EVALUATION OF CONDITIONS FOR ELECTRICITY PRODUCTION BASED ON BIOMASS

Final Report

by

The EC-ASEAN COGEN Programme
Bangkok, Thailand

for

RAMBOLL

August 1998

The EC-ASEAN COGEN Programme is an economic cooperation programme between the European Commission (EC) and the Association of South-East Asian Nations (ASEAN) coordinated by the Asian Institute of Technology (AIT), Bangkok, Thailand. Its aim is to accelerate the implementation of proven technologies generating heat and/or power from wood and agro-industrial residues.

TABLE OF CONTENTS

Title		Page
List of Figures		i
List of Tables		ii
Executive Summary		iii
Introduction		1
Chapter 1.	Identification of Major Biomass Sources in Thailand	2
	1.1 Agricultural sectors	2
	1.2 Wood sector	5
Chapter 2.	Availability of Biomass Residues	17
	2.1 Determining Crop-to-Residues-Ratio	17
	2.2 Sugar cane residues	18
	2.3 Paddy residues	19
	2.4 Oil palm residues	22
	2.5 Coconut residues	23
	2.6 Wood processing residues from sawmills and plymills	24
	2.7 Eucalyptus dendrothermal plantations	26
Chapter 3.	Assessment of the Potential Resources for Electricity Production from Biomass Residues Based on Proven Technology	27
	3.1 Power potential at the mills/industry level	27
	3.2 Other uses of biomass residues	31
	3.3 Summary	33
Chapter 4.	Assessment of Possible Major Potential Resources Likely to be Exploitable in the Near Future Provided Specific Obstacles are Removed	34
	4.1 Sugar cane residues	34
	4.2 Paddy residues	34
	4.3 Oil palm residues	35
	4.4 Coconut residues	35
	4.5 Dendrothermal power from Eucalyptus	36
Chapter 5.	Major Technologies for the Exploitation of Renewable Energy Sources	37
	5.1 Technology characterisation	37
	5.2 Comparison of the combustion technologies	49
	5.3 Biomass conversion technologies in Thailand for power generation	50
Chapter 6.	The Technological Infrastructure of the Main Technologies and Barriers Towards Successful Dissemination of the Technologies	51
	6.1 The technical component	51
	6.2 The human component	53
	6.3 The information component	53
	6.4 The organisational component	54
Chapter 7.	Assessment of the Financial Situation with Focus on the Major Sub-Sectors Identified	58
	7.1 Market outlook for wood and agro-industries	58
	7.2 Sources of finance	60
Conclusion		64
References		

List of Figures

Figure 1. Sugarcane production in Thailand by province, 1995/96
Figure 2. Sugarcane production density in Thailand by province, 1995/96
Figure 3. Location and milling capacity of sugar mills in Thailand, 1994/95
Figure 4. Paddy production by province in Thailand, 1995/96
Figure 5. Paddy production density by province in Thailand, 1995.96
Figure 6. Number of rice mills with milling capacities of 5 tph and over, per province in Thailand, 1996
Figure 7. Fresh fruit bunch production by province in Thailand, 1995
Figure 8. Fresh fruit bunch production density by province in Thailand, 1995
Figure 9. Location of palm oil mills in Southern Thailand
Figure 10. Log production by province in Thailand, 1995
Figure 11. Rubber wood flow from plantation to products
Figure 12. Energy requirement and supply in the sugar industry
Figure 13. Energy requirement and supply in the rice industry
Figure 14. Energy requirement and supply in the palm oil industry
Figure 15. Energy requirement and supply in saw mills
Figure 16. Energy requirement and supply in plymills
Figure 17. Fixed bed gasifiers
Figure 18. Steam injected gas turbine
Figure 19. Intercooled steam-injected gas turbine
Figure 20. Integrated gasification combined cycle
Figure 21. Fuel cell

List of Tables

Table 1. Production in the sugar, rice and palm oil sectors of Thailand (in tonnes), 1990-1995
Table 2. Number of rice mills by region in Thailand, 1991-1995
Table 3. Registered planters and planted areas of oil palm, 1994
Table 4. Production trends in the coconut and cassava sectors of Thailand (‘000), 1990-1996
Table 5. Trends in log production for Thailand (excluding rubber wood), 1990-1995
Table 6. Sawmills and plymills per region in Thailand, 1996
Table 7. Crop-to-residue ratios of various agricultural crops in Thailand
Table 8. Residues from harvesting and processing of sugar cane per province in Thailand, 1995/96
Table 9. Fuel characteristics of bagasse
Table 10. Residues from harvesting and processing of paddy per province in Thailand, 1995/96
Table 11. Fuel characteristics of rice husks
Table 12. Fuel characteristics of rice straw
Table 13. Residues from the processing of FFB per province in Thailand, 1995
Table 14. Characteristics of FFB residues
Table 15. Residues from the processing of coconuts in Thailand, 1995/96
Table 16. Fuel characteristics of coconut residues
Table 17. Log production per province in Thailand, 1996
Table 18. Potential rubber wood waste power generation in Thailand, 1997
Table 19. Biomass energy balance table for Thailand, 1993-1995
Table 20. Characteristics of palm oil mill effluent and the Department of Environment (Malaysia) Standards
Table 21. Combustion on grate - examples
Table 22. Atmospheric fluidised bed combustion - examples
Table 23. Co-firing - example
Table 24. Atmospheric gasification - example
Table 25. Whole tree energy concept - example
Table 26. Steam injected gas turbine (STIG) concept - example
Table 27. Integrated gasification combined cycle (IGCC) concept - example
Table 28. Qualitative evaluation of combustion technologies
Table 29. Wood residue versus energy requirements in the wood-based industry
Table 30. Summary of barriers and ways to overcome them
Table 31. Major rice exporters, 1994-1998
Table 32. Wood production and consumption, 1990-1996
Table 33. Export credit agencies
Table 34. Different funding schemes and their sources

EXECUTIVE SUMMARY

Rationale of the Study

Thailand's increasing consumption of fossil fuels, and consequently, a growing dependence on fuel imports poses to be one of the major challenges the Thai government faces to-date. As a response, the National Energy Policy Office (NEPO) has elaborated on a programme to stimulate the development and efficient use of renewable energy in the country. The Danish Energy Agency together with the Danish consulting company Ramboll, and other selected specialists, are assisting NEPO in developing a renewable energy strategy and an action programme for the promotion of biomass and waste utilisation, solar electrical, solar thermal and wind energy.

As part of the overall programme, the EC-ASEAN COGEN Programme has been commissioned to conduct a study on conditions for electricity production based on biomass in Thailand. The study is aimed at providing background information for NEPO for prioritising the resources available for the promotion of renewable energy, to provide information necessary for analysing the financial, economic and environmental implications of possible pricing incentives, and to identify the main barriers in the dissemination of the utilisation of biomass for energy purposes.

Biomass Energy Sources in Thailand

Biomass is an important renewable source of energy and has been used to provide energy to human activities. In the rural areas of Thailand where energy markets do not exist, biomass fuels are not traded and are mostly home-grown or collected by family labour. In energy markets where modern technology and competition dictates the use of more efficient and clean fuels, biomass is gaining an increased commercial value.

The Food and Agriculture Organization cites that biomass (including wood fuels) contributes more than one-third of the energy in Thailand, wherein two-thirds are consumed in the residential sector (mostly rural households for domestic energy needs) and the rest in industries. From 1993 to 1995 alone, a 13% increase in biomass consumption in Thailand was recorded. Supply of biomass is available from various sources: forests, wood plantations, agricultural and industrial residues, and even municipal solid wastes. Waste products from wood and agro-industries are the least expensive and most accessible. The next cheapest sources would be wood fuels available from plantations and home backyards. The availability of the biomass, however, can be restricted by the availability of land for planting, crop patterns and season.

The sugar, rice and oil palm sectors are the three major potential biomass energy sources in the country. Sugar and rice are mostly concentrated in the North and North-eastern provinces of the country, while palm oil is found mostly in the Southern provinces. Residues obtained from the harvesting and milling of the agricultural produce can be utilised as fuel for energy generation (either in the form of power, heat, or both power and heat). The table below shows the national production trends in tonnes of sugarcane, paddy and oil palm from 1990 - 1995.

Crop year	Sugarcane	Paddy	Oil Palm (Fresh Fruit Bunch)
1990/91	40,660,624	17,193,000	1,191,769
1991/92	47,479,508	20,400,000	1,315,990
1992/93	39,826,701	19,917,000	1,351,917
1993/94	37,822,875	18,447,000	1,526,416
1994/95	50,597,339	21,111,000	1,817,806
1995/96	57,973,760	22,016,000	2,255,450

Source: Office of Agricultural Economics, 1996a

The wood industry is also a major source for biomass energy. This includes residues from teak logs which are highly concentrated in the Northern and Southern parts of the country, and rubber wood mostly found in the South. Eucalyptus plantations which abound in the North-eastern provinces are also a major potential source for wood residues.

Electricity Production from Biomass Waste

The processing of biomass in the industrial mills in Thailand result to a large production of residues. These residues are considered wastes and are disposed off through various methods such as open burning and dumping. One of the more useful uses of these residues is as fuel for the mills' heat and power requirements. In general, the residues are utilised in very inefficient systems, which most often than not, also cause environmental problems. Technological developments in the energy sector now allows for the utilisation of these residues in a more efficient and clean manner. Proven technologies for heat and power generation in industrial mills are now available in the market, and the uptake of these technologies in Thailand could result to energy self-sufficiency in the mills. Moreover, the mills would gain economic and environmental benefits in the process.

Biomass residues availability. Based on Crop-to-Residues-Ratios (CRR) for rice husks, bagasse, palm oil residues (except palm oil mill effluent), and wood, it has been estimated that about 26 million tonnes of residues were produced from the rice, sugar, palm oil and wood industries of Thailand in 1995. This is summarised in the table below.

Sector	Residues (tonnes)	Primary Energy (ktoe)
Sugar - bagasse	16,812,390	3130
Rice - rice husk	4,843,520	2347
Palm Oil - fibre + shells + empty fruit bunch	947,290	222
Wood - wood residues	342,453	93

Technical power potential and structural power capacity. Among the biomass sectors, there is high potential for electricity production in the sugar, rice, oil palm and wood industries. Using proven technologies, fuels have been more or less limited to bagasse in the sugar industry, rice husks in the rice industry, fibres + shells + empty fruit bunches in the palm oil industry, and wood residues in the wood industry.

The potential for electricity production can be viewed in two ways: the technical power potential and the structural power capacity. The former is the power potentially available if all residues are utilised in energy systems, calculated from the energy content of the residue and without taking into account the industry structure and system efficiencies of the mills. The latter refers to the power capacity that could be installed in mills that have processing capacities above the minimum threshold for which energy systems are appropriate. The calculation takes into account the size and milling duration of the mill.

Based on some assumptions regarding the biomass sectors and the agro-industries in Thailand, as well as the technology involved, the following results have been obtained from the study:

Sector	Residue	Theoretical Power Potential	No. of mills in Thailand		Structural Power Potential
			Total	Above min. size	
Sugar	Bagasse	5797 GWh/year	46	46	1900 MW
Rice	Rice husk	2422 GWh/year	>44000	78	66MW
Oil Palm	EFB+Shell+Fibre	379 GWh/year	15	15	69 MW
Wood	from log production	86 GWh/year	777	data not available	data not available
Wood	from rubber wood	data not available	about 200	data not available	950 MWe

Future prospects for biomass fuels. The potential for exploiting biomass residues other than those already identified is still quite huge, e.g. cane trash in the sugar industry, rice straw in the rice industry, palm oil mill effluents in the palm oil industry, coconut residues in the coconut industry, and dendro power from plantations. Harnessing such potential is still constrained by factors such as inappropriate technologies, other competitive uses of the residues (especially for higher value-added products), lack of information on the residues (as related to the level of research and development efforts), etc.

Technologies for the Exploitation of Biomass Energy Sources

Biomass conversion technologies can be classified into three categories: traditional, state-of-the-art, and emerging technologies. Traditional technologies are conventional technologies which have been used for a long time without any technological barrier. Most of the existing technologies employed in Thai industries belong to this category. System (boiler) efficiencies may range from 50% to above 80% and may have none or minimal environmental features to meet current environmental standards.

State-of-the-art technologies are currently available in the market, with minimal developmental barriers, although its uptake is still limited to a few industries. Considered more efficient and more environment-friendly than traditional technologies, these types of technologies have mainly been taken into account in this study, especially in deriving the structural power capacity in Thai agro-industries.

Emerging technologies are long-term technologies requiring further research before commercialisation can be considered. There is very little information about the uptake of such technologies in Thailand even on a pilot or demonstration scale.

A qualitative evaluation of combustion technologies are presented in the table below.

Criteria	Pile Burners		Stoker Boilers			Suspension Boilers	Atmospheric Fluid. Bed Comb.	
	underbed fuel feed	overbed fuel feed	stationary sloping grate	travelling grate	vibrating grate		BFB	CFB
Construction related criteria								
- design simplicity	+	++						
- design volume and compactness						+	+	+
- erection speed								
- modest capital cost at small scales	+	+					+	+
Operation related criteria								
- combustion control	+	-	-					
- load response rate	--	--			+	+		
- turn down ratio								
- steam data insensitive for fuel variation			-					
- uninterrupted operation capability	-	-						
- modest start up/shut down time								
- reliability	-	+						
- operation convenience	-	+						
- maintenance friendly				-	+			
- operating experience	++	++	++	++	+		o	o
Fuel related criteria								
- fuel moisture design flexibility	++	++	+	+	++	--	+	+
- fuel size design flexibility	++	++	+	+	+	--	++	+
- fuel moisture switching flexibility	++	++	-	-		--	o	o
- fuel size switching capability	++	++	-	-		--	+	o
- fossil fuel co-firing capability					+	++		
- fuel firing resistance			-				-	-
- boiler tube erosion resistance								-
- explosion safety						-		
Efficiency related criteria								
- boiler efficiency	--	--				+	+	+
- carbon burnout efficiency					+		+	++
- modest excess air requirement							+	+
- modest fan capacity requirement						+	-	--
Emission related criteria								
- NO_x avoidance	-	-	o	o	+		++	++
- acid gases absorption							+	++
- N_2O avoidance							-	-

Source: Broek et al., 1995
Note : From the left to the right, the technologies become more modern.
Plus sign indicates a positive criterion of a plant.
Minus sign indicates a negative criterion of a plant.
O sign indicates a neutral characteristic of a plant.

Barriers and the Successful Dissemination of Biomass Technologies

The successful dissemination of a technology does not depend on the technical aspects of the equipment alone. It is influenced by other factors that are equally or even more important than just the technology. There are four main components in the technological infrastructure of the main technologies identified. These are the technical, human, information and organisational components.

Technical component. The "technical" component refers to the performance and the stage of the development of the technological solutions. This includes aspects such as operational performance, reliability of the equipment, and their references showing that the technologies are proven. Among the barriers related to this component are: lack of successful references/demonstration projects, the perception that advanced equipment are complicated to operate, the difficulty in burning biomass fuels due to its non-homogeneity, etc.

Human component. The "human" component touches on issues related to the people's perception of the technology, as well as some cultural influences in the adaptation of the technology. The barriers related to this component are: energy not being a core business of wood and agro-industrialists, and the risk of being the first to fail. The implementation of demonstration projects and the presentation of successful references are valuable in overcoming these obstacles.

Information component. The "information" component relates to the sources of information available to the potential customers about the use of the technologies, such as their record of references, availability of assistance centres to obtain information regarding equipment suppliers, financing, etc. The barriers that fall within this category are: lack of institutions giving information and advice, lack of awareness among potential users on government rules and incentives, and not enough technical and economic information to make a decision.

Organisational component. The "organisation" component covers aspects related to the structure of the industry, transportation, as well as policy, legal and governmental issues. The barriers identified under this category are: structure of the industry, uncertainty of biomass fuel supply, policy, legal and government issues, and financial barriers.

The table below summarises the different barriers as follows:

Components	Barriers	Possible solution
Technical component	• lack of successful references • seen as complicated to operate • the quality of biomass as a fuel is not homogeneous	⇒ implementation of demonstration projects ⇒ suppliers to simplify operation; training of operators ⇒ adequate testing of samples
Human component	• energy not a core business of potential users • risk of being the first to fail	⇒ create awareness of benefits and opportunities ⇒ references in similar environment; demonstration projects
Information component	• lack of institutions giving information and advice • lack of awareness among users on government rules and incentives • not enough technical and economic information to make a decision	⇒ strengthening of relevant networks ⇒ information drive ⇒ availability of funds or services to conduct feasibility studies
Organisational component	• structure of the industry - size of mills - transportation problems - seasonality • uncertainty of biomass fuel supply • policy, legal and government issues • financial barriers	⇒ thorough investigation of these aspects in the feasibility of projects ⇒ initiatives to boost yield and productivity ⇒ government incentives/ support measures? ⇒ innovative financial strategies; government incentives?

Financial Outlook for the Wood and Agro-Industries in Thailand

It is expected that the rice industry in Thailand will steadily grow. With this, the implementation of energy projects in the mills could also advance. The rubber wood industry, where there exists a steady supply of raw materials from the replanting of rubber wood, also offers a good environment for the implementation of biomass energy technologies. In other industries, the market is not expected to grow compared to the previous years. The two major reasons cited for this are the economic crisis that hit Thailand and the region, and the El Niño phenomenon. The economic crisis may remain for a while, but the situation could improve both for Thailand and the region. Likewise, the effect of El Niño is not expected to last long. Thus, there is reason to believe that, in general, the wood and agro-industries in Thailand could recover in the next few years. By that time, the financial market may also have improved, which will make it easier for the mill owners to decide to invest in modern and highly efficient technologies.

The successful implementation of biomass energy projects is highly dependent on the available financing. Even if the projects are financially viable, traditional sources of finance such as commercial banks are reluctant to finance biomass energy because of the risks involved. However, some multilateral and bilateral institutions have developed specialised credit facilities (e.g. loans, equity and grants) for alternative and renewable energy. The institutions identified are shown in the following table.

Source of Fund	Equity Participation	Loan	Other Schemes
World Bank			guarantees
International Finance Corporation (IFC)	up to 35%	yes	
Global Environment Facility (GEF)	US$20,000-250,000	US$20,000-250,000	
Global Carbon Initiative			investment in emissions reduction
Renewable and Energy Efficiency Fund			preparatory costs
Environmental Fund		yes	
OECFV		yes	
JEXIM		yes	
Export Credit Agencies		low off-market subsidised rates	
EC-ASEAN COGEN Programme			grant
International and Bilateral Agencies			
Environmental Enterprise Assistance Fund		yes	

Innovative strategies for renewable energy financing are also identified. For small scale projects (<1MW), there is a need to develop innovative financial mechanisms to cascade affordable financing to the end-users and to seek assistance for institutional, infrastructure and capacity building. The main financial barrier for small scale/non-grid systems (<1MW) is the inability of most end-users to afford the up-front purchase of renewable energy systems. Financial strategies identified for these systems are finance leasing programs, finance service providers and mortgage financing. In the case of medium scale (1-20MW) and large scale(>20MW) projects, the same financing rules apply as to conventional energy projects. Most of these projects are normally proposed by national utility companies, rural electric cooperatives or private sector companies that can be financially appraised and held financially responsible. Normally these projects will require backing of various investment and risk insurance.

Given the rapidly expanding needs for financing renewable energy projects, several emerging innovative financing mechanisms have evolved. Some these mechanisms are: third party financing through an energy service company (ESCO); leases; vendor credits; targeted project credits; direct consumer credits; acceptance of equipment as collateral by suppliers; support for project preparation and development; the Global Environment Facility (GEF); and activities implemented jointly (AIJ) by two or more countries.

INTRODUCTION

Thailand, being a highly agricultural-based country, produces huge amount of biomass residues annually. In 1995, an estimated 26 million tonnes of residues were produced from four of its large agricultural sectors, namely, rice, sugar, palm oil, and wood industries. More often than not, these residues are simply left in the fields, or disposed off by farmers and millers through open-burning.

The potential for utilising biomass residues as fuel has already been widely documented. This may range from its use as a landfilling material, filler in brick manufacturing, biogas production, fuels for simple cooking stoves in households (e.g. rice husks or wood), for power or heat generation in conventional combustion systems (e.g. bagasse or oil palm residues), and even for more efficient and high technology systems such as cogeneration. The availability and usefulness of the residues, however, depends a lot on the geographical distribution of the biomass resource; and its utilisation for energy use is very much related to the cultural practices of the people.

The EC-ASEAN COGEN Programme has been commissioned to conduct a study on conditions for electricity production based on biomass in Thailand.

Objectives of the Exercise

The specific objectives of the exercise are to:

1. to provide background information for the National Energy Policy Office of Thailand to prioritise the resources available for promotion of renewable energy and to develop a strategy for future pricing incentives;
2. to provide information necessary for analysing financial, economic and environmental implications of possible pricing incentives;
3. to identify the main barriers to further dissemination of the utilisation of biomass for energy purpose.

The following steps are taken in order to achieve the above-stated objectives:

- Assessment of the energy resource potential in Thailand. This includes 1) the assessment of potential resources of renewable energy for electricity production from biomass waste based on proven technologies, and 2) the assessment of possible major potential resources likely to be exploitable in the near future, provided specific obstacles are removed. ;
- Identification of major technologies for the exploitation of renewable energy resources and the characterization of each technology type;
- Assessment of the technological infrastructure of the main technologies, and identification of major barriers towards successful dissemination of the technologies;
- Assessment of the financial situation with focus on peculiarities regarding the subsectors of renewable energy production in question.

Chapter 1. Identification of Major Biomass Sources in Thailand

Biomass is an important renewable source of energy and has been used to provide energy for human activities since time immemorial. In the rural areas of Thailand where energy markets do not exist, biomass fuels are not traded and are mostly home-grown or collected by family labour. In energy markets where modern technology and competition dictates the use of more efficient and clean fuels, biomass is gaining an increased commercial value.

The Food and Agriculture Organization cites that biomass (including wood fuels) contributes more than one-third of the energy in Thailand, wherein two-thirds are consumed in the residential sector (mostly rural households for domestic energy needs) and the rest in industries (FAO, 1997). From 1993 to 1995 alone, a 13% increase in biomass consumption in Thailand was recorded. Supply of biomass is available from various sources: forests, wood plantations, agricultural and industrial residues, and even municipal solid wastes. Waste products from wood and agro-industries are the least expensive and most accessible. The next cheapest sources would be wood fuels available from plantations and home backyards. The availability of the biomass, however, can be restricted by the availability of land for planting, crop patterns and season.

This chapter shall focus on the major biomass sectors as potential energy sources from the wood and agricultural sectors of Thailand. A discussion on dendrothermal plantations and applications will also be included. It is important to note however, that though it is a major potential source of biomass for energy, the wood sector is also characterised with high competitive uses of its raw materials and/or residues for other downstream wood industries. Hence, wood plantations solely for power may not be justifiable in some aspects. Nevertheless, by virtue of its being part of Thailand's energy plan, the consequent discussions on the wood sector will still explore the possibilities of dendro plantations for energy.

1.1 Agricultural sectors

The sugar, rice and oil palm sectors are the three major potential biomass energy sources in the country. Residues obtained from the harvesting and milling of the agricultural produce can be utilised as fuel for energy generation (either in form of power, heat or both power and heat).

Table 1 shows the national production trends of sugarcane, paddy and oil palm from 1990 - 1995.

