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POWER GENERATION THROUGH RESIDUES OF SOME WOODY BIOMASS SPECIES.

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ABSTRACT

Scientists and technocrats are exploring renewable energy sources due to increasing energy demand and concerns with conventional fuels. Biomass has emerged as a promising source of power generation due to its inherent advantages such as carbon neutrality, lower ash content, and lower SOx and NOx emissions. This article examines three components derived from residues of five different woody plant species that have no commercial use. These plant species are Ficus benghalensis (locally known as Banyan), Azadirachta indica (locally known as Neem), Ficus religiosa (locally known as Pippal), Madhuca longifolia (locally known as Mahua), and Eucalyptus globulus (locally known as Eucalyptus).Analyses have been conducted to determine the original values and gross calorific values (GCV) of all the biomass species, as well as a coal sample. Different ratios of Pippal leaves and branches mixed with coal, and Mahua leaves and bark mixed with coal, were tested to determine the best coal-biomass blend for power generation. The results showed that as the percentage of biomass in the coal-biomass blend increased, the ash content decreased and volatile matter increased. The ultimate analysis was also carried out on selected biomass species of Banyan, Mahua, and Pippal. The carbon and hydrogen contents of both Pippal and Mahua leaves were found to be higher, resulting in higher calorific values. The varying energy values of plant components are related to their combined C and H contents. As the calorific value is the most important property of any fuel, including biomass fuel, regression equations were derived using proximate and ultimate analysis data to predict the gross calorific values of the studied biomass species.

Key words: ash fusion temperature, bulk density, calorific value, decentralized power generation, proximate analysis, regression analysis, ultimate analysis, woody biomass

I.INTRODUCTION

The ever-increasing demand for energy, coupled with the negative environmental impact of conventional power plants, has made the use of renewable energy sources the most effective option for power generation. The depletion of fossil fuels has forced scientists to consider alternative energy sources that are promising and can replace traditional fuels. Due to the unstable situation of conventional fossil fuels, rising costs of gas and oil, and expected shortages in the future, there is fear that the security of energy supply needed for sustainable economic development may be threatened. Conventional fuels are finite and non-renewable, which is why it is crucial to explore new, non-traditional sources of energy that are environmentally friendly and renewable. Biomass, with its carbon neutrality, low greenhouse gas emissions, and wide availability, has become one of the most sustainable energy sources on the planet. India, being a developing nation, requires sustainable development. Energy is an indispensable component of economic development in India. Agriculture and industry, which are major contributors to the country's economy, rely heavily on energy. India is currently ranked as the ninth largest economy in the world, with an impressive GDP growth rate of 8.7% and 7.5% in the last five and ten years respectively. In 2010, India was the fifth country with the largest true GDP growth rate in the world. This immense economic growth has resulted in an increased demand for energy resources in India. Between 2011 and 2012, India was ranked as the fourth country with the highest consumption of natural gas and crude oil in the world, following the United States of America, China, and Russia. Despite the global economic downturn, India's energy needs have continued to increase over the years. Thermal coal-fired power plants generate more than 65% of India's electricity **[1].** With the limited availability of coal and other conventional fuels, generating energy by planting rapidly-growing biomass species has become a necessary and attractive option for power generation in India. Sustainable production and application of biomass in energy production can help address fundamental issues related to climate contamination, energy emergencies, power transmission losses, and land development waste. India has a total forest area of about 697,898 km2, which comprises 21.23% of the geographical area of the country. Around 3 crore hectares of waste land is available for forestation in India, making biomass energy production one of the most promising sources of renewable energy**[2]**.

Biomass projects have shown promising results, but research into their potential is still in its early stages. The properties of biomass fuels vary between species and have a significant impact on power plant design and efficiency. To fully realize the benefits of biomass energy for energy production, it is essential to have a fundamental understanding of its different properties, such as chemical composition (including both proximate and ultimate analysis), energy value, bulk density, ash fusion temperature, combustion reactivity, etc. This topic presents the results of studies on proximate analysis, ultimate analysis, calorific values, bulk densities, ash fusion temperatures, and regression analyses related to the calculation of heating values from proximate and ultimate analysis data of different residual components of woody biomass species, including Ficus benghalensis (also known as Banyan), Azadirachta indica (also known as Neem), Ficus religiosa (also known as Pippal), Madhuca longifolia (also known as Mahua), and Eucalyptus globulus (also known as Eucalyptus). The impact of these properties on power generation has also been discussed.

