm> (July 1, 2004).
20. Department of Agricultural Extension (DOAE), 2004. **Agricultural Statistic and Database**, DOAE, Ministry of Agriculture and Cooperatives, Thailand, 2004, via <URL: http://www.doae.go.th/stat/index.htm> (July 18, 2004).
21. Department of Alternative Energy Development and Efficiency (DEDE), 1999. **Potential of Renewable Energy Resources in Thailand**, DEDE, Ministry of Energy, Thailand, via <URL: http://203.150.24.8/dede/renew/renew_index.html > (June 15, 2004).
22. Department of Alternative Energy Development and Efficiency (DEDE), 2003a. **Electricity Power in Thailand 2002**, DEDE, Ministry of Energy, Thailand, 2003.
23. Department of Alternative Energy Development and Efficiency (DEDE), 2003b. **Oil and Thailand 2002**, DEDE, Ministry of Energy, Thailand, 2003.
24. Department of Alternative Energy Development and Efficiency (DEDE), 2003c. **Final Report on Residential Energy Consumptions in Non-municipal Area**, DEDE, Ministry of Energy, Thailand, May 2003.
25. Department of Alternative Energy Development and Efficiency (DEDE), 2003d. Report on Potential of Biomass Energy in Thailand, Renewable Energy Department, DEDE, Ministry of Energy, Thailand, via <URL: http://203.150.24.8/dede/renew/bio_p.htm> (March 22, 2004)**.**
26. Department of Alternative Energy Development and Efficiency (DEDE), 2003e, **Renewable Energy… New Chance for Thailand**, *Presentation at the Energy Strategy Workshop*, Bangkok, Thailand, 28 August, 2003, via <URL: http://www.eppo.go.th/admin/moe-workshop1/index.html > (March 27, 2005).
27. Department of Alternative Energy Development and Efficiency (DEDE), 2004a. **Renewable Energy in Thailand: Ethanol and Biodiesel**, *Conference on Biofuels: Challenges for Asia Future*, Bangkok, August 30, 2004.
28. Department of Alternative Energy Development and Efficiency (DEDE), 2004b. **Report on Renewable Energy Development and Planning**, DEDE, Ministry of Energy, Thailand.
29. Department of Alternative Energy Development and Efficiency (DEDE), 2004c. **Thailand Energy Situation 2003**, DEDE, Ministry of Energy, Thailand, 2004.
30. Department of Alternative Energy Development and Efficiency (DEDE), 2004d. **Renewable Energy in Rural Village Project: Tambon Srisurat, Rachaburi**, DEDE, Ministry of Energy, Thailand, September 2004.
31. Department of Alternative Energy Development and Efficiency (DEDE), 2004e. **Electricity Power in Thailand 2003**, DEDE, Ministry of Energy, Thailand, 2004.
32. Electricity Generating Authority of Thailand (EGAT), 2002. **Demonstration Project of PV Power Generation and Distribution in Mae Hong Son**, Renewable Energy Department, Research and Development Division, EGAT, via <URL: http://www.egat.co.th/rdo/energy/MHSmain.html> (March 2, 2004).
33. Etcheverry, J., 2003. **Renewable Energy for Productive Uses: Strategies to Enhance Environmental Protection and the Quality of Rural Life**, University of Toronto, 2003, via <URL: http://www.martinot.info/Etcheverry_UT.pdf > (November 2, 2004).
34. Fertilizer Advisory, Development and Information Network for Asia and the Pacific (FADINAP), 2004. **Integrated Plant Nutrition Systems,** *Training Manual*, Sri Lanka, 2004, via <URL: http://www.fadinap.org/ipns/srilanka/ipnsmanual/index.htm > (October 15, 2004).
35. Food and Agriculture Organisation (FAO), 2004. FAOSTAT, Online and multilingual database, via <URL: http://apps.fao.org > (July 12, 2004).

