DESIGN OF AGRIWASTE FUEL: WAYS AND MEANS

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Abstract: Energy crops (energy plantations), are not being used in the region & organized markets do not exist. Consequently, quantity and price information for agriwaste energy crops need to be designed. The analysis is also based on the assumption that differences in soil quality, climate, and land use across the region will create geographic variation in the cost and potential supplies of energy crops. Production of both energy crops and conventional crops are prone to land quality and climate. Consequently, prices of agriwaste should show geographic variability reflective of that sensitivity. It is designed and modeled to capture the effect of these three factors on energy crop price and supply. With the fossil fuels gradually depleting and hydro sources reaching 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.

Key Words: Energy Plantations, Soil Quality, Yields, agriwaste, Sustainability, Economic viability.

1. Introduction

India being agriculture based economy, 65% of its GDP comes from either agriculture or agro based industry [61,62]. Any enhancement of income from this sector is based upon adequate supply of basic inputs in this Sector. Regular and adequate power supply is one such input. But the status of power supply in our country is deteriorating day-by-day with a major share of power produced being sent to the industry and urban areas. Hence, there is a perennial shortage of power in the agriculture sector. Consequently, there is an urgent need to produce more power, in order to fulfill the needs of agriculture sector effectively. Energy consumption in India has gradually increased from 65 million tonnes of oil equivalent (mtoe) in 1973 to 400 mtoe by 2001, showing a growth rate of over eight per cent during the entire period. The per capita energy consumption has also increased from 108 kilograms of oil equivalent (kgoe) in 1970-71 to about 400 kgoe in 2000-2001, which is still very low as compared to the global level [61,62]. India, with a total land area of 328.8 million hectares (mha) [62] has an estimated human population of 1000 million and a live stock strength of about 500 million, with a major percentage living in about 5, 80000 villages [62]. The annual production of food grains is 150 million metric tones (mmmt) [19, 21,47,54,62,62]. Though there is no authentic data available with regard to the quantity of agricultural and agro-industrial residues, its rough estimate can be put at about 350 million tones (mt) per year [54,62]. It is also estimated that the total cattle refuse generated is nearly 250 mt per year [62]. Further, nearly 20% of the total land is under forest cover, which produces approximately 50 mt [62] of fuel wood and with associated forest waste of about 5 mt [54,62]. The total availability of agriwaste, energy plantations and agro-industrial waste in the country is placed around 405mt per year [6,54,62].

The ever increasing need and demand for energy: especially electrical power energy: the fast pace of depletion of fossil fuels had focussed the attention of the world towards the non-conventional energy resources. Biomass in general and agriwaste in particular is being considered as one of the alternatives with possibly the highest potential. During the last three decades number of researchers, academicians, experts, professionals and administrators have researched and deliberated on the issues concerned with this aspect and other related issues like cost economics, efficiencies and environmental impact etc. [3,6,19,20,21]. Taking into account the utilization of even a fraction (say 40%) [6,54,62] of agriresidue and agro industrial waste as well as energy plantations on one million hectare (mha) of wastelands for power generation through bio energy technologies, a potential of some 20,000 MW[62] of power is estimated. Present research is on soil quality, climate, and land use of agriwaste combustion which is focused on improvements of existing system with respect to ease of operation, higher efficiency, higher calorific value of composite fuel, low cost of fuel (including transportation, labour and maintenance cost and marketing cost) and emission controls by designing and modeling of new agriwaste technology which can mitigate the problems of existing conventional combustion systems to a great extent is fluidized bed combustion system.

1.1 Agricultural residues:

An agricultural residues survey was carried out to cover the cotton, sugarcane maize, rice, and wheat crops, both
for the rabi and the kharif seasons. Samples were drawn from different areas in accordance with agro-ecological zonation, and for different productively conditions. The estimated quantities of crop residues and classification based on shapes & sizes are given in Table (1.1 a & b).

