International Journal of Emerging Technology and Advanced Engineering
Volume 3, Special Issue 3: ICERTSD 2013, Feb 2013, pages 577-582
An ISO 9001:2008 certified Int. Journal, ISSN 2250-2459, available online at www.ijetae.com

ROLE OF BIOMASS ENERGY FOR SUSTAINABLE DEVELOPMENT OF RURAL INDIA: CASE STUDIES

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ABSTRACT

Biomass has a very high potential as a renewable energy resource because of its reliability and availability everywhere around the globe. It is the fourth highest primary energy resource in the world after oil, coal, and gas, contributing about 10.6% of the global primary energy supply. Many studies suggest that biomass can become an important primary energy source in the future global energy system, with dedicated biomass plantations being the major biomass supply source. Biomass can be converted into three main types of product: electrical/heat energy, transport fuel and chemical feedstock. Energy can be recovered from biomass either by direct combustion of the fuel or through initial gasification and subsequent combustion. Both methods are favoured because of its efficient and environment-friendly applications. Gasification is the process of generation of combustible mixture of H_2, CO, CO_2, CH_4 and N_2 with lower heating value commonly known as producer gas. These gases are used in many applications based on the conversion technology and fuel preparation. Biogas gas can also be generated by biochemical process to be utilized for cooking and engine operation. In the present paper, role of biomass energy for sustainable development of rural India has been discussed. Implementation of such cases have been presented and discussed.

Keywords: Biomass, biomass energy, combustion, gasification, Bio-methanation, case study

1. INTRODUCTION

World's energy consumptions are mostly dependent on fossil fuels such as coal, oil and natural gases. But fossil fuels are getting depleted and also site specific. On the other hand, energy consumptions are rapidly increasing due to increase in population loads as well as urbanization and industrialization specifically in the developing countries like China, India, Srilanka, Bangladesh etc. Burning of fossil fuels is a major source of greenhouse gas emissions responsible for global warming. The World is now under pressure not only due to the shortage of reserved fossil fuels but also for environmental pollution, ecological imbalance, global warming and its effects is coming in the form of number of natural disasters such as Tsunami, cyclone, floods, draught etc. during the present decade. Depletion in the fossil fuel reserve and resulting increase in petroleum prices has called for a search of alternative energy resources or non-conventional energy sources to drive the nation towards sustainable development. India's GDP has been growing quite fast in recent past and it is forecasted that it would continue to do so in the coming several decades. To realize the growth in GDP, it is necessary that corresponding growth in demand of primary energy as well as electricity is estimated and plans are made to meet the demand [1]. In this connection, renewable sources such as solar, wind, biomass etc. are getting more importance to maintain or to improve GDP with the overall development [2]. But there have certain drawbacks or know-how, reliability of renewable sources, due to which it is not capable to achieve target potential within the next decade. Recently, Indian government is showing interest regarding nuclear power to mitigate substantial power shortage and to save environment, considering substitution of renewable sources. But there is an environmental risk due to the disposal of radioactive materials coming from nuclear power plants. Nuclear power is also site specific and not suitable for small distributed power generation which is more important for a diversified country like India. In these circumstances, there is a possibility of reliability and economic evaluation of small autonomous power systems or distributed systems containing only renewable energy sources [3].

The recent economic growth in India has increased the electricity demand in the country considerably. The present electricity generating capacity in India is about 1,45,626 MW (as on August 31, 2008)[4]. A large share (64.6%) of it comes through the generation by the thermal power plants, fuelled with coal (53.2%), gas (10.5%) and oil (0.9%).

Presented at International Conference on Energy Resources and Technologies for Sustainable Development, 07-09 February 2013, Howrah, India.

ICERTSD2013-06-282

However, there is a substantial shortage of power in the country amounting to over 73000 million kWh during the period April, 2007 to March, 2008 [5]. To overcome the shortage, a capacity addition of about 75000 MW had been projected in the 11th Five year plan through which the country is presently undergoing (2007-2012).

