Study on Future Prospects of Power Generation by Bagasse, Rice Husk and Municipal Waste in Uttar Pradesh

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ABSTRACT

The use of bagasse, rice husk and municipal solid waste as a fuel for power generation can be an option to supplement the growing power demand as the conventional power source i.e. fossil fuel is diminishing day by day. So bagasse, rice husk and MSW have the substantial potential of such energy to be tapped in a synergistic manner. The potential of power generation by bagasse in Uttar Pradesh is 1400 MW which can replace approximately 560 tonne of coal otherwise. The green house emissions are also lower in the burning of bagasse reducing the environmental pollution. Also the potential of power generation by rice husk in Uttar Pradesh is 257.05 MW which is equivalent to energy of approximately 102 tonne of coal. At district Etawah the power generation by rice husk is approximately 9.45 MW. Likewise the potential of power generation by MSW in Uttar Pradesh is 258 MW which can save approximately 103 tonne of coal. If the power is generated by all these non conventional fuels in Uttar Pradesh then the overall power generation potential would be 1916.5MW equivalent to 766.42 tonne of coal. Even the blending of rice husk with the bagasse and MSW both is possible to have appreciable calorific value in case of scarcity of any one of three at a place. An effort is made here to study and analyze keeping the availability and environmental pollution in view of all these resources at district Etawah of Uttar Pradesh in the country.

Keywords: *Bagasse, rice husk, municipal solid waste, non conventional fuels, power generation, environmental pollution*

1. INTRODUCTION

As the conventional fuels such as coal, petroleum etc. are limited in the nature therefore alternate source of the energy for the fulfillment of the future demand is required. The power production by the conventional fuels is not environment friendly means the emission control of the power plants working with the conventional fuels is completely not possible the emission control of harmful gasses such as NO_x, SO_x etc. and other pollutants is partially possible with conventional fuels. Today the focus is concentrated on the renewable energy sources such as solar power, wind power, geothermal energy, ocean tidal power, hydropower, electricity by biomasses and municipal solid waste. These all are the environment friendly. The electricity production through bagasse, rice husk and municipal solid waste is more easily adoptable and can be easily applicable to most of the part of the country. Electricity through these sources is cheaper than the electricity produced by the conventional fuels and also the emission is very low and this small amount of the emission can be easily controlled compare to the emission of the conventional fuels.

India is the world's seventh largest country in the area and world's second largest country in the population. India is the one of the fast growing country and also due to the very large population power demand is very high and this results in the large scale emissions during power generation which is due to the use of conventional fuels. Thus there is requirement of alternatives which will help in meeting the future power demand and emission control.

As the India produces sugarcane and paddy in huge amount it is world known that the India is the second largest producer of the sugarcane in the world after Brazil and due to very huge population it is very

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beneficial and reliable to use bagasse, rice husk and MSW for sustainable development of the country.

1.1 *Bagasse*

India is the second largest producer of sugarcane in the world after the Brazil which produces about 390 million tonnes. This amount of sugarcane produced in 5300 hectares. India produces sugarcane approximately 340 million metric tons/year with the production rate of 78.44 tones/ha from an area of 4,300,000 ha yielding nearly 50 million metric tons of bagasse, which is mostly used as a captive boiler fuel and as a raw material in paper industry. India has potential for producing electricity production using bagasse 3,000GWh/year. India placed at top position in Asia for producing sugarcane then after China which produces approximately 100 MT in 1200 Hectares. Thailand produced 75 MT in 1000 Hectares. Other countries Australia, Colombia, Cuba, Pakistan and Mexico etc. also produced sugarcane at low level. Uttar Pradesh produces 38.78% of the total production of India. Bagasse is the by-product of the cane crushing in the sugar mills. Bagasse is the fibrous material and mill run bagasse contains the moisture in large amount approximately 48-50 %. The calorific value of the bagasse is depends upon the moisture content of the bagasse and the amount of the sucrose present in the bagasse. The drier system is introduced to increase in steam fuel ratio thereby savings of bagasse. Boiler efficiency is also increased due to drier. As 10-12% of water is evaporated from the bagasse in the drier, excess air requirement is reduced to a certain extent; thereby flue gas volume is reduced hence, power consumed by the ID fan is also reduced considerably. When the bagasse is dried, it gains a certain temperature and spontaneously burns in suspension, hence boiler pressure and temperature fluctuations are always in control. Boiler steam production capacity is also increased due to more intake of dried bagasse for fixed volume of furnace; so boiler capacity is increased up to 10 to 15%. There is no maintenance cost on drier. The limitation is that the drier should not run when the outlet flue gas temperature falls below 70°C as its dew point temperature lies in the range of 60-65°C, which causes corrosion to equipment.

