Report

on

THE STATUS OF BIOMASS GASIFICATION

in

Thailand and Cambodia

Prepared for:

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Executive Summary

The importance of using biomass efficiently to address global warming and resources shortages are well-known and documented. Biomass, which is environment-friendly, can replace fossil fuels for thermal and electricity applications. Biomass gasification, due to its high electrical efficiency compared to other biomass-based electricity generation systems in the lower and middle range of power, is emerging as a promising technology in many developed and developing countries. Therefore, biomass gasification is highly appropriate for decentralized energy systems. They appear to be important alternatives to conventional heat and power generation systems, specifically in countries with available feedstock, higher oil prices and shortages of existing supplies.

Chapter 1 discusses different types of biomass gasification technologies available and required supporting equipment and processes. Gasification is primarily a thermo-chemical process, converting biomass into combustible gases (mixture of CO, CH_4 and H_2) at elevated temperatures. Since these gases have other pollutants, it requires extensive purifications before being used in electricity generation applications. Therefore, a gasifier should entail a series of gas cleaning and conditioning equipments. Gasifiers are mainly characterized according to the direction of flow of feedstock and air. Fixed bed updraft, fixed bed downdraft, circulating fluidized bed, bubbling fluidized bed, entrained flow and multi-stage gasifiers are being commonly used for different applications.

Chapter 2 of the report gives details on the comparison between different types of gasifiers and their operating parameters and identified possible solutions for commonly experienced problems and drawbacks. Higher amount of tar concentration in the producer gas and ash agglomeration in the gasifier are identified as the two major problems in biomass gasification. Several gas cleaning methods are being practiced around the world and extensive research is being carried out on successful gas cleaning technologies. This chapter also reviews the state of the art of biomass gasification technologies around the world. Biomass gasifiers are currently being used for thermal applications, electricity generation and rural electrification programs, co-firing in boilers for both heat and power generation and in large scale combined cycle power generation.

During last 5 years, fixed bed gasification technologies have made a significant progress in many Asian countries such as India and China. Research and development in gasification in Thailand started more than 20 years ago while Cambodia installed its first biomass demonstration plant only in 2003. This study reviews the status of the existing commercial biomass gasification projects in these two countries. It also identifies the types of fuels and technologies used, application of producer gas, and associated problems.

A questionnaire has been prepared and sent to the plant operators to collect the relevant data. The questionnaire used for data collection and the case studies from plant visits are given in Appendices I and II, respectively.

Chapter 3 discusses the status of and barriers for biomass gasification in Thailand. Gasification plants were identified from several sources of information, contacts and through field visits. Gasifiers are available from several manufacturers in Asian countries, such as India, Japan, China, and also from in-house technology and manufacturing. The study identified 26 gasification plants in Thailand, which can be classified into two types: thermal and electrical applications. Of these, 7 are thermal gasification plants with total capacity of 5.526 MW and 19 are for electricity generation applications in Thailand. Almost all the identified biomass gasification plants for electricity generation are fixed bed downdraft gasifiers in the range 10-400 kW and 1,500 MW plant consisting of two 750 MW gasifiers, which is under the construction phase. On the other hand, gasifiers for thermal application vary in its technology type from bubbling fluidized bed, downdraft to updraft. Out of total 26 plants, the technology of 17 plants were identified as having 14 downdraft gasifiers, 2 updraft gasifiers and a bubbling fluidized bed gasifier. Rice husk and wood chip are two major fuel types while corn cob, waste plastic, charcoal and old tyre rubber are also in use.

In Thailand, almost all the gasification plants for electricity generation application have failed after a short period of operation. The study also identified the major problems and barriers for the development of biomass gasification. High tar content is the major technical barrier in biomass gasification power generation plants in Thailand. At the same time, the fuel properties and gas quality monitoring and analyzing remains in a very poor situation in all the plants. None of the failed commercial plants measured the moisture content of the fuel, and the calorific value, the composition or the flow rate of producer gas. However, most of the barriers are related to non-technical issues. One of the most important barriers to an accelerated penetration of all biomass conversion technologies in Thailand is inadequate resource supply or the high prices for biomass fuels such as rice husk. Lack of trained operators for imported plants is also a major hurdle in penetration of the technology in the past.

About 55 biomass gasification plants were identified in Cambodia, of which almost all are for electricity generation applications for rural electrification and small and medium enterprises. The major types of SMEs, which use biomass gasification, are rice mills, ice plants, rural electricity enterprises, brick factories, garment factories, and hotels. Technology for most of the plants is from Ankhur Technologies- India and most of the plants are 200 kW in capacity with the maximum installed capacity of 600 kWe (2x300kWe, under construction). Almost all the gasifiers use producer gas and diesel in a dual fuel mode, replacing about 75% of the diesel usage. The feedstocks for gasification are rice husks, corn cobs, wood chips, coconut shells, cane sugar residues (bagasse), peanut shells etc.

The major non-technical barrier is the lack of availability of technical expertise and training and awareness programs for plant operators.

In order to overcome the above identified barriers, the report recommends that there is a need for motivated and skilled labour at all levels, both in Thailand and in Cambodia. A technical advisory service or consultancy service should be made available. Formation of a technical committee would be useful in this regard.

The industrial sector involvement in R&D and technology demonstration activities is very poor in both the countries. There is also a need for clear standards and regulation on gasifier manufacture, emission standards, and other health & safety aspects. Thailand and Cambodia can adopt more sophisticated tar cleaning technologies rather than using the wet scrubbers alone. This may include some of the effective mechanisms like using fabric filters and recycling the tar and dust collected, hot gas rigid barrier filters such as ceramic or sintered metal barriers or a combination of wood dust filter bed, the cotton filter, and sand bed filters. Recent progress in catalytic conversion of tar can also be used. For heat applications, it is not necessary to eliminate the tar from the fuel gas, thus any reliable gasifier system can be used successfully.

The cost of feedstock must be taken into consideration, even if it can be obtained initially for free, to make sure that there is sufficient profitability over the plant life. Therefore, proper feasibility study would ensure sustainability of a plant.

In Cambodia, producer gas from rice husk fired gasifiers can replace about 75% of the diesel use in the existing rice mills, which is equivalent to about 74,460 ton per year, hence the foreign exchange on import of diesel. This can also mitigate about 208,488 $tCO_{2\text{-eq.}}$ annually.

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Abbreviations

BFB	Bubbling fluidized bed
CFB	Circulating fluidized bed
CHP	Combined heat and power
BIGCC	Biomass integrated gasification combined cycle
EDC	Electricite Du Cambodge
ER	Equivalence ratio
GHG	Greenhouse gas
GWh	Giga Watt hour
HFO	Heavy furnace oil
IGCC	Integrated gasification combined cycle
LCV	Low calorific value
MWe	Mega Watt- electrical
MWth	Mega Watt- thermal
MSW	Municipal solid waste
NGO	Non-governmental organization
SMEs	Small and medium enterprises
SPP	Small power producer
VSPP	Very small power producer

Chapter 1
Introduction

1.1 General

Biomass feedstock

Biomass is an organic material, including plant matter from trees, grasses, and agricultural crops. The chemical composition of biomass varies among species, but basically consists of high, but variable moisture content, a fibrous structure consisting of lignin, carbohydrates or sugars, and ash. Biomass is very heterogeneous in its natural state and possesses a heating value lower than that of coal (Ciferno and Marano, 2002).

Gasification

Gasification is a more than century old technology, which flourished before and during the Second World War. The technology disappeared soon after the Second World War, when liquid fuel (petroleum based) became easily available. During the 20th century, the gasification technology roused intermittent and fluctuating interest among the researchers. However, today with rising prices of fossil fuel and increasing environmental concern, this technology has regained interest and has been developed as a more modern and sophisticated technology.

Gasification is primarily a thermo-chemical conversion of organic materials at elevated temperature with partial oxidation. In gasification, the energy in biomass or any other organic matter is converted to combustible gases (mixture of CO, CH_4 and H_2), with char, water, and condensable as minor products. Initially, in the first step called pyrolysis, the organic matter is decomposed by heat into gaseous and liquid volatile materials and char (which is mainly a non-volatile material, containing high carbon content). In the second step, the hot char reacts with the gases (mainly CO_2 and H_2O), leading to product gases namely, CO, H_2 and CH_4 (Dasappa et. al., 2004). The producer gas leaves the reactor with pollutants and therefore, requires cleaning to satisfy requirements for engines. Mixed with air, the cleaned producer gas can be used in gas turbines (in large scale plants), gas engines, gasoline or diesel engines.

Producer gas is a mixture of carbon monoxide, hydrogen and methane, together with carbon dioxide, nitrogen and other incombustible gases (Balat et. al, 2009). Depending on the carbon and hydrogen content of the biomass and the properties of the gasifier, the heating value of the producer gas, ranges between 4 to 20 MJ/m^3. The heating value also depends on the type of gasifier agent or the oxidant. The oxidant used can be air, pure oxygen, steam or a mixture of these gases. Air-based gasifiers typically produce a producer gas containing a relatively high concentration of nitrogen with a low heating value between 4 and 6 MJ/m^3. Oxygen and steam-based gasifiers produce gas containing a relatively high concentration of hydrogen and CO with a heating value between 10 and 20 MJ/m^3 (Ciferno and Marano, 2002).

Biomass gasification offers certain advantages over directly burning the biomass. Unlike, power generation with direct burning of biomass in a boiler, gasification can be used for very small scale decentralized power generation projects up to 20 kW. A gas producer is a simple device consisting of usually cylindrical container with space for fuel, air inlet, gas exit and grate. It can be made of fire bricks, steel or concrete and oil barrels. Since gas is produced first, some of the problematic and poisonous chemical compounds can be cleaned and filtered before it is burned (EPA-CHP, 2007).

Gasifier alone is of little use. The complete gasification system consists of fuel conditioning units, gasifier, gas cleaning units and gas utilization units. The basic processes that take place in the biomass gasification plant and supporting equipment are shown in Figure 1.

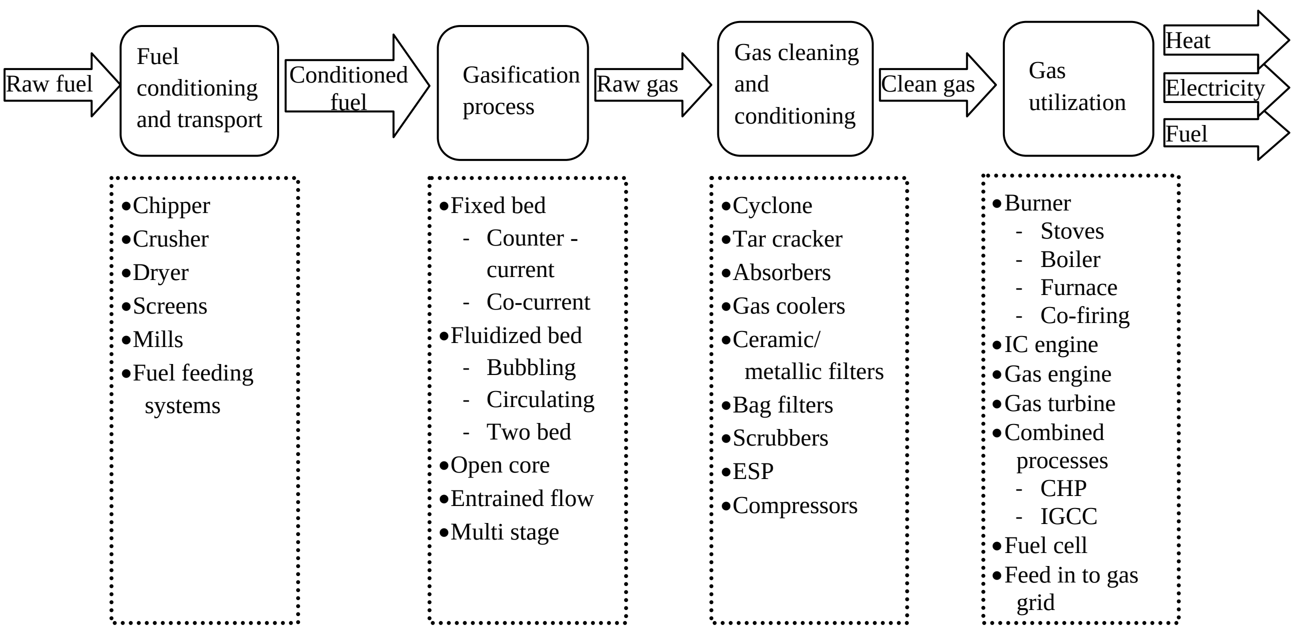

Figure 1: Basic process steps of a biomass gasification plant

Biomass Gasification Technologies

Based on the design of gasifiers and the type of fuels used, there exists different kinds of gasifiers. Figure 2 shows three principal types of gasifiers: fixed bed systems, fluidized bed systems and entrained flow systems. All these processes can be operated at ambient or increased pressure and serve the purpose of thermo-chemical conversion of solid biomass.

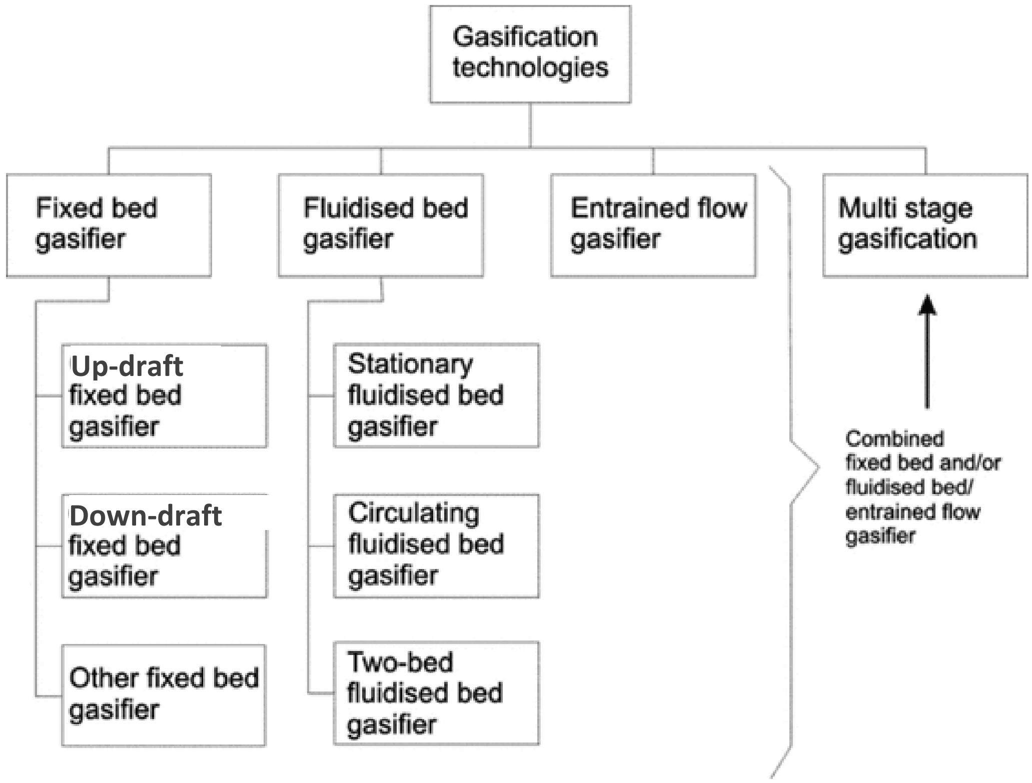

Figure 2: Overview of the different gasification technologies
(Source: BIOS, 2010)

Five major types of classification are fixed-bed updraft, fixed-bed downdraft, fixed-bed crossdraft, bubbling fluidized bed, and circulating fluidized bed gasifiers, which are demonstrated in Figure 3. Differentiation is based on the means of supporting the biomass in the reactor vessel, the direction of flow of both the biomass and oxidant, and the way heat is supplied to the reactor (Ciferno and Marano, 2002). Fixed bed gasifiers are typically simpler, less expensive, and produce lower heat content - producer gas. Fluidized bed gasifiers are more complicated, more expensive, and produce a gas with a higher heating value.

The product gas from biomass gasification can be used to generate electricity or heat or both heat and electricity using a combined heat and power (CHP) system called integrated gasification combined cycle (IGCC or BIGCC, Biomass-fired IGCC). Several demonstration and commercial CHP plants have been developed around the world as alternatives to the use of fossil fuel for electricity production.

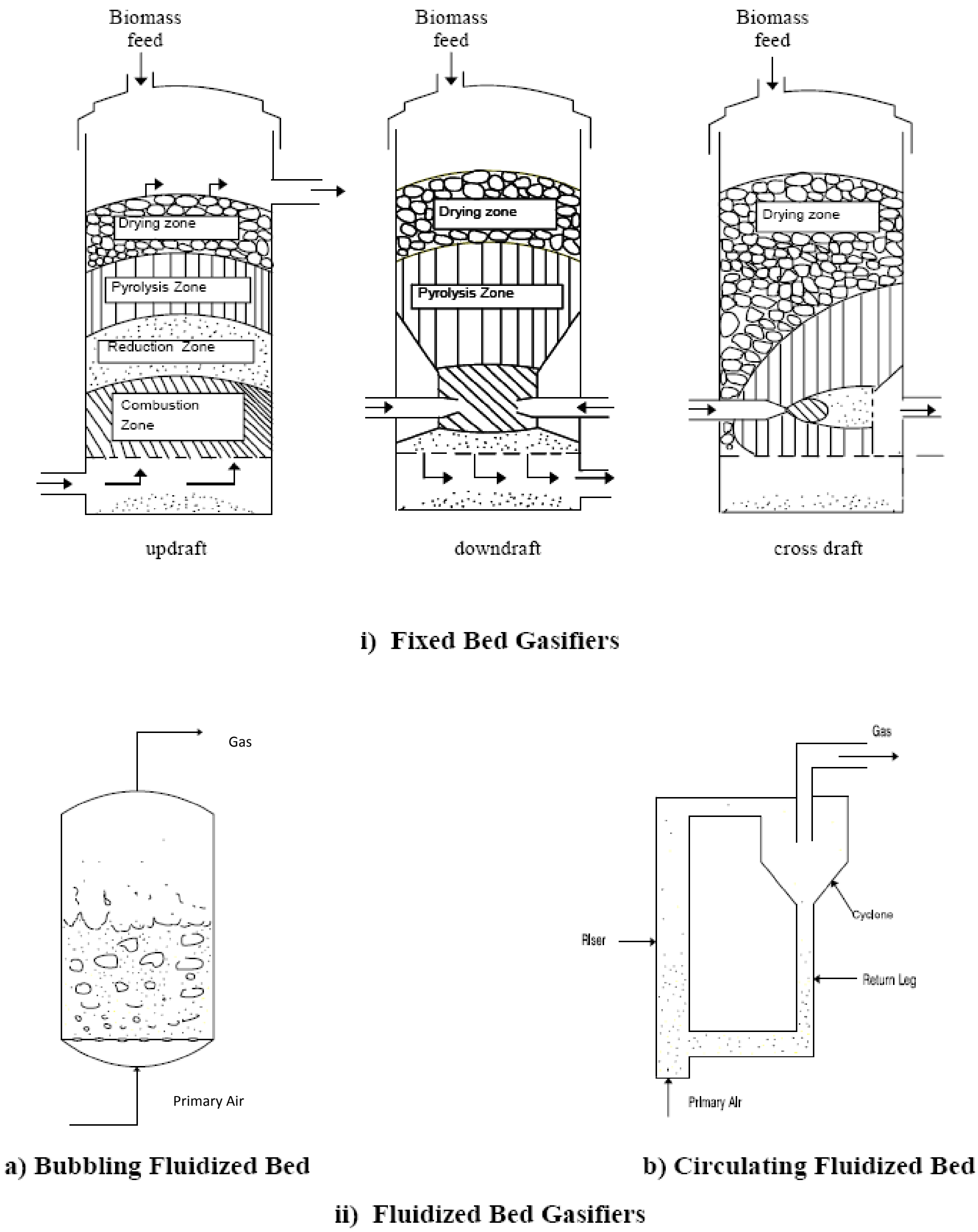

Figure 3: Different kinds of gasifier configurations
(Sources: Bhattacharya and Salam, 2006)

1.2 Objective of the study

The objective of the study is to review the status of the existing commercial biomass gasification projects in Thailand and Cambodia. It will also identify the types of fuels and technologies used, application of producer gas, technical reliability, social, environmental and financial issues. The study also suggests solutions for the problems identified.

1.3 Methodology

The existing biomass gasification projects in Thailand and Cambodia were identified using online resources, contacting gasifier suppliers, government organizations, universities, and R&D organizations. A questionnaire was developed (Appendix I) and sent to the plants. 11 plants in Thaialnd and 7 plants in Cambodia were visited. Through the questionnaire and the visits the relevant information and data on operational practices, technological, social and environmental issues related to biomass gasification were collected. The data, information, and observations during the plant visits were analyzed to identify major problems and drawbacks of biomass gasification in both the countries. Simultaneously, the case studies, best practices and technological innovations from other countries were reviewed to identify the best available solutions and technologies.

Chapter 2

Literature Review of Biomass Gasification Technologies

2.1 Comparison of biomass gasification technologies

The choice of one type of gasifier over other is dictated by fuel, its final available form, size, moisture content and ash content. Table 1 lists the advantages and disadvantages for various gasifier types.

Table 1: Relative advantages and disadvantages of gasifier types

Gasifier	Advantages	Disadvantages
Updraft fixed bed	Mature for small-scale heat applications Can handle high moisture No carbon in ash	Feed size limits High tar yields Scale limitations Low heating value gas Slagging potential
Downdraft fixed bed	Small-scale applications Low particulates Low ta r	Feed size limits Scale limitations Low heating value gas Moisture-sensitive
Bubbling fluid bed	Large-scale applications Feed characteristics Direct/indirect heating Can produce higher heating value gas	Medium tar yield Higher particle loading
Circulating fluid bed	Large-scale applications Feed characteristics Can produce higher heating value gas	Medium tar yield Higher particle loading
Entrained flow fluid bed	Can be scaled Potential for low tar Potential for low methane Can produce higher heating value gas	Large amount of carrier gas Higher particle loading Particle size limits

Source: EPA-CHP, 2007

Fixed bed gasifiers are more suitable for small scale power generation and industrial heating applications. Acceptable fuels for different gasifier types and their range is given in Table 2. Table 3 compares the operating parameters of fixed bed gasifiers.

Gasification technology can also be classified depending on the gasifying agent: air, steam, steam–oxygen, air–steam, oxygen-enriched air, etc. Main advantages and technical challenges based on the gasifying agent, gasifier type and the operation are discussed in Table 4.

