ESTIMATION OF POWER GENERATION POTENTIAL OF AGRICULTURAL BASED BIOMASS SPICEIS AND COAL-BIOMASS MIXED BRIQUETTES

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF

MASTER OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

BY

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DEPARTMENT OF MECHANICAL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA, ORISSA-769008
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CERTIFICATE

This is to certify that the thesis entitled **"Estimation of Power Generation Potential of Agricultural Based Biomass Species and Coal – Biomass Mixed Briquettes"** submitted by **Mr. Karun Kumar Dahariya** in partial fulfillment of the requirements for the award of **Master of Technology Degree** in **Mechanical Engineering** with specialization in **"Thermal Engineering"** at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under our supervision and guidance.

To the best of our knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

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CONTENTS

LIST OF TABLE

LIST OF FIGURE

ABSTRACT

With the advancement in technology the power consumption is rising steadily. This necessitates that in addition to the existing source of power such as coal, water, petroleum etc. other sources of energy should be searched out and new and more efficient ways of producing energy should be devised. Power generation from biomass becomes attractive way for energy generation due to their high energy potential and less pollutants. Present work deals with the determination of proximate analysis of different components, such as wood, leaf and nascent branch and energy content of different components of Cajanus cajan (local name-arhar, pigeon pea) and Arachis hypogaea (local name-peanut, ground nut) shell and their power generation potential and land requirement for plantations. These biomass components separately mixed with coal sample in different-different ratio and also their proximate analysis has done and their energy values are determined to find out the best suitable mixture for power generation. Estimation has been made for power generation potential of these biomass species and coal-biomass mixed briquettes for a small thermal power plant on decentralized basis.

As it is evident from result that both the biomass species has less ash content and high volatile matter when mixes with coal in the ratio of 80:20 and different component of pigeon pea has higher calorific value as compared to groundnut shell. Components of pigeon pea has higher calorific value with selected coal, due to that when it mixes with coal calorific value of mixture increase as the quantity of pigeon pea biomass increases in the mixture of coal-biomass briquette. In order to meet the yearly power requirement of the order of 73×10^5 kWh for a group of 10-15 villages, 4315 ha (in case of use of pigeon pea residue) and 5024.84 ha (in case of use of groundnut shell) land are required for plantation but when coal-biomass mixed briquette is used as fuel for power generation in the ratio of 80:20 it is found that it requires 197.91 ha (in case of use of coal-pigeon pea briquette) and 891.33 ha land(in case of use of coal-groundnut shell briquette) which is more feasible because it reduces the dependency on agricultural residues and also land requirement for plantation.

Keywords- Biomass, coal-biomass briquette, proximate analysis, calorific value, energy value

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Fossil fuels are the major source of power generation worldwide. About 87% of the world's energy supply comes mainly from fossil fuels. The share of fossil fuels is more than 90% in case of India. The demand of energy is increasing by leaps and bound due to rapid industrialization and population growth, the conventional sources of energy will not be sufficient to meet the growing demand. Consumption of fossil fuel causes to emit large amount of pollutants such as carbon dioxide, sulphur oxides, bottom ash, fly ash, etc. which are hazardous for human survival on the earth planet as well as environment. Conventional sources are non-renewable and bound to finish one day. Due to these reasons it has become important to explore and develop non-conventional energy resources to reduce too much dependence on conventional sources and development of alternative sources of energy which are renewable and environment friendly.

Power generation from biomass becomes attractive way for energy generation due to their high energy potential and less pollutants. Sustainable production and utilization of biomass in power generation can solve the vital issues of atmospheric pollution, energy crisis, waste land 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. Besides electricity supply 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 transmission and distribution network. To exploit biomass species in electricity generation, characterization of their various properties like energy values, chemical compositions, reactivity towards oxygen, bulk densities, etc. is essential. Present work deals to determine the proximate analysis, calorific value and energy value of two selected biomass species and mixed-biomass briquette and to find out the best suitable ratio for power generation and land required for plantation.

1.2 Biomass Energy

Biomass energy is the utilization of energy stored in organic matter. It is humanity's oldest external source of energy, dating back to prehistoric man's first use of fire. And biomass is still an important part of the world's energy system; the use of traditional biomass-charcoal, firewood, and animal dung-in developing countries accounts for almost 10% of the world's primary energy supply.

Bioenergy can be utilized in varied applications:

- Biomass can be combusted to produce heat (large plants or localized biomass boilers), electricity, or used in combined heat and power (CHP) plants.
- Biomass can also be used in combination with fossil fuels (co-firing) to improve efficiency and reduce the build-up of combustion residues.
- Biomass has potential to replace petroleum as a source for transportation fuels.
- Biomass is also used in conjunction with fossil fuels for electricity generation in "waste-to-energy" projects. These are niche applications, which depend on the biomass having no other commercial value and being in close proximity to the application

1.3 Why Bio-mass energy?

Biomass is an attractive energy source for a number of reasons:

- Biomass is a renewable energy source generated through natural processes and as a by-product of human activity.
- It is also more evenly distributed over the earth's surface than fossil fuel energy sources, and may be harnessed using more cost effective technologies.
- It provides us the opportunity to be more energy self-sufficient and helps to reduce climate change.
- It helps farmers, ranchers and foresters better manage waste material, providing rural job opportunities and stimulating new economic opportunities.

1.4 BIOMASS: CLASSIFICATION

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 disturbed by its availability and cost.

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 calorific value. Because of the various associated drawbacks, their costs are lesser and sometimes even negative.

1.5 Energy Generation from Biomass

A brief description of the technologies for energy generation from biomass is as follows.

(a) Combustion

In this process, biomass is directly burned in presence of excess air (oxygen) at high temperatures (about 800°C), liberating heat energy, inert gases, and ash. Combustion results in transfer of 65%–80% of heat content of the organic matter to hot air, steam, and hot water. The steam generated, in turn, can be used in steam turbines to generate power.

(b) Transesterification

The traditional method to produce biodiesel from biomass is through a chemical reaction called transesterification. Under this method, oil is extracted from the biomass and it is processed using the transesterification reaction to give biodiesel as the end-product.

(c) Alcoholic Fermentation

The process of conversion of biomass to biofuels involves three basic steps:

1. Converting biomass to sugar or other fermentation feedstock
2. Fermenting these biomass-derived feedstock using microorganisms for fermentation.
3. Processing the fermentation product to produce fuel-grade ethanol and other fuels.

(d) Anaerobic Digestion

In the absence of air, organic matter such as animal manures, organic wastes and green energy crops (e.g. grass) can be converted by bacteria-induced fermentation into biogas (a 40%-75% methane-rich gas with CO_2 and a small amount of hydrogen sulphide and ammonia). The biogas can be used either for cooking/heating applications, or for generating motive power or electricity through dual-fuel or gas engines, low-pressure gas turbines, or steam turbines.

(e) Pyrolysis

Pyrolysis is a process of chemical decomposition of organic matter brought about by heat. In this process, the organic material is heated in absence of air until the molecules thermally break down to become a gas comprising smaller molecules (known collectively as syngas).

The two main methods of pyrolysis are “fast” pyrolysis and “slow” pyrolysis. Fast pyrolysis yields 60% bio-oil, 20% bio-char, and 20% syngas, and can be done in seconds. Slow pyrolysis can be optimized to produce substantially more char (~50%) along with organic gases, but takes on the order of hours to complete.

(f) Gasification

In this process, biomass reacts with air under extreme temperatures and results in production of producer gas, to produce power (or) react with pure oxygen to produce synthesis gas for fuel production. The combustible gas, known as producer gas, has a calorific value of 4.5 - 5.0 MJ/cubic meter. A wide range of biomass in the form of wood or agro residue can be used for gasification.