II.LITERATURE REVIEW

1.Energy Challenges and Renewable Energy Scenario in India

India is expected to produce 669.6 million tons of oil equivalents (MTOE) by 2016-2017 and 844 MTOE by 2021-2022, which will satisfy around 71% and 69% of its energy consumption in those years, respectively**[1]**. The remaining energy needs will be met through imports which are projected to be about 267.82 MTOE and 375.68 MTOE by 2016-2017 and 2021-22, respectively. In the past decade, India has experienced significant economic growth, but to maintain this growth rate and become self-sufficient in energy, sustainable development is essential. However, the high economic growth is also putting pressure on its energy resources which can only be fulfilled by utilizing renewable energy sources. Developing countries like India have a higher requirement for energy, which leads to higher carbon dioxide (CO_2) emissions. To reduce CO_2 emissions by 30% by 2030, diverse options like nuclear, biomass, solar, and wind energy should be implemented as alternative energy sources for energy production, despite some additional costs**[24].** The release of CO_2 gas into the atmosphere is mainly caused by burning fossil fuels. Electricity is the biggest consumer of energy and has been growing steadily in comparison to other forms of energy. According to Dunn and Flavin **[25],** carbon dioxide is the most important greenhouse gas that contributes to "anthropogenic climate change". India is a developing country with over 1.2 billion people and a large territorial area of 2,973,189 square kilometers, as well as vast natural resources. The country's increase in electricity consumption is closely related to economic development and rising pollutant emissions. The growth of new commercial enterprises, plants, business hubs, and consumer goods industries to support its ever-expanding population has caused a significant increase in electricity consumption and, as a result, CO_2 emissions. The only way to reduce anthropogenic climate change is to implement various renewable energy programs, especially biomass energy. In addition to the aforementioned causes, the ongoing regional and political issues in the Middle East have compelled India to explore alternative energy sources for its future energy security. Rastogi **[26]** analyzed India's energy consumption pattern, particularly the consumption of oil and oil products, and calculated the risk factor for India as it imports around 71% of its oil requirement, up to 66% of which comes from the Middle East. Therefore, there is a critical need to adopt a comprehensive energy security model to safeguard India's energy future. According to the report by AP Energy publication **[27],** India is committed to increasing its renewable energy share, which can significantly contribute to electricity production. It has been projected that it will supply around 15% of the total electricity need by 2020. The energy sector in India is striving to meet global energy standards with sustainable energy production by substantially reducing carbon emissions through the frequent use of renewable energy. The government is also launching new energy initiatives to address climate issues. The Ministry of New and Renewable Energy, in collaboration with the Ministry of Power, initiated the Jawaharlal Nehru National Solar Mission, which is one of the most noteworthy environment-friendly energy solution initiatives in India. The National Solar Mission is focused on 20 GW grid solar power, 2 GW of offgrid capacity, including 20 million square meters of solar thermal collector area and 20 million solar lighting systems by 2022.

The last three years have witnessed remarkable progress in the renewable energy sector with the launch of several new initiatives. Biomass energy and wind power have become the fastest-developing renewable energy sectors in the country. The increasing trend in the use of renewable energy is evident from the cumulative deployments of 2079 MW of wind power and 411 MW of biomass power in 2013 alone.

Modern biomass demand has increased manifold, which has turned out to be the driving force for international trade. Biofuels and wood pellets have become particularly significant entities in the biofuel trade. Worldwide production and transport of wood pellets surpassed 22 million tons, excluding 8.2 million tons of pellets traded globally.