However, regardless of the developments, a part of the country, mostly in the rural areas, does not yet have the access to electricity. The challenges involved in providing electricity access in rural areas of India could be understood by the fact that only about 43.5% of rural households (60.18 million out of 138.27 million) had access to grid supplied electricity as per 2001 census data [6]. To mitigate the gap, the government has seriously taken up rural electrification programme setting the goal as "**Mission 2012: Power for All**"[4]. Power generation, transmission, distribution, regulation, conservation and communication strategies have been devised to achieve the objective. Notwithstanding, the plans and efforts in implementing the program, some skepticism exists in achieving the goal. Most of the power production in the country takes place as centralized generation in the central, state and private sectors. The power is then transmitted and distributed through the extension of the grid. The problems of high transmission and distribution losses, frequent disruption in supply of grid power, practical difficulties and financial un-viability of extending grid to remote and inaccessible areas, dispersed population in small villages resulting in low peak loads etc. are bothering the rural electrification program in the country [7].

2. BIOMASS POTENTIAL IN INDIA

India, being a tropical country, has tremendous potential for energy generation through biomass and its residues. Biomass energy is normally found in the form of firewood, agricultural residues such as bagasse, crop straw, animal dung and wastes generated from agro-based industries.

Biomass can be classified into two types: woody and non-woody. Non-woody biomass comprises agro-crop and agro-industrial processing residue. Municipal solid wastes, animal and poultry wastes are also referred to as biomass as they are biodegradable in nature. The main biomass sources are as listed below.

- Wood and wood waste: forest wood, wood from energy plantations, saw dust, tree branches and leaves etc.
- Agricultural residues: rice husk, bagasse, groundnut shells, coffee husk, straws, coconut shells, coconut husk, arhar stalks, jute sticks etc.
- Aquatic and marine biomass: algae, water hyacinth, aquatic weeds and plants, sea grass beds, kelp, coral reef etc.
- Wastes: municipal solid waste, municipal sewage sludge, animal waste, paper waste, industrial waste etc.

Wood and wood wastes are available especially in the forest areas as well as hilly regions such as Himalayan and north eastern region of India. These are also available from energy plantation of fast growing species due to abundant availability of barren land in India. North eastern part of India is full with plenty of forest residues and tea wastes which are the sources of primary energy of this region.

Agricultural residues can be divided into major two groups: crop residues and agro-industrial residues. Crop residues are plant materials left behind in the farm after removal of the main crop produce such as straws of rice, wheat, millet, sorghum, oilseed crops, maize stalks and cobs, cotton stalks, jute sticks, sugar cane trash, mustard stalks etc. The agro-industrial residues are groundnut shells, rice husk, bagasse, cotton waste, coconut-shell and coir pith [8]. Agricultural crop residues produced in India are two type; field-based residues and processing-based residues. It is reported an estimation of total agricultural crop residues in 1994 is 602.10 million tonnes and projected 889.71 million tonnes for the year 2010 as tabulated in Table 1. [9].

Table 1. Agricultural crop residues produced in India [9]

	Production in million tonnes	
Field-based residues	1994	2010 (projected)
Rice straw	214.35	284.99
Wheat straw	103.48	159.98
Millet stalks	19.42	17.77
Maize stalks	18.98	29.07
Cassava stalks	0.38	0.40
Cotton stalks	19.39	30.79
Soybeans (straw and pods)	12.87	34.87
Jute stalks	4.58	1.21
Sugar cane tops	68.12	117.97
Cocaa pods	0.01	0.01
Groundnut straw	19.00	23.16
Sub-total	480.56	700.22
	Production in million tonnes	
Processing-based residues	1994	2010 (projected)
Rice husks	32.57	43.31
Rice bran	10.13	13.46
Maize cob	2.59	3.97
Maize husks	1.90	2.91
Coconut shells	0.94	1.50
Coconut husks	3.27	5.22
Groundnut husks	3.94	4.80
Sugar cane bagasse	65.84	114.04
Coffee husk	0.36	0.28
Sub-total	121.54	189.49
Total	602.10	889.71

As the rural economy of the country is largely dependent on the agricultural production, biomass power shows a lot of promise in rural electrification schemes [10]. In the hilly terrain of the country, like in the Himalayas and the north-eastern states, forest woods are available as biomass.

