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Characterization of the Properties of Different Woody Biomass Species & Estimation of Their Power Generation Potentials

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Abstract: In view of energy and environmental problems associated with the use of fossil fuels (coal, petroleum and gas) in power generation, an increasing attention is being paid world-over by the scientists and technocrats for the utilization of renewable energy sources in power generation, metallurgical industries etc. There are various type of renewable energy sources such as solar, wind, hydropower, biomass energy etc. out of these renewable en-ergy sources, biomass is more economically viable for almost all the continents in the world. Biomass is a carbonaceous material and provides both the thermal energy and re-duction for oxides, where as other renewable energy sources can meet our thermal need only. Amongst all the solid fuel like coal etc. biomass is the purest fuel consisting of very lesser amount of ash materials. The power generation potential data for renewable energy sources in India clearly indicates that the biomass has potential to generate more than 17000 MW of electricity per year in India. However, the country is locking in exploitation of biomass in power generation. Till date, India has been capable to generate only 2000 MW (approx.) of electricity per year in spite of declaration of several incentives by the govt. of India. Hence, there is an argent need to increase the utilization of biomass in power generation. The present project work is a positive step towards energy and envi-ronmental problems facing the world. The presently selected forestry biomass species has no any commercial use and are underutilized. An attempt has been made in this study to assess the proximate and energy content of different components of Neem (Azadirachta indica), Banyan tree (Ficus benghalensis), Pippal (Ficus religiosa),Mahua (Madhuca longifolia) biomass species (all woody).

Keyword: *Biomass, Calorific Value, Electricity Generation, Proximate Analysis, Woody Biomass.*

1. Introduction

Due to fast depletion of fossil fuel resources for power generation and growing concern over the environmental degradation caused by conventional power plants, power genera-tion from biomass is becoming an attractive option throughout the world. Sustainable pro-duction and utilization of biomass in power generation can solve the vital issues of atmos-pheric pollution, energy crisis, wasteland development, rural employment generation and power transmission losses. Thus, the development of biomass-based power generation system is thought to be favorable for majority of the developing nations including India. Unlike other renewable, biomass materials, pre-dried up to about 15% moisture, can be stored for a considerable period of time without any difficulty [1]. Besides electricity sup-ply to the national power grids, biomass offers giant opportunities for decentralized power generation in rural areas at or near the points of use and thus can make villagers/ small industries self dependent in respect of their power requirements. It is observed that the decentralized power generation systems reduce peak loads and maintenance cost of trans-mission and distribution network [2].

In India, biomass fuels dominate the rural energy consumption patterns, accounting for over 80% of total energy consumed [3]. A number of developed countries derive a significant amount of their primary energy from biomass: USA 4%, Finland 18%, Sweden 16% and Austria 13%. Presently biomass energy supplies at least 2 EJ year^{-1} in Western Europe which is about 4% of primary energy (54 EJ). Estimates show a likely potential in Europe in 2050 of 9.0–13.5 EJ depending on land are as. This biomass contribution repre-sents 17–30% of projected total energy requirements up to 2050 [2].

1.1.Biomass Potential in Electricity Generation:

Biomass resources are potentially the world's largest and most sustainable energy sources for power generation in the 21st century [4]. The current availability of biomass in India is estimated at about 500 million metric tonnes per year. Studies sponsored by the Ministry has estimated surplus biomass availability at about 120 – 150 million metric tonnes per annum covering agricultural and forestry residues corresponding to a potential of about 17,000 MW. This apart, about 5000 MW additional power could be generated through bagasse based cogeneration in the country's 550 Sugar mills, if these sugar mills were to adopt technically and economically optimal levels of cogeneration for extracting power from the bagasse produced by them [5]. The details of the estimated renewable energy potential and cumulative power generation in the country have been outlined in Table1, indicating that the available biomass has a potential to generate around 17,000 MW of electricity. Around 70 Cogeneration projects are under implementation with surplus capac-ity aggregating to 800 MW. States which have taken leadership position in implementation of bagasse cogeneration projects are Andhra Pradesh, Tamil Nadu, Karnataka, Maharash-tra and Uttar Pradesh. The leading States for biomass power projects are Andhra Pradesh, Chhattisgarh, Maharashtra, Madhya Pradesh, Gujarat and Tamil Nadu [5].