Table 2: Gasifier systems and gasifier fuels

Biomass Fuel	Gasifier Type	Capacity Range	Application
Power Gasifiers			
Wood blocks	Fixed-bed/down-draft	< 500 kWe	Electricity/shaft power
Charcoal	Fixed-bed/down-draft	< 50 kWe	
Rice husk	Fixed-bed/down-draft	< 200 kWe	
Coconut shell	Fixed-bed/down-draft	< 500 kWe	
Heat Gasifiers			
Wood/charcoal	Fixed-bed/cross-draft	< 5 MW_{th}	Process heat
Coconut shell	Fixed-bed/up-draft		

Source: Bhattacharya and Salam, 2006

Table 3: Comparison between operation parameters of fixed bed gasifiers

Gasifier type	Downdraft	Updraft	Open core	Cross draft	Cross draft heat
Start up time (min)	10-20	15-60	15-60	10-20	15-60
Sensitivity to fuel Characteristics	Sensitive	Not sensitive	Very sensitive+	Sensitive	Not sensitive
Tar production full load (g/Nm^3 gas)	< 0.5	1-15	10-15	< 0.1 †	N.A.
Size & volume gas cleaning section	Small	Big	Big	Small	N.A.
Quantity residual tars	Small	Big	Big	Very small	None
Sensitivity to load fluctuations	Sensitive	Not sensitive	Not sensitive	Sensitive	Not sensitive
Turn down ratio	3-4	5-10	5-10	2-3	8-10
Cold gas heating value full load (MJ/Nm^3)	4.5-5.0	5.0-6.0	5.5-6.0	4.0-4.5	N.A.

Source: Stassen and Knoef, 1995

Notes:

+ Only rice husk
† Low volatile content (< 10 %wgt) charcoal
N.A. Not applicable

Fuel preparation

Theoretically, almost all kinds of biomass with moisture content of 5-30% can be gasified. However, not every biomass fuel can lead to the successful gasification because most biomass feedstocks are inconsistent in moisture, density, size and thermal energy or the carbon content.
For example, mechanical handling of straw is difficult due to its low bulk density (<200 kg/m^3). It must be either handled in bales or must be chopped or pelletized to enable mechanical or pneumatic handling. Some types of wood are soft, moist and stringy and tend to interfere with certain mechanical feeding methods, such as screw feeders. Biomass feedstock preparation can be broken down into two steps: feed size selection/reduction and feed drying. Biomass is resized

and reshaped using various methods, including rotating knives, rollers, hammer milling, chopping, shredding, pulverizing and pelletizing. Biomass is transported from storage silos or lock hoppers to the gasifier via a conveyor, a pneumatic system or bucket elevators.

Table 4: Advantages and challenges of different gasifying agents, designs and operation

	Main advantages	Main technical challenges
Gasifying Agents		
Air	1. Partial combustion for heat supply of gasification 2. Moderate char and tar content	1. Low heating value (3–6 MJ N/m^3) 2. Large amount of N_2 in syngas (e.g., 450% by volume) 3. Difficult determination of ER (usually 0.2–0.4)
Steam	1. High heating value syngas (10–15 MJ N/m^3) 2. H_2-rich syngas (e.g., 450% by volume)	1. Require indirect or external heat supply for gasification 2. High tar content in syngas 3. Require catalytic tar reforming
Carbon dioxide	1. High heating value syngas 2. High H_2 and CO and low CO_2 in syngas	1. Require indirect or external heat supply 2. Required catalytic tar reforming
Gasifer design		
Fixed/moving bed	1. Simple and reliable design 2. Capacity for wet biomass gasification 3. Favorable economics on a small scale	1. Long residence time 2. Non-uniform temperature distribution in gasifiers 3. High char or/and tar contents 4. Low cold gas energy efficiency 5. Low productivity (e.g., 5GJ /m^2/h)
Fluidized bed	1. Short residence time 2. High productivity (e.g., 20–30 GJ /m^2 /h) 3. Uniform temperature distribution in gasifiers 4. Low char or/and tar contents 5. High cold gas energy efficiency 6. Reduced ash-related problems	1. High particulate dust in syngas 2. Favorable economics on a medium to large scale
Gasifier operation		
Increase of temperature	1. Decreased char and tar content 2. Decreased methane in syngas 3. Increased carbon conversion 4. Increased heating value of syngas	1. Decreased energy efficiency 2. Increased ash-related problems
Increase of pressure	1. Low char and tar content 2. No costly syngas compression required for downstream utilization of syngas	1. Limited design and operational experience 2. Higher costs of a gasifier at a small scale
Increase of ER	Low char and tar content	Decreased heating value of syngas

Source: Wang, et. al., 2008

The key to a successful design of gasifier is to understand the properties and thermal behavior of the fuel as fed to the gasifier. A gasifier fuel can be classified according to i) energy content of the fuel, ii) bulk density, iii) moisture content, iv) dust content, v) volatile matters and vi) ash and slagging characteristics.

Therefore, biomass for gasification processing also need some kind of pretreatment as drying or chopping before entering the gasifier. Raw biomass has relatively higher water content and for optimal gasification conditions, drying is required. Pre-treatment, as minimizing the size of the feedstock, is preferred and depends on following process application. The majority of the gasification technologies require feedstock moisture to be below a specified level. Table 5 explains the requirement of feedstock preparation depending on the type of gasifier.

Table 5: Feedstock preparation requirement for different types of gasifiers.

Gasifier type	downdraft	updraft	open-core	cross-draft
Size (mm)	20-100	5-100	1 - 3 (rice husk)	40 - 80 (charcoal)
Moisture content (% w.b.)	< 15-20	< 50	< 12 (rice husk)	< 7 (charcoal)
Ash content (% d.b.)	< 5	< 15	approx. 20	< 6
Morphology	uniform	reasonable uniform	uniform	uniform
Bulk density (kg/m^3)	> 500	> 400	> 100	> 400
Ash melting point (^{o}C)	> 1250	> 1250	> 1000	> 1250

Source: Stassen and Knoef, 1995

2.2 Problems/ drawbacks in biomass gasification and possible solutions

After a proper selection of the kind of technology that matches the specific requirements, such as type of fuel, capacity, application, etc., the main problem in using producer gas is to condition them such that it matches the final application. In the gasification process, with the exception of generating useful products, many by-products such as fly ash, NO_x, SO_2 and tar are also formed.

Another major problem related to the application of biomass gasification technologies is the removal and disposal of ash. Therefore, before using the producer gas for other applications, the main impurities should be removed. The treatment methods and possible solutions to the tar and ash removal issues are discussed below in detail.

a) Tar Removal

The major problem in biomass gasification is to deal with the tar formed during the process (Balat, et. al., 2009: Bergman et. al., 2002). Tar derived from biomass gasification will be condensed as temperature is lower than its dew point, which then block and foul process equipments like fuel lines, filters, engines and turbines. It was reported that tar content in the producer gas from an air-blown circulating fluidized bed (CFB) biomass gasifier was about 10 g/m^3. For other types of gasifier, tar content varied from about 0.5 to 100 g/m^3. However, most applications of product gases require a low tar content, of the order 0.05 g/m^3 or less. Hence, tar disposal becomes one of the most challenging problems to be addressed during biomass gasification.

Particulate dust and tar removal technologies can broadly be divided into two categories: (1) treatments during gasification and (2) hot gas cleaning after gasification (Balat et. al., 2009: Wang et. al., 2008). Up to now, a great amount of work concerning tar reduction or reforming has been reported. They can be mainly categorized into five main groups (Han and Kim, 2008).

i) Mechanism methods like cyclones, scrubbers, filters (baffle, fabric, ceramic), granular beds, rotating particle separator (RPS) and electrostatic precipitators;
ii) Self-modification, selecting optimal operation parameters for gasifier or using a low tar gasifier;
iii) Catalytic cracking;
iv) Thermal cracking and
v) Plasma methods

i) Mechanism methods

Mechanism methods include scrubber, filter (bag filters, baffle filters, ceramic filters, fabric filters), cyclone and electrostatic precipitator (Han and Kim, 2008; Wang et. al., 2008). The primary use of these devices is to capture particles and tar from the product gases. A great amount of experimental results demonstrated that the methods were also considerably efficient in removing tar accompanied with effective particles capture. Tar separation efficiency ranging from 51% to 91% had been reported in a venturi scrubber used to purify the product gases from a countercurrent rice husk gasifier. It is proved that tar concentration in the fuel gases was lower than 20–40 mg/Nm^3 after a high-efficient scrubber system.

Except for venturi scrubber, other scrubbers such as water scrubber and wet scrubber are also widely used and proven as an effective removal technology for particulates, tar and other contaminants. Tar levels down to 20–40 mg/m^3 and particulate levels down to 10–20 mg/m^3 can be achieved with a water scrubber. 60% of tar also can be removed from the raw gases by wet scrubbing in a CFB gasifier. Nevertheless, these systems are fairly expensive. Moreover, the mechanism methods only remove the tar from product gases, while the energy in the tar is lost. Table 6 shows the tar reduction efficiency in various gas cleaning systems.

Table 6: The reduction efficiency of particle and tar in various gas cleaning systems.

	Particle reduction (%)	Tar reduction (%)
Sand bed filter	70–99	50–97
Wash tower	60–98	10–25
Venturi scrubber		50–90
Wet electrostatic precipitator	499	0–60
Fabric filter	70–95	0–50
Rotational particle separator	85–90	30–70
Fixed bed tar adsorber		50

Source: Han and Kim, 2008

The disadvantages of wet cleaning are as follows: (a) since the product gases are at a high temperature, reducing the temperature during wet cleaning, decreases the net energy efficiency of the process; and (b) the waste water needs to be treated extensively before discharge which is a capital-intensive process (Kumar et. al., 2009). Condensing tars dramatically foul gas cleaning equipment and liquid tar droplets that enter prime movers hamper the operation of these end-use applications of the syngas.

In conventional water-based gas cleaning systems, tars and condensed water are mixed, creating an often costly and difficult water treatment problem (Bergman et. al., 2002). In this case, the wastewater from scrubbing can be cleaned using a combination of a settling chamber, a sand filter and a charcoal filter. However, it may increase the capital cost. To overcome the problem, several measures for tar removal have been studied or are under investigation. Few attempts have been made to scrub the product gases with oil instead of water. However, the operating cost increases with these arrangements. For example, Energy Research Centre of the Netherlands (ECN) in 2001, started developing a new technology called "OLGA" to establish tar removal from syngas on the basis of non-water scrubbing liquid (Bergman et. al., 2002).

Activated carbon is a highly efficient sorbent, and is widely used to control a number of gaseous pollutions emission.

ii) Self-modification

The operating parameters play a very important role in the distribution of products during biomass gasification. The important parameters include temperature, equivalence ratio (ER), the type of biomass, pressure, gasifying medium and residence time, etc. Certainly, the selection of parameters also depends on the type of gasifier. Besides affecting the fraction of tar during biomass gasification, operation parameters also influence the tar properties. The type of gasifer is another important parameter affecting the yield of tar. Table 7 shows the typical tar content in producer gas depending on the type of technology that is used.

Table 7: The typical tar content in producer gas in different gasifiers.

	Fixed bed		Fluidized bed	
	Updraft	Downdraft	Bubbling	Circulating
Mean tar content (g/Nm^3)	50	0.5	12	8
The range of tar (g/Nm^3)	10-150	0.01-6	1-23	1-30

Source: Han and Kim, 2008

Wang et. al. (2008) noted that 20% of secondary air injection to the primary air injection above the biomass feeding point in a fluidized bed gasifier reduced 88.7% (wt) of the total tar for the gasification in temperatures from 840 to 880 ºC. Sun et. al. (2009) found out from an experiment on the effect of the secondary air on rice husk cyclone gasifier that secondary air can be used as both a gas cleaner and a gasifier. The mechanism proposed for tar removal due to addition of the secondary air is that a part of tar is burnt with the supplied air and the other part is further thermally cracked into secondary tar in local high temperature zone.

Asian Institute of Technology (AIT) has carried out extensive research on tar reduction by multi-stage gasification. Supply of secondary air between the two stages (i.e. pyrolysis zone and gasification zone) of the reactor generates a high temperature zone in the gasification zone of the reactor which creates a favourable environment for tar cracking. The two stage gasifier developed at AIT has been successfully demonstrated the advantages of multi-stage approach of wood gasification by reducing the tar content of the producer gas up to 50 mg/Nm^3 (Dutta, 1998). Over the period, this gasifier has been modified and improved in terms of operational practices and tar removal.

iii) Thermal cracking

In thermal cracking method, the raw gases derived from gasification or pyrolysis are heated to a high temperature, where tar molecules can be cracked into lighter gases. However, experiments have shown that biomass-derived tar is very refractory and hard to crack by thermal treatment alone. In order to effectively decompose the tar, it was suggested to increase residence time, such as using a fluidized bed reactor freeboard, but this method was only partially effective. The direct contacting with an independently heated hot surface, required significant energy supply and decreased the overall efficiency. The method is also partly effective and depends on good mixing. Partial oxidation by adding air or oxygen could increase CO levels at the expense of conversion efficiency decrease and operation cost enhancement.

iv) Catalyst cracking

Gasification plants have started to combine both primary and secondary treatment measures in recent past. In primary methods, the operating parameters such as temperature, gasifying agent, equivalence ratio, residence time and catalytic additives play important roles in the formation and decomposition of tar. Although secondary methods are proven to be effective, treatments inside the gasifier are gaining much attention due to economic benefits. Due to the advantages of converting tar into useful gases and adjusting the compositions of product gases, catalyst cracking has been of interest since the mid 1980s (Wang et. al., 2008**;** Han and Kim, 2008). The pilot plants, demonstration plants and implemented projects have shown that catalytic cracking of tars is a very effective process. The type of catalysts can be categorized into four groups: dolomite catalysts; alkali metal and other metal catalysts; nickel catalysts and novel metal catalysts (Wang et. al., 2008**;** Han and Kim, 2008). Tar conversion in excess of 99% has been achieved using dolomite, nickel-based and other catalysts at elevated temperatures of typically 1075–1175 K (Balat et. al., 2009).

v) Plasma gasification

Plasma gasification is a gasification process that decomposes biomass into basic components, such as H_2, CO, and CO_2 in an oxygen- starved environment at an extremely high temperature. Plasma is an ionized gas produced by electric discharges. A plasma torch is a tubular device that has two electrodes to produce an arc. It is an independent heat source that is not affected by the feed characteristics nor the air/ oxygen/steam supply. When electricity is fed, an arc is created, and the electricity is converted into heat through the resistance of the plasma. A plasma torch can heat the biomass feedstock to a temperature of 3000 ºC or higher (up to 15,000 ºC). Under such extremely elevated temperature, the injected biomass stream can be gasified within a few milliseconds without any intermediate reactions (Zhang et. al., 2010). The plasma technique has high destruction and reduction efficiencies. Any form of wastes, e.g., liquid or solid, fine particles or bulk items, dry or wet, can be processed efficiently. In addition, it is a clean technique with little environmental impact.

b) Ash agglomeration mechanism and reduction

Ash-related problems including sintering, agglomeration, deposition, erosion and corrosion are the main obstacles to economical and viable applications of biomass gasification technologies. Alkali metals, such as potassium, react readily with silica, even at temperatures far below 900 ºC, by breaking the Si–O–Si bond and forming silicates or reacting with sulfur to produce alkali sulfates. The alkali silicates and sulfates have melting points even lower than 700 ºC and tend to deposit on the reactor walls and leave a sticky deposit on the surface of the bed particles, causing bed sintering and defluidization. Furthermore, the presence of ash such as alkali in syngas can cause problems of deposition, corrosion and erosion for equipment that utilizes syngas such as a gas turbine (Wang et. al., 2008).

Fluidized bed gasification performs better than fixed bed gasification to reduce ash-related problems since the bed temperature of fluidized bed gasification can be kept uniformly below the ash slagging temperature. The low gasification temperature can also reduce the volatilization of ash elements such as sodium and potassium into the syngas, thus improving the quality of syngas.

Leaching and fractionation are the two main pre-treatments used to reduce ash-related problems. The efficiency of water leaching on the removal of inorganic elements depends on biomass feedstocks.

2.3 Lessons from other countries

2.3.1 Gasification with gas engine for heat and power production

a) The NOVEL biomass gasification CHP system- Kokemäki power plant, Finland

Condens Oy and VTT Finland developed a Novel gasification process, (Figure 4) that combines fixed bed updraft gasifier with catalytic gas cleaning process to produce a product gas suitable for gas engines.

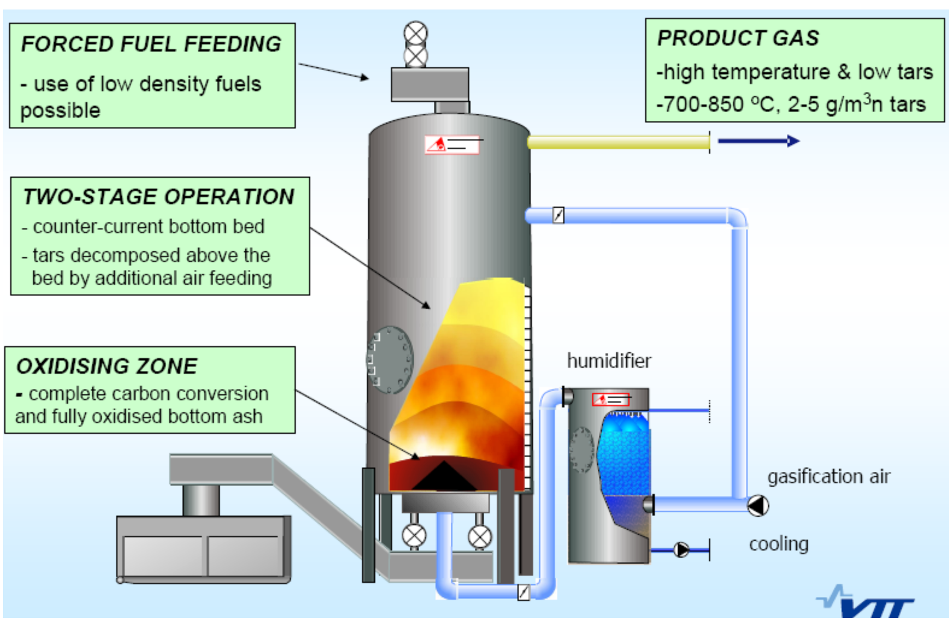

Figure 4: Fixed bed updraft Novel gasifier by Condens Oy

(Source: Makkonen, 2009)

This gasifier has been installed at a CHP power plant in Kokemäki (Figure 5). Biomass residues and energy crops are used as fuels. The feedstock is dried to about 20% moisture by using low-temperature waste heat from the plant and fed at the top of the gasifier. The produced gas is cleaned by a tar reformer, cooled and scrubbed in a wet scrubber, boost and injected in the three turbocharged 0.6 MWe gas engines to produce 1.8 MWe power and 4.3 MWth for district heating (Nilsson, 2008).

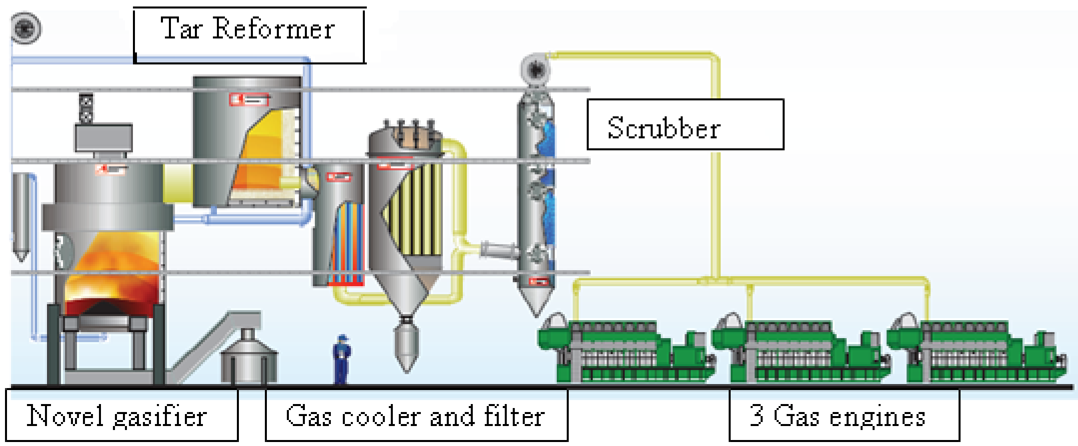

Figure 5: The Novel gasifier CHP system- Kokemäki power plant, Finland
(Source: Makkonen, 2009)

b) Biomass CHP plant Güssing, Austria

The CHP plant generates 2 MWe by a gas engine for electricity production and 4.5 MWth for district heating (Nilsson, 2008). The fluidized bed gasifier consists of two zones, a gasification zone and a combustion zone (Figure 6).

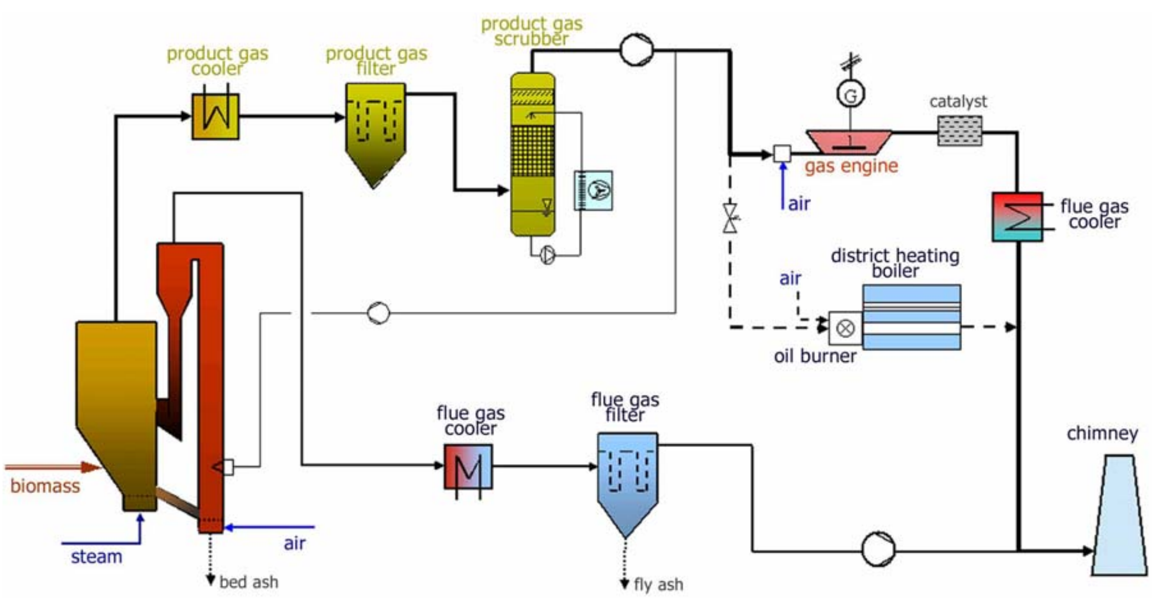

Figure 6: Biomass CHP plant Güssing, Austria
(Source: Kurkela, 2009)

The bed material is circulated between these two zones while the gaseous products are kept separated. The circulating bed material promotes heat transfer between the combustion and the gasification zones. The fuel is fed into the gasification zone in a bubbling fluidized bed and is gasified with steam, which is generated in the gas cooling section. The syngas will therefore be almost completely nitrogen free. The bed material, together with some carryover char, circulates to the combustion zone. This zone is a circulating fluidized bed and is fluidized with air to burn the char particles. The exothermic reaction in the combustion zone provides energy for the endothermic steam gasification zone. With this concept it is possible to produce a medium calorific value product gas of over 12 MJ/Nm^3 dry without the use of pure oxygen.

