Biomass Energy

In the past few years, there have been significant improvements in renewable energy technologies along with declines in cost. The growing concern for the environment and sustainable development, have led to worldwide interest in renewable energies and bio-energy in particular. Biomass can be converted into modern energy forms such as liquid and gaseous fuels, electricity, and process heat to provide energy services needed by rural and urban populations and also by industry. This paper explains the different ways of extracting energy from biomass and a comparison is made among them. This paper also explains about the potentiality of biomass energy in India, analyses current situation compares bio-energy and other options for promoting development, brings out the advantages over the other renewables putting forth the drawbacks to be overcome to make it still more successful. This paper analyses current situation compares bio-energy and other options for promoting development, explore the potential for bio-energy.

1. Introduction

In past 10 years or so, considerable practical experience has accumulated in India as well as in other developing and industrialized countries, on biomass energy production and conversion. India is pioneer among developing countries, with significant indigenous efforts in promoting renewable energy technologies. The importance of bio-energy as a modern fuel has been recognized. India has about 70,000 villages yet to be connected to the electricity grid. The supply of grid power to rural areas is characterized by

(a) Low loads
(b) Power shortages
(c) Low reliability
(d) Low and fluctuating voltages
(e) High transmission and distribution costs and power losses

Decentralized power generation based on renewables is an attractive option to meet the energy needs. The availability of biomass such as wood, cow-dung, leaf litter in rural areas is more. Hence a choice of biomass energy especially in rural areas is more reasonable but at the same time the technology is being developed to meet the large-scale requirements using biomass.

Biomass energy has played a key role in the time of Second World War when there was a fuel deficiency. Many vehicles, tractors and trucks used wood gasifies, which generate producer’s gas, running an internal combustion Engine. One of the major advantages of biomass energy is that it can be used in different forms. For e.g., Gas generated from the biomass can be directly used for cooking or it can be used for running an internal combustion Engine for developing stationary shaft power or otherwise coupled to generator for generating electric power.

The subsequent sections explain about the different ways of extracting energy from biomass, explaining about technological and economic aspects followed by a case study. The issue of land availability for biomass (wood) production is also discussed.

2. Motivation

There are several renewable and non-renewable energy options for power generation at the decentralized level. It is necessary to understand why biomass-based energy options should receive priority over other options and to discuss the advantages to local and global communities as well as the environment.

Biomass is renewable fuel used in nearly every corner of the developing countries as a source of heat, particularly in the domestic sector. Biomass energy includes energy from all plant matter (tree, shrub, and crop) and animal dung. Biomass, unlike other renewables, is a versatile source of energy, which can be converted to modern forms such as liquid and gaseous fuels, electricity, and process heat. For example, small-scale (5-100 KW), medium-scale (1-10 MW), and large scale (about 50 MW).

