1st International Conference on New Frontiers ibn Biofuels held on Jan 18-19, 2010 by Delhi Technical University at Delhi.

**ID: P-154**

# Power Generation Potential of Biomass Residue of Maize

**Saroj Kumar Patel[*], Mithilesh Kumar[1]**

[*]Mechanical Engineering Department

[1]Metallurgical and Materials Engineering Department

National Institute of Technology, Rourkela, Orissa-769008, India

E-Mail: skpatel@nitrkl.ac.in

## ABSTRACT

India is an agricultural country with a major share of rural population. It has still many remote villages without any electricity supply. This paper reports the experimental results of proximate analysis and calorific values of different components of maize crop residue. Its potential towards electricity generation and corresponding land requirement for plantation has also been calculated. The results show that approximately 1100 hectares of land are required to generate 20 MWh/day of electricity. The results are also compared with that of coal samples of six different local mines being used in thermal power plants. This comparison reveals that maize waste can be used to generate considerable amount of power output with negligible emission of suspended particulate matters. Its ash fusion temperatures are also experimentally found out and it is observed that it can be used safely up to a temperature of $800^0$C without any clinker formation in the boiler.

**Keywords:** calorific value, electricity generation, maize, proximate analysis

## 1. INTRODUCTION

India is a developing country and agriculture has always been the mainstay of its economy accounting for 17.8 per cent of its gross domestic product during 2007-08 [1]. It constitutes the backbone of rural India whose inhabitants are more than 70% of total population. As a result, lot of agricultural wastes are generated and remain unutilized. Maize is the third most important food grain crop in India and considered a promising option for diversifying agriculture in upland areas of India. Its current consumption stands around 16 million tons and it is expected to go over 30 million tons by 2020 [2].

Even today there are many remote villages in India without any electricity supply. The remoteness and thin population make the grid supply of electricity highly uneconomical. Moreover, there is always a growing concern due to fast depletion of fossil fuel resources for power generation and corresponding pollution of the environment. Therefore, biomass is being considered as one of the alternative sources of electricity generation.

Biomass resources are potentially the world's largest and most sustainable energy source for power generation in the 21$^{st}$ century. The total potential of non-woody biomass available for energy production in India was estimated to be 472 pJ in 1996-97, and the proposed value for the year 2010 is 656 pJ [3]. As shown in Figure 1, the estimated global electricity generation capacity of biomass is about 11,000 TWh which is greater than that of all other renewable energy sources [4]. It clearly indicates that the current biomass use is much below the available potential. The estimated power generation potentials of various renewable energy sources in India have been outlined in Table 1 [5]. It is fairly clear from Figure 1 and Table 1 that the power generation potential of biomass is considerably high in the world including India.

Sustainable production and utilization of biomass in electrical power generation can also solve the problems of rural unemployment, utilization of wasteland, and transmission losses in grid network. Accordingly, the system of biomass-based power generation is being given priority in most of the developing nations including India. Unlike other renewable substances biomass materials, pre-dried up to about 15% moisture content, can be stored for a considerably long period of time without any difficulty. Besides electricity supply to the national grids, biomass offers tremendous opportunities for decentralized power generation in rural areas at or near the points of use and thus can make villagers/ small industries self-dependent in respect of their power requirements.

To exploit biomass species in electricity generation, it is necessary to find out their various properties like calorific value, chemical composition, reactivity towards oxygen, bulk density, etc. This paper deals with the experimental work on proximate analysis and calorific values of different components of maize, and their impact on electricity generation. It also experimentally finds out the ash fusion temperatures to confirm its safe operation in the boiler.

## 2. EXPERIMENTAL

### 2.1 MATERIAL COLLECTION

In this work, the waste residues of maize were collected from the coastal area of Orissa state of India. Its botanical specie name is *Zea Mays* and family name is G*ramineal*. Its components like stump, corn pad, leaf and bark were removed separately and air dried in a cross ventilated room for about a month till their moisture contents were reduced to be in equilibrium with that of the atmosphere. The air-dried biomass were crushed into powders and then processed for their proximate analysis and calorific value determination.