The produced gas is cooled by water heat exchangers, which reduce the temperature from 850-900°C to 140-150°C. The first cleaning step is a pre-coated fabric filter for removal of particulates and condensed tars. These particles are returned to the combustion zones of the gasifier. After that, the gas is scrubbed to remove rest of the tar and ammonia, using biodiesel as scrubbing liquid. The dust from the fabric filters, the spent scrubber liquid saturated with tars, and condensate from the scrubber are recycled to combustion zone of the gasifier. By scrubbing, the temperature of the gases reduces to about 40°C, which is necessary for the gas engine. The cleaned gas is compressed and finally fed to the gas engine for production of electricity. The availability of the gasifier and the gas engine has been reported to be successful and is expected to grow yearly due to experience and new technology breakthrough. The gasifier has been in operation for 36,400 hours and the engine for 31,700 hours by the first of March 2008 (Nilsson, 2008).

c) Skive biomass gasifier, Denmark

The biomass CHP facility in Skive, Denmark is an air-blown bubbling fluidized bed gasifier developed by Carbona Company and in operation since late 2005. The gasifier converts 110 tons/day (20 MW) wood fuel into 6 MW electricity and 12 MW district heat. The overall efficiency is 87% and electrical efficiency of 28%. The plant includes fuel feeding, gasification, gas cleaning (tar reforming catalyst, filter and scrubber), gas cooling and distribution. The gas engines are specially developed for low calorific gas combustion.

The produced gas pass through a cyclone, a catalytic tar cracking unit, gas cooling unit and gas cleaning unit (Figure 7). The tar cracking is based on the Novel tar cracking/reforming system, which has been developed and tested together with VTT in pilot plant and also at the demonstration biomass gasification plant in Kokemäki, Finland. The catalytic cracker operates at 900 °C and uses a Nickel-based catalyst that converts tars and ammonia to CO, H_2O and N_2. Water cooled gas cooler reduce the temperature of gas from 900 ºC to 200 ºC and bag filter operates at 200 ºC (Patel, 2006).

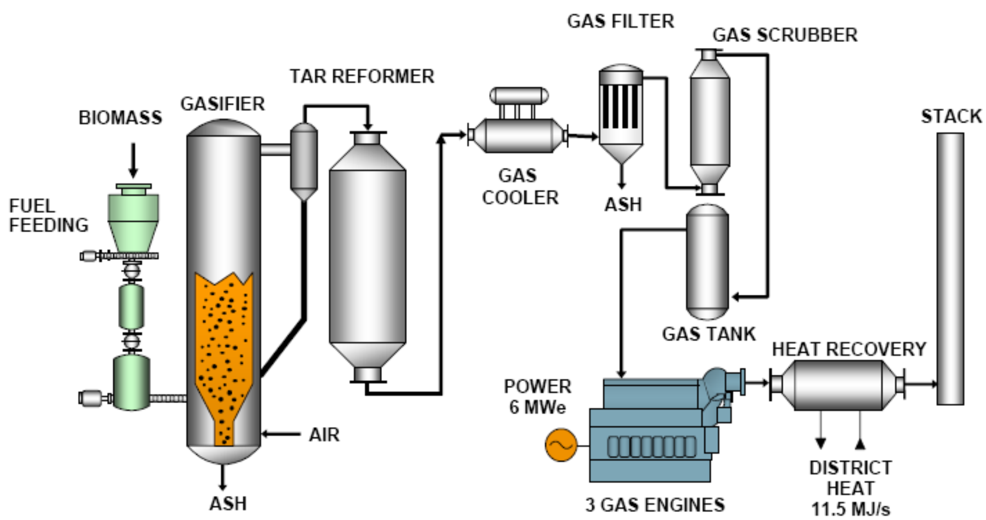

Figure 7: Process diagram of the Skive biomass gasification, Denmark

(Source: Silo, 2008)

2.3.2 Biomass gasifier for thermal applications

a) BIONEER gasifier- Finland

The gasifier was developed and constructed by the Energy Department of Finish Ministry of Trade and Industry in co-operation with VTT. Eight BIONEER gasifiers were commercialized in 1985-1986, five in Finland and three in Sweden. Four plants are operated with wood or wood and peat mixture, while the rest are operated with peat only. BIONEER gasifier is an updraft fixed bed gasifier with the outputs of the range of 4-5 MWth. These gasifiers are coupled to district heating boilers and drying kilns. Biomass is fed from the top and residual ash is discharged by a rotating cone shaped grate at the bottom. The temperature of the combustion zone is regulated by humidifying gasification air. Air and steam are fed as the gasification media through the grate. Most of the gasifiers are still in operation at small district heating plants to provide circulating hot water.

Problems faced by BIONEER gasifier (VTT, 2002) are:

- Several other potential fuels such as crushed bark, saw dust and crushed demolition cannot be used mainly due to fuel flowing problems.
- Use of gasifier gas without further gas treatment is limited to applications, where gas can be burnt close to the gasifier. The tar fouls the gas pipeline leading from the gasifier into the boiler and shortens the period after which the gas pipe must be cleaned by burning tars. In Finish plants gas line has been cleaned once in 2-6 weeks depending on the fuel properties.

b) Pyroflow Gasifier

In 1981, Ahlstrom Corporation (former name of Foster Wheeler) developed the first 3 MWth capacity pilot CFB gasifiers, from its successful CFB Pyroflow combustion technology. It is a CFB, which operates at atmospheric pressure. The atmospheric CFB gasification system is simple. The system consists of a reactor where the gasification takes place, a uniflow cyclone to separate the circulating bed material from the gas, and a return pipe for returning the circulating material to the bottom part of the gasifier. All of the above mentioned components are entirely refractory lined. Typically, after the uniflow cyclone, hot product gas flows into the air preheater which is located below the cyclone. The gasification air blown with the high pressure air fan is fed to the bottom of the reactor via an air distribution grid. When the gasification air enters the gasifier below the solid bed, the gas velocity is high enough to fluidize the particles in the bed. At this stage, the bed expands and all particles are in rapid movement. The gas velocity is so high that many particles are conveyed out of the reactor and into the uniflow cyclone. In the uniflow cyclone, the gas and circulating solid material flow in the same direction – downwards – both the gas and solids are extracted from the bottom of the cyclone, a difference compared to a conventional cyclone (Palonen and Nieminen, 2004). Most of the solids in the system are separated in the cyclone and returned to the lower part of the gasifier reactor. These solids contain char, which is combusted with the fluidizing air that is introduced through the grid nozzles to fluidize the bed. This combustion process generates the heat required for the pyrolysis process. The coarse ash accumulates in the gasifier and is removed from the bottom of the gasifier with a water cooled bottom ash screw (Anttikoski, 2002).

The first commercial Ahlstrom Pyroflow CFB gasifier was commissioned in 1983 at the Wisa Forest Pulp and Paper Mill in Pietarsaari, Finland. The fuel for the 35 MWth (about 150 t/day of biomass) gasifier is primarily bark and sawdust, sized up to 5cm, and dried at 150°C to about 15% moisture content. The biomass is fed from the side into the circulating sand of an air-blown CFB gasifier maintained at about 900°C. The hot fuel gas at 700°C is fed directly to a lime kiln (Figure 8).

The energy fed into the lime kiln is controlled by fuel flow and the gasification temperature is controlled by air flow. The controlled system is digitized. Target of 85% replacement of oil was achieved in few months and the pay back period was 2 years. Since then, between 1985 and 1986, three more gasifiers, two in Sweden (25 MWth at Norrsundet Bruks, AB, Norrsundet and 27 MWth at ASSI, Karlsborg Bruk, Karlsborg) and one in Portugal (15 MWth at Portucel, Rodao Mill), were built and commissioned for firing lime kilns. These gasifiers produce lime kiln fuel from bark and waste wood, and they also utilize a part of the generated gas in drying plants (Anttikoski, 2002).

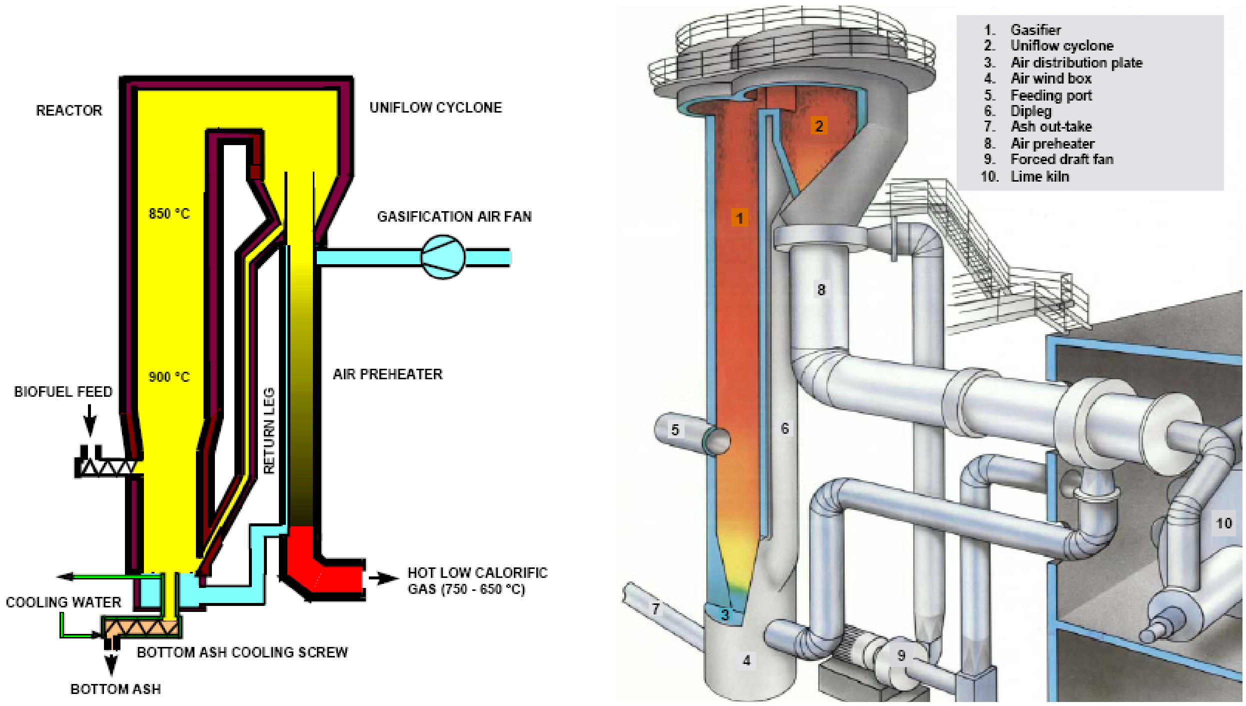

Figure 8: The Pyroflow CFB gasifier

(Sources: Siro, 2004: Anttikoski, 2002: Palonen and Nieminen, 2004)

c) Gotaverken Project (Varo), Sweden

The Gotaverken (Kvaerner) process employs a CFB gasification process developed in a 2 MWth pilot plant at the Royal Institute of Technology. Sized and dried fuel is fed a few meters above the bottom of the gasifier to create two distinct zones. In the upper zone, biomass is flash pyrolyzed by coming in contact with hot circulating dolomite, at a temperature of 645°C, and produces fuel gas rich in CO and some tars. In the lower zone the recycled residual char is combusted with air to produce the hot flue gas that promotes flash pyrolysis in the upper zone. The circulating bed of dolomite promotes tar cracking and reduces the amount of heavy hydrocarbons produced in the gasifier. The LCV fuel gas is partially cooled in a heat exchanger to preheat gasification air and then burnt in a lime kiln. The plant start up was in 1987 and turned over to the customer in 1988. A typical gas composition is 15% CO, 10% H_2, 5% CH_4, 3% C2+, 16% CO_2, 8% H_2O, and 43% N_2.

2.3.3 Biomass gasification for rural electrification, heating and other domestic applications

a) Gosaba power plant, West Bengal, India

A 500 kW (5 x 100 kW) biomass gasifier based power plant has been installed and commissioned in Gosaba Island, West Bengal, India in July 1997 for electrification of five villages comprising more than 10, 000 people. In the Gosaba power plant, the gasification technology is from Ankur, India and consists of five 100 kW down draft closed-top gasifiers (Figure 9). Each 100 kW unit is equipped with a water-sprayed gas cooling system, a two-stage gas cleaning system, a blower and a Ruston engine (165 HP- diesel engine). Fuelwood is supplied to the plant from local saw mills. The Gosaba power plant has been in continuous operation since July 1997. Total electricity generated during the period July 1997 to December 1999 was 351,798 kWh. Average fuelwood and diesel consumption per kWh of electricity generated were 0.822 kg and 0.135 l, respectively. The producer gas replaces about 59% of the total diesel requirement if the plant would run by diesel only (Ghosh et. al., 2004).

In the Gosaba power plant, engine lubrication oil needs to be changed and the turbo chargers require cleaning after about 225 hours of operation. Water is circulated separately at a flow rate of 2880 l/hr through the gas cooling tower and the ash removal system. In both cases water needs a replacement by fresh water after about 220 h of operation. In the gas cleaning system wood dust filter bed and the cotton filter need to be changed after 48–50 h of operation (Ghosh et. al., 2004).

Figure 9: 5 x 100 kW biomass gasifier at Gosaba Island, West Bengal, India.
(Source: Abe, 2005)

b) Biomass gasification in China

For example, in China, about 160 sets of gasification system have been operated for domestic cooking by independent users or through centralized gas supply networks, 370 sets for wood drying processes and about 150 sets for electricity generation by 2004. The total biomass energy converted into fuel gas by gasification rose up to 0.9 trillion kJ. Most of the energy derived for biomass gasification is used for wood drying industry (62.5%) followed by domestic cooking (25.5%). Only 6% of energy was applied for electricity generation and 6% for boiler heating (Leung, et. al., 2004).

A 1.2-MW gasification plant has established in a rice mill located in Changxing, Zhejiang Province, China. The system has been able to run safely and continuously for 4 years, from October 2004 to June 2008, till the plant was closed due to management problems at the rice mill. As shown in Figure 10, the gasification system consists of an air-blown fluidized bed gasifier, a combined gas cleaner (including an inertial separator, a cyclone separator, two Venturi tubes and two water scrubbers), and a power generation subsystem (containing four gas engines of 200 kW, and one gas engine rated at 400 kW), in addition to a wastewater treatment system.

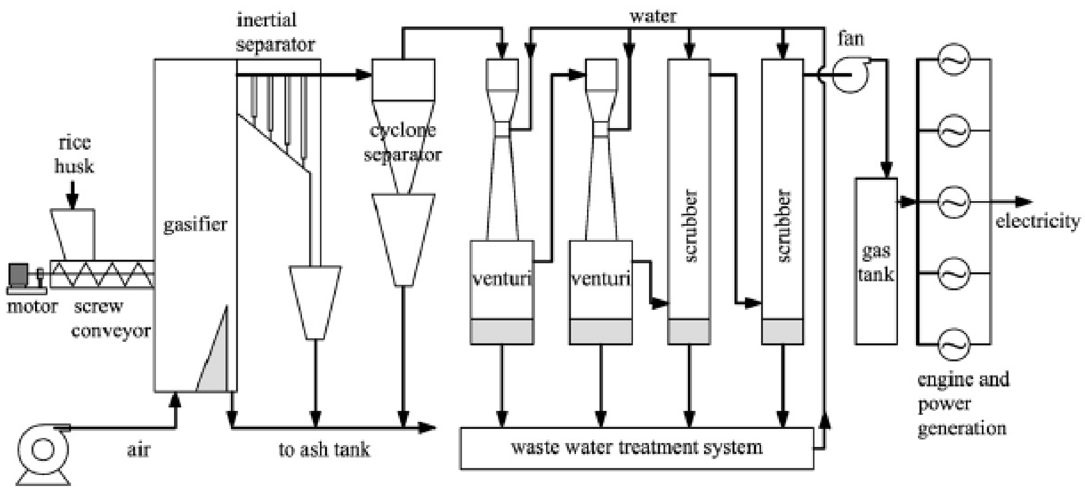

Figure 10: Schematic of 1.2-MW rice husk gasification and power generation plant at Zhejiang Province, China.
(Source: Wu et. al., 2009)

2.3.4 Gasification for co-firing in a boiler for heat and power production

a) Kymijärvi power plant Lurgi, Finland

The Kymijärvi power plant located, in the Finnish city Lahti, was originally commissioned in 1976 as a heavy oil-fired unit, but in 1982 it was modified for pulverized coal firing. Steam production is 125 kg/s at 540°C/170/40 bar and maximum output is 185 MWe and 260 MWth, which is served to the national electricity grid and as district heating for the citizens of Lahti. The unit operates about 7000 h/year, and is usually shut down during the high summer season. The plant also has a natural gas-fired gas turbine in use when heating demand is low. In 1998, an atmospheric air-blown CFB gasifier was connected to the plant, delivered by Foster Wheeler, and provided low-calorific gas to the coal boiler (Figure 11). The aim of the Lahti gasification project was to demonstrate direct gasification of wet bio-fuels and the use of hot, raw and low-calorific gas directly combusted in the existing coal-fired boiler (Nilsson, 2008).

The gasifier is a single gasifier vessel with a cyclone and an air preheater for heating the gasification air to approximately 400°C (Figure 11). The LCV gas is cooled from approximately

830-850°C to 700°C before it is transported in a pipeline to the boiler. The raw gas is directly combusted (at 750°C) in specially designed (low-calorific) gas burners in the boiler (Nilsson, 2008) and it has no adverse effect on the performance of the boiler. Emissions are reduced and the heating surfaces in the boiler stay relatively clean. The heating value of the LCV gas is approximately 2.0-2.5 MJ/Nm^3. The breakdown of fuels in the boiler is approximately: 11% LCV fuel gas from the gasifier, 69% coal, 15% natural gas to boiler, and 5% natural gas to gas turbine. The annual average total efficiency is approximately 80%, the fuel to power efficiency with gas turbine in operation is 35%. The gas turbine has increased the efficiency by 4% points. The plant supplies 200 MWe power to the national grid and 250 MWth heat to the town and surrounding houses.

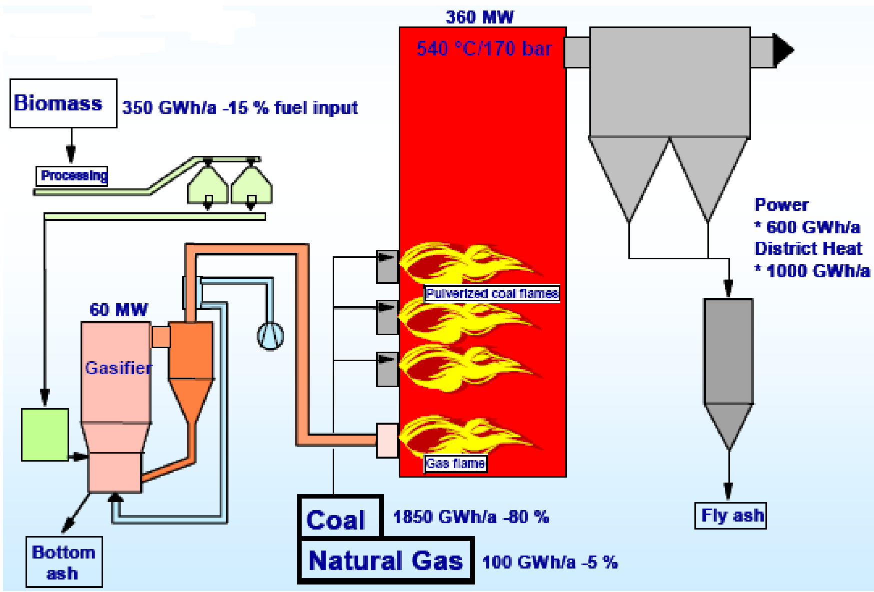

Figure 11: Gasification in connection of an existing power plant to replace fossil fuel, Kymijärvi Power Plant, Lahti, Finland.

(Source: Nilsson, 2008)

During the first year (1998), the operational hours of the gasifier were 4730 hours and during 2001 (end of November) 6255 hours and the total operating time between 1998 and 2002 was 27,000 hours, generating 1,700 GWh. The energy production of the gasifier has during first three years been close to the original design value 300 GWh and during the year 2001 it has been as high as 400 GWh (until the end of November) (Anttikoski, 2002). With all the fuel fractions, except shredded tyres, the operation of the gasification process has been good.

The gasification of biofuels and co-combustion of gases in the existing coal-fired boiler offers many advantages such as: recycling of CO_2, decreased SO_2 and NO_x emissions, efficient way to utilize biofuels and recycled refuse fuels, low investment and operation costs, and utilization of the existing power plant capacity. Furthermore, only small modifications are required in the boiler and possible disturbances in the gasifier do not shut down the whole power plant.

b) Zeltweg BioCoComb Project- Austria

A biomass gasifier for bark, wood chips, sawdust, etc. has been installed at the 137 MWe pulverized coal fired power station of Verbund-Austrian Hydro Power AG in Zeltweg, Austria.

Partial gasification of the biomass is carried out at a temperature of 820°C, in a circulating fluidized bed reactor, which maintains uniform temperatures throughout the gasifier. Temperatures are low to prevent slagging. The low calorific value (LCV) gas produced is directly led via hot gas duct into an existing pulverized coal fired boiler for combustion. The gas produced substitutes approximately 3% (~ 10MWth) of the coal fired in the boiler. The biomass fuel from plants is used in its raw form. The carryover char from partial gasification passes through a cyclone separator and is fully combusted in the coal boiler. The plant started its trial runs in November 1997 and has been in successful commercial operation since January 1998.