Source: Biomass energy systems (1996) pp117

Table: 1.1 (b): Classification of agriwaste based on physical shape and size and in terms of ash content (%)

<table>
<thead>
<tr>
<th>Ash content</th>
<th>Powdery</th>
<th>%age</th>
<th>Coarse/granular material</th>
<th>%age</th>
<th>Stalk-like material</th>
<th>%age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low ash</td>
<td>-</td>
<td>-</td>
<td>Kikar (Acacia)</td>
<td>0.6</td>
<td>Grewia optiva</td>
<td>0.3</td>
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<td></td>
<td>-</td>
<td>-</td>
<td>Walnut shell</td>
<td>0.4</td>
<td>(bhillal) Elphant grass (Miscanthus)</td>
<td>0.7</td>
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<td></td>
<td>-</td>
<td>-</td>
<td>Labakshi</td>
<td>0.75</td>
<td>Khar wood</td>
<td>0.8</td>
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<tr>
<td></td>
<td>-</td>
<td>-</td>
<td>Amla seeds</td>
<td>1.2</td>
<td>Corn cob</td>
<td>1.2</td>
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<td></td>
<td>-</td>
<td>-</td>
<td>Cedar cones</td>
<td>1.5</td>
<td>Mata stick</td>
<td>1.2</td>
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<td></td>
<td>-</td>
<td>-</td>
<td>Waste from Dabar</td>
<td>1.5</td>
<td>Vetix negundo</td>
<td>1.5</td>
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<td></td>
<td>-</td>
<td>-</td>
<td>Pine needle</td>
<td>1.5</td>
<td>Carissa carandas</td>
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<td></td>
<td>-</td>
<td>-</td>
<td>Harid</td>
<td>1.6</td>
<td>Soyabean stalk</td>
<td>1.5</td>
</tr>
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<td></td>
<td>-</td>
<td>-</td>
<td>Coffee spent</td>
<td>1.8</td>
<td>Sunflower stalk (without spongy part)</td>
<td>1.9</td>
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<td></td>
<td>-</td>
<td>-</td>
<td>Bagasse</td>
<td>1.8</td>
<td>Adhatoda vasica</td>
<td>2.0</td>
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<td></td>
<td>-</td>
<td>-</td>
<td>Coconut shell</td>
<td>1.9</td>
<td>Mulberry stick</td>
<td>2.1</td>
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<tr>
<td></td>
<td>-</td>
<td>-</td>
<td>Khandsari bagasse</td>
<td>2.6</td>
<td>Artmessa parviflora</td>
<td>2.3</td>
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<td></td>
<td>-</td>
<td>-</td>
<td>Fibre of green coconut</td>
<td>2.8</td>
<td>Tea of bush stem</td>
<td>2.5</td>
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<td></td>
<td>-</td>
<td>-</td>
<td>Subabul leaves</td>
<td>3.6</td>
<td>Rhus cotinus</td>
<td>3.0</td>
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<td></td>
<td>-</td>
<td>-</td>
<td>Groundnut shell</td>
<td>3.6</td>
<td>Besaram</td>
<td>3.1</td>
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<td></td>
<td>-</td>
<td>-</td>
<td>Tea waste</td>
<td>3.8</td>
<td>Jowar straw</td>
<td>3.1</td>
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<td></td>
<td>-</td>
<td>-</td>
<td>Arhar stalk</td>
<td>3.8</td>
<td>Lantana cammara</td>
<td>3.5</td>
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<td></td>
<td>-</td>
<td>-</td>
<td>Maliotus philippensis</td>
<td>3.7</td>
<td></td>
<td></td>
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<td></td>
<td>-</td>
<td>-</td>
<td>Thukal kanda</td>
<td>3.8</td>
<td></td>
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<tr>
<td>Medium ash</td>
<td>-</td>
<td>-</td>
<td>Cherry coffee</td>
<td>4.0</td>
<td>Congress grass (Parthenium)</td>
<td>4.2</td>
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<td></td>
<td>-</td>
<td>-</td>
<td>Sunflower branch</td>
<td>4.3</td>
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<td></td>
<td>-</td>
<td>-</td>
<td>Kokrihu (Xanthium strumarium)</td>
<td>4.5</td>
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<td></td>
<td>-</td>
<td>-</td>
<td>A grade grass</td>
<td>5.2</td>
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<td></td>
<td>-</td>
<td>-</td>
<td>Coffee chaff</td>
<td>4.6</td>
<td>Chrothia</td>
<td>5.2</td>
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<tr>
<td></td>
<td>-</td>
<td>-</td>
<td>Cotton shells</td>
<td>4.6</td>
<td>Castor stick</td>
<td>5.4</td>
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<tr>
<td></td>
<td>-</td>
<td>-</td>
<td>Waste from Dabar (Bark)</td>
<td>5.1</td>
<td>Dry potato waste</td>
<td>5.8</td>
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<td></td>
<td>-</td>
<td>-</td>
<td>Areacnut shell</td>
<td>5.1</td>
<td>Bagi stick</td>
<td>7.1</td>
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<td></td>
<td>-</td>
<td>-</td>
<td>Coconut coir</td>
<td>5.8</td>
<td>Sweet sorghum stalk</td>
<td>7.4</td>
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<td></td>
<td>-</td>
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<td>Coconut waste (top cover)</td>
<td>6.3</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>-</td>
<td>-</td>
<td>Tea leaves</td>
<td>6.7</td>
<td></td>
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<td></td>
<td>-</td>
<td>-</td>
<td>Soyabean husk</td>
<td>7.2</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>-</td>
<td>-</td>
<td>Sugarcane leaves</td>
<td>7.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>-</td>
<td>Bagasse pith</td>
<td>8.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