Table 1. Production in the sugar, rice and palm oil sectors of Thailand (in tonnes), 1990-1995

Crop year	Sugarcane	Paddy	Oil Palm (Fresh Fruit Bunch)
1990/91	40,660,624	17,193,000	1,191,769
1991/92	47,479,508	20,400,000	1,315,990
1992/93	39,826,701	19,917,000	1,351,917
1993/94	37,822,875	18,447,000	1,526,416
1994/95	50,597,339	21,111,000	1,817,806
1995/96	57,973,760	22,016,000	2,255,450

Source: Office of Agricultural Economics, 1996a

Sugar sector

Production trends. The sugar sector is characterised by large-area farm holdings with ownership ranging from individual farmers/families to large corporations. Production is therefore highly concentrated and contained. Figures 1 & 2 show the sugar cane production and production densities per province for 1995/96.

Sugar mills. There are 46 sugar mills in the country which in crop year 1994/95, processed about 99% of the sugar cane produced in the country. This suggests that only a very small percentage of the produce may be sold in the domestic markets for household consumption. Most of the residues from sugar cane processing can therefore be sourced at the mills, and that the sugar cane tops (stumps and leaves, etc.) resulting from the harvest are left in the fields by the farmers. The mills and their relative sizes are plotted in the map shown in Figure 3.

Rice sector

Production trends. Paddy production in Thailand remained steady over the years, and cropping pattern for paddy is characterised by 2 kinds of paddy output: major rice during the rainy months of May to September, and second rice during the dry months of November to February. Production of second rice depends largely on the farmers' skill and available resources. Since this is done during the dry season, almost always, production is realised through irrigation practices.

Paddy field ownership are of extremely varying sizes, ranging from less than a hectare for an individual farmer to thousand hectares for farmer co-operatives and the like. All throughout the country, small-sized paddy fields are a common site.

Paddy production and production densities on a provincial level for 1995/96 are shown in Figures 4 & 5, respectively. The highest producing provinces are Suphan Buri and Singburi in the Central Plain region, and Nakhon Ratchasima and Buriram in the North-eastern region. About 39% of the total national output comes from the Northeastern region, 30% from the Central Plain, 27% from the Northern region, and 4% from the Southern region.

Rice mills. The Ministry of Industry estimates that more than 44,400 rice mills existed in the country in 1995 (Table 2), are of extremely varying mill sizes and scattered across the country. Unlike the sugar industry where most of the produce go to a few processing mills, the rice industry's structure makes it more difficult to trace the flow of the paddy produce. Consequently, it is reasonable to assume that residue production from the processing of paddy is also widely scattered among the thousands of rice mill units across the country.

As the global rice industry had become more competitive, a large number of marginal rice mills in the country had to shut down their operations due to their inability to compete with the more progressive mills in the country. The Rice Millers Association of Thailand lists about 17,000 commercial and active rice mills in 1996. Of this, 15,000 are small/household businesses (2 to 5 tonnes per day milling capacity) mainly found in the North and Northeastern provinces, and the rest are medium to large scale mills. Mills have an average milling duration of 5760 hours per year.

In recent years, a number of large rice mills have been going for automated systems, and this has increased their milling duration to about 11 months per year, 24 hours a day. About 78 rice mills in 1996 are estimated to have milling capacities of 80 tonnes per day and over, 49 of which have milling capacities of over 100 tonnes/day (Rice Millers Association, 1997). Figure 6 gives the location of Thai rice mills with hourly capacities of 80 tonnes per day (~ 5 tonnes per hour) and over.

Table 2. Number of rice mills by region in Thailand, 1991-1995

Year	Region				
	Northeastern	Northern	Central Plain	Southern	Thailand (total)
1991	25,403	10,453	5,422	4,412	45,690
1992	25,296	10,335	5,291	4,406	45,328
1993	25,213	10,183	5,223	4,400	45,019
1994	24,905	10,104	5,156	4395	44,560
1995	24888	10,065	5,129	4,390	44,472

Source: Factory Control Division, Ministry of Industry, 1996 (from OAE, 1996a)

Oil palm sector

Production. The major oil palm planting areas are located in the southern part of Thailand, consisting of 6 provinces: Krabi, Surat Thani, Chumporn, Satun, Trang and Prachuab-Kirikan (Figure 7). A small portion of palm oil production is found in the eastern region, consisting of planted areas on Chonburi and Rayong.

A survey conducted by the Office of Agricultural Economics during 1990-1994 showed that the harvested area and output of oil palm (fresh fruit bunch) have steadily increased over the years. Figure 8 shows the production density of fresh fruit bunch (FFB) in the country. Palm oil produced from the crop demands a very competitive price in the world market for vegetable oils, and thus, the Thai government has laid out ambitious expansion plans of the oil palm industry in its 8th National Development Plan.

Many oil palm producers are small farmers or farmer co-operatives and settlements (Table 3). The individual farm land holdings has an average area of 7.18 ha/household. The others are privately-owned large scale enterprises, with farm sizes averaging 379 ha/company. The fresh fruit bunch is mostly harvested during August-November (the peak season) each year, accounting for 42 percent of total output harvested the year round.

Table 3. Registered planters and planted areas of oil palm, 1994

Provinces	Company		Co-operatives		Private Farms		Total	
	No. of Farms	Pln. Area (ha)	No. of Farms	Pln. Area (ha)	No. of Farms	Pln. Area (ha)	No. of Farms	Pln. Area (ha)
Prachuab Kirikhan	1	704	-	-	81	1560	82	2264
Chumpon	10	4638	1340	7274	4063	18568	5413	30480
Surat Thani	24	16157	390	1891	1916	17896	2330	35944
Nakhon Si Thammarat	-	-	1	4000	110	725	111	4725
Trang	5	976	1	7680	245	4083	251	12739
Satun	21	1910	432	2144	472	3566	925	7620
Krabi	32	12394	1593	7650	2543	16830	4168	36874
Others	4	307	11	880	569	4117	584	5304
Total	97	37086	3768	31519	9999	67345	13864	135950

Source: OAE, 1996b

Palm oil mills. Palm oil processing factories can be classified into two: 1) large scale mills which crush the palm fruit but do not crush palm kernels (producing crude palm oil and not palm kernel oil), typically with an average capacity of 100-200 metric tonnes FFB/day. Currently, there are 15 large palm oil factories with a total capacity of 2.4 million metric tonnes FFB per year; 2) small scale whole palm crushing mills which have been adapted from original coconut oil processing mills. Currently, there are 26 palm oil processing mills of this size with a total capacity of 320,000 metric tonnes FFB per year. Palm oil output from these mills are of the mixed type: crude palm oil and palm kernel oil.

The mills are located close to the oil palm planting areas. The proximity of the factories to planting areas is necessary in order to allow harvested fresh fruit bunches to be transported to the crushing mills within 24 hours. Figure 9 shows the location of (some) palm oil mills in the South of Thailand.

Other agricultural sectors

By virtue of their being potential energy sources, two other biomass sectors in Thailand need mentioning: coconut and cassava/tapioca). (Due to limited information, only a brief discussion on the cassava sector will be given here.)

Production figures of coconut (nut) and cassava in Thailand for 1990 to 1995 are presented in Table 4.

Table 4. Production trends in the coconut and cassava sectors of Thailand ('000), 1990-1996.

Year	Coconut			Cassava		
	Planted area (ha)	Harvested area (ha)	Production (tonnes)	Planted area (rais)	Harvested area (rais)	Production (tonnes)
1990	393	346	1426	1530	1488	20,701
1991	389	337	1379	1492	1434	19,705
1992	388	336	1411	1492	1451	20,356
1993	388	345	1462	1456	1438	20,203
1994	381	339	1435	1411	1383	19,091
1995	426	335	1413	1295	1245	16,217
1996	n.a.	n.a.	n.a.	1262	1228	17,388

n.a. - not available
Source: OAE, 1996a

Coconut. Coconut is predominantly a traditional smallholder crop in Thailand and is grown principally for the domestic market. The coconut provides a large resource for food, feed, fuel, timber, fibre and numerous other products. In fact, the whole tree itself, from the palm leaves, the fruit, the trunk, down to the roots, serve various purposes, one of which may be energy-related. Since the coconuts are harvested all year round, the process provides continuous sustained processing and energy supplies with minimal storage requirements. In recent years, markets which make use of coconut residues, e.g. husks and shells, for the production of higher value added products in the local and export markets have developed. This includes, among others, the jewellery industry, the ornament/decor industry, and construction industry (coco lumber). Still a lot of residues are not utilised and hence, create disposal problems. Burning of the residues as fuel is therefore another option for its utilisation.

Cassava. Cassava is grown in almost all parts of the country, especially in the Northeast. Human consumption of cassava is very small, and most of the roots are used for tapioca starch. The production of tapioca starch results in wastes and polluted wastewater. On the average, a kilogramme of fresh roots yields 0.2 kg of starch and between 0.4 and 0.9 kg of cake. Wastewater is also produced during the processing and it is from wastewater that biogas is produced after a series of treatments (technology will not be discussed here).

The production of biogas from tapioca starch wastewater has already been proven to be feasible, though its uptake is still very much low-key in Thailand. Its use has been limited mainly to demonstration plants in rural applications aimed to produce energy for cooking (Tanchicharoen and Wibulswas, 1995). The downstream tapioca industries e.g. the starch industry is seen to eventually benefit from this technology if the wastes from cassava processing are harnessed to the fullest. (It is also worthwhile to mention that biogas can also be obtained in the palm oil mills (effluent), pulp and paper mills, alcohol distilleries, etc.) The need for high capital investment and the uncertainty of the system economics prevent the widespread use of wastes from the cassava/tapioca industry (as well as those from the other agro-industries) for biogas production.

1.2 Wood sector

Log production. The process of felling trees in the forests and converting them to logs is associated with wastes (branches, stumps, leaves, etc.). Log recovery rates vary from place to place depending on the methods used, but generally, a 50/50 ratio is often considered reasonable.

Accessibility to the residues may be a major reason why wood residues from logging are left to rot in the forests. Moreover, in places where population is particularly sparse, there may be low demand for wood fuels.

Due to the limited information on the forest and logging industries of Thailand, these aspects will not be included in the study. Focus will be on the mainstream aspect: sawmills and plywood industries. Information about the industry however, is a highly sensitive one. Published figures on log consumption by the mills may not necessarily reflect the true nature of the industry, brought about un-accounted cross-border trade of wood products between Thailand and its neighbouring countries. Nevertheless, this study shall consider the official figures from the Forestry Department (Table 5).

Figure 10 shows the distribution of local log production in the country for 1995. Local log production figures excludes logs from rubber plantations. The highly producing provinces are Nathariwat and Yala in the South of Thailand, Mae Hong Son and Lampang in the North. Production density figures for logs may not be very significant at this point since available forest area statistics only shows the total forest land area in the country, and this includes all forest types such as evergreen, pine, mangrove, mixed deciduous, dry dipterocarp, swamp, bamboo and forest reserves.

Table 5. Trends in log production for Thailand (excluding rubber wood), 1990-1995

Year	Log prodn. (tonnes)	Imports (tonnes)	Exports (tonnes)	Net national prodn.
1990	344,152	1,293,174	0	1,637,326
1991	162,054	1,223,041	0	1,385,095
1992	83,401	1,425,263	0	1,508,664
1993	45,408	956,703	1,181	1,000,930
1994	43,629	1,084,229	0	1,127,858
1995	23,229	964,508	18,314	969,423

Note: Production includes teak and confiscated timber only.

Sawmills and plymills. The number of sawmills and plymills has been in a decline since the forest closing policy in 1989. Demand for wood however, still continue, as reflected in the country's import figures while there has been a development in the secondary processing industry mainly for exporting pulp and paper, furniture and wood-based panels using wood imports.

Table 6. Sawmills and plymills per region in Thailand, 1996

Mill type	Region					
	Total	**Bangkok**	**Central**	**North**	**Northeast**	**South**
Sawmill-powered	**683**	47	251	63	64	258
Sawmill-manual	**73**	6	30	22	8	7
Plymill	**21**	6	33	0	0	4
Total mills	**777**	59	314	85	72	269

Source: Royal Forestry Department, 1996

Rubber wood plantations. Thailand has been the number one producer of natural rubber in the world, averaging 2 million tonnes per year (FAO, 1997). Apart from harvesting the latex, wood from the rubber tree is both used as fuel and as timber. As fuel, huge amounts are generated on field (in form of branches, chunks) after the trees are cut down for rotation, and in the processing factories (off-cuts and sawdust). The rotation period for rubber trees is 25-30 years, after which rubber trees are cut down for replantation. The steady supply of wood from the replanting scheme of rubber makes the power plant(s) fuelled by rubber wood a promising project.

Plantations are concentrated in the southern part of Thailand. In the last decade, rubber wood has become an important source of timber for the furniture industry. This had led to a considerable competition between the brick industry (which used rubber wood as an energy source) and the former.

Dendrothermal plantations. Dendrothermal power is used as a general concept for electricity generation based on wood fuels. The master plan for dendrothermal power programme in Thailand proposes that lands unsuitable for permanent agriculture (marginal agricultural lands and degraded forests) be utilised for wood plantations (NEA, 1987). Steep lands with risks of erosion are excluded. During that time, 600,000 hectares of marginal lands were identified to be suitable for plantation of fast-growing trees estimated to generate about 1,200 MWe (NEA, 1987). In 1993, about 17.5 million hectares of lands were classified as ‘idle and unclassified lands’ (this includes degraded national forest reserves) (Royal Forest Department, 1996). Thirty four percent (almost 6 million ha) of this is found in the North-east of Thailand where the wood fuel crisis is very severe and where there are extreme seasons of prolonged droughts and floods.

Eucalyptus plantations. Several years since the conception of the plan, several tree-planting programmes have been started out in different regions of the country. Government feasibility studies on Eucalyptus plantations, most of which have sprouted in the North-east of Thailand, yielded the most promising results. There are a number of reasons for the choice of the eucalyptus: it is the most common fast growing species for pulp and wood fuel production, it is less susceptible to hazards and calamities, it is fire resistant, and its density and calorific value make the wood excellent to use in thermal power production. Once established, a eucalyptus plantation is easy to manage and it will sustain for a period of 3-4 rotations for 25-30 years.

The ban on wood forest logging in 1988 however, may have affected the development of the dendro thermal power programme of the country, which to date has seen little progress. Moreover, the increasing interest in the use of wood for other high value added products in the furniture, pulp and paper industries, etc., brings less justification for the use of dendro plantations solely for energy.

Chapter 2. Availability of Biomass Residues

Residues are used for many purposes: as fodder, fertiliser, fibre, feedstock, fuel, etc. In most local communities, residues are oftentimes thought of as wastes, are of no economic value, and are traded freely. In an enterprising environment, however, where uses for these residues are discovered and developed, they sooner or later acquire a monetary value.

Many factors have to be considered with regards to residues: seasonality of the biomass crops, ownership, location and access, its economic value, environmental considerations, its present and other competing uses. This chapter discusses availability of biomass residues in Thailand.

2.1 Determining Crop-to-Residue Ratios

Crop-to-residue ratios (CRRs) are the estimates of residues derived from the production of agricultural crops. Studies on the determination of CRRs for various agricultural crops in Thailand have been done in the past. Foremost among the studies were those performed at the Energy Program of the Asian Institute of Technology (Thailand), the National Energy Administration (Thailand), the Chulalongkorn University (Thailand), The Office of Agricultural Economics (Thailand), and the Regional Energy Development Programme of the UN-ESCAP (Thailand). The CRRs used by the EC-ASEAN COGEN Programme for this particular study rely on published literature as well as practical industrial experience. These are conservative estimates which takes into account crop variety, location, differing moisture content, etc.

The following table summarises the CRRs as determined by the above-mentioned institutions.

Table 7. Crop-to-residue ratios of various agricultural crops in Thailand

Crop	Residue	Crop-to-Residue Ratio	Reference
Paddy	Rice Husk	1:0.26	United Nations (1985)
		1:0.30	Arthayukti (1986)
		1:0.237 - 0.299	Bhattacharya (1989)
		1:0.22-26	TISTR, 1984
		1:0.22	**COGEN (1994)**
	Rice straw	1:1.757	Bhattacharya (1993)
		1:1.0-2.9	Kristoferson (1991)
		1:1.4	Ishaque (1991)
		1:0.416	Arthayukti (1993)
		1:0.410-0.506	Bhattacharya (1989)
		1:1.08	tentative average
Sugar cane	Bagasse	1:0.299	OAE (1987)
		1:0.276-0.314 (average = 0.299)	NEA (1976-1981)
		1:0.29	**COGEN (1994)**
	Cane Trash	1:0.67	USAID (1986)
Oil Palm	Empty Fruit Bunch+Fibres+Shells	1:0.48	Prasertsan and Prasertsan (1996)
		1:0.38-0.45 (average = 0.42)	**COGEN (1996)**
Coconut (nut)	Coconut husk	1:0.35	United Nations (1985)
		1:0.35	Arthayukti, et. al. (1983)
		1:0.23	OAE (1987)
		1:0.419	Bhattacharya (1989)
		1:0.35	**COGEN (1994)**
	Coconut shell	1:0.12	Bhattacharya (1989)
		1:0.15	**COGEN (1994)**
Cassava root	Cassava stalk	1:0.085	Bhattacharya (1993)
		1:0.161	United Nations (1985)
		1:0.162	Arthayukti, et. al. (1983)
Wood	Wood residues	1:0.45-0.55	Carre, J, et. al. (1992)
		1:0.50	**COGEN (1994)**

2.2 Sugar cane residues

Sugar cane residues are basically of two types: the cane residues made up of leaves and tops of cane plants (also known as cane trash) that remain behind in the field after the harvest, and bagasse which is the fibrous residue delivered after the extraction of the juice from the sugar cane in mills. The precise amount of biomass available from cane residues (on field) can be expected to vary with plant varieties, climate and soil conditions, etc. A detailed study conducted in the Dominican Republic concluded that, on the average, there was 0.67 tonnes of crop residues left in the field (at 50% moisture content) for every tonne of cane stalks harvested. Based on this, field visits conducted in the Central and Eastern regions of Thailand by a team of specialists in 1986 suggest that the amount of field trash in Thailand are of the same magnitude (USAID, 1986; Kadyszewski et al, 1989). Based on a CRR of 1:0.29 for bagasse (COGEN estimate) and 1:0.67 for cane trash, residues produced from the harvest and processing of sugar cane in 1995/96 for Thailand are calculated and shown in Table 8.

Table 8. Residues from harvesting and processing of sugar cane per province in Thailand, 1995/96

Region / Province	Planted area (hectares)	Harvested Area (hectares)	Sugar cane (tonnes)	Cane Trash* (tonnes)	Bagasse (tonnes)
THAILAND	**1,004,627**	**985,004**	**57,973,760**	**38,842,419**	**16,812,390**
1) NER	310,520	301,409	19,064,379	12,773,134	5,528,670
Nakhon Phanom	2,712	2,658	142,439	95,434	41,307
Sakon Nakon	3,091	2,906	161,063	107,912	46,708
Nong Khai	487	472	25,368	16,997	7,357
Udon Thani	76,175	75,009	4,786,197	3,206,752	1,387,997
Nong Bua Lam Phu	3,427	3,016	197,673	132,441	57,325
Loie	14,284	13,712	955,857	640,424	277,199
Mukdakan	12,782	11,632	666,993	446,885	193,428
Yasothon	647	621	35,165	23,561	10,198
Kalasin	9,271	9,178	527,513	353,434	152,979
Khon Kaen	43,038	41,798	2,762,924	1,851,159	801,248
Maha Salakham	2,362	2,354	144,707	96,954	41,965
Roi Et	1,329	1,329	78,634	52,685	22,804
Buriram	15,746	14,801	824,307	552,286	239,049
Surin	220	220	10,133	6,789	2,939
Chaiyaphum	62,334	60,464	3,830,806	2,566,640	1,110,934
Nakhon Ratchasima	62,616	61,239	3,914,600	2,622,782	1,135,234
2) NR	235,189	229,382	13,737,074	9,203,840	3,983,751
Nakhon Sawan	63,382	62,033	3,625,560	2,429,125	1,051,412
Phetchabun	5,787	5,770	322,899	216,342	93,641
Uthai Thani	21,062	19,588	1,159,327	776,749	336,205
Kamphaeng Phet	74,276	72,552	4,828,730	3,235,249	1,400,332
Tak	1,588	1,588	85,674	57,402	24,845
Phichit	4,978	4,530	262,229	175,693	76,046
Phitsanulok	9,435	9,340	494,548	331,347	143,419
Phrae	4,385	4,385	220,262	147,576	63,876
Lampang	5,974	5,954	277,212	185,732	80,391
Sukhothai	28,205	27,529	1,701,074	1,139,720	493,311
Uttaradit	15,384	15,383	718,936	481,687	208,491
Chiang Mai	618	616	34,866	23,360	10,111
Chiang Rai	115	115	5,757	3,857	1,670
3) CP	458,918	454,213	25,172,307	16,865,446	7,299,969
Lop Buri	42,996	42,566	2,172,642	1,455,670	630,066
Saraburi	6,629	6,496	334,382	224,036	96,971
Chai Nat	3,522	3,492	278,287	186,452	80,703
Nakhon Pathom	18,494	18,309	1,097,845	735,556	318,375
Sing Buri	6,387	6,354	513,544	344,074	148,928
Suphan Buri	98,136	97,548	6,185,052	4,143,985	1,793,665
Ang Thong	2,905	2,880	228,841	153,323	66,364
Kanchanaburi	129,381	128,408	6,484,032	4,344,301	1,880,369
Prachuap Khiri Khan	12,107	12,083	581,259	389,444	168,565
Phetchaburi	6,178	5,875	309,939	207,659	89,882
Ratchaburi	54,129	53,942	2,561,802	1,716,407	742,923
Chachoengsao	14,072	13,228	710,220	475,847	205,964
Prachin Buri	1,470	1,220	112,501	75,376	32,625
Sra Kaew	10,214	10,112	606,442	406,316	175,868
Chon Buri	39,059	38,504	2,268,616	1,519,973	657,899
Rayong	9,052	9,017	482,989	323,603	140,067
Chanthaburi	4,185	4,180	243,914	163,422	70,735

* at 50% moisture content
Source: OAE, 1996a

The highest concentration of residues are found in the Central Plains, where most of sugar mills are also located. The capacity in the sugar industry has expanded rapidly, as the average mill sizes have grown over the years. This is brought about by the intensifying competition among millers and the attractiveness of the international markets which makes Thailand number two in the export markets (next to Cuba).

Characteristics of residues

Bagasse varies in composition, consistency, and heating value, depending on the climate, type of soil upon which the cane is grown, variety of cane, harvesting method, amount of cane washing and the efficiency of the milling plant. Quantitative analysis of bagasse from various studies display variations in figures and are presented in Table 9.

Table 9. Fuel characteristics of bagasse.

Reference	Moisture Content (%)	Ash (%)	C (%)	N (%)	S (%)	H (%)	LHV (MJ/kg)
Therdyothin, 1992	50						8.99
Wibulswas, 1990	50	1.5	24.5	0.14	0.07	3.0	
Bhattacharya, 1993	49		43.3				
Tamnanthong, 1986	51	2.08		0.13	0.07	2.96	
Bhattacharya, 1982			47.3			6.1	
Turnbull et al, 1996	50	2.25	46	0.4		6.3	
Strehler and Stutzle, 1987	50			0.30			7.75
COGEN	50						7.8

In Thailand, the average moisture content of bagasse varies from 49% to 53% (OCSB, 1988). When freshly piled, bagasse has a bulk density in the range of 125 to 150 kg/m3 depending on the dryness and particle size, as well as the amount of compaction in piling. It contains low percentage of ash (normally less than 1% for soil-free bagasse) and negligible sulphur (Payne, 1991).