The main advantages of the BioCoComb concept are:

- drying of feed biomass is not required since the resulting LCV gas is acceptable for co-firing,
- partial gasification of biomass results in a smaller gasifier,
- no gas cleaning or cooling is required thus preventing tar condensation problems,
- relatively low gasification temperatures prevents slagging,
- there are favourable effects on power plant emissions (CO_2, NO_x),
- there were no substantial modifications to the existing coal fired boiler.

2.3.5 Other innovative developments in biomass gasification

a) Two stage gasification

The aim of a 'single-stage' gasifier is to convert organic substances entirely in one reactor. However, as biomass and other waste bio materials are more heterogeneous in their physical and chemical compositions, the gasification of fuels with inconsistent properties have to deal with several problems and difficulties. As a remedy, various 'multi-stage' processes are currently under development or already in operation. The high volatile amount of biomass, which is released rapidly as gaseous substances during pyrolysis, is taken into account in numerous reactor concepts by spatial subdivision of the fuel conversion steps. These concepts can be categorized as 'single-line' or 'double-line' processes. 'Single-line' processes use only one main stream of mass through a number of reactors which are arranged in series. 'Double-line' processes divide the mass stream into at least two partial streams which pass through parallel-arranged reactors (Hamel et. al., 2007). These two processes are explained in Figure 12.

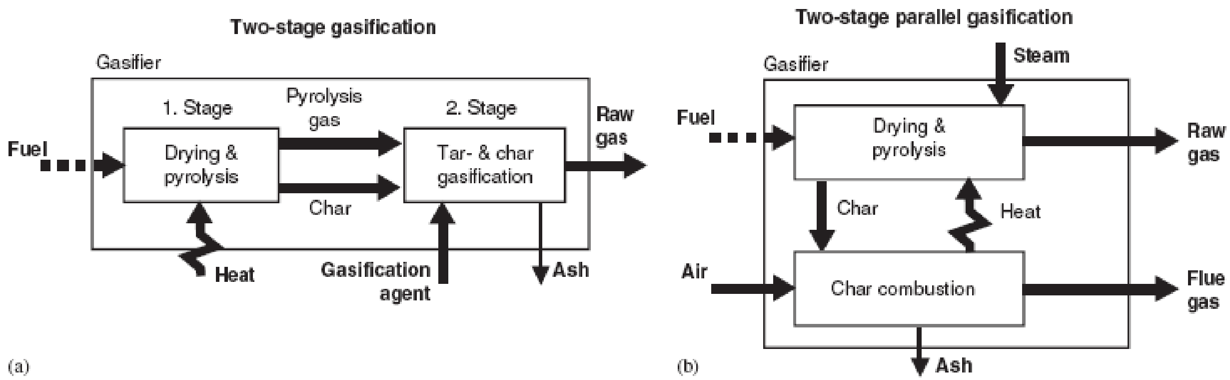

Figure 12: Two-stage single-line and two-stage double-line gasification concept.
(Source: Hamel et. al., 2007)

In the two-stage 'single-line' gasification process, the fuel is dried and pyrolysed in the first stage in an indirectly heated pyrolyser. The pyrolysis products are subjected to partial oxidation by air in a narrow zone between pyrolyser and char gasifier. The product gas has to pass the hot char bed which leads to substantial tar cracking and results in low tar content in the product gas.

Viking two-stage gasification process, developed at the Technical University of Denmark is shown in Figure 13 and is an example of a single line two stage gasifier. The separation of the pyrolysis and the gasification processes results in a gas with very low tar content.

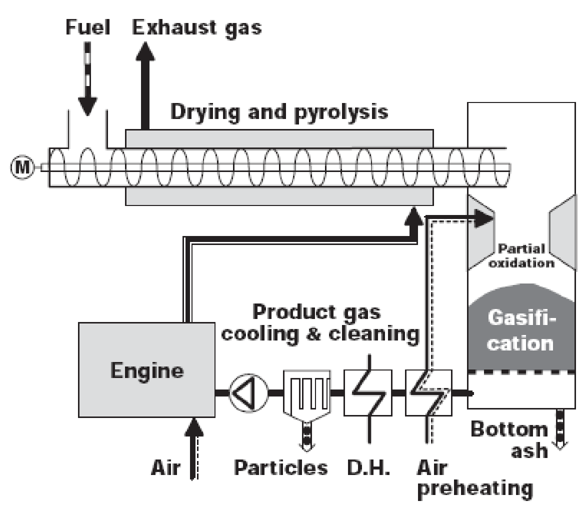

Figure 13: Viking Two-stage gasification process, developed at the Technical University of Denmark.
(Source: Lettner, et. al., 2007)

In parallel line multi stage gasification, the mass stream is divided into at least two partial streams which are processed in several parallel-arranged reactors. The heat needed for gasification can be produced separately by using air for combustion without affecting the gas quality of the gasification reactor (Hamel et. al., 2007).

A similar principle has been realized with FERCO's SILVAGAS process, which consists of two circulating fluidized beds. The first CFB is used for pyrolysis and partial gasification with steam. The second CFB is used to combust the remaining char from the gasification CFB. The endothermic gasification of the fuel takes place in a stationary fluidized bed connected via a chute to the combustion chamber which is operated as a circulating fluidized bed. It is also an example of indirectly heated gasification technology. It utilizes a bed of hot particles (sand), which is fluidized using steam. Solids (sand and char) are separated from the producer gas via a cyclone and then transported to a second fluidized bed reactor. The second bed is air blown and acts as a char combustor, generating a flue gas exhaust stream and a stream of hot particles. The hot (sand) particles are separated from the flue gas and recirculated to the gasifier to provide the heat required for pyrolysis. This approach result in producing a product gas that is practically nitrogen free and has a heating value of 15 MJ/m^3 (Ciferno and Marano, 2002: Kurkela, 2009). The process is schematically shown in figure 14.

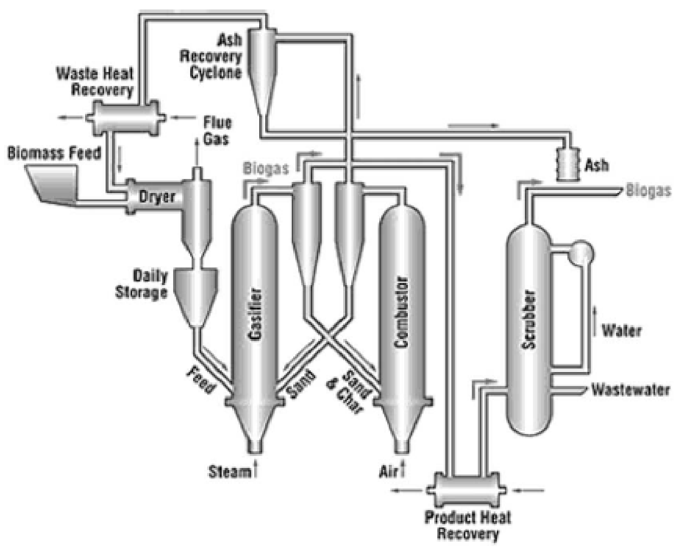

Figure 14: Schematic of the FERCO CFB gasification process

(Source: Malkow, 2004)

Chapter 3

Status of and barriers for Biomass Gasification in Thailand

3.1 Overview of bioenergy use in Thailand

Biomass has been the traditional energy source in Thailand. Various types of biomass available are mostly in the form of non- plantation resources like (i) agricultural residues, (ii) residues from wood and furniture industry, (iii) animal manure, (iv) municipal solid wastes and landfill gas, and, (v) waste water (Garivait et.al, 2006).

Resources

The agricultural residues available for energy in Thailand is estimated to be about 65 and 72 Million tones (Mt) in 2005 and 2010, respectively (Table 8). The major residues are from sugar cane, paddy and oil palm; they contribute to more than 95% of all agricultural residues. The main problems associated with the use of agricultural residues are its high cost for collection and transportation. The agriculture residues used in 2007 was around 5 Million tons (DEDE, 2007) indicating that less than 10% of the available residues are currently used.

Table 8: Agricultural residues in Thailand

Product	Residue	Residue available for energy (Mt)	
		2005	2010
Sugarcane	Bagasse	15.90	17.15
	Top & trash	18.94	20.42
Paddy	Husk	5.46	5.67
	Straw (top)	7.26	7.54
Oil palm	Empty bunches	1.06	1.37
	Fiber	0.59	0.76
	Shell	0.12	0.16
	Frond	10.50	13.53
	Male bunches	0.94	1.21
Coconut	Husk	0.45	0.45
	Shell	0.18	0.18
	Empty bunches	0.07	0.07
	Frond	0.31	0.31
Cassava	Stalk	0.57	0.52
Maize	Corn cob	1.17	1.31
Groundnut	Shell	0.05	0.05
Cotton	Stalk	0.24	0.24
Soybean	Stalk, leaves, shell	0.73	0.73
Sorghum	Leaves & stem	0.25	0.28
Total		64.80	71.95

Source: Sajjakulnukit et.al, 2005

Policies

Thailand's Ministry of Energy estimates that the potential of power generation in Thailand from biomass, municipal solid wastes (MSW) and biogas is 3,700 MW by 2011 (Amranand, 2008). The Thai Ministry of Energy, in its 15 year Renewable Energy Plan for 2008-2022, targets to increase its supply from alternative energy sources to 20.4%. In the Plan, biomass shares 84% of total electricity generation from renewable sources and 91% of thermal energy applications from total thermal energy from renewable sources. Table 9 shows the contribution of different renewable energy resources for achieving the target by 2011.

Table 9: Thailand's target of renewable and alternative energy use in 2011

Fuel Type	Electricity		Heat	Alternative Fuel		Total
	MW	ktoe	ktoe	M liters/day	ktoe	ktoe
Target in 2011	3,246	1,033	3,851	21.31 [1]	6,426 [1]	11,311
Solar	45	4	5			9
Wind	115	13				13
Hydropower	156	18				18
Biomass	2,800	940	3,660			4,600
MSW	100	45				45
Biogas	30	14	186			200
Ethanol				3	820	820
Biodiesel				4	1,258	1,258
NGV				508(mmscfd)	4,348	4,348
Existing in 2006	2,061		1,789	0.5		
Share (%)		6.63% [2]			23.22% [3]	13.5% [4]

Source: Amranand, 2007

Remarks:

1. NGV equivalent to 14.31 M Litres/day of diesel.
2. Share (%) of RE power generation replacing electricity demand in 2011 (182,832 GWh).
3. Share (%) of ethanol, bio-diesel and NGV utilization replacing diesel and gasoline consumption in 2011.
4. Share (%) of RE and alternative energy replacing commercial energy in 2011

Renewable energy development is promoted by several policy instruments such as establishment of mechanisms to compensate for the avoided external costs of biomass power generation, for example through a so-called environmental "adder" on top of the normal buy-back rate, access to power grid under clear and fair terms and conditions, development of a market for biomass waste resources. The main agricultural residues from paddy (rice husk, rice straw), sugarcane (bagasse, leave, etc.) are used for electricity generation of SPPs (Small Power Producers) and VSPPs (Very Small Power Producers). The number of biomass-based power generation plants increased from 35 plants in 2006 with total capacity of about 574 MW to 54 plants with total capacity of 1,129.75 MW in 2007 (Table 10). These plants use only 5% of the residue potential. However, most of these biomass power plants are large rice factories, paper mills and palm oil factories.

Table 10: Status of biomass power generation capacity of SPPs and VSPPs (Oct 2007)

Fuel	Sum of Installed Capacity/ (MW)	Sum of Sold to grid/ (MW)
Bagasse	788.3	294.8
Biogas	10.6	6.8
Black liquor	32.9	25.0
Eucalyptus bark	9.8	8.0
MSW	4.7	2.6
Oil palm wastes	23.4	18.3
Rice husk	102.0	83.8
Rice husk/Eucalyptus bark	134.6	91.0
Rice straw	0.6	0.3
Wood wastes	23.0	20.2
Grand Total	1,129.7	550.8

Source: Energy for Environment Foundation, 2009

3.2 Status of Biomass Gasification in Thailand

Biomass gasification processes are available under industrial, development at pilot scale and demonstration scales in Thailand. Gasifiers are available from several manufacturers in Asian countries, such as India (Ankhur), Japan (Satake), China (Fengyu electric and Time Pro) and also from in-house technology and manufacturing. In addition, there is extensive research and development for improvement of biomass gasification design and gas cleaning activities at universities and research institutes. The list of research and development institutes is given in Appendix IV. Except for the government and research organizations, biomass gasification is a commercial activity in Thailand and for many private entrepreneurs, biomass gasification is not their only business.

Several biomass gasification plants have been installed in Thailand during last 5 years. 25 of the plants are identified in the study out of which 15 plants are in industrial/ commercial applications and 10 are either government supported demonstration plants or plants with research and development purposes in the universities. Table 11 summarizes the details of identified plants and Figure 15 shows the location map of those. Further, all the existing, identified electricity generation plants are less than 400 KW in size and there is 1.5 MW plant under construction phase.

Majority of these plants are based on fixed bed gasifiers. All the electricity generating plants use fixed bed downdraft gasifiers whereas, gasifiers for thermal application vary in its technology type from bubbling fluidized bed, downdraft to updraft. Out of the total 25 plants, there are 13 downdraft gasifiers, 2 updraft gasifiers and a bubbling fluidized bed gasifier. The technology in other plants has not been identified due to lack of access to information and contact details.

According to the generation capacity, just above 80% is for thermal applications and only less than 20% of capacity is used for electricity generation.

Five of the electricity generating plants use diesel engine or modified diesel engines for power generation, one uses a gasoline engine and only three plants among the identified plants, use gas engines.

The type of fuel shows a diversified nature among the plants. Rice husk and wood chip are the two major fuel types while corn cob, waste plastic, charcoal and old tyre rubber are also in use.

However, most of the commercial scale and demonstration plants have failed after a short period of operation. Supreme Renewable Energy Co. Ltd is the only commercial scale plant with more than 2 years of operational practices in biomass gasification power generation in Thailand. At the same time, the fuel properties and gas quality monitoring and analyzing remains in very poor situation in all the plants. None of the failed commercial plants measure the moisture content of the fuel, and the calorific value, the composition or the flow rate of producer gas.

Table 11: List of identified biomass gasification plants in Thailand.

	Site/ plant	Capacity	Reactor type	Gas cleaning system	Engine type	Biomass fuel	Application	Working condition
	Power							
1	Thermal Tech Ltd., Samutsakorn	200 kWe	Downdraft	Cyclones, wet scrubbers	Diesel	Waste plastic	Feed electricity to grid	Not in operation
2	A+ Power Co., Ltd., Nhongmoung, Lopburi	1,500 kWe	Downdraft	Cyclone, 3x2 wet scrubbers, fabric filter	Gas	Wood chip	Feed electricity to grid	Under construction
3	Rice Mill, Lam Luk Ka	80 kWe	Downdraft (3 stage)	Cyclones, HE, wet scrubbers	Diesel	Rice husk	Electricity in rice mill	Not in operation
4	Supreme Renewable Chiang Rai.	150 kWe	Downdraft	Cyclone, Venturi scrubber, HE, water trap, woodchip-sawdust filter, bag filter	Diesel	Corn cob	Feed electricity to grid	In operation
5	Tha-Khlong Agricultural Cooperation, Lopburi	400 kWe	Downdraft (3 stage)		Gas	Rice husk		Not in operation
6	Ubon Rachathani University	80kW+	Downdraft (Double throat)	Cyclone, wet scrubber	Diesel	Firewood/ corn cob	Water pumping	In operation
7	Rajamangala University of Technology Thanyaburi, Pathumthani	30 kWe	Downdraft	Cyclones, HE	Gasoline	Charcoal	Feed electricity to grid	In operation

	Site/ plant	Capacity	Reactor type	Gas cleaning system	Engine type	Biomass fuel	Application	Working condition
8	Suranaree University of Technology, Nakhon ratchsima	100 kWe	Downdraft Chilled	water scrubber	Gas	Any	Feed electricity to grid	
9	Rice Mill Ban Non Muay, Surin	20 kW	Downdraft (Two stage)	Cyclones, wet scrubbers, bag filters	Diesel	Rice husk	Used in the rice mill	Not in operation
10	Prachuap Khiri Khan Province	100 kW	Downdraft			Woodchip/ coconut shells	Feed electricity to grid	
11	Asian Institute of Technology, Pathumthani	25 kW_{th}/ 10 kW_e	Downdraft			Woodchip		
12	Naresuan University,	10 kW	Downdraft			woodchip		
13	Rice Mill, Chai Nat					Rice husk		
14	Prince of Songkla University, Songkla	30 kWe				Woodchip		
15	Suratthani							
16	Marry Rice Mill	200 kW						
17	Alei Rice Mill	2 x 200 kW						
18	Achen Rice Mill	4 x 200 kW						
19	Lecai biomass power plant	3 x 200 kW						
	Heat							
20	Lime and Minerals, SaraBuri		Updraft	Cyclone	N.A.	Old tyre rubber	Lime kiln	In operation
21	Agricultural Industry Kahokoh, Petchabun	320 kWth	Imbert Downdraft	Cyclone, HE	N.A.	Corn cob	Drying Kaffir Lime Leaves	Not in operation
22	Thai Ceramic Company, Saraburi	4 x 5,000 kWth	Bubbling fluidized bed	No	N.A.	Rice husk	Ceramic industry	In operation
23	Ruang Silp 2 factory, Ratchaburi	26 kWth	Downdraft	Cyclone, HE, tar trapper, wet scrubber, dust filter	N.A	Woodchip	Ceramic industry	
24	Sattahil fish processing, Chon Buri	300 kWth	Updraft	Cyclone	N.A.	Woodchip	Heat for boiling fish	Not in operation
25	Siam Cement Thongsong, Nakorn srithammarat							
26	Siam Cement Ta Luang							

N.A. Not applicable

Figure 15: Location map of identified biomass gasification plants in Thailand

3.3 Major problems and barriers for biomass gasification in Thailand

The major problems and barriers are categorized into two groups: technical and non-technical. Despite many R&D efforts over the last decades, commercial status is still not achieved due to several technical and non-technical reasons.

Technical barriers

The moisture content of the biomass is one of the most significant parameters influencing the operating performance of the gasifier. The reactor temperature, which is influenced by the moisture content, affects both the gas heating value and the gas composition. There are some plants which have been shut down due to inability to reach the gas flow rate, heating value and composition to run the engine.

High tar content is the major technical barrier in biomass gasification power generation plants in Thailand. As in the case of other countries, the simple scrubbing approach has failed repeatedly to provide long term operational reliability and in addition, it creates a serious environmental problem because of the large quantities of condensate produced. Tar was tagged to be the major reason for lack of confidence in biomass gasification projects.

Melting of bottom ash, which leads to slagging effects in the gasifier and other pipe lines, is also a major problem, especially when plastic or municipal solid waste is used as fuel.

Lack of technology development and manufacture within the country is a hurdle for the development of biomass gasification. Some demonstration plants have been scaled up from university pilot projects but they have failed due to problems such as tar condensation, insufficient gas flow rates and gas properties, higher ash content, etc.

Modified diesel engines are mainly used as dual fuel engines. These engine modifications are mostly done without any technical expertise or knowhow.

Non-technical barriers

The majority of the barriers are related to non-technical issues. One of the most important barriers to an accelerated penetration of all biomass conversion technologies in Thailand is inadequate resource supply or high prices for biomass fuels such as rice husk. There are evidences that some biomass gasification plants have shifted back to lignite mainly due to increased prices and inadequate supply of rice husk. As Thailand is one of the major agriculture based countries, the demand for biomass resources for other technologies also needs to be considered. The competition from such technologies may cause a steep price rise and low supply of fuel. For example, biomass power generation from combustion boilers is more established and popular among rice mills and other agro industries in Thailand. Therefore, gasification has to compete with such challenges. Sometimes, government policies or environmental regulations can affect the choice of technology. However, there are no specific preferences of policies on biomass gasification.

Government legislations, energy policies and cost of electricity and other fossil fuels have a direct impact on penetration of biomass heat/power projects in general. Most plants have commissioned either to get the benefit of higher adder tariffs from electricity sale or to reduce the energy cost in their own plant. The waste plastic fuelled plant has shifted to that fuel mainly targeting the profit of higher feed in tariff adder for electricity sale from MSW, compared with biomass residues.

Lack of skill in operation of imported plants is a major hurdle in fast penetration of biomass gasification in Thailand. Some plants are forced to close down due to unavailability of skilled operators. Most of the time, the plant operators do not follow the recommended procedures and technical details carefully.

No proper feasibility study is done for almost all the plants before commissioning.

Chapter 4
Status of and barriers for Biomass Gasification in Cambodia

4.1 Overview of bioenergy use in Cambodia

Wood and wood charcoal accounts for approximately 80% of total national energy consumption in Cambodia. 80% in urban and 94% in rural areas use it for cooking. Wood is used in huge quantities mainly in brick industry, hotel and restaurants (Duraisamy, 2010).

In Cambodia, 22% of the total population has access to electricity (60% in urban and 10% in rural areas). Phnom Penh, with 10% of country's population, uses more than 85% of total electricity in the country. For non-electrified areas, mostly batteries or kerosene or solar lanterns are used for lighting in rural areas. The middle income group's households also use high capacity (12-18hp) diesel engine coupled to a 3-5 kW generator, consuming large amounts of diesel (Duraisamy, 2010).

The electricity distribution consists of 22 small isolated power systems and there is no transmission line between the load centers. There was only 323 km of 115 kV electricity distribution grid line in 2008. By 2010, it has been extended up to 477 km of 115 kV and 197 km of 230 kV lines and have plans to extend 115 kV line to 853 km and 230 kV line to 1,509 km and 500 kV line to 220 km by 2020 (Choumnit, 2010).

The total Installed capacity in 2007 was 390.66 MW, of which 19.9% belonged to EDC (Electricite Du Cambodge) (77.86 MW), 53.1% was owned by IPPs (207.3 MW) and 27% (105.5MW) was imported (EDC, 2007). Total energy generation in 2007 was 1378.1 GWh, out of which 1109.6 GWh was in Phnom Penh. In Cambodia, 80.17% of installed capacity is from HFO and 10% is from diesel. In Phnom Penh, 35.3%, 31.0%, 23.9%, 8.7% and 1.1% of electricity sale is for residential, commercial, industrial, government and other sectors, respectively (EDC, 2007).

The average electricity tariff is US¢ 9-25/ kWh for EDC grid and US¢ 40-80/ kWh in rural areas (Chanmakaravuth, 2010). However, the tariff varies dramatically depending on the location and the source of electricity. For example, the average tariff is $ 0.18/ kWh in Phnom Penh, $ 0.25 - 0.40/kWh in urban areas, $ 0.5 – 1.0 /kWh in rural areas with diesel generators and $ 0.16 /kWh in communities cross- boarder connecting to Thailand and Vietnam (Choumnit, 2010).

