BAGASSE AS A NON-CONVENTIONAL SOURCE OF ENERGY

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ABSTRACT

Every year millions of tons of agricultural wastes are generated which are either destroyed or burnt inefficiently in loose form causing air pollution. These wastes can be recycled & can provide a renewable source of energy by converting biomass waste into different form of energy sources. This recycled fuel is beneficial for the environment as it conserves natural resources. For this the biomass is the main renewable energy resource.

In this paper the raw material including bagasse as biomass. Bagasse is the crushed outer stalk material formed after the juice is squeezed from sugar cane, in sugar mills. Bagasse characteristics vary in composition; consistency, etc. were densified into briquettes at high temperature and pressure using different technologies. We discuss the various advantages, factors that affecting the biomass briquetting and comparison between coal and bagasse briquetting. The details of the study were highlighted in this paper.

Keywords: Biomass, Bagasse, Briquetting, Potential, Process, Technologies, Sugarcane

I. INTRODUCTION

Many of the developing countries produce huge quantities of agro residues but they are used inefficiently causing extensive pollution to the environment. The major residues are bagasse as sugarcane production waste, rice husk, coffee husk, coir pith, jute sticks, groundnut shells, mustard stalks and cotton stalks. [1,2] India is the second biggest sugarcane growing country in the World, only behind Brazil. Pondicherry has many sugarcane plantations of its own, and surrounding Tamil Nadu is the biggest sugarcane growing states in the India. [3]

Sugar industry is the second largest agro based industry in India after textile. About 5 crores of sugarcane farmers, their dependents and large mass of labourers are involved in sugarcane cultivation, harvesting and ancillary activities. This constitutes 7.5% of rural population. Dry leaves, left in field after harvest of sugarcane, are called trash. On an average, a hectare of sugarcane generates about 10 tonnes of trash. Because it has no value as cattle fodder, and because it also resists decomposition, the trash is burnt in situ, in order to clear the field for the next crop. The main waste product of sugarcane production is a material known as bagasse. Bagasse is the fibrous residue that remains in large quantities upon the crushing of sugarcane to remove the sugar juices.

1 Ton sugarcane = 300 Kg of bagasse

Bagasse pith is usually removed in a process known as "moist de-pithing' in the sugar factory itself. Following table indicate top most sugar factory in terms of sugar crushing across the south Gujarat. [2]

Factory	Bardoli	Gandvi	Madhi	Chalthan	Maroli	Valsad	Sayan	Mahuva	Unai
Sugarcane crushed(MT)	1954267	1107100	1210012	1105891	243573	265332	1137206	661029	78961
Factory	Ganesh	Coper	Kamrej	Pandvai	Narmada	Vadodara	Kodinar	Talala	
Sugarcane crushed(MT)	592370	400219	510063	556741	715592	367029	241159	120936	

Table 1.1: Sugercane factories at south Gujarat[2]