The efficient use of cane trash for energy requires that after cane harvesting, the cane trash should be allowed to dry for 4-6 days in order to reduce its moisture content from 50% to 30%.

Use of residues

A portion of the cane trash are collected for sale to feed mills, while freshly cut green tops are sometimes collected for farm animals. In most cases, however, the residues are burned or left in the fields to decompose. Bagasse has been traditionally used as a fuel in the sugar mill itself, to produce steam for the process and electricity for its own use. As the sugar milling process produces a lot more bagasse than is required by the mill to produce electricity, most sugar mills have not been designed to utilise bagasse efficiently from an energy savings point of view. The boilers are designed with low efficiencies in order to incinerate all the bagasse produced by the mill.

While a number of studies have reported that cane trash can also be utilised as fuel in boilers, there still has to evolve proven and reliable systems in Thai sugar mills running on cane tops and leaves. This aspect shall be explored further in Chapter 4.

2.3 Paddy residues

The normal harvesting practice of paddy in Thailand leaves huge quantities of rice straw which contains the top portion of the rice stem with three to five leaves. CRR estimates for this type of rice straw vary a great deal, ranging from 0.41 to 0.56 (Case 1). Another harvest practice is to cut the paddy straw two inches above the ground, thereby containing all the top portion of the rice stem. CRR estimates for this type of rice straw range from 1.0 to 1.757 (Case 2). The latter is seen to become a general practice in the future if rice straw obtains an economic value for the farmers (Bhattacharya, 1989).

Rice husks are generated in 44,000 rice mills all over, at varying quantities depending on the milling input capacities.

Table 10 shows the calculated aggregate residues available from the harvest and milling of paddy in Thailand for crop year 1995/96 on a per province basis. Average CRR values for rice straw is taken to be 1.08. Rice husks are calculated using COGEN's estimate of 0.22.

Table 10. Residues from harvesting and processing of paddy per province in Thailand, 1995/96

Region / Province	Planted Area (HA)	Harvested Area (HA)	Paddy Prodn* (tonnes)	Rice Production (Tonnes)	Husks (22%) (Tonnes)	Rice Straw (108%) (Tonnes)
THAILAND	**9,185,119**	**8,153,920**	**33,866,860**	**22,013,481**	**7,450,709**	**36,576,209**
1) NER	5,123,954	4,795,560	13,210,790	8,587,022	2,906,374	14,267,653
Nakhon Phanom	152,104	127,027	369,497	240,173	81,289	399,056
Sakon Nakon	266,773	247,042	607,795	395,067	133,715	656,418
Nong Khai	181,350	141,253	422,778	274,806	93,011	456,600
Udon Thani	330,372	297,335	741,919	482,248	163,222	801,273
Nong Bua Lam Phu	135,019	121,517	312,695	203,252	68,793	337,711
Loie	58,451	56,692	220,381	143,248	48,484	238,012
Mukdakan	60,441	59,232	166,861	108,460	36,710	180,210
Yasothon	176,898	160,442	383,710	249,412	84,416	414,407
Ubon Ratchathani	471,432	435,839	1,163,454	756,246	255,960	1,256,531
Amnat Charoen	159,982	134,737	383,812	249,478	84,439	414,517
Kalasin	199,177	195,676	710,396	461,758	156,287	767,228
Khon Kaen	316,443	301,597	793,215	515,590	174,507	856,672
Maha Salakham	268,524	258,622	718,921	467,299	158,163	776,434
Roi Et	344,378	334,279	912,401	593,061	200,728	985,393
Buriram	452,856	447,620	1,228,583	798,580	270,288	1,326,870
Si Sa Ket	400,382	380,803	1,065,519	692,588	234,414	1,150,760
Surin	462,952	442,212	1,175,468	764,055	258,603	1,269,505
Chaiyaphum	200,986	185,048	477,247	310,211	104,994	515,427
Nakhon Ratchasima	485,433	468,588	1,356,137	881,490	298,350	1,464,628
2) NR	2,043,638	1,618,758	9,011,205	5,857,289	1,982,465	9,732,101
Nakhon Sawan	377,750	272,449	1,292,188	839,923	284,281	1,395,563
Phetchabun	180,884	141,191	796,535	517,748	175,238	860,257
Uthai Thani	82,385	73,742	250,704	162,958	55,155	270,761
Kamphaeng Phet	197,792	193,734	1,219,728	792,824	268,340	1,317,306
Tak	37,715	37,319	150,957	98,122	33,210	163,033
Phichit	225,159	141,332	1,154,800	750,621	254,056	1,247,184
Phitsanulok	217,433	141,788	1,069,236	695,004	235,232	1,154,775
Nan	28,273	24,232	135,101	87,816	29,722	145,910
Phrae	40,508	34,333	206,058	133,938	45,333	222,543
Lampang	68,560	66,964	312,529	203,144	68,756	337,531
Sukhothai	144,382	121,650	466,807	303,425	102,698	504,152
Uttaradit	71,919	49,853	388,907	252,790	85,560	420,020
Chiang Mai	80,034	74,855	350,981	228,138	77,216	379,060
Chiang Rai	162,719	134,214	677,032	440,071	148,947	731,194
Mae Hong Son	20,064	19,534	80,640	52,416	17,741	87,091
Lamphun	25,674	25,580	124,489	80,918	27,388	134,448
Phayao	82,388	65,985	334,512	217,433	73,593	361,273
3) CP	1,562,017	1,305,487	10,166,604	6,608,299	2,236,653	10,979,932
Lop Buri	145,157	117,618	633,452	411,744	139,359	684,128
Saraburi	64,408	55,116	294,784	191,610	64,853	318,367
Chai Nat	145,157	143,488	1,469,026	954,868	323,186	1,586,548
Nakhon Nayok	71,648	49,299	303,123	197,030	66,687	327,373
Nakhon Pathom	50,364	46,940	626,872	407,467	137,912	677,021
Nonthaburi	19,771	17,451	297,626	193,457	65,478	321,436
Pathum Thani	47,282	40,082	524,833	341,142	115,463	566,820
Ayutthaya	137,840	110,679	568,855	369,756	125,148	614,363
Sing Buri	46,517	21,311	456,486	296,716	100,427	493,005
Suphan Buri	146,918	122,644	1,690,418	1,098,773	371,892	1,825,652
Ang Thong	58,973	39,850	377,820	245,583	83,120	408,045
Bangkok	21,740	18,601	170,320	110,708	37,470	183,945
Kanchanaburi	55,272	51,054	255,883	166,324	56,294	276,353
Prachuap Khiri Khan	9,183	9,183	26,248	17,061	5,774	28,347
Phetchaburi	48,375	44,428	319,509	207,681	70,292	345,070
Ratchaburi	55,864	50,976	365,064	237,292	80,314	394,269
Chachoengsao	142,393	117,678	967,787	629,062	212,913	1,045,210
Prachin Buri	106,815	83,232	254,543	165,453	55,999	274,906
Sra Kaew	113,114	95,887	266,595	173,287	58,651	287,923
Samut Prakan	9,593	7,707	89,734	58,327	19,741	96,912
Samut Sakhon	5,776	5,776	38,280	24,882	8,422	41,342
Samut Songkhram	618	618	4,368	2,839	961	4,717
Chon Buri	29,456	27,620	81,045	52,679	17,830	87,528
Rayong	5,908	4,708	16,074	10,448	3,536	17,360
Chanthaburi	14,524	14,524	43,989	28,593	9,678	47,508

Trat	9,350	9,017	23,872	15,517	5,252	25,782
4) SR	455,509	434,115	1,478,262	960,871	325,218	1,596,523
Chumphon	28,536	27,172	74,409	48,366	16,370	80,362
Nakhon Sri Thammarat	129,695	126,504	409,298	266,044	90,046	442,042
Phatthalung	67,543	60,038	247,447	160,841	54,438	267,243
Songkhla	60,359	53,941	221,615	144,050	48,755	239,344
Surat Thani	49,924	49,582	155,415	101,020	34,191	167,848
Krabi	8,797	8,209	23,346	15,175	5,136	25,214
Trang	18,337	18,119	64,095	41,662	14,101	69,223
Phangnga	3,738	3,558	8,374	5,443	1,842	9,044
Phuket	235.2	235.2	732	476	161	791
Ranong	3,316	3,129	8,100	5,265	1,782	8,748
Satun	16,834	16,031	55,431	36,030	12,195	59,865
Narathiwat	19,820	19,732	63,217	41,091	13,908	68,274
Pattani	37,248	36,799	116,395	75,657	25,607	125,707
Yala	11,128	11,065	30,386	19,751	6,685	32,817

Source: Agricultural Statistics of Thailand, Crop Year 1995/96
* derived from rice production (ratio = 100:65; paddy to rice)

Fuel characteristics of residues

Variations on the properties of rice husks are being reported in different studies. These are summarised in Table 11. Again, discrepancies may be due to the variety of paddy, place of origin and harvest practices.

Table 11. Fuel characteristics of rice husks

Reference	Moisture (%)	Ash (%)	C (%)	N (%)	S (%)	H (%)	LHV (MJ/kg)
Bhattacharya, 1993	12.37		36.8				14.48
Bhattacharya, 1982		15.5	38.5	0.5		5.7	15.37
Therdyothin et al, 1988	8.6	20.9			0.1		15.8
Bin Abas, 1991	5.72	17.14	37	0.36	0.14	4.71	14.16
FAO, 1982	7.26	24.75					
UNDP/ESCAP, 1985		22.68	14.01				14.76
Mahajan and Mishra, 1992	8.92	17.34		1.5	0.1	4.7	13.61
COGEN	10.0	20.00					13.2

Rice straw is relatively moist, with moisture content which varies between 10-25% and even higher and with heating values from 10 MJ/kg to 16 MJ/kg. It is relatively bulky relative to its energy content with volumes approximately 10-20 times that of coal (CBT, 1992). Table 12 shows characteristics of rice straw from various studies.

Table 12. Fuel characteristics of rice straw

Reference	Moisture (%)	Ash (%)	C (%)	N (%)	S (%)	H (%)	LHV (MJ/kg)
FAO, 1977	12.7			0.56			
Strehler and Stutzle, 1987	17	17.4	41.44	0.67			10.9
Bhattacharya & Shrestha, 1990	12.71	21.05					16.02
Bhattacharya et al, 1993	12.71		39.84				16.02
CBT, 1992	15	3.0-4.0	42.0-43.0	0.35-0.41	0.13-0.16	5.0-5.2	
Christiansen, 1992	17	4.0					14.0

Use of residues

Rice straw is principally used as an industrial raw material for fibre in the paper industry. It is also used as an animal feed. To some extent, it is used as field cover to retain soil moisture, as protection from heat, for weed control and to provide humus to the soil. Most of the rice straw however, is burned in the fields and the ash is used as organic fertiliser by the farmers. Buangsuwon (1990) reports that 50% of straw produced in Thailand are used as animal feed, 30% for the paper industry (as raw material), 10% for other uses, 10% as field wastes, and 0% for energy use.

Paddy husk is used as an energy source through direct combustion in large rice mills or as fuel in the production of charcoal from wood logs. Koopmans and Koopejan (1997) cites that about 50-70% of the husks are used by the rice mills themselves. The remaining 30-50 % apparently are not used. According to USAID (1990), only about 30 to 50% of the husk generated is used for energy purpose. Intarapravich et al (1995) also reports that 87% of the total rice husk is used for industry consumption and the remaining 13% is discarded as waste.

Other uses of the rice husk are: as filler in the brick industry, as domestic fuel for cooking, and occasionally, as a bedding material for animals.

2.4 Oil palm residues

Trends in fresh fruit bunch production over the years show an increasing yield (in kgs per rai), from 2193 kg/rai in 1993 to 2455 kg/rai in 1995. This could be attributed to either the use of high-yielding variety or to the maturity of the oil palm trees. The Office of Agricultural Economics reports that generally, oil palm starts to give fruits on its third year, while the highest yields are expected from 8-15 years. Oil palm trees are replanted after 25 years.

Unless harvesting the fresh fruit bunch is done on the 25th year, there are not much oil palm residues left on the fields. Most of the biomass residues are obtained after the processing of fresh fruit bunch in the palm oil mills. Residues from the process are generally broken down (in % of total FFB weight) as follows: 23% empty fruit bunch, 13% fibres, and 6% shells. Calculations for palm oil residues from the processing of FFB are shown in Table 13.

Table 13. Residues from the processing of FFB per province in Thailand, 1995

Region (State) / Province	Planted area (in hectares)	Harvested area (in hectares)	FFB Production (in tonnes/year)	Residues Production		
				Shell (6%)	Fibre (13%)	EFB (23%)
THAILAND	**168,132**	**147,014**	**2,255,450**	**135,327**	**293,209**	**518,754**
Prachuab Kiri Khan	5,108	3,648	47,975	2,879	6,237	11,034
Chonburi	3,782	3,085	35,165	2,110	4,571	8,088
Rayong	369	355	3,136	188	408	721
Chumpon	31,027	24,440	368,822	22,129	47,947	84,829
Nakhon Sri Thammarat	836	273	3,571	214	464	821
Songkla	1,804	1,321	16,957	1,017	2,204	3,900
Suratthani	44,563	41,180	654,203	39,252	85,046	150,467
Krabi	62,772	57,396	907,464	54,448	117,970	208,717
Trang	6,494	5,468	78,548	4,713	10,211	18,066
Phangnga	1,255	877	11,069	664	1,439	2,546
Ranong	933	556	8,382	503	1,090	1,928
Satun	9,121	8,374	119,814	7,189	15,576	27,557
Narathiwat	24	13	112	7	15	26
Yala	43	26	232	14	30	53

Source: OAE, 1996b

Characteristics of residues

Palm oil residues obtained from two palm oil mills in the south of Thailand were analysed by the Thailand Institute of Technological Research. Results of the analysis are summarised in Table 14.

Table 14. Characteristics of FFB residues

	Empty Fruit Bunch			Fibres			Shells		
	Sample 1	Sample 2	Average *	Sample 1	Sample 2	Average *	Sample 1	Sample 2	Average *
Moisture, % (wet)	61.5	55.7	58.6	33.1	43.9	38.5	9.9	11.9	10.9
Ash, %	2.2	2.3	2.25	3.7	3.2	3.45	2.9	1.3	2.10
HHV, kJ/kg	8579	8830	8700	13392	11341	12370	18456	18498	18480
Chloride, %	0.33	0.43	0.38	-	-		-	-	
LHV, kJ/kg			7240			11400			18200

Source: TISTR, 1996
* EC-ASEAN COGEN Programme (from TISTR, 1996)

The HHV and LHV largely depend on the moisture and ash contents of the residues. Moisture contents of the samples are always questionable since the milling process do not produce residues with consistent moisture content, and it takes time for the analysis to be carried out and evaporation could have occurred before the analysis takes place.

Use of residues

The palm oil industry has traditionally been using the residues coming from the process as fuel to generate the steam and power requirements of the mill. Normally, the fibres and the shells are more than sufficient for this need. However, technologies are available to utilise the EFB as well, and if burnt properly, can provide large quantities of energy.

The analysis showed a particularly high chloride content in EFB. Other biomass such as wood could be expected to have a chloride content of less than 0.1%. There are good reasons to be concerned about this since the presence of chloride in the flue gas can lead to corrosion problems (e.g. high temperature corrosion especially in the surfaces of the superheater.)

Interestingly, palm oil residues do not only find its way to the combustion systems of the mills as fuel. In recent years, a lot of research and development in the industry of Malaysia (which is the world's leading palm oil producer) has been initiated, and palm oil residues are becoming a more traded commodity as raw material in the fibreboard industry, pulp and paper industry, etc. Although the Thai industry is still highly focused on the production of palm oil, there is no discounting the possibility that the residues would be utilised for higher value added products in the future.

2.5 Coconut residues

Coconut husks and shells are the main residues generated by the coconut industry at the copra processing plants. They represent about 50% of the coconut fruit. The husk is a remarkable natural lightweight reinforced protective package, while the coconut shell is very hard, brittle and has a similar composition to hardwood though lower in cellulose and higher in lignin content (UNIDO-APCC, 1995). COGEN estimates that husks and shells are obtained from the coconut (nut) at CRRs of 35% and 15% respectively. Calculated production of the residues based on these ratios are shown in Table 15.

Table 15. Residues from the processing of coconuts in Thailand, 1995/96

Production (tonnes)	Coconut husks (35%) (tonnes)	Shells (15%) (tonnes)	Total Residues (tonnes)
1,414,000	494,900	212,100	707,000

Characteristics of residues. Table 16 shows the various estimates of coconut husks and shells obtained from different studies.

Table 16. Fuel characteristics of coconut residues

Reference	Residue	Moisture (%)	Ash (%)	C (%)	N (%)	S (%)	HV (MJ/kg)
Bhattacharya et al, 1993	husk	10.3		47.34			18.62
	shell	8.7		46.7			18.09
Grover, 1995	husk	30	3.5		0.26		18.10
	shell	3.4	1.25	51.05	0.35	0.10	20.186
COGEN	husk						11.4
	shell						16.2

Use of coconut (nut) residues. The actual amount of coconut residues currently used for energy purpose is not known, but the greatest use is probably in copra kilns where shells and husks are used together with fuel wood to dry the coconut kernel for copra. Other major use is as a cooking fuel in households. The coconut shell, being one of the highly valued biomass fuels is also converted to charcoal. As an activated carbon, it has certain outstanding properties that can not be duplicated in other materials. In Thailand, activated carbon is used in about 119 coconut oil mills. Coconut husks may also be converted to fibres for matting and mattresses.

2.6 Wood processing residues from sawmills and plymills

The 1996 provincial production of logs (excluding rubber wood) in Thailand are presented in Table 17. The net national production figure is derived by taking into account both exports and imports of logs for the same year. A CRR of 50% is used for the calculation of available wood waste from the net national production of logs.

Table 17. Log production per province in Thailand, 1996

Region/Province	Teak	Others	Total Production (tonnes)
Thailand	**10,684**	**33,209**	**29,504**
North	**10,581**	**8,503**	**13,157**
Chiang Rai			0
Lamphun	12	96	76
Mae Hong Son	3,215	1,546	3,333
Lampang	3,762	1,909	3,970
Nakhon Sawan	59	2,036	1,467
Phayao		5	
Phichit			0
Phrae	34	193	
Petchabun		55	39
Phitsanulok	3	26	
Sukhothai	9	19	
Kamphaeng Pet	108	262	259
Uthai Thani	1	864	606
Chiang Mai	552	575	789
Nan	260	397	460
Uttadarit	79	284	254
Tak	2,487	236	1,906
North East	**17**	**4,064**	**2,836**
Kalasin	2	603	424
Khon Kaen		60	42
Chaiyaphum		146	102
Nong Khai		895	627
Nakhon Phanom	2	20	
Mukdahan	13	214	159
Maha Sarakham		5	4
Udon Thani		499	349

Nongbua Lumphoo		5	
Nakhon Ratchasima		743	520
Roi Et			0
Loei		153	107
Surin			0
Si Sa Ket		39	27
Sakon Nakhon			0
Yasothon		142	99
Buri Ram		150	105
Umnad Chareun		3	
Ubon Ratchathani		387	271
North-east	**82**	**1,463**	**126**
Kanchanaburi			0
Lop Buri		1	
Phra Nakhon Si Ayuttaya	71	1	50
Pathumthani		9	
Ratchaburi		4	
Petchaburi		190	
Prachuap Khiri Khan		95	67
Suphan Buri		11	
Samut Songkhram	8		6
Nonthaburi	3	2	4
Chai Nat		1,150	
Central	**2**	**430**	**281**
Chon Buri		30	
Rayong		2	1
Chanthaburi		71	50
Trat		19	13
Cha Choeng Sao		142	99
Prachin Buri		32	22
Sa Kaew		12	8
Nakhon Nayok	2	122	87
South	**2**	**18,749**	**13,105**
Chumphon		179	125
Phangnga		112	78
Surat Thani		30	
Phuket	2		1
Krabi		180	126
Nakhon Si Thammarat		129	90
Trang		9	6
Phatthalung		53	37
Satun		42	29
Songkhla		52	36
Yala		4,927	3,449
Pattani		436	305
Narathiwat		12,600	8,820

Log prodn. (tonnes)	**Imports (tonnes)**	**Exports (tonnes)**	**Net national prodn.**	Available wood waste
29,504	655,410	9	684,905	342,453

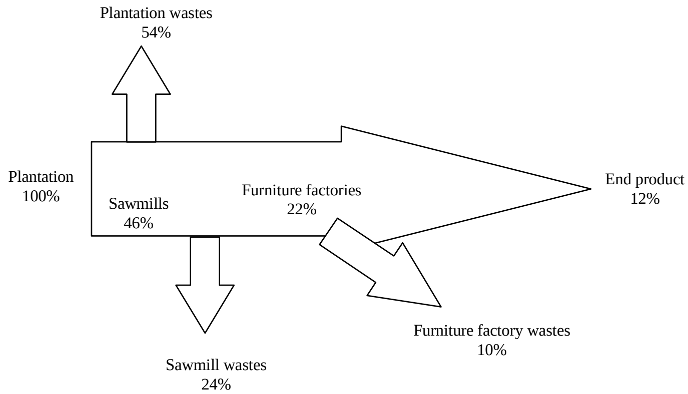
Characteristics of residues. COGEN's estimates for the moisture content and heating value of wood are 50% and 11.4 MJ/kg, respectively. Considering the complexity of the wood industry, various literature provide different data on wood characteristics. The figures considered above are conservative, average estimates, but that which may not necessarily reflect the true nature of a wood species in question (e.g. rubber wood).

Rubber plantation residues

A study by Prasertsan and Vanapruk (1997) showed that there are a total of 1.92 million hectares of rubber plantation in the country, with rubber trees having a life cycle of 25-30 years. With this, biomass from 3.5% (67,200 hectares) of the planting area are available every year, corresponding to about 392.5 tonnes of green wood per hectare. In absolute terms, about 26,376,000 tonnes of green rubber wood are available every year. 54% of the biomass represent the small branches (less than 6 inches in diameter) and leaves which are left in the fields and/or are burned. 46% (12,132,960 tonnes) are transported to the sawmills where sawing would yield only 22% sawn wood from the total volume (or 2,669,251 tonnes).

The flow of the biomass is shown in Figure 11.

Figure 11. Rubber wood flow from plantation to products



In terms of residue generation therefore, wood wastes from plantations, sawmills and furniture factories are about 14,243,040 tonnes, 2,911,910 tonnes and 266,925 tonnes, respectively, for a total of 17,421,875 tonnes.

Characteristics of the residues. Dry rubber wood has a heating value of 17.9 MJ/kg, with a volumetric shrinkage of 10%, density of 630 kg/m^3 (Prasertsan and Vanapruk, 1997).

2.7 Eucalyptus dendrothermal plantations

The thermal values for the wood from the various parts of the tree do not differ very much. Therefore, all parts e.g. trunk, roots, stump, branches, twigs and even the leaves could be utilised as fuel for energy production (NEA, 1987). The dendro thermal power programme (DTP) of Thailand, however, does not consider the roots, stumps, and leaves. Roots and stumps will be used for production of the forthcoming coppice generations. The leaves will provide a valuable source of nutrition and increase the organic material in the soils. The main part of the biomass will be the stem including the bark and all the bigger branches.