There are several renewable energy (especially bioenergy) promotion programs in the energy development strategy in Cambodia. Rural electrification fund, efficient cook stove programs, national biogas program and promotion of rice husk gasifiers are some of them.

4.2 Status of Biomass Gasification in Cambodia

In 2003, SME Cambodia, a non-governmental organization in Cambodia, initiated a village electrification demonstration and pilot project in Anglong Tha Mey, Banan District, Battambang province. The system produces electricity from locally grown biomass fuelwood and corn cob. This pilot project operated for over 3 years and successfully demonstrated among the farmer-villagers, the potential and benefits of growing biomass fuelwood and generating electrical energy for local consumption at about 30% of the cost of the producing electricity with diesel fueled generators. The small (7kW) pilot project was expanded in 2007 from 70 households to 250 households. After that, Battambang rice miller invested in a 200kW rice husk burning biomass gasification system developed by ANKHUR Technologies. The system was installed and commissioned in August 2006. This 200 kW gasifier fueled with waste rice husks reduced diesel oil consumption of the mill's diesel engine by 75% or about 5,500 liters per month (SME Cambodia, 2008).

After the successful demonstration of the above two projects during 2007, four more new Cambodian rice mills, a brick factory and an ice making plant purchased and installed gasifier equipment. The energy savings realized by the first 5 SMEs, by installing gasification equipment and substituting diesel, was and continues to be impressive. Cambodian commercial rice mills and other rural SMEs can reduce their diesel fuel consumption by 70%-75% by using the producer gas in the existing diesel engines. Mechanically driven rice mills using their existing diesel engines need only 25%-30% of the rice husk produced by the mill to replace 70%-75% of the diesel fuel consumed (SME Cambodia, 2008). Gas engines are hardly used in Cambodia and therefore not locally available.

In Cambodia, the total number of biomass gasifiers installed so far is about 90, out of which, about 40 gasifiers are installed by SME Renewables (Knowles, 2010). The list of identified plants is given in Table 12 and the location map is shown in Figure 16. All the identified plants in Cambodia are commercial/ industrial scale plants and are used for generating electricity for rural electrification or use in SMEs. Technology for most of the plants is from Ankhur Technologies- India and most plants are 200 kW in capacity and the maximum installed capacity is 600 kWe (2x300 kW from Ankhur, under construction). Almost all the gasifiers use producer gas and diesel in a dual fuel mode. Most of the time, used diesel engines are modified and used for these. Producer gas replaces about 75% of the diesel usage and approximately 6kg of rice husk replaces about 1 litre of diesel.

The feedstocks for gasification are rice husks or corn cobs, wood chips, coconut shells, cane sugar residues (bagasse), peanut shells, etc. The major types of SMEs, which use biomass gasification, are rice mills, ice plants, rural electricity enterprises, brick factories, garment factories, and hotels. For rice husk plants, there is no fuel cost and for ice plants and others, rice husk price is at 0 to 5 USD per ton; the cost of transportation is around 1to 3 USD per ton within 20 km and 5 to 8 USD for more than 40 km (SME Cambodia, 2008).

Table 12: List of identified and visited biomass gasification plants in Cambodia

<table>
<tr><th></th><th>Site/ plant</th><th>Installed year</th><th>Capacity</th><th>Reactor type</th><th>Gas cleaning system</th><th>Engine type</th><th>Biomass fuel</th><th>Application</th><th>Working condition</th></tr>
<tr><td>1</td><td>Te Keang Rice Mill, Kampong Chhnang</td><td>Dec-2008</td><td>200 kWe</td><td>Downdraft</td><td rowspan="7">Wet scrubbers, moisture removal, course filter (rice husk), 3 passive filters (saw dust), bag filter</td><td>Diesel</td><td>Rice husk</td><td>Electricity is used in rice mill</td><td>In operation</td></tr>
<tr><td>2</td><td>Bat Doeng Electricity Enterprise, Kampong Speu</td><td>Dec-2008</td><td>200 kWe</td><td>Downdraft</td><td>Diesel</td><td>Rice husk/ wood chip</td><td>Rural electrification using mini grid</td><td>In operation</td></tr>
<tr><td>3</td><td>Yam Loung Rice Mill, Battambang</td><td>Jul-2009</td><td>300 kWe</td><td>Downdraft</td><td>Diesel</td><td>Rice husk</td><td>Electricity is used in rice mill</td><td>In operation</td></tr>
<tr><td>4</td><td>Yin Pou Rice Mill, Banteay Mean Cham</td><td>May-2008</td><td>200 kWe</td><td>Downdraft</td><td>Diesel</td><td>Rice husk</td><td>Electricity is used in rice mill</td><td>In operation</td></tr>
<tr><td>5</td><td>Teng Sarith Ice Factory, Phnom Penh</td><td>Jul-2010</td><td>200 kWe</td><td>Downdraft</td><td>Diesel</td><td>Rice husk</td><td>Electricity is used in ice factory</td><td>In operation</td></tr>
<tr><td>6</td><td>Ley Chhinh Rice Mill, Battambang</td><td>Jul-2010</td><td>600 kWe</td><td>Downdraft</td><td>2x 300 Diesel</td><td>Rice husk</td><td>Electricity is used in rice mill</td><td>Under construction</td></tr>
<tr><td>7</td><td>Eap Sophat Ice Factory, Siem Reap</td><td>Jul-2007</td><td>150 kWe</td><td>Downdraft</td><td>Diesel</td><td>Rice husk</td><td>Electricity is used in ice factory and sell</td><td>In operation</td></tr>
<tr><td></td><td colspan="9">Other identified plants</td></tr>
<tr><td>8</td><td colspan="9">LEAP Man Ice Factory, Mongkul Borei, Banteay Mean Chey</td></tr>
<tr><td>9</td><td colspan="9">Electricity Prey Totoeng, Prey Totoeng, Prey Chhor, Kampong Cham</td></tr>
<tr><td>10</td><td colspan="9">Lor Gnor Pheng Rice Mill, Skun town, Choeung Prey, Kampong Cham</td></tr>
<tr><td>11</td><td colspan="9">Lor Eak You Rice Mill, Pa Av, Choeung Prey, Kampong Cham</td></tr>
<tr><td>12</td><td colspan="9">HENG Chhat Stone Crushing, Takream, Banan, Battambang</td></tr>
<tr><td>13</td><td colspan="9">SOK Kung Rice Mill, Chum Teav, Mongkul Borei, Banteay Mean Chey</td></tr>
<tr><td>14</td><td colspan="9">TAN Va Rice Mill, Kork Tumlap, Mongkul Borei, Banteay Mean Chey</td></tr>
<tr><td>15</td><td colspan="9">LAY Ser Rice Mill, Thmar Korl Town, Battambang</td></tr>
<tr><td>16</td><td colspan="9">CHAO Mei Rice Mill, Chamnorm, Mongkul Borei, Banteay Mean Chey</td></tr>
<tr><td>17</td><td colspan="9">NGOV Meng Rice Mill, Thmar Korl Town, Battambang</td></tr>
<tr><td>18</td><td colspan="9">HUO Rice Mill, Thmar Korl Town, Battambang</td></tr>
<tr><td>19</td><td colspan="9">Electricity Kanh Chreach, Pra Srer Muk, Kanhchreach Town, Prey Veng</td></tr>
<tr><td>20</td><td colspan="9">UNG Simon Rice Mill, Svay Antor Town, Prey Veng</td></tr>
</table>

21	ROS Neng Rice Mill, Svay Antor Town, Prey Veng
22	CHHUN Thom Rice Mill, Svay Antor Town, Prey Veng
23	Electricity Svay Antor, Svay Antor Town, Prey Veng
24	CHHITH Bun Than Rice Mill, Prey Veng Town, Prey Veng
25	NGOV Huong Rice Mill, Prey Veng Town, Prey Veng
26	PHEACH Sophat Rice Mill, Takeo Town, Takeo
27	CHAY Kimting Rice Mill, Kork Tumlap, Mongkul Borei, Banteay Mean Chey
28	TOEM Prech Rice Mill, Takeo Town, Takeo
29	KHUTH Thanh Rice Mill, Kralanh district town, Siem Reap
30	THOUNG Vay Ice Factory, Kralanh district town, Siem Reap
31	LOEM Lom Rice Mill, Siem Reap District Town, Siem Reap
32	HOEU Chy Rice Mill, Kralanh district town, Siem Reap
33	Heng Lay Rice Mill, Boeng Pring, Thmar Korl, Battambang
34	HENG Sokha Rice Mill, O'Porng Morn, Takream, Banan, Battambang
35	TAING Cheng Rice Mill, O'Taky, Battambang
36	Electricity of Bovel, Bavel District, Battambang
37	Village electrification in Battambang, Anlong Tmei Village, Banan District, Battambang Province
38	Song Heng Rice Mill, Chery, Haysan, Battambang
39	Sann Mab Rice Mill, Kork Tunlap, Mongkul Borei, Banteay Mean Chey
40	Seav Pisith, Phnom Penh
41	Chao Khor Rice Mill, Kralanh District Town, Siem Reap
42	Chang Kornmeng Rice Mill, Pteah Prey, Sampov Meas, Pursat
43	Khy Thay Brick factory, Prey Khmer, Rolea Pa Ea, Kampong Chhnang
44	Sour Kheang Rice Mill, Batheay, Choeung Prey, Kampong Cham
45	Chea Sinat Garment factory, Kbal Koh, Kean Svay, Kandal
46	Pav Nam Rice Mill, Prek Ho, Takhmao, Kandal
47	Lok Seap Rice Mill, Prek Ho, Takhmao, Kandal
48	Fang Vun Rice Mill, Phnom Touch, Mongkul Borei, Battambang
49	Khiev Moeung Rice Mill, O'Taky, Battambang
50	Tech Sreang Rice Mill, Kampong Tralach, Kampong Chhnang
51	Sann Ty Rice Mill, Rohal, Preah Net Preach, Banteay Mean Chey
52	Sambo REE, Kampong thom
53	Kheng Hourt Rice Mill, Thmar kol, Battambang
54	Vinh Cheang Rice Mill, Tbong Kmom, Kampong cham
55	Naga Thom, Siem reap

Sources: Personal visits: SME Cambodia, 2008 and other sources.

Figure 16: Location map of identified biomass gasification plants in Cambodia

In Cambodia, biomass gasification technology is comparatively better established than in Thailand. Since, there are no other popular biomass conversion technologies (similar to firing of biomass in boilers for power generation in Thailand), there are plenty of available feedstocks, especially agro residues, either free of charge or at low cost. Therefore, there is still a good potential of development of biomass gasification technologies in Cambodia.

The main advantage and social impact of biomass gasification projects is that it is being used for rural electrification projects, where there is no access to electricity grid. Similarly, SMEs get many indirect advantages such as the ability to expand the production capacities, reducing the energy cost and hence producing the products at cheaper unit cost.

Research and development, demonstration plants and technology dissemination work are mainly carried out by private organization and NGOs, while they are totally handled by the government in Thailand.

According to Chanmakaravuth (2010), there are 24,048 rice mills in Cambodia with a total annual rice production capacity of 4.96 million tons. Considering 20 liter of diesel is required for milling a ton of rice, total annual diesel consumption and related GHG emission is estimated to be 99.3 million liters and 277,984 tCO_{2-eq}, respectively (Chanmakaravuth, 2010). Assuming that 75% of diesel oil could be replaced by producer gas from rice husk fired gasifiers in rice mills, it is estimated that 74.5 million liters of diesel can be saved which can reduce about 208,488 tCO_{2-eq}, annually.

4.3 Major problems and barriers for biomass gasification in Cambodia

Technical barriers

Similar to Thailand, lack of technology development within the country itself is a hurdle for the development of biomass gasification projects. Some demonstration plants have been scaled up from university pilot plants but have unfortunately failed after scaling up.

Even though plants are managed to remove tar by using several gas cleaning mechanisms such as wet scrubbers, moisture removal, course filter (rice husk), passive filters (saw dust), bag filter, the wastewater treatment is a major concern in Cambodia.

Similar to Thailand, ash removal has also been a major problem in Cambodia.

Non-technical barriers

The major non-technical barrier is the lack of availability of technical expertise and training and awareness programs for plant operators.

Chapter 5

Improvements and Suggestions to Overcome the Problems in Biomass Gasification

a) Thailand

After 15 years of extensive research and development and much funding, there are still only a few commercially operating plants in Thailand compared to many other Asian developing countries like India and China.

There is a need for motivated and skilled labour at all levels. Attention needs to be paid to establish an operational skills base. Technical advisory service or consultancy service should be available. Formation of a technical committee would be useful in this regards.

Technology must be mature, based on proven prototypes and long-term duration testing. Scale-up, demonstration, replication and optimization are needed to commercialize the technology. However, scaling up issues should be considered carefully. There are plenty of R&D work being carried for innovation in biomass gasification technologies. For example, there is a trend to separate combustion, pyrolysis and/or reduction zones by multi-step gasification. However, after successful pilot plant test, none of these modifications are used in demonstration projects or at commercial scale. Demonstration plants need governmental support not only for R&D and first installations, but also for their complete lifetime. Inadequate concerns after the first trial runs cause all the demonstration plants for power generation to fail only few months after the installations.

One important observation is that all R&D work and demonstration projects are financed and commissioned by government and universities. There is a clear lack of involvement of industrial sector in these activities, whereas, in most other countries, in which biomass gasification have become more competitive, there is a clear private sector involvement in R&D and demonstration projects. India, China, Finland are few major examples, where demonstration projects are sponsored by private enterprises. This kind of industry-research involvement would lead to proper scaling up of pilot plants.

There is a strong need for clear standards and regulations on gasifier manufacture, emission standards, and other health & safety aspects.

In addition to the development or import of rather fuel specific gasifiers, there is currently a strong need for fuel flexible gasifiers that are also able to convert difficult fuels, e.g. high alkali and high ash content fuels.

There are many lessons learnt from other countries, which can be implemented to the biomass gasification industry in Thailand. To address the issues related to tar formation and condensation in gas cleaning processes, the following measures have been proven successful in different countries: Thailand either can import these technologies or adopt this tar cleaning technologies rather than using the wet scrubbers alone.

Some developmental effort has been put on charring of biomass and subsequent gasification of char with a view to avoid problems relating to tar through use of relatively simple designs typically developed for charcoal as fuel.

In some successful plants, the first cleaning step is a fabric filter for removal of particles and some of the tars. These particles are returned to the combustion zones of the gasifier. After that, a scrubber section removes the rest of the tar, and the produced condensate with saturated tar is fed into the combustor. Therefore, using fabric filters and recycling the tar and dust collected would be useful.

Hot gas rigid barrier filters such as ceramic or sintered metal barriers are proven successful for tar removal as there is no need of gas cooling, hence preventing condensation. These filters provide the opportunity to produce a clean fuel gas while retaining the sensible heat of the fuel gas. Ceramic filter can withstand temperatures around 900°C, while metal filters around 500°C. Bag filters or the textile filter can remove particles as effective as ceramic hot gas filters (Nilsson, 2008). The systems, which use wood dust filter bed, the cotton filter, and sand bed filters are proven successful in India.

A secondary partial oxidation reactor is used as a tar cracker to remove any tars present in producer gas. About 20% of secondary air injection to the primary air injection above the biomass feeding point in a fluidized bed gasifier reduced 88.7% (wt) of the total tar for the gasification in temperatures from 840 to 880 ºC.

Recent progress in catalytic conversion of tar gives a credible option of average technical strength. For heat applications, it is not necessary to eliminate the tar from the fuel gas and thus any reliable gasifier system can be used successfully. Although heat applications are relatively easy, there are only very few examples in the market. The most successful has been the 4x5MWth bubbling fluidized bed gasifier, used in a ceramic factory.

It is necessary to demonstrate that a local skilled workforce can operate gasification plants when it is commissioned. The client can get help from technology provider in this regards.

Moisture content of fuel is one of the major parameters, which determines the efficiency of a gasifier. However, most of the time, the moisture content is not measured and not known. It is important to measure the moisture content of fuel and the composition of producer gas. Composition of producer gas determines how efficiently an engine can run with the available flow rate and gas composition.

The cost of feedstock must be taken into consideration, even if it can be obtained free initially, to ensure there is sufficient profitability over the plant life. Therefore, proper feasibility study would ensure sustainability of a plant.

b) Cambodia

There is a need for motivated and skilled labour at all levels. For gasification plants, attention needs to be paid on establishing an operational skills base. Technical advisory service or consultancy service should be made available. Capacity building at all levels on technical services and financial and business management is recommended. Special training programs for plant operators, development of technology fact sheets, guidebooks, etc. would be valued in this sense.

The establishment of gasifier fabrication unit(s) and technological service unit in the country in partnership with private sector investors is recommended to overcome the barrier of lack of available in-house technology.

There is a strong felt need for clear standards and regulations on permitting procedures, fabricating gasifiers, emission standards, and other health & safety aspects. Regulation and standardization is also required to stop replicating plants without any technical expertise or knowledge.

Chapter 6
Conclusions and Recommendations

Together with hydro power, biomass is the most important energy source in the Mekong region countries, since all the countries are primarily agri-based. At the same time, as both the countries have targeted for higher share of renewable energy in the future national energy demand, electricity generation from biomass, specially, agricultural residues, would be one of the most important pathways to meet these objectives.

In Thailand, only 26 biomass gasification plants between the capacity of 20- 400 kW are identified and 80% of the capacity is used for industrial thermal applications. Only one commercial scale biomass gasification electricity generation plant was identified. Therefore, biomass gasification for thermal applications, especially where there is a requirement for high temperature thermal applications is more proven in Thailand. The major problem of tar removal will not be a barrier in the case of technology development for thermal application.

On the other hand, there are electricity generation plants with up to 3 years of operating experience in Cambodia, which shows that the technology is potentially successful in the country. Atmospheric, air-blown, downdraft fixed bed gasification process has been successful in these small scale projects and the capacity of 200 kW has been commonly used.

The future potential threat of standardization and environmental concerns may demand requirement for a complex and expensive gas cleaning and wastewater systems in both the countries.

In general, for economical advantages, gasifiers need to run at its full load conditions. Therefore, correct design of the plant is essential (dimensioning for base load coverage), especially in rural electrification and SME projects, where the load is fluctuating. In addition, a long term supply contract of biomass is recommended. Additional technical constraints need to be addressed in the long term development of small and medium term biomass gasification plants. The technology must be highly available. The plant must be designed to run at partial load and be able to stand quick load changes.

As of now, biomass fuel is easily and cheaply available in Cambodia. Gasification technology is well established with no other competitive technologies in the region, hence Cambodia can go for the latest larger scale gasification installations (specially using rice husk). By replacing 75% of energy consumption of all the existing rice mills in Cambodia, the country can annually save 74,460 ton of diesel and hence cut down its foreign exchange expenditure. On the other hand, it accounts for 208,488 tCO_2 of annual GHG emission reduction.

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Appendix I- Questionnaire used for the survey

List of required data and information- Biomass gasification study

Please provide the following information as much as possible.

	Description	Answer
1	**Project location**	
2	**Client:** Who own and operate the facility? (name, contact details)	
3	**Year** of installation	
4	**Technology** (updraft. downdraft, fluidized bed, open, bubbling fluidized bed, circulating fluidized bed, etc.)	
5	**Supplier** of the gasifier and engine (name, contact details?	
6	**Biomass fuel** characteristics - Type of fuel?	
	- Moisture content?	
	- Calorific value?	
	- Consumption rate?	
	- When does this fuel arrive (seasonally) and how is it stored?	
	- How much is the fuel cost when it reaches the plant site?	
	- Should it be dried or stored for a minimum period of time?	
	- Should it be pre-processed such as by briquetting and what is the cost of this?	

	- What's the size of fuel feed to the gasifier?	
7	**Capacity** (kWth, kWe)	
	Efficiency	
8	**Gas Properties** - Gas composition	
	- Calorific value	
	- Gas flow rate	
9	**Application** or the use - Feed to the grid (how many kWh)	
	- Village electrification (No. of houses)	
	- Industry/ type (thermal or electricity)	
	- Other uses (thermal or electricity and for what purpose?)	
	- Daily hours of operation	
10	**Project performance** **Technical reliability** - What types of technical shortcomings are experienced?	
	- Do you face material or spare parts problems?	
	- What is the expected lifetime of the plant?	

	Social impact - Employment for the local population, (to grow the trees, and/or operate the power plant, etc.)?	
	- Improvements in other infrastructure in the area (state what)?	
	- Other (state)	
	Environmental concerns and measures - How do you remove ash/ slag from the combustion system? What use of it?	
	- How do you remove tar (cyclone, filter bags, wet scrubber, electrostatic precipitator, etc.)? Explain.	
	- Do you measure flue gas properties and do they match with environmental regulations (particulate matter, tar level, etc.)?	
	- Do you experience any noise at any stage of the process (feeding system, compressor, engine)? What measures are taken?	
	- How do you treat wastewater from gas cleaning stage (if any)?	
	- Have you ever experience explosions in the gasifier/ gas storage?	
	Problems and difficulties faced and O&M activities - Is the system user friendly or not?	
	- Is there a biomass supply shortage?	

	- Is there an automatic feeding system?	
	- Do you adhere to the recommended fuel characteristics (Moisture level and size of biomass, etc.)?	
	- Do you measure the moisture level of feed biomass? How?	
	- Is there fouling and slagging	
	- Is there corrosion	
	- Is there fuel blockages	
	- Do you add any catalyst or additives to the gasification bed?	
	- Do you adjust the temperature/ pressure etc.? When?	
	- Do the gas specifications match with engine requirements?	
11	**Economics** - Total investment cost	
	- Operating cost	
	- Production cost/ kWh	
	- Revenue	

Appendix II- Biomass gasification case studies in Thailand and Cambodia from plant visits and literature

Case study 1

Gasification plant at Thermal Tech Ltd., Samutsakorn, Thailand

The original design of the gasifier is a fluidized bed dryer for gasifying risk husk. The owners have modified it without any technical expertise into a plastic waste updraft gasifier. The main motives behind plastic instead of rice husk are;

1) The higher adder for MSW compared to biomass in the government tariff.
2) The client owns his own landfill and therefore, it doesn't cost to get waste plastic. Moreover, he gets the benefit of land reclaiming.
3) The client stated that using rice husk is not economical

Waste plastic gasification plant at Samutsakorn

The plant has produced 200 kWe from waste plastic and has fed into the grid. A gas engine is used for electricity generation. Fuel is crushed into particles of 6-10 mm in size before feeding the gasifier. The fuel consumption is 150 kg of plastic/ hr. However, the plant experiences problems due to slagging in the gasifier and could not run for more than consecutive 5 hours. After 5 hours of operation, plant needs to be stopped for maintenance.

Crushed plastic for feeding the gasifier

Two cyclone separator and 3 wet scrubbers are been used in the gas cleaning system and wastewater is discharged just after open pond treatments.

