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Agri charcoal as a fuel for power generation: An Initiative

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ABSTRACT

The prevention climatic changes induced by anthropological greenhouse gas emissions, is one of the of severe major challenges for the current and future generation of mankind hence this study investigates in providing a cheaper and cleaner fuel in burning from post harvesting agricultural wastes. Coal and wood have been the primary fuel used subsequently and produce lot of polluting gases like carbon monoxide, sulphur dioxide, carbon dioxide which has consequences on health. The agriculture waste is bio degradable and decomposes/burns. Since waste can be a source of energy after mixing the waste material of different calorific value, the agriculture waste can be converted into fuel cakes or by modifying charcoal by destructive distillation process by using of effective carbonizer. The results obtained with multifuel (Agri charcoal) further stronger the idea of setting small power plants, dedicated to rural sector of India.

Introduction

Particularly its electrical form of energy, has become virtually the life blood of human life. Undoubtedly, it is one of the most vital inputs to industry. In fact, there is no field of human activity where the role of energy can be under estimated. But, with a growing demand, both due to rise in populations as well as fast industrialization, the gap between the available electric power and its requirement is ever growing. With the fossil fuels gradually depleting and hydro sources having reached the verge of full exploitation, we have been compelled to think in terms of searching for and developing alternative sources of energy. Over the recent years the problem of environment pollution, sustainability and safety have been added to the scene, calling for development of power generation systems which are techno economically viable, sustainable and safe. Several alternative sources of energy are being thought of, including the nuclear, solar, geothermal, wind, tidal and the biomass based. Keeping in view the three fold objective stated above viz. Economic-viability, sustainability and safety, biomass as a source of energy holds a bright promise. In biomass too, agriwaste biomass is of particular interest to India, especially because our economy is agro-based.

Taking into account the utilization even a portion (say about 40%) of agri-residue & agro industrial waste as well as energy plantation on one million hectare (mha) of wastelands for power generation through Bioenergy Technologies, a potential of some 18000 MW of power has been estimated by MNES. Energy plantation has its due position in the scene of power generation as 1mha can develop 3500 MW while the estimated available area for energy plantation of North zone of India is 93 mha. Table 1 and 2 show the current availability and energy potential of agricultural residue in the North zone of India.

These tables amply illustrate that substantial amount of power can be produced using generating systems based on agricultural waste/residue available throughout the country through appropriate conversion techniques, at a competitive cost.

Table 1. Availability of Agricultural Residue in India

Type of Residues	Energy Potential (MW)	Quantity of Agriwaste Required (Million Tonnes)	Available Agriwaste in Northern Zone (Million Tonnes)
Agricultural residue	9500	90	350
Agro-Industrial Residue	9500	50	70

Source: *"Biomass Programme in India: An overview" NP Singh, MNES, New Delhi*

Table 2. Agri Residue Estimates in North Zone

Sr. No.	Agri-Residue	Percentage Per Acre **	Quantity Available in Northern Zone (Million Tonnes)
1.	Wheat straw	33.5*	20.65
2.	Rice husk	12.0	8.16
3.	Cotton stalks	8.0	12.46
4.	Sugarcane Bagasse	32.0	12.88
5.	Ragi & Bajra straw	77.0	15.00
6.	Groundnut shells	6.7	8.00
7.	Maize	50.0	12.00

**These values depend upon the type and methods adopted.*

*Source**R & D requirements in Biomass combustion & Gasification" O.P. Rao, CSIR, New Delhi*

Table 3 below gives a list of existing agriwaste-based power plants in various parts of India as developed over the past decade.Pertaining to state of Punjab only rice waste is utilized to generate power in last decade. While there are other wastes available in the state which can be used to generation of electricity for the benefit of rural population.Table 4 gives the information of different energy sources and their potential of power supply. As we aspect, the agri-waste, agro-industrial waste

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and energy plantation gives the maximum power potential. It further gives the bright future of this area to be utilized for power generation.