Fig 1.1 Sugar Crop Distribution Areas on the Indian Map

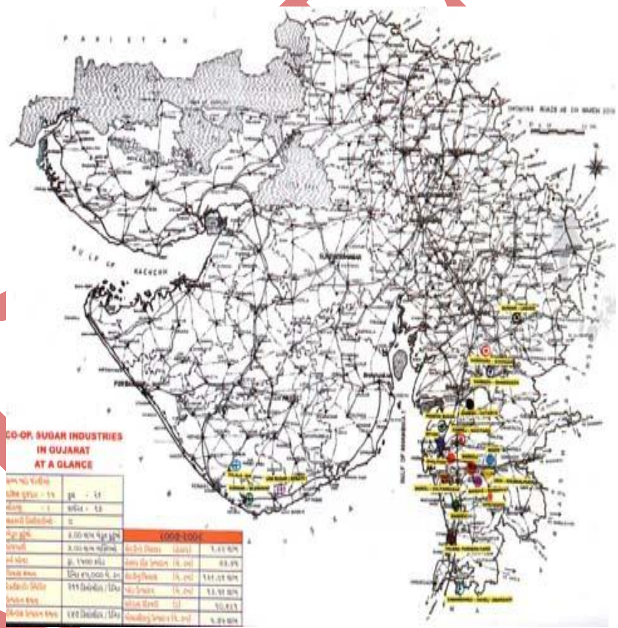

Fig. 1.2 Gujarat Sugar Industries Map

II. ADVANTAGES AND DISADVANTAGES OF BAGASSE BRIQUETTING

2.1 Briquetting technique is densification of the loose biomass; this is achieved by subjecting the biomass to heavy mechanical pressure to form compact cylindrical form known as briquettes. Owing to high moisture content direct burning of loose bagasse in conventional grates is associated with very low thermal efficiency and widespread air pollution. The conversion efficiencies are as low as 40% with particulate emissions in the flue gases in excess of 3000 mg/ Nm³ In addition, a large percentage of unburnt carbonaceous ash has to be disposed off.

Fuel	**Density g/cm^3**	**Calorific value Kcal/Kg**	**Ash content %**
Coal	1.3	3800-5300	20-40
Biomass Briquette from			
Bagasse	0.074	4200	4.0
Saw dust	1.7	4600	0.7
Ground Nutshell	1.05	4750	2.0
Rice husk	1.3	3700	18.0
Saw dust cotton	1.12	4300	8.0

Table 2.1: Comparison Coal and Biomass Characteristics Source

2.2 Following are the advantages and disadvantages of bagasse briquetting:

2.2.1 Advantages:

a) High calorific value ranges between 3,500-5,000 Kcal/Kg.

b) Moisture percentage is very less (2-5%) compared to lignite, firewood & coal where it is 25-30%.

c) Economic to users compared to other forms.

d) Briquettes can be produced with a density of 1.2g/cm³ from loose biomass of bulk density 0.1 to 0.2 g/cm³.

e) Easy in handling and storage due to its size.

f) Consistent quality.

2.2.2 Disadvantages:

a) High investment cost and energy consumption input to the process

b) Undesirable combustion characteristics often observed e.g., poor ignitability, smoking, etc.

c) Tendency of briquettes to loosen when exposed to water or even high humidity weather text into it.[1]

III. COMPARISON BETWEEN BAGASSE BASED BRIQUETTE AND COAL

Characteristics	*Bagasse*	*Bagasse based Briquette*	*Coal*
Calorific Value(CV)X 100	4000 Kcal/Kg	4080 Kcal/Kg	4000 Kcal/Kg
Moisture content(M)	45-55 % by weight	2-5 % by weight	4-6% by weight
Ash Content(A)	2 – 10 %	2 – 10 %	25-30%

Table 3.1 Comparisons of bagasse and coal [4]

Fig. 3.1 Comparison Chart of Bagasse, Bagasse Based Briquette, Coal [4]

IV) FACTORS AFFECTING DENSIFICATION / BRIQUETTING

The factors that greatly influence the densification process and determine briquette quality are:

4.1 Temperature and pressure

a) It was found that the compression strength of densified biomass depended on the temperature at which densification was carried out.

b) Maximum strength was achieved at a temperature around 220°C.

c) It was also found that at a given applied pressure, higher density of the product was obtained at higher temperature.

4.2 Moisture Content

a) Moisture content has an important role to play as it facilitates heat transfer.

b) Too high moisture causes steam formation and could result into an explosion. - Suitable moisture content could be of 8-12%.

4.3 Drying

a) Drying depends on factors like initial moisture content, particle size, types of densifier, throughout the process.

4.4 Particle Size and Size reduction

a) The finer the particle size, the easier is the compaction process.

b) Fine particles give a larger surface area for bonding.

c) It should be less that 25% of the densified product.

d) Could be done by means of a hammer mill.

e) Wood or straw may require chopping before hammer mill.

