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A Resurch Literature Survey On Power Generation Potential Of Non-Woody Biomass And Coal-Biomass Mixed Briquettes

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Abstract:

This paper is a review of research work of last few years on Non-woody Biomass and coal-biomass Mixed Briquettes. It features a broad discussion on the application of biomass. In this paper we are discussing classification & properties of bio-mass, Technology for decentralized power generation, power generation potential from biomass & bagases based cogeneration, A source of power generation in small industries, Environmental & climate change benefits, A Research literature survey on biomass, Advantages & Scope for future work also. There are various type of renewable energy sources such as solar, wind, hydropower, biomass energy etc. out of these renewable energy 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 reduction 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. Presently, co-firing (coal + biomass) has been proved to be more attractive and economically viable technique for power generation. In the present work, briquettes were prepared by mixing non-coking coal from Orissa mines and the related biomass species in different ratio (coal: biomass = 95:05, 90:10, 85:15, 80:20). The objectives have been to examine their energy values and power generation potential.

Keywords: *proximate analysis, ash fusion temperature, electricity generation, energy content, non-woody biomass species.*

1.Introdction

Biomass is renewable organic matter derived from trees, plants, crops or from human, animal, municipal and industrial wastes. Biomass can be classified into two types, woody and non-woody. Woody biomass is derived from forests, plantations and forestry residues. Non-woody biomass comprises agricultural and agro industrial residues and animal, municipal and industrial wastes. Biomass does not add carbon dioxide to the atmosphere as it absorbs the same amount of carbon in growing as it releases when consumed as a fuel. Its advantage is that it can be used to generate electricity with the same equipment that is now being used for burning fossil fuels. Biomass is an important source of energy and the most important fuel worldwide after coal, oil and natural gas. Bio-energy, in the form of biogas, which is derived from biomass, is expected to become one of the key energy resources for global sustainable development. Biomass offers higher energy efficiency through form of Biogas than by direct burning. Biomass contains stored energy from the sun. Plants absorb the sun's energy in a process called photosynthesis. The chemical energy in plants gets passed on to animals and people who eat these plants. Biomass is a renewable energy source because we can always grow more trees and crops and waste will always exist.

Figure 1: Bio-mass plant

1.1.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 disturbed by its availability and cost.

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

2.Power Generation Potential From Biomass And Bagasse Based Cogeneration

Biomass resources are potentially the world's largest and most sustainable energy sources for power generation in the 21st century (Hall & Rao, 1999). 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 (Ministry of New and Renewable Energy). The details of the estimated renewable energy potential and cumulative power generation in the country have been outlined in Table1.1 (MNRE, 2011), indicating that the available biomass has a potential to generate around 17,000 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 (http://mnre.gov.in/prog-biomasspower.htm).

S.No	Resources	Cumulative Achievements (in MW upto 31.01.2011)
Deployment of Off-grid / decentralized renewable energy systems		
Off-Grid/Distributed Renewable Power (including Captive/Cogeneration Plants)		
1.	Biomass Power / Cogen.(non-bagasse)	274 MW
2.	Biomass Gasifier	128 MWeq
3.	Waste-to- Energy	68 MWeq
4.	Solar PV Power Plants	4 MWp
5.	Aero-Generators/Hybrid Systems	1 MW
	Total	**461 MWeq**
Decentralized Energy Systems		
1.	Family Type Biogas Plants	43.26 lakh
2.	SPV Home Lighting System	6,69,805 nos.
3.	Solar Lantern	8,17,549 nos.
4.	SPV Street Lighting System	1,22,697 nos.
5.	SPV Pumps	7,495 nos.
6.	Solar Water Heating - Collector Area	3.97 million sq.m.