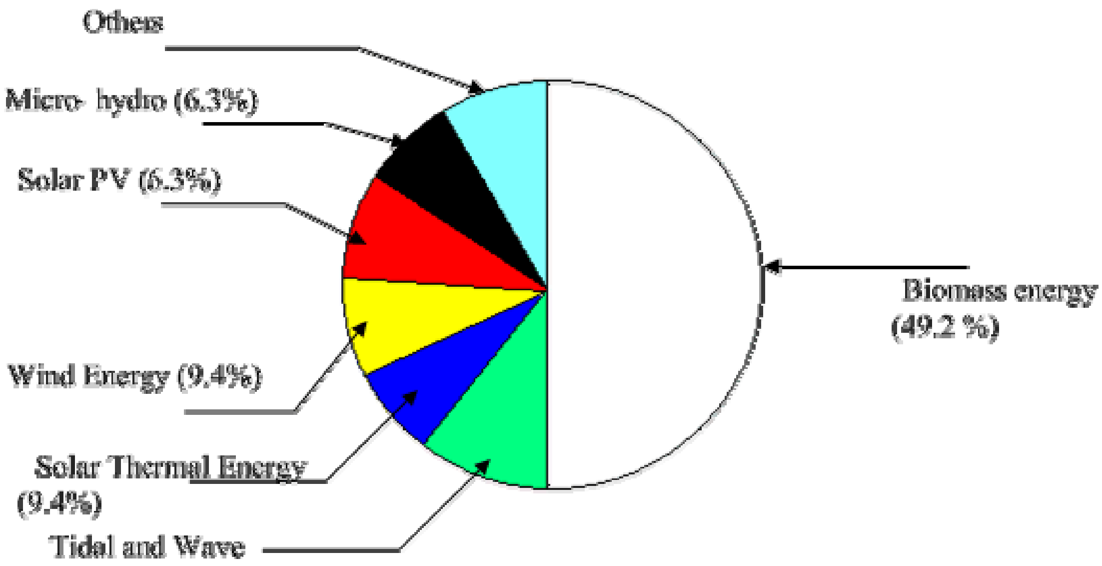

Fig 1: Expenditure on different renewable energy programmes for 1992-1997 indicating the share of bioenergy technologies for renewables in India

It can be seen from the figure the importance of biomass energy in Indian context.

Advantages of biomass gasify energy over other renewable energy options:

1. Suitable in most locations

2. Varying capacity can be installed; any capacity can be operated, even at lower loads; no seasonality.
3. Need for storage of energy is not required.

Advantages and drawbacks of biogas energy over other renewable energy options:

1. It can be used directly for cooking, or heating water from the abundantly available dung and dried plant leaves in rural areas.
2. Capacity determined by availability of dung. Not suitable for varying loads.
3. Not feasible to locate at all the locations.

3. Different Ways of extracting energy from biomass

The different methods of biomass extraction can be broadly be classified as:

1. Anaerobic Digestion
2. Gasification
3. Liquefaction

(a) Solid fuel combustion

The simplest and most common way of extracting energy from biomass is by direct combustion of solid matter. Majority of the developing countries especially in rural areas obtain the majority of their energy needs from the burning of wood, animal dung and other biomass. But burning can be inefficient. An open fireplace may let large amounts of heat escape, while a significant proportion of the fuel may not even get burnt.

(b) Gasification

Gasification is a process that exposes a solid fuel to high temperatures and limited oxygen, to produce a gaseous fuel. This is a mix of gases such as carbon monoxide, carbon dioxide, nitrogen, hydrogen and methane.

Gasification has several advantages over burning solid fuel. One is convenience – one of the resultant gases, methane, can be treated in a similar way as natural gas, and used for the same purposes.

Another advantage of gasification is that it produces a fuel that has had many impurities removed and will therefore cause fewer pollution problems when burnt. And, under suitable circumstances, it can produce synthesis gas, a mixture of carbon monoxide and hydrogen. This can be used to make almost any hydrocarbon (e.g., methane and methanol), which can then be substituted for fossil fuels. But hydrogen itself is a potential fuel of the future.

(c) Paralysis

Paralysis is an old technology with a new lease of life. In its simplest form it involves heating the biomass to drive off the volatile matter, leaving behind the black residue we know as charcoal. This has double the energy density of the original material. This means that charcoal, which is half the weight of the original biomass, contains the same amount of energy – making the fuel more transportable. The charcoal also burns at a much higher temperature than the original biomass, making it more useful for manufacturing processes. More sophisticated Paralysis techniques have been developed recently to collect the volatiles that are otherwise lost to the system. The collected volatiles produce a gas rich in hydrogen (a potential fuel) and carbon monoxide. These compounds, if desired, can be synthesized into methane, methanol and other hydrocarbons. 'Flash' Paralysis can be used to produce bio-crude – a combustible fuel.

(d) Digestion

Biomass digestion works by the action of anaerobic bacteria. These microorganisms usually live at the bottom of swamps or in other places where there is no air, consuming dead organic matter to produce, among other things, methane and hydrogen.

We can put these bacteria to work for us. By feeding organic matter such as animal dung or human sewage into tanks – called digesters - and adding bacteria, we can collect the emitted gas to use as an energy source. This can be a very efficient means of extracting usable energy from such biomass – up to two-thirds of the fuel energy of the animal dung is recovered.