1.6 Various Bio-energy Processes and Feedstock

There are so many ways for converting biomass into bioenergy. This bioenergy conversion depends on type of biomass available like agricultural residues; forest waste, municipal waste etc. Some of bioenergy processes are given in table 1.6.1

Table 1.6.1-Summary of bioenergy processes, feedstock and products

Process	**Biomass feedstock**	**Products**	**Features/ Highlights**
Thermal Conversion			
Combustion	Diverse biomass	Heat and power	Combustion can be applied for biomass feedstock with moisture contents up to at least 60 % Combustion is ideally suited for power segments which works well beyond 5 MW Combustion is a established technology working on the regular Rankine cycle Combustion comprises over 85% of installed capacity for biomass based power production in India (excluding biomass cogeneration) The process works well for most types of biomass

Thermo-chemical Conversion			
Gasification	Diverse biomass	Low or medium-Btu producer gas	Gasification systems are well-suited for small-scale applications. The process can work at low scales – as low as 20 kW, and works well up to 2 MW. Currently, less than 125 MW of cumulative installed capacity in India (less than 15% of total biomass power capacity, excluding biomass cogeneration). Gasification can produce a high purity syngas for catalytic conversion processes for the production of liquid biofuels. This process is currently in pilot phase.
Pyrolysis	Wood, Agricultural Waste Municipal Solid Waste	Synthetic Fuel Oil (Bio-crude), Charcoal	Pyrolysis is not well established currently in India or elsewhere in the world. Pyrolysis is a simple, low-cost technology capable of processing a wide variety of feedstock Typically pyrolysis plants work well beyond 2 MW scale.

Biochemical Conversion			
Anaerobic Digestion	Agricultural Waste, Municipal Solid and Liquid Wastes, Landfills and Animal Manure	Biogas	Anaerobic digestion is a commercially proven technology and is widely used for recycling and treating wet organic waste and waste waters Anaerobic digesters of various types were widely distributed throughout India and China. Anaerobic digestion is increasingly used in small size, rural and off-grid applications at the domestic and farm-scale. Small scale biogas for household use is a simple, low-cost, low-maintenance technology, which has been used for decades.
Alcohol fermentation	Agricultural Waste, Sugar Or Starch Crops, Wood Waste, Pulp Sludge and Grass Straw etc.	Ethanol	Sugar molasses is extensively used as a feedstock for alcoholic fermentation Recent advances in the use of lignocellulose biomass as a feedstock may allow bioethanol to be made competitively from woody agricultural residues and trees.

Chemical Conversion			
Pressing/extraction Transesterification	Oils from plant seeds and nuts etc. Fats from animal tissues	Biodiesel	Transesterification is a fairly simple and well-understood route to produce biodiesel from biomass. Glycerol, a by-product obtained from the process is difficult to be removed. Meanwhile it can be used as fuel in stationary applications, or can be converted into other high-value products Jatropha is used as a source for biodiesel production in India. Food crops such as soybean are also used as sources in some countries.

1.7 Estimation of Biomass Potential and Availability in India

Biomass is the third largest primary energy resource in the world, after coal and oil. In all its forms, biomass currently provides about 1250 million TOE which is about 14% of the world's annual energy consumption. Biomass is a major source of energy in developing countries, where it provides 35% of all the energy requirements. The current availability of biomass in India is estimated at about 500 million metric tons per year. The table1.7.1 illustrated below shows the bioenergy potential of various crop residues in India.

Table 1.7.1-Renewable Bio-Feedstock in India and their Availability for Heat and Power Generation[a]

Crop	**Residue**	**Biomass Produced (kt/Yr)**	**Power potential (MW)**	**Calorific potential (Mcal/sec)**
Arecanut	Fronds	788.5	94	22.4
Arecanut	Husk	212.3	25	5.9
Arhar	Stalks	5120.2	609	145.4
Arhar	Husk	614.4	73	17.4
Bajra	Stalks	12039.4	1433	342.2
Bajra	Cobs	1986.5	236	56.3
Bajra	Husk	1805.9	215	51.3
Banana	Residue	11936.5	1421	339.4
Barley	Stalks	563.2	67	16
Barseem	Stalks	71.6	8	1.9
Black pepper	Stalks	29.1	3.5	0.8
Cardamom	Stalks	43.6	5	1.1
Cashew nut	Stalks	148.2	18	4.2
Cashew nut	Shell	41.2	4.5	1.0
Castor seed	Stalks	1657.2	197	47
Castor seed	Husk	41.4	5	1.1

Casuarina	Wood	211.8	25	5.9
Coconut	Fronds	7278.9	866	206.8
Coconut	Husk & pith	3184.7	379	90.5
Coconut	Shell	1321.9	157	374.9
Coffee	Pruning & wastes	1457.6	173	41.3
Coffee	Husk	133.4	16	3.8
Coriander	Stalks	188.3	22	5.2
Cotton	Stalk	31358.3	3733	891.6
Cotton	Husk	10789.1	1284	306.6
Cotton	Bollshell	10789.1	1284	30.6.6
Cow gram	Stalks	48.5	5.7	1.3
Cumin seed	Stalks	182.6	21.7	5.182
Dry chilly	Stalks	268.6	32	7.6
Castor seed	Husk	41.4	5	1.1
Groundnut	Shell	13148.2	1565	373.8
Groundnut	Stalks	1972.2	235	56.1
Guar	Stalks	233.3	28	6.7
Horse gram	Stalks	191.3	23	5.5

Jowar	Cobs	5043.5	600	143.3
Jowar	Stalks	17147.8	2041	487.4
Jowar	Husk	2017.4	240	57.3
Kesar	Stalks	9.4	1	0.23
Kodo millets	Stalks	3.13	0.4	0.95
Linseed	Stalks	86.3	10	2.3
Maize	Stalks	23421.3	2788	665.9
Maize	Cobs	3536.4	421	100.5
Masoor	Stalks	600.3	71.4	17.053
Meshta	Stalks	1605.4	191	456.1
Meshta	Leaves	40.1	5	1.1
Moong	Stalks	671	80	19.1
Moong	Husk	91.5	11	2.6
Moth	Stalks	17.8	2	0.47
Mustard	Stalks	6999	833	198.9
Mustard	Husk	1658.1	197	47.0
Niger seed	Stalks	94	11	2.6
Others	Others	0.34	0.04	0.009
Paddy	Straw	149646.9	17815	4255

Paddy	Husk	19995.9	2380	568.4
Paddy	Stalks	322.3	38	9.0
Peas & beans	Stalks	27.4	3.2	0.764
Potato	Leaves	832.5	99	23.6
Potato	Stalks	54.8	6.5	1.5
Pulses	Stalks	1390.4	165	39.4
Ragi	Straw	2630.2	313	74.7
Rubber	Primary wood	1495.3	178	42.5
Rubber	Secondary wood	996.9	118	28.1
Safflower	Stalks	539.3	64	15.2
Sunnhemp	Stalks	14.1	1.6	0.382
Sawan	Stalks	0.22	0.02	0.004
Small millets	Stalks	600.1	71.4	17
Soyabean	Stalks	9940.2	1183	282.5
Sugarcane	Tops & leaves	12143.9	1445	345.1
Sunflower	Stalks	1407.6	167	39.8
Sweet potato	Stalks	12.8	1.5	0.358

Tapioca	Stalks	3959	471	112.4
Tea	Sticks	909.8	108	25.7
Til	Stalks	1207.7	144	34.3
Tobacco	Stalks	204.8	24.3	5.8
Turmeric	Stalks	32.3	4	0.955
Urad	Stalks	782.6	93	22.2

Source: Energy Alternatives India

Total -511041.39 MW

[a] *Estimations are approximated for a unit megawatt (MW) power plant*

1.8 Estimation of Renewable Bio-Feedstock in India and their Availability for Heat and Power Generation

Studies sponsored by the Ministry have estimated surplus biomass availability at about 120 – 150 million metric tons per annum covering agricultural and forestry residues corresponding to a potential of about 18,000 MW. This apart, about 5000 MWadditional 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.