Table 1: Deployment off-grid/decentralized renewable energy system

Sl. No.	Name of the State	Installed			Under Installation			Grand Total		
		Nos.	M^3	KW	Nos.	M^3	KW	Nos.	M^3	KW
1.	Andhra Pradesh	16	1785	197	30	3265	358	46	5050	555
2.	Bihar	0	0	0	2	50	6	2	50	6
3.	Gujarat	2	285	30	13	1105	130	15	1390	160
4.	Haryana	1	2200	115	1	170	20	2	2370	135
5.	Karnataka	40	6005	621.5	47	5275	570.5	87	11280	1192
6.	Maharashtra	34	5160	539.5	18	1785	200	52	6945	739.5
7.	Punjab	6	865	97.5	8	3155	333	14	4020	430.5
8.	Rajasthan	0	0	0	3	190	21	3	190	21
9.	Tamil Nadu	15	1710	193.5	36	27695	2900.5	51	29405	3094
10.	Uttarakhand	3	205	21	4	265	32	7	470	53
11.	Uttar Pradesh	0	0	0	12	1350	155	12	1350	155
12.	Madhya Pradesh	1	350	25	1	35	3	2	385	28
13.	Chhattisgarh	1	170	45	1	85	10	2	255	55
14.	Kerala	36	1010	118	3	75	9	39	1085	127
15.	West Bengal	1	340	60	0	0	0	1	340	60
16.	Odisha	0	0	0	1	30	4	1	30	4
	Total	**156**	**20085**	**2063**	**180**	**45540**	**4752**	**336**	**64615**	**6815**

Table 2: State-wise/Year-wise List of Commissioned Biomass Power/Cogeneration Projects in MW (as on 31.03.2011)

3.Biomass-A Source Of Power Generation In Small Scale Industries

In India, there are over 11 million small-scale registered industrial units that provide employment to more than 27 million people (Kumar & Patel, 2008). They contribute to 40% of the country's industrial production and 34% of exports. A major number of these units require large quantities of electrical energy. The high cost of supply, which is mostly unpredictable and unreliable on account of scheduled / unscheduled power cuts, drives industries to invest in imprisoned power generation. As fossil fuels are limited and polluting, such order provides an attractive platform to renewable for providing different energy solutions to particularly small and medium enterprises, industrial and commercial establishments. Biomass energy systems can be deployed to meet power requirement in industries. Such electricity generation will help industries in becoming independent and relieve pressure on fossil fuels.

4.Biomass-Environmental And Climate Change Benefits

Over the past few years, people throughout the world have become very much aware of the terms 'global warming' and 'greenhouse gases'. This has to do with what is going into the atmosphere and how it affects our way of life. When fossil fuels are burned they send carbon dioxide (CO2), sulphur oxides (SOx), NOx emissions and ash production into the atmosphere. It is believed that these emissions stay there for tens of thousands of years and are creating a barrier, which separates the earth from the sun. Reducing this threat to the atmosphere is one of the Environmental Benefits of Biomass.

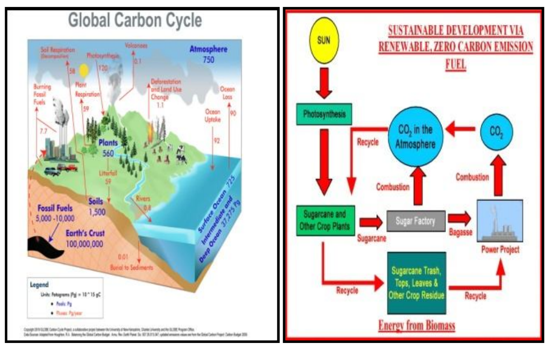

Figure 2: Carbon cycle

5.Literature Survey On Bio-Mass

India's energy challenges are multi–pronged (Ravindranath et al, 2009). They are manifested through growing demand for modern energy carrie

a fossil fuel dominated energy system facing a severe resource crunch, the need for creating access to quality energy for the large section of deprived population, vulnerable energy security, local and global pollution regimes and the need for sustaining economic development. Renewable energy is considered as one of the most promising alternatives. Recognizing this potential, India has been implementing one of the largest renewable energy programmes in the world. Among the renewable energy technologies, bioenergy has a large diverse portfolio including efficient biomass stoves, biogas, biomass combustion and gasification and process heat and liquid fuels. India has also formulated and implemented a number of innovative policies and programmes to promote bioenergy technologies. However, according to some preliminary studies, the success rate is marginal compared to the potential available. This limited success is a clear indicator of the need for a serious reassessment of the bioenergy programme. Further, a realization of the need for adopting a sustainable energy path to address the above challenges will be the guiding force in this reassessment. In this paper an attempt is made to consider the potential of bioenergy to meet the rural energy needs:

- biomass combustion and gasification for electricity;
- biomethanation for cooking energy (gas) and electricity;
- efficient wood-burning devices for cooking.