Indian Sugar mills both in the private and co-operative / joint sector have accepted the importance of implementing high efficiency grid connected cogeneration power plant for generating exportable surplus. Gujarat, being one of the leading sugarcane producer and processor states, has the potential to set up Bagasse base co-generation power plants. The proposed project envisages setting up of a Bagasse based co-generation power plant, either to be added in an existing Sugar Mill or as a stand alone unit for power generation. Cogeneration in sugar industry to produce excess power and exported to the State Electricity Board grid has gained momentum and is the order of the day. The successful operation of four full fledged cogeneration plants in Uttar Pradesh and a few more in other states have given the required confidence for the sugar industry to implement cogeneration plants. The state wise potential of bagasse cogeneration in India is tabulated below.

Table 1: State wise potential of Bagasse base cogeneration in India

Sr. No.	State	Potential (MW)
1	Maharashtra	1250
2	Uttar Pradesh	1250
3	Tamil Nadu	500
4	Karnataka	500
5	Andhra Pradesh	300
6	Bihar	300
7	Gujarat	250
8	Punjab	150
9	Other	500
10	Total	5000

1.2 Rice husk

Every year approximately 120 million tons of paddies are produced in India. This gives around 24 million tons of rice husk and 4.4 million tons of rice husk ash every year. The use of rice husk for electricity generation in efficient manner is likely to transform this agricultural by-product or waste into a valuable fuel for industries and thus might help in boosting the farm economy and rural development. India being the second largest rice producer in the world, rice is major food grain for the people of the southern and some of the northern states in India and also for the people of at least 15 other countries in the world. Production of rice paddy is associated with the production of essentially two by-products, rice husk and rice bran, husk also called hulls, consists of the outer shell covering the rice kernel. As generally used, the term rice husk refers to the by-product produced in the milling of paddy and forms 16-25% by weight of paddy processed. In the majority of rice producing countries much of the husk produced from the processing of rice is either burnt for heat or dumped as waste. The state-wise area, total production, and productivity (i.e., average yield) of rice and composition of rice husk are given in table 2 and 3 respectively.

Table 2: State-wise area, production, and yield of rice in India (1998-99)

State	Area, M ha	Percent of total area, %	Production, M t	Percent of total production, %	Yield, kg/ha
Andhra Pradesh	4.11	9.4	11.40	13.3	2,770
Assam	2.42	5.5	3.25	3.8	1,340
Bihar	5.10	11.7	6.63	7.7	1,300
Gujarat	0.62	1.4	1.02	1.2	1,640
Haryana	1.08	2.5	2.43	2.8	2,250
Jammu and Kashmir	0.27	0.6	0.59	0.7	2,180
Karnataka	1.43	3.3	3.60	4.2	2,520
Kerala	0.35	0.8	0.66	0.8	1,890
Madhya Pradesh	5.31	12.2	5.37	6.2	1,010
Maharashtra	1.48	3.4	2.47	2.9	1,670
Orissa	4.45	10.2	5.39	6.3	1,210
Punjab	2.52	5.8	7.94	9.2	3,150
Tamil Nadu	2.39	5.5	8.22	9.6	3,440
Uttar Pradesh	5.93	13.6	11.60	13.5	1,960
West Bengal	5.90	13.5	13.30	15.5	2,250
Others	1.24	1.0	2.08	2.4	1,680
All India	**44.60**	**100.0**	**86.00**	**100.0**	**1,930**

Table 3: Composition of Rice husk

Carbon	44.99%
Hydrogen	6.39%
Oxygen	8.15%
Nitrogen	0.42%
Sulfur	0.05%
Moisture	11%
Ash	14.16%
LHV(Lover heating value)	12.34%

Average calorific value of rice husk is 3410-3520 Kcal/kg.

1.3 Municipal Solid Waste

The fast depletion of the conventional resources and growing awareness and concern regarding the environmental effects of their utilization, there has been major thrust in recent past to identify and develop alternate energy sources. India generates about vast amount MSW in hundreds of tones which when converted to fuel have appreciable calorific value. The cost of fuel is also much lesser than that of conventional fuel. The process of using waste as a fuel source and converting it to energy is not a new phenomenon in India. Rural India has gained considerable experience in an anaerobic digestion and biomass gasification since independence through the use of animal and agricultural waste.