The details of the estimated renewable energy potential and cumulative power generation in the country have been outlined in Table 1.8.1 (MNRE, 2013), indicating that the available biomass has a potential to generate around 18,000 MW of electricity. The Ministry has been implementing biomass power/co-generation programme since mid-nineties. A total of 288 biomass power and cogeneration projects aggregating to 2665 MW capacity have been installed in the country for feeding power to the grid consisting of 130 biomass power projects aggregating to 999.0 MW and 158 bagasse cogeneration projects in sugar mills with surplus capacity aggregating to 1666.0 MW. In addition, around 30 biomass power projects aggregating to about 350 MW are under various stages of implementation. Around 70 Cogeneration projects are under implementation with surplus capacity aggregating to 800 MW. States which have taken leadership position in implementation of bagasse cogeneration projects are Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra and Uttar Pradesh. The leading States for biomass power projects are Andhra Pradesh, Chhattisgarh, Maharashtra, Madhya Pradesh, Gujarat and Tamil Nadu.

Table 1.8.1-New & Renewable Energy
Cumulative deployment of various Renewable Energy Systems/ Devices in the country as on 31/03/2013

Renewable Energy Programme/ Systems	Target for 2012-13	Deployment during March,2013	Total Deployment in 2012-13	Cumulative achievement up to 31.03.2013
I. POWER FROM RENEWABLES:				
A. GRID-INTERACTIVE POWER (CAPACITIES IN MW)				
Wind Power	2500	416.55	1698.80	19051.45
Small Hydro Power	350	80.12	236.93	3632.25
Biomass Power	105	1.20	114.70	1264.80
Bagasse Cogeneration	350	36.50	352.20	2337.43
Waste to Power Urban	20	-	6.40	96.08
Industrial		-	-	-
Solar Power (SPV)	800	240.02	754.14	1686.44
Total	**4125.00**	**774.39**	**3163.17**	**28068.45**

Renewable Energy Programme/ Systems	Target for 2012-13	Deployment during March,2013	Total Deployment in 2012-13	Cumulative achievement up to 31.03.2013
B. OFF-GRID/ CAPTIVE POWER (CAPACITIES IN MW_{EQ})				
Waste to Energy- Urban-	20.00		13.82	115.57
Industrial		-	-	-
Biomass(non-bagasse) Cogeneration	60.00	28.06	88.65	471.15
Biomass Gasifiers- Rural-	1.50	-	0.672	16.792
Industrial	10.00	1.48	7.50	141.58
Aero-Generators/Hybrid systems	0.50	0.22	0.46	2.11
SPV Systems (>1kW)	30.00	16.86	34.45	124.67
Water mills/micro hydel	2.00(500 Nos.)	-	1.35 (270 nos)	10.65 (2131 nos)
Total	**126.00**	**46.62**	**146.90**	**882.57**
II. REMOTE VILLAGE ELECTRIFICATION				
No. of Remote Village/Hamlets provided with RE Systems	-	-	-	-
III. OTHER RENEWABLE ENERGY SYSTEMS				
Family Biogas Plants (No. in lakhs)	1.25	0.33	1.10	46.55
Solar Water Heating - Coll. Areas (Million m^2)	0.60	0.60	1.41	6.98

Source: MNRE, Figures at the end of March, 2013

1.9 Aims and Objectives of the Present Project Work

1. Selection of non-woody biomass species and estimation of their yield by field trial.
2. Determination of proximate analysis (% moisture, % volatile matter, % ash and % fixed carbon contents) of their different components, such as wood, leaf and nascent branch.
3. Mixed these biomass components separately with coal sample in different-different ratio.
4. Characterization of these biomass components for their energy values (calorific values).
5. Characterization of coal mixed biomass components for their energy values (calorific values).
6. Estimation of power generation potentials of these biomass species for a small thermal power plant on decentralized basis.
7. Comparative study of coal and mixed coal-biomass in different ratio of 95: 05, 90: 10, 85: 15 and 80: 20 with respect to selected biomass species.

CHAPTER 2
LITERATURE SURVEY

LITERATURE SERVEY

Combustion converts coal into useful heat energy, but it is also a part of the process that engenders the greatest environmental and health concerns. Combustion of coal at thermal power plants emits mainly carbon dioxide (CO_2), sulphur oxides (SOx), nitrogen oxides (NO_x), CFCs,other trace gases and air borne inorganic particulates, such as fly ash and suspended particulate matter (SPM). CO_2 produced in combustion is perhaps not strictly a pollutant (being a natural product of all combustion), nonetheless it is of great concern in view of its impact on global warming. The carbon dioxide emitted as a product of combustion of coal (fossil fuels) is currently responsible for over 60% of the enhanced greenhouse effect ***(Raghuvanshi et al.,2006***). For every ton of fossil fuels burned, at least three quarters of a tone of carbon is released as CO_2. It has been found that 0.8–0.9 kg/kW h CO_2 is emitted in Indian power plants.

The use of biomass to provide partial substitution of fossil fuels has an additional importance as concerns global warming since biomass combustion has the potential to be CO_2 neutral. This is particularly the case with regard to agricultural residues or energy plants, which are periodically planted and harvested. During their growth, these plants have removed CO_2 from the atmosphere for photosynthesis which is released again during combustion. Biomass materials with high energy potential include agricultural residues such as straw, bagasse, coffee husks and rice husks as well as residues from forest-related activities such as wood chips, sawdust and bark. Residues from forest-related activities (excluding wood fuel) account for 65% of the biomass energy potential whereas 33% comes from residues of agricultural crops ***(Werther et al.,2000)***.Biomass can supply heat and electricity, liquid and gaseous fuels .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 areas (10% of useable land, 33 Mha), yields (10–15 oven-dry tones (ODt) ha^{-1}), and recoverable residues (25% of harvestable). This biomass contribution represents 17–30% of projected total energy requirements up to 2050. The relative contribution of biofuels in the future will depend on markets and incentives, on continuous research and development progress, and on environmental requirements. Land constraints are not considered significant because of the predicted surpluses in land and food, and the near balance in wood and wood products in Europe.

In a case study of Haryana state (*Chauhan Suresh,2010)* discussed that being an agricultural state, Haryana has a huge potential of biomass availability in the form of crop residue and saw dust. In the agricultural sector, a total 24.697 MTy^{-1} of residue is generated, of which 71% is consumed in various domestic and commercial activities within the state. While in agro based industrial sector, a total of 646 KT y$^{–1}$ of sawdust is generated, of which only 6.65% is consumed in the state. Of the total generated biomass in the state, 45.51% is calculated as basic surplus, 37.48% as productive surplus and 34.10% as net surplus. The power generation potential from all these three categories of surplus biomass is 1.499 GW, 1.227 GW and 1.120 GW respectively.

In an another case study of Punjab state (*Chauhan Suresh,2012)* discussed that around 40.142 Mt y$^{–1}$ of the total crop residue is generated from various major and minor crops, of which around 71% is consumed in various forms, resulting in 29% as a net surplus available for power generation. Basic surplus and net surplus crop residues for power generation potential were estimated in each district.Sangrur, Ferozpur, Amritsar, Patiala and Ludhiana are the major surplus biomass potential districts, while Rupnagar, Nawashahar, Hoshiarpur, Fatehgarh Sahib, Faridkot and Kapurthalla are least surplus biomass potential districts within the state. It has been estimated that around 1.510 GW and 1.464 GW of power in the state can be generated through basic surplus and net surplus biomass respectively.

In view of high energy potentials in non-woody biomass species and an increasing interest in their utilization for power generation (*Kumar and Patel, 2008*), an attempt has been made in this study to assess the proximate analysis and energy content of different components of *Ocimumcanum* and *Tridaxprocumbens* biomass species (both non-woody) and their impact on power generation and land requirement for energy plantations. The net energy content in *Ocimumcanum* was found to be slightly higher than that in *Tridaxrocumbens*. In spite of having higher ash contents, the barks from both the plant species exhibited higher calorific values. The results have shown that approximately 650 and 1,270 hectares of land are required to generate 20,000 kWh/day electricity from *Ocimumcanum* and *Tridaxprocumbens* biomass species. Coal samples, obtained from six different local mines, were also examined for their qualities and the results were compared with those of studied biomass materials. This comparison reveals much higher power output with negligible emission of suspended particulate matters (SPM) from biomass materials.