High ash Industriebiomassu.dust | 9.9 | Copper of castor | - | B grade grass | 8.8 |

Tobaco sawdust | 19.1 | Oil seeds | 9.0 | Jowar stalk | 9.5 |

Fly dust | 19.2 | Sal seed husk | 9.4 | Ageratnum conyozides | 9.5 |

Jute dust | 19.9 | Sunflower | 10.1 | C ciliarns grass | 9.7 |

De-oiled bran | 28.2 | Waster hyasinth | 10.8 | Bammara weeqi | 10.9 |

Dal lake weed | 48.7 | Mentha piperscens | 13.5 | Ficus | 10.9 |

Tobacco dust | 49.4 | Effluent sludge | 14.4 | Hybrid napier grass | 11.5 |

M mustard | 15.4 | Mustard shell | 15.4 | Ground paddy straw | 15.5 |

Senna leaves | 17.25 | - | - |

Spearumut | 18.1 | - | - |

Sal seed leaves | 19.7 | - | - |

Decaffeinated tea waste | 19.8 | - | - |

Rice husk | 22.4 | - | - |

Source: Biomass energy systems

2. Briquetting of Agriwaste:

2.1 Process:

Briquetting is the process of densification of agriwaste to produce homogeneous, uniformly sized solid pieces of high bulk density which can be conveniently used as a fuel. The densification of the agriwaste can be achieved by any one of the following methods:

(i) Phyrolysed densification (briquetting) using binder

(ii) Direct densification (briquetting) of agriwaste using binder

(iii) Binder less briquetting

Except wood, all other agriwaste species have very low bulk densities. Accordingly, these are inconvenient and uneconomical to handle, store, and transport.
Furthermore, the direct use of these materials for energy is associated with inefficient conversion and widespread combustion-related pollution. For efficient and pollution free utilization, it is imperative to process these materials so as to make them convenient fuels. The main feed preparation techniques are sizing, like making chips; densification; briquetting, pelletization and carbonization. To carry out the above operations, it is invariably desirable to dry the materials, either naturally in the sun or through mechanical processing.

2.2 Drying:
While green wood contains 50–55% moisture, several agro-residues have the same or higher moisture content. These need to be dried to extract maximum energy. Table (1.4) gives the heating values of typical agriwaste on a wet and dry basis. Firstly, agriwaste is dried in the sun up to 20 – 25% moisture and later by thermal processes. While various systems are employed for drying, the most common practice for chips and powder materials is to simultaneously convey and dry the materials in entrained bed or flash pneumatic driers.

2.3 Size reduction:
Many agriwaste residues are cut into smaller sizes for easy handling and efficient combustion. Straw and stalk-type materials are chopped by chaff-cutters into granular materials, either for baling or for easy transportation. Similarly, sticks are shredded for their efficient use in boilers. Size reduction is needed for their use either in fluidized or other burning applications. Though size reduction is necessary for many operations, it is desirable to use the materials in the original form as each conversion operation needs energy, and their handling results in the loss of material.