V. BAGASSE BRIQUETTING PROCESS

Briquetting is the process of densification of biomass to produce homogeneous, uniformly sized solid pieces of high bulk density which can be conveniently used as a fuel. The densification of the biomass can be achieved by any one of the following methods: (i) Pyrolysed densification using a binder, (ii) Direct densification of biomass using binders and (iii) Binder-less briquetting.[5] Depending upon the type of biomass, three processes are generally required involving the following steps:

5.1 Sieving - Drying - Preheating - Densification - Cooling –Packing

5.2 Sieving - Crushing - Preheating - Densification - Cooling –Packing

5.3 Drying - Crushing - Preheating - Densification - Cooling –Packing

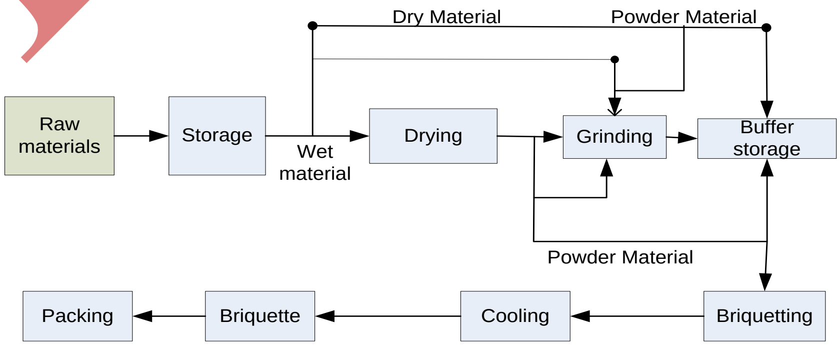

Fig. 5.1 Briquette making processes

When sawdust is used, process A is adopted. Process B is for agro- and mill residues which are normally dry. These materials are coffee husk, rice husk, groundnut shells etc. Process C is for materials like bagasse, coir pith (which needs sieving), mustard and other cereal stalks.

VI. BIOMASS BRIQUETTING TECHNOLOGIES

Biomass densification represents a set of technologies for the conversion of biomass residues into a convenient fuel. The technology is also known as briquetting or agglomeration. Depending on the types of equipment used, it could be categorized into five main types:

a) Piston press densification
b) Pelletizing
c) Screw press densification
d) Low pressure or manual presses
e) Roll press densification

6.1 Piston press densification

There are two types of piston press 1) the die and punch technology; and 2) hydraulic press. In the die and punch technology, which is also known as ram and die technology, biomass is punched into a die by a reciprocating ram with a very high pressure thereby compressing the mass to obtain a compacted product. The standard size of the briquette produced using this machine is 60 mm, diameter. The power required by a machine of capacity 700 kg/hr is 25 kW. The hydraulic press process consists of first compacting the biomass in the vertical direction and then again in the horizontal direction. The standard briquette weight is 5 kg and its dimensions are: 450 mm x 160 mm x 80 mm. The power required is 37 kW for 1800 kg/h of briquetting.[6] This technology can accept raw material with moisture content up to 22%. The process of oil hydraulics allows a speed of 7 cycles/minute (cpm) against 270 cpm for the die and punch process. The slowness of operation helps to reduce the wear rate of the parts. The ram moves approximately 270 times per minute in this process.

Fig. 6.1 Briquettes made from a hydraulic press

Fig. 6.2 Briquette made by screw extruder

6.2 Screw press

The compaction ratio of screw presses ranges from 2.5:1 to 6:1 or even more. In this process, the biomass is extruded continuously by one or more screws through a taper die which is heated externally to reduce the friction.[7] Here also, due to the application of high pressures, the temperature rises fluidizing the lignin present in the biomass which acts as a binder. The outer surface of the briquettes obtained through this process is carbonized and has a hole in the centre which promotes better combustion. Standard size of the briquette is 60 mm diameter.