Characteristics of the wood. The heating value for the wood is in the range of 19-20 MJ/kg dry substance and examples from Thailand shows an average value of 19.5 MJ/kg. The moisture content of fresh wood varies between 45-55%. It is estimated that the average moisture content of the wood delivered to the wood yard will be in the order of 45%. Ash content of Eucalyptus samples are found to be 1.5% but if contamination from the ground (soil) occurs during the transport of the wood, the total content of ashes in the fuel increases to 4% (NEA, 1987).

Chapter 3. Assessment of the Potential Resources for Electricity Production from Biomass Residues Based on ***Proven*** Technology

Energy consumption is rising quite rapidly in Thailand, making the energy sector a major national priority. As presented in the previous chapter, Thailand produces huge amounts of agricultural and wood residues each year. These have great potential for use as fuel in small to medium scale energy projects.

The discussion in this chapter relies heavily on COGEN's experience in the field of power and heat generation in Thailand involving biomass fuels and proven combustion technologies.

3.1 Power potential at the mills/industry level

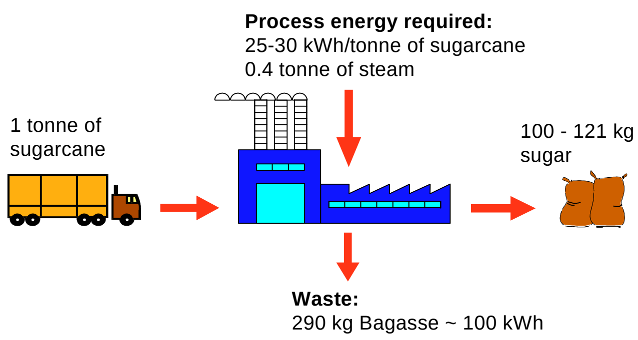
Two commonly-used terms in this chapter need clarification: technical power potential and structural power capacity. Technical power potential is the power potentially available if all residues are utilised in energy systems. It is calculated based on the energy content of the residue and does not take into account the industry structure and system efficiencies of the mills.

Structural power capacity refers to the power capacity that could be installed in mills that have processing capacities above the minimum threshold for which energy systems are appropriate. The calculation takes into account the size and the milling duration of the mill.

Sugar sector

Bagasse is the predominant fuel source of the industry for its energy requirements. The energy equipment used in mills are the conventional type utilising low pressure boilers of 20 bar. With the current efficiency of the installed boilers in Thailand, it takes an average of 9 kg of bagasse to produce 1 kWh of electricity. Thus, some mills use their bagasse just enough to cover their energy requirements. Others recover even less energy than is required by the mill. Because of this, some mills have to supplement their energy needs by power from the grid and producing steam using a separate fuel oil boiler. In contrast, with an efficient high pressure boiler (80 bar, 520^{o}C), about 3 kg of bagasse is sufficient to produce 1 kWh of electricity. This highly efficient system will allow production of much more electricity than what the mill requires. Assuming that all bagasse is utilised in this manner, there is a theoretical power potential of about 5700 GWh/year. Figure 12 shows the energy requirement and supply in the sugar industry.

Figure 12. Energy requirement and supply in the sugar industry

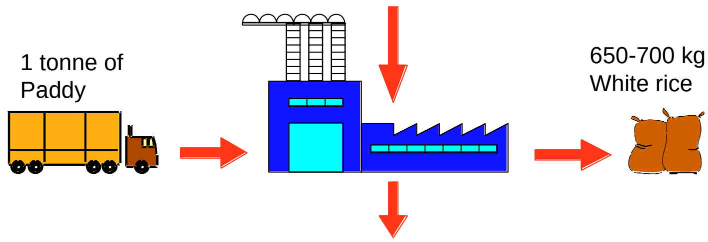


Using available figures for 1994/95, 50.5 million tonnes of cane were milled in Thai sugar mills, producing about 14.645 million tonnes of bagasse (or 99% of total residues available for that year). The average milling duration of Thai sugar mills is 2500 hours in a year. Assuming that all mills go for high pressure systems, there is a structural power capacity of at least 1900 MW to be implemented in Thailand.

Rice sector

Energy consumption patterns in Thai rice mills may vary, depending on whether the mill is a parboiled rice mill or white rice mill. The former consumes more energy than the latter due to the energy requirements for milling as well as parboiling. Simple milling may require 30 kWh/tonne of paddy, while parboiling included requires up to about 60 kWh/tonne of paddy (Figure 13).

Figure 13. Energy requirements and supply in the rice industry



The energy required by the rice mill can be obtained from the utilisation of the husks which is the by-product of the milling process. In many mills, the husks are burned in very inefficient step grate furnaces which leave black ash with high percentage of unburned carbon. Assuming that all rice husks are utilised for power generation, and that it takes 2 kg of rice husk to produce 1 kWh, there is a theoretical power potential of 2422 GWh/year. Note should be taken, however, that in reality, not all residues can be utilised in this manner, because, for each rice milling unit, there is a minimum processing capacity of 5 tonnes per hour below which, a rice-husk fired energy system is not appropriate. The size of the individual mill and the industrial structure of the rice milling sector are therefore relevant in determining the immediate potential for power capacity installation.

It is estimated that in 1996, only 78 rice mills had milling input capacities of over 5 tph, with a cumulative capacity of 550 tph. This translates to about 121 tph of rice husks. If utilised as fuel for power generation, this represents a structural power capacity of 66 MW.

Recent installations of rice husk-fired power plants in Thailand which make use of efficient combustion technologies, have been proven to utilise lesser than 2 kg of rice husk for every 1 kWh generated. This implies an even greater potential for power generation in the rice industry.

Palm oil sector

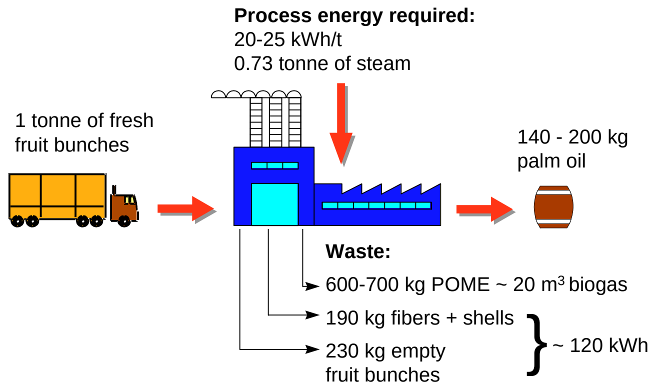
Palm oil factories traditionally have been designed to provide for their own energy needs (process heat and electricity) by utilising diesel gensets and turbo-generators. However, more efficient energy conversion technologies that utilise the palm oil residues such as EFB, fibres and shell, which yield considerable quantities of electricity, are currently promoted in the energy markets. Thus, palm oil factories have the potential of generating large amounts of electricity using their own palm oil residues, and extra power generated can be exported to the national grid for added income to the mill. Figure 14 presents the energy requirements and supply in a palm oil mill.

In order for the residues to be utilised as fuel, certain requirements have to be reached with regards to their moisture and ash content, the carbon and volatile contents, the higher heating value, and the chloride content. Analysis of the palm oil residues needed for energy generation show that in order for residues to be used as fuel, EFB moisture content should be mechanically reduced to 50% (on wet basis), fibres 40%, and shells 10% to 20% (on wet basis). An average of 15% for the shells is taken as the industry standard.

Taking all these into account plus a general efficient combustion system, an average figure 2.5 kg of mixed residues is required to generate 1 kWh of electricity. Utilising all palm oil residues represent a theoretical power potential of about 380 GWh/year.

With a total FFB production of 2.25 million tonnes for 1995/96 in Thailand, and average milling duration of 5520 hours per year, the structural power capacity for the whole of Thailand is 69 MW.

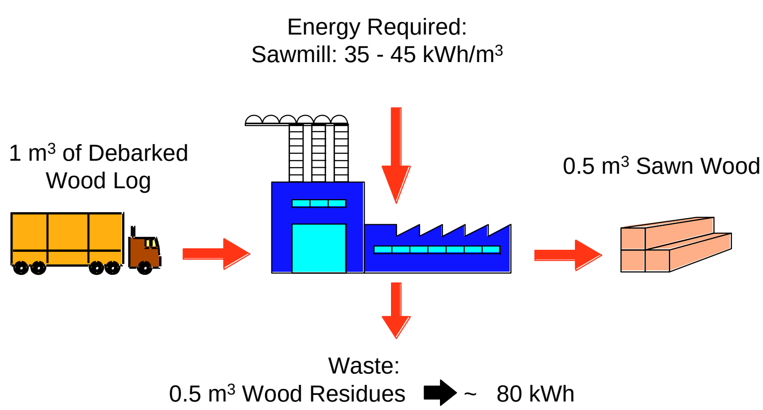
Figure 14. Energy requirements and supply in the palm oil industry



Sawmills and plymills

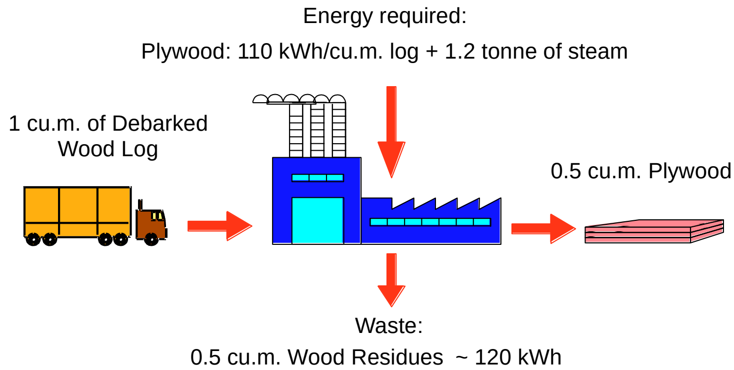
Sawmill residues which constitute shavings, off-cuts and sawdust are partly used by the sawmills as fuel for their steam requirements in drying processes. Where a local demand exists, these are also used as a source of energy for brick and lime burning, as raw material for parquet making, blockboard, etc. Sawdust is also briquetted, carbonised and sold as a high grade charcoal. Figure 15 shows the energy requirement and supply in sawmills.

Figure 15. Energy requirement and supply in sawmills



Within the plywood industry, literature suggests that while 30-50% of the residues are used for power and steam generation in Malaysia and Indonesia, there is little use of the residues in Thai plymills (Koopmans and Koppejan, 1997). However, if the plymills are part of integrated wood complexes, part of the residues are used as a raw material in blockboard and particle board production. Figure 16 shows the energy requirement and supply in plymills.

Figure 16.   Energy requirement and supply in plymills



Based on COGEN's experience with the wood industry, an average conservative estimate of 4.0 kg of wood fuel are required to generate 1 kWh of electricity. Therefore if all wood residues in Thailand amounting to 342,500 tonnes in 1996 (see Table 17 in Chapter 2) are utilised as fuel, a theoretical power potential of about 86 GWh/year can be generated. However, this collective potential does not reflect practicality, since the power plants are suitable only to sawmills and plymills of certain sizes where the waste quantity is sufficient to feed the plants continuously.

Energy needs in the mills vary widely but as a general rule, mills can meet both their thermal and electrical energy needs by using their wood residues as fuel. For cogeneration however, COGEN's experience shows that plymills should have a minimum milling capacity of 40,000 m^3/year, while sawmills should have 10,000 m^3/year in order for cogeneration systems to be feasible. Regrettably, very little information about the mills in Thailand are available, and therefore, actual structural power capacity figures have to be obtained through an intensive survey of the industry.

Power from rubber wood. A study conducted by Prasertsan and Vanapruk (1997) may shed some light about the power capacity in Thai sawmills and wood factories if applied to the use of rubber wood wastes taken from the mills themselves (Table 18)

Table 18.   Potential rubber wood waste power generation in Thailand, 1997

Provinces	0.5 - 1 MWe	1 - 3 MWe	3-6 MWe	6-10 MWe	> 10 MWe
Chumporn	2				
Surrattani	7 (1)	21 (1)	5	1 (1)	1 (73 MWe)
Krabi	1	2	1		
Satun	1	3			
Ranong	1	1		1	
Pangnga	2 (1)	1	1		
Pattalung		1			
Trang	8	9	5	1	
Pattani	2	4		1	
Yala	10 (1)	6 (1)	4 (1)	2	
Nakornsri	11 (1)	3	3	4	1 (44 MWe)
Songkhla	9 (2)	9 (1)	5 (1)	4	1 (52 MWe)
Narathiwas	3	2	1		1 (41 MWe)
Chonburi	(3)	1		(2)	1 (254 MWe)
Rayong	4 (2)	6	3		1 (17 MWe)
Chantaburi	1	1 (1)			
Total	62 (11)	70 (4)	28 (2)	14 (3)	6

Note: Figures represent the number of sawmills; those in parenthesis represent other wood product factories
Source: Prasertsan and Vanapruk, 1997

The study suggests that approximately 950 MWe can be produced from 200 sites. Energy produced in small plants, about 500 MWe, are suitable enough for the mills' requirements, while sales to the grid is also possible in bigger mills. The study further recommended that the minimum feasible size for cogeneration in the plants is 6 MWe.

The feasibility of utilising the biomass left in the rubber plantations depends a lot on the economics involved, especially if transportation costs allow it. Moreover, a 6 MWe power plant requires a sustainable plantation area which covers a radius of 5.8 km (Prasertsan & Vanapruk, 1997).

It should be noted that the area where rubber wood is planted is also suitable for other crops such as oil palm. As rubber wood is in direct competition with these crops, it is possible that in the future, rubber wood planters may shift to other crops. For example, there appears to be a move in Thailand for the government to encourage the plantation of oil palm to augment the lack of supply of raw material for palm oil. With the right incentives, the rubber wood planters may decide to convert their land into an oil palm plantation. Nonetheless, even if this happens and farmers stop replanting the rubber wood that have reached their lifetime and are cut, it will take years before substantial area are converted if farmers have to wait for the lifetime of rubber wood to be reached before replanting the land with other crops.

3.2 Other uses of biomass residues

It is worthy to note that while biomass finds its use for power generation in the industries, it is also widely utilised for other uses: as fuel for cooking and heating purposes in the domestic sector, as well as for other non-energy use in both the industrial and domestic sectors. A wide range of literature covers the non-power uses of biomass, but with varying statistics as to the extent of usage. Firstly, variations may be attributed to the following: a) definition of biomass; b) different methods in gathering/obtaining data; c) different sources from which the survey is made; d) differing conversion factors, etc.

FAO has extensively discussed the status of the differing biomass databases that exist today and those which are highly referenced (see RWEDP-FAO, 1997). Not surprisingly, large data gaps are found between these databases, e.g. FAO, United Nations (UN), World Resources Institute (WRI), International Energy Agency/OECD, and EDP-Asia. The biomass energy balance figures in Table 19 should therefore be taken as a mere indication of the status of the other uses of biomass residues in Thailand. It has been lifted from the EDP-Asia database with data coming mainly from the Thai Energy Situation, a publication of the Department of Energy Development and Promotion, Thailand.

Table 19. Biomass energy balance table for Thailand, 1993-1995

BIOMASS ENERGY (in Kilo Tonne Oil Equivalent, ktoe)

	Fuelwood			**Charcoal**			**Rice husks**			**Bagasse**			**Dung**			**Biomass unspecified**			**TOTAL biomass energy**		
	1993	**1994**	**1995**	**1993**	**1994**	**1995**	**1993**	**1994**	**1995**	**1993**	**1994**	**1995**	**1993**	**1994**	**1995**	**1993**	**1994**	**1995**	**1993**	**1994**	**1995**
SUPPLIES																					
Primary energy production	15180	16221	16476	0	0	0	571	483	621	1979	2667	3135	0	0	0	0	0	0	17730	19371	20232
Biomass from forest land (all types)	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	0	0	0
Biomass from agro- and other land	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	0	0	0
industrial biomass residues, etc.		na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	0	0	0
Import	0	0	0	11	14	13	0	0	0	0	0	0	0	0	0	0	0	0	11	14	13
Export	0	0	0	-10	-7	-5	0	0	0	0	0	0	0	0	0	0	0	0	-10	-7	-5
Stock +/-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Statistical differences	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ENERGY SUPPLIES GROSS	**15180**	**16221**	**16476**	**1**	**7**	**8**	**571**	**483**	**621**	**1979**	**2667**	**3135**	**0**	**0**	**0**	**0**	**0**	**0**	**17731**	**19378**	**20240**
TRANSFORMATION																					
Transfers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Electric power production	0	0	-7	0	0	0	0	0	-9	0	0	-286	0	0	0	0	0	0	0	0	-302
CHP production	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heat production	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Electricity/CHP private sector	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other conversion processes/Industrial	-11415	-12319	-12683	0	0	0	0	-33	-27	0	0	0	0	0	0	0	0	0	-11415	-12352	-12710
Refined liquid/gas/solid products	0	0	0	4124	4451	4581	-38	0	0	0	0	0	0	0	0	0	0	0	4086	4451	4581
Distribution/transport losses	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Own/internal use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unspecified and other losses	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-energy use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FINAL ENERGY SUPPLIES	**3765**	**3902**	**3786**	**4125**	**4458**	**4589**	**533**	**450**	**585**	**1979**	**2667**	**2849**	**0**	**0**	**0**	**0**	**0**	**11809**	**10402**	**11477**	**11809**
CONSUMPTION																					
Industry incl. construction	714	776	739	0	0	0	530	448	584	1979	2667	2849	0	0	0	0	0	0	3223	3891	4172
Agriculture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Transport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Commercial/public service	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Domestic use	3051	3126	3047	4125	4458	4589	3	2	1	0	0	0	0	0	0	0	0	0	7179	7586	7637
Urban	42	32	24	118	96	79	0	0	0	na	na	na	na	na	na	na	na	na	160	128	103
Rural	3009	3094	3023	4007	4362	4510	3	2	1	na	na	na	na	na	na	na	na	na	7019	7458	7534
Unspecified	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL CONSUMPTION	**3765**	**3902**	**3786**	**4125**	**4458**	**4589**	**533**	**450**	**585**	**1979**	**2667**	**2849**	**0**	**0**	**0**	**0**	**0**	**0**	**10402**	**11477**	**11809**
% to total consumption for the year	**36.19**	**34.00**	**32.06**	**39.66**	**38.84**	**38.86**	**5.12**	**3.92**	**4.95**	**19.03**	**23.24**	**24.13**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**			

Source: EDP-Asia (from Thailand Energy Situation, 1993-1995) ; na - not applicable/not available

3.3 Summary

The processing of biomass in industrial mills result to a large production of residues. These residues are considered wastes and are disposed off through various methods, one of which is as fuel for the mills' heat requirements. The residues however, are utilised in very inefficient systems, which most often than not also cause environmental problems. Technological developments in the energy sector now allows for the utilisation of these residues in a more efficient and clean manner. Proven technologies for heat and power generation in industrial mills are now available in the market, and the uptake of these technologies in Thailand would result to energy self-sufficiency in the mills. Moreover, the mills would gain economic and environmental benefits in the process.

A summary of the existing power potential from biomass based on proven technology in Thailand is shown in the following table.

Sector	Residue	Theoretical Power Potential	No. of mills in Thailand		Structural Power Potential	Remarks
			Total	Above Threshold		
Sugar	Bagasse	5797 GWh/year	46	46	1900 MW	potential use of cane trash is explored further in Chapter 4
Rice	Rice husk	2422 GWh/year	>44000	78	66MW	potential use of rice straw is explored further in Chapter 4
Oil Palm	EFB+Shell+Fibre	379 GWh/year	15	15	69 MW	biogas production from POME is discussed in Chapter 4
Wood	from log production	86 GWh/year	777	data not available	data not available	
	from rubber wood	data not available	about 200	data not available	950 MWe	

Chapter 4. Assessment of Possible Major Potential Resources Likely to be Exploitable in The Near Future Provided Specific Obstacles are Removed

This chapter discusses the potential of exploiting biomass residues for electricity generation and other energy uses if barriers to its utilisation are removed. The discussion relies heavily on published literature and various reports.

4.1 Sugar cane residues

Cane trash in Thailand represent a significant agricultural biomass resource that is under-utilised. Under-utilised in the sense that its current use has been restricted to non-energy related and low-economic value activities. It is generally similar to bagasse as a fuel in most respects, the major difference of which could only be moisture content and possibly ash content. If cane trash is allowed to dry on field for 4-6 days, moisture content may drop from 50% at harvest to 30% or lower (USAID, 1986). Further drying during storage could result in a fuel of 20-25% moisture, thereby enhancing its usefulness as a source of energy. With the current efficiency of installed boilers and turbines in Thailand, it is estimated that a power potential of 180 kWh/tonne at 30% moisture and 245 kWh/tonne at 25% moisture is possible (USAID, 1986). Therefore at the current sugar cane production level of 57.9 million tonnes, it is expected that about 29 million tonnes (at 25% moisture) or 31 million tonnes (at 30% moisture) of high quality boiler fuel can be produced. If utilised with the current state of installed boilers and turbines, this could represent a theoretical power potential ranging from 5580 to 7105 MW!

The above discussion presupposes that all cane trash are collected from the fields. Nature, however dictates that some cane trash has to remain in the fields to provide organic matter to the soil, to retain moisture and inhibit weed growth, while the new cane shoots are starting to grow. Though beyond the scope of this study, estimates that approximate the net residue available on field are available (see Therdyothin et al, 1992). Most estimates give a 70% utilisation rate of cane trash available for energy purpose, while the remaining 30% remain on field for soil conditioning. The figures shown above represent the theoretical estimate that might be attained if this under-utilised residue is tapped to the fullest.

4.2 Paddy residues

As discussed in Chapter 3, rice husk is mainly utilised as fuel in Thai rice mills. As in various rice-residue fired plants in the U.S., Europe, Japan as well as in other Asian countries, plants are also designed to run on rice husks. There has been limited application on the use of rice straw as an industrial fuel due to the logistical problems associated with its collection from the fields and its low ash melting temperature which can create slagging problems in furnaces.

USAID (1990) reports that rice straw was tested in a commercial furnace designed to burn bales of agricultural residues for the production of heat. Ash tended to cling to the unburned material and retarded combustion. Unless the bales are shaken periodically to remove the ash, the air temperature declined steadily and the complete combustion of the large round bales required up to 24 hours.

The energy content of rice straw has been measured at around 15 MJ/kg, which is about the same as that of rice husk. A study by the Punjab Agricultural University in 1986 (as cited by the USAID report) used an estimate by Gariboldi Engineering that about 2.6 tonnes of straw would be needed to produce 1 MW of power in a low pressure plant. This is highly dependent however, on the moisture content of the straw.

If applied to Thai conditions where rice straw is about 37 million tonnes (see discussion on Paddy Residues, Chapter 2), this would imply a power potential of about 14200 GWh/year. This more or less approximates USAID's report that 'the potential energy in the world's annual production of rice straw is about 5 times as large as the annual output of the rice husks.'

4.3 Oil palm residues

Not much has been said so far about the utilisation of the palm oil mill effluents (POME) for the production of biogas. Studies conducted by Prasertsan and Prasertsan (1996) revealed that the average figure of POME from Thai mills is about 0.87 m^3/tonne of FFB (~ 600 kg POME). Since discharge standards of effluent from the palm oil industry has not been set in Thailand yet, the general standards for any other effluent is enforced. (Environmental guidelines of the palm oil industry are however, being developed and standards are anticipated to be implemented by the year 2000).