3. Factors influencing agriwaste utilization:
Several factors pertaining to material, technological, environmental, economic, fiscal, managerial, etc., influence the utilization of agriwaste as source of energy, especially for power generation.

3.1 Design and Modeling Agriwaste Fuels:
Agriwaste materials are highly volatile when compared to coal. Over 80% of the heating value of agriwaste fuel is obtained from its volatile matter. Specific gravity indicates the amount of solid material in a given volume, and is inversely correlated with moisture content. Moisture content depends not only on natural conditions but also the storing conditions – whether stored in ponds or on dry decks. In general, agriresidue from young plantations contains more water than wood from an old plantation of the same species. Water contained in the agriwaste adds to its transportation cost. An increase in the moisture content from 10 to 30% in straw decreases its calorific value by 28% [Source: Biomass energy systems]. The calorific value or heat of combustion for a given volume of agriwaste material is primarily determined by its chemical composition, moisture content, and specific gravity. The prices of agri residues are given in table (1.2) and briquetised agriwaste fuel prices in table (1.2 a,b,c,d).
So that 20 x 20 x 20 room will have 1728000

Briquette size 3 x 2 x 1 Wt. 72 kg = 0.072 kg
= 2303994.2 briquettes
Wt. of 1728000 briquettes = 1728000 x 0.052 = Wt.
of 2303994.2 briquettes = 1658875.59 kg
= 89856 kg = 165.8875 tonnes

Similarly
12 x 6 x 6 size briquette will weight 1.750 g
12 \times \frac{6}{12} \times \frac{6}{12} = \text{Cubic feet}

20 \times \frac{20}{6} \times \frac{20}{6} = \frac{20 \times 20 \times 20}{12 \times 6 \times 6} \times 12^3

= \left[\frac{6.66 \times 10 \times 20}{12^3} \right] \times 12 \times 12
= \frac{20}{2} \times \frac{20}{2} \times 144 = 10 \times 10 \times 144

No. of briquettes = 14,400 Wt. of briquettes = 0.052
= 748.8 kg = .7488 tonnes

\frac{3}{12} \times \frac{2}{12} = \frac{20}{3} \times \frac{20}{2} = \frac{20}{3} \times \frac{20}{2} \times 144 = 6.666

x 10 x 144 No. of briquettes = 9600 Wt. of briquettes = 9600 x 0.072
= 691.2 kg = 6912 tonnes

\frac{12}{12} \times \frac{6}{12} = \frac{20}{12} \times \frac{20}{6} = \frac{20}{12} \times \frac{20}{6} \times 144 = 1.66

x 3.33 x 144 No. of briquettes = 796.8 Wt. of briquettes = 1394.4 kg
= 1.3944 tonnes


4. Technologies for combustion:
Combustion is the dominant and established technology to harness the energy from agriwaste. Several firing methods have been developed such as grate firing, stoker firing, pulverized fuel firing and fluidized-bed combustion. The selection of the most appropriate firing method depends upon the size of the unit, fuel conditions (moisture, feed size), and the energy product.

4.1 Energy Chart and Its Cost - Cost Analysis
Specification of binderless technology extrusion briquettes
Calorific value: 18540 – 19776 kJ/kg
Diameter: 70 mm
Length: 450 mm
Weight: 5.30 kgs per meter
Moisture: 7%
Ash content: 5-7%
Sulphur & phosphorous: Nil
We can see that the fuel briquettes are the much cheaper and most convenient energy source. The cost of coal is almost comparable, but its availability, wagon movement, quality and transit wastage are completely uncertain.

Cost of fuel briquettes: Rs. 1500 per ton
Cost of fire wood (15% moisture): Rs. 800 per ton
(moisture loss & cutting charges not included)
Basis: 30% moisture fire wood per ton is Rs.800 + cutting &
Wastages Rs. 60. Thus total cost is Rs. 860.