As cities increase in size and as rural migrants move to urban areas, the generation of municipal solid waste (MSW) is expected to grow considerably. More recent estimates that approximately 48 million tones of urban solid waste are generated annually in India and is increasing by approximately 1.3% each year. On average, only 60-70% of this amount is collected for disposal. Although it is reported that approximately

94% of that waste is sent to landfills and 5% is composted, the media frequently reveal that municipalities mostly either burn or bury their garbage without appropriate environmental controls. The quantity of municipal solid waste in urban centers and typical composition & properties of Indian MSW are tabled below

Table 4: Quantity of municipal solid waste in urban centers

Population Range (in millions)	number of Urban Centers (Sampled)	Total population (in millions)	Average per capita value (kg/capita/day)	Quantity (tones/day)
<0.1	328	68.300	0.21	14343.00
0.1-0.5	255	56.914	0.21	11952.00
0.5-1.0	31	21.729	0.25	5432.00
1.0-2.0	14	17.184	0.27	4640.00
2.0-5.0	6	20.597	0.35	4640.00
>5	3	26.306	0.50	13153.00

Moisture content (%) - 50.00%
Bulk density (MT/m^3) - 0.40-0.60%
Gross calorific value of MSW (Kcal/kg) – 1032

Table 5: Typical composition & properties of Indian MSW

Organic fraction/biomass	35.00%
Woody biomass	15.00%
Paper	5.00%
Rags & Textiles	5.00%
Plastic	0.05%
Rubber etc.	4.85%
Glass	0.05%
Metals	0.05%
Stones	20.00%
Sand/ Earth	15.00%

2. ADVANTAGES

a) Cost of production of electricity is much more reduced in compare to electricity produced by conventional fuels.
b) Waste of power plant by using bagasse and rice husk as a fuel i.e. ash is useful in many Industries like cement manufacturing, rain force bricks etc.
c) Bagasse, MSW and rice husk works as renewable source of energy.
d) Proper waste disposal takes place because of utilization of MSW as a boiler fuel.
e) As the production of electricity is approximately pollution free therefore electricity production is eco-friendly.
f) Due to the proper utilization of the MSW it reduces or eliminates the water, air, land pollution at the dumped site completely.
g) The use of bio-mass for power generation enhances the economy of the industry and plant.
h) Use of these fuels will be very helpful in meeting the future and present power demand for India because India has very high availability of these fuels. Hence power production by these fuels in India is very beneficial and good at present and as well as for future.

3. CALORIFIC VALUE

Calorific value is the amount of heat generated from combustion of a unit weight of a substance, expressed as kcal/kg. The calorific value is determined experimentally using Bomb calorimeter in which the heat generated at a constant temperature of $25^{O}C$ from the combustion of a dry sample is measured. Since the test temperature is below the boiling point of water, the combustion water remains in the liquid state. However, during combustion the temperature of the combustion gases remains above $100^{O}C$ so that the water resulting from combustion is in the vapour state shows typical values of the residue and calorific value for the components of municipal solid waste. The calorific values of solid waste by experimentation and blending of solid waste with rice husk by experimentations are tabled below in table 5 and 6 respectively.

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Table 6: Calorific Values of Solid Waste by Experimentation

S. No.	Sample	Mass of Fuel 'X' Gm	Mass of Water in Bomb W'gm	Water Equiv. lent 'w' kg	Initial Temp 't1'	Final Temp 't2'	Higher Calorific Value Kcal/kg	Lower Calorific Value Kcal/kg
1	Solid waste	1	1771	0.128	26.5	27.40	1709.10	1051.36
2	Solid Waste	1	1771	0.128	26.5	27.43	1766.07	1108.33
3	Solid waste	1	1771	0.128	26.5	27.36	1633.14	957.41
4	Solid waste	1	1771	0.128	26.5	27.39	1690.11	1032.38
5	Solid waste	1	1771	0.128	26.5	27.41	1728.09	1070.36
6	Solid waste	1	1771	0.128	26.5	27.42	1747.08	1089.35
7	Solid waste	1	1771	0.128	26	27.38	1671.12	1013.39

Average calorific value of municipal solid waste is 1027.75 Kcal/kg.