Saw dust from the wood processing units located in these areas can supply biomass for the generation of power. Sustainability in the supply of biomass is an important issue in the implementation of the technology in remote villages.

3. ENERGY FROM BIOMASS

Many studies suggest that biomass can become an important primary energy source in the future global energy system, with dedicated biomass plantations being the major biomass supply source. Biomass can be converted into three main types of product: electrical/heat energy, transport fuel and chemical feedstock [11]. Energy can be recovered from biomass either by direct combustion of the fuel or through initial gasification and subsequent combustion. Out of these two methods, the latter one is favoured because of its efficient and environment-friendly applications.

Gasification is the process of generation of combustible mixture of H_2, CO, CO_2, CH_4 and N_2 with lower heating value commonly known as producer gas. These gases are used in many applications based on the conversion technology and fuel preparation. Some of the applications are as follows also depicted in figure 1. Byproducts generated from biomass are presented in figure 2.

- Biomass gasification system for engine power of automotive vehicles, irrigation pumping etc.
- Biomass gasification system of engine power of distributed power generation unit
- Biomass gasification for heat and power application in process industry
- Biomass gasification system for hydrogen production
- Biomass gasification system for chemical feed stock
- Gasification system for IGCC power plant
- Co-firing of producer gas with natural gas and other gaseous fuels
- Biomass gasification system with gas turbine for power generation

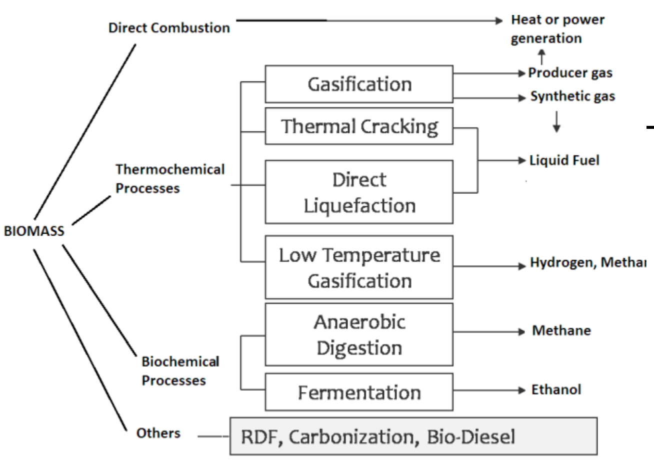

Fig. 1. Conversion of biomass into useful products

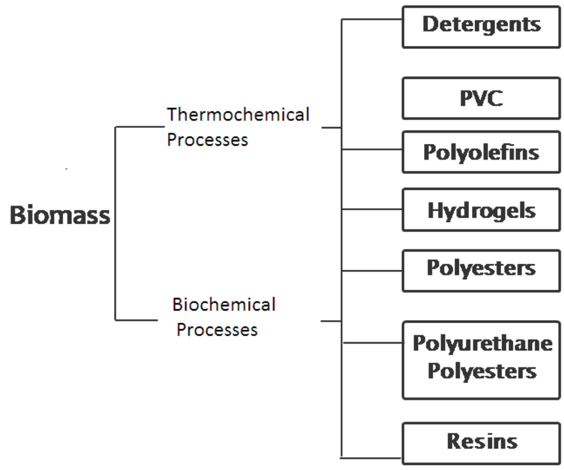

Fig. 2. Byproducts from biomass

4. CASE STUDIES

Few case studies have been presented to show the feasibility of the energy production from biomass using different conversion technologies for useful purpose is as follows:

4.1 *Case 1: 2x 4.5 MWth Bamboo Dust Gasification project in HPCL* [12]

This is the world's largest biomass gasifier installation and the first in India successfully commissioned in September 2007 for thermal application using bamboo dust, which is generated as waste from the paper industry, *HPCL* (Nagaon Paper Mill & Cachar Paper Mill) in Cachar district, Assam. The bamboo dust is briqueted as a preparatory process to increase its bulk density. It has given an innovative solution for the bamboo dust that is considered as waste for the industry. Moreover, it consumes energy and expenditure for its disposal and creates hazardous problems to the environment. This gasifier plant not only saves valuable fuel energy but also provides an effective solution to the bamboo dust waste. Case data has been presented in the table 2 to show the yearly saving as well utilization of bamboo dust for useful purpose.