Biogas technology uptake in Thailand is still not a common practice. Related experiences in Malaysia however, show a big potential in the utilisation of POME for biogas production.

The POME is a highly polluting process waste. In a conventional palm oil mill, 600-700 kg of POME is generated for every tonne of processed FFB. In Malaysian mills, the Department of Environment requires the treating of the POME to an acceptable standard before it can be discharged. Anaerobic digestion is widely adopted in the industry as a primary treatment for POME. Biogas is produced in the process in the amount of 20 m^3 per tonne FFB. Table 20 presents some comparative figures of POME characteristics and the DOE standards.

Table 20. Characteristics of Palm Oil Mill Effluent and the Department of Environment (Malaysia) Standards

Parameters	POME	DOE Standards
pH	4.0	5.0 - 9.0
BOD (Mg/L)	25,000	100 (50)*
Suspended Solids (Mg/L)	19,000	400
Total Nitrogen (Mg/L)	707	200**
Ammoniacal Nitrogen (Mg/L)	35	100**
Oil and Grease (Mg/L)	8,000	50
Temperature (^oC)	80-90	45

Source: Ma and Ong, 1986

* This additional limit is the arithmetic mean value determined on the basis of a minimum of four samples taken at least once a week for four consecutive weeks.

** Value on filtered sample.

	Calorific Value	Quantity	Potential Energy per Tonne FFB
Biogas from POME	5,330 kcal/m^3	20 m^3/tonne FFB	447 MJ

Source: Chua, 1991

Translating the potential energy of 447MJ per tonne FFB to Thailand total FFB production for 1995/96, and assuming that all POME undergo treatment for biogas production, there exists a power potential of 96 GWh/year from Thai palm oil mills.

4.4 Coconut residues

There are a number of on-going R&D projects in Thailand for the use of coconut industry waste for energy (Naka, 1995). Among these are the design, fabrication and operation of a single-drum kiln and a continuous drum retort for the carbonisation of waste wood or coconut shell. The new design of a single drum kiln incorporates basic improvement over the traditional single-drum kiln, resulting in a marked increase in charcoal yield from 22% to 33%. Another study is being done at the Chulalongkorn University to make coconut shell charcoal by fluidised bed.

In general, however, the use of coconut residues for energy in Thailand is still limited and not quite documented.

4.5 Dendrothermal power from Eucalyptus

The NEA study has come up with the following assumptions regarding fuel requirements should the DTP programme of Thailand be implemented successfully:

Size of plant	3 MW	10 MW	25 MW
m^3 solid volume	33,563	95,895	209,770
m^3 loose volume	83,908	239,737	524,425
tonnes, 35% moisture	29,200	83,429	182,500

Source: NEA, 1987

In terms of wood supply, the above fuel requirements would be as follows:

Size of plant	3 MW	10 MW	25 MW
Wood to fell:			
m3 solid	35,307	100,878	220,671
Wood to transport:			
tonnes, 45% moisture	35,113	100,322	219,454

Source: NEA, 1987

The required planting area (in hectares) to meet the above conditions are as follows:

Size of plant	3 MW	10 MW	25 MW
Productive forest area required (in hectares) at the following yield assumptions:			
3.2 m^3 per rai	1,765	5,004	11,034
4.8 m^3 per rai	1,177	3,363	7,356
5.6 m^3 per rai	1,009	2,882	6,305
6.4 m^3 per rai	883	2,522	5,517

Source: NEA, 1987
6.25 rai = 1 hectare

Chapter 5 Major Technologies for the Exploitation of Renewable Energy Sources

5.1 Technology characterisation

According to the degree of maturity, biomass conversion technologies can be classified into three categories:

- Traditional technologies
- State-of-the-art technologies
- Emerging technologies

<u>Traditional technologies</u>

Traditional technologies are conventional technologies which are used for a long time without any technological barrier. The major traditional technologies are:

Pile burners. Approximately fifty years ago, all common ways of burning wood waste involved some form of pile burning. The pile burning combustor was typically composed of number of cells. Each of the cells consisted of a lower, refractory lined combustion chamber with a grate floor to support fuel pile and an upper, second combustion chamber. The furnace and the boiler were separated with the furnace generally located above the secondary combustion chamber. The pile burning boiler designs were simple to design and inexpensive.

In pile burning system, wood waste is normally piled as high as ten to twelve feet. Combustion air flow upward through the grates from underneath the pile and inward from the cell walls providing oxygen for combustion, cooling air for the grates and promoting turbulence and fuel drying. Most of the fuel will be burned on the grates. Burning of the volatiles will be completed in the secondary combustion zone where overfire air is introduced. Operating temperatures typically ranged from 1100°C to 1400°C. Typically, pile burners had a slow response time to demand fluctuations.

The combustion process is very difficult to accurately control and the cells had to be shutdown periodically for cleaning. The load and the amount of excess air are difficult to control. Due to high operating temperatures, the wood ash actually slagged and pooled on top of the grate. The ash is then manually broken up and removed from the furnace.

Pile burners are capable of handling wood fuel with a high moisture content with large quantities of dirt and contaminants mixed in with the fuel. Fuel sizing is less critical with pile burners than with other combustion systems.

Relative to other combustion technologies, the efficiency is low. Especially in older designs, boiler efficiency is low, generally 50% to 60%, due to large surface area of the furnace and the absence of radiant air heating. The high operating temperatures will basically be a disadvantage with respect to thermal NO_x creation.

Combustion on grate. There are three kinds: stationary sloping grate system, travelling grate system, and vibrating grate system.

<u>Stationary sloping grate system</u>. The concept of the stationary sloping grate was already developed in the late 1920s. Fuel is introduced at the top of the grate and slides down the grate. The fuel burns as it proceeds the bottom. This system is also referred to as semi-pile burning. Characteristic problems with early designs included avalanching of the fuel on the grate and difficulty in controlling both the steam load and the rate of combustion.

<u>Travelling grate system.</u> In travelling grate spreader stoker designs, the entire bottoms of the furnace is a slow moving platform or conveyor forming the grate. The grate is cooled by air fed from under the grate. In this way, the grate mechanism and its cooling system defines the maximum acceptable undergrate air temperature which, correspondingly, defines the moisture content of the fuel that can be burned. Water cooled walls could be used to prevent slag formation adjacent to the stoker. Fuel is fed from a pneumatic spreader stoker system located on the front of the furnace. Smaller and dryer

fuel particles are burned in suspension, while the larger particles fall in a thin layer on the moving grate. The fuel has to burn at a uniform rate and a sufficient speed.

Vibrating grate system. The vibrating grate system offers the benefit of spreading the fuel so that small piles that might form on the grate are levelled out. There are less moving parts than with the moving grates and therefore less maintenance is required. Fuel can be mechanically distributed by screw feeders located at the top of the grate. Recent boilers use water-cooled vibrating grates, allowing the use of high temperature undergrate air and a higher percentage of overfire air. This at its turn enables lower combustion temperatures and therefore better control of NO_x formation. Another advantage of lower quantities of underfire air is lower unburned particle carry-over. Other advantages of the system are:

- load control capabilities comparable to those of an oil burner, because of the fact that a large amount of the fuel is burned in suspension; and
- possibility to switch to 100% firing of alternative fuels such as oil or gas without any further protection of the grate.

Usually, fuel switching capacity of grate systems is limited. Moisture content should typically be kept within about 10% of the design rate. Fluctuations in moisture content outside this range result in significant changes in flue gas flows and in heat transfer rates. Fuels with low melting ashes, like many agricultural wastes, are typically kept below approximately 15% (heat input) of the total boiler fuel. The simplicity and flexibility of the grate system makes this design one of the most adaptable units to co-fire solid fuels. The difference in bulk density of fuels may create difficulties in using the same spreader or distributor for both fuels.

Efficiencies of recent designs range up to about 84% (LHV) for travelling grates and 96% (LHV) for vibrating grates. In the 1980s many of these systems adopted a staged combustion process in order to meet with NO_x emissions standards.

Examples of combustion on grate systems are presented in Table 21.

Table 21. Combustion on grate - examples

Parameter	**Unit**	**Value**	**Value**	**Value**
Plant size	MWe	2.5	50	34
Technology type	-	inclined moving grate	travelling grate	water cooled vibrating grate
Plant	-	Chia Meng	McNeil Plant	Måbjergværket CHP Plant[4]
Country	-	Thailand	USA	Denmark
Start up year	-	1997	1984	1993
Technology				
Fuel used (moisture)	%	rice husk (10)	wood (47)	straw (16) wood (40) msw[1] (23) natural gas (0)
Steam data: - temperature - pressure - flow	 °C bar kg/s	 420 34 17	 510 92 61	 520 100 35
Efficiencies: - boiler (LHV) - turbine (gross) - net (LHV)	 % % %	 - - -	 83 39 30	 89 36 30
Cost				
Investment costs (1992 US$)	$/kW$_e$	1550[2]	1800	2900
Emissions				
Emissions: - NO_x - CO - particulates	 mg/Mj$_{in}$ mg/Mj$_{in}$ mg/Mj$_{in}$	 150[3] 33[3] -	 74 177 4	 108 130 -

[1] municipal solid waste
[2] In 1997 US $
[3] Average emission in ppm unit
[4] For CHP plants, a theoretical estimation has been made of how much electricity could be generated when there was no heat supply
Source: Broek et al., 1995, COGEN

State-of-the-art technologies

State-of-the-art technologies are the technologies, that can be used at the present time with minimal developmental barriers. The major technologies are:

Suspension burning. Suspension fired boilers resemble pulverised coal boilers in that the combustion occurs while the fuel particles are pneumatically suspended in an air stream. An important attraction of the suspension fired boilers is the reduced furnace size due to drier fuel.

Two basic types of suspension burners are available for use on steam generators, namely cyclonic burners and solid-fuel burners. Cyclonic burners are designed to mix fuel and air in the correct proportion and to complete combustion before swirling particles of fuel reach the end of the refractory chamber. Solid-fuel burners mix the air and fuel together in the correct proportion and ignite the combustible mixture. Burnout of fuel particles is completed in a vertical cylindrical furnace.

Elaborate fuel preparation and feeding system are required for suspension firing system. For proper combustion, biomass fuels are required to have a moisture content of less than 15% and a fuel particle size of less than 6mm. If fuels like wood chips or straw are used, it has to be dried and processed through a hammer-mill to reduce the particle size. The presence of dry fine fuel particles creates a potential explosion hazard. Thus, suspension burning fuel handling systems require more careful design than conventional biomass fuel handling systems.

The efficiency of a suspension fired boiler is, as high as 80% (HHV). This is partly caused by low excess combustion air required, which results in a better heat transfer because of lower flue gas velocity. NO_x emission control can be undertaken in a similar way as with pulverised coal firing. Burners should be adjusted in such a way that temperature peaks within the combustion area are prevented.

Atmospheric fluidised bed combustion. Of the different fluidised bed boilers which are used at the moment, most of them are either bubbling (BFB) or circulating fluidised bed (CFB) boilers.

In fluidised bed combustion, the primary combustion air from the bottom of the furnace is injected with such high velocity that the material inside the furnace becomes a seething mass of particles and bubbles. This seething mass consists of both the fuel and of granular inert material. When starting up boiler, this inert material is heated to ignition point of the fuel at which point the fuel is fed from above the bubbling bed. A steady combustion takes place, in which the fuel, because of the fluidity of the system, is rapidly mixed throughout the bed and in which there is a high heat transfer because of the intimate contact of fuel and inert material. This permits combustion to take place with a minimum of excess air and at a low combustion temperature, typically 800-900°C, as compared with stoker fired boilers. Another advantage of the fast heat transfer is that the installations have relatively high capacity at a relatively small volume.

Bubbling fluidised bed boilers (BFBC). In bubbling fluidised beds, the fluidisation velocities are in the range of approximately 1 to 3 m/s. The main design consideration is to prevent fluidised bed materials from carrying over from the bed into the convection passes. A cyclone can be used to separate small particles from the flue gas. Generally, BFB combustors have lower capital costs in the 15 to 30 MW size compared with circulating fluidised bed combustors. The sizing of the fuel is somewhat less critical than is required for a circulating fluidised bed. According to one study, there were about 110 fluidised bed boilers utilising biomass as fuel world-wide in mid-1980s. At present number of such boilers appears to be much higher.

Circulating fluidised bed boilers (CFBC). With circulating fluidised bed boilers, particles are promoted to escape the furnace area with the flue gases. The primary air velocity is increased to about 4 - 12 m/s, as a result of which more and more of the particles are entrained in the gas stream and leave the vessel. By a cyclone, the fuel particles and the inert bed materials are separated from the flue gas and fed back into the furnace. The difference with the cyclone in the bubbling fluidised bed systems is in its relative size and in the rate at which solids are cycled back to the base of the bed. In a bubbling bed unit the cyclone system is relatively small and it only deals with an insignificant part of total solids inventory in a bubbling arrangement, while in the CFB mode the gas-solid separator is as striking in physical appearance as the main reaction vessel itself and the return leg can contain even more solids than the riser. At CFB gas velocities it is not possible to use in-bed heat-recovery tubes similar to those employed in bubbling bed combustors, instead membrane walls are used. The first commercial CFB combustor was established in 1979. A total of 223 CFB combustor units were reported to be in operation in the early 1990s. A number of these are for biomass burning.

Fluidised bed boilers will be very flexible with respect to moisture content, ash content and size of the fuel, because of the usage of inert medium and the relatively low amount of fuel compared to the total bed mass. Biomass is often fired in fluidised bed boilers in combination with other fuels. This method of co-firing has the advantage that the power plant under consideration is not dependent on just one fuel especially with biomass, which often has major uncertainties in its supply. To burn more than one type of fuel and control the ratio of the mixture, separate fuel feed systems will be necessary. Different pre-treatment facilities have to be available. Fuels with large differences in heating values can require quite complex air supply and flue gas recirculation systems to optimise combustion and heat absorption. The fan system must be capable of supplying air operating efficiency for the best fuel mixture.

Main problems that have been experienced by CFB boilers are erosion of boiler tubes and fuel related problems, generally referred to as fuel fouling. Boiler efficiencies of recently built fluidised bed plants are up to 89% (LHV). When comparing boiler efficiencies, one has to realise that fluidised bed boilers generally will have higher fan power requirements.

Compared with BFB, the CFB boiler carbon burnout efficiency is high because of longer residence times. Unburned carbon losses can be kept lower than 2%. The operating temperatures in FBC boilers are well below the formation point of thermal induced nitrogen oxides. Fuel bound NO_x formation can be reduced by a staged combustion, in which primary air only contains 50-60% of stoichiometric requirements and secondary air is added some distance further up. By including a suitable sorbent in the bed material, sulphur oxide and other acid gases are absorbed as well, eliminating the need for down-stream clean up. For solely biomass combustion sulphur oxide formation is negligible, because of their low sulphur content. Fluidised bed combustion is especially interesting when biomass fuels are co-fired with fuels like peat and coal. For solely biomass fluidised bed combustors, the bed temperature is driven more by the ash deformation temperatures of the fuels being burned. Examples of atmospheric fluidised bed combustion systems are presented in Table 22.

Biomass co-firing. Co-firing is the simultaneous combustion of different fuels in the same boiler. Biomass is well-suited resource for co-firing with coal as an acid rain and greenhouse gas emission control strategy. Co-firing utilising biomass has been successfully demonstrated and is currently practised in the full range of coal boiler types, including pulverised coal boilers, stokers, cyclones, bubbling and circulating fluidised beds. Biomass co-firing is a retrofit application, primarily for coal-fired power plants. Retrofits for coal-fired stokers, cyclones and fluidised bed boilers are potentially simpler and less expensive than for pulverised coal. Retrofits require commercially available fuel handling and boiler equipment. Optimised equipment for efficiently processing some biomass feedstocks to a size suitable for combustion in a pulverised coal boiler will require further development and demonstration. The optimum design for a given power plant will be site-specific and could vary depending on a number of key factors including site layout, boiler type, biomass type and moisture content, level of co-firing, type of existing pulveriser, and pulveriser excess capacity.

Fuel processing requirements are dictated by the expected fuel sources, with incoming feedstocks varying from green whole chips up to 5 cm in size to fine dry sawdust requiring no additional processing. In addition to woody residues and crops, biomass fuel sources could include rice hull, rice straw and other materials. For suspension firing in pulverised coal boilers, biomass fuel feedstocks should be reduced to 6.4 mm or smaller particle size, with moisture levels under 25% (wet basis) when firing in the range of 5% to 15% biomass on a heat input basis. Other boiler types, such as stokers and fluidised beds, are better suited to handle larger fuel particles.

Table 22.   Atmospheric fluidised bed combustion - examples

Parameter	Unit	Value	Value
Plant size	MW	27	46
Technology type	-	bubbling fluidised bed	circulating fluidised bed
Plant	-	Delano I Plant	Händelöverket CHP boiler
Country	-	USA	Sweden
Start up year	-	1991	1994
Technology			
Fuel used Moisture content	- %	agricultural waste 24	wood 50
Steam data: - temperature - pressure - flow	 °C bar kg/s	 513 93 32	 538 70 44
Efficiencies: - boiler (HHV) - boiler (LHV) - turbine (gross) - net (HHV) - net (LHV)	 % % % % %	 78 86 35 26 29	 74 89 38 27 32
Cost			
Investment costs (1992 US$)	US$/kW$_e$	-	1100[1]
Emissions			
Emissions: - NO_x - CO - particulates	 mg/MJ$_{in}$ mg/MJ$_{in}$ mg/MJ$_{in}$	 25 6.5 -	 50 90 10

[1] Cost is only for CFB boiler and pre-treatment of wood
Source: Broek et al., 1995

Substitution of biomass for coal can result in significant reductions in sulphur dioxide emissions. Biomass absorbs about the same amount of carbon dioxide during its growing cycle as is emitted from a boiler when it is burned. Hence, when biomass production is undertaken on a sustainable or close loop basis by raising energy crops, net carbon dioxide emissions on complete fuel cycle basis are considered to be nearly zero. NO_x emissions for a co-fired boiler could be lower than those for a coal-fired boiler due to the lower nitrogen content of biomass and the lower flame temperatures associated with combustion of high-moisture-content biomass feedstocks. In addition, reburn technologies using biomass could provide additional NO_x reductions. Reburning involves a fuel-lean primary combustion stage, followed by a downstream injection of additional fuel in a fuel-rich zone to complete combustion.

An example of biomass co-firing is shown in Table 23.

Atmospheric gasification. Gasification for power production involves devolatilization and conversion of biomass in an atmosphere of steam or air to produce a medium or low calorific gas. This gas is then burned in a diesel engine or used as fuel in a combined cycle power generation cycle involving a gas turbine topping cycle and a steam turbine bottoming cycle. The chemistry and thermodynamics of gasification are basically well-known and simple.

Biomass gasification for the heat application has generally been successful, but much less success has been realised for power applications, where gas quality is of prime importance. Based on the reactor design, the major gasifier categories are fixed bed gasifiers and fluidised bed gasifiers.

Table 23. Co-firing - example

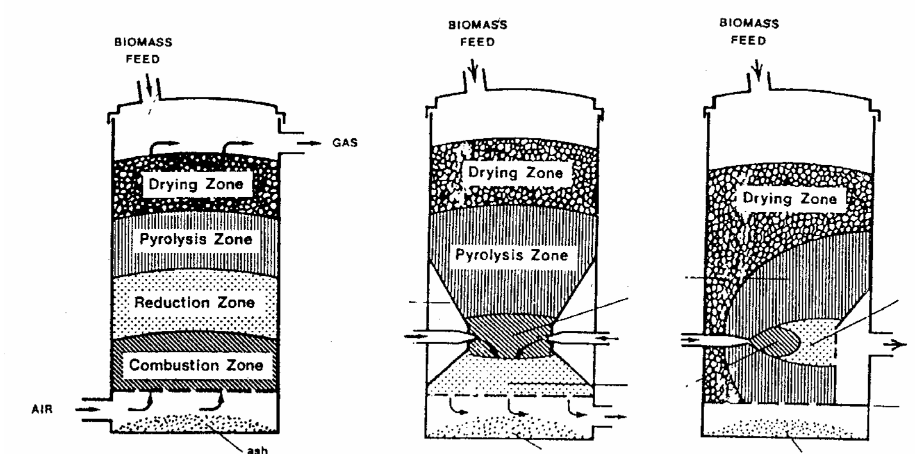
Parameter	Unit	Value
Plant size	MW	100
General Performance Indicators		
Capacity factor	%	85
Coal moisture content	%	7.2
Biomass moisture content	%	21.5
Annual energy delivery	GWh/yr	745
Coal-only Performance Indicators		
Efficiency	%	32.9
Net heat rate	kJ/kWh	10,929
Net power capacity from coal	MW	100
Annual electricity delivery from coal	GWh/yr	745
Coal consumption (wet)	MT/yr	276,175
Annual heat input from coal @ 31,751 kJ/kg	TJ/yr	8,138
Total annual heat input	TJ/yr	8,138
Biomass Co-firing Performance Indicators		
Co-firing rate (heat input from biomass)	%	10
Thermal efficiency	%	32.7
Net heat rate.	KJ/kWh	11,015
Net power capacity from coal	MW	90
Net power capacity from biomass	MW	10
Annual electricity delivery from coal	GWh/yr	670
Annual electricity delivery from biomass	GWh/yr	74
Coal consumption (dry)	MT/yr	250,525
Biomass consumption (dry)	MT/yr	42,933
Annual heat input from coal @ 31,751 kJ/kg	TJ/yr	7,382
Annual heat input from biomass @19,104 kJ/kg	TJ/yr	820
Total annual heat input	TJ/yr	8,202
Capital Cost		
Total biomass handling	$/kW	133.6
Civil structural work	$/kW	36.9
Modifications at burners	$/kW	3.0
Electrical	$/kW	16.4
Subtotal (A)	$/kW	189.9
Contingency @30%,).3*(A)	$/kW	57.0
Total direct costs (B)	$/kW	246.9
Engineering @ 10%, 0.1*(B)	$/kW	24.7
Total capital requirement	$/kW	271.6

Source: USDOE/EPRI, 1997

Fixed-bed gasification. A typical design for a fixed-bed gasification plant for the generation of electricity will include the following major units: biomass receiving and storage, drying, gasification, particulate removal and a generator system. Drying is carried out in a rotary flue gas dryer. Hot flue gases from the engine exhaust will be used to evaporate water from the biomass feed. The final moisture content of biomass fed to the gasifier should be 15%. The product gases flow through the hot part of the bed and heavy tars produced in pyrolysis crack to form more combustible gas components. For gas cleaning, fuel gas is led through a cyclone to the air preheater, where gasification air is heated to 300°C. The gas is eventually cooled to approximately 40°C, and part of water vapour present in gas will condense. Finally the gas is filtered through a fabric filter to remove the remaining solid particulates. A diagram is shown in Figure 17.

In a study carried out by VTT Energy in 1995, the fixed bed gasifier is used with a diesel engine for the generation of electricity. Approximately 15% of the energy fed into the diesel engine is supplied with diesel oil while the rest of the requirement was provided by fuel gas. The engine is not equipped with a turbocharger. The efficiency of the engine is 33% (based on LHV). The generator efficiency is 92% in this size class.

Figure 17.   Fixed bed gasifiers



Fluidised-bed gasification. Atmospheric-pressure fluidised bed gasification is commercially proven technology for coal, peat and wood wastes. A fluidised-bed gasification system for power generation consists of the following major units: biomass receiving and storage, milling and drying, gasification and tar cracking, water wash of the raw gas, and a generator system. Final moisture content of the biomass feedstock should be 15%.