Consumption:
15% Moist fire wood 202 kgs - Cost 202 x 0.86 = Rs.173.70
7% Moist briquettes 101 kgs - Cost 101 x 1.50 = Rs. 151.50
8% Moist fire wood 163 kgs - Cost 163 x 1.00 = Rs. 163
Using briquettes % of cost saving over fire wood of 15% moisture = 33
Using briquettes % of cost saving over fire wood of 8% Moisture = 29

Trials were made in a FBC system analysis as are under.
Cost of carbonized charcoal consumed: 6 kgs x Rs. 12.00 = Rs. 72.00
Cost of fuel briquettes consumed: 11 kgs x Rs. 2.00 = Rs. 22.00
Thus percentage of saving using fuel briquettes = 40%

This cost saving is apart from the convenience of very good combustion, temperature maintenance, time saving, smokeless environment and clean space saving. Normally fire wood consumption is unknown as it is brought in bulk and consumed again in bulk. Using briquettes the cost of energy can be calculated very easily as it is packed in 5, 10, 15 & 25 kgs packing.

5. Major Pre-Requisites for briquetting of agriwaste
- Raw Material Mix – There should be a minimum of three raw materials and none of them should be soft with high lignin or oil content.
- Raw Material Storage – Stock of material should be around 3 months of production capacity to maintain desired mix in the lean season.
- Briquetting Press – Presses should be in a position to work for 20 hours in a day and six days a week without heating.
- Pre-Processing Equipment – (i) Efficient drying is essential, (ii) Proper grinding to achieve desired bulk density is necessary; (iii) Heating of biomass may also increase the production and reduce the costs of power and wear of parts.
- Reliable and Adequate Power Supply – Continuous working of plant is desirable to increase the output and reduce the wear cost.

5.1 Resources:
It is true that the traditional sources of energy are important for rural as well as urban areas. Although no doubt there will be shifts in the use of energy (mainly upgrading, yet in some cases downgrading in the use of different types of energy as well), the overall impression appears to be that the use of traditional sources of energy will remain important and most probably will increase in absolute terms. The increased use of energy, be it different sources such as oil, gas, electricity and coal or conventional sources of energy such as wood fuels, residues, etc. will put more pressure on the resource base. In order to be able to judge whether an increased use of traditional fuels will put more pressure on the resources, an overview of the resource base is given. Research deals only with logging residues as well as residues from wood processing such as sawmilling and the manufacture of plywood and particle board and wood residues generated from crop plantation operations such as pruning, replanting of trees, agricultural residues like rice husk & straw, wheat straw & husk, cotton stalks, cotton pods, sunflower stock & husk, etc.

Residues are used for many purposes and such uses often are site specific. Besides being used as fuel, residues are also used as Fodder, Fertilizer, Fibre, Feedstock and further uses. Although end-uses for the first 5F’s may be obvious, the latter “F” comprises for instance residues being used as a soil conditioner (coconut coir dust used to retain moisture in the soil, straw as a growing medium for mushroom, coconut husks as a growing medium for orchids, packing material, etc. In some cases residues may even have a multi-purpose use: rice husk can be burnt as fuel with the ash being used by the steel industry as a source of carbon and as an insulator. Rice straw can be used as animal bedding and subsequently as part of compost (fertilizer), crop waste can be used as a feedstock for biogas generation (fuel), with the sludge being used as fertilizer, etc.

6. Amount of residues consumed:
As it is clear, very little is known about the amounts of residues consumed for various purposes possibly with the exception of the sugar industry. This lack of knowledge is thought to be due to the scattered nature of the residue generation, its seasonality and differences in local situation both with regard to the production and use of residues, competing uses which may have a very localized influence on the availability and price of residues.

7. Constraints:
Residues have many uses in the villages of developing countries, both agricultural and non-agricultural, which would be potentially threatened if residues were diverted to use as a briquetting feedstock. The uses are as fertilizer, fodder, fuel, fibre and feedstock for chemicals (sometimes known as the ”5Fs” - see Fig.1.3. Many of the uses are site specific and are difficult to identify from aggregated statistics. Residues are used in rural industries as well as for domestic and farm uses.

