Agricultural Waste to Energy for Rural India: A Smart way to Clean Energy

Chandra Shekhar Singh[1], Dr. R. K. Raghuwanshi[2]

[1, 2]Jims Engineering and Technical Campus, Gr.Noida, 201310 Uttar Pradesh, India

Abstract: ***India, where a majority of the populations are living in the rural area, can only maintain its rate of growth if the rural energy security is ensured. India's rural sector cannot be only dependent on the conventional source of energy. There are several renewable source of energy source that can not only fulfil the rural energy needs but also would be a step towards the sustainable & clean development. Rural agro waste in India might be an option for potential energy source and other valuable product that can enhance the standard of living of rural people. This paper represents the various feasible technologies that may a route to convert rural waste to clean energy in addition with environmental benefits.***

Keywords: Pyrolysis, Anaerobic, Fluidization, Briquetting

1. Introduction

In India about 70% populations (83.3 crore)[1] are living in rural area and the majority involve in agricultural activities. For the mobilization of this large population and to support their activities a huge amount of energy is required. There is huge gap between demand and supply. And this huge gap of energy can not only be fulfilled by the conventional source of energy at the economical price. So Agro waste available in rural area can be utilized to address this energy scarcity. Agrowaste[2] are the product of the various agricultural activities like harvesting waste, dairy farm manure, poultry waste etc. Agricultural waste has enormous potential to encounter the energy issue in rural India. However, to mitigate this problem of energy one should understand the pattern of energy consumption in rural India which is entirely different from the urban area. This paper present the various options and their impact to harness the energy from the locally available agro waste.

2. Energy consumption trend in India

In rural India, an individual house hold uses multiple form of energy. It also depends upon the individual's income group[3] (*Kowsari & Zerriffi, 2011).*Low income group of rural area widely use cow dung and fuel wood obtained from the nearby forests and usage of modern fuel like kerosene, LPG and electricity increases with the earning capacity of the family. However, India is a widely diverse country and the living pattern, food habits change rapidly. Although, majority of the rural people use biomass and kerosene to fulfill their energy needs. Table no.1 gives a general habit of energy use of the rural people in India.

Table 1: (Area of energy consumption in rural India)

Area of consumption	*Source of energy*
Cooking	Cow dung, fuel wood, harvest waste(crop residue),charcoal, LPG, kerosene, Electricity
Lightening	Kerosene ,electricity
Energy for agriculture activities like irrigation pump, farm machinery	Electricity, kerosene, diesel
Others like mobile charging, television set, computer etc.	Electricity, battery bank charged with solar photo voltaic cell

Source: field survey

Table no. 1 shows the few common areas where majority of the rural India consume energy. The pattern of energy consumption can also be differentiating according to the income level of the households. The pattern can be generalized by the classical energy ladder[3] in figure no.1. Integrated Energy Policy (2006) estimated that the minimum energy requirement of households of 5.5 people per month was 30 units for lightening and space heating. And 6 kg LPG per for cooking purposes (Planning Commission, 2006).Figure no.2 shows the type of fuels for the cooking purpose in rural India for the year 2009-2010. However, in recent years there has been a lot of change in energy consumption pattern for the energy in rural area but still majority of the population depends on the conventional fuel route for their energy need.

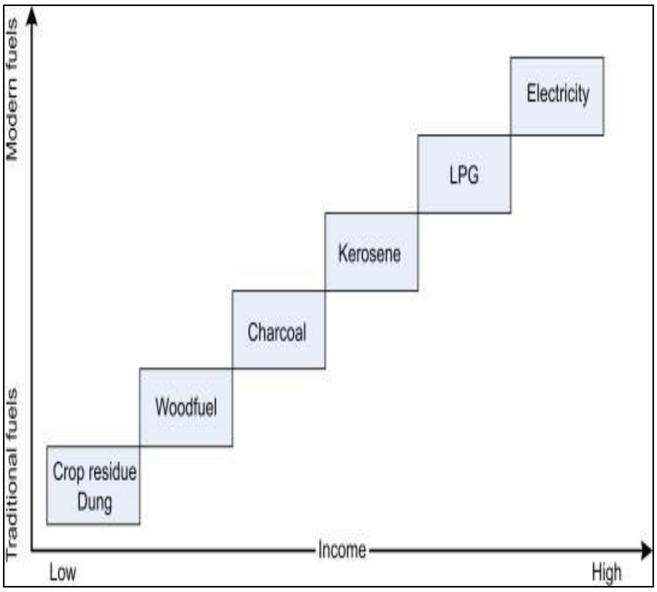
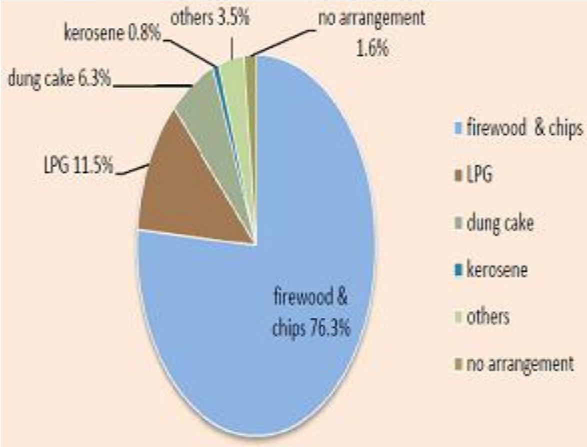


