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Agricultural Residue Potential for Electricity Generation in Bangladesh

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Abstract: *Renewable energy based electricity generation is getting momentum around the world to mitigate the rapid depletion of fossil fuel and its negative impact on environment. Bangladesh is an energy poor country has given the emphasis to extract energy from available renewable sources. Rural energy need of the country is mainly met by agricultural residue. This paper presents the country's total agricultural residue potential available during the fiscal year 2012-2013. The assessment estimated that the total amount of dry recoverable agricultural residue is 36.48 million tons. This amount has an energy potential of 582.36 Peta Joules (PJ) which is equivalent to 161.81 Trillion Watt hour (TWh) of electricity. The paper also shows the present status of electricity generation based on agricultural residue in Bangladesh.*

Keywords: *Energy crisis, Agricultural residue, Electricity, Bangladesh.*

I. Introduction

Bangladesh is an over populated south Asian country located between 20°34' and 26°38' north latitude and 88°01' and 92°41' east longitude [1]. The country has a total area of 147,570 sq. km of which only 8% is used for human settlement. The population of the country was reached to 164.4 million with a density of 1114.05 persons per sq. km by year 2013 [2]. In this modern era, energy is the prime mover for the technological advancement of any country like Bangladesh. However, the lack of energy security is the main barrier for country's development facing in recent days. Most of the energy requirement of the country is met by indigenous commercial sources like natural gas, coal and petroleum products. These energy sources are diminishing hastily to increase country's electricity production. Only natural gas accounts almost 85 % of the total power generation and the supply expected to be inadequate by 2016 [3]. The maximum electricity generation in the country's history 6675 MW in fiscal year 2013 was not adequate to meet the increasing demand and up to December, 2013 the installed generation capacity has increased to 10264 MW [4]. It is found that only 53% of the total area has the access to use national grid power. Country's per capita electricity consumption 292 kWh is quite below compared to other countries of the world. In addition, almost 70% of the total population in Bangladesh live in rural areas and are very poor. They have no significant contribution in Gross Domestic Product (GDP) growth and estimated about 838 USD per capita during year 2012-2013. There is a close relationship between the GDP growth rate and electricity generation growth rate as presented in Figure 1 [5]. It is necessary to increase 1.4% electricity consumption to increase the GDP by 1% [6].

Recently, the government along with several non-government organizations has taken some initiatives and started some renewable energy based electricity generation programs to trim down the utilization of fossil fuel and also its environmental impact. Agricultural residues are the major sources of biomass energy in Bangladesh contribute significantly to rural primary energy consumption. Bangladesh has a huge potential of agricultural residues which can be an effective option for electricity production.

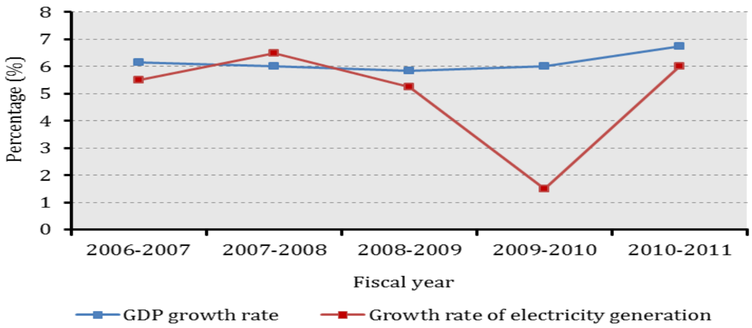

Fig. 1: Relationship between GDP growth rate and electricity generation growth rate [5]

II. TECHNOLOGY FOR POWER PRODUCTION

The intrinsic chemical energy of agricultural residue is directly converted to heat or electricity or intermediate biofuel by thermo-chemical and bio-chemical conversion. The main thermo-chemical conversions are direct combustion, gasification and pyrolysis.

2.1. Direct combustion

In direct combustion, the residues are burned directly with sufficient air to produce heat which is used to generate steam in boiler. This steam drives a generator to produce electricity. It is the cogeneration of heat and electricity as shown in Figure 2 [7]. Direct combustion is the simplest technology and contributes about 97% of bio-energy production in the world [8].