6.3 Roller Press

In a briquetting roller press, the feedstock falls in between two rollers, rotating in opposite directions and is compacted into pillow-shaped briquettes. Briquetting biomass usually requires a binder. This type of machine is used for briquetting carbonized biomass to produce charcoal briquettes.

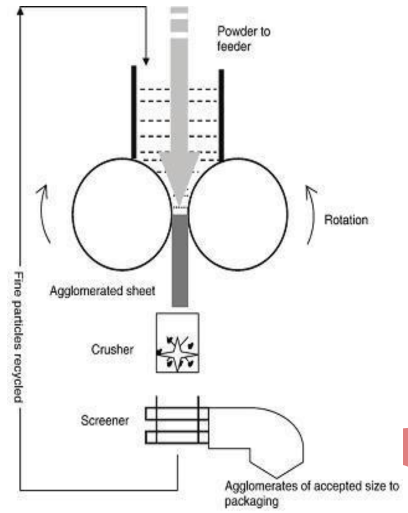

Fig. 6.3 Roller Press For Agglomeration Of Biomass

Fig. 6.4 Briquettes Made From A Pellet Mill.

6.4 Pelletizing

Pelletizing is closely related to briquetting except that it uses smaller dies (approximately 30 mm) so that the smaller products are called pellets. The pelletizer has a number of dies arranged as holes bored on a thick steel disk or ring and the material is forced into the dies by means of two or three rollers. The two main types of pellet presses are: flat/disk and ring types. Other types of pelletizing machines include the Punch press and the Cog-Wheel pelletizer. Pelletizers produce cylindrical briquettes between 5mm and 30mm in diameter and of variable length. They have good mechanical strength and combustion characteristics. Pellets are suitable as a fuel for industrial applications where automatic feeding is required. Typically pelletizers can produce up to1000 kg of pellets per hour but initially require high capital investment and have high energy input requirements.

6.5 Manual Presses and Low pressure Briquetting

There are different types of manual presses used for briquetting biomass feed stocks. They are specifically designed for the purpose or adapted from existing implements used for other purposes. Manual clay brick making presses are a good example. They are used both for raw biomass feedstock or charcoal. The main advantages of low-pressure briquetting are low capital costs, low operating costs and low levels of skill required to operate the technology. Low-pressure techniques are particularly suitable for briquetting green plant waste such as coir or bagasse (sugar-cane residue). The wet material is shaped under low pressure in simple block presses or extrusion presses. The resulting briquette has a higher density than the original material but still requires drying before it can be used. The dried briquette has little mechanical strength and crumbles easily. The use of a binder is imperative.

VII. CO-FIRING METHOD OF GENERATION OF HEAT FROM BAGASSE

Co-firing is combustion of two different types of materials at the same time. Two distinct techniques are available to co-fire bio-fuels in utility boilers:

7.1 Direct co-firing:- Biomass fuels are blended with coal in coal yard and the blend is sent to the firing system which is seen in Fig.7.1.

