Empowering Rural India: Energy from Agricultural Residues

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Abstract: - **Energy is the prime factor in ascertaining real, fast paced and effective development. Electricity is one of the most crucial forms of energy. This paper discusses the generation of energy using agricultural residues as biomass feed to biomass based power plants. India is an agrarian country which has a tremendous potential to utilize this mode of electricity generation. The major breakthrough through this process would be the energizing and empowering of rural India. The paper discusses all the technical, economic as well as socio-economic aspects of implementing this mode of energy production.**

The three major utilizations of agricultural residues for generation of energy involve: Ethanol, Pyrolysis Oil and Electricity. These agricultural residues can be used as biomass feed to two different kinds of biomass based power plants viz. combustion plants and gasification plants. This paper discusses the various trade-offs of these processes and the usage of agricultural residues as feed to them. The technical as well as economic aspects of these processes are discussed especially referring to India. Finally, analyzing India's potential and shortcomings we have suggested a general outline of employing this modus operandi of generating energy in terms of electricity and economically empowering rural India.

Keywords: Agricultural Residues, Biomass, Combustion, Energy, Gasification.

I. INTRODUCTION

Today, with the global economic crisis up-surging, economies all around the world endeavor to attain stability. India being a largely agrarian economy is in need to reform its rationale behind how it manages energy. Farming has always been a major pedestal of India's economy. A farmer, an entrepreneur produces a variety of crops yet only 25 - 40 per cent of these crops earn him money while the rest 60 - 75 per cent termed as residue are wasted. Often this residue is burnt. With the advent of technology that utilizes this residue in producing energy, a land holding creates opportunities for an extra income for the farmer.

Coming to the focus of this paper "Energy (electricity) from Agricultural Residue", if this residue is used to generate electricity via biomass based power plants across the nation, rural India can be refurbished to complement urban India. This creates a myriad of opportunities to implement faster rural development. India's annual production of residue accounts to 500 million tons with the processing of agricultural produce by mechanical operations even more of residue is produced. These residues retain around 25 per cent of nitrogen, 25 per cent of phosphorous, 50 per cent of sulfur and 75 per cent of potassium from the original plant. Hence, these residues have a prodigious potential to accelerate India's energy growth.

1. Residues being burned by farmers

II. ENERGY FROM AGRICULTURAL RESIDUES – HOW?

There are many alternative uses of agricultural residues like livestock feed, soil fertilization, bagasse is used to produce paper, composting, thatching for rural homes, etc. But ethanol, pyrolysis oil or electricity produced from it act as sources of energy:

A. Ethanol

Ethanol, a transport fuel can be produced by lignocellulosic conversion of residue. Large plants have already been set up in Japan, US and Canada. This process is not exactly economical as of yet and imposes environmental threat. Hence, intensive R&D is going on. Theoretically, residues in India can produce 156 billion liters of ethanol, which could take care of 42 per cent of India's oil demand for the year 2012.

B. *Pyrolysis Oil*

Pyrolysis Oil is produced by quick combustion of biomass that is rapidly condensed to ensure oil generated is approximately equivalent to diesel. Charcoal (20%) is produced as a by-product and can be used as cooking fuel. Plants have been set up in US, Canada and China. Yet R&D is underway to optimize the process. In Sweden a 500 kW power plant is running successfully on pyrolysis oil. India has a capability of producing 400 billion kg of pyrolysis oil which could suffice 80 per cent of India's oil demand in 2012.

C. *Electricity*

Electricity can be produced from these residues via Biomass based power plants to different scales. Small scale power plants (500 kW) run on produce gas obtained from agricultural residue. Large scale power plants (10 – 12 MW) operate through combustion of these residues straight away. This process has been discussed in depth in the next section.