Table 7: Calorific value of MSW with Rice husk

S. No.	Sample	Initial temp (t_1)	Final temp (t_2).	Higher calorific value (Kcal/kg)	Lower calorific value (Kcal/kg)
1	Rice husk 50% + solid waste 50%	26 °C	27.56°C	2962.44	1946.73
2	Rice husk 40% + solid waste 60%	26°C	27.45°C	2753.55	1737.84
3	Rice husk 30% + solid waste 70 %	26°C	27.34°C	2544.66	1528.95
4	Rice husk 20% + solid waste 80%	26°C	27.28°C	2430.72	1415.01

The calorific value of the blend of rice husk and municipal solid waste is less than the calorific value of the fuel blend of rice husk and bagasse.

4. STOCKS OF BAGASSE, RICE HUSK AND MSW

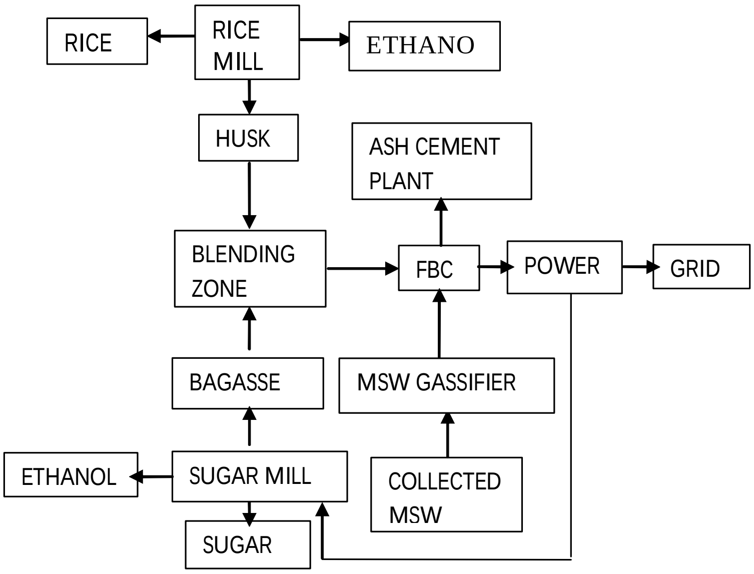
The stock of bagasse, rice husk and MSW available as per references in district Etawah, state of Uttar Pradesh and India is shown in the table 8 below.

Table 8: Stock Status in Etawah, Uttar Pradesh & India [18, 19, 20, 21, 22, 23]

Fuel	Etawah	Uttar Pradesh	India
Bagasse	Nil	23.4 million tonnes	102 million tones
MSW	35.75 metric tonne/day	5699 metric tonnes/day	48 x 10^6 tonne/year
Rice Husk	79,425 tonne/year	1.70 MT/year	13.5 MT/year

5. COMBINED POWER PRODUCTION BY BAGASSE, RICE HUSK AND MSW

The schematic diagram of combined power production by bagasse, rice husk and MSW is depicted below:



6. RESULTS AND DISCUSSION

The electricity generation by bagasse, rice husk and MSW for Etawah and Uttar Pradesh is calculated as following

6.1 Bagasse

Formula for Calorific value	**Power generation by Bagasse in Uttar Pradesh**
GCV = 4600-12s-46w NCV = 4250-12s-48.5w s- Sucrose % in bagasse w- Moisture % in bagasse If s and w expressed in per unit of bagasse then GCV= 4600(1-w)-1200s NCV= 4250-4850w-1200s	India is the second largest producer of sugarcane in world and in India; Uttar Pradesh alone produces 38.77% of the gross production of sugarcane. Uttar Pradesh produces 130 million tones of the sugarcane. 40 % of sugarcane is used for gur and khandsari and 60% sugarcane used for crystalline sugar. As it is known that approximately 30% is the bagasse by weight in sugarcane. Sugarcane used for sugar production = $\frac{130 \times 60}{100}$ =78 million tones Therefore total bagasse = $\frac{78 \times 30}{100}$ = 23.4 MT Since mill wet bagasse contains approximately 50% moisture and if plant with drier which uses temperature of flue gases to dry the bagasse and easily the moisture content will become 43% and it increase the steam fuel ratio and therefore power generation. Calorific value of bagasse by formulae GCV= [4600(1-w) – 1200 s] kcal/kg NCV = [4250 – 1200 s – 4850 w] kcal/kg We are considering that power plant is equipped with the dearator, economizer and drier etc.