The paper focuses on analysing the effectiveness of bioenergy in creating this rural energy access and its sustainability in the long run through assessing: the demand for bioenergy and potential that could be created; technologies, status of commercialization and technology transfer and dissemination in India; economic and environmental performance and impacts; bioenergy policies, regulatory measures and barrier analysis. The whole assessment aims at presenting bioenergy as an integral part of a sustainable energy strategy for India. The results show that bioenergy technology (BET) alternatives compare favourably with the conventional ones. The cost comparisons show that the unit costs of BET alternatives are in the range of 15–187% of the conventional alternatives. The climate change benefits in terms of carbon emission reductions are to the tune of 110 T C per year provided the available potential of BETs are utilized. A majority of the Indian population does not have access to convenient energy services (LPG, electricity) (Pillai et al, 2009).

Though India has made significant progress in renewable energy, the share of modern renewables in the energy mix is marginal. This paper reviews the status and potential of different renewables (except biomass) in India. The trends in the growth of renewables in India and establishes diffusion model as a basis for setting targets. The diffusion model is fitted tot the past trends for wind, small hydro and solar water heating and is used to establish future targets. The economic viability and greenhouse gas (GHG) saving potential is estimated for each option. Several renewables have high growth rates, for example wind, Photovoltaic (PV) module manufacture and solar water heaters. New technologies like Tidal, OTEC, Solar thermal power plants and geothermal power plants are at the demonstration stage and future dissemination will depend on the experience of these projects Bio-energy technologies (BETs) are presented as potential carbon abatement opportunities substituting fossil fuel or traditional (less efficient) biomass energy systems (Ravindranath et al, 2006). Cost of energy (produced or saved) of BETs is compared with fossil fuel and traditional biomass energy systems to estimate the incremental cost (IC). The IC of carbon abatement for each of the selected BETs (in

$kWh-1 or $GJ-1) is estimated using the carbon emission (tCkWh-1 or tC GJ-1) reduction obtained by substituting fossil fuel and traditional biomass alternatives. The abatement costs are estimated and compared for ten combinations of BETs (with seven technology alternatives) substituting conventional technologies. The analysis indicates that out of the ten project cases six have negative ICs in the range of 37 to 688 $ tC-1 and four have positive ICs in the range of 52–162 $ tC-1 mitigation. The negative ICs indicate that the suggested alternatives are cheaper than the original technologies. Thus, results indicate that the chosen BETs are cost-effective mitigation opportunities and are currently aggressive candidates under Clean Development Mechanism. 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 Ocimum canum and Tridax procumbens biomass species (both non-woody) and their impact on power generation and land requirement for energy plantations. The net energy content in Ocimum canum was found to be slightly higher than that in Tridax procumbens.

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 Ocimum canum and Tridax procumbens 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. The recent statements of both the European Union and the US Presidency pushed in the direction of using renewable forms of energy (Angelis-Dimakis et al, 2010), in order to act against climate changes induced by the growing concentration of carbon dioxide in the atmosphere. In this paper, a survey regarding methods and tools presently available to determine potential and exploitable energy in the most important renewable sectors (i.e., solar, wind, wave, biomass and geothermal energy) is presented. Moreover, challenges for each renewable resource are highlighted as well as the available tools that can help in evaluating the use of a mix of different sources 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. The heating value is one of the most important properties of biomass fuels for design calculations or numerical simulations of thermal conversion systems for biomass (Sheng et al, 2005). There are a number of formulae proposed in the literature to estimate the higher heating value (HHV) of biomass fuels from the basic analysis data, i.e. proximate, ultimate and chemical analysis composition. In the present paper, these correlations were evaluated statistically based on a larger database of biomass samples collected from the open literature. It was found that the correlations based on ultimate analysis are the most accurate. The correlations based on the proximate data have low accuracy because the proximate analysis provides only an empirical composition of the biomass. The correlations based on the bio-chemical composition are not reliable because of the variation of the components properties. The low accuracy of previous correlations is mainly due to the limitation of samples used for deriving them. To achieve a higher accuracy, new correlations were proposed to estimate the HHV from the proximate and ultimate analyses based on the current database.