Gas cleaning system

Engine wearing **Slagging**

Tar condensation and wastewater generation

Case study 2
Biomass gasification plant at A+ Power Co., Ltd., Lopburi, Thailand

The plant is under commissioning and planned to start operation in September 2010. The plant consists of 2x 950 kWe downdraft gasifiers, which will generate electricity using woodchips by operating on 24 hours basis and feed electricity to the grid.

The fuel consumption is 1 ton/hr and it must be pre processed to 7 cm in size. The higher temperature zone of oxidization stage by secondary air generates tar free producer gas.

Secondary air supply into the combustion zone of the gasifier

cyclone separators, 6 wet scrubbers and bag filters are used to clean the gas, before feeding into the gas engine.

Case study 3
Lime Mineral Biomass gasification- Saraburi, Thailand

The Lime Mineral Co. Ltd. in Saraburi uses updraft gasifier for thermal application in the limestone plant. The capacity of the limestone plant is 10 tons of limestone per day. The technology was developed in house.

Rubber gasification plant at Lime Minerals, Saraburi

Rubber from old tyres, at a rate of 5-10 tons/day is used as a feedstock. The old tyre costs 1200 THB/ton when it reaches the site. However, the price is still cheaper than biofuels when compared with its heating value. Whole tyres are manually fed to the gasifier at the rate of 4-5 tyres per hour. The plant runs 24 hours a day and the expected life is about 10 years. The investment was only about 3 million THB.

The gas is cleaned in a cyclone and the ash is removed from the bottom of the gasifiers without stopping its operation. The operators sometimes experience explosions inside the gasifier.

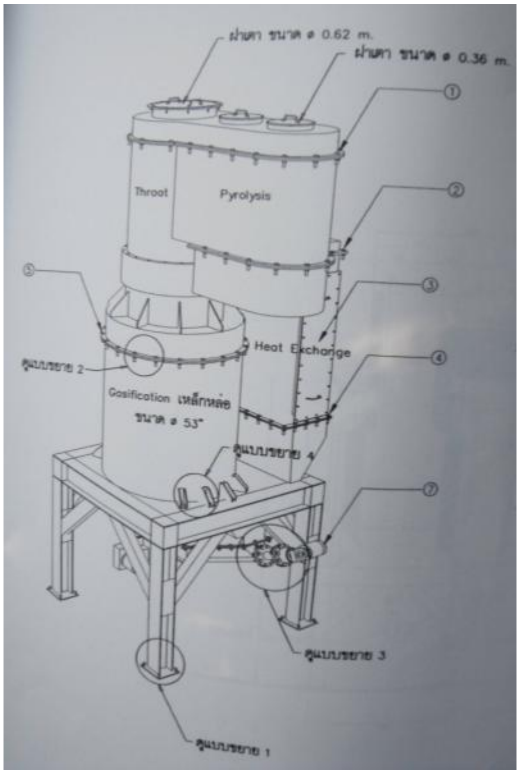
Other observations
The surrounding air was heavily polluted and the area was full of particles and bad smell. The dark ash was spread all over the area.

Case study 4
Rice Mill and Central Market, Agricultural Cooperative at Lam Luk Ka, Pathum Thani, Thailand


Rice husk plant at Pathum Thani Province

The plant is located at Rice Mill and Central Market, Agricultural Cooperative Lam Luk Ka, Pathum Thani Province. This plant is installed under the development and demonstration of biomass gasification for community project by DEDE. The technology was developed at the Energy and Environmental Engineering Center, Faculty of Engineering, Kasetsart University and it was scaled up after a successful pilot plant testing. The implementation program is a joint effort by Kasetsart University and DEDE.

A three stage downdraft gasifier of 80 kW was installed. Rice husk is used as a feedstock. There are four zones in the gasifier. First, the pyrolysis and drying zone is mounted outside of gasifier reactor by using waste heat recovery system from the engine. Second, combustion and reduction processes occur inside the reactor by using the air as the gasifier medium. Third, the producer gas is sent to cyclone to separate solid particles and then, it is sent to a heat exchanger and a scrubber to remove tar and reduce temperature before being fed to an engine. Fourth, the power unit is a modified diesel engine of 80 kW capacity used to produce the electricity to be used in the rice mill or to be exported to the grid.

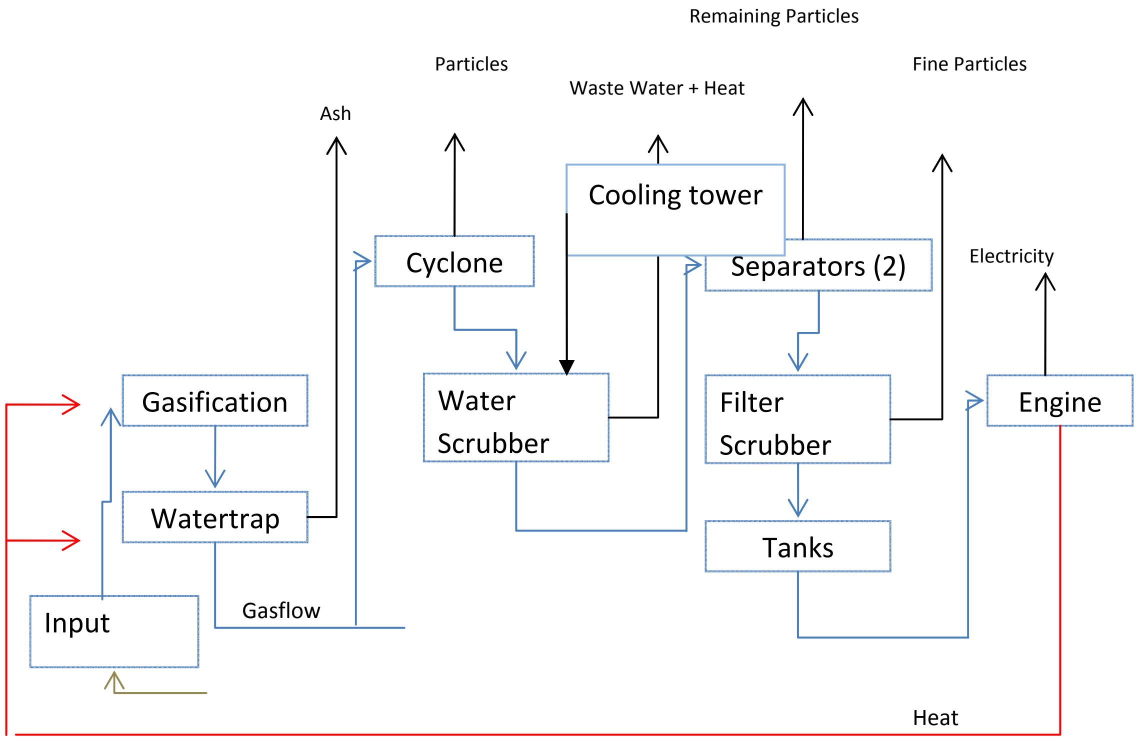


Three stage downdraft gasifier of 80 kW

The gas flow rate of 240 m^3/hr averages a heat rate of 4,500 kJ/m^3. The rice consumption is 85 kg/hr. The overall yield of gas production was approximately 92%. The investment cost was 5 million Baht and the estimated payback period is 7 years. Currently, the plant is not in operation.

Tested composition of producer gas

Gas	**%**
CO	14.45
H_2	5.57
CH_4	3.03
CO_2	15.98
N_2	59.34



Flow chart of the gas cleaning process

Case study 5

Gasification power plant of Supreme Renewable Energy Co. Ltd. It located at Wiang Kaen, Chiang Rai, Thailand

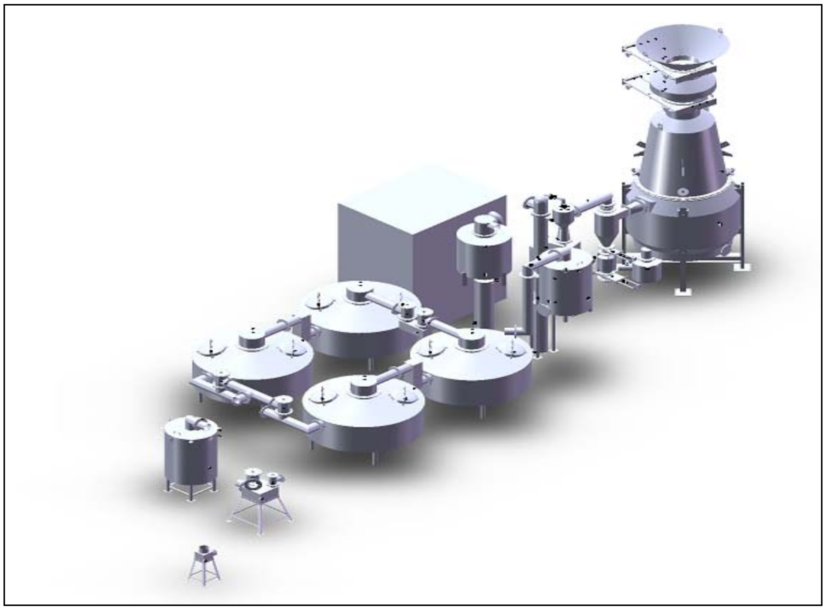
Supreme gasification power plant

Supreme energy biomass gasification plant is located in Wiang Kaen, Chiang Rai. The installed capacity is 150 kWe by using corn cobs, and wood as fuels. This plant supplies electricity to PEA grid and receives an adder of 0.3 Baht/kWh since April 2008. Supreme feeds 150kWh x 7650 h of electricity to PEA grid annually at a rate of 4.2 THB/kWh. It is equivalent to the electricity supply of 120 households in a rural electrification project. Actually, this is the first commercial generation power plant, which is connected to PEA grid. The overall efficiency of the plant is calculated as 25-30%. The expected life of the plant is 20 years.

This plant was constructed in 2006 and commissioned in 2008. The investment cost is as high as 30 million Baht approximately. This company is planning to construct another community power plant by using gasification technology of capacity 2 MW with investment cost of 60 million Baht.

Technological details

This plant uses downdraft gasifier technology. The technology is from Ankhur Scientific Technologies, India and it has been modified by German engineers. A modified diesel engine from Jiam Pattana company is been used for power generation by producer gas.



Flow diagram of plant

(Source: Supreme Renewable Energy Co. Ltd.)

Gasifier operators buy corn cob, store and dry it (natural drying in store or sun dried if needed) down to 10-12% moisture content before feeding to the gasifier. The moisture content is measured hourly. The size of feedstock is maintained at 2cm diameter and 6cm in length. Feedstock is fed continuously on the top of gasifier with mass flow rate of 150-224 kg/hr. The company does not experience any feedstock shortage at the moment.

The temperature and pressure of reactor are measured. Drying and pyrolysis process occur at about temperature 600-800 ^{o}C. Then, in the combustion zone, temperature is 1,400 ^{o}C. Partial combustion occurs in this zone because of limited oxygen. The reduction process begins at the bottom of the gasifier, producer gas is produced in this zone. Producer gas escapes from the gasifier with temperature of 400-500 ^{o}C. It is sent to the ventury for reducing temperature. Water is sprayed in this position resulting in gas temperature decrease from 400-500^{o}C to 40 ^{o}C. The moisture content in the gas is separated by woodchip in a first stage filter unit and saw dust in a second stage filter unit. The gas flow rate is measured as 500 cfm (about 850 m^3/hr) and the calorific value as 4.5 MJ/ m^3. Finally, the gas is sent to the engine to produce electricity.

Gas cleaning

The producer gas is cleaned through several stages such as cyclone, wet scrubber, water separator, heat exchange (chilled water at 10 ºC, 8RT chiller -10 kW), water trap (moisture removal), filter (wood chips) and bag filters to collect wood particles before sending to the engine.

Gas treatment systems

Tar is removed from the producer gas in a wet scrubber, a water separator and a heat exchanger and used as wood preservative. Only about 0.5 kg of tar is collected per month.

Technical problems

A modified diesel engine is used to run from producer gas. Therefore, the engine has some problem related to cooling system, pipe connection (not designed for gas) and pipe leakage.

The system needs to be cleaned after every 500 hrs of operation. It needs about 8 hrs for cleaning.

Environmental concerns

Flue gas properties are not measured.

Social benefits

10 people are directly employed in the plant.

Waste water removed from wastewater pond is given to farmers to use as organic pesticide.

Case study 6
20 MWth gasification plant at Thai Ceramic Company, Saraburi, Thailand

Thai ceramic Co. Ltd. (TCC) belongs to the Siam Cement Group of companies. The main motive for TCC to go for biomass gasification was the rising share of energy cost in their manufacturing environment due to rising fuel prices.

Gasifier specifications are as follows:

Capacity- 4 x 5 MWth
Technology- Circulating fluidized bed gasifier (in house technology- reactor dia. 1.8 m)
Fuel
Fuel- Mainly rice husk (eucalyptus wood chips- when there is a shortage of rice husk)
Fuel rate- 0.8- 0.9 tons/hr (20 ton/day)
Moisture content is < 15%, store in a stock yard for drying
Current price is 1800 THB/ ton
Plant operates 24 hrs/ day for high temperature thermal energy applications.
Ash Production rate: 0.13 tons/hr (2-3 ton/day)
There are 2 NG gas burners for start up and an ash discharge pipe at the center of reactor bed.

Rice husk to producer gas conversion ratio: 1 kg rice husk produces 2m^3 gas or 2 Mcal heat.
Gas flow rate : 2 Nm^3/ kg of biomass
Calorific value : 3200 Mcal/hr
Cost of heat : 0.6 Baht/kcal at 1200 Baht/ton of rice husk
Investment cost: 1 million baht/ 1 MWth (only for the reactor)
10 million baht/ 5 MWth (overall investment)
Expected life time is over 5years (Payback period is less than 2 years).

- BFBC technology was selected by the technology development group especially because the bottom ash is disposed in the form of powder and they plan to study if they can extract silica from the ash. Currently, ash is given out to farmers to use as a fertilizer.
- High temperature producer gas was used at the special gas burner. Flame temperature reached1050 ^{o}C. Heating from gas burner was used in spray dryers in ceramic industry to dry the processed clay.
- Producer gas outlet temperature was maintained at 500 ºC to avoid tar condensation. As the gas is not cooled, tar will not be condensed. Therefore, as long as the final use is non-food product, where fly ash contamination is not a problem, the system does not need sophisticated technique for gas cleaning.

- However, the gas piping system faces very high temperatures. This reactor has a positive gas pressure that can cause gas leakage and lead to smoke odor problem in the working area.
- According to the developers of this gasifier system, the main problem is the unreliability of the gas cleaning system. Whenever the wet cleaning applies, waste water treatment is a huge problem.
- Very recently, the factory face shortage of rice husk supply and very higher prices of about 1800 THB/ton of husk.

In one of the other pulp and paper companies in SCG group (Siam Phoenix Co. Ltd.) in Lampang province, this gasifier is up scaled to 2.5 m reactor diameter and use for gasification of low grade coal. The capacity is 30 MWth.

The same technology has been developed and implemented in another SCG ceramic company in Mariwasa, Philippine for a 14 MW plant. It uses wet process gas cleaning system to reduce tar in the feed gas to the IC engine. It was found that waste water was a crucial problem and a cause project failure.

Mariwasa Project:

- 15 MWth, BFB
- Rice husk rate: 4-5 t/h
- Saving 15 MB/y
- Start to operate: May 2009

In conclusion, users have confidence in gasifier technology for heating application in non-food production processes.

Case studies from Cambodia

Case study 7
Te Keang Rice Mill, Sala Lek Pram, Kampong Tralach, Kampong Chhnang, Cambodia

The rice mill uses a fixed bed, downdraft gasifier from Ankhur Technologies, India. The capacity of the plant is 200 kWe. Electricity is been used at the rice mill. The plant operates 10-12 hrs/day on an average.

The capacity of the mill is about 2 ton/hr of paddy or about 900 – 1200 kg/hr of rice and the fuel consumption for the gasifier is about 200 kg/hr of rice husk.

There is a series of gas cleaning equipments such as wet scrubber, moisture remover, a coarse filter, three passive filters and a safety filter. The course filter uses rice husk as a filtering medium and rice husk is changed every week. The passive filters use saw dust as a filtering medium. Rice husk is changed every week and the bag filters are used as safety filter before sending the gas into duel fuel mode modified diesel engine (Mitsubishi).

The problem of tar condensation and wastewater generation

The gasifier system costs about 70,000 US$ (total including installation, one year warranty, one year spare parts, one year after sale service) – excluding civil work and generator set.

Case study 8
Bat Doeng Electricity Enterprise, Bat Doeng, OuDong, Kampong Speu, Cambodia

It is a Rural Electricity Enterprise (REE): electricity is generated from the rice husk fired gasifier and is sold to the villagers. The mini grid system has been constructed by the company. The plant uses a 200 KW Ankhur (India) fixed bed downdraft gasification system. The plant operates 20 hr/day. The system is also backed up by stand by diesel generators.

The company buys rice husk from farmers (12 kg bag = 800 Riel, 1 US$ = 4250 Riel) and electricity is sold at 2500 Riel/kWh. Average monthly consumption of rice husk is about 5460 kg.

There is a series of gas cleaning equipment such as wet scrubber, moisture remover, a coarse filter, three passive filters and a safety filter. The course filter uses rice husk as the filtering medium. Rice husk is changed every 4-7 days. The passive filters uses saw dust as filtering medium. The bag filters are used as safety filter before sending the gas into duel fuel mode modified diesel engine (Mitsubishi).

Series of gas cleaning equipment

Rice husk ash is sold to farmers as fertilizer at a rate of 300 Riel per bag at about 25 kg.

The plant's monthly operation and maintenance cost include salary for 12 directly employed staff = 1500 US$/month (including operation manager's salary of 250 US$/month), maintenance and repair (about 300 US$). The plant is scheduled for maintenance every 100 hrs of operation for changing the lubricant.

The problem of tar condensation and wastewater generation

Problematic ash disposal

Case study 9
Teng Sarith Ice Factory, Doung Kor, Phnom Penh, Cambodia

The plant is an Ankhur manufactured 200 kWe downdraft gasifier for electricity generation by using rice husk. Electricity is used to operate the vapour compression chiller at the ice making plant.

The gas cleaning system is very much similar to the earlier two gasification systems and it consists of a series of gas cleaning equipment such as wet scrubber, moisture remover, a coarse filter, three passive filters and a safety filter. In addition, the producer gas temperature is reduced and tar is removed using chilled water.

A series of gas cleaning equipment

Case study 10
Yam Loung Rice Mill, Popeal Kher, OTaky, Battambang, Cambodia

The plant is an Ankhur manufactured 300 kWe, fixed bed downdraft gasifier. It is used for electricity generation using rice husk and use into the rice mill. The plant uses a second hand Hino engine in duel fuel mode to generate electricity.

Rice husk from the mill is used. Not much details on the use of rice husk is available. The owner also does not bother about these details. Since he is using rice husk from his mill he is very happy. This replace diesel and save money while solving the disposal problem of rice husk.

The gas cleaning system is similar to the other Ankhur systems, which consist of a series of gas cleaning equipment such as wet scrubber, moisture remover, a coarse filter, three passive filters and a safety filter.

The present rice production is 2-3 ton/hr. The mill has already started expansion up to 10 ton/hr. and bought a 500 kWe gas engine from Japan to be used after expansion.

There are minor operation and maintenance problems in the plant, such as damage of the inside cement lining (insulation) of the gasifier which, need to be repaired or replaced every 6 months. Ash removal is a continuous problem.

Case study 11
Ley Chhinh Rice Mill, Lvea, Bovel, Battambang, Cambodia

The plant is in commissioning stage with a 600 kWe, Ankhur manufactured, fixed bed downdraft gasifier. The mill produces 4 ton/hr rice.

Two second hand Mitsubishi engines are used – 2x300 kWe (engine costs12000 US$/engine).

The problem of tar condensation and wastewater generation

The total price for the gasifier system is 160,000 US$ and 20% initial payment was done by the owner and the balance 80% was by a loan from SME renewables Cambodia (interest 1.08% per month)

Case study 12
Yin Pou Rice Mill, Kork Tunlap, Mongkul Borei, Banteay Mean cham, Cambodia

The plant uses an Ankhur fixed bed, downdraft, 200kWe gasifier for electricity generation using rice husk at the rice mill. However, at present, the plant runs at half the design capacity. Rice production rate of the mill is 1.5 ton/hr

A second hand Mitsubishi diesel engine is used in duel fuel mode.

The sawdust removed from the filters is recycled (three times) to the combustion chamber after drying. Filters are cleaned once a month. Ash removal water is recycled after settling in a pond (same for all visited plants)

Two persons were directly employed in the gasifier system operation (mainly 1 for feeding rice husk and the other for removing ash). However, the owner complained that the problems faced are mainly due to not following proper operational procedures.

Production cost is around 300 Riel/kWh and the grid electricity price cost 1100 Riel/kWh (Grid electricity from Thailand). The gasifier system cost is about 73,000 US$. The plant runs 24 hrs per day. The payback period is only 2 years.

Case study 13
Eap Sophat Ice Factory, Kralanh District Town, Siem Reap

A 150 kWe, Ankhur manufactured, fixed bed downdraft gasifier is used for electricity generation using rice husk. The plant buy rice husk. The electricity is mainly used in the ice making plant.

A series of gas cleaning equipments

Diesel used with producer gas is about 5-6 l/hr. Without producer gas diesel used = 30 l/hr. So, on an average, producer gas substitutes about 25 l/hr of diesel for producing 150 kWe. The price of diesel is = 0.77 US$/l.