Agri-residue has traditionally been a handy and valuable source of heat energy all over the world in rural as well as the sub urban areas. In spite of rapid increase in the supply of, access to and use of fossil fuels, agri-residue is likely to continue to play an important role the developing countries in general and India in particular, in the foreseeable future. Thus, developing and promoting techno-economically viable technologies to utilize agri-residue waste based charcoal for power generation, remains a pursuit of high

Priority

One way of accomplishing this is to set up agriwaste based captive power plants in agro-based industries and small capacity power generation plants in rural areas as decentralized power supply sources. In these power plants, instead of water-head, diesel oil or coal, we can use agriwaste based charcoal and agro-industrial waste to produce electricity.

One such power plant can satisfy the power need of a cluster of 25 to 30 nearby villages. The agriwaste, like rice-straw, saw-dust, sugarcane-trash, coir-pith, peanut-shells, wheat-stalks and straw, cotton-seed, stalks and husk, soyabean stalks, maize stalks & cobs, sorghum, bagasse, waste wood, walnut shells, sunflower seeds, shells, hulls and kernels and coconut husk can be fruitfully utilized in power generation. This stuff is otherwise a waste and liability and it consumes a lot of effort on its disposal; apart from being a fire and health hazard.

Power Generation from Agri Residue based charcoal

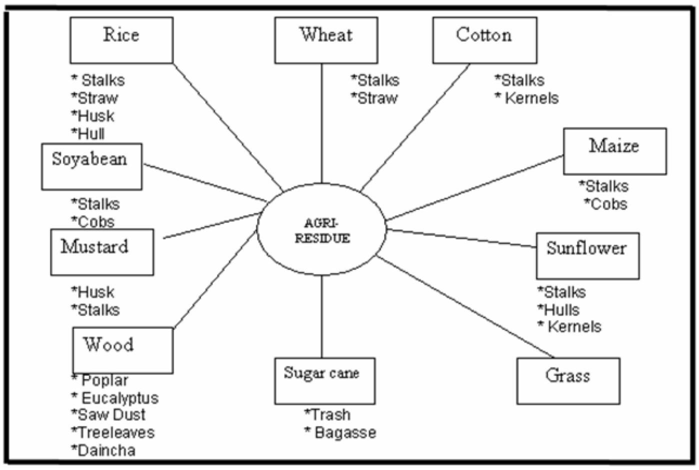

Figure:-1 Types of Agriwaste

FigureNo.1

In addition it causes serious air pollution in the form of smoke, unburnt suspended particles and unwanted addition of heat to atmosphere. Surely, agriwaste stuff at present is available in abundance and prospects of its utilization in producing energy are enormous. Figure No.1 shows various types of agriwaste which are obtained from various crops and plants.

Literature Survey

Technology related developmental efforts are afoot to devise appropriate and economic power generation systems from agri-residue all over the world. Literature surveyed unfolds the technology related developmental efforts which have been made mainly in USA, UK, China, Mexico, Hawaii, Vietnam, Nepal, India, Pakistan etc. Diverse aspects of the problem have been examined and the results of the studies are reported at national and international forum.

Objectives: The present work has been formulated with the following objectives:

- To study the availability of different types of agri-residue in a cluster of villages in district.
- To investigate the agri- residue based electric power potential for a cluster of villages.
- To develop agri-waste based charcoal multifuels and to study their energy related characteristics.

The present work will try to explain the economic viability of agriwaste use in 0.5 MW, 0.8 MW units.

Agri Charcoal - Multifuel:

The literature survey reveals that a lot of theoretical and experimental work has been carried out by many researchers in the field of biomass and its prospect as an energy source. The following significant points emerge from the literature survey:

- Efforts for generating electric power from biomass are afoot in several countries like USA, UK, China, Mexico, Hawaii, Vietnam, Nepal, India, Pakistan, Ukraine, Thailand, Philippines etc.
- The research carried out the world over in this area, is focused mainly on use of one available agri-residue (say rice straw, wheat straw, rice husk) as feed stock. The feasibility of using composite agri-residue fuel as feed stock still needs a lot of research efforts.
- There is a general consensus among researchers that agri-residue holds a promising future as a renewable source of energy. The techno-economic viability of this power generating option can be enhanced by supplementing available agri-residue with energy crops and round the year availability of feed stock can be made a reality.
- A lot of R&D work is going on Biomass Gasifiers at IISc (Bangalore), TERI (New Delhi) and NARI (Phaltan).