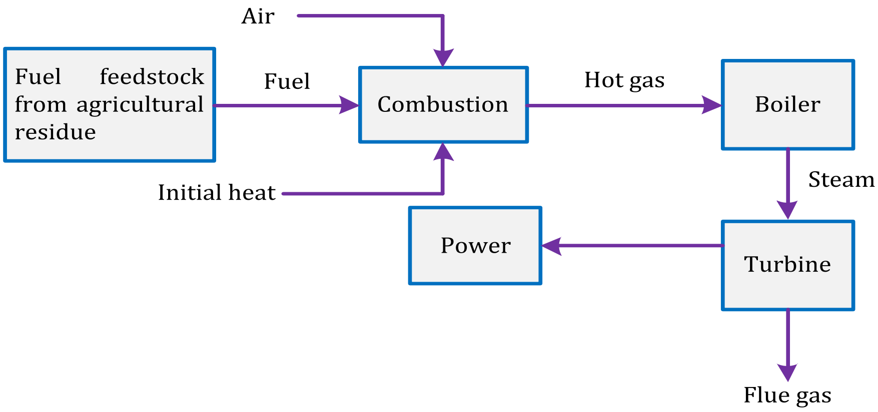

Fig. 2: Flow diagram of direct combustion [7]

2.2. Gasification

Gasification is the intermediate step between pyrolysis and combustion which produces mixture of combustible gases by partial oxidation. The gas resulting from this process mainly consists of Carbon Monoxide (CO), Hydrogen (H), Methane (CH_4) and Carbon dioxide (CO_2) [7]. This flammable gas is then used in a combined gas and steam turbine to generate electricity. Figure 3 demonstrates the simple diagram of gasification for electricity generation [7].

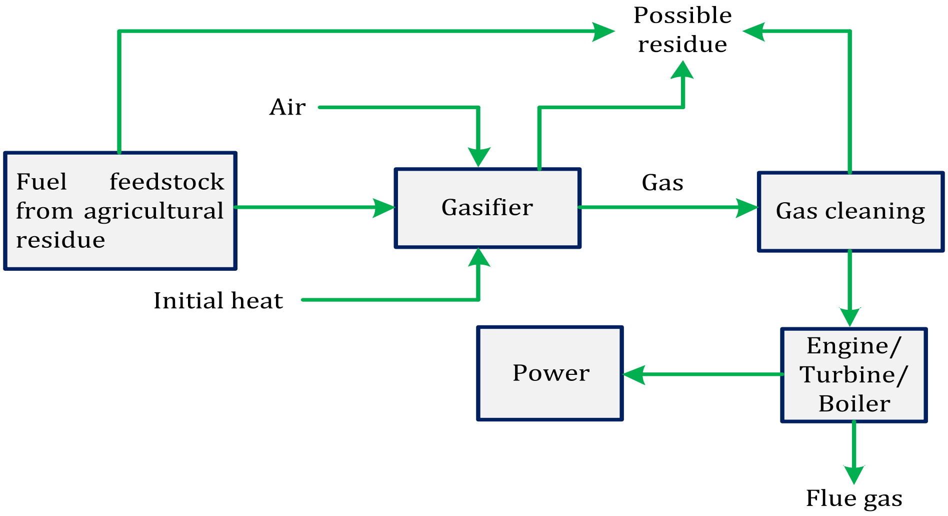

Fig. 3: Possible flow diagram of gasification [7]

2.3. Pyrolysis

Pyrolysis is a thermal decomposition of organic components in biomass wastes in absence of oxygen at mediate temperature about 500 ^{0}C which yield tar (bio-oil, bio-fuel, bio-crude), char (activated carbon) and gaseous fractions (fuel gases) [9]. The pyrolysis oil is burned to generate electricity. Moreover, the oil can be effectively used in cooking and lighting purpose alternative to kerosene [10]. Figure 4 illustrates the pathway of pyrolysis for electricity generation [7].

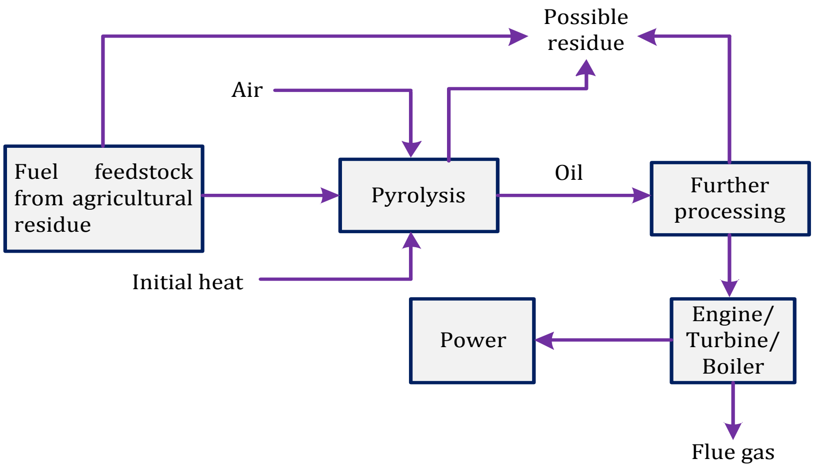

Fig. 4: Possible pathway of pyrolysis [7]