Table -1, Electricity Generation Potentials of Renewable Energy Sources in India

Renewable Energy Programme / Systems		Target for 2010-11	Achievement during March 2011	Total achievement during 2010-11	Cumulative achievement up to 31.03.2011	Potential (MW)
GRID-INTERACTIVE POWER (CAPACITIES IN MW)						
Wind Power		2000	872.68	2350.35	14157.10	45195
Small Hydro Power		300	56.70	307.22	3042.63	15000
Biomass Power		**455**	**-**	**143.50**	**997.10**	**16881**
Bagasse Cogeneration			31.50	321.50	1667.53	5000
Waste to Power	Urban	17	-	-	19	2700
	Industrial		-	7.50	53.46	
Solar Power (SPV)		200	5.29	26.5	37.66	
Total		**2972**	**966.17**	**3156.66**	**19974.48**	

Source: MNRE, Figures at the end of March, 2011

1.1. Use of Biomass – A Remedy to Combat Pollution Emissions from Power Industries:

Sulphur oxides (SOx), nitrogen oxides (NOx), suspended particulate matters (SPM) and carbon dioxide are considered to be the basic pollutants emitted from thermal power plants. All these pollutants have unfavorable effects upon environment and social welfare. Various authors [6] write that the basic causes of acid rain are the SOx and NOx pollut-ants, while global warming is due to CO2 emission.

Since all green plants use CO2 for their growth, plantation of biomass species for electric-ity generation may be an effective way to slow the build-up of CO2 in the atmosphere. Biomass is practically free from sulphur, nitrogen and heavy metals and has much lower ash content (1-3 wt.%) than coal [7]. Hence, unlike fossil fuels, biomass use in electricity generation is not likely to pollute

the atmosphere with SOx, NOx, SPM, etc.

1.2. Biomass: classification and properties

The overall biomass resources can be broadly categorized into two parts based on its avail-ability in the natural form.

1.2.1. Woody biomass: Woody biomass is characterized by high bulk density, less void age, low ash content, low moisture content, high calorific value. Because of the multitude of advantages of woody biomass its cost is higher, but supply is limited. Woody biomass is a preferred fuel in any biomass-to energy conversion device; however its usage is dis-turbed by its availability and cost.

1.2.2. Non-woody biomass: The various agricultural crop residues resulting after harvest, organic fraction of municipal solid wastes, manure from confined livestock and poultry operations constitute non-woody biomass. Non-woody biomass is characterized by lower bulk density, higher void age, higher ash content, higher moisture content and lower calo-rific value.

1.3. Technical Approach For Biomass Conversion Processes

1.3.1. The advances in bio-energy technologies (BETs) over the last few decades have enabled a significant increase in the utilization of biomass for power generation. Key tech-nologies available for promoting power generation from biomass in India are gasification, combustion, co-firing and bio-methanation. Gasification

1.3.2. Biomass gasifiers are devices promoting thermo-chemical conversion of biomass into high energy combustible gas for burning in gas turbine (BIG / GT). Biomass, particu larly woody biomass, can be converted to high-energy combustible gas for use in internal combustion engines for mechanical or electrical applications. Biomass gasifiers are devices performing thermo-chemical conversion of biomass through the process of oxidation and reduction under sub-stoichiometric conditions. Gasifiers are broadly classified into updraft, downdraft and cross draft types depending on the direction of airflow. Gasifier systems with various capacities in the range of 1 kg/h to about 500 kg/h are presently in use. These systems are used to meet both power generation using reciprocating engines or for direct usage in heat application. The prime movers are diesel engines connected to al-ternators, where diesel savings up to 80% are possible. Among the biomass power options, small-scale gasifiers (of 20–500 kW) have the poten tial to meet all the rural electricity needs and leave a surplus to feed into the national grid. The total installed capacity of bio-mass gasifier systems as of 2011 is nearly 130 MW [8].

1.3.3. Co-Firing

1.3.4. Co-firing is defined as the simultaneous combustion of two different fuels in a

boiler. It involves substituting biomass for a portion of the fossil fuel used in a boiler. Ad-vantages of co-firing the combustion of two different types of materials at the same time. One of the advantages of co-firing is that an existing plant can be used to burn a new fuel, which may be cheaper or more environmentally friendly. For example, biomass is some-times co-fired in existing coal plants instead of new biomass plants.