Methodology of Study: To achieve the said objectives, following methodology was adopted:

Data (Area under crops, Grain production, Agri-residue output) pertaining to different local growing crops were collected through field visits.

- Multi fuels were developed by using local available crops.
- Testing of Multifuels and energy crop was carried out for studying their energy related properties i.e. calorific value, ash content and moisture content with the help of Bomb Calorimeter and Muffle Furnace.
- On the basis of available agri-residue and using wasteland for energy plantation, capacity of electric power plant was calculated.

Materials:

The agricultural waste after post harvesting (Wheat straw, Rice straw, Mustard straw, outward grass. Sugarcane trash, Maize stalks, Groundnut shells) contains large amount of organic matter.

Binder:

The binder is the material which is used to bind or strengthened the various agriculture wastes and to retain its shape various binders can be used e.g. Special Mud but to increase the calorific value of the agriculture waste we will use commonly used fuel cow dung

Methodology/Principle

A simple crushing and deforming by the method of Screw Press which is also used in oil expellers is used to crush the agriculture waste into small cakes. That cakes or ball are heated in absence of oxygen in the carboniser due to which the moisture or the other waste gas will be expelled and the cake or charcoal will have high heat producing value. This methodology is one of simple and cheapest methodology to convert the agriculture waste into any charcoal or fuel which has high calorific value.

Preparation of the binder

The binder for agri charcoal is prepared from cowdung. Cowdung is a commom fuel used in rural areas as fuel for cooking. It is easily available with dairy farms and rural areas. Collected cowdung Kneaded properly and is ready to mix with shredded Agri waste .

Shredding of Agri-waste

For the shredding of agri-waste shredding machine Figure No.2 is used which works on 3 phase supply. Rice straw, Danicha, grass, sarkanda. Were collected. Collected agri-waste was dried in sunlight for one day and then dried agri-waste was put in the shredding machine.

Shredded material was collected from the box at the bottom of the machine. Shredded agri-waste was again dried for one day in sunlight. At the end, fuel was made out of this shredded waste.But the care should be taken that Agriwaste is properly dried. While putting shredding material in the machine do not insert hand in the machine, and lastly wires of shredding machine should be properly insulated.

Fig.2 shredding machine

Briquetting with screw press

It is one of the oldest or simplest low cost systems in this system the reducing worms are installed, the reducing worms act like a press FigureNo.3 which crushes and force to mix and dung properly. The reducing worm is a technique in which is commonly used in oil expeller to expel. Oil from oil bearing seeds like mustard, ground nut, etc… but in this case we need much less amount of power and energy since we just have to churn and mix dung with agriculture waste and form a simple cake or ball. In the end where cake comes out we can use any giving simple die or metal cutting so we can get ball or cake or strips or any shape from screw press extruder Figure No.40 .

Results and discussion:

1. Objectives: The objective of the tests carried out was to get the calorific value, ash content and moisture content of multi-fuels developed. The study was initiated with the aim of investigating the agri-residue based electric power potential in cluster of villages, exploring the possibility of utilizing composite agri-fuel for power generation and studying sarkanda as energy crop.

2. Experimental Results: The tests carried out for proximate analysis and calorific value of multi-fuel briquettes.Table 5.1 shows the Calorific value, ash content and moisture content of multi-fuels.