Figure 1: Classical Energy Ladder (*Kowsari & Zerriffi, 2011*)



3. Potential and Status of Biomass & Status of Biomass power in India

3.1 Potential and Status of Biomass

In India, two seasons are main for agriculture activities, one is Kharif and Rabi (monsoon period in north-east).Agricultural sector in India produces a great amount of the agricultural residue as by product. The total residue availability is estimated at 877 Mt[4] for 2030–31. Since, India is an agricultural country and a huge quantity of agro waste is available throughout the year. Approximate study shows, 350 million tonnes of agricultural waste is produced year round which can generate the 17,000 MWe of power. This large amount of waste could be utilized to produce biogas, biofuel, syngas and producer gas and feed stock for electricity generation to reduce the total energy demand of the rural area. Figure no.3 shows the availability and forecasting of different agro waste production in India.

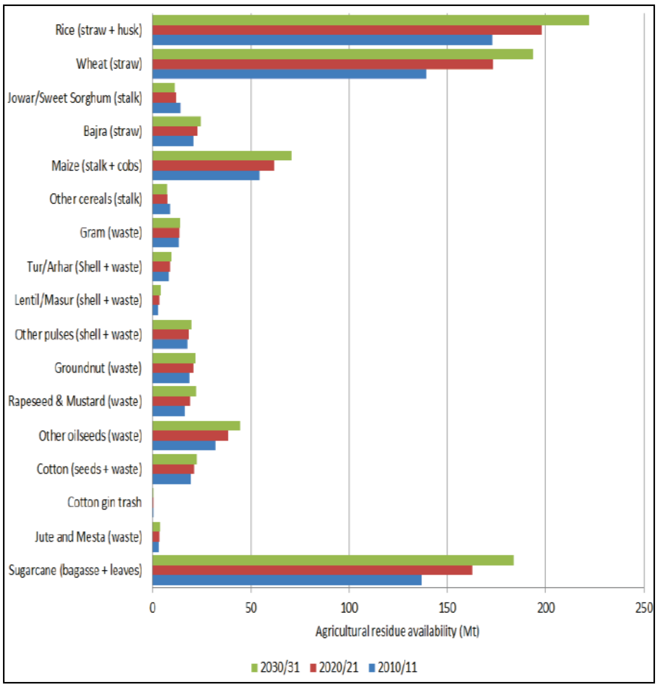


Figure 3: Various crop residues availability in India (Source: Biofuel road map of India, November 2015)

3.2 Status of Biomass Power in India

India has recognized the importance of the renewable biomass energy and a lot of work has been done in this regard. Ministry of new and renewable energy (MNRE), India (a separate ministry working in field of renewable energy) is dedicated to promote the use of renewable energy in urban and rural India. As in India more than 70% of the population depends upon the Biomass for their Energy needs. MNRE, Government of India has realized the power and potential of biomass/waste in India and has started a number of initiatives for the promotion of efficient conversion of biomass into the fuel. Table no.2 shows the cumulative achievement of the India in the field of biomass power production both grid interactive and off-grid. Table no 2 also shows the latest development in the installation of households biogas plant. it can observe from the table that biomass power generation from the agro residue alone is 4882.33MW.India is now looking for the rapid development in the fields of biomass power by promoting it by financial subsidy and awareness.