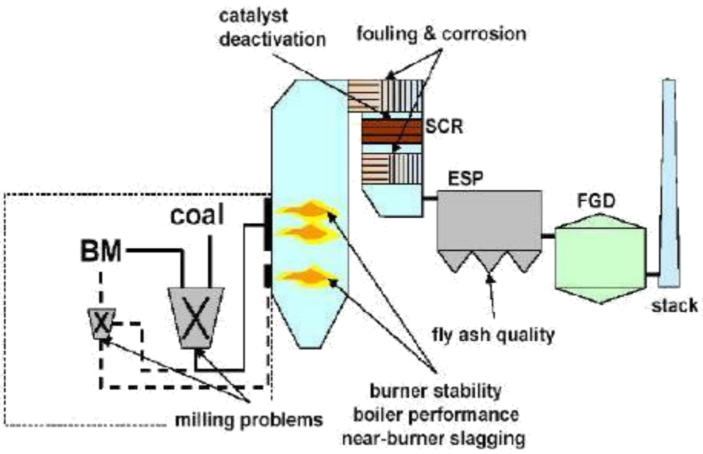

Fig. 7.1 Direct Co-Firing System

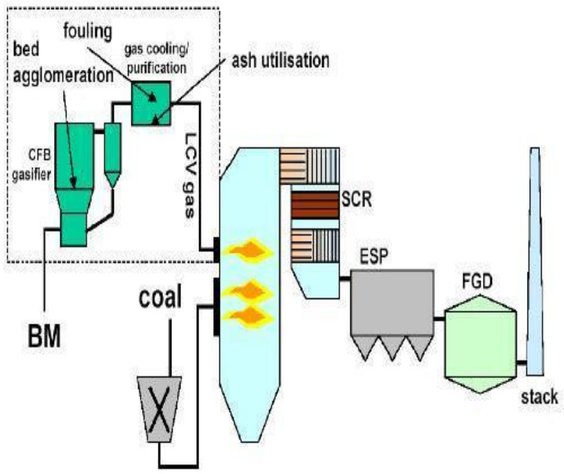

Fig. 7.2 Indirect Co-Firing System

7.2 Indirect co-firing:- The biomass is prepared separately from the coal and injected into the boiler without impacting the coal delivery process Fig. 7.2. The first approach, in general, is used with less than 5 wt. % co-firing. [8]

7.3 Case study on Vasudhara Dairy- Co-firing system of steam-coal and Bio-coal.

Cost effectiveness with use of steam-coal and Bio-coal as a Boiler fuel.

Sr. No	Month	Milk Throuput(Lit)	Cones of Steam coal+ Bio Coal(Kg)	Total	Rate/Ton(Rs) Landed	Total Cost(RS)	Milk proc./Kg coal	Coal/Lit (Rs.)	Qty of Cond. Recovery per day.
1	Jan 10	1,10,20,788	203116+0	203116	4000+0	812464	54.25	0.073	11351
2	Feb 10	97,68,185	21352+189632	210984	4000+3550	758601	46.29	0.077	9371
3	Mar 10	1,07,33,252	12580+209758	222338	4000+3550	794960	48.27	0.074	13167
4	Apr10	1,05,00,000	173400+0	173400	4100+0	710940	60.55	0.067	12897

Table: 7.1 Vasudhara dairy- co-firing system data

Name of supplier	Material	Name of testing Lab	GCV	DOS
M/s Narayan Traders	Steam coal	Premier Analytical Laboratory, Nagpur	5168 Kcal	02.01.2010
M/s Jayshree Traders	Steam coal	Premier Analytical Laboratory, Nagpur	4809 Kcal	09.01.2010
M/s Renewal Bio-Energy	Bio coal	Mantra, Surat	4790 Kcal	17.02.2010

Table: 7.2 The gross calorific value certificates from the supplier for fuel supply

As per trial results

1) The consumption ratio of steam coal: Biocoal = 1 : 1.19

2) The GCV comparison of steam coal : Biocoal = 5100 : 4700 (1 : 0.92)

3) The Rate comparison of steam coal : Biocoal = 4100 : 3550 (1 : 0.86)

Example of trial during April 2010

Sr. No.	Parameter	Steam Coal (Actual)	Biocoal(Expected)
1	Consumption	173.400 MT	206.346 MT
2	Rate	4100/ Ton	3550/Ton
3	GCV	5100	4700
4	Total Cost	Rs. 7,10,940	Rs. 7,32,528
5	Saving	Rs. 21,588.30	

Table: 7.3 Boiler trials during April 2010

SR NO.	Rate different	Steam coal	Biocoal	Saving
1	550	Economic	Costly	21588
2	655	At par	At par	0
3	700	Costly	Economic	9363
4	800	Costly	Economic	29998
5	900	Costly	Economic	50632
6	1000	Costly	Economic	71267

Table: 7.4 Rate different of steam coal & biocoal with respect to GCV

Year	Price of fuel(Rs./TR)	
	Biocoal	Steam coal
2006	2800	3500
2010	3550	4100
2013-2014	5000	6300

Table: 7.5 Price of fuel used at Vasudhara dairy in boiler during different year.