Another, related, technique is to collect gas from landfill sites. A large proportion of household biomass waste, such as kitchen scraps, lawn clippings and pruning, ends up at the local tip. Over a period of several decades, anaerobic bacteria are at work at the bottom of such tips, steadily decomposing the organic matter and emitting methane. The gas can be extracted and used by 'capping' a landfill site with an impervious layer of clay and then inserting perforated pipes that collect the gas and bring it to the surface.

(e) Fermentation

Like many of the other processes described here, fermentation isn't a new idea. For centuries, people have used yeasts and other microorganisms to ferment the sugar of various plants into ethanol. Producing fuel from biomass by fermentation is just an extension of this old process, although a wider range of plant material can now be used, from sugar cane to wood fiber. For instance, the waste from a wheat mill in New South Wales has been used to produce ethanol through fermentation. This is then mixed with diesel to produce 'dishelm', a product used by some trucks and buses in Sydney and Canberra.

An elaborated discussion on Digestion and Gasification, which are the major ways employed in India, are explained in subsequent sections.

4. Anaerobic Digestion

Anaerobic Digestion is a biochemical degradation process that converts complex organic material, such as animal manure, into methane and other byproducts.

What is Anaerobic Digester?

Anaerobic digester (commonly referred to as an AD) is a device that promotes the decomposition of manure or “digestion” of the organics in manure to simple organics and gaseous biogas products. Biogas is formed by the activity of anaerobic bacteria. Microbial growth and biogas production are very slow at ambient temperatures. These bacteria occur naturally in organic environments where oxygen is limited. *Biogas is comprised of about 60% methane, 40% carbon dioxide, and 0.2 to 0.4% of hydrogen sulfide.* Manure is regularly put into the digester after which the microbes break down the manure into biogas and a digested solid. The digested manure is then deposited into a storage structure. The biogas can be used in an engine generator or burned in a hot water heater. AD systems are simple biological systems and must be kept at an operating temperature of 100 degrees F in order to function properly. The first methane digester plant was built at a leper colony in Bombay, India. Biogas is very corrosive to equipment and requires frequent oil changes in an engine generator set to prevent mechanical failure. The heating value of biogas is about 60% of natural gas and about 1/4 of propane. Because of the low energy content and its corrosive nature of biogas, storage of biogas is not practical.

There are two major types of biogas designs promoted in India

1. Floating Drum
2. Fixed Dome

The floating drum is an old design with a mild-steel, Ferro-cement or fiberglass drum, which floats along a central guide frame and acts as a storage reservoir for the biogas produced. The fixed dome design is of Chinese origin and has dome structure made of cement and bricks. It is a low-cost alternative to the floating drum, but requires high masonry skills and is prone to cracks and gas leakages. Family biogas plants come in different size depending on the availability of dung and the quantity of biogas required for cooking. *The average size of the family is 5-6 persons, and thus biogas plant of capacity 2-4 m^3 is adequate. The biomass requirement is estimated to be 1200 liters for a family.*

Comparison between two designs:

Fixed dome	**Floating Drum**
Digester and gas holder, masonry or concrete structure	Digester, masonry, Gas holder, mild steel or fiberglass
Requires high masonry skills	Low masonry or fabricating skills
Low reliability due to high construction failure	High reliability, gas holder prefabricated
Variable gas pressure	Constant gas pressure
Digester could be inside the ground	Requires space above ground for three tanks; inlet, digester, outlet
Low Cost (2 m^3 = Rs.5000)	Low Cost (2 m^3 = Rs.8000)