36. Food and Fertilisers Technology Center (FFTC), 2001. **Application of rice husk Charcoal,** *extension leaflet*, Tokyo, Mai 2001, via <URL: http://www.fftc.agnet.org/library/abstract/pt2001004.html > (November 10, 2004).
37. GEF/FAO, 2002. **Workshop on Productive Uses of Renewable Energy: Experience, Strategies, and Project Development**, FAO Headquarters, Rome, Italy, June 18-20, 2002.
38. Global Emission Model for Integrated Systems (GEMIS), 2002. **GEMIS Database Version 4.14**, GEMIS, September 2002, via <URL: http://www.oeko.de/service/gemis/en/index.htm> (August 4, 2004).
39. Greacen, C., 2004. **The Marginalization of "Small is Beautiful": Micro-hydroelectricity, Common and the Politics of Rural Electricity Provision in Thailand,** *PhD Thesis,* Energy and Resources Group, University of California, Berkley, Fall 2004.
40. Greacen, C., Greacen, C.S. and Plevin, R., 2003. **Thai power: Net metering comes to Thailand**, *Refocus*, Volume 4, Issue 6, pp.34-37, November-December 2003.
41. Green, D., 2004.**Thailand's solar white elephants: an analysis of 15 year of solar battery charging programmes in northern Thailand**, *Energy Policy,* Volume 32, Issue 6, pp. 747-760, April 2004.
42. Hongladarom, P., 2005. **Thailand Power Development for Sustainable Energy**, *presented at the Regional Workshop on Electricity and Development,* AIT, Thailand, 28-29 April 2005.
43. Ibrahim, M., Anisuzzaman, M., Kumar, S. and Bhattacharya, S.C., 2002. **Demonstration of PV micro utility system for rural electrification**, *Solar Energy,* Vol. 72, No.6, pp. 521-530, 2002.
44. International Energy Agency (IEA), 2002. **Energy and Poverty**, *World Energy Outlook 2002*, Chapter 13, IEA, Paris, September 2002, via <URL: http://www.worldenergyoutlook.org/pubs/weo2002/EnergyPoverty.pdf > (October 15, 2004).
45. Intarangsi A., Kiatpakdee W., 2000. **The Experience on Biogas Technology in Thailand: From Development to Delivery**, *paper presented at the global dialogue on the role of the Village in the 21st Century - Jobs, Crops and Livelihood,* Bonn, Germany, August 2000.
46. Jaimsin, A., 2005. **Solartron plans a new factory**, *Bangkok Post*, Bangkok, Thailand, 31 January 2005.
47. Jain B.C., 2000. **Commercialising biomass gasifiers: Indian experience**, *Energy for Sustainable Development*, volume IV No. 3, pp. 72-82, October 2000.
48. Kapadia, K., 2004. **Productive uses of renewable energy: A Review of Four Bank-GEF Projects**, January 2004, via <URL: http://www.martinot.info/Kapadia_WB.pdf > (13 June, 2004).
49. Karstad E., 2000. Is briquetting the answer**?**, *Presented at the Village Power Conference,* Washington DC, USA, December 2000, via <URL**:**http://www.rsvp.nrel.gov/vpconference/vp2000/vp2000_conference/commercial_elsen_karstad1.pdf > (July 15, 2004).
50. Keawsompong S., Piyachomkwan K., Walapatit S., Rodjanaridpiched C. and Sriroth K., 2002. Ethanol Production from Cassava Chips: Simultaneous Saccharification and Fermentation Process, BIOTEC Knowledge Center, Bangkok, Thailand, 2002, via **<URL:** http://knowledge.biotec.or.th/doc_upload/2004123151846.doc > (July 12, 2004).
51. Kositchotethana, B., 2004. **Green' hypermarket shaping up,** Bangkok Post, Bangkok, Thailand, 20 October 2004. Via <URL: http://netmeter.org/en/story/21 > (10 November 2005)
52. Lew D., 1998. **Lessons learned in small-scale renewable energy dissemination: a comparison of China and Thailand**, National Renewable Energy Laboratory, USA, September 1998.
53. Lertsuridej, P., 2004a. **Policy on New and Renewable Energy Technology promotion in Thailand,** *Technical Digest of International PVSEC-14,* Bangkok, Thailand, March 2004.
54. Lertsuridej P., 2004b. **Renewable Energy for Sustainable Development: A Global Challenge,** *presented at the International Conference for Renewable Energies***,** Bonn, Germany, 1-4 June 2004.

55. Limjeerajarus, N., Shrestha, R.M., and Kumar, S., 2004a. **Data collation and Compilation for Thailand**, *AIT Energy Access II Final report*, submitted to Global Network on Energy for Sustainable Development (GNESD), March 2004.
56. Limjeerajarus, N., Shrestha, R.M., and Kumar, S., 2004b. **Renewable Energy Technologies for Rural Electrification in Thailand: Assessment of Selected Options**, *Proceedings of the International Conference for Renewable Energies,* Bonn, Germany, 1-4 June 2004.
57. Limmeechokchai B and Chawana, S., 2005. **Sustainable energy development strategies in the rural Thailand: The case of the improved cooking stove and the small biogas digester,** *Renewable and Sustainable Energy Reviews,* In Press, Corrected Proof.
58. Martinot, E., 2002. **Grid based Renewable Energy in Developing Countries: Policies, Strategies, and Lessons from the GEF**, *presented at World Renewable Energy Policy and Strategy Forum*, Berlin, Germany, June 13-15, 2002, via < URL: http://www.martinot.info/Martinot_WCRE2002.pdf> (October 26, 2004).
59. Martinot, E., Chaurey, A., Lew, D., Moreira, J.R. and Wamukonya, N., 2003. **Energy Markets in Developing Countries**, prepared for NREL/DOE/USAID Third Energy Analysis Forum "Understanding the U.S. Strategic Interests in Expanding Renewable Energy Systems Worldwide" Washington, DC, June 11-12, 2003.
60. Martinot E., 2004a. **Global Renewable Energy Markets and Policies**, *Forthcoming in New academy review special edition on climate change*, spring 2004, via <URL: http://www.martinot.info/Martinot_NAR.pdf > (October 26, 2004).
61. Martinot E., 2004b. Renewable Energy Policies and Barriers, Forthcoming in *Encyclopaedia of Energy,* Cutler J. Cleveland, ed. (Academic Press/Elsevier Science, 2004) < URL: http://www.martinot.info/Beck_Martinot_AP.pdf > (October 26, 2004)
62. Ministry of Energy of Thailand, 2004. **Bioenergy Revolution Strategy for Asia,** *twenty second asean ministers on energy meeting (22nd AMEM)*, Makati City, Metro Manila, Philippines, 9 June 2004.
63. Moog R., 2002. **'Pure play' for Thailand photovoltaics manufacturer,** *Photovoltaics Bulletin,* Volume 2002, Issue 5, pp 7-9, May 2002.
64. National Statistical Office (NSO), 2003a. **Core Economic Indicators**, Division of Economic Statistics Analyzing and Forecasting Group, Statistical Forecasting Bureau ,NSO, Thailand, via <URL: http://www.nso.go.th/eng/indicators/eco/economy.htm > (July 19, 2004).
65. National Statistical Office (NSO), 2003b. **Labour Force Survey**, Economic and Statistic Bureau, NSO, Thailand, via <URL: http://www.nso.go.th/thai/stat/stat_23/toc_2.html > (July 19, 2004).
66. National Statistical Office (NSO), 2003c. Agriculture Census, Economic Statistics Division, NSO, Thailand, 2003, via <URL: http://www.nso.go.th/thai/stat/stat_23/toc_10.html> (July 8, 2004)
67. National Economic and Social Development Board (NESDB), 2002. **Macro Economic Outlook**, NESDB, Thailand, 2002, via <URL: http://www.nesdb.go.th/econsocial/macro/macro_eng.php> (September 13, 2004).
68. National Economic and Social Development Board (NESDB), 2004. **Gross Domestic Product: Q1/2004,** NESDB, Thailand, 2004, via **<URL:** http://www.nesdb.go.th/econSocial/macro/NAD.htm#qgdp**>** (May 6, 2004).
69. National Economic and Social Development Board (NESDB), 1992-2002. **Poverty and Income Dissemination,** NESDB, Thailand, 2002, via <URL: http://poverty.nesdb.go.th/poverty_new/pov_incidence/default.htm > (March 6, 2004).
70. Pacudan, R., 2003. **Grid-Based Renewable Energy Promotion in SE Asia: Case of the Philippines and Thailand**, *Proceedings of the Conference on Renewable Energy on the Market,* Sonderborg, Denmark, September 2003.
71. Prasertsan, S. and Sajjakulnukit, B., 2005**. Biomass and biogas energy in Thailand: Potential, opportunity and barriers,** *Renewable Energy,* In Press, Corrected Proof.