From above case study and below graph conclude that if different in price of Biocoal and Steam coal increase result in increase in saving of overall fuel cost of the plant as the plant run on co-firing generation method.

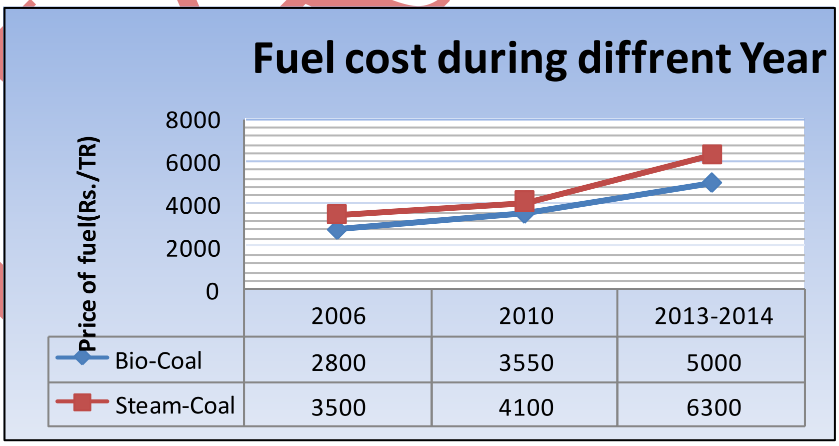

Fig: 7.3 Fuel cost of Vasudhara dairy

VIII. ETHANOL AS A BIOFUEL PRODUCTION FROM BAGASSE

8.1 Production of Bio-ethanol from Sugar Molasses Using Saccharomyces Cerevisia

8.1.1 *Experimental methods:* A known quantity of sugar molasses and Baker's Yeast (*saccharomyces cerevisiae*) were taken in fermentation flask and kept in a constant temperature shaker. An anaerobic condition was maintained for four days and during this period, the strain converts sugar into bio-ethanol with the evolution of CO_2. A known fermented sample was collected for every 12 h interval. The same procedure was repeated to optimize the parameters such as pH, Temperature, substrate concentration and yeast concentration.

8.1.2 *Identification of bio-ethanol:* About 5 to 10 ml fermented sample was taken and pinch a of potassium dichromate and a few drop of H_2SO_4 were added. The colour of the sample turns from pink to green which indicates the presence of bio-ethanol.

8.1.3 *Determination of sugar concentration:* 100 ml of distilled water and mixed with 5 ml of conc. HCL acid and is heated at 70 ˚C for a period of 10 min. The obtained sample was neutralized by adding NaOH and it was prepared to 1000 ml and taken into burette solution. The 5 ml of Fehling A and 5 ml of Fehling B were taken and mixed with 10 to 15 ml of distilled water in a conical flask and Methylene blue indicator was added. The conical flask solution was titrated with burette solution in boiling conditions until disappearance of blue colour. The sugar concentration was calculated by using the formula given below.

8.1.4 *Determination of ethanol concentration and pH:* The sample was fermented to different pH values between 1.0 and 8.0 to obtain maximum yield of bio-ethanol by adding lime or sulphuric acid. The samples were kept in anaerobic condition for a period of four days and the fermented solution was analyzed for every 12 h intervals.