Table 2. Yearly Furnace oil save and net saving per year. [12]

No of Hours Working per Day	24 hrs
Furnace oil Saved per Day 260 x 24	6240 ltrs
Amount Saved per Day 6240 @ 21*	Rs. 1,31,040/-
Yearly saving for 300 working days	Rs. 3,93,12,000/
Internal Power consumption 220x24x2x300	Rs. 31,68,000/-
Spares @ Rs 70 per ton 70x1.1x24x300	Rs.5,54,400/-
O & M @ Rs 30 per ton 30x1.1x24x300	Rs.2,37,600/-
Total expenditure	Rs.39,60,000/-
Net Saving per year	Rs.3,53,52,000/-

4.2 Case 2: BGFP Project at Village – Talwade, Taluka-Trimbakeshwar, District- Nashik (Maharashtra) [13]

This is a biogas plant, biogas generated from cow dung and agicultural waste etc. The gas generated from the plant have been purified with 98.4% methane through test conducted by Shriram Institute for Industrial Research, Delhi (NABL). The purity of the enriched biogas is continuously monitored by online analyzing system along with calibration. The purified biogas is equivalent / similar to CNG. The biogas generation capacity of the plant is approx. 500 cum per day. The purity of biogas is about 98% and compressed to 150-bar pressure for filling in cylinders. The upgraded biogas is used for power generation, cooking and industrial application. The slurry of biogas plant is used as an organic fertilizer in nearby agro fields. The field trials have indicated 150% growth in agro-production and substantial improvements in the quality. The salient features of BGFP project are given in table 3 below:

Table 3. The salient features of BGFP project [13]

Particulars	Description	Remarks
Quantity processed	12.5 MT	Cow dung, agricultural waste etc.
Biogas generated	500 NM^3	
Purified/Upgraded Biogas	270 NM^3	
Purified Biogas used for captive power generation	81 NM^3	30 %
Power generated	160 units	
Purified/Upgraded Biogas Filled in Cylinders at 150 bars	16 Cylinders of 9 kg each filled.	Equivalent to Rs. 5040 of CNG or Rs. 7200 of commercial LPG
Slurry / Manure	20000 Litres/day	Used as liquid fertilizer worth Rs. 10000.

4.3 Case 3: 5 X 100 KWe Biomass gasifier plant at Gosaba in Sunderbans, West Bengal [14]

This plant is based on the biomass gasifier duel fuel power generation system (70% biomass + 30% diesel) which was installed at Gosaba Island, Sunderbans in June, 1997 with the prior initiate from West Bengal Renewable Energy Development Agency (WBREDA). The Gosaba Village has become a mini town due to availability of electricity which was un-electrified due to distant from grid. At the same time, it is maintaining its own entity as a village due to its isolation from the mainland. Summary of the plant operation at that time is given in table 4 [14]:

Table 4. The salient features of *Biomass gasifier plant*

Plant Capacity	5 X 100 kW
No. of consumers	1150
Operation hours	16 hours (9-AM to 1-AM Next Day)
Tariff	INR 5.6/kWh for Domestic INR 6.75/kWh for Commercial INR 8.00/kWh for Industrial
No. of manpower	22
Fuel efficiency	(90cc diesel + 850 – 900g of wood) per kWh
Cost of fuel	INR 35/40kg half dry wood.

4.4 Case 4: Sree Rayalseema, 5.5MW biomass power plant, District: Kurnool,Andhra Pradesh, India

Sree Rayalseema is a 5.5MW grid connected biomass power plant in the Kurnool district of Andhra Pradesh, India. The plant uses agricultural waste as its fuel, such as cotton husk, ground nut shells, sunflower waste, etc. This project was the first of its kind in the region results in emissions savings of *ca 19000* tons of carbon dioxide every year that earn through CDM and also creates a market for the waste products. The project generates an additional income source for local farmers and labourers, estimated at 200 direct and 150 indirect permanent jobs.