Calorific value with drier	**Calorific value without drier**
GCV = 4600 (1-w) – 1200 s = 4600 (1-.43) – 1200 × 0.02 = 2598 kcal/kg Where w is moisture content s is % of sucrose in unit bagasse NCV = 4250–1200 s – 4850 w = 4250 – 1200 × 0.02 – 4850 × 0.43 = 2140.5 kcal/kg	GCV = 4600 (1-w) – 1200 s = 4600 (1-0.5) – 1200 × 0.02 = 2276 kcal/kg NCV = 4250 – 1200 s – 4850 w = 4250 – 1200 × 0.02 – 4850 × 0.5= 1850 kcal/kg

6.1.1 Power for Uttar Pradesh : The input parameters used for the purpose of analysis are given below [24]:

Table 9: Input Parameters

Description	**Value**
Turbine inlet temperature	510?C
Turbine inlet pressure	65 bar
Condenser pressure	0.035 bar
Mechanical efficiency of turbine	95%
Efficiency of alternator	90%
Efficiency of boiler	80%
Calorific value of fuel	7733 kJ/kg

Enthalpy values at 6.5 MPa and 510°C, h_1 = 3440.11 kJ/kg
and entropy at 6.5 MPa & 510°C, s_1 = 6.8687 kJ/kgK
Condenser pressure = 0.035 bar (3.5 kPa), h_2 = 2037.80 kJ/kg
The pump work has been neglected as it is very low compare to the turbine work.
Work done by turbine, η_{Th} (h_1-h_2) = 0.85×(3440.11 - 2037.80) = 1191.96 kJ/kg
η_{mech} 95% & efficiency of alternator η_{alt} 90% then
Alternator output = $W_T \times \eta_{mech} \times \eta_{alt}$ = 1191.96×0.9×0.95 = 1019.12 kJ/kg

m_1 rate of steam consumption/kWh, $m_1 = \frac{3600}{1019.12}$ = 3.53 kg/kWh
heat consumption = $m_1 (h_1-h_{fg})$ =3.53(3440.11 – 111.23) = 11750.94 kJ/kWh
As efficiency of boiler is 80% $= \frac{11750.94}{0.80}$

Heat consumption = 14688.67 kJ/kWh
Amount of fuel×Calorific value = Heat consumption
Amount of fuel $= \frac{heatconsumption}{calorificvalue} = \frac{14688.67 kJ \times kg}{7733 kJ \times kWh}$ =1.89 kg/kWh =1.9 kg/kWh
Now if we want to produce 1400MW power for 350 days & 24 hours then amount of fuel required = 1400×8400×1.9×1000 = 2.23×10^{10} kg = 22.3 MT

6.2 Rice husk

Energy Balance and Related Analysis of 5 MW Power Plant
Given that plant has to operate for 24 hrs and 350 days a year. Minimum amount of electricity generated = 5 x 24 x 350 = 42,000MW/year. Amount of heat required to produce 42,000MW/year = 151,200GJ/year Considering that approximately 30% of heat generated in the boilers. The boilers need to provide 504,200GJ/year. Based on calorific value of 13.33 GJ/tone (Govindarao, 1980) for the rice husk with 90% combustion efficiency, the quantity of rice husk needed to produce the required amount of energy will be 504,200 ÷ 0.90 ÷13.33 = 42,010.50 tonnes/year (approx.) This clearly indicates that to produce 1MWh, approximately 1 tonne of rice husk is required. Since rice husk has ash content of 18%, the 1MW power plant can produce approximately 1134 tonnes/yogh amorphous ash. 42,010.50 x 18 % = 7,561.890 tonnes/year of RHA (approx.)