Renewable energy sources and technologies have potential to provide solutions to the long-standing energy problems being faced by the developing countries (*Kumar et al, 2010*).
The renewable energy sources like wind energy, solar energy, geothermal energy, ocean energy, biomass energy and fuel cell technology can be used to overcome energy shortage in India. To meet the energy requirement for such a fast growing economy, India will require an assured supply of 3–4 times more energy than the total energy consumed today. The renewable energy is one of the options to meet this requirement. Today, renewable account for about 33% of India's

primary energy consumptions.India is increasingly adopting responsible renewable energy techniques and taking positive steps towards carbon emissions, cleaning the air and ensuring a more sustainable future. In India, from the last two and half decades there has been a vigorous pursuit of activities relating to research, development, demonstration, production and application of a variety of renewable energy technologies for use in different sectors. In this paper, efforts have been made to summarize the availability, current status, major achievements and future potentials of renewable energy options in India. This paper also assesses specific policy interventions for overcoming the barriers and enhancing deployment of renewables for the future.

CHAPTER-3

EXPERIMENTAL WORK

EXPERIMENTAL WORK

3.1 Selection of Materials

In the present project work, two different types of non-woody biomass species Cajanus cajan (local name-arhar, pigeon pea) and Arachis hypogaea(local name-peanut, ground nut) shell has been collectedfrom the local area. These biomass species were cut into different pieces and there different component like leaf, nascent branch and main branch were separation from each other. These biomass materials were air-dried in cross ventilator room for around 30 days. When the moisture contains of these air-dried biomass sample came in equilibrium with that of the air, they were crushed in mortar and pestle into powder of -72 mess size. Coal sample for making the blend was collected from Lingaraj mines of Orissa. These materials were than processed for the determination their proximate analysis and Energy values.

3.2 Proximate Analysis

Proximate Analysis consist of moisture, ash, volatile matter, and fixed carbon contents determination were carried out on samples ground to -72 mess size by standard method. The details of this analysis are as follows;

3.2.1 Determination of Moisture

One gm. (1 gm.) of air dried -72 mess size powder of the above said materials was taken in borosil glass disc and heated at a temperature of 110 ^{0}C for one hour in air oven. The discs were then taken out the oven and the materials were weight. The percentage loss in weight was calculated which gives the percentage (%) moisture contains in the sample.

3.2.2 Determination of Ash Content

One gm. (1 gm.) of -72 mess size (air dried) was taken in a shallow silica disc and kept in a muffle furnace maintained at the temperature of 775^{0}C. The materials were heated at this temperature for one hour or till complete burning. The weight of the residue was taken in an electronic balance. The percentage weight of residue obtained gives the ash contained in the sample.

$$\% \ Ash = Wt. \ of \ residue \ obtained \times 100 \ / \ Initial \ wt. \ of \ simple.$$

3.2.3 Determination of Volatile Matter

One gm. (1 gm.) of -72 mess size (air dried) powder of the above said materials was taken in a volatile matter crucible (cylindrical in shape and made of silica). The crucible is covered from top with the help of silica lid. The crucible were placed in a muffle furnace, maintained at the temperature of 925^0 C and kept there for 7 minute. The volatile matter crucibles were then taken out from the furnace and cooled in air. The de-volatized samples were weighted in an electronics balance and the percentage loss in weight in each of the sample was calculated. The percentage volatile matter in the sample was determined by using the following formula

$$\% \ volatile \ matter \ (VM) = \% \ lass \ in \ weight - \% \ moisture$$

3.2.4 Determination of Fixed Carbon

The fixed carbons in the simple were determined by using the following formula.

$$\% \ FC = 100 - (\% \ M + \% \ VM + \% \ Ash)$$

Where, FC: Fixed carbon, M: Moisture, VM: Volatile Matter

3.3 Calorific Value Determination

The calorific values of these species (-72 mesh size) were measured by using an Oxygen bomb calorimeter (shown in Fig.3.3.1); 1 gm. of briquetted sample was taken in a nicron 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 nicrom 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 fussed wire and the rise in temperature of water was automatically recorded. The following formula was used to determine the energy value of the sample.

Gross calorific value (GCV) = {(3922 × ΔT) / (Initial wt. of simple) − (heat released by cotton thread + Heat released by fused wire)}

Where, 3922 is the water equivalent water apparatus and ΔT is the maximum temperature rise.

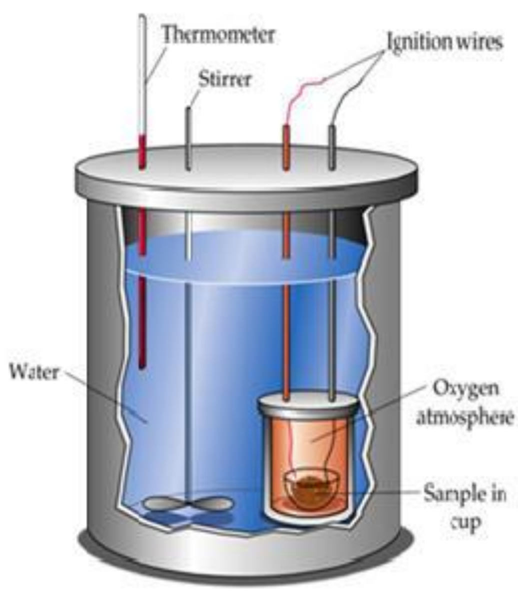

Figure 3.3.1: Structure of Oxygen Bomb Calorimeter

CHAPTER-4
RESULT AND DISCUSSION

RESULT AND DISCUSSION

4.1 Proximate analysis of presently selected plant components obtained from agricultural residue:

It is important to determine the moisture contents, ash contents, volatile matter and fixed carbon of a fuel energy source to know their power generation potential. Thus the study of proximate analysis of fuels energy sources gives an approximate idea about the energy values and extent of pollutant emissions during combustion. Agricultural based biomass has large amount of free moisture. To decrease the transportation cost and increase the calorific value which must be removed. In the plant species selected for the present study the time required to bring their moisture contents into equilibrium with that of the atmosphere was found to be in the range of 25-30 days during the summer season (temp 35 –42^{0}C, humidity 12-25 %).

Table 4.1.1: Proximate analysis and calorific values of Groundnut shell, different component of pigeon pea and coal

Component	**Proximate analysis wt. %, air dried basis**				**Calorific value (kcal /kg, dry basis)**
	Moisture	**Volatile matter**	**Ash**	**Fixed carbon**	
Groundnut Shell					
Shell	6.00	65.00	10.00	19.00	3654.59
Pigeon Pea					
Stump	9.00	68.00	9.50	13.50	5815
Branch	10.00	69.00	7.50	13.50	4081
Leaf	9.00	65.00	10.50	15.50	5630
Bark	5.00	74.00	8.50	12.50	3846
Seed cover	10.00	65.00	10.00	15.00	4081
Coal					
Lingaraj Mines	8.90	21.70	41.20	29	4237