72. Ramingwong, T., Lertsrimongkol, S., Asnachinda, P. and Praserdvigai, S., 2000. **Update on Thailand Geothermal Energy Research and Development**, *Proceedings of the World Geothermal Congress*, pp. 377-386, Kyushu-Tohuku, Japan, May 28 - June 10.
73. RERIC- Regional Energy Resources Information Center (RERIC), 2002. **Renewable Energy Technologies in Asia - A Regional Research and Dissemination Programme Phase II: A Summary of Activities and Achievements in the Philippines,** RERIC, AIT, Thailand, 2002.
74. Rosillo-Calle F. and A. B. Cortez L., 1998. **Towards ProAlcool II—a review of the Brazilian bioethanol programme**, *Biomass and Bioenergy,* Volume 14, Issue 2, pp. 115-124, 23 March 1998.
75. Sajjakulnukit, B., 2002. **Policy analysis to identify the barriers to the development of bioenergy in Thailand**, *Energy for Sustainable Development*, Volume VI No. 3, pp. 21-30, September 2002.
76. Sajjakulnukit, B., 2003. Biomass Energy in Asia: The Case of Thailand, presented at The National Dissemination Seminar on Asian Regional Research Programme in Energy, Environment and Climate (ARRPEEC), Bangkok, Thailand, April 2003, via <URL:http://www.arrpeec.ait.ac.th/news/dissemination/Biomass%20Thailand%20Presentation.ppt > (July 21, 2004)
77. Sajjakulnukit, B., and Verapong, P., 2003. **Sustainable Biomass Production for Energy in Thailand**, *Biomass and Bioenergy*, Volume 25, Issue 5, pp. 557-570. November 2003.
78. Srisovanna, P., 2004. **Thailand's Biomass Energy,** *paper presented at Electricity Supply Industry in Transition: Issues and Prospect for Asia,* AIT, Thailand, January 2004, via <URL: http://www.cogen3.net/doc/countryinfo/thailand/ThailandBiomassEnergy_report.pdf> (July 22, 2004).
79. Shrestha, R.M., Kumar, S., Tudoc, M.J. and Sharma, S., 2004. **Institutional Reforms and their Impact in Rural Electrification: South and Southeast Asia**, Sub regional technical report by Asian Institute of Technology, prepared for GNESD, Thailand, April 2004.
80. SMIs in Asia, 2002. **Special Issue: Desiccated Coconut Industry**, SMIs in Asia Newsletter, AIT, Thailand, March 2002, via <URL: http://www.serd.ait.ac.th/smi2/Newsletter%20Special%20Issue%20-%20DC%20-%20March%202002.pdf > (January 24, 2004)
81. Somashekhar, H.I, Dasappa, S. and Ravindranath, N.H., 2000.**Rural bioenergy centres based on biomass gasifiers for decentralized power generation: case study of two villages in southern India**, *Energy for Sustainable Development,* volume IV No. 3, pp. 55-63, October 2000.
82. Soponronnarit S., 1995. **Solar drying in Thailand**, *Energy for Sustainable Development,* Volume II No. 2, pp. 19-25, July 1995.
83. Srisovanna, P., 2004. **Thailand's Biomass Energy,** *paper presented at Electricity Supply Industry in Transition: Issues and Prospect for Asia,* AIT, Thailand, January 2004, via <URL: http://www.cogen3.net/doc/countryinfo/thailand/ThailandBiomassEnergy_report.pdf> (July 22, 2004).
84. Sriuthaisiriwong, Y., 2000. **A Study of PV Pumping and Battery Charging Stations in Thailand**, Master Thesis, AIT, Bangkok, Thailand
85. Sriuthaisiriwong, Y. and Kumar, S., 2001. **Rural Electrification Using Photovoltaic Battery Charging Stations: A Performance Study in Northern Thailand**, *Progress in Photovoltaics: Research and Applications*, Volume 9, Issue 3, pp. 223-234, 2001.
86. Sørensen B., 2004. *Renewable Energy: Its physic, engineering, environmental impacts, economics & planning,* Third Edition, Elsevier Academic Press, 2004.
87. Szwarc, A. 2004. **Fuel Ethanol Production and Use: A Technical Overview**, *presented at the Conference on Biofuels: Challenges for Asia Future*, Bangkok, August 30, 2004.
88. Wongsapai, W., 2004a. **Electricity from Solar Energy in Thailand (1)**, *Matichon Weekly*, 24 (1245), pp. 29-30, June 25, 2004 (in Thai).
89. Wongsapai, W., 2004b. **Electricity from Solar Energy in Thailand (2)**, *Matichon Weekly*, 24 (1246), pp. 36, July 2 2004 (in Thai).