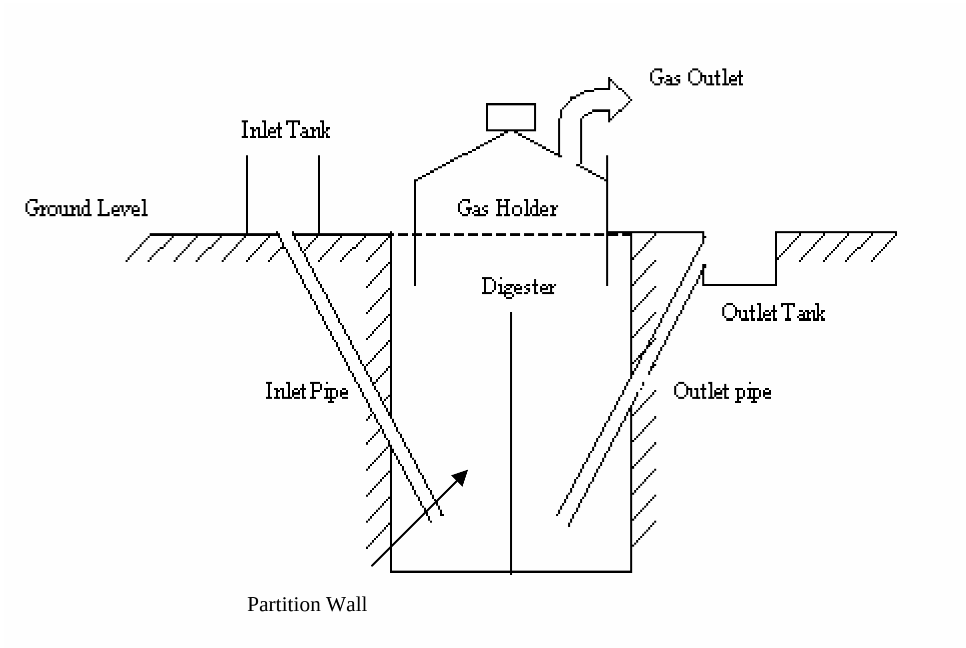

Figure 2: Floating Gasholder drum design (a conventional Indian design)

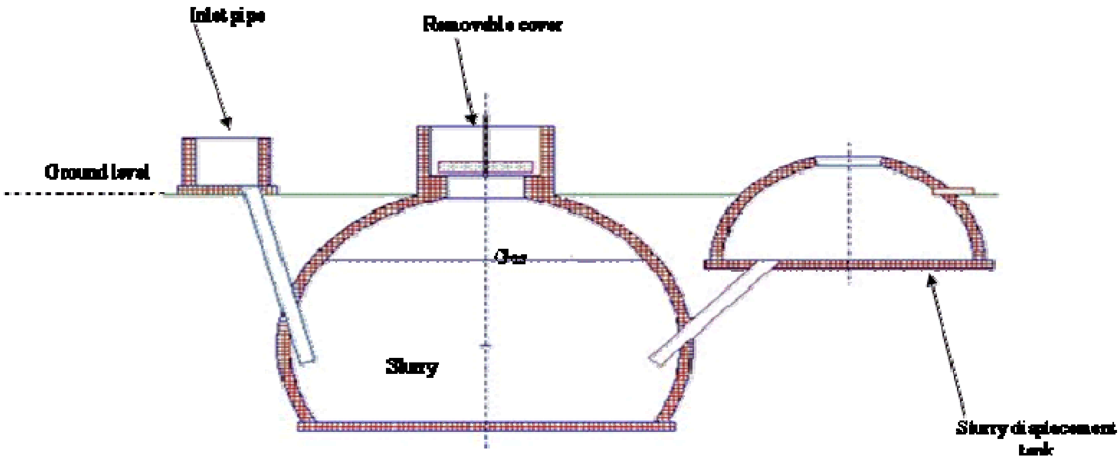

Figure 3: Spherical shaped fixed - dome plant

Uses of Biogas

Biogas can be directly used for cooking by supplying the gas though pipes to households from the plant. Biogas has been effectively used as a fuel in industrial high compression spark ignition engines. To generate electricity an induction generator can be used and is the simplest to interface to the electrical grid. Induction generators derive their voltage, phase, and frequency from the utility and cannot be used for stand-by power. If a power outage occurs generator will cease to operate. Synchronous generator can also be used to connect to the grid. However, they require expensive and sophisticated equipment to match the phase, frequency and voltage of the utility grid. Biogas can also be used as fuel in a hot water heater if hydrogen sulfide is removed from the gas supply.