### 2.2 PROXIMATE ANALYSIS AND CALORIFIC VALUE

Analyses for moisture, volatile matter, ash and fixed carbon contents were carried out on samples ground to –72 mesh size by standard method [6]. Moisture content in each sample was determined by heating it at $105 \pm 5^0$C for 1 h in an air oven, while the determination of volatile matter content involved heating the sample (contained in silica VM crucible ) at $925^0$C for 7 min. For the estimation of ash, 1 g of sample was burnt in a muffle furnace at $700^0$C. The calorific values of the above ground samples were measured by Bomb Calorimeter [7].

## 3. RESULTS AND DISCUSSION

### 3.1 PROXIMATE ANALYSIS AND CALORIFIC VALUE

The study of proximate analysis of fuels is important because it gives an approximate idea about the energy values and the extent of pollutant emissions during combustion. The biomass waste contains a large amount of free moisture, which must be removed to decrease the transportation cost and increase the calorific value. The proximate analyses of different components of maize are presented in Table 2. The moisture content is minimum in leaf whereas it is maximum in bark. Out of all components, the corn pad contains the highest amount of volatile matter slightly followed by the stump. The bark has the minimum volatile matter but maximum moisture content. The ash content is minimum in corn pad while it is maximum in leaf. The leaf contains the lowest fixed carbon where as the corn pad contains the highest. The leaf has the highest ash content but the lowest fixed carbon content.

The calorific value of a fuel is an important criterion in judging its quality for electricity generation since it gives an idea about the energy value of the fuel. As shown in Table 2, the calorific value of the corn pad is the highest and that of leaf is the lowest. The major chemical constituents affecting the calorific values of carbonaceous materials are carbon and hydrogen. The above variation in calorific values of plant components is obviously related to the combined effects of their carbon and hydrogen contents. The above variation in calorific values of plant components is obviously related to the combined effects of their carbon and hydrogen contents.

### 3.2 ASH FUSION TEMPERATURES

Ash fusion temperature of solid fuel is an important parameter affecting the operating temperature of boilers. Clinker formation in the boiler usually occurs due to low ash fusion temperature and this hampers the operation of the boiler. Hence the study of the ash fusion temperature of solid fuel is essential before its utilization in the boiler. The four characteristic ash fusion temperatures were identified as : (i) initial deformation temperature (IDT) – first sign of change in shape; (ii) softening temperature (ST) – rounding of the corners of the cube and shrinkage; (iii) hemispherical temperature (HT) – deformation of cube to a hemispherical shape; and (iv) fluid temperature (FT) – flow of the fused mass in a nearly flat layer. These four temperatures are listed in Table 3 from which it may be concluded that the boiler operation with paddy residues can be carried out safely (without clinker formation) up to the temperature of $800^0$C.

### 3.3 ESTIMATION OF DECENTRALIZED POWER GENERATION UNIT

For the estimation of power generation to meet the electricity requirements of villages, a group of 10-15 villages consisting of 3000 families may be considered, for which one power station could be planned. The electricity requirement for lighting and domestic work in these villages may be 6

MWh/day. An additional 14 MWh/day (approx.) may be required for agriculture (irrigation) and small scale industries situated in a group of villages. Thus, a power plant should be capable of generating 20 MWh/day (i.e., 7.3 GWh/year) for a group of 10-15 villages.

The design of energy plantation of maize for power plant of 20 MWh/day capacity has been presented in Table 4 and Appendix. The results indicate that in order to meet the yearly power requirement of the order of 7.3 GWh for a group of 10-15 villages, 1124 hectares of land should always be ready for harvesting, in order to have perpetual generation of power.

### 3.4 COMPARISON WITH COALS

The results of proximate analysis and calorific values of six different types of locally available non-coking coals being used for electricity generation in Orissa (India) were reported by Kumar and Patel [8] and shown in Table 5. This table also shows that the calorific values of all components of maize except leaf are superior than that of coals of Hingola mine. The ash contents in all these coals are much higher (range : 39-60%) and they are expected to pollute the environment heavily with SPM (suspended particulate matter). This is a big problem and the solution is not easy. On the other hand, all components of maize waste have ash content much less than all the available coals listed in Table 5.