Crop residues are generally scattered and would require considerable effort to collect. Unless farmers are all compensated for their efforts they will place a low priority on collection especially since this activity would compete with other post-harvest activities. Mechanisation would improve the efficiency of collection but, in addition to the technical constraints, mechanisation, if available, would add to the farmer’s costs. Agri-processing residues do not suffer from this collection problem since they are generated at a central location. Annexation of a briquetting plant to an agro-processing industry with a residue disposal problem, for example rice mills, has a significant advantage for cost savings.

7.1 Technical Constraints:
There are two specific areas where technical constraints hinder the exploitation of agricultural residues as a briquetting feedstock. The first is for those field residues which have no competing uses, collection would at present rely on hand gathering since mechanised methods
ether do not exist or are not available at a size appropriate to fields in developing countries.

7.2 Financial Constraints:
It is difficult to give general advice on the financial performance of briquetting plants since the data is highly site specific. The handling, transport and storage costs are high and can form a significant part of the fuel production costs. In India, a study by TERI (1995) shows that transport and residue costs can make up more than 50% of total costs. However, an earlier study in Malaysia identified cost of energy, availability of labour and a steady supply of raw materials as most significant influences on manufacturing cost.

Where possible a residue should be selected which requires minimal pre-treatment, for example, paddy husk requires no drying. Storage of seasonally produced residues will be required for continuous use throughout the year to maximize the capacity utilization factor or a mixture of feedstocks can be used but it is important to check if any variations in briquette composition affects quality and match users specifications. Continuity of supply to a user is essential if briquettes are to complete with other fuels such as fuel wood or coal.

7.4 Institutional Constraints:
A lack of an indigenous briquetting press manufacturer also means that the commissioning, maintenance, spare parts and back-up facilities, infrastructure is weak and has been heavily reliant on imported technology and expertise. Briquettes are a new product and the market does not perceive the advantages of briquettes over fuelwood. Marketing strategies are lacking.

7.5 Environmental Constraints:
These may not be as great a barrier as might at first be envisaged. Not all residues make good fertilizers and farmers already actively select those residues best suited to this purpose. The response of crops to organic manures is extremely varied, some crops show dramatic increase while others show little effect. What is apparent is that the effect on the crop depends upon the type of soil and the preparation and method of application of the compost. Probably of much greater significance is the effect of residue removal on erosion both from the wind and water. Some residues make reasonable substitutes for fuelwood and are utilized as such. Traditional farmers also remove field residues for a number of sound agricultural reasons; different composting abilities, disease prevention; ease of planting succeeding crops.

The most significant environmental problem in the briquetting plant is likely to be dust and fumes which can be overcome by suitable extraction equipment. This should be constructed in such a way so as not to cause a nuisance to people living in the vicinity of the plant. Preventative action naturally adds to costs.

8. Conclusions and Recommendation:
Agriwaste production and conversion has attracted attention from the scientists and technologists only recently. The earlier lack of attention was mainly due to the following reasons.

- Cheap availability of fossil fuels.
- Agriwaste is considered to be inconvenient to handle and process.
- Agriwaste energy sources require flexible management.

The most important factors in promoting AGRIWASTE RESEARCH are:
- Increasing prices of fossil fuels.
- Foreseeable depletion of fossil fuels, particularly oil.
- Pollution from use of fossil fuels specially greenhouse gases.s
- Agriwaste is renewable.
- Agriwaste contains negligible sulphur.
- The efficiency of conversion of agriwaste can be sufficiently enhanced with the application of appropriate and advanced technologies.
- Direct combustion is the dominant technology utilized for harvesting energy from agriwaste but it is characterized by low efficiencies.
• Several firing methods exist for the direct combustion of agriwaste: grate firing, suspension firing, and fluidized-bed combustion. The selection of the most appropriate firing method depends upon the size of unit, condition of the fuel, and the energy product (steam). The grate-fired systems have been mostly used because of their flexibility. Fluidized bed combustion, because of the technical merits, is emerging as an alternative to grate-fired combustion.

• Finally, harvesting, collection, transport, and material processing affect agriwaste utilization technically and economically. Therefore, R & D in these areas is to be continued together with the conversion technologies.

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