2.Biomass as a Renewable Energy Source and its Potential

Thermal power plants use coal for combustion, which mainly emits carbon dioxide (CO_2), oxides of nitrogen (NO_x), oxides of sulphur (SO_x), CFCs, and other trace gases. The carbon dioxide created during combustion is a major concern because of its contribution to global warming. A study by Raghuvanshi et al. **[31]** on coal-based power generation in India identified the need to use renewable energy to reduce emissions. The study found that carbon dioxide from coal combustion currently contributes to over 60% of the greenhouse effect. When 1 tonne of fossil fuel is burnt, 750 kg of CO_2 is released into the atmosphere. On the other hand, using biomass as a fuel in power plants reduces the emission of particulate matter, as it contains the least amount of sulphur and other emissions-related particles. The use of biomass in fractional substitution of fossil fuels is particularly significant in reducing global warming since biomass combustion can be CO_2 neutral. Woody and agricultural plants, which are periodically sowed and harvested, remove CO_2 from the atmosphere through photosynthesis. Werther et al. **[32]** analyzed that biomass residues with high energy potential include forest-related residues, such as wood chips, bark, leaf, and sawdust, which account for nearly 65% of the biomass potential. Agricultural residues, such as straw, paddy husks, and bagasse, make up the rest. A number of developed countries such as the USA (5%), Finland (19%), Sweden (17%), and Austria (14%) obtain a significant amount of their primary energy from biomass. Currently, out of 54 EJ of primary energy, biomass energy provides 2 EJ per year in Western Europe. Factors such as energy demands, incentives for bio-energy use, continuous research, and ecological needs will affect the future of biomass.

Case studies by Chauhan **[33, 34]** on biomass potential in the states of Punjab and Haryana show that around 40.142 MT/year and 24.697 MT/year of overall crop residue are produced from a variety of crops, of which only about 71% is utilized, resulting in the availability of 29% as a net surplus in both states. It has been estimated that roughly 1.5101 GW and 1.4641 GW of power in the state of Punjab can be produced through basic surplus and net surplus biomass respectively. For the state of Haryana, where basic surplus is calculated as 45.51%, productive surplus is 37.48%, and net surplus is 34.10% of total biomass available.

As of 2011, about 400 million people in India did not have access to electricity. It was also found that about 836 million people (i.e., around 72% of the population) relied on traditional biomass for cooking. A significant proportion of the country's inhabitants still need access to cleaner and more modern forms of energy [35]. Therefore, an efficient and productive exploitation of biomass as a power source in India is still in its early stage and needs to be developed.

3.Biomass Conversion Processes

Biomass conversion processes come in various types. In a study conducted by Kucuk and Demirbas, they identified three processes; namely, chemical, thermo-chemical, and biochemical processes**[36]**. The study suggested that for the chemical method, important parameters include pre-hydrolysis, concentration of acid, temperature, time of reaction, and moisture content of exploited material. For thermo-chemical processes, the parameters are pressure, temperature, reaction time, and added catalysts or reactants. For biochemical processes, the factors are reaction temperature, moisture, pH, and reaction time.

Out of all the biomass conversion processes, co-firing is considered the most efficient. It provides a short-term solution for reducing CO2 emissions from fossil fuel power plants. Meanwhile, long-term CO2 reduction technology, such as oxy-firing, CO2 sequestration, and carbon loop combustion, are still being discussed. However, an incremental addition in CO2 reduction can be achieved by quickly implementing biomass co-firing in almost all fossil-fuelled power plants with minimal modifications and reasonable financing.

If most conventional power plants globally adapt co-firing, the overall decrease in CO2 emissions would be significant. Co-firing is considered the most proficient method for electricity production from biomass and, as such, suggests CO2 avoidance cost less than that for CO2 sequestration from present power plants. Basu et al**[37].** conducted a study on several co-firing options, including a novel external firing or indirect firing method that utilizes combustion or gasification in the existing power plant. They compared two of the indirect or external firing options with direct firing of biomass in pulverizing mills with gasification. It was found that the efficiency of direct co-firing is higher compared to indirect co-firing.

The design of devices used in such biomass conversion processes plays an important role. Mukunda et al**.[38]** conducted a study on such devices and emphasized the requirement for renewable energy, especially the use of biomass in developing countries. They classified biomass in terms of woody and pulverized and compared its energetic value with fossil fuels. Gasifier-combustor, combinations of gasifier, engine, and alternator for production of heat and electricity are some of the technologies involved and are used for both woody and pulverized biomass. Emphasis is given to the use of pulverized biomass in cyclone combustors to obtain high-grade heat. The techno-economic aspects are discussed to show the feasibility of these mechanisms in the existing global scenario. It is deduced that the vital constraint for the exploitation of bio-energy technologies comes from the absence of recognition of their actual potential.