Co-firing can also be used to improve the combustion of fuels with low energy content. For example, landfill gas contains a large amount of carbon dioxide, which is non-combustible. If the landfill gas is burned without removing the carbon dioxide, the equipment may not perform prop-erly or emissions of pollutants may increase. Co-firing it with natural gas increases the heat content of the fuel and improves combustion and equipment performance. As long as the electricity or heat produced with the biomass and landfill gas was otherwise going to be produced with non-renewable fuels, the benefits are essentially equivalent whether they are co-fired or combusted alone. Also, co-firing can be used to lower the emission of some pollutants. For example, co-firing biomass with coal results in less sulphur emissions than burning coal by itself [9].

2. Experimental work

2.1 Materials selection:

In the present project work, two different types of woody biomass species were collected from the local area and their components (bark, leaf & branch) were removed separately and kept for air drying in a cross ventilated room for about a month.

The species considered are:

1. Pippal (Ficus religiosa),
2. Mahua (Madhuca longifolia)
3. Neem (Azadirachta indica)
4. Banyan (Ficus benghalensis)

2.2 Proximate Analysis

Analysis for moisture, volatile matter, ash and fixed carbon contents were carried out on samples ground to -72 mess size by standard method [10]. The details of these tests are as follows.

2.2.1 Moisture Determination :

One gram of air dried powdered sample of size -72 mess was taken in a borosil glass cru-cible and kept in the air oven maintained at the temperature 110°C.The sample was soaked at this temperature for one hour and then taken out from the furnace and cooled in a desic-cator. Weight loss was recorded using an electronic balance. The percentage loss in weight gave the percentage moisture content in the sample.

2.2.2 Volatile Matter Determination

One gram of air dried powdered sample of size -72 mess was taken in a volatile matter crucible (made of silica) and kept in the muffle furnace maintained at the required tem-perature of 925°C.The sample was soaked at this tem perature for seven minutes and then crucible was taken out from the furnace and cooled in air.

VMC= (% loss in weight – moisture present in the sa mple)

2.2.3 Ash Content Determination

One gram of air dried powdered sample of size -72mess was taken in a shallow silica disc and kept in the muffle furnace maintained at the temperature of 775°C.The sample was kept in the furnace till complete burning. Weight of ash formed was noted down and the percentage ash content in the sample was determined.

2.2.4 Fixed Carbon Determination

The fixed carbon content in the sample was determined by using the following formula: FCC (Wt. %) =100-Wt %(Moisture + Volatile matter + Ash)

2.3 Calorific value determination

The calorific values of these species (-72 mesh size) were measured by using an Oxygen bomb calorimeter [10]; 1 gm. of briquetted sample was taken in a crucible. A 15 cm long cotton thread was placed over the sample in the crucible to facilitate in the ignition. Both the electrodes of the calorimeter were connected by a fuse wire.

Oxygen gas was filled in the bomb at a pressure of around 25 to 30 atm. The water (2 lit.) taken in the bucket was continually starred to homogeneous the temperature. The sample was ignited by switching on the current through the fused wire and the rise in temperature of water was automatically recorded. The following formula was used to determine the energy value of the sample.

The calorific value was calculated by using the following formula:

Gross calorific value (GCV) = {(W.E.× ΔT) / (Wo)} ─ (heat released by cotton thread+ Heat released by fused wire)}

Table-2: Proximate data & total energy content of Pippal & Mahua Biomass

specimen	Moisture content (in	Ash content (in %)	Volatile matter con-	Fixed carbon con-	Gross calorific value (in kcal/kg) (in KJ/kg)

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		%)		tent (in %)	tent (in %)		
Pippal							
I.	leaf	10	9	59	22	5282	22185
II.	bark	11	20	51	18	3311	13908
III.	branch	13	11	60	16	3768	15826
Mahua							
IV.	leaf	9	14	57	20	4637	19475
V.	bark	10	23	53	14	2443	10260
VI.	branch	8	10	68	14	3712	15590