The key technical issues in woody biomass pre-treatment (Zhu and Pan, 2010): barriers to efficient cellulose saccharification, pre-treatment energy consumption, in particular energy consumed for wood-size reduction and criteria to evaluate the performance of a pre-treatment. A post-chemical pre-treatment size-reduction approach is proposed to significantly reduce mechanical energy consumption. Because the ultimate goal of biofuel production is net energy output, a concept of pre-treatment energy efficiency (kg/MJ) based on the total sugar recovery (kg/kg wood) divided by the energy

consumption in pre-treatment (MJ/kg wood) is defined. It is then used to evaluate the performances of three of the most promising pre-treatment technologies:
steam explosion, organosolv and sulphite pre-treatment to overcome lignocelluloses recalcitrance (SPORL) for softwood pre-treatment. The present study found that SPORL is the most efficient process and produced highest sugar yield. Other important issues, such as the effects of lignin on substrate saccharification and the effects of pre-treatment on high-value lignin utilization in woody biomass pre-treatment, are also discussed.
The potential for the use of renewable sources of energy in China and India and their cost effectiveness in air pollution abatement in Asia is studied (Boudri et al, 2002) This is done through an integrated assessment of the costs and the environmental impacts of several types of renewables, in comparison with fossil fuels. Results for different scenarios for fuel use in China and India for the period 1990–2020 are presented. The acidification model RAINS-ASIA is used to analyse environmental impacts (exceedance of critical loads for acidification) and to perform an optimization analysis, aiming at minimizing abatement costs. The costs of sulphur dioxide (SO2) emission-control through the switch to renewable energy sources are analysed and compared with the costs of controlling the emissions from fossil fuels (e.g. through flue gas desulfurization). For the environmental targets analysed in this study an increased use of renewable energy could cut SO2 emission control costs in China by 17–35% and in India by more than two thirds Postulates that Thailand has a high potential to utilize renewable energy for electricity generation especially from agricultural waste (Santisirisomboon et al, 2000); however, at present only a small fraction of biomass is used for energy purposes. This study aims to estimate the potential of biomass power generation and its impact on power generation expansion planning as well as mitigating carbon dioxide emission from the power sector. The harvest area and crop yield per area are taken into consideration to estimate the future biomass availability. The supplies of biomass are then applied as a constraint in the least cost electricity generation expansion-planning model. The cost of CO emissions is also added to the fuel costs as carbon taxation to make biomass power generation competitive to fossil fuels and then the optimum value of CO charge is found out. In addition, levels of CO limitation from power generation are also introduced to mitigate CO emissions. Renewable energy is basic to reduce poverty and to allow sustainable development (Goldemberg and Teixeira, 2004). However, the concept of renewable energy must be carefully established, particularly in the case of biomass. This paper analyses the sustainability of biomass, comparing the so-called ‘‘traditional’’ and