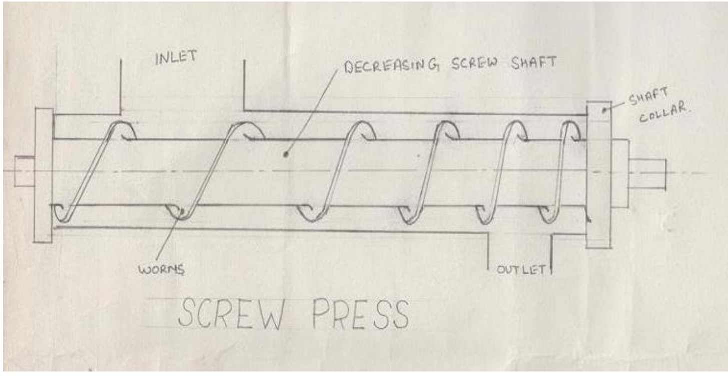

Fig. 3 Screw press

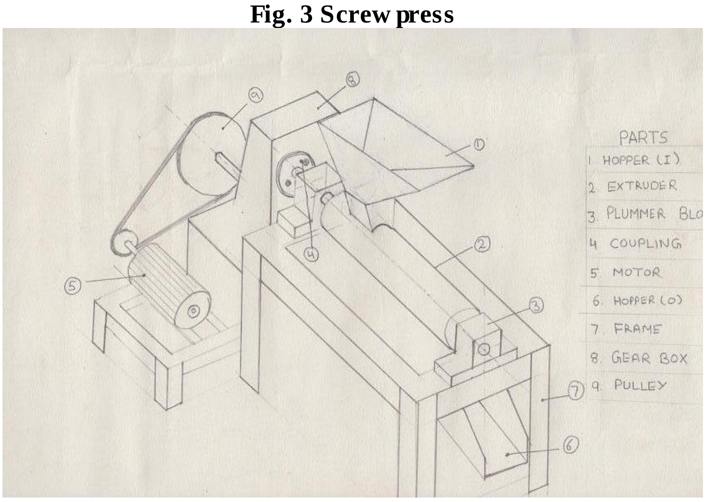

Fig.4 Extruder

The multi-fuel MF_1 its highest calorific value and least ash content but it has maximum moisture content. The multi-fuel MF_2 gives least calorific value.

Calculations for Agri-Residue based Power Plants

Calculation work was carried out for 0.5 MW capacity agri-residue based power plant by taking plant load factor of 0.7. Fuel requirement/year for plant was calculated to be 6990 tonnes. Total agri-residue production per year in said cluster is 17639 tonnes. By using approx. 40% of this, fuel demand for 1 MW plant can be satisfied. Table 5.2 shows the calculation work for 1 MW plant. Similarly, calculation work was carried out for 2MW, 5 MW, and 6 MW plants. The fuel requirement for 5 MW was calculated to be 34952.4 tonnes and 41942.88 tonnes respectively, which can be easily be fulfilled by a cluster of 40 villages for 5 MW and a cluster of 50 villages for 6 MW, approximately. Per unit energy cost for 5 MW and 6 MW plant is less as compared to .9 MW and 1 MW plants. For 2 & 5 MW, cost/kWh was calculated Rs.2.23 and Rs.2.10 respectively, whereas, for 1 MW plant it came out to be Rs.4.25, which is almost double of the per unit cost for 5 & 6 MW plant. Tables 5.3 show the calculation for 2 MW which is nearly equal to 5 MW and 6 MW plants.

Discussion of the Results

For investigating the agri-residue based electric power potential in cluster of villages, total agri – residue(Rabbi and Kharif) in year 2007 was estimated which came to be 17639 tonnes covering all major local crops & other waste. Calculation work was carried out for 1 MW agri-residue based power plant which produces 6132000 kWh of energy at 0.7 load factor. The fuel consumption for this plant came to be 6990 tonnes which is approx. 40% of the total agri-residue production in cluster. So by using approx. 40% of available agri-residue, fuel demand of 1 MW plant can be satisfied.