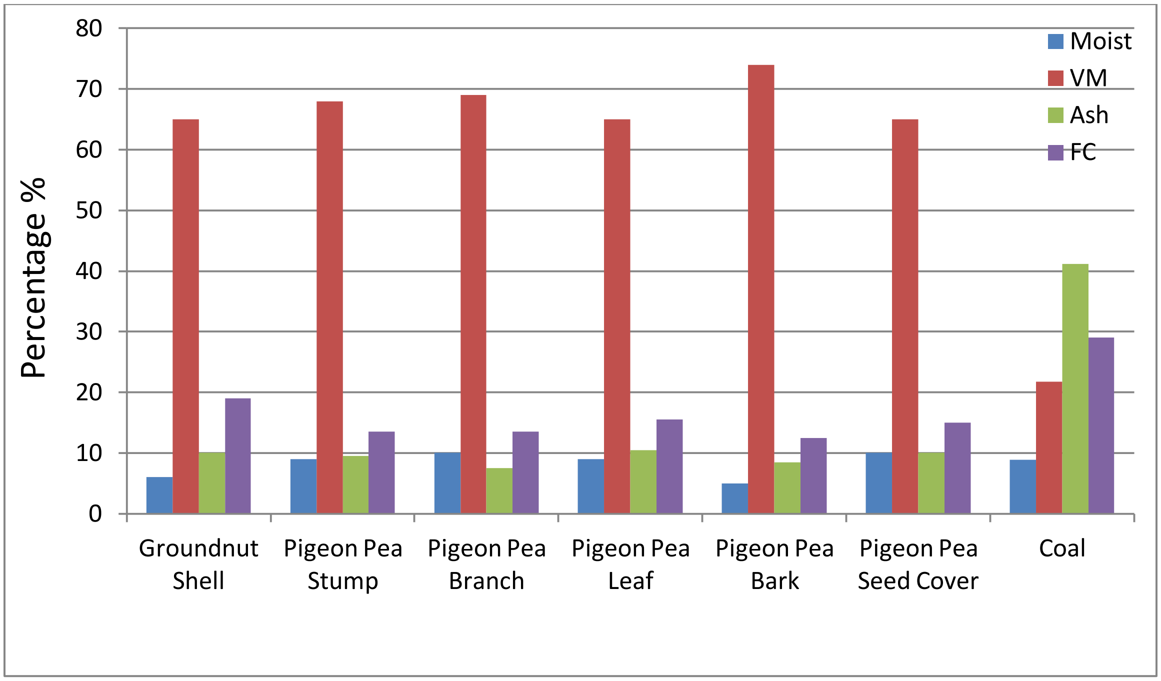

Figure: 4.1.1 Variation of Proximate Analysis of Groundnut Shell, Pigeon Pea and Coal

The proximate analysis and calorific values of different components of pigeon pea and groundnut shell, coal and coal-biomass mixed briquette in different ratios are presented in tables 4.1.1 to 4.1.7 and variation ofproximate analysis of mixed coal-biomass briquettes are shown in figure 4.1.1 to 4.1.7 Which shows that both the biomass species has less ash content and high volatile matter when mixes with coal in the ratio of 80:20.In conventional power plant bottom ash produced by the combustion of coal is a major problem, so it is always desires to use less ash content fuel.

Table 4.1.2: Proximate analysis and calorific values of Coal-Biomass (Pigeon Pea Stump) mixed briquette in different ratios

Ratio (Coal: Biomass)	Proximate analysis wt. %, air dried basis				Calorific value (kcal /kg, dry basis)
	Moisture	Volatile matter	Ash	Fixed carbon	
95:05	8.90	24.10	39.62	27.38	4315.90
90:10	8.91	26.33	38.03	26.73	4394.80
85:15	8.92	28.65	36.45	25.98	4473.70
80:20	8.93	30.96	34.86	25.25	4552.60

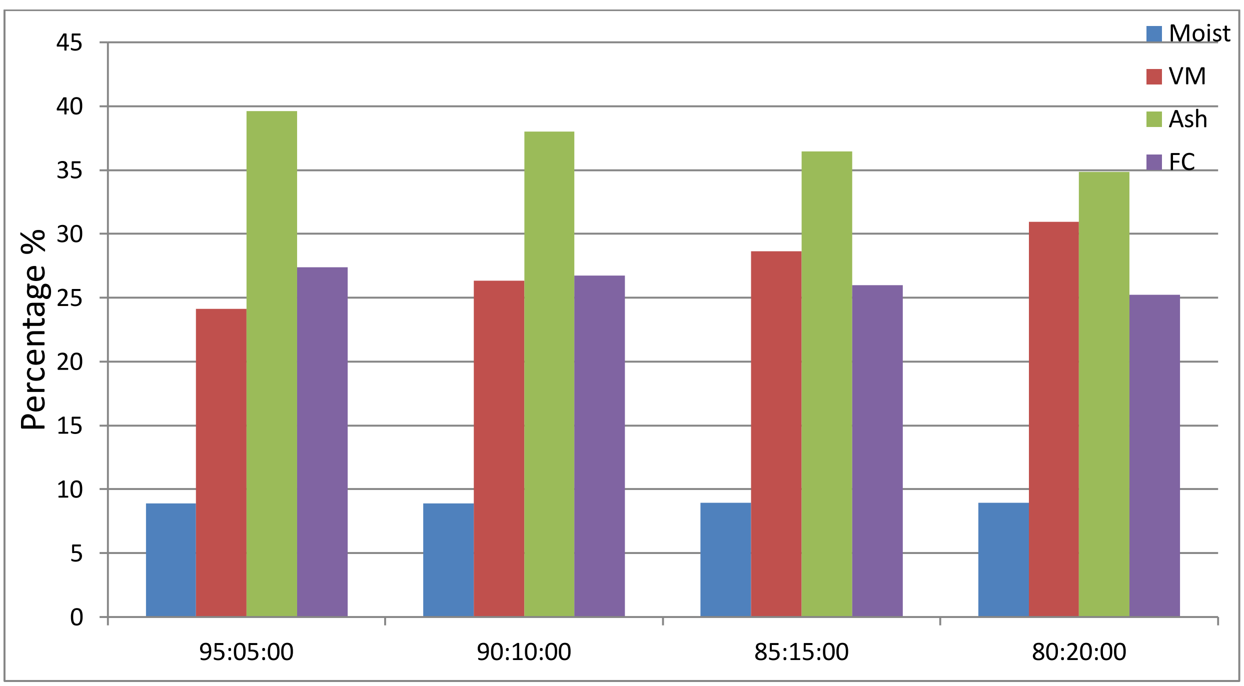

Figure: 4.1.2 Variation of Proximate Analysis of Mixed Coal-Biomass (Pigeon Pea Stump)

Table 4.1.3: Proximate analysis and calorific values of Coal-Biomass (Pigeon Pea Branch) mixed briquette in different ratios

Ratio (Coal: Biomass)	**Proximate analysis wt. %, air dried basis**				**Calorific value (kcal /kg, dry basis)**
	Moisture	**Volatile matter**	**Ash**	**Fixed carbon**	
95:05	8.95	24.06	39.52	27.50	4229.20
90:10	9.01	26.43	37.83	26.73	4221.40
85:15	9.06	28.79	36.14	26.00	4213.60
80:20	9.12	31.16	34.46	25.26	4205.80

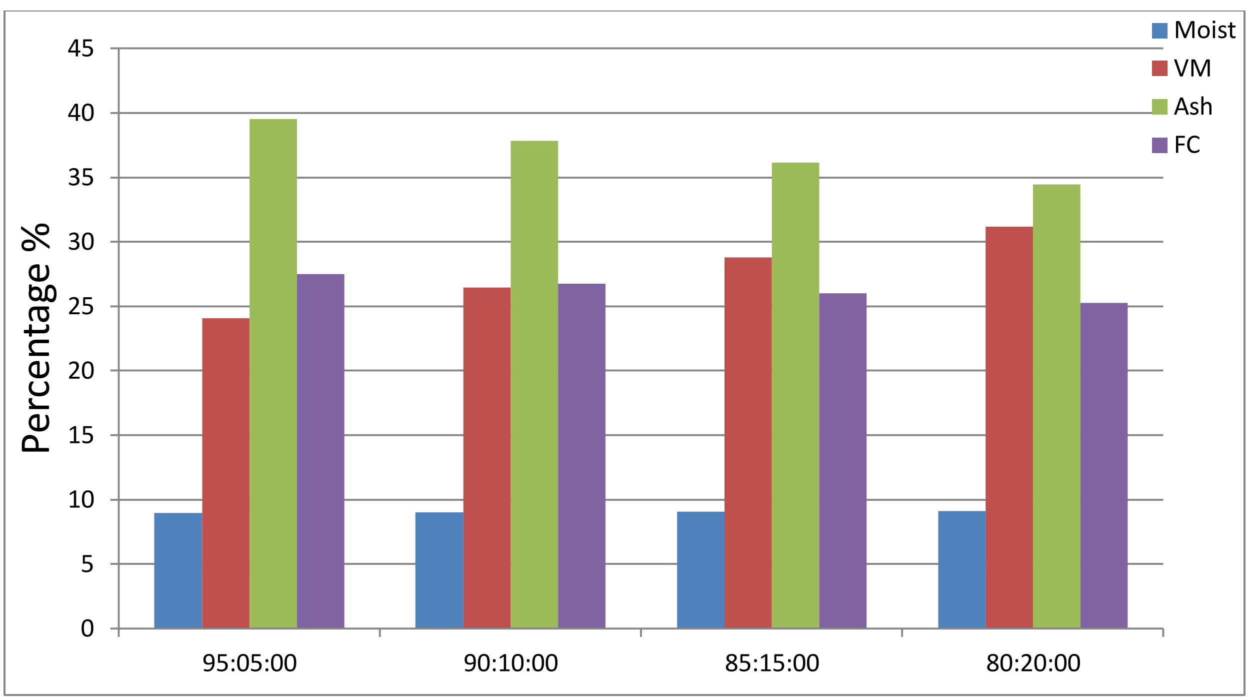

Figure: 4.1.3 Variation of Proximate Analysis of Mixed Coal-Biomass (Pigeon Pea Branch)