90. Wongsapai, W., 2004c. **Master plan and Conceptual design of Thailand Energy Museum**, *Report submitted to Department of Alternative Energy Development and Efficiency*, Bangkok, September 2004 (in Thai).
91. World Bank, 2001. **Wind Energy Resource Atlas of Southeast Asia**, Asia Alternative Energy Programme (ASTAE), World Bank, September 2001.

Appendix 1

Summary of Field Survey

1. Village Selection

The field survey was realised simultaneously in 3 villages in 3 different regions as shown in Figure 1-1.

Figure 1-1: Location of the surveyed villages

The villages were chosen according their representativeness (in terms of size, richness, natural resources, climate conditions, use of different energy sources, kind of productive activities) of their respective region. In order to assess previous RETs projects, the villages selected had all one of these technologies implemented (or being implemented).

Due to time constraints, the surveyed villages had to be accessible by road and not too far from Bangkok (up to 6 hours), therefore excluding remote villages not reached by the grid.

2. Data Collection

This survey aimed at emphasising some specific points of energy needs in rural Thailand, in order to facilitate the choice of RETs suitable to satisfy the main energy requirements of the poor. Specifically, it was meant to give a precise idea of **the cost of energy** (both in actual and relative (compared to other expenses) values), to d**etail the different energy requirements** (and fuel used) for each activity and **the type of devices used**.

In each village, the survey focussed on:

- Village head + 3 poor households
- 3 productive activities (agriculture, small scale production, small scale business)
- 2 social services (school, health centre,…)

For each energy consumer interviewed (domestic household, production unit, social service, etc.) the procedure followed was the same:

Socio-Economic Background
Household: Number of people living in the household, main assets, income, etc.
Production unit: Number of units in the village, number of people working in this particular unit, quantity produced, unit selling price of the quantity, etc,…
Social Service: number in the village, number of people working, number of users, etc.

Energy requirements and the way they are currently satisfied
List of energy requiring devices
Power consumed by each particular device
Hours of use per day/month
Fuel used
Main problems encountered
Monthly expenditure for the different fuels used

General Expenditures
List of monthly expenses not related to energy

3. Villages Surveyed

Table 1-1: Summary of surveyed villages

	Village 1	Village 2	Village 3
Name	Sisurat	Klong-Hra-Lon	Nong-Jig
Region	Central	North	North-East
Province	Ratchaburi	Phitsanulok	Nakhon Ratchasima
Total Population	2,026	349	456
Area of cultivated land	1,129,600 sq.m.	4,438,400 sq.m.	960,000 sq.m.
N° of small scale enterprises	1 factory Coconut	2 factories Banana drying Organic fertilisers	0
N° of small scale Businesses	1 hotel 8 shops	7 shops	3 shops

Number of Schools	1	1	1
Level of School	Primary school	Primary school	Kindergarten, primary school, secondary school, high school
Number of health centers	None	1	1
Surveyed productive activity 1	Lemon, olive, rose-apple, farm	2 factories Banana drying Organic fertilisers	Restaurant
Surveyed productive activity 2	Coconut factory	Banana drying Banana leaves fertiliser	Rice farm
Surveyed productive activity 3		Restaurant	Pig Farm
Number of Schools	1	1 (shared between 4 villages)	1 (shared between 2 villages)
Health Services	School	School/Health Centre	School/Health Centre
RETs surveyed	Coconut shelves charcoal	Improved banana drying	PV pumping

4. Results

Table 1-2: Share of energy consumption of poor rural households in Thailand

	Village 1 (Central)	Village 2 (Northern)	Village 3 (North-Eastern)
Cooking	63 %	40 %	41%
Convenience	11 %	15 %	17%
Lighting	4 %	7%	13%
Transportation	18 %	32 %	13%
Entertainment	4 %	4 %	5%
Others	1%	2 %	1%

Table 1-3: Expenses breakdown of poor rural households in Thailand

	Village 1 (Central)	Village 2 (Northern)	Village 3 (North-Eastern)
Food	76%	49%	65%
Communication	3%	16%	2%
Energy	19 %	25%	28%
Maintenance	1 %	5%	4%
Others	1 %	5%	1%

Figure 1-2: Share of energy consumption for two different production activities

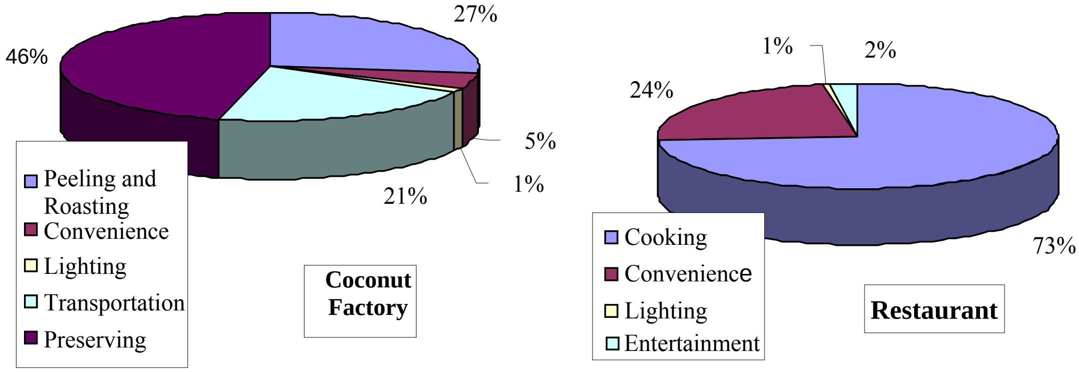
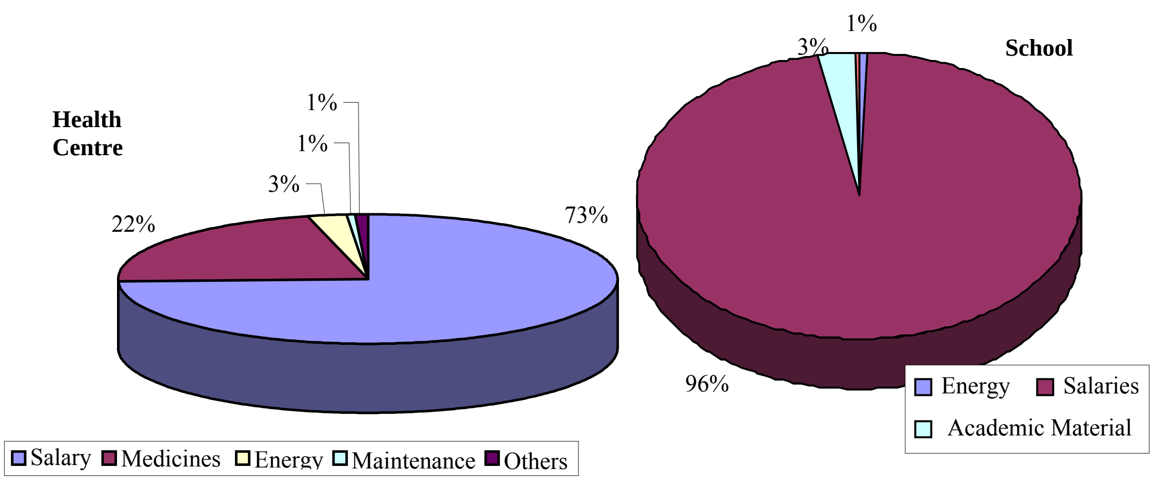