Table 3. State-wise List of Agriresidue/Agriwaste Power Plants

S. No	State	Agri-waste exploited	1993	1994	1995	1996	1997	1998	1999	2000	Total capacity in MW
1.	Andhra Pradesh	1. Rice husk 2. Deoiled bran 3. Bagasse	-	-	-	-	1.0	-	10.0	1.0	12.0
2.	Gujarat	Fuel Wood	-	-	-	-	-	-	0.5	-	0.5
3.	Haryana	1.Cotton stalks 2. Mustard straw 3. Rice straw	4.0	-	-	-	-	-	-	-	4.0
4.	Karnataka	Coconut shell					1.0	-	10.0	26.0	37.0
5.	Maharashtra	Bagasse	1.5	-	1.5	4.5	1.5	-	-	-	9.0
6.	Madhya Pradesh	Rice husk	-	-	-	-	-	-	5.0	-	5.0
7.	Punjab	Rice straw	-	10.0	-	-	-	-	-	-	10.0

Table 4. Renewable Energy Potential in Punjab

S. No	Energy Sources	Country Potential	State Potential	Power generation Potential
1	Biogas Plants	12 Million (nos)	424700(nos)	164 MW
2	Biomass (agri-residue, agro-industrial waste & energy plantation)	17000MW	1000 MW	1000 MW
3	Small Hydro	10,000 MW	140 MW	140 MW
4	Municipal Solid Waste	27.4 Million tones/yrs	3.5 Million tones/yrs	100 MW
5	Cogeneration (Sugar)	5000 MW	140 MW	140 MW
6	Cogeneration (other industry)	1000 MW	150 MW	150 MW
7	Solar Energy	$5x\ 10^{15}$ k Wh/yr	2228.5 k Wh/m^2 / yr	-----------

Table 5.1.Calorific Value, Moisture Content & Ash Content of Composite Fuels

S.No	Multifuel	Agri Charcoal CV		Moisture Content (%age)	Ash Content (%age)
		(Mj/kg)	(kcal/kg)		
1	MF_1	17.33	4126.2	8.25	4.27
2	MF_2	17.00	4047.6	7.8	5.88
3	MF_3	17.17	4088.1	7.3	5.21
4	MF_4	17.10	4071.4	8.06	6.58
5	MF_5	17.19	4029.9	7.5	6.95

Table 5.2. Calculations for 1 MW Unit

S.No	Particulars	Unit	Value
1	Installed Capacity	k W	1000
2	Cost of Project***	Lacs	1100
3	Cost/ kW (2)/ (1)	Rs.	110000
4	Interest on Capital during construction @ 10% on (2)	Lacs	110
5	Total (2)+(4)	Lacs	1210
6	Cost / k W including (5)/(1)	Rs.	121000
7	Annual generation in k Wh @ 70% Load Factor: 1000 x 0.7 x 8760	k Wh	6132000
8	Auxiliary consumption * @ 5% on (7)	k Wh	306600
9	Units sent out (7) – (8)	k Wh	5825400
10	Fuel consumption*	Kg/ k Wh	1.14
11	Fuel consumption per year (10)x(7)	k g.	6990480
12	Annual fuel cost @ Rs. 700** per tonne: 700/1000x 6990480	Rs.	4893336
13	Fixed Charges*:	Lacs	
	1. Interest charges @ 10% on(5)		121
	2. O&M charges @ 2.5% on (2)		27.5
	3. Depreciation charges @ 3.5% on(2)		38.5
	Total:		**187**
14	Total fixed and running charges/year (12)+(13)	Rs.	23593336
15	Cost/ k Wh generated (14)/(7)	Rs.	3.85
16	Cost/ k Wh at Bus (14)/(9)	Rs.	4.05
17	Cost/ k Wh at Bus with profit of 5%	Rs.	4.25
18	Total Requirement of Fuel/ year	tonnes	6990.5
19	Requirement of Fuel/ day	tonnes	19
20	Requirement of Fuel / hour	tonnes	0.8

*Source: "Studies in techno-economic aspects of power generation from agri-waste in India", by B. Lonia.
** Source: Local survey and "Biomass assessment study", Pranam consultants.
*** Source: Approximate assessment based on literature survey.