‘‘modern’’ biomass and discusses the need for statistical information, which will allow the elaboration of scenarios relevant to renewable energy targets in the world. Biomass-based energy devices developed in recent times (Mukunda et al, 1994). The need for this renewable energy for use in developing countries is first highlighted. Classification of biomass in terms of woody and powdery (pulverized) follows, along with comparison of its energetics with fossil fuels. The technologies involved, namely gasifier-combustor, gasifier-engine-alternator combinations, for generation of heat and electricity, are discussed for both woody biomass and powdery biomass in some detail. The importance of biomass to obtain high-grade heat through the use of pulverized biomass in cyclone combustors is emphasized. The techno economics is discussed to indicate the viability of these devices in the current world situation. The application packages where the devices will fit in and the circumstances favourable for their seeding are brought out. It is inferred that the important limitation for the use of biomass-based technologies stems from the lack of recognition of their true potential. Calorific values of forest waste originating from forestry works such as woodland cleaning, reforestation and, all other silviculture tasks, were measured by static bomb calorimetry (Regueira et al, 2001). These waste materials, heretofore considered as useless refuse, are beginning to be used as alternative fuels in wide social sectors all over the world. Two of the main forest species, eucalyptus and pine existing in Galicia are included in this study. Some other parameters such as elementary chemical composition and heavy metal contents, moisture, density and ash percentage after combustion in the bomb, were also determined. The experimental results, with calorific values exceeding 20 000 kJ /kg make it advisable to use these materials as alternative fuel. Proposed a method to evaluate and exploit the energetic resources contained in different forest formations (Regueira et al, 2004). This method is based on the use of a combustion bomb calorimeter to determine the calorific values of the different samples studied. These results were complemented with chemical analysis of the samples and with environmental and geomorphological studies of the zones, samples were taken. Predicted ash fusion temperatures by using the chemical composition of the ash has previously been conducted only with linear correlations (Ozbayoglu and Ozbayoglu, 2005). In this study, a new technique is presented for predicting the fusibility temperatures of ash. Non-linear correlations are developed by using the chemical composition of ash (eight oxides) and coal parameters (ash content, specific gravity, Hardgrove index and mineral matter content). Regression analyses are conducted using information for Turkish lignites. Regression coefficients and variances of nonlinear and linear correlations are compared. The results show that the non-linear correlations are superior to linear correlations for estimating ash fusion temperatures.

Potential applications of renewable energy sources to replace fossil fuel combustion as the prime energy sources in various countries and discusses problems associated with biomass combustion in boiler power systems (Demirbas, 2005). Here, the term biomass includes organic matter produced as a result of photosynthesis as well as municipal, industrial and animal waste material. Biomass is an attractive renewable fuel in utility boilers. The compositions of biomass among fuel types are variable. Ash composition for the biomass is fundamentally different from ash composition for the coal. Especially inorganic constituents cause to critical problems of toxic emissions, fouling and slugging Metals in ash, in combination with other fuel elements such as silica and sulphur and facilitated by the presence of chlorine, are responsible for many undesirable reactions in combustion furnaces and power boilers. Elements including K, Na, S, Cl, P, Ca, Mg, Fe and Si are involved in reactions leading to ash fouling and slagging in biomass combustors.

6.Conclusion

This paper gives a detailed description of Non-woody Biomass and coal-bimass Mixed Briquettes In this paper we discuss the classification & properties of bio-mass, Technology for decentralized power generation, power generation potential from biomass & bagases based cogeneration, A source of power generation in small industries, Environmental & climate change benefits, A Research work literature on biomass & Scope for future work and following are the different conclusions drawn from the present work:

- Both plant species (Gulmohar and Cassia tora) showed almost the similar proximate analysis results for their components, the ash contents being more in their leaves and volatile matter content less in Cassia tora wood and leaf.
- Mixed ratio of Both biomass with coal(in four different ratio) also showed the same proximate analysis results, the ash contents being more when 95% coal mixing with 5% biomass and volatile matter is more when 80% coal mixing with 20% biomass.

- The non-wood biomass species showed highest energy values for their branch, followed by wood, leaf and nascent branch.
- Amongst the both biomass species Gulmohar has the highest energy value compared to Cassia tora.
- Amongst the four different ratio, ratio 80:20 gives the highest energy value compared to 95:05, 90:10, 85:15.
- Energy values of coal mixed Gulmohar biomass component were found to be little bit higher than that of coal mixed Cassia Tora biomass component.
- Calculation results have established that nearly 177 and 872 hectares of land would be required for continuous generation of 41242.38 kWh per hectares from Gulmohar and 8371.05 kWh per hectares from Cassia tora biomass species.
- The ash fusion temperature of all the species are coming above the range of boiler operation, this would avoid clinker formation in the boiler.
- This study could be positive in the exploitation of non-woody biomass species for power generation.