6.2.1 Production of Electricity using Rice Husk in Etawah - Case Study : Etawah district of Uttar Pradesh where the total amount of rice husk is generated from different rice mill situated in Bharthna and Etawah is about 79425 metric ton/year. The related data for availability of Rice Husk is shown below

Table 9: Number of rice mills and their capacity Distt- Etawah

Sr. No.	Code No.	Name Of Rice Mill	Milling Capacity (Tonne/hour)
1	07-27-01-01	Badhumal Hukumat Rai	2.50
2	07-27-01-02	Maa Vaishno Rice Mill Pvt. Ltd.	4.00
3	07-27-01-03	Ankur Rice Mill	6.00
4	07-27-01-04	Chambamal Harjeet Singh	3.00
5	07-27-01-05	Madanlal Harish Kumar	3.00
6	07-27-01-06	Savanshree Rice Mill	2.50
7	07-27-01-07	S.S. Rice Mill	3.00
8	07-27-02-08	Durga Rice Industries	5.00
9	07-27-02-09	Anubhav Traiders	1.50
10	07-27-02-10	S.P. Rice Mill	3.00
11	07-27-02-11	Yadvendra Rice Industries	4.00
12	07-27-02-12	Yadvendra Agrotech Pvt. Ltd.	4.00
13	07-27-02-13	Yadav Agro Industries	4.00
14	07-27-02-14	Krishnalal Ashok Kumar	1.25
15	07-27-02-15	Matadin Balmukund	2.00
16	07-27-02-16	Harish Kumar Murtilal	2.00
17	07-27-03-17	Jamuna Prasad Ashvani Kumar	1.00
18	07-27-03-18	Jagannath Ashok Kumar	3.00
19	07-27-03-19	Mohit Rice Mill	4.00
20	07-27-03-01	Yadav Rice Mill	3.00
21	07-27-04-02	Mathura Prasad Ram Swaroop	1.25
22	07-27-04-03	Narsingh Das Kuar Bhadur	1.25
23	07-27-04-04	Sanjeev Mini Rice Mill	0.80
24	07-27-04-05	Deepak Rice Mill	7.00

Table 10: Number of Rice Mills and their Capacity Bharthna, Distt- Etawah

Sr. No.	Code No.	Name of Rice Mill	Milling Capacity (tonne/hour)
1	07-27-05-01	Krishna Rice & Daal Mill	3.00
2	07-27-05-02	Bhagwati Rice Mill	3.50
3	07-27-05-03	Yadav Chura & Rice Mill	1.88
4	07-27-05-04	Shri Durga Trading Industries	1.88
5	07-27-05-05	Shiv Shakti Rice Mill	2.00
6	07-27-05-06	Vishal Rice Mill	3.00
7	07-27-05-07	Gayatri Rice & Daal Mill	0.75
8	07-27-05-08	Kishan Rice Mill	1.88
9	07-27-05-09	Sri Bajrang Rice & Daal Mill	2.50
10	07-27-05-10	Partumal Lakhhumal Rice Mill	1.80
11	07-27-05-11	Vishal Industries	1.88
12	07-27-05-12	Beedhamal & Sans.	1.49
13	07-27-05-13	Seerumal Meharchand Rice Mill	3.00
14	07-27-05-14	Balmukund Bhagwan Das Rice Mill	3.00
15	07-27-05-15	Moti Rice mill	1.00
16	07-27-06-16	Mahaveer Rice Mill	3.00
17	07-27-06-17	K.G. Rice & Daal Mill	3.00
18	07-27-06-18	Jai Rice Industries	3.00
19	07-27-06-19	Mahaveer Industries	3.00
20	07-27-06-20	Umesh Chandr Vinod Kumar Rice Mill	1.88
21	07-27-06-21	Mahashakti Rice Mill	3.00
22	07-27-06-22	Mahalakshmi Rice Mill	3.00
23	07-27-06-23	J.S. Rice Industries	1.50
24	07-27-06-24	Gagan Rice Mill	1.50
25	07-27-06-25	S.K. Enterprises	3.00
26	07-27-06-26	Banke Bihari ji Rice Mill	3.00
27	07-27-06-27	Pawan Sut Agro. Industries	1.75
28	07-27-06-28	Mahadev Rice & Daal Mill	1.75
29	07-27-06-29	Krishna Industries Rice Mill	2.00
30	07-27-07-30	Guru Mukh Das Shankar Lal Rice Mill	3.75
31	07-27-07-31	Mehar Chand Sewal Das Rice Mill	3.00
32	07-27-07-32	Avadh Industries	3.00
33	07-27-07-33	Krishn Gopal & Sons.	4.00
34	07-27-07-34	New Chauhan Rice Mill	3.00
35	07-27-07-35	Yadav Rice & Daal Mill	1.80
36	07-27-07-36	Lakshmi Rice Mill	1.40
37	07-27-07-37	Shiv Rice Mill	1.25
38	07-27-07-38	J.R. Bhatiya & Sons.	3.00
39	07-27-05-39	Shri Karoli Devi Rice Plant	4.00
40	07-27-05-40	Ganga Rice Mill	4.00
41	07-27-05-41	Kanhaiya Rice Mill	3.00
42	07-27-05-42	Kayam Rice Mill	3.00
43	07-27-05-43	Girish Chandra & Brothers	1.40