## 4. RESULTS

The main conclusions made out of the present work are outlined below.

1. The maximum content of moisture, volatile matter and ash are observed to be in bark, corn pad and leaf of maize respectively.
2. The corn pad has maximum fixed carbon content and calorific value compared to all other components.
3. The waste of maize crop can be safely used in the boiler up to a temperature of $800^0$C without any risk of clinker formation.
4. Nearly 1100 hectares of land would be required for continuous generation of 20 MWh electricity per day from maize waste.
5. There exists local coal mine of which coals used for power generation compared to which maize waste has been found to have more calorific value. On the other hand, all components of paddy waste have much lower ash content than the coals of all the six local mines.
6. Thus, the present work could be useful in the exploration of maize waste for power generation in small decentralised power plant suitable in rural areas.

## REFERENCES


1. Annual Report 2008-09, Ministry of Agriculture, Govt. of India, July 2009. http://agricoop.nic.in/AnnualReport08-09/Agriculture%20English%20book.pdf (Accessed on November 26, **2009**).
2. Commodity Online. http://www.commodityonline.com/news/India-to-consume-30mn-tonnes-of-maize-in-2020-17373-3-1.html (Accessed on November 26, **2009**).
3. Ravindranath, N.H.; Somashekar, H.I.; Nagaraja, M.S.; Sudha, P.; Sangeetha, G.; Bhattacharya, S.C.; Salam, P.A. Assessment of sustainable non-plantation biomass resources potential for energy in India. Biomass and Bioenergy **2005**, *29*, 178-190.
4. Renewable energy statistics: renewable energy at a glance in the world. Akshay Urja **2006**, *2*.
5. Renewable energy statistics: renewable energy at a glance in India. Akshay Urja **2005**, *1*.
6. Methods of tests for coal and coke. Indian Standard IS: 1350, Part I **1969**.
7. Agrawal, B.C.; Jain, S.P. A Text Book of Metallurgical Analysis, 3rd Ed., Khanna Publishers, New Delhi **1980**.
8. Kumar, M.; Patel, S.K. Energy values and estimation of power generation potentials of some non-woody biomass species, Energy Sources, Part A **2008**, *30*, 765-773.