Figure 1-3: Example of share of energy expenses in the total running cost of a health centre and a school in rural Thailand



Appendix 2

Regional Data of Potential of Renewable Energy in Thailand

Figure 2-1: DEDE's solar map of Thailand

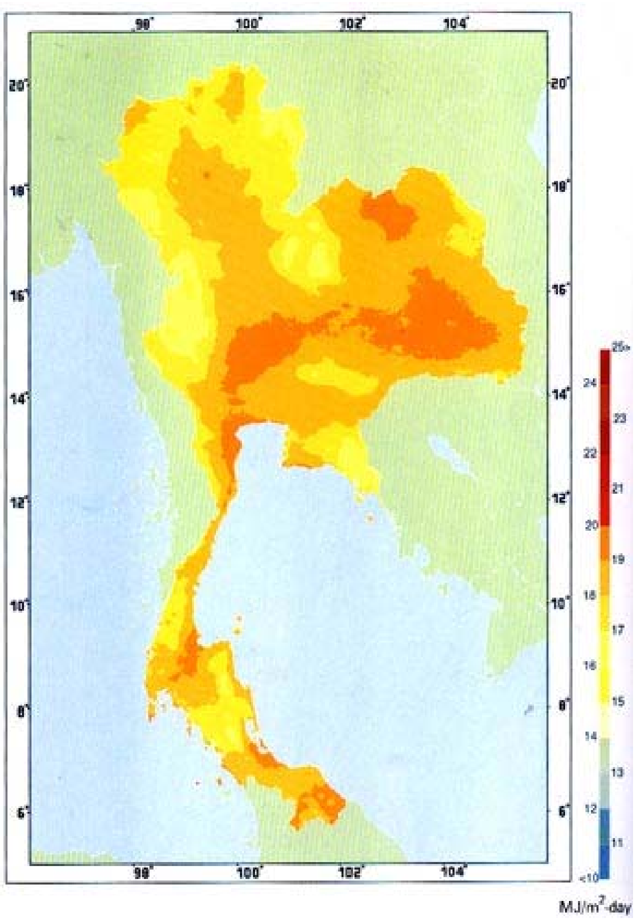
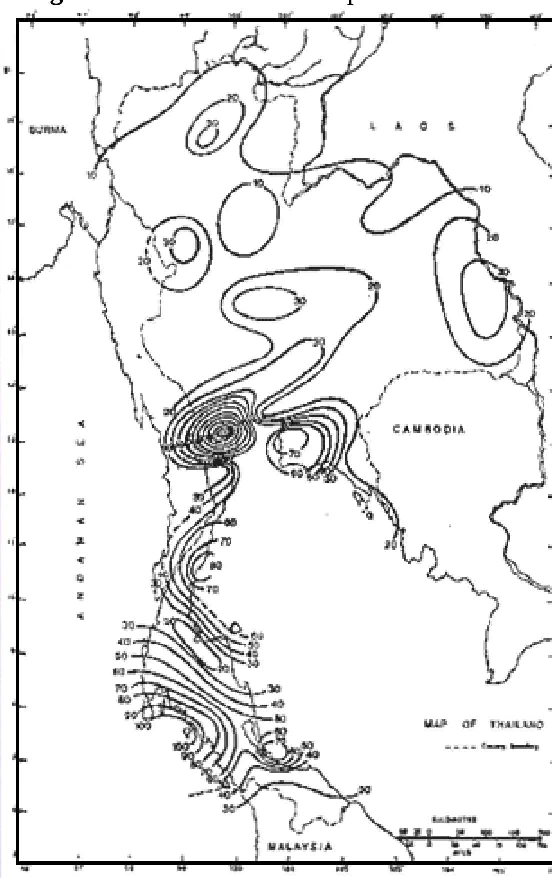
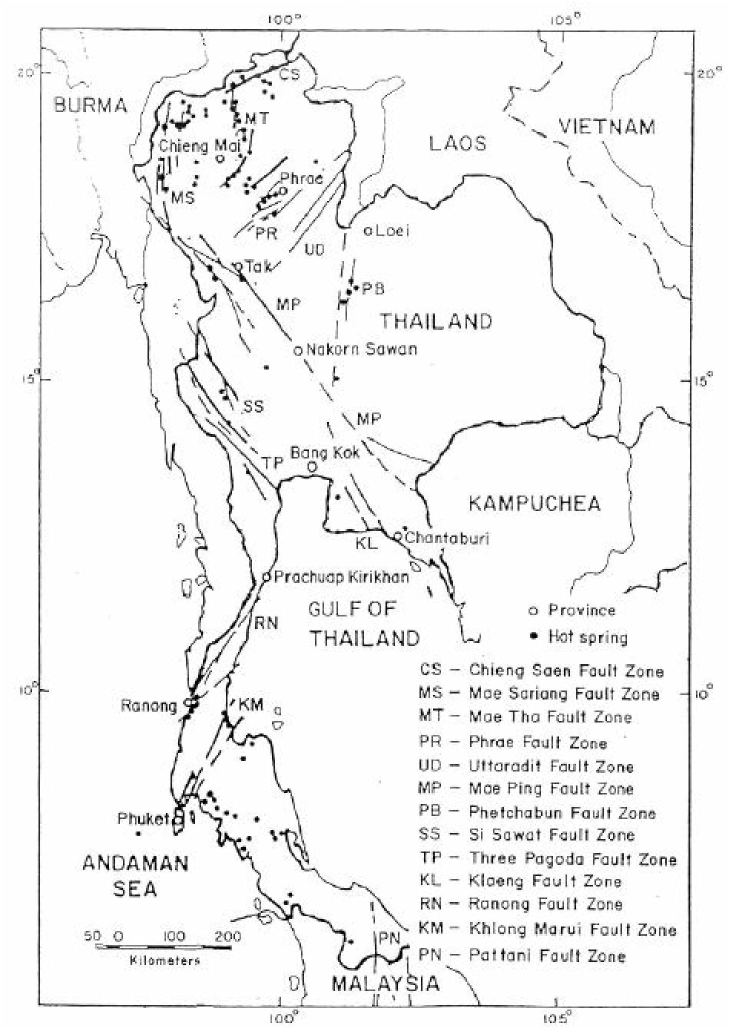