6.2.2 Status of electricity production using Rice Husk in ETAWAH : The electricity production using rice husk in Etawah district is summarized below:-

Rice husk production approx	**79425 metric ton/Year**
Amount of energy produce = 79425×0.90×13.33 (If combustion efficiency 90%, calorific value of rice husk 13.33 GJ/tonne)	**952861.725 GJ/Year**
Total heat generated for electricity =952861.725 ×0.3 (If 30% of heat generated in the boilers converted in electricity)	**285858.175 GJ/year**
Minimum production of electricity (285858.175 ×1000) ÷ 3600	**79405.143 MWh/Year**
Capacity of plant in MW (79405.143) ÷ (24 × 350) (If plant run for 24 hours and 350 days a year)	**9.45 MW**

6.2.3 Status of electricity production using Rice Husk in Uttar Pradesh : The electricity production using rice husk in Uttar Pradesh is summarized below:-

Total paddy production	**13.5 MT**
Amount of paddy processed in Rice Mills = (13.5 × 0.80) (since 80% of paddy processed in the big capacity rice mills.)	**10.8 MT**
Total amount of Rice Husk from paddy = (10.8 × 0.20) = 2.16MT (As 20% by weight is the amount Rice husk in unit weight of paddy)	**2160000 Tonnes**
Amount of energy produced = 2160000 × 0.90 × 13.33 (Taking combustion efficiency 90% and calorific value 13.33GJ/tonne)	**25913520 GJ/Year**
Minimum amount of heat = 25913520 × 0.30 (Considering 30% of boiler heat converted into the electricity)	**7774056 GJ/Year**
Minimum electricity produced = $(7774056 \times 10^3)/3600$	**2159460 MWh/Year**
Capacity of electricity produced = $\frac{2159460}{350 \times 24}$ (If plant run for 350 days and 24 hours in a year)	**257.07 MW**

6.3 Municipal Solid Waste (MSW)

Theoretical net power generation potential based on International Journal of Environmental Science

Net calorific value = Gross calorific value – Latent heat of water vapour formed = (GCV – mass of hydrogen percent weight of fuel burned × 0.09 × latent heat of steam) = GCV – 0.09 × H × 587 = 1080 – 0.09 × 2.65 × 587 = 940 kcal/kg H = % of hydrogen, Given, NCV = 940 kcal/kg, % of hydrogen = 2.65%
Power production by MSW in Etawah
The total waste from Etawah city is 65 metric tonnes (w) The total amount of useful waste is only 55% of the total amount of the waste available Useful waste from 65 metric tonnes = (65 × 55) ÷ 100 = 35.75 tonnes Energy recovery potential = NCV×w×1000/860 = 940×35.75×1000/860=39075.58 kWh Power generation potential = 1.16 × NCV × w/24 = 1.16 × 940 × 35.75/24 = 1624.24 kW/day = 1.624 MW/day (approx)

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Total power generation by Municipal Solid Waste in Uttar Pradesh

Total urban population according to the census 2010-2011

- 72.2% of the total population.
- India has 641000 in habited villages.
- Uttar Pradesh 199,581,477 (population)
- % of population = 16.49%
- Rural population = 131658339
- Urban = 34539582
- Area of up (in km^2) = 240928
- Sex ratio = 908
- Density/km^2 = 828

Calculation of total amount of waste produced in urban areas = total urban population × amount of waste per capita in kg = 34539582 ×0.300 kg =10,361.87 tonnes

As total useful waste for power generation is only 55% of the total waste

Therefore, Amount of useful waste = (10361.87 × 55) ÷ 100 = 5699 tonnes

Net power calculation for UP

Net calorific value = gross calorific value – latent heat of water vapour formed

=GCV–mass of hydrogen per unit fuel burnt×.09×latent heat of steam=GCV–(.09×H×587)

= 1080 – (.09 ×2.56 × 587) = 940 kcal/kg

H= % of hydrogen

The total waste from urban areas of Uttar Pradesh = 5699 tonnes

Net energy recovery potential=NCV×w×1000/860=940×5699×1000/860

= 6,229,170.686 kWh

Power generation potential in per day = 1.16 × NCV × W/24 = 1.16 × 940 × 5699/24

= 258,924.56 kW/day **= 258.92 MW/day (approx.)**

6.4 Power production by different Fuels in Uttar Pradesh

Based on study the following patterns shown in figure shows the power production by different fuels in Uttar Pradesh.