5. Case Study of Community Biogas programmes in India

Biogas Electricity in Pure Village

In India, Biogas option is considered largely as a cooking fuel. The need for considering decentralized electricity options and the potential of biogas is analyzed. A field-demonstration programme was implemented in pure village in South India to use cattle dung in a community biogas plant to generated electricity for services such as pumping drinking water and home lighting.

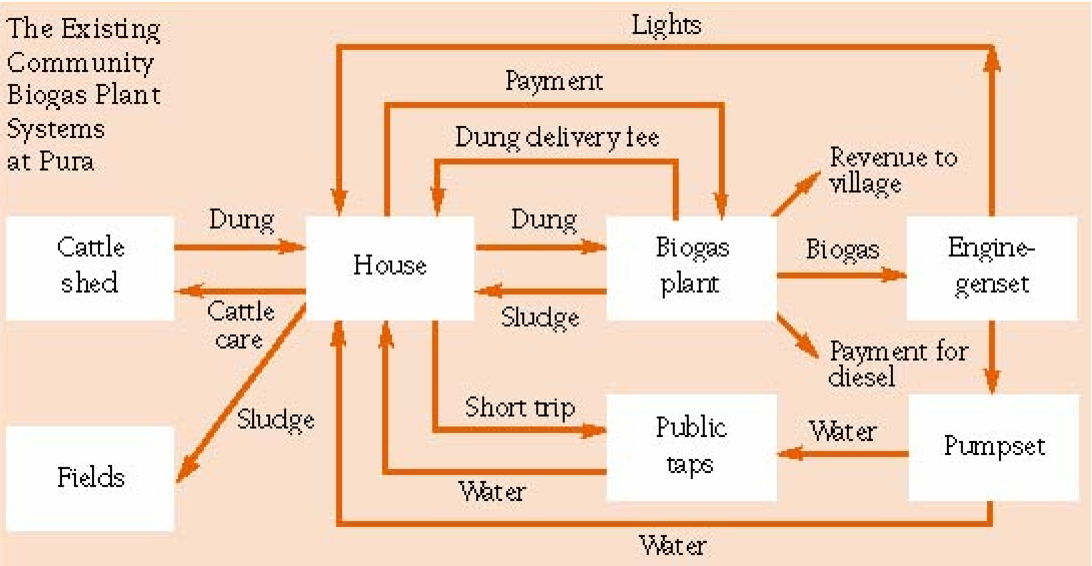

Fig 4: Community Biogas Plant in Pura Village

Technology

The Indian floating-drum design shown in fig.1 with modified dimensions for cost reductions was used. The Pure biogas plants have a capacity to digest up to 1.2 t cattle dung/day and produce 42.5-m3 biogas/day. Sand bed filters were installed to remove excess water and convert the sludge to dung-like consistency for subsequent use as a fertilizer. The filtrate, which contains the required anaerobic microorganisms, is mixed with the input dung. A 5 kW diesel engine is connected to a 5kVA, 440 V three-phase generator of electricity generation.

Lighting

Out of 87 house holds in the village 39 already had grid electricity, there are 103 fluorescent tube lights of 20 W capacity connected biogas generated electricity. Forty-seven houses opted for one tube light and 25 houses have two tube lights. Lighting is provided in the evening for 2.5 hours/day. Even homes connected to the grid had lighting connections from the biogas system.

Water supply

A submersible pump is connected to a tube well and water is pumped to storage tanks for 1 hour and 40 minutes/day. The majority of the households have opted for private taps at their doorsteps.