4.Chemical Properties and Ash Fusion Temperature Test of Biomass

Studying the chemical properties of a fuel, such as proximate analysis, ultimate analysis, calorific value, ash fusion temperature, etc, is important in selecting a fuel to be used in a power plant. Kumar et al.**[39]** conducted a study on the characteristics of four herbaceous non-woody plant species, namely, Eupatorium, Anisomales, Sida, and Xanphium, and calculated the power generation potential. They compared the calorific values of biomass species with locally available coal and found the superior energy value of biomass compared to coal. Similar studies were carried out by Kumar and Patel on two non-woody biomass species, namely, Ocimum canum and Tridax procumbens.**[40]** Later, in a similar way, Kumar et al.**[41]**explored power generation potentials of three forestry non-woody biomass species, namely, Sida Rhombifolia, Vinca Rosea, and Cyperus. In addition, they studied bed agglomeration problems associated with boilers and found that the biomass considered for the study showed higher fusion temperatures and are safe to be used. Blends of coal and biomass play a vital role in mitigating emissions. Demirbas studied the blending characteristics of biomass with coal in a coal-fired boiler.**[42]** He compared the co-firing technology with other conversion processes and found that co-firing is more efficient and advantageous. Later, Demirbas**[43]** suggested the significant variation of fuel properties with respect to coal. He found that the ash content varies between 1-16% while nitrogen percentage varies between 0.2-1%. Similarly, carbon percentage varies between 35-43%. Variation of sulphur in biomass is very less and lies below 0.1%. Other important variations as compared to coal are high moisture content, high chlorine content, low bulk density, and low heating value. Biomass has less carbon content as compared to coal. But, the oxygen content is higher in case of biomass. Despite these variations, he suggested that biomass still stands as a potential fuel source.s as the most eligible renewable fuel to replace fossil fuels.
The study of biomass ashes is essential when considering the agglomeration of boiler beds. Hiltunen et al. **[44]** analyzed various types of biomass ashes and categorized them into three groups based on their composition. The first group contains Ca and K rich and Si lean biomass ash, the second group contains Si rich and K, Ca lean biomass ash, and the third group contains K, Ca, and P rich biomass ash. The first group belongs to woody biomass, while the rest belong to agricultural biomass. They also studied the effect of the combustion of these fuels on circulating fluidized bed boilers which are widely used for biomass combustion.

Boiler-related ash problems include slagging and fouling. Slagging occurs when ash deposits on furnace surfaces that are directly exposed to flame radiation, while fouling occurs in the convective section of the boiler. Slagging and fouling can cause excessive ash deposition on the heat transfer surfaces of boilers, decreasing their efficiency and, in extreme cases, causing power units to shut down. Ash fusion temperatures play a crucial role in identifying these problems. The composition and softening temperature of the ash can be related to the formation of slagging and fouling in boilers **[45].**

5.Decentralized Power Generation Structure in Rural Areas

In rural areas, decentralized energy production is becoming increasingly important. Kumar and Gupta **[50]** calculated the land and biomass required for decentralized power generation in rural areas. They found that a cluster of 15-20 villages comprising nearly 3000 families could be planned for one power plant that would generate 20000 kWh of electricity per day, which is equivalent to 7300 MWh per year. Kumar et al. **[39]** calculated that approximately 118, 66, 90, and 114 hectares of land would be required for the continuous generation of electricity from Eupatorium anisomales, Sida, and Xanphium biomass species, respectively. Further, Kumar and Patel **[40]** studied 18-month-old Ocimum canum and Tridax procumbens plant species and calculated their land requirements to be 650 and 1274 hectares, respectively, to produce the same amount of electricity. Similarly, Kumar et al. **[41]** considered Sida Rhombifolia, Vinca Rosea, and Cyperus non-woody plants and estimated that around 44, 52, and 82 hectares of land would be needed to produce the said amount of electricity. Furthermore, Kumar and Patel **[51]** investigated the power generation potential of blends of coal, cattle dung, and rice husk in the context of decentralized power generation.

III.OBJECTIVE

The present project work aims to achieve the following objectives:

1. Select and collect woody biomass species from the local area.
2. Conduct experimental investigations on the proximate analysis of different components of residues from selected woody biomass species.
3. Characterize the energy values of these biomass components.
4. Determine the bulk densities of the selected biomass species.
5. Determine the ash fusion temperatures of ashes obtained from selected plant species.
6. Characterize coal mixed biomass components for their energy values and conduct a comparative study of coal and biomass mixed samples in different ratios.
7. Determine the ultimate analysis of some selected biomass species.
8. Establish regression equations for calculating calorific values from proximate and ultimate analyses data of the biomass samples.
9. Estimate power generation potentials, requirements of land area, and coal-biomass blends.