III. AVAILABLE AGRICULTURAL RESIDUES IN BANGLADESH

Bangladesh is an agriculture based country where over 60% of the total populations earn their livelihood by cultivation. The economy of Bangladesh is significantly affected by agricultural sector and almost 65% of country's economic activities are based on agriculture. Although the country has about 64% agricultural land however over 50% of the agricultural workers do not have their own land. The main crops produced in the country are rice, sugarcane, vegetables, wheat, jute, pulses, coconut, maize, millet, cotton and groundnut. In 2007-2008 total crop production in Bangladesh was 46.34 million tons which has increased to 61.09 million tons in 2012-2013 as shown in Table 1 [1, 11-17].

Table 1: Annual agricultural crops production scenario in Bangladesh (10^5 tons) [1, 11-17]

Crops	2007-2008	2008-2009	2009-2010	2010-2011	2012-2013
Rice	289.31	313.17	322.57	335.42	344.30
Wheat	8.44	8.44	9.69	9.72	10.36
Maize	13.46	7.30	8.87	10.18	20.42
Sugarcane	49.84	52.33	44.91	46.71	73.00
Jute	8.39	-----	9.24	18.48	16.57
Pulse	2.04	1.96	2.18	2.31	7.67
Coconut	3.34	3.16	4.02	3.26	3.26
Millet	0.23	0.24	0.24	-----	0.24
Groundnut	0.44	0.47	0.53	0.54	1.26
Vegetable	86.85	106.22	108.69	111.94	132.21
Cotton	0.08	0.09	0.11	0.16	0.28
Tea	0.590	0.590	0.600	0.61	0.55
Tobacco	0.4	0.4	0.5 4	0.79	0.79
Barley	0.001	0.001	0.001	0.005	0.007
Total	463.42	461.89	504.7	540.125	610.917

In Bangladesh, biomass is the foremost renewable energy source accounts about 70% of total primary energy consumption basically in rural areas. On the other hand, only agricultural residues contribute 48% of the total biomass energy consumption. Bangladesh has a sufficient agricultural crops potential to generate huge amount of residues. Amount of residue production depends on the agricultural crops production. Agricultural biomass is commonly used for cooking, heating, fertilizer, animal feeding, bedding etc. in rural areas in Bangladesh as illustrated in Table 2. Typically, agricultural residues vastly meet the household energy demands in rural and semi-urban areas as well as industrial purposes.

Table 2: Utilization pattern of agricultural residue in Bangladesh

Agricultural crops	Residue	Utilization
Rice	Rice straw	i. Animal feed ii. Animal bedding iii. Housing materials iv. Fuel
	Rice husk	i. Poultry bedding ii. Cattle feed iii. Fuel
Wheat	Wheat straw	i. Fuel ii. Housing material
Jute	Jute stalk	i. Fuel ii. Housing material
Groundnut	Groundnut straw	i. Fuel ii. Animal feed
Vegetable	Vegetable plants	i. Fuel ii. Animal feed
Pulse	Pulse straw	i. Fuel ii. Animal feed
Sugarcane	Sugarcane leafs	i. Fuel ii. Animal feed
	Sugarcane bagasse	i. Fuel
Maize	Maize leaf and straw Maize husk	i. Fuel ii. Animal feed i. Fuel

Agricultural crop residues are mainly comprise two types of residue such as field residue and process residue. All field residues are not recoverable. Only 35 % of field crop residues can be recovered without affecting the future yields and rests are used for fertilizer and other purposes [18]. On the contrary, 100% of crop processing residues are recoverable for energy production purpose [19]. The agricultural residue potential depends on the amount of crops and agricultural lands. The estimation of residues potential from field and crop processing area is very difficult due to the lack of actual residue generation data. Thus, the amount of residue generation is estimated on the basis of Residue Production Ratio (RPR). Considering the moisture content of each crop, dry amount of crops residues are estimated. Total net recovery of residue is 36.48 million tons comprises of 23.70 million tons (64.97%) field based residue and 12.78 million tons (35.03%) process residue. Total amount of energy that can be recovered from the agricultural residues estimated as 582.36 Peta Joule (PJ) includes 378.60 PJ (65.01%) from field residue and 203.76 PJ (34.99%) from process residue as shown in Table 3. This recoverable amount is equivalent to 19.88 million tons coal and can produce about 161.81 TWh of electricity. Although Bangladesh has a huge potential of agricultural residues, however total recoverable amount are not available for electricity generation. It is possible to obtain about 80.91TWh per year considering 50% availability for electricity generation.