III. Biomass Based Power Plants

Biomass based power plants make use of biomass to generate energy. In our case fresh agricultural residue is the biomass. These plants are highly efficient and generate heat, process steam, electricity, synthesis gas, and/or bio-oil. Biomass based power plants produce electricity in two ways:

- From Combustion of Biomass
- From Gasification of Biomass

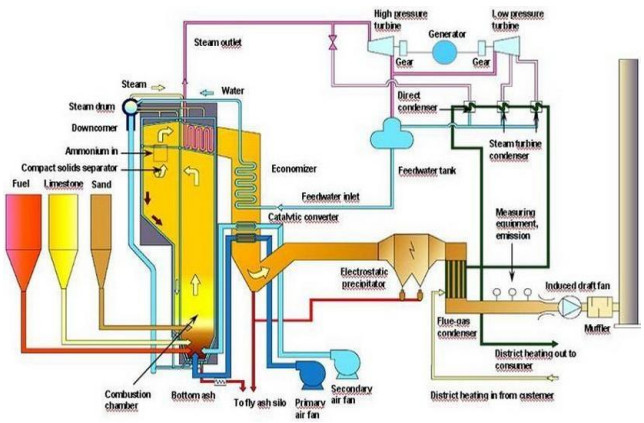
A. Energy from Combustion of Biomass

The working of these plants is similar to coal based power plants wherein the only difference is the use of agricultural residue as fuel instead of coal.

Biomass is pre-treated before the fuel is admitted onto a combustion grid where it is burnt. Heat of combustion is utilized in a boiler to generate heated steam. This steam in turn operates on a turbine and generates electricity. Such biomass combustion power plants generally require at least the following components:

- Residue storage to store the residue to be used as biomass fuel. Generally, the residue is stored in silos.
- The boiler where steam is generated by the combustion of residue.
- A turbine or a Generator to produce electricity from steam.
- A condenser to cool and condense the steam.

Sometimes, even pollution control equipment or devices are part of the plant.



2. Schematic Diagram of Direct Combustion

Agricultural residues are primarily of two types:

- Dry Residues – Straws or husks of crops fall under this category. These can be used directly in combustion plants.
- Wet Residues – These have a higher water content and are not efficient enough for direct combustion. Intensive pre-treatment is required.

Before any residue is used in the plant it needs to undergo a proximate as well as an ultimate analysis. The proximate analysis helps determine the moisture, volatile material, ash and carbon contained in the residue. This type of information guides the pre-treatment process. The ultimate analysis of residue to be used detects the elemental content i.e. amount of carbon, oxygen, nitrogen, sulfur, hydrogen and chlorine contained in the residue. Such information is a way to evaluate the usefulness of the residue as a combustion fuel. Higher is the content of carbon; higher is the quality of the residue to burn. A higher content of nitrogen or sulfur means the combustion process will emit high proportions of SO_x and NO_x gases which are pernicious to the environment. Also, before choosing any type of residue to be used its physical properties like variation in size, impurities present and density must be determined and taken into consideration.

Common examples of agricultural residues utilized as biomass fuel for combustion include rice straw, wheat straw, hay straw, barley straw, rape stalks, thistle stalk, husk, bagasse, etc.

3. Rice Husk 4. Wheat Straw 5. Crushed Bagasse

6. Wheat Straw 7. Sugarcane Bagasse Pellets 8. Barley Straw

B. Energy from Gasification of Biomass

Gasification plants give higher efficiency compared to combustion plants of the same dimensions. Also, lesser quantity of fuel is used up to generate equal amount of electricity as in a combustion plant. Gasification of biomass converts it into synthesis gas that is used in a gas engine to produce electricity and heat. The plant is compact and hence is very well suited for a rural setting.

This technology produces less CO_2 and NO_x gases per a unit of electricity generated. A gasification plant has a reduced environmental impact due to lesser amount of fuel consumed in the process. Decentralised stationing of plants helps minimize the losses due to complex and lengthy grid networks. Moreover, the same helps create employment opportunities for eco-friendly production of energy. Governments would tend to support small plants which operate locally utilising locally produced residue based biomass fuel.

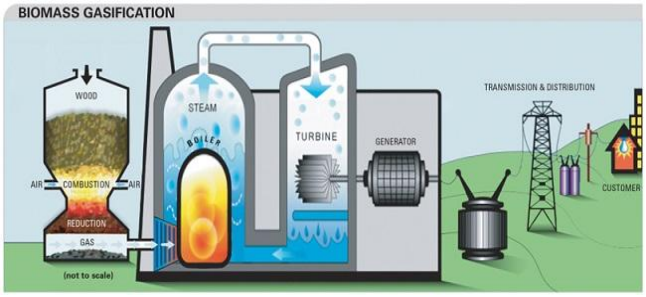
Changes in expected output i.e. electricity generated due to varying requirements of electricity can be handled with ease. This ensures elasticity in such plants' operation especially the amount and input rate of feed. Varying requirements of electricity can be understood from the fact that this mode of energy production supplements the traditional and other ways of doing the same.