4.5 Case 5: 100% producer gas engines at 1MW power station in Tamil Nadu State [14**]**

This is a 1 MW capacity of 100% producer gas based grid connected power generation commissioned in December 2004 which is operated by Arashi Hi-Tech Bio-Power Pvt. Ltd in Coimbatore, Tamil Nadu State as independent power producer (IPP). They have started the operation in 2002 using duel fuel engines but finally engines have been replaced with 4 x 250 kW *Cummins* producer gas engines and an additional gasifier. Currently Juliflora (*Prosopis juliflora*) wood which is very common legume woody weed in the state used as the feedstock and the system has already been operated over 4,000 hours.

4.6 Case 6: 10MW Biomass Based Power Plant at Gangarampur, south Dinajpur, West Bengal [15]

This is a 10 MW biomass based power plant utilizing 100 % rice husk, 85 % Rice Husk + 15 % biomass promoted by Aston field Renewable Resources Private Limited ("ARRPL") with the prior allotment through West Bengal Renewable Energy Development Agency (WBREDA with the intention of sale to the State grid as per the provisions of Indian Electricity Act 2003.

ISSN 2250-2459, *Volume 3, Special Issue 3: ICERTSD 2013, Feb 2013, pages 577-582*

The power will be evacuated to the 132/33kV grid substations at Gangarampur. Further a provision has been kept as per MNRE (Ministry of New & Renewable Energy) Guideline to fire 85% Rice husk & 15% coal. However, this option will occur very rarely, since, there is abundance of locally available biomass in the district.

5. PROSPECTS

With the prior presentation of the six case studies in the above, certainly any one can recommend for the implementation of such project anywhere in the country where biomasses are available. That means technology is not a problem for the conversion of biomasses into useful energy as well as products. But whether it is techno-economically viable option or not and also question may raise regarding the reliability about the abundant biomass resources for a long run. It has been studied that the energy from biomass will be a reliable energy option where there is lack of conventional sources and located far away from the grid and availability of abundant biomass other than wood biomass are present.

6. CONTEMPORARY ISSUES

Energy from biomass always faces with a number of issues: these are not only technical also ecological as well as local-economical. Products of the processes are directly related with the available raw biomass material at inlet and process parameters. Properties of the raw material always vary with the biomass species, source as well as location and seasonal basis. Composition of the biomass also varies with age of the plant as well as species. So based on the available plant materials process parameters have also been changed to have a reliable final product, but most of the cases decrease the conversion efficiency. On the other hand, wood biomass is not a reliable option due to deforestation regulation act. Non-woody biomasses have some drawbacks due to high bulk density and lower energy density that gives more transportation and operational cost. Furthermore, there is no regulatory market for biomass like coal; oil etc., prices are varied with local availability that may vary with time. Therefore prior implementations of such biomass projects always face problem of reliability due to these issues.

7. CONCLUSIONS

Biomass has a very high potential as a renewable energy resource because of its reliability and availability everywhere around the globe. Many studies suggest that it can become an important primary energy source in the future global energy system, with dedicated biomass plantations being the major biomass supply source. Biomass can be converted into three main types of product: electrical/heat energy, transport fuel and chemical feedstock.

Energy can be recovered from biomass either by direct combustion of the fuel or through initial gasification and subsequent combustion. In the present paper, different technological option for energy production from biomass has discussed and presented with suitable case studies. In the above case studies, 100% producer gas engine for gasification and purified methane production form bio-methanation may get more reliable energy option because they are free from conventional resources. Moreover plants are showing more viable option where abundant available waste biomasses are available with the process industry such as bamboo dust for paper industry, rice husk for rice mill etc. Energy from biomass will be a reliable energy option where there is lack of conventional sources and located far away from the grid and abundant availability of biomass other than wood biomass. Finally prior implementations of biomass energy projects always face problem of reliability due to the issues like identical biomass composition, bulk density as well as energy density at the inlet of the process and also cost varies due to non regulatory market for biomass.

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