Figure 2-2: DEDE's wind map of Thailand



Source: DEDE (1999)

Figure 2-3: Major fault zones and hot springs in Thailand



Source: Ramingwong et al (2000)

Table 2-1: Agricultural residues availability and Recoverable Energy Potential (REP)

Agriculture Product	Production (kt/year)	Residue Name	Residue Generated (kt/year)	Surplus Availability Factor[105]	Available Residue (kt/year)	Recoverable Energy Potential (REP) (PJ/year)
Sugarcane	56,394	Bagasse Top &Trashier	14,099 17,031	0.207 0.986	2918 16793	24.25 146.01
Paddy	22,332	Husk Straw (top)	5,136 9,982	0.469 0.684	2409 6828	34.37 69.95
Cassava	18,084	Stalk	1,591	0.407	648	11.93
Maize	4,533	Corn cob	1,133	0.670	759	13.70
Oil palm	2,688	Empty Bunches Fiber Shell Frond Male bunches	1,150 395 132 7,000 626	0.584 0.134 0.037 1.000 1.000	672 53 5 7000 626	12.00 0.93 0.09 68.78 10.23
Coconut	1,419	Husk Shell Empty bunches Frond	514 227 70 319	0.595 0.378 0.843 0.809	306 86 59 258	4.96 1.54 0.90 4.13
Groundnut	147	Shell	47	1.000	47	0.6
Cotton	75	Stalk	242	1.000	242	3.51
Soybean	359	Stalk, Leaves, Shell	956	0.760	727	14.13
Sorghum	225	Leaves & Stem	282	0.648	183	3.51
Total	**106,256**		**60,933**		**40,618**	**425.51**

Source: Sajjakulnukit (2003)

[105] Ratio of available residue /total residue generated.

Appendix 3

Table 3-1: Policy outlines for objective 1

To make RETs economically competitive compared to conventional sources of energy.		Internal Factors	Weaknesses	Strengths	
			Conflicting priorities (e.g.: diesel prices kept low to encourage economic growth)	Government already inclined to promote RETs	Funds available for RETs promotion initiatives (ENCON Fund)
External Factors					
Threats	High cost of some RETs components			Making RETs imports financially more attractive	Providing financial incentives for RETs manufacturers
	Potential public opposition to removal of subsidies to fossil fuels			Promoting RETs for creation of income generating activities and reducing energy expenditures in the long run	Providing financial incentives for RETs users
	Potential public opposition to high cost of RETs electricity generation			Promoting electricity producing RETs reducing energy expenditures in the long run	Providing financial incentives for RETs electricity producers
Opportunities	Examples of successful pricing policies favourable to RETs available			Reflecting the real costs of conventional sources	Providing financial incentives for RETs users
	Rising and unstable international prices of oil and gas		Assessing the long term eeconomic impact of the current subsidy plans	Reflecting the real costs of conventional sources	

Table 3-2: Policy outlines for objective 2

To raise awareness on RETs and their applications throughout the country		Internal Factors	Weaknesses		Strengths
			Lack of targeted campaign and information available on RETs	Lack of RETs lobby	Campaign for energy efficiency already implemented ('Divided by 2')
External Factors					
Threats	Familiarity of the users with conventional energy sources		Demonstration of promising RETs		Using existing structures to promote mature RETs and ensure accessibility of the campaign to the most remote communities as well as to less educated and ethnic minorities
	There is a low level of understanding of energy issues and communication in the remote areas is difficult		Including RETs classes in School programmes		Using existing structures to promote mature RETs and ensure accessibility of the campaign to the most remote communities as well as to less educated and ethnic minorities
Opportunities	Strong/good availability of media and network		Diffusing success stories of RETs for creation of income generating activities and reducing energy expenditures in the long run	Encouraging the creation of a RETs lobby	
	Good physical Infrastructures (roads, electricity grid) available		Diffusing success stories of RETs for creation of income generating activities and reducing energy expenditures in the long run	Sharing experiences among the different stakeholders	