Table 4.1.4: Proximate analysis and calorific values of Coal-Biomass (Pigeon Pea Leaf) mixed briquette in different ratios

Ratio (Coal: Biomass)	Proximate analysis wt. %, air dried basis				Calorific value (kcal /kg, dry basis)
	Moisture	Volatile matter	Ash	Fixed carbon	
95:05	8.90	23.86	39.66	27.58	4306.65
90:10	8.91	26.03	38.13	26.93	4376.30
85:15	8.92	28.19	36.59	26.30	4445.95
80:20	8.93	30.36	35.06	25.65	4515.60

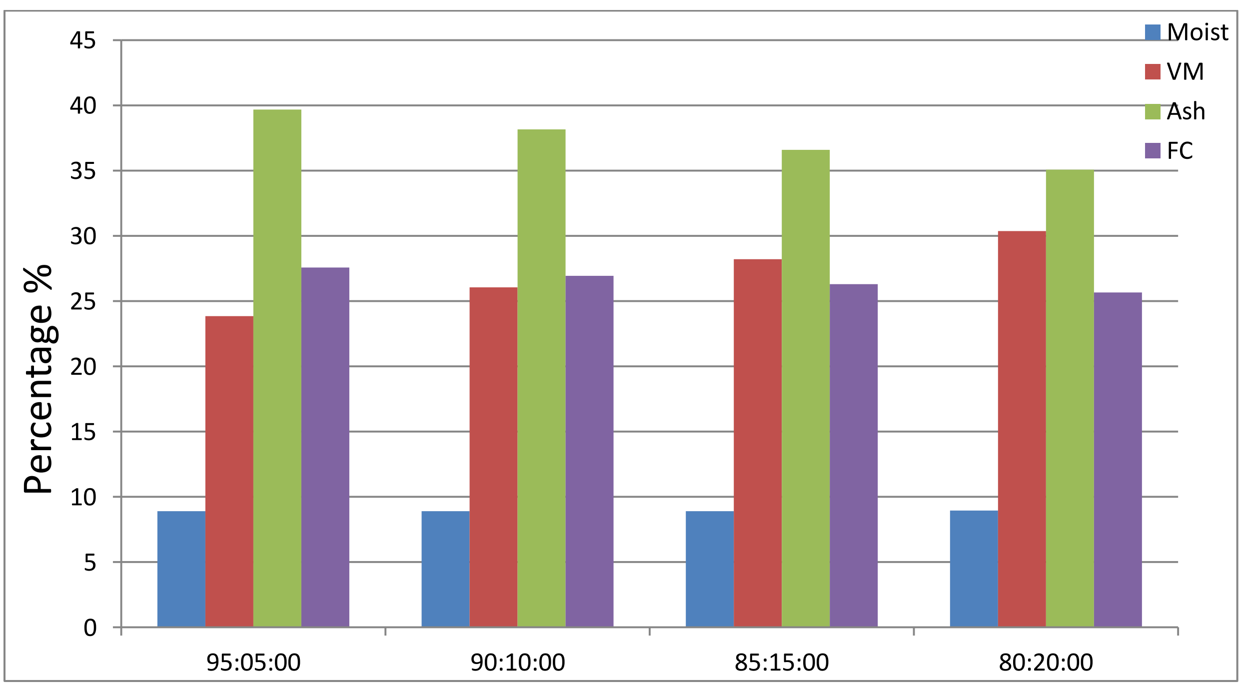

Figure: 4.1.4 Variation of Proximate Analysis of Mixed Coal-Biomass (Pigeon Pea Leaf)

Table 4.1.5: Proximate analysis and calorific values of Coal-Biomass (Pigeon Pea Bark) mixed briquette in different ratios

Ratio (Coal: Biomass)	Proximate analysis wt. %, air dried basis				Calorific value (kcal /kg, dry basis)
	Moisture	Volatile matter	Ash	Fixed carbon	
95:05	8.70	24.31	39.56	27.43	4217.45
90:10	8.51	26.93	37.93	26.63	4197.90
85:15	8.31	29.54	36.29	25.86	4178.37
80:20	8.12	32.16	34.66	25.06	4158.80

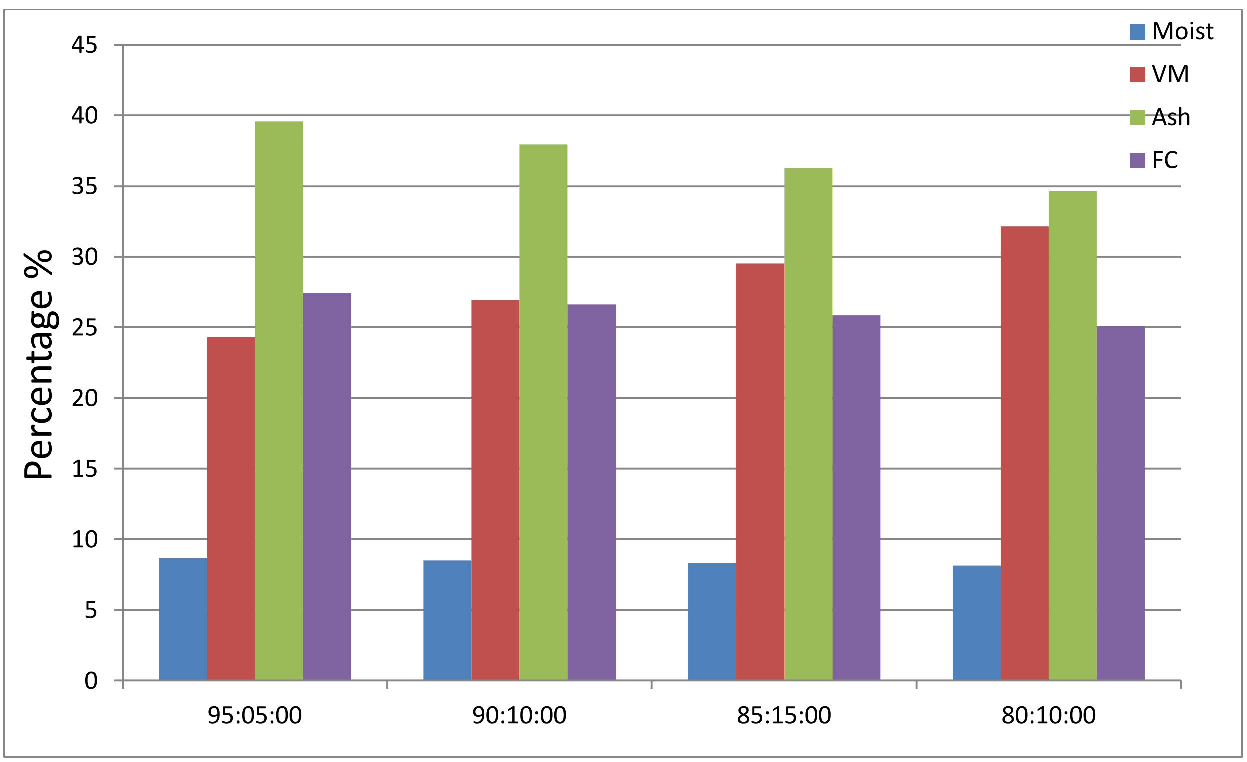

Figure: 4.1.5 Variation of Proximate Analysis of Mixed Coal-Biomass (Pigeon Pea Bark)