One more advantage of this technology is that it requires no pre-treatment of residue based biomass fuel.

Working of a Gasification Plant: The heterogeneous biomass feed fed to the process undergoes a thermal chemical process aided by moist air.

The Reactor (Gasifier) – The reactor is divided into zones. The moisturized heterogeneous biomass is admitted to the reactor from the top. The upper zone encompasses a drying process. Under this zone is a zone where pyrolysis occurs. Pyrolysis is the process of thermochemical disintegration of organic substances at higher temperatures in anaerobic conditions. After these zones the feed passes through a zone of reduction where its gasification takes place. The bottom of the reactor consists of an integrated grate system above which combustive oxidation of the feed takes place. Hot moist air required for this oxidation process is supplied from the bottom of the reactor.

The process cracks down the heterogeneous feed at a molecular scale giving it a very homogeneous composition. This homogeneous product is known as Synthesis Gas (syngas). This syngas can be used to manufacture valuable products or it can be burned in a gas engine to generate electricity. This is in fact one of the most efficient know technology to produce electricity.



9. Schematic Diagram of Biomass Gasification

C. Potential of Biomass Based Power Plants

The efficiency of such plants is a function of the type of agricultural residues used, the technology employed, and availability of particular residues, location of plant with reference to the place where residues are to be produced or simply, the transporting distance, and a few other factors.

Biomass combustion plants can be scaled from 1 MW to 35 MW while biomass gasification plants can be set up to scales ranging from 2 – 10 KW to 2 – 5 MW.

Biomass gasification can become a way to enmesh private sector in this errand of energy generation from residues. Gasification plants operate at comparatively smaller scales than the combustion plants and hence, showcase a capability of alluring stakeholders which would eventually increase private sector involvement in the energy sector. Hence, the public sector may not need to be strained with this mammoth task of energizing a country as gigantic as India.

IV. The Quantitative Scenario

Let's for a moment imagine a world without electricity, doesn't it seem impossible. Mostly everything we do nowadays requires electricity. Electricity is a pioneer for development and a requisite for a higher standard of living. Here in India, agricultural activities are practiced on a very large scale. So, higher agricultural produce and hence, a higher amount of residue is generated.

A. Statistical Analysis of Agricultural Residues

Amongst the different types of agricultural residues generated throughout the nation, what proportion of them is really accessible to the energy production sector is a crucial point to be discussed when assessing the quantitative responsiveness of residual biomass.

The alternate courses of action for the utilization of crop residues are many in number. The table below enlists the surplus that remains to be exploited for energy production on a state wise scale:

State	Rice (Million tons)	Maize (Million tons)	Groundnut (Million tons)	Cotton (Million tons)	Mustard Rapeseeds (Million tons)	Coconut (Million tons)
Andhra Pradesh	11. 45	1. 43	2. 03	1. 66	NA	10. 93
Assam	4. 00	NA	NA	NA	0. 14	1. 36
Bihar	5. 42	1. 46	NA	NA	0. 10	NA
Chhattisgarh	3. 24	NA	NA	NA	NA	NA
Goa	NA	NA	NA	NA	NA	1. 25
Gujarat	1. 01	0. 62	0. 69	1. 16	0. 23	NA
Haryana	2. 68	NA	NA	1. 38	0. 55	NA
Himachal Pradesh	0. 68	NA	NA	NA	NA	NA
Jammu & Kashmir	NA	0. 53	NA	NA	NA	NA
Jharkhand	1. 64	0. 11	NA	NA	NA	NA
Karnataka	3. 73	2. 11	0. 90	0. 98	NA	17. 54
Kerala	0. 75	NA	NA	NA	NA	54. 96
Madhya Pradesh	0. 96	1. 20	0. 24	0. 24	0. 36	NA
Maharashtra	1. 95	0. 22	0. 46	1. 80	NA	2. 44
Meghalaya	NA	NA	NA	NA	NA	NA
Orissa	4. 61	NA	0. 06	NA	NA	1. 1
Punjab	9. 15	0. 46	NA	1. 20	0. 07	NA
Rajasthan	NA	1. 01	0. 18	0. 81	1. 31	NA
Tamil Nadu	7. 22	0. 19	1. 46	0. 33	NA	31. 58
Uttar Pradesh	11. 54	1. 49	0. 10	NA	0. 90	NA
West Bengal	12. 43	0. 09	NA	NA	0. 42	3. 31
Others	3. 09	0. 47	0. 10	0. 09	0. 13	1. 5
All India	85. 55	11. 39	6. 22	9. 65	4. 21	125. 9

According to a report by The Ministry of New and Renewable Energy, The Government of India, India has a scope of generating 2664.63 MW of electricity using agricultural residue as biomass based fuel in biomass based plants.