Table 3: Energy potential of agricultural residue in 2012-2013

Crop residues	RPR		Moisture content		Dry residues recovery (10^3 tons)	Lower calorific value		Energy content (PJ)
	Value	Ref.	(%)	Ref.		(GJ/ton)	Ref.	
Field residues								
Rice straws	1.695	[20]	12.7	[20]	17831.55	16.30	[20]	290.65
Wheat straws	1.75	[21]	7.5	[22]	586.96	15.76	[22]	9.25
Maize stalks	2	[21]	12	[22]	1257.87	14.70	[22]	18.49
Sugarcane leafs	0.3	[21]	50	[24]	383.25	15.81	[21]	6.06
Jute stalks	3	[21]	9.5	[22]	1574.56	16.91	[22]	26.63
Pulses residue	1.9	[22]	20	[22]	408.04	12.80	[22]	5.22
Millet stalks	1.75	[21]	15	[23]	12.50	12.38	[21]	0.15
Groundnut straws	2.3	[21]	12.1	[24]	89.16	17.58	[24]	1.57
Vegetables residue	0.4	[22]	20	[22]	1480.75	13.00	[22]	19.25
Cotton stalks	2.755	[21]	12	[22]	23.76	16.40	[22]	0.39
Tobacco Stalks	2.0	-----	8.9	[25]	50.39	17.70	[25]	0.89
Barley straws	1.75	[23]	15	[23]	3.64	12.38	[23]	0.05
Total Field Based	------	------	------	-----	23702.43	------	------	378.60
Process residues								
Rice husk	0.267	[20]	12.4	[20]	8052.90	16.30	[20]	131.26
Rice bran	0.083	[20]	9	[22]	2600.50	13.97	[21]	36.33
Maize cob	0.273	[21]	15	[22]	473.85	14.00	[22]	6.63

Maize husks	0.2	[21]	11.1	[24]	363.07	17.27	[22]	6.27
Sugarcane bagasse	0.29	[21]	49	[20]	1079.67	18.10	[21]	19.54
Groundnut husks	0.477	[21]	8.2	[24]	55.17	15.66	[24]	0.86
Coconut shells	0.12	[21]	8	[22]	35.99	18.53	[21]	0.67
Coconut husks	0.41	[21]	11	[22]	118.96	18.53	[21]	2.20
Total Process Based	-----	-----	------	-----	12780.11	------	------	203.76
Total	-----	-----	-----	-----	36482.54	------	------	582.36

IV. AGRICULTURAL RESIDUES BASED POWER GENERATION IN BANGLADESH

Recently, Bangladesh has started to generate electricity from agricultural residues. A 250 kW rice husk gasification power plant has been already established at Kapasia, Gazipur is the first ever biomass based power plant in Bangladesh. Total cost of the project was about 2.5 crore comprising 60% from World Bank, 20% from Infrastructure Development Company Limited (IDCOL) and 20% from Dreams Power Private Limited (DPPL) [26]. The plant consists of downdraft gasifier unit, gas purification unit, dual-fuel generator, four electric motors and a spray pond. All the equipment was exported from Ankur Scientific Energy Technologies Private Limited, India. The schematic diagram of the plant is illustrated in Figure 5 [27]. A certain amount of diesel is required to run the generator due to the lower calorific value of producer gas. The plant consumes rice husk at a rate of 300 kg/hr. It has a gasification temperature range between 1050 to 1100 ^{0}C with an efficiency of almost 75%. The producer gas has an average calorific value greater than 1050 kcal/Nm^3 and flows at a rate of 625 Nm^3/hr. [27]. The electricity Production cost of the plant is about 4.3 BDT/kW. The plant has started its commercial operation in October, 2007 and able to deliver power to at least 200 households and over 100 commercial entities of that area. Currently, one unit of the plant is on running condition that produces only 56 kW of electricity [28].