In 1995, VTT Energy carried out a study for fluid bed gasification system together with a diesel engine for power generation. The gasifier is an air-blown, atmospheric pressure circulating fluidised-bed reactor. The gasifier operates at 830°C. Air enters through the bottom grid to maintain fluidisation. Biomass pyrolysed, and the products react further to produce a fuel gas mixture composing mainly of hydrogen, carbon monoxide, carbon dioxide, water vapour, lower hydrocarbons, and some tars. Most of the entrained solids are separated in the cyclones and recycled back to the reactor. Gasification air is preheated to about 200°C by cooling the product gas. About 10% of the energy fed into a diesel engine is supplied with diesel oil while the remaining 90% is provided by fuel gas. The engine is equipped with a turbocharger. The efficiency of the engine is 40% (based on LHV). The power output is de-rated with 10% compared to the nominal output with natural gas.

An example of atmospheric gasification is presented in Table 24.

Table 24. Atmospheric gasification - example

Parameter	Unit	Value	Value
Plant size	MW	0.1	5.8
Technology type	-	Fixed-Bed Gasification	Fluidised-Bed Gasification
Feedstock			
Wood feed (as received)	t/d	4.1	166
Moisture (as received)	%	50.0	50.0
Moisture after dryer	%	15.0	15.0
Gasification			
Carbon conversion	%	98.0	99.5
Wood feed rate (dry basis)	kg/s	0.024	0.958
Air to wood ratio	kg/kg	1.95	1.76
Raw gas pressure	bar	1	1
Raw gas LHV	MJ/kg	4.59	5.00
Power System			
Fuel gas temperature	°C	40	40
Fuel gas LHV	MJ/kg	4.72	4.59
Fuel gas flow	kg/s	0.07	2.99
Diesel Engine power	MW	0.1	5.9
Plant power consumed	MW		0.1
Net output power	MW	0.1	5.8
Overall			
Wood input (LHV basis) [1]	MW	0.45	17.2
Wood input (HHV basis)[1]	MW	0.54	20.9
Overall efficiency (LHV)	%	22.5	33.8
Overall efficiency (HHV)	%	18.6	27.9
Investment Costs[2]			
Capital Cost	ECU/kW	900	2100
Fixed costs	ECU/MWh	51	15
Variable Costs (fuel, fuel oil)	ECU/MWh	43	29
Capital Cost	ECU/MWh	15	34
Total Cost	ECU/MWh	120	83

[1] Includes diesel oil
[2] 1995 figures
Source: VTT Energy, 1995

Emerging technologies

These are long-term technologies requiring further research before commercialisation can be considered. The technologies considered in this study are:

Whole tree energy concept (WTE). The WTE concept combines features of pile burners and stoker systems. The technology has not yet been tested at commercial scale but there appears to be no technological barrier doing so. All of the WTE process operations are said to be based on commercially available equipment and yet the project as a whole is a radical departure from the traditional industry practice.

WTE is a combustion process in which drying with low temperature air is integrated into the process. The fuel is fed into the boiler in the form of whole trees, cut into pieces of equal length. Combustion takes place in three phases. In the first phase, combustion takes place in the pile of trees under sub-stoichiometric conditions. In the second phase the volatiles that are released from the first phase burn. The final phase of the combustion occurs below the bed as the char falls through the openings in the grate and is burnt.

The flue gases first preheat the combustion air, coming from the condensing heat exchanger. The waste heat of the flue gas is used to preheat the ambient air. The major part of the hot dry air is used to dry the wood stacked in a huge air-inflated building for 30 days before it is conveyed to the boiler and burned. Some parts of the system have prove successful as a result of tests, but this is not the case for the complete integrated system. Data provided from the tests showed that the boiler efficiency at lower heating value was 90% while the net electric efficiency was 38.3%

A 10 MW_e pilot plant operating with mixed hardwoods produced positive test results from the flue gas analysis, indicating low NO_x , SO_x, and unmeasurable levels of condensable organics. Particulate emissions rates were close to meeting emission standards without any type of particulate collection. Another example of a 100 MW_e plant employing the WTE concept is presented in Table 25.

Table 25. Whole tree energy concept - example

Parameter	Unit	Value
Plant size	MW	100
Technology		
Fuel	-	Whole tree
Initial moisture content	%	45
Final moisture content, as fired	%	25
HHV, as fired	MJ/kg	13.2
LHV, as fired	MJ/kg	12.0
Carbon burnout efficiency	%	99.9
Particulate removal efficiency	%	99.8
Net electric efficiency, LHV	%	38.3
Boiler efficiency, LHV	%	90
Turbine efficiency, gross	%	41.5
Costs (1992 US$)		
Equipment cost	US$	101,625,847
Total capital requirement	US$	151,436,378
Total capital requirement	US$/kW	1,514
Emission		
SOx	mg/MJ	0.17
NOx	mg/MJ	18.5

Source: Broek et al., 1995

Steam-injected gas turbine (STIG). Steam injected gas turbines are commercially available gas turbine system, in which steam is produced from the gas turbine exhaust heat by means of a heat recovery steam generator (HRSG), the steam being used for industrial process applications, or at times of low steam demand, being injected into the turbine combustor to pass through the turbine (Figure 18). STIG technology makes it possible (if the extra electricity produced when the steam load decreases can be used) to overcome the problem of poor part-load performance which limited the use of simple-cycle gas turbines to cogeneration applications involving constant steam loads.

Because of the high specific heat of steam/air mixture in the turbine, the gas turbine produces more electrical power at higher efficiency, with increasing steam injection, which in turn also lowers the flame and gas temperature in the combustion zone and reduces NOx formation.

The steam injected gas turbine for electricity generation mainly consists of following major units: wood receiving and storage, milling and drying, gasification, particulate removal, and a steam injected gas turbine power system. The gas turbine is a aeroderivative type, and has been used for many years in industrial operations with distillate fuels and natural gas. Combustion air is compressed slightly bellow 19 bar. The air needed for gasification is extracted and fed to a booster compressor, which further raises the pressure of the extracted air. Fuel gas is combusted at around 1180 ^oC. The flue gases are expanded through the turbine, which generates electricity through a generator. The cooled flue gases are led to the HRSG, in which steam is generated to be injected into the gas turbine combustor.
An example of STIG is presented in Table 26.

Figure 18. Steam injected gas turbine.

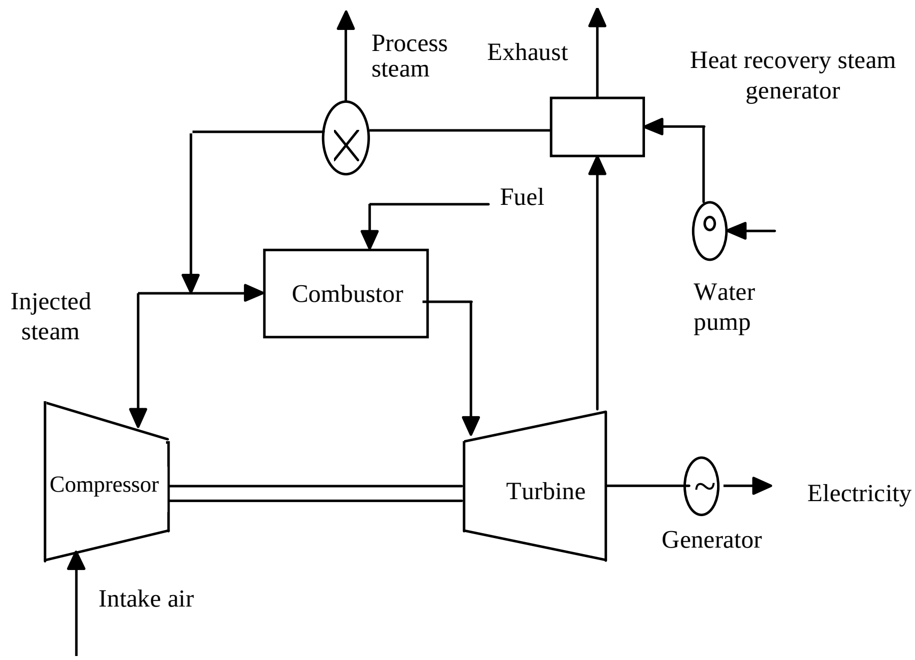


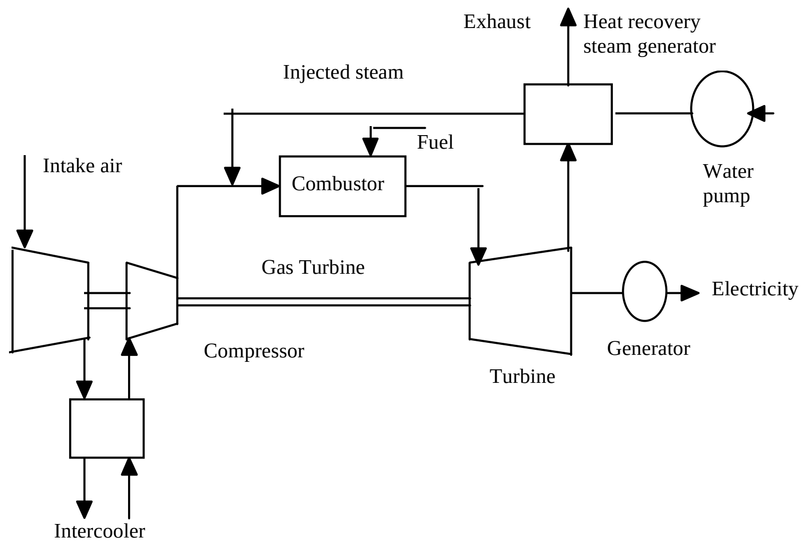
Table 26. Steam injected gas turbine (STIG) concept - example

Parameter	**Unit**	**Value**
Plant size	MW	25
Feedstock		
Wood feed (as received)	t/d	708
Moisture (as received)	%	50
Moisture after dryer	%	15
Gasification		
Carbon conversion	%	99.5
Wood feed rate (dry basis)	kg/s	4.10
Air to wood ratio	kg/kg	1.75
Raw gas pressure	bar	23
Raw gas LHV	MJ/kg	5.05
Power System		
Fuel gas temperature	°C	480
Fuel gas pressure	bar	22
Fuel gas LHV	MJ/kg	5.05
Fuel gas flow	kg/s	11.96
Combustion temperature	°C	1180
Steam pressure	bar	22
Steam temperature	°C	357
HRSG stack temperature	°C	465
Gas turbine power	MW	24.5
Plant power consumed	MW	0.9
Net output power	MW	23.6
Overall		
Wood input (LHV basis)	MW	67.6
Wood input (HHV basis)	MW	82.9
Overall efficiency (LHV)	%	34.9
Overall efficiency (HHV)	%	28.4
Investment Costs[1]		
Capital cost	ECU/kW	1300
Fixed costs	ECU/MWh	7
Variable costs (fuel, fuel oil)	ECU/MWh	28
Capital cost	ECU/MWh	21
Total cost	ECU/MWh	56

[1] 1995 figures
Source: VTT Energy, 1995

Intercooled steam-injected gas turbine (ISTIG). The intercooled steam injected gas turbine is an advanced version of the STIG, increasing the efficiency due to the cooling provided in the intercooler to the compressed air in the gas cycle (Figure 19). This cooling provides higher efficiency due to the lesser compressor work required and the turbine can operate at high turbine inlet temperature owing to the improved cooling of the turbine blades with air bled from the compressor.

Figure 19. Intercooled steam-injected gas turbine



ISTIG can double the output of a simple cycle gas turbine with an overall power-cycle efficiency of above 50% and a high degree of NOx control. Although the ISTIG is not commercially available, it could be brought to the market in 3-5 years, if there were sufficient commercial interest.

Integrated gasification combine cycle (IGCC). This system uses simple Brayton gas cycle and is essentially a combined cycle in which the products of gasification are burnt in a combustor to drive a gas turbine while the heat in the exhaust flue gases is recovered in an HRSG that in turn drives a steam turbine. This results to high overall efficiencies with the prospect of even higher efficiencies if high temperature turbines and hot gas cleanup systems were developed (Figure 20).

Wood chips are screened and hogged to a proper size, and dried in a dryer. Dried wood is conveyed to storage silos adjacent to the gasifier building. It is then transferred to a gasifier. Several gasifier options are possible such as atmospheric or pressurised gasifiers. Air is extracted from the compressor section of the gas turbine and fed into the gasifier. Fuel gases exiting the gasifier are cooled in the product gas cooler and then cleaned. The cleaned fuel gas is combusted in a gas turbine, producing electric power and a high temperature exhaust stream. A heat recovery steam generator (HRSG) is employed to recover this heat to generate high temperature, high pressure steam that is then expanded in a steam turbine to produce additional power.

An example of IGCC is presented in Table 27.

Fuel cell. Fuel cells are electrochemical devices which convert a primary fuel into electricity with efficiencies up to 65%, and the possibility of using the heat rejected in the process for on-site thermal consumption (Figure 21). The operation of fuel cells requires hydrogen and oxygen. The hydrogen can be obtained from primary sources such as natural gas, coal oil or biomass, and oxygen either supplied from air or pure.

The operation of a fuel cell involves feeding gaseous fuels continuously to the fuel cell's negative electrode (anode), while oxygen or air (oxidant) is fed continuously to the positive electrode (cathode). A continuous electrochemical reaction occurs which produces an electrochemical potential or voltage and electric current similar to that of conventional lead-acid battery. Several fuel cell types are currently under development; the phosphoric acid fuel cell (PAFC) is closest to commercialisation. The PAFC fuel cell operates at approximately 2149°C and has a cycle efficiency of as high as 45%. By 2020, advanced fuel cell designs could reach efficiencies of about 57%.

Besides the high electricity conversion efficiency, additional benefits are low pollutant emissions, good behaviour under partial load, short construction and replacement time. Fuel cells can be found in all kind of applications were mechanical energy is required, the main final uses being combined heat and power in Industry and buildings, transport and electricity production.

No cell testing has been done to date with biomass derived gases despite the several advantages that biomass has over coal in this application. Biomass' primary advantage its very low sulphur content. Sulphur containing species are a major concern in fossil fuel-based fuel cell systems since all fuel cells are very sensitive to this contaminant. An additional biomass advantage is its high reactivity. This allows biomass gasifiers to operate at lower temperatures and pressures while maintaining throughput levels comparable with their fossil fuel counterparts.

Figure 20. Integrated gasification combined cycle

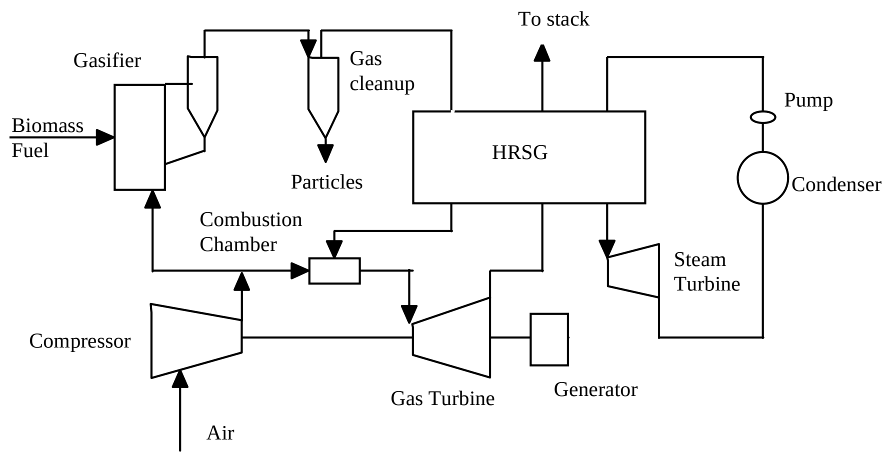
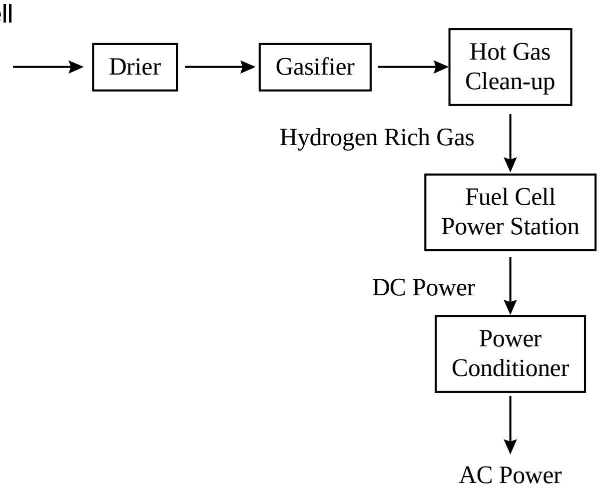


Table 27. Integrated gasification combined cycle (IGCC) concept - example

Parameter	**Unit**	**Value**
Plant size	MW	9.96
General		
Project title	-	ARBRE
Country	-	U.K.
Status	-	design
Technology		
Gasifier	-	Atmospheric circulating fluid bed
Tar removal	-	Catalytic tar removal
Gas cleaning	-	Bag filter/scrubbing
Installed capacity	MWe/MWt	9.96
Fuel	-	Wood
Fuel flow rate	t/h	6.75
Net electric output	MWe	8
Net heat output	MWt	0
Electric efficiency	%	30.6
Overall efficiency	%	30.6
Costs		
Project cost	MUS$	47.884
Gasifier cost	MUS$	4.421
Gas turbine cost	MUS$	5.741
Total equipment cost	MUS$	24.233
O + M costs	MUS$/y	4.466
Cost of biomass	US$/odt	40.53
In equivalent Cost kWe net	US$/kW	2,781

Source: Graig et al., 1995

Figure 21. Fuel cell



5.2 Comparison of the combustion technologies

A summarised comparison of the various combustion technologies discussed above are presented in Table 28.

Table 28. **Qualitative evaluation of combustion technologies**

Criterion	Pile Burners		Stoker Boilers			Suspension Boilers	Atmospheric Fluid. Bed Comb.	
	underbed fuel feed	overbed fuel feed	stationary sloping grate	travelling grate	vibrating grate		BFB	CFB
Construction related criteria								
design simplicity	+	++						
design volume and compactness						+	+	+
erection speed								
modest capital cost at small scales	+	+					+	+
Operation related criteria								
combustion control	+	-	-					
load response rate	--	--			+	+		
turn down ratio								
steam data insensitive for fuel variation			-					
uninterrupted operation capability	-	-						
modest start up/shut down time								
reliability	-	+						
operation convenience	-	+						
maintenance friendly				-	+			
operating experience	++	++	++	++	+		o	o
Fuel related criteria								
fuel moisture design flexibility	++	++	+	+	++	--	+	+
fuel size design flexibility	++	++	+	+	+	--	++	+
fuel moisture switching flexibility	++	++	-	-		--	o	o
fuel size switching capability	++	++	-	-		--	+	o
fossil fuel co-firing capability					+	++		
fuel firing resistance			-				-	-
boiler tube erosion resistance								-
explosion safety						-		
Efficiency related criteria								
boiler efficiency	--	--				+	+	+
carbon burnout efficiency					+		+	++
modest excess air requirement							+	+
modest fan capacity requirement						+	-	--
Emission related criteria								
NO_x avoidance	-	-	o	o	+		++	++
acid gases absorption							+	++
N_2O avoidance							-	-

Source: Broek et al., 1995
Note : From the left to the right, the technologies become more modern.
Plus sign indicates a positive characteristic of a plant.
Minus sign indicates a negative characteristic of a plant.
0 sign indicates a neutral characteristic of a plant.

5.3 Biomass conversion technologies in Thailand for power generation

Combustion on grate is widely used in Thailand, for electricity generation/cogeneration with almost all biomass residues. For rice husk, fluidised bed combustion and gasification are also used.

In Thailand, the major industries which utilise biomass for power generation are: Rice industries, Sugar industries, Wood industries and Palm oil industries.

Rice industries uses direct combustion for power generation/cogeneration. Combustion on grate is a common practice. Gasification is also a possible option for small rice mills which are not connected with the grid. Rice husk gasifiers can be competitive with diesel power plants in the output of 70 to 200 kWe. At present there are few industrial gasification systems reported to be in operation in Thailand.

Electricity generation/cogeneration by direct combustion in sugar industries is an old practice. Most sugar mills were designed to consume virtually all of the bagasse produced during the milling season, with little concern for efficiency.

At present all sugar mill use back pressure steam turbine cogeneration systems to generate electricity and steam to supply their internal need. The capacity of the power plant use in Thailand vary from 700 kW to 12 MW. The boiler efficiency and cogeneration efficiency are 63 % and 60 % respectively. Extraction cum condensing turbine enables additional power for export by utilising the surplus bagasse in the mill. With co-firing option, it is possible to generate and export power during the off season also. Use of cane trash together with excess bagasse is also a possible option.

Wood industries normally use direct combustion for thermal application. In few plants wood is mixed with rice husk for power generation/cogeneration.

In palm oil industries, direct combustion for cogeneration is used for long time, to meet mill power and steam requirements. However, in most of the plants, empty fruit bunches are not used as fuel. By using empty fruit bunches for energy purpose, it is possible to export considerable amount of electric power to the grid.

Rice straw, coconut husk are not used for power generation in Thailand. They are used for thermal application only.

Chapter 6. The Technological Infrastructure of the Main Technologies and Barriers Towards Successful Dissemination of the Technologies

The successful dissemination of a technology does not depend on the technical aspects of the equipment alone. It is influenced by other factors that are equally or even more important than just the technology. There are four main components in the technological infrastructure of the main technologies identified. These are the technical, human, information and organisational components. The description of these components and the barriers related to each component are presented below.

The "technical" component refers to the performance and the stage of the development of the technological solutions. This includes aspects such as operational performance, reliability of the equipment, and their references showing that the technologies are proven.

The "human" component touches on issues related to the people's perception of the technology, as well as some cultural influences in the adaptation of the technology.

The "information" component relates to the sources of information available to the potential customers about the use of the technologies, such as their record of references, availability of assistance centres to obtain information regarding equipment suppliers, financing, etc.

The "organisation" component covers aspects related to the structure of the industry, transportation, as well as policy, legal and governmental issues. Some of the main underlying barriers fall with in this component.

6.1 The technical component

Lack of successful references

The first main barrier in this category is the lack of references of successful projects on biomass cogeneration in the region. Cogeneration has been used for a long time in some industries such as the sugar and the palm oil industries. In fact, it is possible to find some energy plants in the sugar industry in the region which are operating for more than 50 years. However, these equipment have been operating inefficiently. Advanced, efficient cogeneration equipment using, for example, high pressure systems are not commonly used.

For example, although some of the newest and largest sugar mills in the region are found in Thailand, there is no single sugar mill here which has a cogeneration plant operating at a pressure higher than 60 bar. The same is true in the palm oil industry. The Southern Palm Oil Company was on the verge of implementing a 50 MW cogeneration plant using advance technology to use the residues coming from the palm oil process as fuel. However, the project was cancelled after the economic crisis hit Thailand in July of 1997.

The rice industry recently produced a few good references of energy plants using rice husks as fuel. The two largest rice mills in Thailand have implemented this technology. Recently, the third largest rice mill (Chia Meng Rice Mill) installed a 2.5 MW cogeneration plant using a German technology. This project was supported by the EC-ASEAN COGEN Programme within the framework of its Full Scale Demonstration Project scheme.