Given on the next page is a table that encompasses state wise biomass power generation projects and their outcome: (Everything in MW)

State	Up to 31.03.2003	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	Total
Andhra Pradesh	160.05	37.70	69.50	12.00	22.00	33.00	9.00	20.00	..	363.25
Bihar		--	--	--	--	--	--	--	9.50	9.50
Chhattisgarh	11.00	--	--	16.50	85.80	33.00	9.80	43.80	32.00	231.90
Gujarat	0.50	--	--	--	--	--	--	--	--	0.50
Haryana	4.00	--	2.00	--	--	--	--	1.8	28.00	35.80
Karnataka	109.38	26.00	16.60	72.50	29.80	8.00	31.90	42.00	29.00	365.18
Madhya Pradesh		1.00	--	--	--	--	--	--	--	1.00
Maharashtra	24.50	--	11.50	--	40.00	38.00	71.50	33	184.50	403.00
Punjab	22.00	--	--	6.00	--	--	--	34.50	12.00	74.50
Rajasthan		7.80	--	7.50	8.00	--	8.00	--	42.00	73.30
Tamil Nadu	106.00	44.50	22.50	--	42.50	75.00	43.20	62.00	92.50	488.20
Uttarakhand	--	--	--	--	--	--	--	--	10.00	10.00
Uttar Pradesh	46.50	12.50	14.00	48.50	--	79.00	172.00	194.50	25.50	592.50
West Bengal		--	--	--	--	--	--	16.00	--	16.00
Total	483.93	129.50	136.10	163.00	228.10	266.0	345.4	447.6	465.0	2664.63

V. SHORTCOMINGS

The issues with utilizing agricultural residue as biomass fuels and the process itself include:

- Lower efficiency compared to techniques using mineral oils and coal.
- The Food VS Energy imbalance can be a menace.
- Transportation costs of residues add to the total cost on a higher note making the process less economical.
- The process is not entirely impervious to environmental degradation pertaining to its GHG emissions.

Yet, with all its setbacks this process of power generation proves to be better than the traditional methods employed.

VI. CONCLUSION AND OUR SUGGESTIONS

After studying every aspect of the process of generation of electricity from agricultural residue utilizing biomass combustion or gasification plants, we believe with all their positive as well as negative trade-offs these processes can be put to action with certain bounds and an existence of equilibrium between the involvement of the private and public sectors into it.

Public Sector Involvement:

The main focus of governments should be the framing of policies that regulate, control and at the same time benefit these processes.

Private Sector Involvement:

Involvement of the private sector frees the government from working directly on field with the process and gives it an opportunity to administrate and actually govern the implementation of the whole idea. Moreover, this brings to light one more area for small scale private schemes to flourish and hence accelerates India's growth as well as creates business opportunities.

But since the efficiency of this process though high but not as high as the current methods employed, we suggest that these processes should be used for full fledge rural development. Electricity is the basis of development. Villages all around the nation can be equipped with small scale biomass plants that suffice that particular village's need for electricity. In this way every village can fruit from the gift of electricity. Also, since small scale plants can work on locally available agricultural residue, the transportation cost is eliminated which makes the electricity so generated very economical. This can make rural India independent of the urban cache. This would be a step to actually **Empower Rural India**.

These processes are substitutes to the use of coal and mineral oil for power generation. Coal and mineral oils are degrading gradually and their deposits are becoming scarcer. India hardly has any of these left with it and hence, a majority of capital or national income lost in imports pertains to the purchase of coal and mineral oil from other nationalities. The use of agricultural residue for power generation wherein the amount of residue generated within the domestic territory is enormous can help substantially depreciate the imports of coal and mineral oil.

To conclude, we would like to say that we think there can be no better utilization of what is commonly considered to be waste than using it to produce one of mankind's best known inventions: electricity.

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