Table 4.1.6: Proximate analysis and calorific values of Coal-Biomass (Pigeon Pea seed cover) mixed briquette in different ratios

Ratio (Coal: Biomass)	Proximate analysis wt. %, air dried basis				Calorific value (kcal /kg, dry basis)
	Moisture	Volatile matter	Ash	Fixed carbon	
95:05	8.95	23.86	39.64	27.55	4229.2
90:10	9.01	26.03	38.08	26.88	4221.4
85:15	9.06	28.19	36.52	26.23	4213.6
80:20	9.12	30.36	34.96	25.56	4205.8

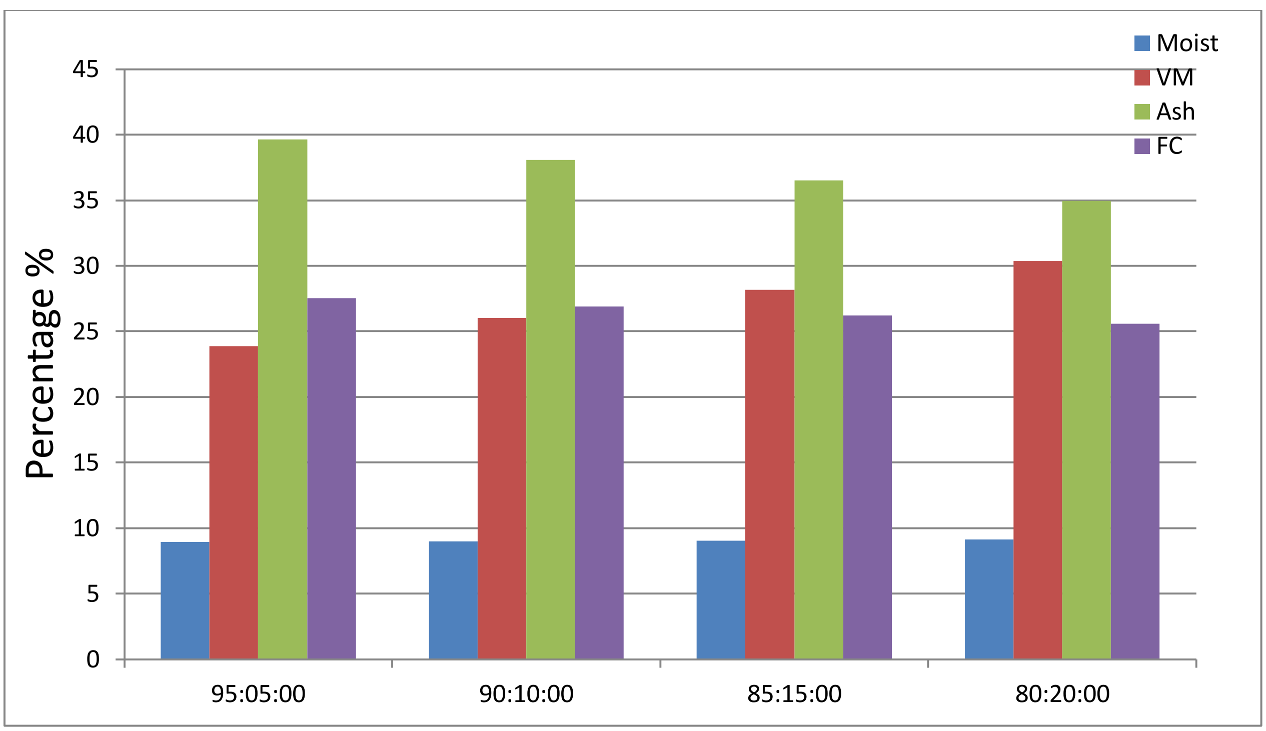

Figure: 4.1.6 Variation of Proximate Analysis of Mixed Coal-Biomass (Pigeon Pea seed cover)

Table 4.1.7:Proximate analysis and calorific values of Coal-Biomass (Groundnut Shell) mixed briquette in different ratios

Ratio (Coal: Biomass)	Proximate analysis wt. %, air dried basis				Calorific value (kcal /kg, dry basis)
	Moisture	Volatile matter	Ash	Fixed carbon	
95:05	8.75	23.865	39.64	27.74	4207.87
90:10	8.61	26.03	38.08	27.28	4178.75
85:15	8.46	28.19	36.52	26.82	4149.63
80:20	8.32	30.36	34.96	26.36	4120.51

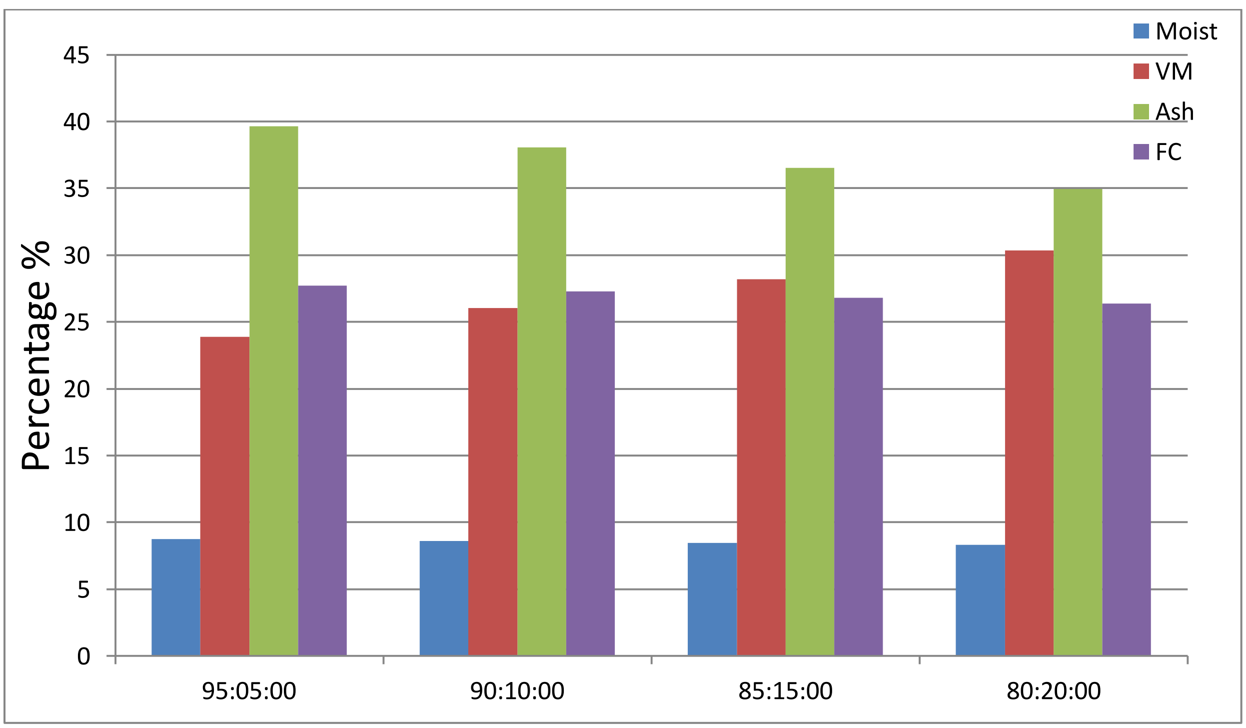

Figure: 4.1.7 Variation of Proximate Analysis of Mixed Coal-Biomass (Groundnut Shell)

4.2 Calorific Values of Presently Selected Agricultural Residue Components:

Power generated from any fuel energy sources can be estimated on the basis of calorific value of the fuel sources due to which calorific values of the fuel energy source is an important criteria to judging its quality to be used in electricity generation in power plants. It gives an idea about the energy content ofthe fuel and the entrant of electricity generation.