IV.METHODOLOGY

1.Proximate Analyses of Studied Biomass Components

The studies of proximate analyses of fuels give an approximate idea about the energy values and the extent of pollutant emissions during combustion. The proximate analyses and gross calorific values of different components of Banyan, Neem, Mahua, Pippal, and Eucalyptus biomass species have been outlined. Additionally, the proximate analysis and gross calorific value of a non-coking semi-bituminous type coal collected from Ananta mines has been discussed.

It can be noted that the ash contents of both Banyan and Neem biomass species are highest in their leaves, followed by their branches and barks. In contrast, in both Pippal and Eucalyptus biomass species, the barks of both species have the highest ash content, followed by their branches and leaves. In Mahua biomass species, the bark contains the highest ash, followed by its leaf and branch. Among all the 15 studied biomass samples, the leaf of Eucalyptus has the lowest ash content, while Mahua bark has the highest ash content.

Moreover, ash contents of all the biomass components are found to be much less than that of the coal sample, which has an ash content of 42 wt.%. Furthermore, in Banyan biomass species, the fixed carbon content in the bark is the highest, followed by its leaf and branch. In the case of Neem biomass species, the bark has the highest fixed carbon content, followed by its branch and leaf. In Pippal biomass species, the leaf has a higher fixed carbon content, followed by its bark and branch. Mahua leaf has greater fixed carbon content, in contrast to its bark and branch. In Eucalyptus plant species, the fixed carbon content in the branch is highest, followed by its leaf and bark.

Overall, Neem bark contains the highest amount of fixed carbon content (i.e., 25 wt.%) among all the 15 studied samples, while its leaf contains the least percentage of fixed carbon content (i.e., 13 wt.%). It is observed that fixed carbon content of coal is higher than that of the biomass samples.

Moisture content is more or less the same among all the 15 studied biomass samples, which ranges between 8 wt.% to 13 wt.%. The bark of Banyan and branch of Pippal have the highest moisture content (i.e., 13 wt.%), while the leaves of Banyan and Eucalyptus and the branches of Mahua and Eucalyptus have the lowest moisture content (i.e., 8 wt.%) among all the 15 studied biomass samples. Moisture content in coal is the lowest.

As observed from Table 1, the volatile matter content shows a similar distribution in leaves and barks of Neem and Banyan biomass species, which ranges between 56 wt.% to 58 wt.%. But their branches contain a higher amount of volatile matter compared to their other components. It can be observed that the branches of all the studied biomass species have the highest volatile contents, while their barks have the lowest, except for Eucalyptus. In Eucalyptus plant species, the leaf has the highest volatile matter content, whereas its branch has the lowest. The branch of Mahua and leaf of Eucalyptus plant species have the highest volatile matter content (i.e., 68 wt.%), while the bark of Pippal has the lowest volatile matter content (i.e., 51 wt.%) among all the 15 studied biomass species. In the case of the coal sample, volatile matter content is very low compared to the biomass species.

Table 1: Proximate Analyses and Gross Calorific Values of Different Components ofStudied Biomass Species and Coal

Component	**Proximate analysis (wt.%, dry basis)**				**Gross calorific value (dry basis) (MJ/kg)**
	Moisture content	**Ash content**	**Volatile matter**	**Fixed carbon content**	
Banyan					
Leaf	8	17	57	18	15.692
Bark	13	10	56	21	15.894
Branch	12	14	60	14	13.444
Neem					
Leaf	9	21	58	12	14.059
Bark	12	8	56	24	17.856
Branch	11	12	62	15	14.285
Pippal					
Leaf	10	9	59	22	19.711
Bark	11	20	52	18	13.862
Branch	13	11	60	16	15.775
Mahua					
Leaf	9	14	57	20	19.414
Bark	10	24	53	14	14.783
Branch	8	10	68	14	17.295
Eucalyptus					
Leaf	8	6	69	19	22.141
Bark	10	11	63	16	17.505