Table-3: Proximate data & total energy content of Neem & Banyan Biomass

specimen	Moisture content (in %)	Ash content (in %)	Volatile matter content (in %)	Fixed carbon content (in %)	Gross calorific value	
					(in kcal/kg)	(in KJ/kg)
Neem						
I. eaf	9	20	58	13	3358.28	14104.77
II. bark	12	7	56	25	3422.05	14372.61
III. branch	10	6	55	19	3312.12	13910.90
Banyan						
IV. leaf	8	17	57	18	3777.71	15866.38
V. bark	13	10	56	21	3795.7	15941.94
VI. branch	11	10	58	15	3210.68	13484.85

3. Results and discussion:

3.1 Proximate analysis of presently selected woody biomass:

In the plant species selected for the present study, the time required to bring their moisture contents into equilibrium with that of atmosphere was found to be in the range of 15 to 20 days during the summer season (temperature :35-45°C and moisture: 6-18%). The studies of the proximate analysis of fuels /energy sources are important because they give an approximate idea about the energy values and extent of pollutants emissions during combus-tion.

i. Freshly chopped woody biomass components have a large amount of free moisture, which must be removed to decrease the transportation cost and increase the calo-rific value.

ii. It appears from these tables that Neem leaf & Banyan leaf has somewhat higher ash and lower fixed carbon contents than the bark of both the species. But, Mahua leaf has the greater fixed carbon content in comparison to the Pippal tree species.

iii. Also, the bark of Mahua & Pippal have higher ash content and lower fixed carbon content.

3.2 Calorific values of presently selected non-woody biomass plant components:

The calorific values of the fuels/energy source are important norms for judging its quality to be used in electricity generation in power plants. It provides an idea about the energy value of the fuel and the amount of electricity generation.

The influence of physical and geographic parameters in the power values is negligible. For this reason, only the average values of the six samples are presented.

It is interesting to note that in the studied plant species, the leaf of Mahua & Pippal exhi-bited the highest calorific value, followed by leaf & bark of Banyan species respectively. Perhaps the fact more remarkable of this research is that the leaf of Pippal tree has the higher calorific value as compared to all other studied biomass species [table- 2 & 3].

1 .Comparison with previous studies:

The calorific results of presently studied samples(Banyan & Neem) were compared with the results of energy potential of the Eucalyptus globulus and the Eucalyptus nitens studied by Perez et al [11].

Table-3: Comparison of studied energy values with the findings of Perez et al

Sl no.	**Present findings**		**Findings of Perez et al**	
	Sample	Gross calorific value(in kJ/kg)	Sample	Gross calorific value (in kJ/kg)
1	Banyan tree leaf	15866.38	E. globules Leaves	12,848
2	Neem tree bark	14372.61	E. globules bark	5,908
3	Banyan tree bark	15941.94	E. nitens bark	7,010
4	Neem tree branch	13910.90	E. nitens thick branch	9,013

Also, the energy values of presently studied species(Pippal & Mahua) were compared with the results of energy values of non-woody biomasses, namely Maize & Paddy residues studied by Kumar & Patel [12].

Table-4: Comparison of studied energy values with the findings of Kumar & Patel

Sl no.	**Present findings**		**Findings of Kumar & Patel**	
	Sample	Gross calorific value (in kJ/kg)	Sample	Gross calorific value (in kJ/kg)
1	Pippal leaf	22185	Maize leaf	13935
2	Pippal bark	13908	Maize bark	15330
3	Mahua bark	10260	Paddy stalk	14884
4	Pippal branch	15826	Paddy leaf	14708

From the comparison [table-3], it is found that the GCV of the presently studied species have higher GCV compared to the findings of Perez et al [11] & the findings of Kumar & Patel [12] who studied the energy potentials of non-woody biomass [table-4].

4. Conclusion:

In the present work four woody biomass species Pippal, Mahua, Banyan & Neem were selected & experiments to determine the proximate analysis & calorific values was done on each of the components of the selected species such as bark, leaf and branch were per-formed. The following are the different conclusions drawn from the present work:

i. All the four plant species showed almost the similar proximate analysis results for their components, the ash contents being more in their leaves.

ii. The woody biomass species showed highest energy values for their leaf, followed by branch and bark in particular Pippal & Neem species.

iii. Amongst the both biomass species Pippal has higher energy values compared to other species.

iv. The present study could be useful in the exploration of woody residue based bio-mass species for power generation.

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