Basic Statistics on Pura Village	July, 1987	1991	1994
Population	430	463	485
Cattle population	241	248	254
Human/cattle ratio	1.78	1.87	1.91
No. of Households	80	87	88
Households with grid electricity			
(number)	34	39	52
(percent)	(43%)	(45%)	(59%)
Households with grid + biogas electricity			
(number)		24	34
(percent)		(28%)	(39%)
Households with only biogas electricity			
(number)		48	36

Fig 5: Table showing the statistics on Pura village

6. Biomass Gasifies:

Biomass, or more particularly wood, can be converted to a high-energy combustible gas for use in internal combustion engines for mechanical or electrical applications. This process is known as gasification and the technology has been known for decades, but its application to power generation is of recent origin. A biomass gasified consists of a reactor where, under controlled temperature and air supply, solid biomass is combusted to obtain a combustible gas called *Producers gas* (consisting of H_2 and CH_4). This gas passes through a cooling and cleaning system before it is fed into a compression ignition engine for generation of mechanical or electricity (by coupling to a generator). An assessment of its potential concluded that India presents a unique opportunity for large-scale commercial exploitation of biomass gasification technology to meet a variety of energy needs, particularly in the agricultural and rural sectors. The large potential of biomass gasification for water pumping and power generation for rural electrification was recognized.