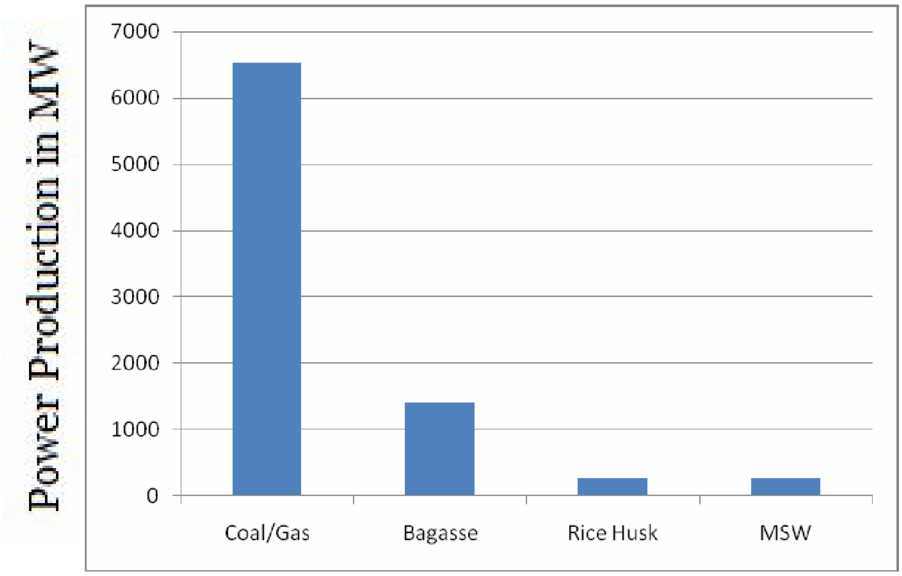

Fig. 2: Different types of Fuels

Table 11: Power production by different fuels in Uttar Pradesh

Type of Fuel	Power Potential (MW)
Coal/Gas	6532
Bagasse	1400
Rice Husk	257.07
MSW	258.98

Total power saved by Bagasse, Rice Husk and MSW = 1400+257.07+258.98 = 1916.05 MW

Power produced by one tonne of coal = 2.5 MW approx.

Amount of coal required to produce 1916.05 MW = 1916.05 ÷ 2.5= 766.42 tonnes

Price of coal per tonne = Rs 4500-5000

Then total amount of money saved = 5000 × 766.42 = Rs 3832100

7. CONCLUSION

Based on the study and results, the following points are concluded.

- The potential of power generation by bagasse in Uttar Pradesh is 1400 MW and it can save approximately 560 tonne of coal.
- The potential of power generation by rice husk in Uttar Pradesh is 257.05 MW and it can save approximately 102 tonne of coal. The potential for power generation at district Etawah by rice husk is approximately 9.45 MW which can save approximately 3.78 tonne of coal if utilized appropriately.
- The potential of power generation by MSW in Uttar Pradesh is 258 MW and it can save approximately 103 tonne of coal and save fuel & money in huge amount.
- If the power is generated by these non conventional fuels in Uttar Pradesh then the overall power generation potential is approximated to be 1916.5 MW which can save about 766.42 tonne of coal. Thus at national level it can save a very large amount of conventional fuels and money both.
- The economic perspective point of view it is seen that price of rice husk/tonne is Rs 2000-2500 while the price of coal/tonne is Rs 4500-5000 means a great saving of conventional fuels and money both.
- With the usage of MSW for power generation garbage dumping/ disposal and environmental problems are minimized.
- The green house emissions are also less compare to the conventional fuels, thus it is useful in reducing the environmental pollution and the global warming.
- The blending of rice husk with the bagasse and MSW both is possible and have appreciable calorific value therefore at any place if any two are available in less amount and one is in appropriate amount then power can be produced by blending of two and money as well as conventional fuels both can saved for future.
- The power generation by bagasse is much more economical than the coal.
- The ash of rice husk used in several industries like as cement industry, cosmetic industry etc.

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