Table 5.3. Calculations for 2 MW Unit

S.No	Particulars	Unit	Value
1	Installed Capacity	k W	2000
2	Cost of Project*	Lacs	1800
3	Cost/kW (2)/(1)	Rs.	90000
4	Interest on Capital during construction @ 10% on (2)	Lacs	180
5	Total (2)+(4)	Lacs	1980
6	Cost / k W including (5)/(1)	Rs.	99000
7	Annual generation in k Wh @ 70% Load Factor: 2000 x 0.7 x 8760	k Wh	12264000
8	Auxiliary consumption * @ 5% on (7)	k Wh	613200
9	Units sent out (7) – (8)	k Wh	11650800
10	Fuel consumption*	Kg/ k Wh	1.14
11	Fuel consumption per year (10)x(7)	k g.	13980960
12	Annual fuel cost @ Rs. 700** per tonne: 700/1000 x 13980960	Rs.	9786672
13	Fixed Charges*: 4. Interest charges @ 10% on(5) 5. O&M charges @ 2.5% on (2) 6. Depreciation charges @ 3.5% on(2) **Total:**	Lacs	 198 45 63 **306**
14	Total fixed and running charges/year (12)+(13)	Rs.	40386672
15	Cost/k Wh generated (14)/(7)	Rs.	3.3
16	Cost/k Wh at Bus (14)/(9)	Rs.	3.46
17	Cost/k Wh at Bus with profit of 5%	Rs.	3.64
18	Total Requirement of Fuel/ year	tonnes	13980.9
19	Requirement of Fuel/ day	tonnes	38.3
20	Requirement of Fuel / hour	tonnes	1.6

*Source: "Studies in techno-economic aspects of power generation from agri-waste in India", by B. Lonia.
** Source: Local survey and "Biomass assessment study", Pranam consultants.

Cost of unit for1MW plant was calculated Rs. 4.25 with 5% of profit. Similarly, calculation work was carried out for 2 MW, 5MW, and 6 MW power plants. Unit cost for 5 & 6 MW plant came out Rs, 2.23 and Rs. 2.10 respectively, which is just half of unit cost for 1MW plant. Capital cost of 5 & 6 MW plant is 22 crore and 24 crore, which is proportionality lesser as compared to 1 MW and 2MW plant. Fuel consumption of 5 & 6 MW plant is 34952.4 tonnes and 41942.88 tonnes respectively. This fuel consumption of 5 & 6 MW plant can be fulfilled approx. by cluster of 20 and 30 villages respectively.

The connected load of cluster under observation is approximately 1200 kW. With load factor and demand factor of 0.5 each, energy consumption per year for this cluster was calculated to be 2628000 kWh units. Energy production from 1 MW plant is 6132000 kWh, which is quite more than cluster requirement. Power generation from 1 MW plant is sufficient to meet requirement of a cluster of 20-30 villages approximately.

Instead of using single agri- residue as fuel for power generation, possibility of using composite agri fuel was explored. Four locally available agri-residues (Wheat Straw, Maize Stalk, and Paddy Straw) were taken for developing multi-fuels. These were mixed in different ratios. Total 8 composite fuels i.e. MF_1, MF_2, and MF_5 were developed and tested as their calorific value, ash content and moisture contents with the help of Bomb Calorimeter and Muffle Furnace. Calorific value, ash content and moisture content were lying in between 4047.6 kcal/kg, 4126.2 kcal/kg (17-17.33 MJ/kg), 4.27-6.95% and 7.3-8.25% respectively. Low value of ash content and uniform value of C.V. make these a good alternative of Indian coal (4000 kcal/kg, 16.8 MJ/kg, 40% ash, Rs. 2500-3000) for small thermal plants. Using different agri-residues independently, as feed stock for boiler gives uneven heating due to large variations in their C.V. and also ash content for some of agri-residues is extremely large i.e. paddy 22.5%, which causes problems in combustion. The benefits from agri-residue based power plants are multiple in terms in terms of rural development and employment generation, in general terms a move to a more sustainable electricity production.

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