Appendix III- Biomass gasification research and development institutes in Thailand

Biomass gasification research and development institutes in Thailand

	Institute	Contact details	Kind of research
1	Asian Institute of Technology	Energy Field of Study, Asian Institute of Technology, P. O. Box 4, Klong Luang, Pathumthani 12120, Thailand	Experimental study on the reduction of tar in the producer gas using multi-stage air supply. Development of gasifier stoves.
2	Chulalongkorn University	Department of Chemical Technology, Faculty of Science, Chulalongkorn University, Phayathai Rd., Pathumwan, Bangkok 10330, Thailand	Experiments on steam reforming, Nickel-Dolomite as a catalyst, experimental study on black liquor gasification in supercritical water
3	Kasetsart University	Department of Environmental Engineering/National Center of Excellence for Environmental and Hazardous Waste Management, Faculty of Engineering, Kasetsart University, Bangkok 10900	MSW gasification in down-draft gasifier
4	National Metal and Materials Technology Center (MTEC)		
5	National Science and Technology Development Agency (NSTDA)		
6	Suranaree University of Technology	School of Chemical Engineering, Suranaree University of Technology, Nakhon Ratchasima 30000,	Experiments and model development in charcoal gasification, experiments on fluidized bed steam gasification
7	Thammasat University	Environmental Technology Program, Sirindhorn International Institute of Technology, Thammasat University, Pathumthani 12121	Experimental study on gasification of kraft black liquor

(Sources: Chaiprasert and Vitidsant, 2009: Sricharoenchaikul, 2009: Ketcong, et. al., 2009: Chiemchaisri, et. al., 2010: Junpirom et. al., 2005: Weerachanchai, et. al., 2009: Sricharoenchaikul, et. al., 2003)

Appendix IV- Biomass gasification technology developers, manufacturers and suppliers around the world

1. Associated Engineering Works (AEW), India

Name	**Associated Engineering Works, (AEW)**	
Contact		
Address	Gamini Compound, Main Road, Tanuku – 534211, Andhra Pradesh, INDIA +phone (91)8819-222950 & 223410, Fax +(91) 8819-224801, Web: http://www.aewgasifiers.com/ Email: aewgamini@rediffmail.com, gasfromwood@gmail.com	
Technology developer / Supplier	Developer, manufacturer and supplier	
Type of gasifier	Downdraft with throat	
Applications	Woody Biomass Based Electrical Gasifiers	GE-100/GE-350/GE-600
	Woody Biomass Based Thermal Gasifiers	GT-500/GT-600/ GT-700/GT-1000
	Rice Husk Based Thermal Mode Gasifiers	GT-650H/GT-750H
	Multi-purpose gasifiers	GE-100-MP
	Gasifier Based Crematorium	GT-600-CR

a) Woody biomass based electrical gasifiers

Model	**GE-100**	**GE-350**	**GE-600**
Rated Electrical output in kVA(Suitable Genset size)	5	20	100
Wood Chip/ Biomass Consumption kg/Hr.	5	20	100
Wood Chips acceptable Range(Any dimension)	15mm-25mm	15mm-40mm	25mm-75mm
Moisture content acceptable range %	Upto 15%	Upto 15%	Upto 15%
Hopper holding capacity in kgs.(Approx.)	50	150	500
Auxiliary power	1 HP	2 HP	12 HP
Water Requirements (l/Min.)	50	150	300
Recirculation Water Tank capacity	--	--	25 m^3
Floor Space required	100 Sq. Ft.	250 Sq. Ft.	2000 Sq. Ft.

b) Woody biomass based thermal gasifier

Model	**GT-500**	**GT-600**	**GT-700**	**GT-1000**
Rated Thermal output in kcal/hr	150,000	250,000	500,000	1,500,000
Replacement of Furnace Oil	upto 15 l/hr	upto 25 l/hr	upto 50 l/hr	upto 150 l/hr
Wood Chip consumption (At max. capacity)	60 kg/hr	100 kg/hr	200 kg/hr	600 kg/hr
Wood Chip acceptable size (any dimension)	1" - 2"	1" – 3"	1" - 4"	2" -6"
Moisture content acceptable range%	Below 15%	Below 15%	Below 15%	Below 15%
Hopper holding capacity in kg	250	500	800	1500
Auxiliary power (approx.)	1 HP	4 HP	6 HP	12 HP
Floor space required	12' x 20'	15' x 30'	20' x 50'	40' x 80'

c) Rice husk based thermal mode gasifiers

Model	GT - 650 H	GT - 750 H
Rated Thermal output in kcal/hr	250,000	625,000
Rice Husk consumption in kg/hr (approx.)	200	500
Auxiliary power needed	10 HP	20 HP
Floor space required	15'x40'	20'x60'

- Rice husk can be fed in its natural form (no briquetting or pulverizing is needed).
- Economical running costs compared to diesel, kerosene, LPG burners.
- Continuously fed throatless gasifiers.
- Ash disposal in moist condition – avoiding fly ash problem.
- Small auxiliary power need.
- Flame temperature up to 900 ºC attainable.
- Industrial heating from locally available rice husk.

d) Multi-purpose Gasifiers

Model	GE - 100 MP
Engine Rating	10 HP
Gasifier Type	Downdraft/Batch feed
Mode	Shaft power for running gadgets
Wood Consumption(kg/hr)	5-6
Wood Chip Size(any dimension)	12-30 mm
Moisture content acceptable	Up to 20%
Hopper holding capacity	40 kg approx.
Average Diesel saving	70%

Gas Cooling method	Water Spray
Type of gas cleaning	Centrifugal tar separation
Auxiliary power	Through engine running
Floor space required	10' x 15'
Gadgets & Attachments	
Paddy De-Husker Milling Capacity	400 kg/hr
Flour Mill Rating	200 kg/hr
Alternator Output	5 kVA
Water Pump size	100 mm x 100 mm (18 l/Sec Discharge)

- 10 HP motive power for running various gadgets.
- Gasifier based dual fuel diesel engine.
- Energisation of tiny and remote villages with motive power.
- Downdraft gasifier with batch feeding.
- Accepts all wood wastes in addition to coconut shells, corn cobs etc.,
- Self employment for village youth.

e) Gasifier Based Crematorium

Model	Cremation Facility
Time taken for cremation	90 Minutes (approx.)
Wood consumption	100 – 125 kg/hr
Power required for blower	1 HP
Rated output of gasifier	2,50,000 kcal/hr
Wood chips size accepted	15 to 75 mm (any size)
Acceptable moisture content of wood chips	Below 15%
Hopper holding capacity of gasifier	500 kg (approx.)
Loading of chips	Intermittent /manual
Approximate floor space required	15’ x 60’

- Wood is the fuel and the system runs on 1 HP blower thereby requiring minimum electric power. In contrast electrical cremations need huge power of the order of 100 kW.
- Economical in operation (around 50% cheaper compared to open wood burning).
- Operation is completed very fast (operation completed in 80-90 Minutes compared to 3-4 hours time requirement by open wood burning).
- Simple and robust design for easy operation and maintenance (unskilled persons can operate the system).
- Environment friendly

2. Ankhur Scientific Energy Technologies Pvt. Ltd. (ASCENT), India

Name	**Ankhur Scientific Energy Technologies Pvt. Ltd. (ASCENT)**	
Contact	Dr. B C Jain	
Address	Ankhur near Old Sama, Jakat Naka, Baroda 390 008, INDIA Ph- 0265-2793098/ 2794021 Fax : 2794042 Website:www.ankurscientific.com, Email: info@ankurscientific.com	
Technology developer / Supplier	Developer, manufacturer and supplier	
Type of gasifier	Downdraft with closed top	
Product range and models (All these series are available for thermal and electrical ~~A~~applications)	WBG series	Uses woody biomass, coconut shells
	FBG series	Uses powdery biomass such as rice husk
	Combo series	Uses both powdery and woody biomass

3. Cosmo Powertech Pvt. Ltd., India

Name	Cosmo Powertech Pvt. Ltd.	
Contact	Mr. B V Ravi Kumar	
Address	Devpuri, Near Jain Public School, Dhamtari Road, Raipur 492015, India Ph- 0771-4011262, Fax 91-771-4013016 Web: http://www.cosmogasifiers.com/aboutus.html Email : cosmo_powertech@yahoo.co.in	
Technology developer / Supplier	Developer, manufacturer and supplier	
Type of gasifier	• Updraft • Downdraft	
Product range and models (mainly for thermal ~~A~~applications)	Downdraft	Cosmo downdraft wood gasifiers can operate on wood like biomass materials and biomass briquettes with a minimum bulk density of 250 kg/m3 and ash content of less than 5%.
	Updraft	Fuel flexibility is the main feature of Cosmo Updraft Multifuel Gasifiers. These gasifiers can operate on either coal or biomass and fuel switching does not require any changes in the reactor.

Downdraft

Capacity Range	120-2400 kWth output (Equivalent to 10-200 liters /hour oil substitution)
Fuel	Wood chips, biomass briquettes, wood like agro residues with ash content up to 5%
Efficiency	70-75%
Gas Calorific Value	1000-1200 kcal/Nm^3 (4.2-5.0 MJ/Nm^3)

Updraft

Capacity Range	600-12000 kWth output (Equivalent to 50-1000 l/hr oil substitution)
Fuel	Biomass or coal with ash content up to 28%
Efficiency	75-85%
Gas Calorific value	1100-1300 kcal/Nm^3 (4.6-5.4 MJ/Nm^3)

4. Grain Processing Industries (India) Pvt. Ltd. (GPI)

Name	**Grain Processing Industries (India) Pvt. Ltd. (GPI)**
Contact	Mr. N. D. Mukherjee
Address	BH 114, Salt Lake, Kolkata-700091, India, Telefax : +91 33 23210809 /, +91 33 23580114 Web: http://www.gpenergy.net/about_us.html Email: grainpro@cal3.vsnl.net.in
Technology developer / Supplier	Developer, manufacturer and supplier
Type of gasifier	Updraft gasifier with provision to inject steam
Unique features	10kW to 1 MW, all updraft gasifiers with complete set of biomass feeding mechanism, cleaning system, etc.
	Beside rice husk, the same plant may also run with wood blocks, saw dust, wood bark, sun flower seed husk, ground nut shell, coconut shell, corn cob etc. The same plant can even accept coal as feedstock, with little modification.
	Unique Gas Cleaning System: gas cleaning and cooling system for power generation purpose, is done in ten stages to ensure that tar and particulate concentration in gas does not exceed 10 mg / Nm^3
	GP Gasifier plant is designed for continuous operation of 24 hours a day and at least up to 300 days at a stretch, after which a brief shut down of 15 days is recommended for annual maintenance.

5. Radhe Renewable Energy Development Pvt. Ltd. (RREDL), India

Name	Radhe Renewable Energy Development Pvt. Ltd. (RREDL)
Contact	Mr. B V Ravi Kumar
Address	Plot No: 2621 / 2622, Road No. - D/2, Gate No. 1, Lodhika G.I.D.C. Metoda, Kalavad Road, Rajkot. (Gujarat), INDIA. Ph: +91-2827-287888 / 287889 Fax: +91-2827-287887 Web: http://www.radhegroup.com/# Email : info@radhegroup.com
Technology developer / Supplier	Developer, manufacturer and supplier
Type of gasifier	Updraft gasifiers, mainly for thermal use
Product range and models (mainly for thermal Applications)	

Models	Thermal Output Capacity in kcal/hr.	Liquid Fuel Replace Capacity (l/Day)
RREDA-900	774000	1080 - 1800
RREDA-1500	1290000	1800 - 3000
RREDA-2000	1720000	2400 - 4200
RREDA-2500	2150000	3000 - 5000
RREDA-3000	2580000	3600 - 6000
RREDA-4000	3440000	4000 - 8000
RREDA-5000	4300000	5000 - 10000
RREDA-6000	5160000	7000 - 12000
RREDA-7000	6200000	10000 - 14000
RREDA-8000	6880000	12000 - 15500

6. Southern Carbons (P) Ltd. (SCL), India

Name	Southern Carbons (P) Ltd. (SCL)
Contact	Mr. K. J. Haris (Managing Director)
Address	Office: Palackal Buildings, Premier Junction, Kalamassery, Cochin. Phone: 0091-484-2540158 Factory: VI/590B, Development Area, Edayar, Bhavanipuram, Pincode: 683 502 Phone: 0091-484-2532685, 0091-484-2543739 Web: http://www.southerncarbons.org/ Email : southcarb@gmail.com
Technology developer / Supplier	Developer, manufacturer and supplier
Type of gasifier	Up draught and down draught gasifiers
Product range and models (mainly for thermal applications)	

7. The Energy & Research Institute, TERI, India

Name	**The Energy & Research Institute, TERI**
Contact	Mr. Sunil Dhingra, Area Convenor, Biomass Energy Technology Applications, dhingras@teri.res.in Mr Amit Kumar, Director, Energy-Environment Technology Division, akumar@teri.res.in
Address	Darbari Seth Block, IHC Complex, Lodhi Road, New Delhi - 110 003, INDIA Tel. (+91 11) 2468 2100 and 41504900 Fax (+91 11) 2468 2144 and 2468 2145 Web: http://www.teriin.org/ Email : mailbox@teri.res.in
Technology developer / Supplier	R&D, technology developer and supplier. Does not manufacture the systems itself.
Type of gasifier	Closed top, downdraft throat-less gasifier for thermal and electrical applications.
Product range	• Development of biomass gasifiers for thermal applications for small and medium scale industries. • Over 440 TERI gasifiers - with a cumulative capacity of about 40MW - are operational in the silk reeling, textile dyeing, cardamom curing, natural rubber processing, chemical extraction, metal smelting and mineral processing sectors. These systems have demonstrated fuel savings to the order of 50% to 60%, along with significant increase in productivity at the enterprise level. • TERI's product range for electricity generation includes (i) 10 kW package for rural electrification, based on charcoal and biomass, both dual fuel as well as 100% producer gas modes, (ii) 100 kW package to generate electricity in dual fuel/100% producer gas mode, and (iii) 150 kW capacities on 100% producer gas engine. Six village-based power plants have been established using this technology.

8. Advanced Bio-residues Energy Technologies Society, ABETS, India

Name	**Advanced Bio-residues Energy Technologies Society, ABETS**
Contact	Prof. P. J. Paul
Address	**Advanced Bioresidue Energy Technologies Society (ABETS)** Combustion Gasification & Propulsion Laboratory (CGPL) Department of Aerospace Engineering, Indian Institute of Science (IISc) Bangalore - 560 012, Karnataka, India Phone: +91-80-23600536 ; +91-80-22932338; Fax: +91-80-23601692 Web: http://cgpl.iisc.ernet.in/site/ Email : mailbox@teri.res.in
Technology developer / Supplier	One of the Action Research Centres set up by the MNRE to undertake research in developing and upscaling woody and non-woody biomass gasifiers.
Type of gasifier	Open top re-burn down draft gasifier

Product highlights and range	• Open top, twin air entry, re-burn gasifier • Longer residence time in the reduction zone at higher temperatures results in the cracking of higher molecular weight products, leading to a gas that is very clean and low on tar • Gasification efficiency is in the range of 75-85% • The patented clean system is capable of reducing the particulate matter from 1000 mg/Nm^3 to just 5 mg/Nm^3 • The gas can be used for thermal and electrical applications including 100% Gas engines. **Range:** From 5 kWe to 1.2 MWe in electrical range and equivalent range in thermal applications **Application:** • Thermal- dryers/ kilns/ furnaces/ boilers/ hot air generators • Electricity generation- stand-alone/ grid-interactive/ captive power

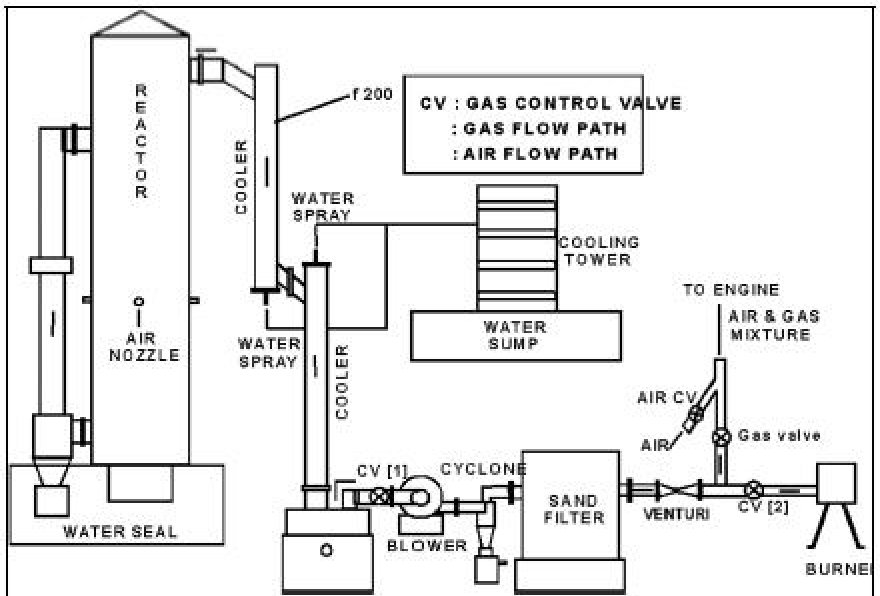


Fig. 2 SCHEMATIC OF WOOD GASIFIER FOR POWER GENERATION APPLICATION

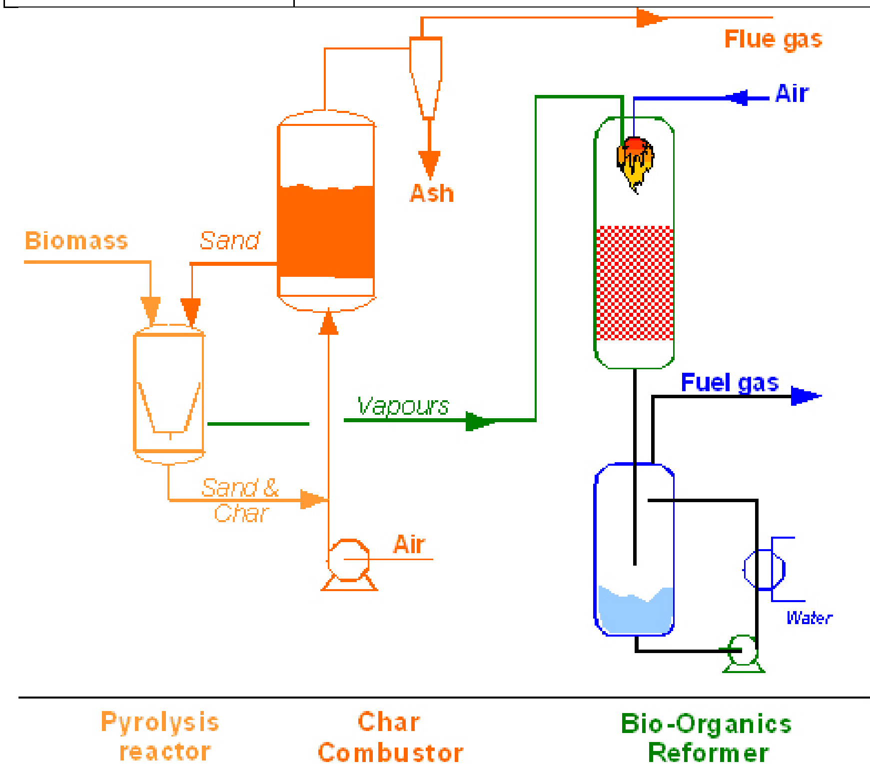
9. Rishipooja Energy & Engineering Company, India

Name	Rishipooja Energy & Engineering Company, India
Contact	
Address	M.G. College Road, Gorakhpur, Uttar Pradesh, India Phone: +91-551-2202797, +91-551-3293147 Web: http://www.urjagen.co.in/ Email : urjagen@gmail.com, urjagen@hotmail.com
Technology developer / Supplier	Developer / manufacturer / supplier
Type of gasifier	Both updraft and downdraft for thermal and electrical

Product highlights and range	• Rice husk based downdraft gasifier – 40kWe to 500kWe (both for power generation and thermal application) • Woody biomass based downdraft gasifier – 10kWe to 500kWe (both for power generation and thermal application) • Woody biomass based updraft gasifier – 10kW to 500kW (for thermal application) • Biomass gasifier for 100 % gas engine from 5 KW to 250 KW single system

10. BTG biomass technology group BV, Netherlands

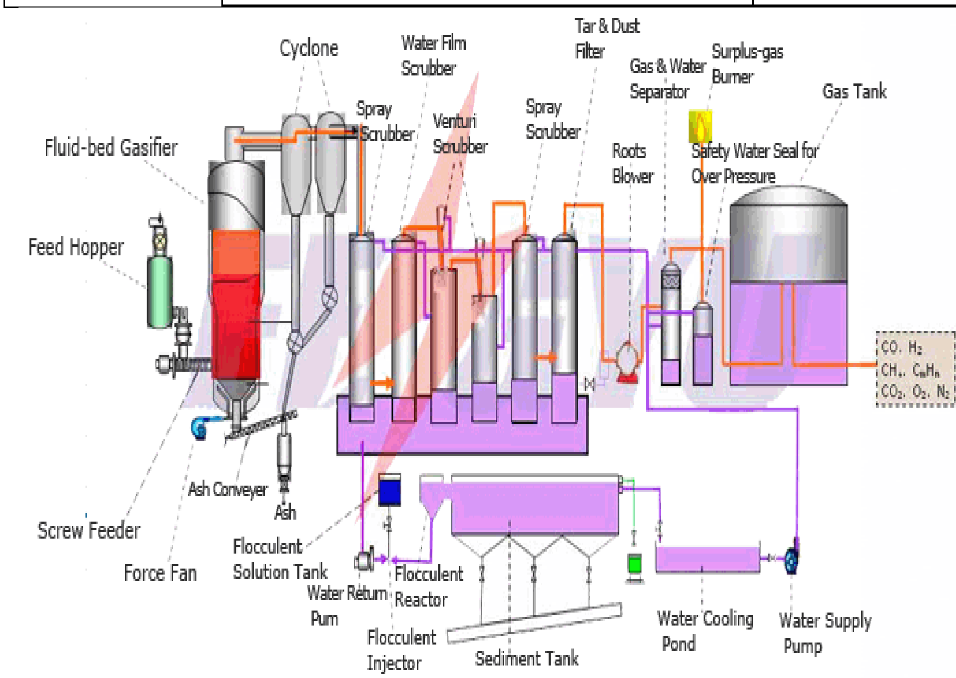
Name	**BTG biomass technology group BV, Netherlands**
Contact	
Address	P.O.Box 217, 7500 AE Enschede, The Netherlands Tel. +31-53-4861186 Fax +31-53-4861180 Web: http://www.btgworld.com Email : office@btgworld.com
Technology developer / Supplier	Research, development, implementation and evaluation of small to medium scale fixed bed biomass gasifiers.
Type of gasifier	Two-stage gasification
Product highlights and range	• Biomass is "vaporized" at low temperatures, and in the second stage the vapours are reformed using catalysts. • The charcoal produced in the pyrolysis stage is used to preheat the biomass and to evaporate the water. Charcoal is not used in the high temperature reforming stage.