Table 3-3: Policy outlines for objective 3

To make mature RETs appropriate to the different local conditions available in the national market.		Internal Factors	Weaknesses			Strengths
			Insufficient research and development for RETs	Lack of adequate mechanisms of transfer of technology	Lack of initiatives locally to produce appropriate RETs based technologies	Infrastructure for local production of RETs exist
External Factors						
Threats	High cost of developing mature RETs				Encouraging development of low cost locally produced RETs	Giving financial incentives for RETs manufacturers
	Familiarity of the users with conventional energy sources				Encouraging development of low cost locally produced RETs	Giving financial incentives for RETs manufacturers
Opportunities	Large resource potential exist throughout the country		Increasing R&D to make RETs appropriate to the local conditions	Promoting international network of knowledge and technology transfer		

Table 3-4: Policy outlines for objective 4

To implement RETs that match users needs		Internal Factors	Weaknesses		Strengths		
			Lack of users' participation in RETs programme design	Lack of technical capability to adapt RETs to users needs	Some academic institutions already active in the field and working with communities	Existence of implementing agencies	Examples of successful application of some RETs to satisfy local needs
External Factors							
Threats	Preference of RETs manufacturers and suppliers to build/produce standard units				Encouraging RETs producer to diversify each given model of RETs in terms of size, capacity and types of application	Encouraging RETs producer to diversify each given model of RETs in terms of size, capacity and types of application	
Opportunities	Large resource potential exist throughout the country		Encouraging the implementing agencies to include the users in the design process to assess the needs	Training the users and some local staff for maintenance and repair in a language they can understand	Encouraging the implementing agencies to assess the potential for RETs before implementation	Encouraging the implementing agencies to assess the potential for RETs before implementation	Scaling up applications from demonstration sites
	Possibility to import some RETs to match users needs				Making RETs imports financially more attractive	Making RETs imports financially more attractive	Scaling up applications from demonstration sites

Table 3-5: Policy outlines for objective 5

To properly install, operate and maintain RETs		Internal Factors	Weaknesses				Strengths
			Lack of investment in building capacity of users for certain RETs	Lack of staff for regular maintenance for certain RETs	Some RETs are made available free of cost to users	Spare parts are not readily available	Existence of some local initiatives of users training
External Factors							
Threats	Remoteness of some areas and language barriers faced by some users		Training the users and some local staff for maintenance and repair in a language they can understand	Training the users and some local staff for maintenance and repair in a language they can understand			
Opportunities	Training facilities and other infrastructures for proper maintenance and operation exist.		Training the users and some local staff for maintenance and repair in a language they can understand	Training the users and some local staff for maintenance and repair in a language they can understand	Implementing a pay per use service	Encouraging RETs spare parts supplier to use existing infrastructure	Scaling up local initiatives of users training

Table 3-6: Policy outlines for objective 6

To develop the agricultural residues market to benefit all the stakeholders		Internal Factors	Weaknesses			Strengths
			Lack of awareness among residues producers and users	Lack of standards for residues	Residues do not belong to the farmers but to the actual producers (e.g. rice mills)	Existence of capacity for biomass based RETs
External Factors						
Threats	Opportunity cost of residues highly fluctuating.					Implementing financial mechanisms to reduce the financial risk of residues based RETs projects
Opportunities	Environmental improvement and avoidance of disposal cost through use of residues as fuel		Promoting biomass based technologies as a way to reduce/avoid disposal cost and to reduce local pollution		Sharing the benefits of residues based RETs among the different stakeholders	
	Large quantity of residues available		Linking the residues producers with the potential users	Defining standards for residues		

Table 3-7: Policy outlines for objective 7

Implementation of RETs based projects by qualified government staff		Internal Factors	Weaknesses	Strengths
			Non specialist staff still implementing RETs	Creation of a government entity to implement RETs
External Factors				
Threats	More benefit package for qualified staff in the private sector			Diffusing success stories of RETs for creation of income generating activities,
Opportunities	Existence good education/training facilities in the country		Investing in staff capacity building	Investing in staff capacity building
	Government policies and programmes to promote RETs		Investing in staff capacity building	

Appendix 4

GNESD Global Network on Energy for Sustainable Development, Facilitated by UNEP	UNEP	Asian Institute of Technology 1959

Questionnaire on Barriers to RETs development in Thailand and appropriate policies to overcome them

Asian Institute of Technology (AIT) in Bangkok is one of the eight centres of excellence of the Global Network on Energy for Sustainable Development (GNESD) (www.gnesd.org), facilitated by UNEP. In the frame work of this network, AIT is carrying out research on the role of renewable energy for productive uses in rural Thailand. An initial assessment report has been prepared.

The report briefly presents the socio-economic background of Thailand and highlights the energy needs in rural Thailand. Few Case studies and examples of use of RETs for productive uses in rural Thailand are described. This leads to the identification of barriers related to RETs diffusion and utilization. Possible policies that could help to overcome the identified barriers are then presented.

After having organized a workshop on 19 October to present its key findings, AIT's GNESD research team has drafted the second part of its report on identification of barriers to RETs diffusion and utilization and policy options to overcome them. This second part is attached herewith.

The third part of this study is to report the stakeholders' reactions to the identified barriers and policy options.

In that respect, we would like to request your kind cooperation by providing us your valuable input on the questions given below.

Best Regards,

AIT Research Team

1) Do you think any important barriers to RETs in Thailand are missing in the report?

[ ] Yes [ ] No

2) If Yes, please list them

a)

b)

c)

Any other comments on the barriers

3) Do you think any important policies to RETs in Thailand is missing in the report?