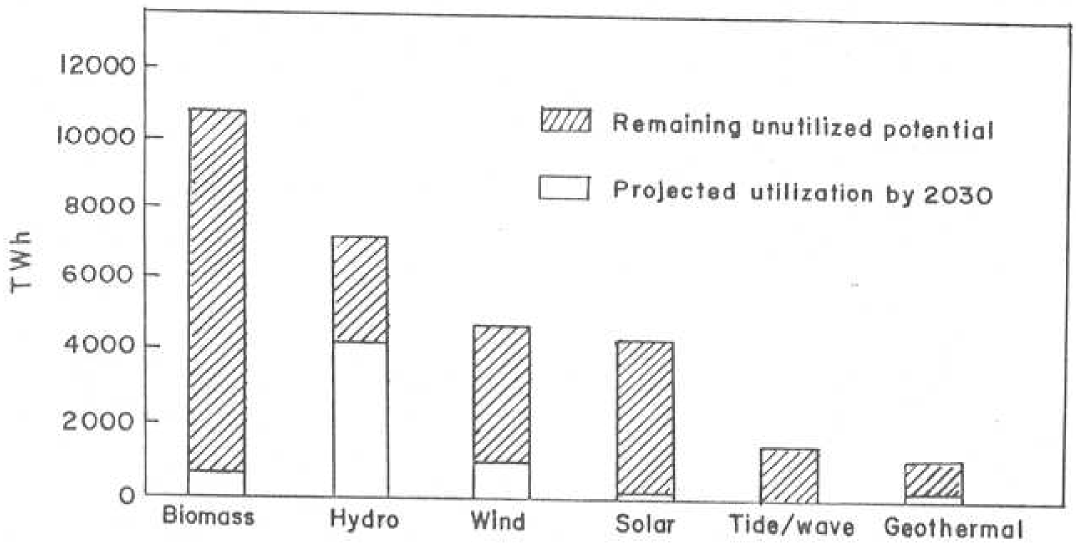


**Figure 1.** World long-term renewable energy potential for electricity generation.

**Table1.** Electricity generation potentials of renewable energy sources in India [4].

| Source | Estimated potential (MW) | Cumulative installed capacity (MW) |
|---|---|---|
| Wind energy | 45,000 | 4,434.00 |
| Biomass energy | 16,000 | 376.00 |
| Bagasse | 3,500 | 491.00 |
| Small hydro (up to 25MW) | 15,000 | 1,748.00 |
| Waste-to-energy | 2,700 | 45.76 |
| Solar photovoltaic | 20 $MW/km^2$ | 2.80 |

**Table 2.** Proximate analysis and calorific values of different components of maize.

| Component | Proximate analysis wt %, air dried basis | | | | Calorific value(kcal /kg, dry basis) |
|---|---|---|---|---|---|
| | Moisture | Volatile matter | Ash | Fixed carbon | |
| Stump | 10.00 | 69.00 | 6.00 | 15.00 | 3524 |
| Corn pad | 8.00 | 70.00 | 1.50 | 20.50 | 4901 |
| Leaf | 4.00 | 65.00 | 20.75 | 10.25 | 3318 |
| Bark | 12.00 | 59.75 | 12.25 | 16.00 | 3650 |

**Table 3.** Ash fusion temperatures of maize waste.

| Ash fusion temperature, $^0C$ | | | |
|---|---|---|---|
| IDT | ST | HT | FT |
| 795 | 850 | 1097 | 1130 |

**Table 4.** Total energy contents and power generation structure from fully grown up maize crop.

| Component | Calorific value (kcal /t, dry basis ) | Biomass production (t/ha dry basis)* | Energy value (kcal/ha) |
|---|---|---|---|
| Stalk | $3524 \times 10^3$ | 3.70 | $13038 \times 10^3$ |
| Corn pad | $4901 \times 10^3$ | 1.00 | $4901 \times 10^3$ |
| Leaf | $3318 \times 10^3$ | 0.85 | $2820 \times 10^3$ |
| Bark | $3650 \times 10^3$ | 0.32 | $1168 \times 10^3$ |

* From field survey

**Table 5.** Proximate analysis and calorific values of non-coking coals obtained from different mines of Orissa (India) [8].

| Coal mine | Proximate analysis (wt.%, dry basis) | | | Calorific value (kcal/kg) dry basis |
|---|---|---|---|---|
| | Volatile matter | Ash | Fixed carbon | |
| Lakhanpur | 21.21 | 52.24 | 26.55 | 3938 |
| Siding | 30.62 | 44.30 | 25.08 | 4952 |
| Hingola | 21.90 | 59.83 | 18.27 | 3355 |
| Yeurve | 35.66 | 38.90 | 25.44 | 4682 |
| Kalinga | 24.77 | 50.77 | 24.46 | 4237 |
| Jagannath | 31.10 | 52.68 | 16.22 | 4660 |

## APPENDIX

### CALCULATION OF LAND REQUIREMENT FOR ENERGY PLANTATIONS

Referring data from Table 4, on oven dried basis the total energy from one hectare of land = $(13038 + 4901 + 2820 + 1168) \times 10^3 = 21927 \times 10^3$ kcal.

It is assumed that conversion efficiency of wood fuelled thermal generators = 30 % and overall efficiency of the power plant = 85 %.

Energy value of the total utilizable biomass obtained from one hectare of land at 30% conversion efficiency = 21927 x $10^3$ x 0.30 =6578.1 x $10^3$ kcal = 6578.1 x $10^3$ x 4.1868/ 3600 = 7650.3 kWh.

Power generation at 85 % overall efficiency = 7650.3 x 0.85 = 6502.8 kWh /ha.

Land required to supply electricity for the whole year = 7.3 x $10^6$ / 6502.8 = 1124 ha.