Table 2: Cumulative achievement in Bio power production in India (Source:MNRE,India)

No.	Sources / Systems	Achievement (as on 31.07.2016)
A. Grid-interactive renewable power		
1.	Biomass Power (Agro residues)	4882.33 MW
2.	Waste to Energy	122.58MW
B. Off-grid/Distributed Renewable Power (including Captive/CHP plants)		
3.	Biomass Power / Cogen.(non-bagasse)	651.91 MW
4.	Biomass Gasifier	182.39 MWeq
5.	Waste-to- Energy	161.39 MWeq
D. Decentralized Energy Systems		
6.	Family Type Biogas Plants	48.60 lakh
MWe = Megawatt equivalent; MW = Megawatt; kW = kilowatt; kWp = kilowatt peak; sq. m. = square meter		

4. Options for Converting the Agricultural Waste into Energy

It has reviewed that each species of agro waste has a specific yield, depending upon the condition of climate, soil, etc.For the converting the bio mass into the more suitable form in terms of efficiency and environmental concern following methods are being used at domestic as well as commercial level.

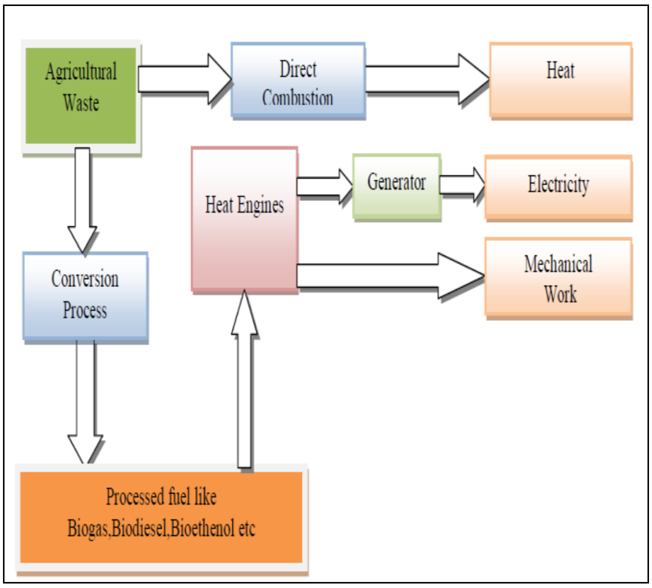


Figure 3: Block diagram for energy conversion route for agro waste

4.1 Anaerobic Digestion or Fermentation

Alcoholic fermentation is used for producing liquid fuel and anaerobic digestion to produce biogas. Plants of vegetables, crop straw, marine crop and manure which are having higher moisture content are more suitable for anaerobic digestion. Anaerobic digestion is the main principal for working for biogas plants in india.it is treatment of the biomass in absence of the air by naturally occurring microorganisms. Treatment of biomass produces mainly the mixture of methane (CH4) and carbon dioxide (CO2) with small traces of nitrogen (N2) and hydrogen sulphide (H2S).This mixture is commonly known as Biogas or Gobar gas in India. And the digested mass contains mainly N, P, K, which is very good fertilizer commonly known as bio fertilizer. The digestion process takes place in three basic steps. The first step is hydrolysis in which complex organic solids converted into soluble compounds. The second step is acidogenisis that involve the conversion of soluble organic materials into short chain acids and alcohols. And in third step which is methanogenesis, converts the yielding of second step into the gases by anaerobic bacteria.

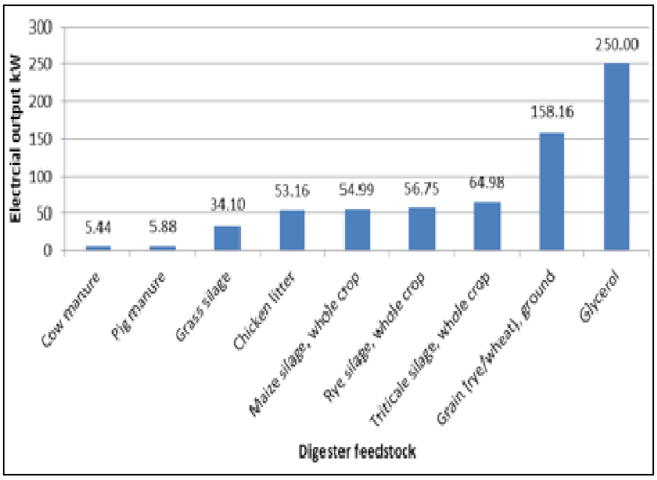


Figure 4: Approximate electrical output 1000tonnes/annum of agro waste (Source: Clarke energy website)

The methane content depends upon the type of waste and the percentage has been reported to vary between 50% to 80%. Biogas can be used for cooking purpose and the processed bio gas can be used for running I.C. engine to produce electricity and mechanical work. The figure no. 4 shows the equivalence of electrical output of per 1000 tonnes of agro waste.

In Indian scenario, Chanakya[5] et. al.2009 has discussed the anaerobic digestion of various biomass feed-stocks as potential source of energy for cooking and other activities. India's most of the household's biogas plants are using animal manure as a sole raw material for the biogas plant [6, 7]. For providing the clean cooking gas[8, 9] to the large population of the rural India, other non cow dung feedstock should be considered.