Branch	8	9	62	21	18.840
Coal					
Ananta	8	42	21	30	17.773

High volatile and fixed carbon contents make ignition easier at low temperatures, inferring high reactivity and enhancing the process of combustion. High ash contents may cause the deposit of slag, creating higher thermal resistance to heat transfer and decreasing combustion efficiency. A high amount of moisture adds weight to the fuel, which reduces its effective bulk density while increasing transport costs and storing size. A high amount of ash and moisture decreases the energy value of fuel.**[49]**

2.Gross Calorific Values of Studied Biomass Components

The potential for power generation from any energy source can be evaluated based on its calorific value, which provides a rough idea of the fuel's quality for electricity production. Therefore, selecting a fuel with a high calorific value is an important criterion for power plant operation.To calculate the gross calorific value of Banyan biomass species' leaf, the sample was subjected to an experiment using a Bomb Calorimeter with a water equivalent of 1987 cal/ºC. The maximum temperature rise observed during the experiment was 1.28 ºC, and the initial weight of the sample was 0.67 g. The calorimeter used a cotton thread and fused wire that released 48 kcal/kg of heat.

3.Determination of Bulk Densities

The bulk densities of various components of the biomass species and coal sample under study were determined. The leaves of all biomass species have lower bulk densities than their barks and branches. In the case of Banyan, Pippal, and Mahua biomass species, the barks have the highest bulk densities, followed by their branches and leaves. In the case of Neem and Eucalyptus biomass species, both the branches have the highest bulk densities, followed by their barks and leaves. Notably, Eucalyptus branches have the highest bulk density of all the studied biomass species (i.e., 366 kg/m3), while Neem leaves have the lowest (i.e., 213 kg/m3). The bulk density of the coal sample is very high compared to all the biomass species (i.e., 690 kg/m3). The bulk densities of agricultural biomass species range from 40-200 kg/m3 **[65].** Comparing the bulk densities of the presently studied woody biomass species with the agricultural biomass species, it can be observed that all the woody biomass species have higher bulk densities. However, the bulk densities of the presently studied biomass species have lower values compared to the studied coal sample. Therefore, to facilitate handling, storage, and transportation, biomass has to be ground and compacted into dense and durable pellets or briquettes.

4.Ash Fusion Temperature Determinations of Selected Biomass Components

The ash fusion temperatures (AFTs) of six different biomass samples were measured, including two samples from each of the three components (leaves, bark, and branches). The components with higher ash content were selected for AFT measurement, which were the leaves of Banyan and Neem, barks of Pippal and Mahua, and branches of Banyan and Pippal. The initial deformation temperature (IDT), softening temperature (ST), hemispherical temperature (HT), and fluid temperature (FT) were measured in the ash sample of Pippal bark just before the start of the experiment.

The IDT is the temperature at which shrinkage in the cubic ash sample occurs. The ST is the temperature at which rounding of the corners of the cubic ash sample takes place. The HT is the temperature at which the ash sample takes on a hemispherical shape during the heating process. The FT is the temperature at which the melted ash sample completely spreads over the surface.

The IDT values ranged from 996-1219 ºC, while the ST values ranged from 1078 to 1330 ºC. The values of HT and FT for Pippal branch were above 1451 ºC, whereas the values for the rest of the components ranged from 1194-1261 ºC to 1254-1308 ºC. Due to limitations of the instrument, measurements above 1451 ºC could not be taken, so those two readings are recorded as >1451 ºC in Table 5.3.

The IDT of ash should be at least 150 ºC more than the operation temperature of the boiler to ensure no formation of agglomerated mass inside the combustors. The results suggest that IDTs of all the studied biomass samples are well above the biomass-based boiler operating temperature, which is around 800-900 ºC. This confirms that none of the studied biomass samples would be problematic during combustion in boilers.

Ash fusion temperature is widely used as a measure of ash fusibility and its agglomeration attributes. Designers and operators can have prior knowledge about the probable clinker formation during combustion of solid fuels in the boilers. Bed agglomeration during combustion of biomass/coal in a boiler disturbs the combustion process and can cause an unscheduled shutdown. The ash having low AFT fuses partially and adheres to the char surface, reducing its combustibility and forming agglomerated mass with the interruption in air supply, which eventually stops the combustion operation.