7.Scope For Future Work

The present study was concentrated on two non-woody biomass species such as Gulmohar and Cassia Tora. The following works are suggested to be carried out in future. Similar type of study need to be extended for another non-woody biomass species available in the local area.The biomass species may be mixed with cow dunk, sewage wastes, etc. in different ratios and the electricity generated potentials of the mixtures may be determined. Pilot plant study on laboratory scale may be carried out to generate electricity from biomass species. 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. New techniques of electricity generation from biomass species may be developed.

8.Reference

1. Angelis-Dimakis A., Biberacher M. and Dominguez J., Methods and tools to evaluate the availability of renewable energy sources, Renewable and Sustainable Energy Reviews, 15 (2011): pp. 1182-1200
2. Boudri J.C., Hordijk L., Kroeze C. and Amann M., The potential contribution of renewable energy in air pollution abatement in China and India, Energy Policy, 30 (2002): pp. 409–424
3. Demirbas A., Potential applications of renewable energy sources, biomass combustion problems in boiler power systems and combustion related environmental issues, Progress in Energy and Combustion Science, 31 (2005): pp. 171–192
4. Goldemberg J. and Teixeira Coelho S., Renewable energy—traditional biomass vs. modern biomass, Energy Policy, 32 (2004): pp. 711–714
5. International Energy Agency (IEA): www.iea.org/Textbase/techno/essentials.htm
6. http://www.ireda.gov.in
7. Kumar M. and Patel S.K., Energy Values and Estimation of Power Generation Potentials of Some Non-woody Biomass Species, Energy Sources, Part A: Recovery, Utilization and Environmental Effects, 30:8, (2008): pp. 765 – 773
8. Kumar A., Kumar K. and Kaushik N., Renewable energy in India: Current status and future potentials- Renewable and Sustainable Energy Reviews, 14 (2010): pp. 2434–2442
9. Ministry of New & Renewable Energy (MNRE): http://mnre.gov.in/prog-biomasspower.htm
10. Mukunda H.S., Dasappa S., Paul P. J., Rajan N.K.S. and Shrinivasa U., Gasifiers and combustors for biomass technology and field studies, Energy for Sustainable Development.1 (1994): pp. 27-38
11. Ozbayoglu G. and Ozbayoglu M.E., A new approach for the prediction of ash fusion temperatures: A case study using Turkish lignites, Fuel, 85 (2006): pp.545-552
12. Pillai I.R. and Banerjee R., Renewable energy in India: Status and potential, Energy, 34 (2009): pp. 970–980
13. Ravindranath N.H. and Balachandra P., Sustainable bioenergy for India: technical, economic and policy analysis, Energy, 34 (2009): pp. 1003–1013

14. Ravindranath N.H, Somashekar H.I., Nagaraja M.S., Sudh P. and Bhattacharya S.C., Assessment of sustainable non-plantation biomass resources potential for energy in India, Biomass and Bioenergy, 29 (2005): pp. 178–190
15. Ravindranath N.H., Balachandra P., Dasappa S. and Rao Usha K., Bioenergy technologies for carbon abatement, Biomass and Bioenergy, 30 (2006): pp. 826–837
16. Regueira L.N., Anon J. A. R., Castineiras J. P., Diz A. V. and Santovena N. M., Determination of calorific values of forest waste biomass by static bomb calorimetry, Thermochimica Acta, 371 (2001): pp. 23-31
17. Regueira L.N., Castineiras J. P. and Anon J. A., Design of an experimental procedure for energy evaluation from biomass, Thermochemica Acta, 420 (2004): pp. 29-31
18. Santisirisomboon J. and Limmeechokchai B., Impacts of biomass power generation and CO2 taxation on electricity generation expansion planning and environmental emissions, Fuel and Energy Abstracts, Energy Policy, 29 (2001): pp. 975-985
19. Sheng C. and Azevedo J.L.T., Estimating the higher heating value of biomass fuels from basic analysis data, Biomass and Bioenergy, 28 (2005): pp. 499–507
20. Zhu J.Y. and Pan X.J., Woody biomass pre-treatment for cellulosic ethanol production: Technology and energy consumption evaluation, Bio resource Technology, 101 (2010): pp. 4992–5002