4.2 Pyrolysis

The biomass like plant residue mainly consists of organic extractive And inorganic minerals and cellulose, polyoses (65-75%) and lignin (18-35%) [10]. Weight percentage of this material depends upon the variety of the bio-mass. The material which is undergone to thermal change is cellulose and lignin. In thermal conversion process biomass converts into the bio-oil and char. And the yielding ratio depends upon the chemical composition and moisture content of the biomass.

Pyrolysis is a basic chemical reaction which can be considered as pre-stage of the both gasification and combustion process. Pyrolysis is a thermal conversion process of biomass in which chemical change caused by heat in absence of the air (oxygen).pyrolysis of the bio-mass results in gases, liquids and solid residues. The gas produced in pyrolysis mainly consists of hydrogen, carbon monoxide, carbon dioxide. Pyrolysis gas also constitutes some quantity of methane and other high hydrocarbons which depends upon the reactor design[11]. The liquid component of the pyrolysis product consists of methanol, acetone, acetic acid water and tar. And the solid part contains carbon and ash. The pyrolysis process may be fast or slow which also a factor in different product yielding. At present, fast pyrolysis is preferred technology with high temperature and short residence time.[12, 13]

Thus, pyrolysis can convert the waste biomass into the valuable product. And it is good renewable option associated with the conversion of solid biomass and waste in valuable liquid product which is easy to transport and storage.

4.3 Gasification

It is also the thermo-chemical process. In gasification process biomass waste converted into a low- medium energy gas utilizing sub-stoichiometric amounts of oxidant[14] (Coovattanachai, 1991). Air gasification is the most simple, cheap and reliable method of gasification. In this process biomass is subjected to partial combustion with limited air supply. The main problem is with the gas produced which is diluted with nitrogen and results in low calorific value. So its suitability is limited with on-site use for process heat. On the other hand, in the oxygen gasification pure oxygen is used to produce gas of high energy content. But this method requires an oxygen plant and thus increases the total cost. Simple air gasification can be of up draft, down draft and cross draft gasifier. They may be fixed bed or fluidized bed. Tar vapours leaving an up draft gasifier seriously interface the working of internal combustion engine, so down draft gasifiers[15] (Barret, et. al., 1985) are used in most of the cases.

A fluidized bed gasifier[16] (LePori and Soltes, 1985) contains a fluidized bed of inert media in which biomass is fed. The gas stream produced carries char with it which is generally separated by cyclone separators. Fluidized beds can gasify a large amount of biomass per unit time. The composition of the gas from the gasifiers depends on the type of biomass used, rate of reaction and the temperature.

4.4 Biomass Briquetting or Palletaization

Biomass briquetting technology[17] is another promising solution to the rural energy need by converting the rural agro waste in fuel briquettes. Agro residues have become one of the most suitable choices for briquetting. Some agro waste can be directly utilised for direct burning but in many cases, a majority of them are not suitable as they are uneven, low energy density and big in size. All these characteristics of agro waste make it burdensome to handle, store and its utility in raw form. Briquetting or palletizing technology can reduce the above mentioned problems associated with solid agro waste in rural India. Biomass briquetting is a densification process of the biomass, in which a set of technologies are used for the conversion of biomass into fuel. Briquetting improves the handling and storage characteristics of the biomass. This technology has been used to enhance the use of biomass in energy production, as it improves the calorific value of a fuel, reduces the handling cost. It can help the use of agro waste as a better fuel option in rural India. Some conversion technologies have been evaluated on the basis of technical, economic assessment, environmental impact and their social impact. The table no. 4 shows a comparative study of the conversion technologies in terms of waste to energy conversion.

Table 3: Evaluation of various conversion technologies (Source: based on reports on rural energy-2020 and TERI)