5.Chemical Characteristics of Blends of Coal and Biomass

The project work focused on studying coal-biomass mixed briquettes, specifically coal-Pippal branch and coal-Mahua bark, due to their higher ash fusion temperatures. The ash contents in the briquettes decreased as the biomass content increased, while their volatile matter contents increased. This is because biomass samples have lower ash content and higher volatile matter content. The fixed carbon contents in the briquettes increased with an increase in biomass content, as biomass samples have much lower ash content. The study showed that adding biomass to coal in the range of 0-15% had a negligible effect on the energy value of coal, as there was no significant change in total carbon and hydrogen contents. Carbon and hydrogen mainly contribute to the energy value of the material.

Similarly, two more blends of coal and biomass were analyzed: coal-Mahua leaf and coal-Pippal leaf. With an increase in biomass content in the blends, the ash content decreased, while the volatile and fixed carbon content increased. The study showed that the addition of biomass to coal had an insignificant effect on the energy value. It is always beneficial to use fuel with low ash content for smooth boiler operation, and biomass mixed with coal substantially decreases the ash content. Therefore, using biomass with coal in co-firing processes can be helpful in mitigating emission and bed agglomeration problems. The requirement of coal decreases with an increase in biomass in the blends, which is a positive step towards minimizing the use of conventional fossil fuels like coal, given the abundance of biomass.

V.CONCLUSION

Based on the results obtained from the current project, the following conclusions can be drawn:

Out of all the biomass species studied, Mahua bark had the highest ash content (24 wt.%), while Eucalyptus leaf had the lowest ash content (6 wt.%). Furthermore, the ash content of all the biomass components studied was significantly lower than that of the coal sample.

In general, the branches of all the biomass species studied had the highest volatile matter content, while their barks had the lowest. Among all the biomass species studied, the Mahua branch and Eucalyptus leaf had the highest volatile matter content (69 wt.%), while Pippal bark had the lowest (52 wt.%).

Neem bark had the highest fixed carbon content (24 wt.%), while its leaf had the lowest (12 wt.%).

Eucalyptus leaf had the highest calorific value (22.141 MJ/kg) among all the biomass components studied, while the Banyan branch had the lowest (13.444 MJ/kg). In general, all the studied biomass samples had higher calorific values than Indian coals, indicating their potential for power generation.

The ash fusion temperatures (particularly ST) of all the biomass species studied were significantly higher than the boiler operation temperature (around 800-900 0C), indicating safe boiler operation with these biomass species.

In the coal-biomass briquettes studied, the ash content and energy values decreased, while the volatile matter content increased with an increase in their biomass contents. Coal-biomass briquettes made by incorporating a lower amount of biomass appear to be more suitable for power generation.

Approximately 86, 683, 256, 154, and 292 hectares of land area are required for power generation of about 7300 MWh/year from each of Banyan, Neem, Pippal, Mahua, and Eucalyptus biomass species, respectively. Therefore, Banyan biomass species appears to be the most suitable for power generation.

VI.REFERENCES

[1] Energy Statistics (2013), Ministry of Statistics and Programme Implementation, http://mospi.nic.in/mospi_new/upload/Energy_Statistics_2013.pdf.
[2] India State Forest Report (2013), Forest Survey of India, http://fsi.nic.in/cover_2013/sfr_forest_cover.pdf.
[3] Executive Summary (2011), International Energy Agency, http://www.iea.org/Textbase/npsum/solar2011SUM.pdf.
[4] Ocean Energy (2014), Energy Alternatives India, http://www.eai.in/ref/ae/oce/oce.html#sthash.YCKUkBeZ.dpuf.
[5] Turcotte D. L. and Schubert G. (2002), Geodynamics, Cambridge, Cambridge University Press.
[6] Key World Energy Statistics (2012), International Energy Agency, www.iea.org/publications/freepublications/publication/kwes.pdf.
[7] Co-firing of Biomass Residues for Electricity Generation in Grid Connected Power Plants (2009), CDM Executive Board, http://cdm.unfccc.int/EB/051/eb51_repan05.pdf.
[8] Key World Energy Statistics (2013), International Energy Agency, http://www.iea.org/publications/freepublications/publication/KeyWorld2013.pdf.
[9] Renewable 2013 - Global Status Report (2013), Renewable Energy Policy Network for the 21st Century, http://www.ren21.net/portals/0/documents/resources/gsr/2013/gsr2013_lowres.pdf.
[10] Annual Energy Outlook (2014), Energy Information Administration, http://www.eia.gov/forecasts/aeo/pdf/0383(2014).pdf.