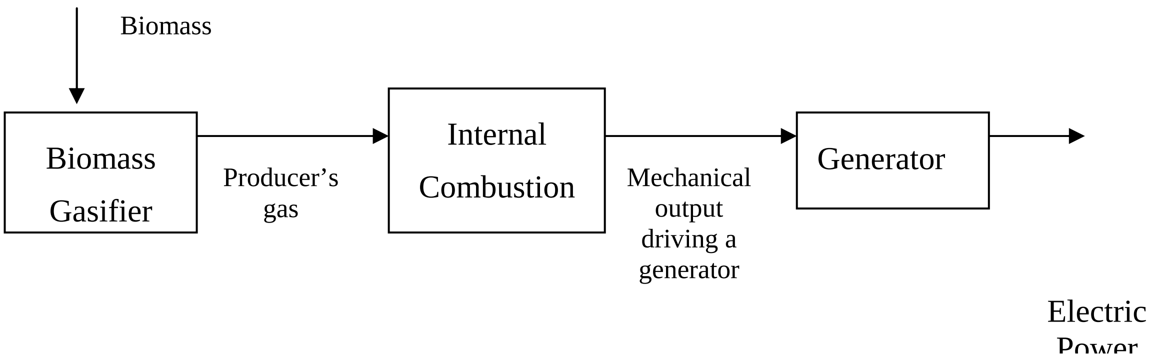

Figure 6: Block diagram of a producers gas electricity system

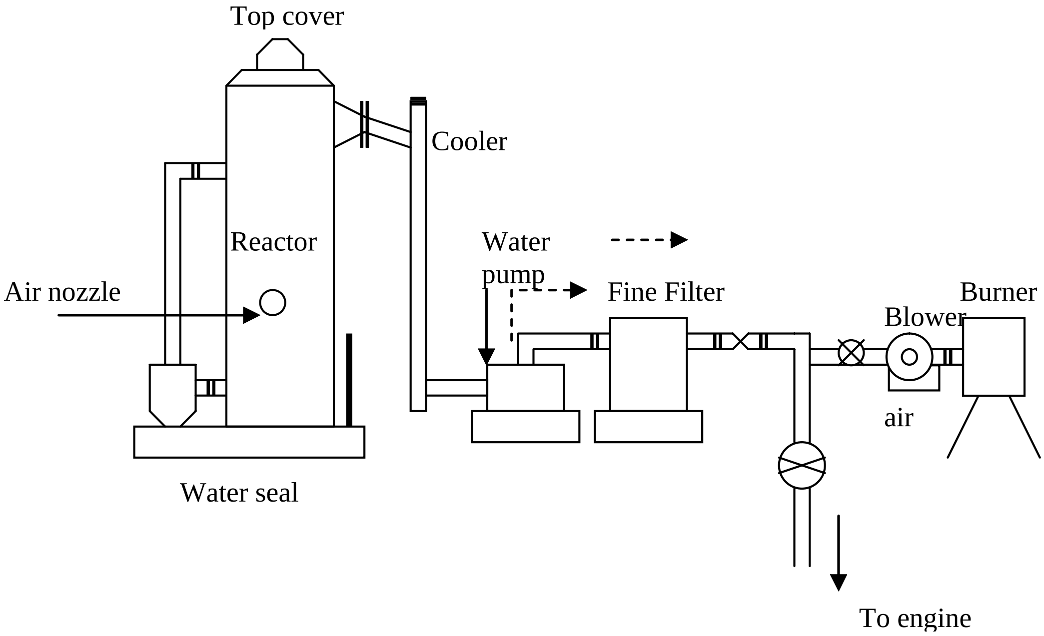

Figure 7: A 20 kW gasifier with cooling and cleaning system

Feed Stocks for producer-gas systems:

A range of crop residues and woody biomass from trees could be used as feedstocks for producer-gas systems. Currently, wood-based systems are available, and designs using other low-density biomass are under development and should soon be available in India. Crop residues with fuel potential are limited, since nearly all cereal and most pulse residues are used as fodder or manure and thus are not available as fuel. It is important to note that currently crop residues are used and have an opportunity cost. Rice husks are used in the cement industry, in rice mills and in the manufacture of bricks. Coconut leaves are used as thatch and the husk as fiber and sugarcane biogases is used in sugar mills. In Punjab, for rice-husk-based power generation systems, the price of residues such as rice husk could increase once new uses and demands are developed. Crop residues may continue to be used as fuel in domestic sector assuming that cooking-energy requirements are going to be met from bio-energy options. Constant supply of crop residues as feedstock cannot be assured over a long period on continuous basis and the transportation of low-density residues is not feasible.

Woody biomass would be the dominant source of feedstock for gasification. The availability of woody biomass and production potentials are discussed in the following section.

7. Case Studies of Producer's gas electricity:

(a) Electrification of Hosahalli, a south Indian village

A small-capacity one-top wood gasified has been developed and implemented a field demonstration program in the non-electrified South Indian village of Hosahalli. The village has a population of 250 and was unelectrified. The farmers' income is mainly from growing mulberry crops, as the area is silk producing. A 20 kW one-top wood gasified was setup to meet the demand for electricity. The plant is providing electricity to the people, who in turn have improved the overall economy and living conditions of the villagers. The loads being served by the power plant include domestic lights, streetlights, drinking water and irrigation tube wells, and a flourmill. The villagers themselves are managing the power plant.

<u>Services provided with Producer-gas electricity</u>

The electricity produced was used for three services: lighting, pumping domestic water, and flour milling.

Lighting

All the 42 houses were provided with a 40 W fluorescent tube and a 15 W incandescent bulb, along with eight streetlights. Connected load is 2.68 kW. Hours of operation: 6 p.m. to 10 p.m.

Water Supply

A submersible pump of 3 hp capacity was connected to a deep tube well. Water is pumped to storage tanks to provide 2-3 hours of water supply per day.

Flour milling

A 7.5 hp flourmill was connected to the producer gas diesel-engine generator. The flourmill, which operated for 2 hours/day, was operated for a few months in 1992; its operation was suspended, as the rate of milling was lower than the desired rate by the village community due to limitations of the 5-kVA system.