In the wood industry, the situation is quite varied. There are wood factories which use their residues as fuel, but in inefficient boilers producing heat for the process or steam to use in old technologies such as steam engines. Only a few mills have started implementing modern biomass energy technologies

Although a few examples of modern biomass energy projects have been implemented as mentioned above, the industries have yet to be fully aware of such projects and the benefits they bring both to the industry and the individual users. During a recent meeting between COGEN and the staff of the

Electricity Generating Public Co. Ltd. (EGCO), EGCO staff confessed they have difficulty finding an example of a successful biomass energy project.

A way to overcome this obstacle is to implement demonstration projects consisting of full scale size equipment in the relevant industries. It will also help to disseminate information regarding references of the same equipment that are implemented in a similar environment as in Thailand.

Advanced equipment is seen as complicated to operate

Another technical barrier is that advanced equipment, cogeneration included, have the reputation of being complicated to operate.

The machinery used in the wood and agro-industries are fairly simple. The people operating them are accustomed to using them for many years. Thus, a modern technology which needs a different area of expertise is not necessarily received with confidence.

In relation to this, several other issues come into the picture. One is related to manpower skills. Some wood and agro-industries claim that the skills of the existing employees of the mills are not enough to handle the new equipment. This means that the potential customer of the equipment has to invest in training his people or hire a new operator. During the boom period in Thailand, this was an expensive investment because skilled workers demand so much and there is no guarantee that they will stay in the company for a long time. At this time, it may not be as difficult to look for a skilled worker to operate an energy plant but the doubt regarding local skills remains.

Another aspect that the potential customers are concerned about is the repair of the equipment in case there is a problem. They feel that there is not enough assurance that the suppliers will provide a quick and satisfactory service whenever one is needed.

Suppliers should therefore take note not to introduce components or instruments in their supply which may not be indispensable in the operation of the equipment. Experience in the region shows that in many instances, operators of equipment have gone back to manual operation or have by-passed instruments after the instruments gave them some difficulties.

Another way to overcome this barrier is to provide appropriate training to the operators of the equipment. The buyer of the technology should see to it that a comprehensive training programme for the operators of the equipment is included in the overall package of the technology offered by the supplier. This training should be done before and during commissioning of the plant, and should include provision of manuals and documentation from the equipment supplier.

Since trained operators for specialised technologies such as energy plant could be in demand and difficult to replace, the experience shows that documenting the training programme through photographs or video could help preserve the knowledge and thus make it easy for transferring to other people.

The quality of biomass as a fuel is not homogeneous

It is a well known fact that biomass is a more difficult fuel to burn than conventional fuels. Biomass fuels also vary from one type to another. And even for the same type of biomass fuel, the quality also varies depending on many factors such as the quality of raw material, the type, nature and procedures of the process, etc. Given these uncertainties, some potential users of biomass equipment are not confident that the equipment that will be installed will be able to handle the range of the quality of biomass that will be produced by their mills.

6.2 The human component

Energy not a core business of wood and agro-industrialists

It should be understood that the main users of biomass cogeneration systems are the processors of wood and agro-industrial products: sugar millers, rice millers, palm oil millers, wood factories, etc. The owners and/or managers of these industries are experts in the processing of their products. But energy generation is out of scope of their core business, and is not within their area of competence. Hence, if a miller is faced with an opportunity to invest, the choice would usually be toward the expansion of the mill or improving the processes rather than in the implementation of an energy plant. During previous discussions with the wood and agro-industrialists, they have always raised the concern that if they implement a biomass energy plant they may not be able to handle the uncertainties related to the operation and maintenance of the equipment.

This tendency may be overcome through proper awareness of the decision makers of the benefits and opportunities of investing in a biomass cogeneration plant. If they could see that implementing a reliable energy system is part of an integrated system which could contribute significantly to the reliability and security of the main processing activity of the mill, the decision makers may look at energy equipment investments at a more favourable angle.

Risk of being the first to fail

Another barrier related to this category is the reluctance of the users to take the risk of being among the first to implement an advance technology. The psychology is that if the venture fails, it is better not to be the one to experience it. Since most of the businesses in the wood and agro-industries are family owned, people know each other in the industry. Any major investment in one mill is known to the others. People for a long time have been talking to each other about using their biomass residues in efficient systems to cover their energy needs. However, the difficulty is to find someone to be willing to blaze the trail and move first into what they consider as the unknown, because if the venture fails, the person might be seen to have made a foolish decision.

Again, the implementation of demonstration projects and the presentation of successful references in a similar environment are valuable in overcoming these obstacles.

6.3 The information component

The barriers that fall within the “information” component refers to the factors related to the flow of information regarding biomass energy and how this information is utilised.

Lack of institutions giving information and advice

One of the barriers to the implementation of biomass cogeneration technologies in Thailand is in connection with the flow and availability of information. In many countries in the ASEAN region, there is a lack of institutions where potential users of the technology could go and obtain sufficient information as well as competent advice in matters related to the choice of technology, legal issues, preparation of agreements/contracts, financing, etc. For example, if a potential buyer of a biomass energy technology needs to know about what technology to purchase, the traditional route is for him to contact an equipment supplier or suppliers who will propose an offer consisting of the technology they propose and the corresponding price for the product. Unfortunately, because of the lack of understanding of the potential customer about the technology proposed, coupled with the general impression that the suppliers are only interested in selling their products, this approach is not so attractive to the potential customer of biomass energy equipment. They believe that they need a neutral institution (government-initiated and operated?) where they could go to and solicit information and advice with minimal or no cost at all.

Lack of awareness among potential users on government rules and incentives

Similarly, there seems to be a lack of information and awareness among the potential users of cogeneration equipment on the government rules, regulations and incentives related to the implementation of biomass energy projects. If a potential user intends to implement a biomass project, where does he start? What are the procedures and regulations that he has to follow? What permits are required? Are there any incentives for these types of projects, and if so, which agency is responsible? These are some typical questions and failing to answer them easily, a potential project owner may abandon the idea in favour of other investment options.

Not enough technical and economic information to make a decision

Since biomass energy investments are considered new and not within the core activity of wood and agro-industries, the potential users need to have sufficient information in their hands before they can be convinced to implement a project of this sort. Their most common complaint is that suppliers easily provide them with an offer without even doing a thorough investigation of the specificities of their situation, which should include issues such as the acceptability of water source, disposal of ash, etc. These potential users, of course, could hire consultants to conduct a thorough feasibility study of the project, but this is an expensive option for some, considering that the project may not go ahead after all.

If a fund for feasibility studies, or even for preliminary engineering and design, is available, which potential project owners could avail, this situation may be less worrying for a potential investor in biomass projects.

6.4 The organisational component

Structure of the industry

The barriers related to the structure of the industry include several factors. One of them is the size of the individual mills. For example, it has been determined by the EC-ASEAN COGEN Programme that in order for a rice mill to implement a project to generate power using rice husks as fuel, the mill must have a milling capacity of 5 tonnes per hour (tph) as a minimum threshold. This is so because a mill of this size can produce residues just enough to provide the amount of steam required by the smallest size of a commercially available turbine. In the wood industry, the minimum threshold capacity is 40,000 m^3/yr. for plymill and 10,000 m^3/yr. for sawmill. Thus, considering this constraint, only about 80 of the >44,000 rice mills in Thailand will be able to implement a power or cogeneration plant fuelled by their own residues. Of course, if we talk about heat generation only, all mills in the wood industry could theoretically implement a boiler to generate heat for the needs in the process.

The application of the technology and the extent of energy production in the wood industry is also affected by the structure and the type of activities in which the business is involved. For example, a company with only a sawmill as an activity, has the potential to implement a cogeneration plant to cover all the power and heat (if drying is required) requirements of the mill. A medium density fibreboard (MDF) plant, however, will have so few residues that it will only be able to implement a heat generation plant. Table 29 shows the structure of the wood complexes vis-à-vis the energy requirements and the type of energy which could be met by using the residues from the mill.

Table 29. Wood residues versus energy requirements in the wood-based industry

Structure of wood complex	**Available residues**	**Residues vs energy needs**	**Conclusion**
Sawmill + Plymill	All	All energy needs (electricity, heat) covered	Excess residues - for sale - for excess power
Sawmill/plymill + Furniture, moulding, frames	All	All energy needs (electricity, heat) covered	Excess residues - for sale - for excess power
Sawmill/plymill + board factory	Bark, sawdust, sanderdust, board edging	Only heat needs covered	Extra residues to be bought if cogeneration is installed
Furniture, Moulding + board factory	Bark, sawdust, sanderdust, board edging	Only partial needs covered	Extra residues to be bought if cogeneration is installed

Source: Guide Biomasse-Energie, Collection Etudes et Filieres, 1994.

In the sugar and palm oil industries, the size of the mills are not so critical because most of them are big enough to implement a cogeneration plant.

Another factor related to the structure of the industry is the transportation problem caused by the fact that biomass is a bulky fuel. Rice husk, for example, has a bulk density of between 100 to 150 kg/m^3. Thus, a truck with 15 m^3 of carrying volume will only be able to carry a maximum of 2.25 tonnes of rice husk per trip. Considering this situation, and added to this is the fact that the logistics of collecting residues from many sources is not so easy, it is recommended that a biomass energy be implemented at the vicinity of the wood or agro-processing mill.

Most of biomass residues come form raw materials that are seasonal in nature. For instance, sugar cane, which produces bagasse, is milled in Thailand for about 4 to 5 months a year. Palm oil and rice, although produced all year round, has low and peak seasons. The operation in wood industries depends a lot on the type and availability of wood used as raw material. The above situations cause some uncertainty for some millers to invest in biomass energy technologies.

The above barriers could be overcome by having a thorough investigation of the feasibility of the project, taking into account the factors mentioned.

Uncertainty of fuel supply

The supply of biomass as a fuel depends on the amount of residues generated by the mill, which in turn depends on a lot of factors such as the capacity of the mill, supply of raw materials, etc. Of all the factors affecting the production of residues for fuel, the supply of raw materials (i.e. sugar cane for the sugar mill, rice paddy for the rice mill, fresh fruit bunches for the palm oil mill, and different types of wood inputs for the wood factory) has been of most concern because a long term agreement with the raw material suppliers is not possible. Recently, the economic crisis in Asia has revealed another dimension to this problem. Normally, and in general, the mills have to sell their products for credit (one month or more). On one hand, they have to pay their raw material suppliers daily in cash. This creates a liquidity problem for the company. Thus, some companies operate nowadays in much less than the maximum capacity. Consequently, less residues are produced by the mills.

Another unfortunate event that contribute to the uncertainty of biomass supply is the effect brought about by natural disasters such as droughts due to the El Niño phenomenon. Historically, Thailand has been fortunate not to experience regular catastrophic natural disasters such as floods, typhoons, etc. However, the occurrence of El Niño has already caused a lot of damage to the agricultural industry in Thailand.

This issue is a serious concern for a potential project owner and can be a major barrier in the implementation of biomass energy projects.

Policy, legal and government issues

In terms of governmental regulations the main barrier that still exists is that the regulations do not provide enough incentives to sell excess power to the grid. The SPP scheme, for example, has about 40% of the installations using biomass as fuel. Yet in terms of the tariff for the buyback of electricity, the regulation does not provide a bias in favour of biomass technologies. The only advantage of a biomass-fuelled energy plant over conventional ones is that EGAT is still open to applications for SPPs using biomass as fuel but not to projects using commercial fuel.

Some of the other barriers related to policy matters that were mentioned during discussions with project (and potential) owners include: the imposition of a demand charge to connect to the utility for backup power (some feel that even after implementing an energy plant to supply their requirements, they still need to connect to the grid for backup purposes); the imposition of penalties for non-supply of required power to EGAT for a firm contract; the inflexibility of EGAT to consider alternative calculations even if they are within the framework of the regulations; and the lower buyback payment for non-firm contracts with EGAT.

Financial barriers

One major problem to the financing of biomass cogeneration plants is that because of the economic crisis in Asia, the owners/developers of potential biomass energy projects are facing difficulties in sourcing financing and, in some cases, cannot put enough of their own funds for the equity portion of the capital.

Other barriers include: high initial capital investment cost; relatively small total investment requirements compared to what banks are used to financing for energy projects; difficulty to guarantee long term supply of fuel, etc.

In addition, because not many banks and financing companies have experience in financing biomass cogeneration projects, they tend to be more cautious in lending to these types of projects.

The above-mentioned governmental and financing barriers are not so easy to overcome. However, if substantial incentives or supporting measures can be provided by the government or relevant institutions to support the implementation of biomass cogeneration, some of these obstacles may have a lesser impact on the projects. These incentives may include provision of loans at low interest rates, more favourable tariff structure for selling power to the grid, government guarantees, support for pre-operating expenses (e.g. feasibility study, design and engineering), waive of penalty and demand charges, waive of fees for government permits, exemption from import duty, etc.

Table 30 shows a summary of the barriers and some possible solutions to overcome them.

Table 30. Summary of barriers and ways to overcome them

Components	Barriers	Possible solution
Technical component	• lack of successful references • seen as complicated to operate • the quality of biomass as a fuel is not homogeneous	⇒ implementation of demonstration projects ⇒ suppliers to simplify operation; training of operators ⇒ adequate testing of samples
Human component	• energy not a core business of potential users • risk of being the first to fail	⇒ create awareness of benefits and opportunities ⇒ references in similar environment; demonstration projects
Information component	• lack of institutions giving information and advice • lack of awareness among users on government rules and incentives • not enough technical and economic information to make a decision	⇒ strengthening of relevant networks ⇒ information drive ⇒ availability of funds or services to conduct feasibility studies
Organisational component	• structure of the industry - size of mills - transportation problems - seasonality • uncertainty of biomass fuel supply • policy, legal and government issues • financial barriers	⇒ thorough investigation of these aspects in the feasibility of projects ⇒ initiatives to boost yield and productivity ⇒ government incentives/ support measures? ⇒ innovative financial strategies; government incentives?

Chapter 7 Assessment of the Financial Situation with Focus on the Major Sub-Sectors Identified

7.1 Market outlook for wood and agro-industries

The rice industry in Thailand plays a significant role towards maintaining stability in Asia's food security, as well as the world's. FAO studies show that Thai rice production is considered one of the steadiest among all grains produced world wide. For the past years (see Table 31), Thailand has been the top exporter in the world with close to 30 % market share in 1997. *Bangkok Post* (12 June 1998) reports that Thailand's position as the world's largest rice exporter will remain for the next 10 years.

Table 31. Major rice exporters, 1994-1998

	1994	1995	1996	1997	1998
Worldwide	16,465	20,997	19,430	18,805	19,856
Thailand	4,738	5,931	5,280	5,275	5,500
Vietnam	2,222	2,308	3,040	3,500	3,500
USA	2,794	3,073	2,624	2,300	2,700
India	600	4,201	3,556	1,750	1,750
Pakistan	1,399	1,592	1,663	1,650	1,700
China	1,519	32	265	900	1,500
Uruguay	396	470	596	650	675
Australia	570	519	475	700	650
Argentina	215	342	367	600	600
EU	185	323	301	350	350
Japan	-	410	200	300	200
Burma	619	645	265	25	-
Indonesia	225	-	-	-	-
S Korea	-	150	-	-	-

Unit: '000 tons
Source: Bangkok Post, Friday, June 12, 1998

With the above outlook of the market, there is confidence that energy investments in the rice industry in Thailand should remain in a secure position. This means that the demand for rice processing will continue, so that a mill which invests in an energy plant will continue to have constant need for power, and there will be a steady supply of rice husk as fuel. At the present, there are a few energy projects that are being planned for implementation using rice husk as fuel.

For the sugar industry, Thailand is the world's second largest sugar-exporting country after Cuba. The country exported more than 4 million tonnes of sugar in 1997 from 56 million tonnes of crushed sugar cane in the same year (*Business Day,* 30 March 1998 and 21 April 1998). However, the present situation of the Thai sugar industry is not so rosy. Several factors contribute to this. One is the El Niño phenomenon which wreaked havoc on sugar cane industry. Because of the catastrophic effect of this phenomenon, Thailand's sugar output has fallen 29 % (from 6.098 million tonnes in 1996-97 to 4.301 million tonnes in 1997-98) after sugar mills closed early this year due to a shortage of available cane. But El Niño is not the only bane to the sugar industry. Factors such as poor management of both the plantation and the mills, lack of government support, and high production costs are also mentioned as causes of low competitiveness of the Thai sugar industry compared to other suppliers in the world market. It is not so much of a wonder then, that not many sugar millers are eager to invest in a project requiring a large and long term investment such as in a high pressure biomass energy system.

The present economic crisis in Thailand does not, of course, help this situation. It is expected that some mills may have to close down within the next couple of years. Already, *Bangkok Post*, 2 March 1998, mentioned that three state owned mills, which are about 40 years old and in need of substantial renovation, would be closed if there are no buyers to end losses that have totalled 300 million baht in the past two years. But among the stronger players, consolidation is expected to take place and initiatives related to productivity and efficiency could become a priority. When this takes place, sugar millers may invest in modern highly efficient energy technologies. Financing could also become easier for these companies.

The palm oil demand and production in Thailand has grown steadily during the past several years. However, because of the weather changes caused by El Niño, the supply of fresh fruit bunches (FFB) has decreased by 40 % within the past 6 months in Thailand, according to a recent discussion with Southern Palm Oil Industry (SPO). Production in Malaysia, the world's largest producer of palm oil, is also down.

The above situation, and the rising production costs, pushed up the prices of palm oil both in the local and in the world market. This seems favourable to palm oil millers; however, because of the liquidity problem caused by the economic crisis, some millers find it difficult to purchase the necessary amount of raw material needed by the mills. Thus, some mills are operated far below their maximum capacity.

On the problem regarding the availability of FFB supply, SPO mentioned that the government through a World Bank funding has initiated a plan to expand the oil palm plantation by an additional 700,000 rais. On a long term basis, there is also a move to convert 6 million rais of the 13 million rais of rubber wood plantation into oil palm plantations. The government will provide incentives such as low interest funds to rubber wood planters who will join the programme. The current oil palm plantation area in Thailand is 1.3 million rais.

Given these initiatives and the government support for the growth of the industry, it is most likely that the palm oil industry in Thailand will rebound from its current slowdown.

The outlook in the wood industry is not so predictable. For the past years the indigenous log production has been steadily decreasing (see Table 32). However, imports of log from other countries have been strong. These imports have been the major source of raw material in the wood industry in Thailand. Nevertheless, it is clear from the table that both the imports and the consumption of wood for wood products is decreasing. It may be interesting to note that about a year ago, the largest particle board factory in Thailand closed down, after some years of operating at a loss. These facts do not present an optimistic picture of the of the future of the wood industry in Thailand.

Table 32. Wood production and consumption, 1990-1996

Year	Log Prod'n. (tonnes)	Imports (tonnes)	Exports (tonnes)	Net national Prod'n.
1990	344,152	1,293,174	0	1,637,326
1991	162,054	1,223,041	0	1,385,095
1992	83,401	1,425,263	0	1,508,664
1993	45,408	956,703	1,181	1,000,930
1994	43,629	1,084,229	0	1,127,858
1995	23,229	964,508	18,314	969,423
1996	29,504	655,410	9	684,905

Source: Royal Forestry Department, various years

One possible factor for the decline in the consumption of traditional wood as raw material is that not long ago, another source of raw material, rubber wood, was started to be utilised. The useful life of rubber wood is about 25 years, after which it has to be cut for the land to be replanted. The trunk of the rubber wood is being utilised for products such as medium density fibreboard, furniture, panels, etc.

Considering that there are 13 million rais of rubber wood plantation in Thailand at present, it appears that the wood industry will continue to have a source of raw material for at least the next 25 years. On the other hand, production of wood products could also be affected by the decrease in local and international demand due to the slump during this economic crisis.

As a summary, it is expected that the rice industry in Thailand will steadily grow. With this, the implementation of energy projects in the mills could also advance. The rubber wood industry, where there exists a steady supply of raw materials from the replanting of rubber wood, also offers a good environment for the implementation of biomass energy technologies. In other industries, the market is not expected to grow compared to the previous years. The two major reasons cited for this are the economic crisis that hit Thailand and the region, and the El Niño phenomenon. The economic crisis may remain for a while, but the situation could improve both for Thailand and the region. Likewise, the effect of El Niño is not expected to last long. Thus, there is reason to believe that, in general, the wood and agro-industries in Thailand could recover in the next few years. By that time, the financial market may also have improved, which will make it easier for the mill owners to decide to invest in modern and highly efficient technologies.

7.2 Sources of finance

World Bank financing sources

The World Bank. One of the goals of the World Bank is to serve as a catalyst for increasing the flow of external capital to its borrowing members; "Cofinancing", the funding of projects by non-World Bank sources which are supported by World Bank Group loans or credits, is one way it performs this function.

Requirements. The Expanded Cofinancing Operations program (ECO), authorised in 1989, is intended to help countries that are close to private financing. ECO is made available to World Bank members and therefore a project sponsor must work together with the World Bank and the host country in the implementation of any ECO arrangement; support is to be provided most frequently in the form of partial guarantees (normally limited to a maximum of 50% of the financing on a present value basis). The World Bank's charter requires that World Bank guarantees benefiting borrowers other than a World Bank member must be counter-guaranteed by a member country.

Structures. Guarantees of commercial loans; guarantees of selected risks of a project (sovereign, but not commercial, risks in context of a limited recourse project financing); guarantees of bond issues; contingent obligations; quasi-equity instruments.

Terms. ECO is to be used to enhance not supplant a World Bank borrower's use of private capital and the credit markets; World Bank involvement can help borrowers to obtain optimum pricing and longer maturities; World Bank generally charges a fee for its involvement in a project, determined on a project-by-project basis.

Contact. Mr. J. Shivakumar, Country Direct
The World Bank
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International Finance Corporation (IFC). A World Bank Group independent member, IFC supplements the World Bank's activities by providing loans and equity without government guarantees to the private sector. IFC's goal is to promote growth in developing countries. IFC will not compete with private capital - IFC finances projects unable to obtain sufficient funding on reasonable terms from other sources. IFC participation, however, often serves as a catalyst for private sector investing and lending.

Equity. Investments made on market terms; IFC may hold up to 35% of a project's equity but will not participate in management.

Loans. IFC normally offers both fixed-rate loans denominated in US dollars or other major currencies and variable rate loans in US dollars; interest rates are determined on a commercial basis (no subsidies); terms usually are 7 to 12 years and are designed to accommodate cash flows; IFC has a participation instrument for large loan syndications which has been used successfully in countries experiencing foreign exchange problems; IFC can arrange contingent financing and liability swaps.

Requirements. IFC prefers to make both an equity investment and a loan; but will provide one without the other, when appropriate; IFC's loan and equity investments usually limited to 25% of project costs

- ratio of IFC project finance to other sources is on average 1 to 5; Largest amount of IFC investment in a project is about US$ 100 million.

Contact. Mr. Khalib Mirza, IFC Chief of Mission
International Finance Corporation
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Global Environment Facility (GEF). The GEF provides grants and consessional funding to recipient countries for projects and programs that protect the global environment and promote sustainable economic growth. GEF is an international initiative of 156 participating governments jointly implemented by the United Nations Development Programme, the United Nations Environment Programme, and the World Bank.

The Facility, originally set up as a pilot program in 1991, was restructured and replenished with over US$ 2 billion in 1994, to cover the agreed incremental costs of activities that benefit the global environment in four focal areas: climate change, biological diversity, international waters and stratospheric ozone.