Technology	Technical Evaluation	Economic Assessment	Environme-ntal Impact	Social Impact
Households Bio gas	Suitable for remote and less developed rural areas for clean energy. not suitable in rich area of coal, solar, wind, and hydropower resources; not suitable in developed regions with access to modern energy Not suitable in regions that experience severe cold.	Cooking gas for household use, Produce high-quality fertilizer that can enhance the agro product yielding at low cost. Increase the financial returns by saving money for cooking gas and fertilizer purchase.	Reduce the waste water pollution by Utilizing livestock manure. Use of cooking gas reduces the indoor air pollution. Reduce the use of chemical fertilizer.	Increases the farmer's income by reducing the expenses on fertilizers, pesticides, and fuel. Reduces the households sanitation problem and improve health Employment generation in construction & maintenance of biogas digester and bio gas enterprise..
Briquetting technology	High energy density provides improved combustion characteristics with high combustion temperatures Biomass stoves burn at high efficiency and produce less pollutents..	It minimizes the labour and straw collection cost. Financial return is proportional to the affordability of pellet fuel price. Small scale production is more economical than large scale.	Its use provides better air quality then burning of conventional fuel. low emissions of particulate matter, CO,NH3, and SO_2, respiratory diseases.	supply of raw materials increases the farmers direct revenue.. Job opportunities in production of product in and manufacturing of fuel pallets, stove and raw material collection
Gsification	Recommended for Indian condition. Excess moisture can affect the production of clean energy. Heat value of producer gas depends upon the design and air used in gasification process. Tar, ash, and alkaline metals present in produces gas is difficult to remove at low cost.	Can be done at small scale. Cost can be reduced by drying of waste under sunlight.	Odour free clean energy	The social impact is similar to that of briquetting technique.

5. Conclusion

The dependence on only conventional fossil fuel cannot be a long term solution of energy demands of India' rural sector nation. The issue of rural energy demand can be addressed to a great extent by the adoption of the various energy conversion technologies of agro waste. And the renewable energy from the agro waste can provides enormous advantages in different way and can contribute significantly in the rural energy demand at least cost with environmental and social benifits.The pattern of energy consumption and a comparative benefits of various conversion technologies in rural India are discussed in this paper. The conversion of agro waste into energy not only solving the energy problem of rural people but also generates employment and neutralise the carbon in addition. Attempt should be made to develop the more efficient equipments and technology so that a decentralised energy system can be constructed with the help of locally available raw material like agro waste. The energy needs once fulfilled leads to the improvement living standard of the people and thereby nation's.

References

[1] Census of India's 2011
[2] Glossary of Environment Statistics, Studies in Methods, Series F, No. 67, United Nations, New York, 1997.
[3] Three dimensional energy profile:: A conceptual framework for assessing household energy use,R Kowsari, H Zerriffi,Energy Policy 39 (12), 7505-7517,2011.
[4] Purohit, P., Fischer, G. 2014. Second-Generation Biofuel Potential in India: Sustainability and Cost Considerations. United Nations Environment Programme (UNEP), Nairobi.
[5] Chanakya HN, Reddy BVV, Modak J. Biomethanation of herbaceous biomass residues using 3-zone plug flow like digesters—a case study from India. Renew Energy 2009;34:416–20.
[6] Bhat PR, Chanakya HN, Ravindranath NH. Biogas plant dissemination: success story of Sirsi, India. Energy Sustain Dev 2001;V(March (1)):39–41.
[7] Reddy AKN. The blessing of the commons. Energy Sustain Dev 1995;II(1):48–50.
[8] Goldemberg J, Johansson TB, Reddy AKN, Williams RH. A global clean cooking fuel initiative. Energy Sustain Dev 2004;VIII(3):5–12.[58]
[9] Reddy AKN. Rural energy consumption pattern—a field study—analysis of results. Biomass Bioenergy 1982;2(4):255–80.
[10] Rowell RM. The chemistry of solid wood. Washington, DC: American Chemical Society; 1984.
[11] Appel HR, Fu YC, Friedman S, Yavorsky PM, Wender I. Converting organic wastes to oil. US Burea of Mines Report of Investigation No. 7560; 1971.
[12] Mohan D, Pittman Jr CU, Steele PH. Pyrolysis of wood/biomass for bio-oil: acritical review. Energy Fuels 2006;20:848–89.
[13] Demirbas A. Producing bio-oil from olive cake by fast pyrolysis. Energy Sources Part A 2008;30:38–44C.
[14] Coovattanachai, N. 1991. Gasification of Husk for Small Scale Power Generation. RERIC International Energy Journal. 13(1):1-17.
[15] Barret, J.R., R.B. Jacko and C.B. Richey. 1985. Downdraft Channel Gasifier Furnace for Biomass Fuels. Transactions of the ASAE, American Society of Agricultural Engineers. Vol. (32): 592-598. St. Joseph, MI.
[16] LePori, W. A. and E. J. Soltes. 1985. Thermochemical Conversion for Energy and Fuel. In : Biomass Energy : A Monograph. E. A. Hiler and B. A. Stout : Editors. Texas A&M University Press, College Station, Texas, USA.
[17] Wilaipon, P. 2007. "Physical Characteristics of Maize Cob Briquettes under Moderate Die Pressure". *American Journal of Applied Science*. 4:995-998.