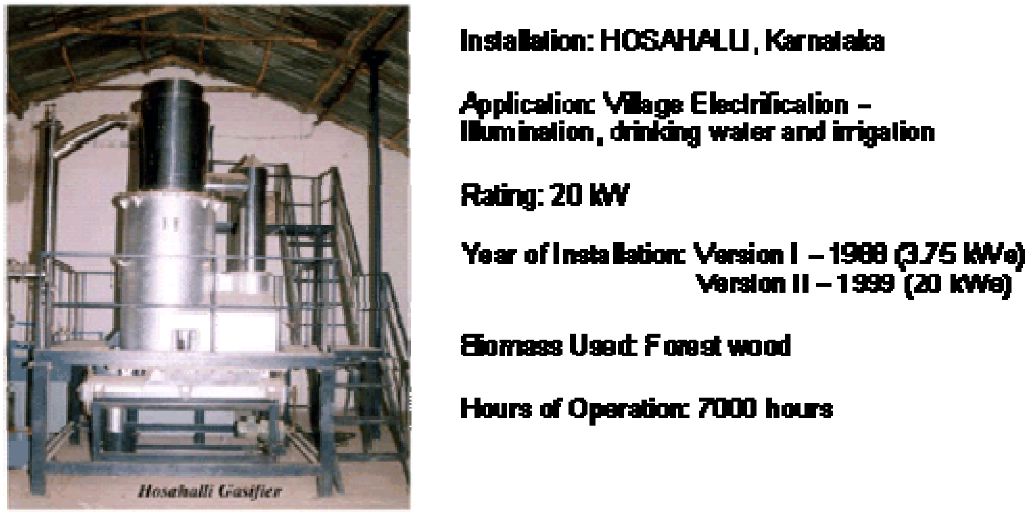

Fig 8: Biomass Gasifier Installed in Hosahalli, Karnataka.

(b) Electrification of Chhotomollakhali, a village in West Bengal

Chhottomollakhali Island in Sunderbans situated in the district of South 24 Parganas, is about 130 km. away from Kolkata. It has a population of about 28,000. The main occupation of the people is fishing and agriculture. It is difficult to extend grid electricity to Chhottomollakhali Island due to prohibitive cost involved in crossing of various rivers and creeks. In the absence of electricity, the economic activities of the Island were suffering. The switching on of the 4x125 kW Biomass Gasifier based Power Plant on 29th June 2001 has changed the life the inhabitants of this remote Island. The plant is catering to electricity needs of domestic, commercial and industrial user's drinking water, hospital, ice factory, etc. Four villages of Chhottomollakhali Island will be benefited with electricity from the power plant.

Plant capacity: 4 x 125 kW

No. Of consumers: 800

Total Project Cost: Rs.1, 46, 70,390/-

Hours of operation:5 PM to 11 PM

Tariff Structure: 4.00 / unit Domestic

4.50 / unit Commercial

5.00 / unit Industrial

Energy Plantation Area: 40 hectares

Fuel Consumption pattern under full:

Load condition

(a) Biomass: 70%

(b) Diesel : 30%

Generation cost (per unit) under full load condition: Rs.2.75

8. Biomass availability issues:

Before assessing the country's bioenergy production potential, it is important to:

i. Estimate the land availability for biomass production,

ii. Identify and evaluate the biomass production options—yield/ha and financial viability,

iii. Estimate sustainable biomass production potential for energy,

iv. Estimate the energy potential of biomass production,

v. Assess the investment required and barriers to producing biomass sustainably for energy.

Different options for wood supply

1. Conservation potential of wood used in cooking.
2. Producing wood on community, government, or degraded forest land.
3. Producing wood on degraded private or farm land.
4. Sustainable harvest from existing forest.
5. Logging waste.

Consideration of options 2 and 3 involves a range of related issues, such as land availability, land quality, competitive uses of land, and sustainability of wood production.

Some proportion of wood currently burnt, as cooking fuel would become available for the producer-gas electricity option. Tree plantations, farm trees, homestead gardens, and degraded lands are the various sources of fuel wood used for cooking. Among these sources, only wood from tree plantations could be considered as easily available as feedstock for power generation.

Woody biomass would be the dominant source of feedstock for gasification. The availability of woody biomass and production potentials are discussed in the following section.

Estimates of degraded land availability in India (Mha):

SPWD; degraded (waste) land quoted in PC	Degraded forest, Degraded non-forest, Total degraded land	Total degraded land 130 Mha
Chambers; land available for tree planting	Cultivated lands, Strips and boundaries, Uncultivated degraded land, Degraded forest land, Land for tree planting	Total Land for tree planting 84 Mha
Kapoor; land available for tree plantation	Agricultural land, Forest land, Pasture land, Fallow, Urban	Total land for tree planting 106 Mha
Ministry of Agriculture	Forest land with < 10% tree crown cover, Grazing land, Tree groves, Culturable waste, Old fallow,	Total degraded land 66 Mha

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