Institutions are selected to act as intermediaries, providing them with US$500,000 to US$1 million loans at long term, low interests. These loans are used by the intermediaries to finance small and medium scale enterprises whose project demonstrate a positive environmental impact and have basic financial viability. The amount of financing, is either debt or equity, that the intermediaries can provide to a specific project may vary from US$20,000 up to a maximum of US$250,000. Examples of projects which will be financed include renewable energy power generation, energy efficiency conversions to existing offices and factories, eco-tourism lodges, sustainable forestry, and harvesting of non-timber products from rainforests.

Operational focal points in Thailand for GEF:

Piamphongsant, Suphavit
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Fax: 662 217 3226

Wongchumpit, Orapin
Director, International Environmental Affairs Division
Office of Environmental Policy and Planning
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Fax: 662 271 4322

Global Carbon Initiative. Recently initiated by the World Bank to explore ways in which market mechanisms and payments may be used to reduce carbon dioxide emissions in developing countries. One concept currently being examined is the **Carbon Investment Fund**, which would obtain funds from industrialised countries and private companies and invest them in emissions reductions in economies in transition and in developing countries.

Renewable and Energy Efficiency Fund. The Fund is expected to handle smaller project than those the IFC normally deals with: to buy down preparatory costs, it will attempt to match it own funding with “soft” funding from other sources (such as the GEF). The idea is to mobilise private sectors funds for renewable projects and ensure that they are financially sustainable.

Special credit available through the Industrial Finance Corporation of Thailand (IFCT)

IFCT is a development financing institution established by a special law in 1959 to assist in the establishment, expansion and modernisation of industrial enterprises in the private sector and to assist in the development of the domestic capital market. The main criteria applied by IFCT in its financing decisions are the commercial and financial soundness of the projects and their contribution to Thailand's economic progress.

Aside from the list provided below, special credit from Sweden, Italy and the Nordic Investment Bank are available as export credit.
Environmental Fund. In compliance with the Enhancement and Conservation of National Environmental Quality Act B.E. 2535, the Thai government has set up the Environmental Fund to encourage investment and operation of the Environmental Protection Program.

Project Eligibility. The eligible projects must have total fixed asset not over 400 million baht and the nature of business being: i) projects invest in the environmental protection system; ii) projects aiming to relocate their own facilities into the appropriate areas, will be supported for removal cost; and iii) projects with legal certification established the common treatment facilities (no limitation on project size).

Terms and Conditions. i) loan must be made in Thai baht; ii) maximum loan amount must not exceed 20% of the total fixed asset, but must not exceed the pollution project investment as per project nature No. 1; iii) maximum loan amount must not exceed 60% of the enterprise's total fixed asset as per project nature No. 2 and 3 and iv) interest rate : 8-8.5%.

Contact. Environment and Energy Conservation Division, Business Promotion Department, IFCT, Tel. 253 7111 ext. 1182

OECFV.

Budget. 5,000 million yen

Maximum loan per project. 300 million baht

Project eligibility criteria. Project must invest in: waste treatment system, recycle system, cleaner technology, central waste treatment, energy conservation, relocation or energy and environmental equipment

Interest rate. 3.95% (yen currency)

Repayment period. 5-7 years

JEXIM.

About the project. i) direct exporter whose minimum annual income is 30% of the total sales; ii) indirect exporter who has sold revenue to direct exporter not less than 50% per year and iii) Japanese company: business having Japanese shareholders.

Currency of loan. yen

Kind of loan. i) long and medium term of loan for projects using foreign currency for buying equipment, raw materials and construction materials and ii) loan for operating expenses for projects needing foreign currency to procure raw materials

Loan period. 1 to 5 years

Interest rate. depends on the currency and loan period, any further information, contact Credit Section Officer or Trade Promotion Office: i) long term loans: 5.85% and ii) short term loans: 5.18%
Maximum loan. 4,000 yen

Export Credit Agencies (ECA)

Government agencies will provide insurance or guarantees to institutions willing to finance the exporter or importer of qualifying exports. ECA's will, at times, also directly fund the purchaser at low off-market subsidised rates, or even make up the differential between the off-market rate and market rates of interest if a bank or other intermediary will do the funding. Information on the ECA are available in the embassies of countries having ECAs. Table 33 is a list of selected countries and the relevant institutions involved in providing export credit.

Table 33. Export credit agencies

Country	Funding/Guarantee	Insurance
Australia	EFIC	EFIC
Austria	OKB	OKB
Belgium	Creditexport Copremex	Ducroire
Canada	EDC	EDC
Denmark	DEFC	EKR
Finland	FEC	VTL
France	BFCE	Coface
Germany	AKS/KFW	Hermes
Greece	ECIF	ECIF
Ireland	ICI	ICI
Italy	Mediocredito	Sace
Japan	J-Exim	Miti
Portugal	COSEC	COSEC
Netherlands	-	NCM
New Zealand	-	EXGO
Norway	Eksportfinans	GIEK
Spain	ICO	GESCE
Sweden	ABSEK	EKN
Switzerland	-	ERG
United Kingdom	ECGD	ECGD
USA	EXIM PEFCO	EXIM OPIC CCC

EC-ASEAN COGEN Programme

The EC-ASEAN COGEN Programme is an economic co-operation programme between the European Commission (EC) and the Association of South East Asian Nations (ASEAN). The aim of the Programme is to accelerate the implementation of proven technologies generating heat and/or power from wood and agro-industrial residues through partnerships between European and ASEAN companies.

Some technologies are technically and economically viable but are not implemented in ASEAN because they are not well-known and have not been tested under local conditions. To overcome this obstacle, the Programme can bring technical and financial assistance to implement Full Scale Demonstration Projects (FSDPs). An FSDP can be defined as the implementation of a proven technology on a full scale basis in order to demonstrate its technical reliability and economic viability. An FSDP is a showcase in ASEAN aiming to convince other potential end-users to select the technology.

Selection criteria. i) technical and commercial viability; ii) replicability and iii) energy and environment impact

Support from the EC-ASEAN COGEN Programme. i) contribution to investment (up to 15% of the total tax free cost of European or Euro-ASEAN equipment); ii) training in ASEAN and/or Europe and iii) monitoring by an independent organisation.

Conditions. The end-user must allow: technical and economic monitoring; dissemination of monitoring results; and visit to the installation.

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International and Bilateral Development Agencies

Examples are the United Nations Development Programme (UNDP), the Netherlands Ministry of Development Co-operation (DGIS), Danish Development Assistance Agency (DANIDA)

Environmental Enterprises Assistance Fund

The Environmental Enterprises Assistance Fund is a non-profit organisation which promotes locally-owned renewable energy and other environmental companies in developing countries. The Fund provides loans, equity capital, technical assistance, and seeks other institutional and individual investors who are concerned that economic growth be environmentally sustainable.

Financing institution. USAID and Winrock International

Eligibility. i) must engage in activities that are environmentally beneficial such the provision of power services to rural communities using biomass and ii) project must be involved in any of the following: small hydro and geothermal systems (<20 MW); energy efficiency and demand-side management technologies and activities; biomass cogeneration; other organic waste management and recycling systems such as combustion and/or anaerobic digestion of animal wastes, municipal wastes and food processing wastes; photovoltaic and hybrid remote power systems; wind electric generation; sustainable agriculture; managed forestry; eco-tourism

Amount of loan. < US$ 2 million

Interest rate. direct loans are made at consessional rates, but equity investments are expected to provide higher returns than conventional financing arrangements

7.3 Innovative strategies for renewable energy financing

Scale of Renewable Energy Project	**Need to:**
Large (>20 MW) Medium (1-20 MW)	• operate within the same financing rules applied to conventional energy projects • seek assistance to level financial playing field
Small (<1 MW)	• develop innovative financial mechanisms to cascade affordable financing to the end-users; and • seek assistance for institutional, infrastructure and capacity building

Small Scale/Non-Grid Systems

Scope. solar photovoltaic home systems, small windpower systems and hybrid solar/wind/diesel systems that have no associated distribution network

Primary financial barrier. inability of most end-users to afford the up-front purchase of renewable energy systems

Financing strategies.

Finance leasing programs
- allows end-user to lease rather than purchase the renewable energy systems
- financing can be aggregated to more central and larger components that are more easily appraised and managed
- tax benefits from depreciation of equipment could accrue to the leasing company
- end-users are relieved of the burden of up-front purchasing of the renewable energy systems
- principal drawback are additional costs assessed by leasing companies resulting to higher financial costs to the end-user
- this model is being tested by the Indian Renewable Energy Development Agency (IREDA) in the implementation of the SPV component of the GEF supported Indian Renewable Resources Project

Finance Service Providers
- approach encourages the creation of renewable energy "micro-utilities" which essentially sell energy services for a price rather than hardware
- financing can be aggregated to the level of the "service provider" rather than the end-user and can be more easily appraised and managed
- end-user is relieved of the operation and maintenance responsibilities of the renewable energy systems which remains with the energy service provider
- end-user required to make periodic payments based on the level of energy services received
- approach has been successfully demonstrated in the Dominican Republic and is now being implemented in 10,000 solar home system program by a rural electric co-operative in Bolivia

Mortgage Financing
- allows homeowners to incorporate the costs of installing renewable energy systems into the overall costs of their homes through mortgage financing
- recourse-based financing that allows financing of renewable energy systems to be aggregated and incorporated into a larger financing program
- primary drawback is that it excludes low-income and non-homeowner segments of the population
- being tested in a rural housing/electrification program in the Republic of South Africa

Medium-Scale/Isolated-Grid Systems

Scope. mini- and small-hydropower, biomass gasifiers and cogeneration systems, wind/diesel/solar hybrids and other medium-scale renewable energy systems in the range of 1-20 MW

Primary financial barriers. project relatively small; isolated and therefore higher risk; more difficult to develop and implement; more difficult to appraise

Note. Most of these projects are proposed by national or state utility companies, rural electric co-operatives or private sector companies that can be financially appraised and held financially responsible. The most notable example is the World Bank financed "Renewable Energy Small Power Project" in Indonesia.

Large-Scale/Grid Connected Systems

- generally financed on a project by project basis where the project is the target of financing and project developers, along with financial institutions becoming partners in the development of the project

Primary financial barriers. size of the investments required; undefined risks associated for newly emerging large-scale renewable energy technologies such as solar thermal power, advanced biomass gasification, ocean thermal energy

Note. Financing of large-scale projects is done with a number of conventional and innovative instruments as the financial requirements and conditions dictate. In all cases, these projects will require backing of various investment and risk insurance.

7.4 Emerging innovative financing mechanisms

Third party financing through an Energy Service Company (ESCO)

Third party financing is the funding of energy saving investments by an outside company, using energy savings to pay for the investment. The main actor in third party financing is an energy service company. The advantage is that the customer does not have to put up cash out to finance the initial investment. It merely has to make payments to the performance contractor (in this case, the ESCOs). The concept of third party financing always includes technical advise. Therefore, the customer does not have to be concerned about technical matters, because it relies on the ESCO for this expertise.

Energy Service Companies (ESCOs) are most often private companies that provide energy efficiency or load reduction services to customers that own or operate facilities such as factories and buildings. ESCOs use their own working capital for identifying and developing projects. All of the activities that ESCOs conduct for a project are bundled into that project's cost. They then use project financing to construct the project. The ESCO will recoup their working capital spent on the project with funds from the project financing. ESCOs normally operate under a performance contract wherein the ESCOs provide energy savings to a customer for a fee, the level of which depends on the amount of energy saved. Performance contracting is defined by the following key attributes:

- performance contracting offers turnkey services, including feasibility analysis, design, engineering, construction management, installation, operation, maintenance, and financing;
- performance contractors are compensated based on measured results;
- most of the technical, financial, and operational risks are borne by the performance contractor.

Leases

This is similar to the ESCO approach with one key exception: the leasing companies are usually not responsible for maintaining and operating the systems. This approach helps to overcome the high first cost barrier as well as helps in aggregate and target project financing to a few business oriented entities. Several forms of leases are capital leases and operating leases.

Capital lease. The customer essentially owns the equipment. At the end of the lease, they have the option of purchasing the equipment. They simply make regular payments to the lessor, usually a leasing company. Capital leases appear on the balance sheet of the customer as both an asset and a liability. The customer may depreciate the equipment and take advantage of the associated tax benefits. It is worth noting that some countries have restrictions on leasing, or do not permit it at all, thereby eliminating this option for some projects overseas.

Operating lease. Have the advantage of shifting risk from the customer to the leasing firm. However, this makes them more expensive for the customer. In an operating lease, neither the leased assets nor lease obligations appear on the balance sheet of the customer. The leasing company retains ownership of the equipment. At the end of the lease, the customer has the option to take title to the equipment, based on fair market value of the equipment, rather than at a price stipulated in the lease. The lessor thus risks having to reclaim and dispose of the equipment. The equipment eligible for these types of leases is limited, due to this constraint.

Vendor credits

Renewable energy vendors are now extending supplier credits to renewable energy consumers and projects to help close financing gaps and in the process to help secure sales. Vendor credits can help overcome some of the perceived technology risks associated with many renewable energy technologies. Consumers and project financiers are more likely to reduce their perception of technology risks if the equipment vendors are willing to financially back their products.

Targeted project credits

Multilateral development banks have recently used this approach to supply financing through national and local banks for renewable energy projects. In many cases, national and local banks may not be familiar or willing to enter new markets or have limited financial resources and therefore service their traditional clients first. By targeting credit for renewable energy projects, the multilateral development banks have encouraged the national and local banks to explore these new and emerging markets. This approach has helped the local and national banks to develop the knowledge and expertise for assessing similar projects in the future resulting to an expanded market base which includes renewable energy project financing. This approach can help overcome the "no track record" financial barrier often faced by new and emerging technologies.

Direct consumer credits

Attaching a consumer credit program to the renewable energy project will help extend the reach of the renewable energy systems to a larger percentage of the market, particularly those financially viable consumers who have no established credit or cash to purchase the renewable energy systems outright.

Acceptance of equipment as collateral by suppliers

Many commercial banks are unwilling to lend to renewable energy projects because they do not consider the equipment as acceptable collateral against their loans. The main reason is that the secondary market for the equipment is uncertain. To overcome this barrier, the equipment suppliers are beginning to indicate their willingness to repurchase their equipment at a prescribed discount in the event the project fails financially.

Support for project preparation/development

In recognition of the fact that renewable energy projects have high development costs to investment ratio, a number of multilateral, bilateral and national sources have established funds or programs to help developers overcome these high development costs. These are specifically technical assistance grants that, in some cases, are repayable when the projects reaches financial closure. The eligibility and conditions for project preparation assistance vary according to the objectives of the supplier of funds.

Global Environment Facility (GEF)

Renewable energy technologies are extremely crucial for the eventual mitigation of greenhouse gases and are therefore a major target of assistance for the GEF. Specifically, GEF resources are used to remove barriers to the commercialisation of renewable energy technologies.

Activities implemented jointly (AIJ)

An emerging opportunity for extensive support of renewable energy projects concept of AIJ to offset greenhouse gas emissions. This is the case where two countries work jointly to find least cost options for reducing their combined greenhouse gases emissions. This is a concept that derives from the UNFCCC and is presently being tested in a pilot phase. Under AIJ, renewable energy projects that displace greenhouse gases emissions in one country (say a developing country) can receive financial support from the other country (say a developed country) if the resulting greenhouse gases emission credits are transferred to the partner country. This concept helps overcome the barrier of not compensating renewable energy projects for their global environmental benefits. The concept can have a very significant impact in the commercial acceptance of renewable energy projects.

Table 34 summarises the sources of funds mentioned and their corresponding schemes.

Table 34. Different funding schemes and their sources

Sources of Funds	Equity Participation	Loan	Other Schemes
The World Bank (WB) **Contact:** Mr. J. Shivakumar Country Director, The World Bank 14th Floor, Tower A Diethelm Towers 93/1 Wireless Road, Bangkok 10330 Tel: 662 252 2305/07; 662 256 7792/4 Fax: 662 256 7795			**Structure:** Guarantees of commercial loans; guarantees of selected risks of a project; guarantees of bond issues; contingent obligations; quasi-equity instruments. **Terms:** The Expanded Cofinancing Operations program (ECO) guarantee support is normally limited to 50% of the financing on a present value basis; WB generally charges a fee for its involvement in a project.
International Finance Corporation (IFC) **Contact:** Mr. Khalid Mirza IFC Chief of Mission International Finance Corporation 14th Floor, Tower A Diethelm Towers 93/1 Wireless Road, Bangkok 10500 Tel: 662 650 9253/8 Fax: 662 650 9259	Investments made on market terms; may hold up to 35% of equity but will not participate in management. **Requirements:** prefers to make both an equity investment and a loan, but may provide one without the other; loan and equity investments usually limited to 25% of project costs - ratio of IFC project finance to other sources is on average 1 to 5; Largest amount of IFC investment in a project: US$ 100 million.	**Interest Rate:** fixed-rate loans: in US dollars or other major currencies variable rate loans: in US dollars interest rates: commercial basis (no subsidies) **Terms:** usually 7 to 12 years IFC has a participation instrument for large loan syndications; IFC can arrange contingent financing and liability swaps.	
Global Environment Facility (GEF) Contact: Office of Environmental Policy and Planning Soi Phibun Wattana 7, Rama VI Road, Bangkok 10400 1) Piamphongsant, Suphavit Senior Environmental Expert Telephone: 662 279 4769 Fax: 662 217 3226 2) Wongchumpit, Orapin Director, International Environmental Affairs Division Telephone: 662 271 4322 Fax: 662 271 4322	Institutions are selected to act as intermediaries, providing them with US$500,000 to US$1 million loans at long term, low interests. Intermediaries can finance small and medium scale enterprises whose project demonstrate a positive environmental impact and have basic financial viability. Equity: US$20,000 - US$250,000	**Debt:** US$20,000 - US$250,000 Applicable for: renewable energy power generation, energy efficiency conversions to existing offices and factories, eco-tourism lodges, sustainable forestry, and harvesting of non-timber products from rainforests.	
Global Carbon Initiative			Initiated by the World Bank to use market mechanisms and payments to reduce carbon dioxide emissions in developing countries. The **Carbon Investment Fund**, may be launched to obtain funds from industrialised countries and private companies and invest them in emissions reductions in economies in transition and in developing countries.
Renewable and Energy Efficiency Fund			The Fund is expected to handle smaller project than those the IFC normally deals with: to buy down preparatory

			costs, it will attempt to match its own funding with "soft" funding from other sources (such as the GEF). The idea is to mobilise private sector funds for renewable projects and ensure that they are financially sustainable.

Sources of Funds	Equity Participation	Loan	Other Schemes
Environmental Fund **Contact:** Environment and Energy Conservation Division, Business Promotion Department, IFCT Tel. 253 7111 ext. 1182		**Project Eligibility:** investment in the environmental protection system; relocation of facilities into the appropriate areas, will be supported for removal cost; projects with legal certification established the common treatment facilities • Total fixed assets of projects not over 400 million baht. **Terms and Conditions:** • Loan must be made in Thai baht. • Maximum loan amount must not exceed 20% of the total fixed asset, but must not exceed the pollution project investment. • Maximum loan amount must not exceed 60% of the enterprise's total fixed asset. **Interest Rate:** 8-8.5%	
OECFV **Contact: IFCT**		**Maximum loan:** 300 million baht **Project Eligibility Criteria:** Project must invest in: waste treatment system; recycle system; cleaner technology; central waste treatment; energy conservation; relocation; energy and environmental equipment **Interest Rate:** 3.95% (yen currency) **Repayment Period:** 5-7 years	
JEXIM		**Currency of loan:** yen **Kind of loan:** • long and medium term of loan for projects using foreign currency for buying equipment, raw materials and construction materials • loan for operating expenses for projects needing foreign currency to procure raw materials **Loan period:** 1 to 5 years **Interest rate:** depends on the currency and loan period - long term loans: 5.85% - short term loans: 5.18% **Maximum loan:** 4,000 million yen	
Export Credit Agencies (ECA)			Government agencies will provide insurance or guarantees to institutions willing to finance the exporter or importer of qualifying exports. ECA's will, at times, also directly fund the purchaser at low off-market subsidised rates, or even make up the differential between the off-market rate and market rates of interest if a bank or other

Sources of Funds	Equity Participation	Loan	Other Schemes
EC-ASEAN COGEN Programme **Contact:** Michael Pennington Project Manager EC-ASEAN COGEN Programme Asian Institute of Technology (AIT) Outreach Building 301/1, P.O. Box 4, Klong Luang, Pathumthani 12120 Thailand Tel: 662 524 5399; Fax: 662 524 5396 E-mail: cogen@ait.ac.th			**Selection Criteria:** technical and commercial viability; replicability; energy and environment impact **Support:** contribution to investment (up to 15% of the total tax free cost of European or Euro-ASEAN equipment); training in ASEAN and/or Europe; monitoring by an independent organisation. **Conditions:** The end-user must allow: technical and economic monitoring; dissemination of monitoring results; and visit to the installation.
International and Bilateral Development Agencies Examples are the United Nations Development Programme (UNDP), the Netherlands Ministry of Development Co-operation (DGIS), Danish Development Assistance Agency (DANIDA)			
Environmental Enterprises Assistance Fund **Financing Institution:** USAID and Winrock International		**Eligibility:** • environmentally beneficial activities such as provision of power services to rural communities using biomass • scope: small hydro and geothermal systems (<20 MW); energy efficiency and demand-side management; biomass cogeneration; other organic waste management and recycling systems; photovoltaic and hybrid remote power systems; wind electric generation; sustainable agriculture; managed forestry; eco-tourism **Amount of Loan:** < US$ 2 million **Interest Rate:** direct loans at consessional rates	

CONCLUSION

Undeniably, there is so much potential for biomass energy (from wood and agro-industries) in Thailand, despite the fact that waste (fuel) availability is very much dependent on the seasonality of the crop (and consequently the milling duration) and other factors, e.g. climatic conditions, crop variety and other competing uses of the waste.

On a per sector basis, the sugar sector is the most crucial one, having the shortest seasonality of 4-5 months per year. It is however, the sector that offers the highest potential for power generation (about 1900 MW), a large amount of which can be exported to the grid. This assumes that all cogeneration plants would work at high pressure systems of 80 bar, rather than maintaining the current industry practice of utilising low pressure systems of 20 bar.

In the case of the rice industry, conditions for power generation is very much dependent on the mill sizes. For big mills where milling operation is 24 hours a day for 11 months, power generation systems are feasible and export to the grid can also be realised to as much as 50% of power produced.

The palm oil industry does not face much problems with regards to seasonality or mill size limitations. The case of the wood industry is rather complicated. The fuel availability for power generation depends very much on the mill sizes and the level of integration of the wood complexes. Wood complexes, especially when they include a board factory may hardly meet their own heat requirements by using their residues. Others may be able to cogenerate, but exporting to the grid is out of the question. Moreover, 'stand-alone' sawmills and plymills should have a certain mill size to ensure feasibility of cogeneration systems in their plant.

The implementation of biomass technologies for energy, however, still leaves much to be desired. Looking beyond the technical potential for utilising biomass residues for power, four main components in the technological infrastructure of the main technologies and the barriers related to its successful implementation have been identified. These are the: technical component, the human component, the information component, and the organisational component.

Among the technical barriers are: lack of successful references, the perception that operation of advanced equipment is complicated, and the quality of biomass as a fuel is not homogeneous. Human barriers include: energy not a core business of wood and agro-industialists, and the risk of being the first to fail. Information barriers include: lack of awareness among potential users on government rules and incentives, and not enough technical and economic information to make a decision. Organisational barriers include: the structure of the industry, uncertainty of fuel supply, policy, legal and government issues, and most importantly, financial barriers.

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