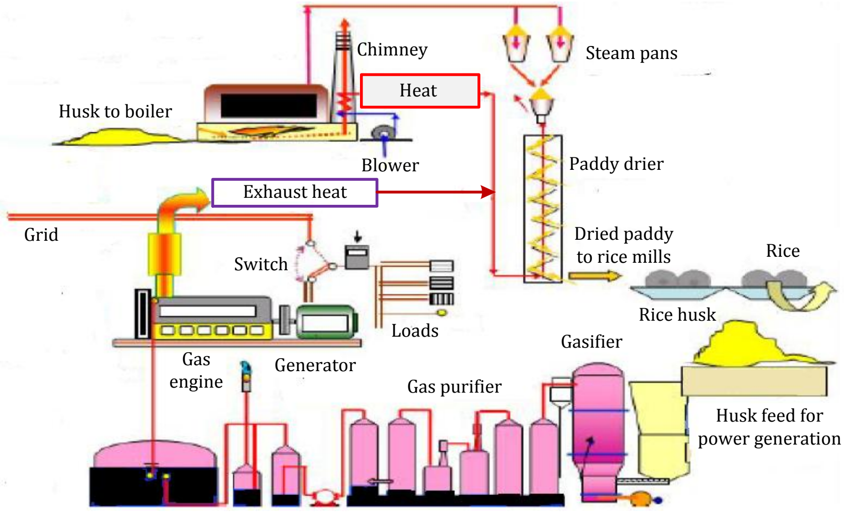

Fig. 5: Schematic diagram of rice husk gasification power plant in Bangladesh [27]

Furthermore, IDCOL is providing fund to establish a 400 kW rice husk gasification power plant along with a precipitated silica plant at Chilarong, Thakurgaon sadar, Thakurgaon by Sustainable Energy & Agro-resource Limited (SEAL). Total cost of the project is estimated about 64.25 million BDT. The plant will supply electricity to the nearby silica production plant, poultry hatchery, thirty irrigation pumps and numerous rice mills in that area [26]. Bangladesh has almost 2000 automatic and semiautomatic rice mills which use about 70% of the total rice. The country has produced about 34.43 million tons of rice in fiscal year 2012-2013. This amount of rice can produce about 8.05 million tons of husk equivalents to 36.47 TWh of electricity. Therefore, it is possible to generate about 460 to 480 MW electricity only using 70% of this husk.

V. BENEFITS AND CHALLENGES OF AGRICULTURAL RESIDUES BASED POWER GENERATION

5.1. Benefits

- *Enhancement of electricity generation:* Most of the rural areas of Bangladesh are un-electrified. Rice husk based power generation can be an effective option to meet the power demand of those areas.
- *Direct employment generation:* Unemployment is one of the major problems in our country that hinders the economic development. The establishment and operation of rice husk based power plant will create new job opportunity for a large number of manpower including engineers, workers and labors.

- *Social impact:* Reliable electricity supply from the plant will enhance the quality of lifestyle by ensuring better education, health and entertainment facilities.
- *Sustainability:* Electricity generation from fossil fuel produces huge amount of CO_2 whereas gasification of rice husk for electricity generation is considered as almost CO_2 neutral.

5.2. Barriers

- *Lack of technology and infrastructure:* Lack of appropriate technology and sufficient infrastructure is the main barrier for the development of biomass gasification power plant.
- *Lack of policy and regulatory:* The lack of clear, long-term and consistent policy, legislative support, sufficient financial incentive policies, programs and goals are another obstacle for the progress of this technology.
- *Lack of Information and human resource:* Lack of technical and economic information among the public and policy makers and expert manpower for installation and management hinder the power generation from the technology.
- *Financial shortage:* Bangladesh is a poor country. Thus, establishment cost of the plant without additional fund from related organization and other country is a burden for our country.

VI. CONCLUSION

Power scarcity remains the main problem in Bangladesh since independence. Renewable energy based electricity generation is the recent addition in power sector of the country. Electricity generation from rice husk gasification is a new technology in Bangladesh. Although the gasification technology is suitable for small power plants in the range of 10 kW to over 100 kW however, rice husk cogeneration plants can play a pivotal role to reduce the country's power crisis. The country produces plenty of agricultural residues every year. During the fiscal year 2012-2013 about 36.48 million tons of agricultural residues are estimated equivalent to 161.81 TWh of electricity. Therefore, the government should take strong initiatives to install agricultural residue based mini-grid power station.

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