11. Chongqing Fengyu Electric Equipment Co. Ltd., China

Name	Chongqing Fengyu Electric Equipment Co. Ltd.
Contact	
Address	Xinqiao Industrial Park, Shapingba District, Chongqing, China Tel: 86-23-6520 3951 Fax: 86-23-6520 3951 Web: http://www.fengyugroup.com/product_93_3432.html Email : fengyu@fengyugroup.com
Technology developer / Supplier	Developer / manufacturer / supplier
Type of gasifier	
Product highlights and series Specifications	FENGYU's fluid-bed biomass gasifier (patented product of Fengyu Group)

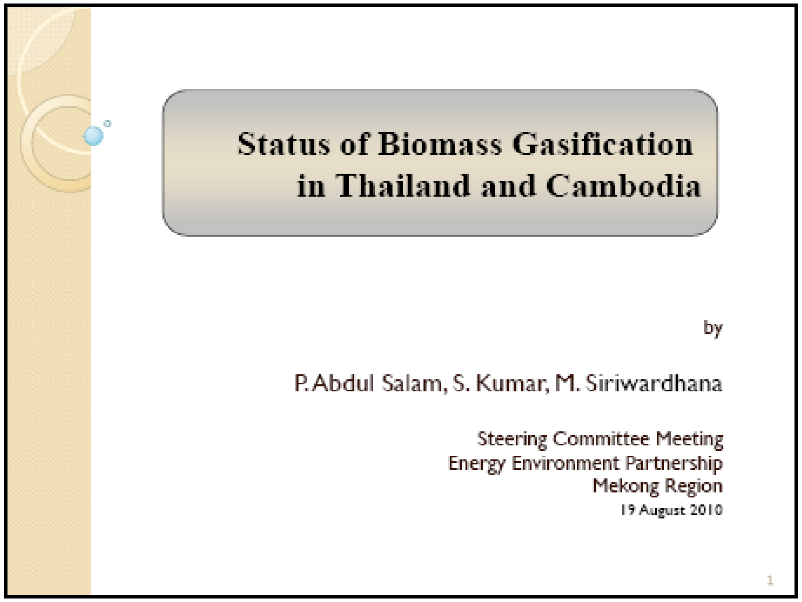
Parameter/TYPE	LHC-200	LHC-400	LHC-600	LHC-800	LHC-1000	LHC1-200
Generated output power (kW)	200	400	600	800	1000	1200
Production volume of biomass gas(Nm^3/hr)	800	1500	2250	3000	3650	4500
Gas temperature of gasification	700-800	700-800	700-800	700-800	700-800	700-800
Gas temperature of the outlet after cooling and cleaning(ºC)	<45	<45	<45	<45	<45	<45
Consumption of biomass fuel(ton/hr)	0.3-0.36	0.6-0.72	0.9-1.08	1.2-1.44	1.5-1.8	1.8-2.16
Volume of circulating water flow(m^3/hr)	6-8	12-15	18-23	24-30	30-37	36-45
Gross weight of gasification furnace (ton)	21.8	26.7	30.8	34.8	38.7	42.5
Ash removing manner	Wet or dry type (screw conveyer collecting &discharger)					
Device of gas cooling& cleaning system	cyclone separator+ spray scrubber+ venturi scrubber+ spray scrubber+ spray filter roots blower alkali water washer+ gas water separator					

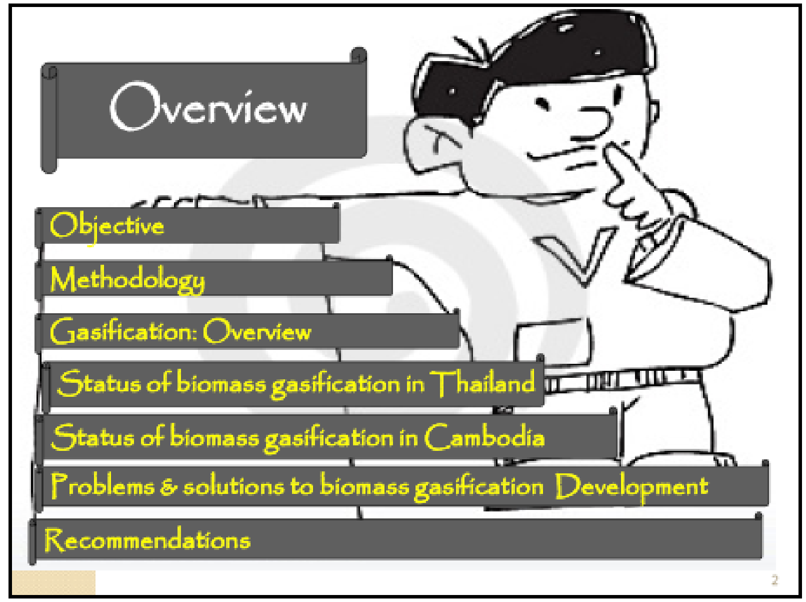


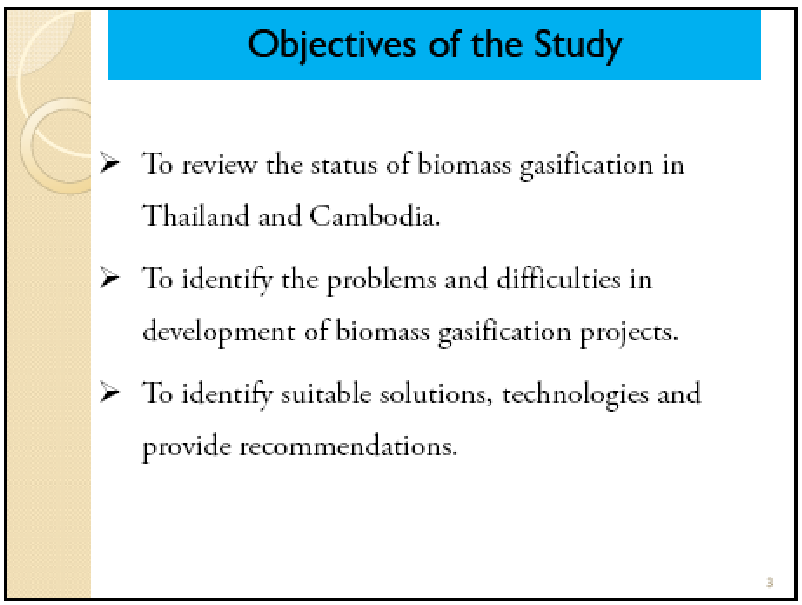
12. Primenergy, L.L.C, USA

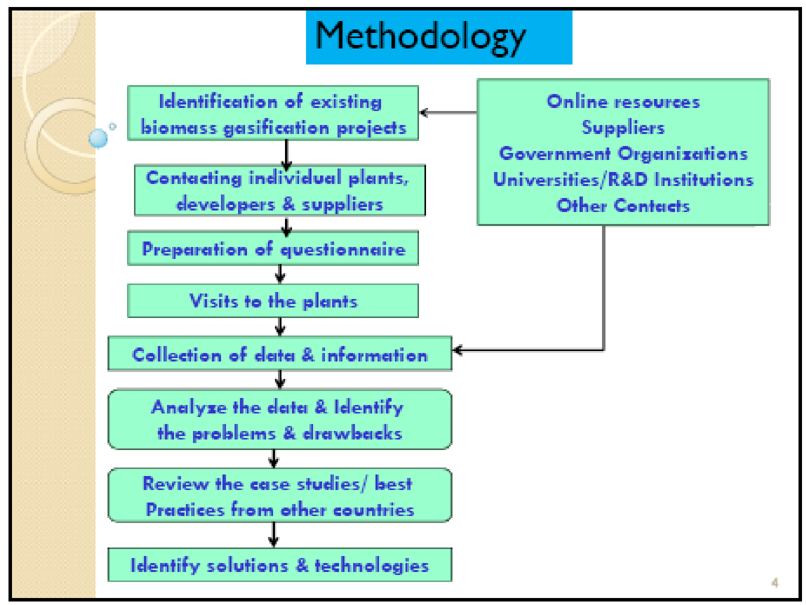
Name	**Primenergy, L.L.C, USA**
Contact	
Address	P O Box 581742 Tulsa Oklahoma 74158, USA Phone: (918) 835-1011 Fax: (918) 835-1058 Web: http://www.primenergy.com/Aboutus.htm Email :
Technology developer / Supplier	Developer / manufacturer / supplier
Type of gasifier	air blown, updraft
Product highlights and range	

Appendix V- Presentation, done at the EEP Steering Committee Meeting, August 2010









What is Gasification?

- Gasification converts a solid fuel to a combustible gas by supplying a restricted amount of oxygen, either pure or from air.
- Gasification of solid fuels such as biomass, peat and coal is a technology that has been applied since 1812 with the foundation of London Gas, Light, and Coke Company.
- The most first important gaseous fuel used (for illumination) was the so-called town gas.
- Fixed bed gasification technology is more than a century old.

What is Gasification?

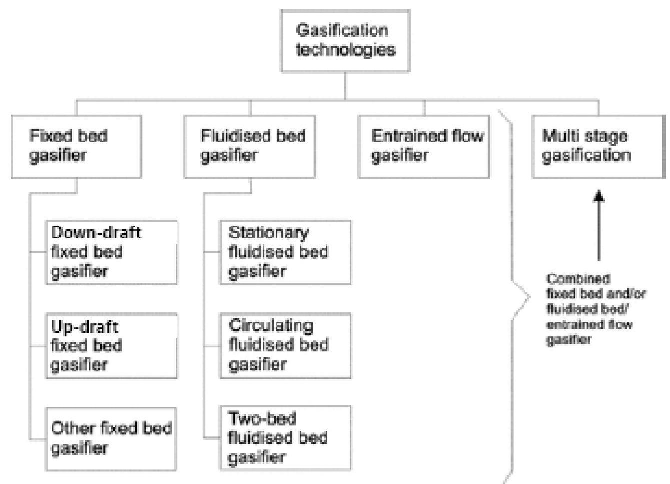
Gasifier-operated Bus, Vietnam

Corn cob gasifier, Thailand

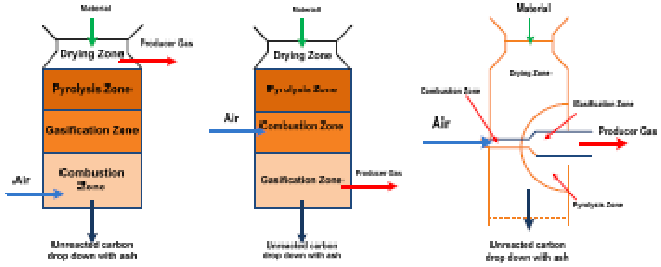
What is Gasification?

- Interest in gasification is growing again in several countries after the setback in 1970s and 1980s.
- There is great interest in the biomass gasification because of:
  - A gaseous fuel is more versatile than a solid fuel. It can be used in boilers, process heaters, turbines, engines and fuel cell.
  - Wide range of biomass feedstocks can be used without major changes in the basic process.
  - It can be used to process waste fuels, providing safe removal of biohazards and entrainment of heavy metals.

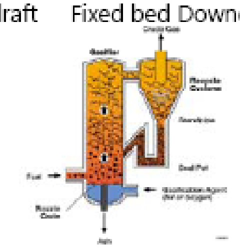
Gasification Technologies



Types of Gasifiers



Fixed Bed Updraft   Fixed bed Downdraft   Cross draft



Fluidized bed

Relative advantages and disadvantages

Gasifier	Advantages	Disadvantages
Updraft fixed bed	Mature for small-scale heat applications Can handle high moisture No carbon in ash	Feed size limits High tar yields Scale limitations Low heating value gas Slagging potential
Downdraft fixed bed	Small-scale applications Low particulates Low tar	Feed size limits Scale limitations Low heating value gas Moisture-sensitive
Bubbling fluid bed	Large-scale applications Feed characteristics Direct/indirect heating Can produce higher heating value gas	Medium tar yield Higher particle loading
Circulating fluid bed	Large-scale applications Feed characteristics Can produce higher heating value gas	Medium tar yield Higher particle loading
Entrained flow fluid bed	Can be scaled Potential for low tar Potential for low methane Can produce higher heating value gas	Large amount of carrier gas Higher particle loading Particle size limits

Status of biomass gasification in Thailand

25 Plants Identified

Electricity Generation – 18 Plants (11 downdraft)	Thermal Applications – 7 Plants (1 BFB, 2 downdraft, 2 updraft)

No of plants visited : 11 (Electricity -8, Thermal – 3)

Status of biomass gasification in Thailand

General Observations:

- Most of the Gasifiers installed are mainly from Asian countries, such as India (Ankhur), Japan (Satake), China (Fengyu electric, Time Pro) and also from in house technology and manufacturing.
- About 80% of the gasifiers used for thermal applications and 20% for electricity generation.
- Rice husk and wood chip are the two major fuel types and corn cob, waste plastic, charcoal and old tyre rubber are also in use.
- All the R&D and demonstration projects are run either by government or universities.
- Most of the commercially developed demonstration plants for power generation have also been failed after few months of operation.

Status of biomass gasification in Thailand

Electricity Generation Plants

Site/ plant	Capacity /kWe	Reactor type	Biomass fuel
Thermal Tech Ltd., Samutsakorn	200	Downdraft	Waste plastic
Rice Mill, Lam Luk Ka	80	Downdraft (3 stage)	Rice husk
Supreme Renewable Chiang Rai	150	Downdraft	Corn cob
Tha-Khlong Agricultural Cooperation, Lopburi	400	Downdraft (3 stage)	Rice husk
Ubon Rachathani University	80	Downdraft (Double throat)	Firewood/ corn cob
Rajamangala University of Technology Thanyaburi, Pathumthani	30	Downdraft	Charcoal
Suranaree University of Technology, Nakhon ratchsima	100	Downdraft	Any
Rice Mill, Chai Nat			Rice husk
Prince of Songkla University, Songkla	30		Woodchip
Naresuan University,	10	Downdraft	woodchip
Rice Mill Ban Non Muay, Surin	20	Downdraft (Two stage)	Rice husk
Prachuap Khiri Khan Province	100	Downdraft	Woodchip/ coconut shells
A+ Power Co., Ltd., Nhongmoung, Lopburi (under construction)	1,500	Downdraft	Woodchip

Status of biomass gasification in Thailand

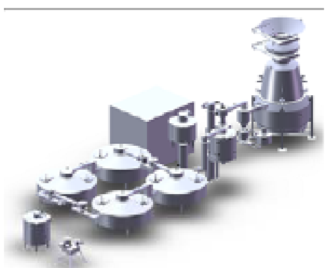
Electricity Generation:

- All the electricity generating plants use fixed bed downdraft gasifiers.
- Existing electricity generation plants are in the range of 20- 400 kW in size and a 1.5 MW plant is under construction phase.
- Electricity generated is mainly fed to the grid or use in rice mills.
- Five modified diesel engines, one gasoline engine and three gas engines are used in visited plants for power generation.

Status of biomass gasification in Thailand

Electricity Generation:

- **Supreme Renewable Energy Co. Ltd. is the only identified plant with more than 2 years of operational practices.**



Supreme gas cleaning system (Ankhur – India)

- **Common Gas cleaning systems consists;**

  Wet scrubber -> Moisture removal -> Rice husk course filter -> (1-3) Sawdust Passive filters -> Bag filter

Status of biomass gasification in Thailand

Electricity Generation:

Use of Plastic Waste

- **None of the failed commercial plants measure the moisture content of the fuel, the calorific value, the composition or the flow rate of producer gas.**
- **Cyclone, wet scrubbers and the heat exchangers are the major gas cleaning equipments used in the plants.**

Status of biomass gasification in Thailand

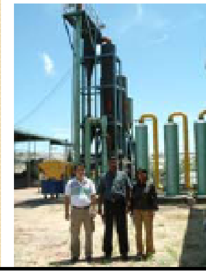
Thermal Applications:

Site/ plant	Capacity/ kWth	Reactor type	Biomass fuel
Agricultural Industry Kahokoh, Petchabun	320	Imbert Downdraft	Corn cob
Thai Ceramic Company, Saraburi	4 x 5,000	Bubbling fluidized bed	Rice husk
Ruang Silp 2 factory, Ratchaburi	26	Downdraft	Woodchip
Sattahip fish processing, Chon Buri	300	Updraft	Woodchip
Lime and Minerals, SaraBuri		Updraft	Old tyre rubber

Status of biomass gasification in Thailand

Thermal Applications:

- Gasifiers for thermal application vary in its technology type from bubbling fluidized bed, downdraft to updraft.
- Plants sizes varies from 20kW to 5 MW in size.
- Thermal energy is mainly used for industrial heating such as in lime kilns, ceramics and drying agricultural products.

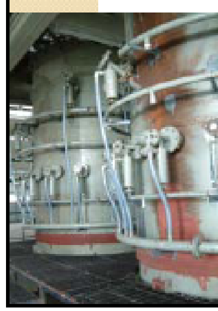


Problems & drawbacks of biomass gasification in Thailand

- Lack of technology development within the country.
- Most of the gasifiers are copied by people who have no knowledge on gasification process.
- Some demonstration plants have been scaled up from university pilot plants and they have been failed after scaling up.
- Modified diesel engines are mainly used as dual fuel engines. These engine modifications are mostly done without any technical experts or knowhow.

Problems & drawbacks of biomass gasification in Thailand

- Gas cleaning and tar cracking or removal remain the major problem in gasification and it has been the major reason for the lack of confidence of biomass gasification projects .
- The simple scrubbing approach has failed repeatedly and it creates a serious environmental problem due to wastewater.



New projects start using secondary air in combustion: from A+ project, which is under construction

Wearing in engine pistons noticed

Problems & drawbacks of biomass gasification in Thailand

- Wastewater problem due to tar and ash removal
- The quantity and quality of the ash and disposal of them
- Slag is a main problem in the case of plastic is used as a feedstock.

Slag formed at plant with plastic fuel

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Problems & drawbacks of biomass gasification in Thailand

- Some plants have been shut down due to inability to reach the gas flow rate, heating value and composition to run the engine.
- There are evidences that some biomass gasification plants have shifted back to lignite mainly due to the higher prices and inadequate supply of biomass fuels such as rice husk.
- Power generation from biomass combustion is more established and popular among rice mills and other agro industries in Thailand. The competition from such technologies cause the price rise of fuel.

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Problems & drawbacks of biomass gasification in Thailand

- Most plants have commissioned either to get the benefit of higher adder tariffs from electricity sale or to reduce the energy cost in their own plant.
- Therefore, government legislations, and energy costs have a direct impact.
- Lack of skill in operation of imported plants is also a major hurdle in fast penetration of biomass gasification in Thailand.
- Some plants are forced to close down due to unavailability of skilled operators.

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Improvements & suggestions to overcome the problems in Thailand

- There is a need for motivated and skilled labour at all levels. Technical advisory service or consultancy service should be available.
- Demonstration plants need governmental support not only in R&D and first installations, but also for the complete lifetime.
- There is a clear lack of involvement of industrial sector in R&D and demonstration activities.
- This kind of industry-research involvement would lead to proper scaling up of pilot plants.
- There is a strong need for clear regulation on permitting procedures, emission standards, and other health & safety aspects.
- Gasifier with proper tar removal needs to introduce.

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Status of biomass gasification in Cambodia

- Application of biomass gasification is well established in Cambodia compared to Thailand.
- There are about 90 biomass gasifiers installed in Cambodia, out of which, about 40 gasifiers have been installed by SME Renewables Cambodia (within the last 5 years)
- Our study identified 53 gasification plants
- 7 plants were visited (4 rice mills, 2 ice factories and a rural electricity enterprise)

Status of biomass gasification in Cambodia

Details of plant visited:

Site/ plant	Capacity/ kWe	Reactor type	Biomass fuel
Te Keang Rice Mill, Kampong Chhnang	200	Downdraft	Rice husk
Bat Doeng Electricity Enterprise, Kampong Speu	200	Downdraft	Rice husk/ wood chip
Yam Loung Rice Mill, Battambang	300	Downdraft	Rice husk
Yin Pou Rice Mill, Banteay Mean Cham	200	Downdraft	Rice husk
Teng Sarith Ice Factory, Phnom Penh	200	Downdraft	Rice husk
Ley Chhinh Rice Mill, Battambang	600	Downdraft	Rice husk
Eap Sophat Ice Factory, Siem Reap	150	Downdraft	Rice husk

Status of biomass gasification in Cambodia

- Almost all installed gasifiers are for electrical usage and use rice husk as fuel.
- Most of the plants have been imported from Ankhur India and the owners are very happy with their plants.
- The size of the plants varies from 100 – 600 kWe. Most of the plants are around 200 kWe.
- Max installed capacity 600 KWe (2 x 300 kWe).
- Almost all the gasifiers use modified diesel engine in dual fuel mode (i.e. diesel and producer gas). Producer gas replace about 75% of the diesel usage.
- Approximately 6 kg of rice husk replaces about 1 litre of diesel. Diesel price is about 0.9 US$/liter.

Status of biomass gasification in Cambodia

- The major types of SMEs, which uses biomass gasification are rice mills, ice plants, rural electricity enterprises, brick factories, garment factories, and hotels.
- There are more than 500 rice mills in Cambodia with capacity of more than one ton per hour.
- It is estimated that there are 100-200 ice plants, brick factories, REEs, rural garment factories, hotels and other SMEs that will benefit from gasifier systems.

EAP Sophat Ice Factory, Kralanh District Town, Siem Reap

Yin Pou Rice Mill, Kork Tunlap, Batambang

Status of biomass gasification in Cambodia

- Fuel varieties found
  - Rice husks
  - Corn cobs
  - Wood chips
  - Coconut shells
  - Cane sugar residues (bagasse)
  - Peanut shells

- The cost of biomass
  - Rice mills- No cost
  - REEs, Ice plants and others-
  - Current rice husk price= $0- $5 per ton

Problems & drawbacks of biomass gasification in Cambodia

- Wastewater treatment and ash removal remains the major problems.
- Lack of trained personal for plant operation is a major problem.
- While all of the imported plants working properly many of the plants copied have operational problems.

Improvements & suggestions to overcome the problems in Cambodia

- **Use of Down draft gasifier with duel fuel mode diesel engine is very well established.**
- **Use of large scale (2 MW) fluidized bed gasifiers with pure gas engine should be explored.**
- **Capacity building on technical and business development activities needed.**
- **There is a strong need for clear regulation on permitting procedures, emission standards, and other health & safety aspects.**

Recommendations for EEP-Mekong

General

- Capacity building at all level on technical services and financial and business management. Ex:Special trainings for plant operators.
- Development of technology fact sheets, guidebooks, and standards on emissions and others
- Establishment of gasifier fabrication unit(s) and technological service unit (one stop service centre) in the region in partnership with private sector investors.

Recommendations for EEP-Mekong

Cambodia

- Estimation of the availability and costs of biomass for energy production
- Feasibility studies on the optimal technology and competitiveness of biomass based energy generation considering the long term effects on the availability of fuel and other issues
- As of now biomass fuel is easily and cheaply available, and gasification technology is well established and no other competitive technologies are established, Cambodia can go for the latest, larger scale gasification installations (specially using rice husk).

Recommendations for EEP-Mekong

Thailand

- Considering that the biomass combustion for heat and power is well established and supply of biomass fuel all round the year is a problem already, establishment of gasification plants using wastes (MSW) and agri residues (except rice husk) are recommended.

Thank You !