[ ] Yes [ ] No

4) If Yes, please list them

a)

b)

c)

d)

e)

f)

5) Please, detail your opinion for each of the presented policies

Examples:

a) Implementing financial mechanisms to reduce high investment costs

Relevance:

[ ] Poor [ ] OK [ ] Good [ ] Excellent

Feasibility:

[ ] Poor [ ] OK [ ] Good [ ] Excellent

Your personal Reaction:

[ ]Support [ ] Acceptance [ ] Conditioned Support

[ ] Opposition [ ] Indifference

Please briefly detail your reaction (for ex: how can it be implemented, why is it not feasible, why do you support/not support this policy, etc.):

Any Other comments on the policy?

We would like to thank you very much for your time and your valuable input

Appendix 5

Table 5-1: Stakeholders reactions/comments to the suggested policy outlines

Policy Option	Government (DEDE) (1)	Government (EPPO) (1)	International Organisations (3)	Research Institutions (2)
Financial Mechanisms	**Conditional Support** - If appropriate (i.e., low cost) technologies is used for communities, there is no financial support - Users should pay at least 50% of RETs cost and this money could be given to local community energy fund.	**Support** - Subsidy from ECON fund - Government has agreed on a policy on tax exemption, tax reduction, etc.	**Support** - Smart subsidies and incentives. - Analysis of cost structure of RETs. - Both financial and economic analyzes have to be conducted for every RETs project.	**Support** - 100% subsidy given to users is not sustainable. - Subsidies do encourage producers, but not for individual users.
Removing subsidies on oil and electricity	**Support**	**Indifferent** - The RTG plans to remove diesel subsidy in 2005, but this will not influence RETs promotion.	**Support** - Oil and electricity subsidy causes pricing distortion and makes RETs uncompetitive.	**Support** - Low subsidized price of oil and electricity makes RETs uncompetitive. - Since electrification level through the grid is high, RETs are feasible only in the most remote areas.
Internalising external costs of energy	**Support** - Carbon credit will be profitable in future.	**Support** - RTG has no plan regarding this in the near future.	**Support** - Should be brought in gradually	**Conditional Support** - Best measure but not feasible due to political considerations
Diversifying RETs promoted	**Support** - Solar and biomass are the most promising RETs in Thailand. - Local and simple technologies (solar dryers, charcoal kilns, improved stoves, etc.) should be encouraged	**Support** - Solar and biomass are the most promising RETs in Thailand.	**Support** - Solar, biomass and biogas have good potential. - Location, the needs and quality of energy required should influence the kind of RETs to be promoted	**Support** - Especially, focus on local know-how.
Promoting local manufacture of RETs	**Support** - The most appropriate technologies should be developed. - Focus should be on low cost	**Support** - Financial incentives would have better effect if used to encourage manufacturers.	**Support** - Replace subsidies with incentives for manufacturers - Analyze carefully the demand, not	**Support** - With financial mechanisms. - Subsidy to manufacturer is more effective than to users.

	technologies		to have too many manufacturers	
Awareness Campaign	**Support (for rural areas)** - Easily-accessible Information centers should be implemented in rural areas.	**Support (for rural areas)**	**Support (for rural areas)** - Should pin-point the benefit that rural participants would earn.	**Conditioned Support** - Not primordial, should focus on rural areas and on proven technologies
Developing Biomass Market	**Support** - Promote long term contracts with a fixed guaranteed price of biomass.	**Support** - Benefits of biomass based RETs should be distributed to all stakeholders	**Support** - Benefits of biomass based RETs should be distributed to all stakeholders. - Market should not be controlled by the government	**Support** - Government should not control the market price. - A part of the residues production could be dedicated to energy
Involving the users in the design process	**Support** - Primordial measure - Each member of the community should decide of the technology they need and want to use	**Support**	**Support** - Primordial measure - Top down approach created many problems in the past.	**Support**
Making the users pay for their consumption	**Support**	**Conditioned Support** - Users should pay according to their financial possibilities.	**Conditioned Support** - This is the ultimate goal, but to start with, free use is a good measure.	**One Support, One Opposition** - Support: Make the users better use their system - Opposition: Not feasible for the poorest. If poorest do not need to pay, other classes will not agree to pay.
Promoting ESCO	**Conditioned Support** - ESCO is appropriate for large scale RETs based project but not at the community level.	**Indifference**	**Conditioned Support** - Good thing but demand should increase first.	**Indifference** - Not a priority, will take time to have reliable RESCO
Network of Stakeholders	**Support** - Workshop, conferences, etc. could be organized to create cooperation of stakeholders	**Support**	**Indifference**	**Support** - Already exists in the case of biogas in Northern Thailand.
Power wheeling	**Support (but not yet feasible)** - Agree that it would have good	**Support (but not yet feasible)** - Agree that it would have	**Support (but not yet feasible)** - Power sector needs to be	**One Support, One Opposition**

	impacts for RETs promotion. - Monopoly of electricity generation is a barrier to the successful implementation of such a policy.	good impacts for RETs promotion. - Monopoly of electricity generation is a barrier to the successful implementation of such a policy.	reorganised first. - Privatization of EGAT is needed	- Support: Energy intensive consumers should be forced to invest in RETs - Opposition: Not feasible because of the low cost of grid electricity.
Green Pricing	**Support (but not yet feasible)** -Agree that it would have good impacts for RETs promotion. - Monopoly of electricity generation is a barrier to the successful implementation of such a policy.	**Support (but not yet feasible)** - Agree that it would have good impacts for RETs promotion. - Monopoly of electricity generation is a barrier to the successful implementation of such a policy.	**Support (but not yet feasible)** - Good measure should be compulsory for large consumer with a strong campaign. -Privatisation of EGAT is also a first step to implement such a policy.	**Conditioned Support** - It might work only in urban areas and for domestic uses.
Other Suggestions	None	- Government policy on RETs is clear now, but the strategy to be implemented is still vague.	None	- General coordination of agencies dealing with RETs in Thailand should be improved. - RETs should be promoted first in energy intensive sectors.