Comparison of the data presented in Table 4.1.1 to 4.1.7 shows that different component of pigeon pea has higher calorific value as compared to groundnut shell. Calorific values of this biomass and mixture with coal has also shown when they mixes in different ratios. Components of pigeon pea has higher calorific value with selected coal, due to that when it mixes with coal calorific value of mixture increase as the quantity of pigeon pea biomass increases in the mixture of coal-biomass briquette.

4.3. Estimation of Decentralize power generation Structure in Rural Areas:

For the estimation of power generation to meet the electricity requirement of villages, a group of 10-15 villages consisting of 3000 families may be considered for which one power station could be planned. The electricity requirement of lighting and domestic work in these villages may be assumed to be order of 6000 kWh/day. In addition to it, a power requirement of 14000 KWh/day (approximate) may be considered for agriculture (irrigation and small scale industries installed in the considered group of villages. Therefore a power plant (to be installed in a group of villages) should have a capacity to generate 6000 + 14000 = 20,000 kWh/day (73×10^5 kWh/year) for a group of 10-15 villages.

The design of energy, plantations from pigeon pea and groundnut biomass species for power plant having a capacity, of 20,000 kWh/day have been presented in Table 4.3.1 The results indicate that in order to meet the yearly power requirement of the order of 73×10^5 kWh for a group of 10-15 villages, 4315 ha (in case of use of pigeon pea residue) and 4315 ha (in case of use of groundnut shell) should always be ready for harvesting, in order to have perpetual generation of power.

Table 4.3.1: Total energy contents and power generation structure from pigeon pea and groundnut shell

Component	Calorific value (kcal /t, dry basis)	Biomass production (t/ha dry basis)	Energy value (kcal/ha)
Stalk	5815×10^3	0.50	2907×10^3
Branch	4081×10^3	0.30	1224×10^3
Leaf	5630×10^3	0.10	563×10^3
Bark	3846×10^3	0.05	196×10^3
Seed cover	4081×10^3	0.20	817×10^3
Groundnut Shell	3654.59×10^3	1.341	4900.80×10^3

. But when coal-biomass mixed briquette is used as fuel for power generation in the ratio of 80:20 it is found that it requires 197.91 ha (in case of use of coal and pigeon pea residue) and 891.33 ha (in case of use of coal and groundnut shell) land which is more feasible because it reduces the dependency on agricultural residue and also land requirement for plantation.

4.4 Energy Calculations for Pigeon pea Biomass

4.4.1 If only biomass (pigeon pea) is used as fuel

Total energy from one hectare of land $= (2907 + 1224 + 653 + 193 + 817) \times 10^3$

$= 5704 \times 10^3$ kcals

It is assumed that conversion efficiency of thermal generators using coal-biomass mixed briquette as fuel = 30 % and mechanical efficiency of the power plant = 85 %.

Energy value of 30% thermal generators = $5704 \times 10^3 \times 0.30$

= 1712×10^3 kcals

= 1990.2 kWh

Power generation at 85 % overall efficiency = 1990.2×0.85

= 1691.67 kWh /ha

Land required for supplying electricity for the whole year

$=73\times10^5/1691.67$

=4315 hectares

4.4.2 If coal-biomass (pigeon pea) mixed briquette in 80:20 ratio is used as fuel

Total Energy = $(4552.60+4205.80+4515.60+4158.80+4205.8) \times 10^3$ kcal/t

$=21638.6 \times 10^3$ kcal/t

Energy value at 30%efficiency ofthermal generators and power generation at 85 % overall efficiency

$=21638.6 \times 10^3 \times 0.30 \times 0.85$ kcal/t

$=5517.843 \times 10^3$ kcal/t

=6414.49 kWh/t

Coal-biomass required for the whole year

$=73\times10^5/6414.49$

=1138 t

Total biomass required

$=1138 \times 0.2$

=227.6 t

Total biomass production/hectare

$=1.15$ t/ha

To supply 227.6 t biomass land required

$=227.6/1.15$

$=197.91$ ha

4.5 Energy Calculations for Groundnut Shell Biomass

4.5.1 If only biomass (groundnut shell) is used as fuel

Biomass (groundnut shell) production dry basis

$= 1.341$ t/ha

Calorific value (kcal /t, dry basis)

$= 3654.59 \times 10^3$ kcal/t

Total energy from one hectare of land

$= 3654.59 \times 10^3 \times 1.341$ kcal/ha

$= 4900 \times 10^3$ kcal/ha

Energy value at 30%efficiency ofthermal generators and power generation at 85 % overall efficiency

$= 4900 \times 10^3 \times 0.3 \times 0.85$

$= 1249.70 \times 10^3$ kcal/ha

$=1452.78$ kWh/ha

Land required for supplying electricity for the whole year

$=73\times10^5/1452.78$

$=5024.84$ ha

4.5.2 If coal-biomass (groundnut shell) mixed briquette in 80:20 ratio is used as fuel

Calorific value of coal-biomass mixed briquette(kcal /t, dry basis)

$=4120.518 \times 10^3$ kcal/t

Energy value at 30%efficiency ofthermal generators and power generation at 85 % overall efficiency

$= 4120.518 \times 10^{3} \times 0.3 \times 0.85$

$= 1050.73 \times 10^{3}$ kcal/t

= 1221.47 kWh/t

Coal-biomass required for the whole year

$= 73 \times 10^{5}/1221.47$

= 5976.37

Total biomass required

= 5976.37 x 0.2

= 1195.27 t

To supply 1195.27 t biomass land required

= 1195.27/1.341

= 891.33 ha

CHAPTER-5
CONCLUSIONS

5.1 CONCLUSIONS

In the present work two non-woody biomass species pigeon pea and ground nut shell were selected. Experiments to determine the proximate analysis, calorific values and ash fusion temperature was done on each of the components of the selected species such as stump, bark, branch, leaf and nascent branch were performed. Estimation has done to analyze how much power can be generated and land requirement for plantation for each of these species. The following are the different conclusions drawn from the present work:

1. Both plant species (pigeon pea and ground nut) showed almost the similar proximate analysis result for their components .Pigeon pea has higher calorific value than groundnut shell.
2. Groundnut shell has lower calorific value, ash content and higher volatile matter than selected coal sample due to that when the percentage of groundnut shell increases in the coal-biomass briquette calorific value and ash content decreases and volatile matter increases.
3. In case of pigeon pea biomass calorific value and volatile matter is higher and ash content is lower than selected coal sample due to that when percentage of pigeon pea increases in the coal-biomass briquette calorific value and volatile matter increases and ash content is decreases.
4. The pigeon pea biomass species showed highest energy values for their branch, followed by wood, leaf and nascent branch.
5. Amongst the four different ratio80:20 gives the less ash content and higher volatile matter and energy value compared to 95:05, 90:10, 85:15.

6. Energy values of coal mixed pigeon pea biomass component were found to be little bit higher than that of coal mixed groundnut shell biomass.
7. In order to meet the yearly power requirement of the order of 73 x 10^5 kWh for a group of 10-15 villages, 4315 ha (in case of use of pigeon pea residue) and 5024.84 ha (in case of use of groundnut shell) land are required for plantation but when coal-biomass mixed briquette is used as fuel for power generation in the ratio of 80:20 it is found that it requires 197.91 ha (in case of use of coal-pigeon pea briquette) and 891.33 ha land(in case of use of coal- groundnut shell briquette).
8. This study could be positive in the exploitation of non-woody biomass species for power generation.

5.2 SCOPE FOR FUTURE WORK

1. Similar type of study can be extended for another non-woody biomass species available in the local area or can be select from the table1.7.1
2. Pilot plant study on laboratory scale may be carried out to generate electricity from biomass species.
3. The powdered samples of these biomass species may be mixed with cow dunk and the electricity generated potential of the resultant mixed briquettes may be studied.
4. New techniques of electricity generation from biomass species may be developed.

CHAPTER-6

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