8.1.5 Bio-ethanol increases along with the increase in fermentation period. The optimized conditions of sugar molasses are of temperature 350C, pH 4.0 and the time 72 h which gives maximum bio-ethanol yield of 53%. The fermentation was carried out under anaerobic condition.[9]

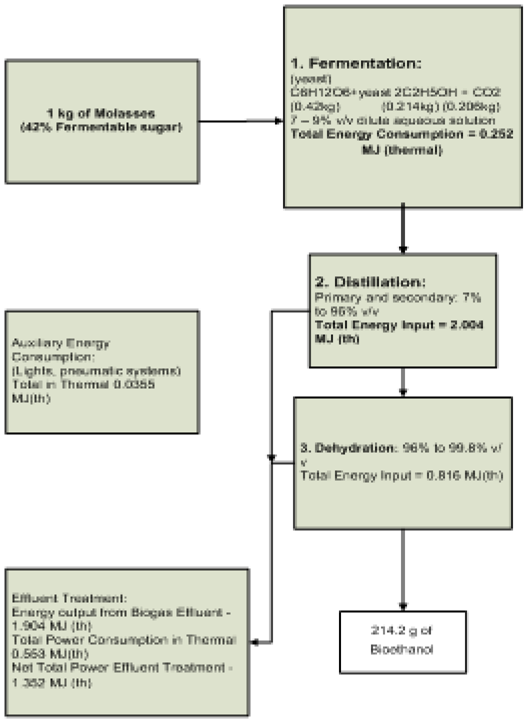

Fig. 8.1 Energy analysis of biochemical conversion of molasses to bioethanol

IX. GASSES FUEL GENERATED FROM BAGASSE

Biogas is a mixture of 60–75% CH_4 and 40–25% CO_2, can be produced from a variety of organic compound through a complex anaerobic digestion processes, and can be upgraded by further steps to bio-methane. It has a calorific value of about 20–25 MJ/m^3 which can be upgraded by removing the carbon dioxide. The produced slurry as digester residue has a potential to be used as fertilizer and soil conditioner. Biogas digester can be operated in different range of temperature as thermophilic system operated at high temperature (50-70˚C), mesophilic system, moderate temperature ranging between 35-40˚C and psychrophilic system that operate at temperature range of 15-25˚C. Operating temperature is very detrimental factor to obtain high gas conversion efficiency with short hydraulic retention time, it takes up to months in a very low temperature. [9]

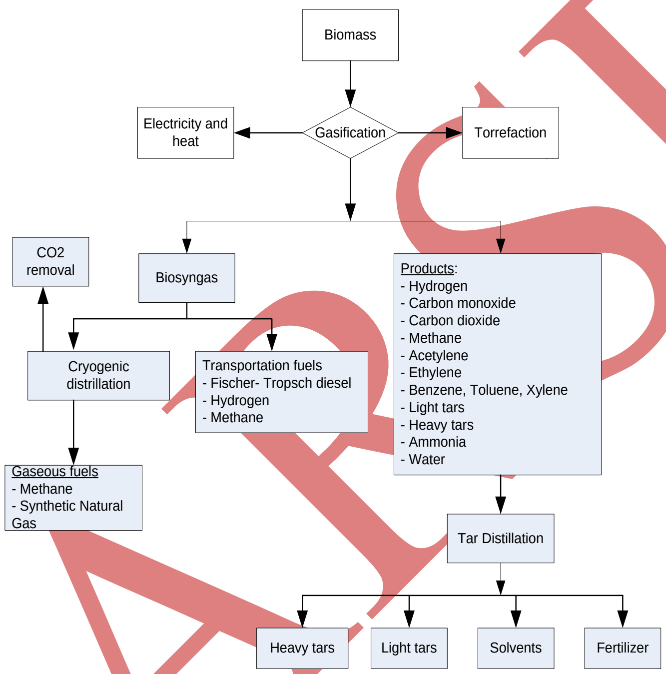

Fig. 9.1 Products from gasification process

9.1 Bagasse gasification in gasifier

The gasification of biomass is a thermal treatment, which results in a high production of gaseous products and small quantities of char and ash. It is a well-known technology that can be classified depending on the gasifying agent: air, steam, steam–oxygen, air–steam, oxygen-enriched air, etc. Gasification is carried out at high temperatures in order to optimize the gas production. The resulting gas, known as producer gas, is a mixture of carbon monoxide, hydrogen and methane, together with carbon dioxide and nitrogen.

9.2 Downdraft gasifier model

Downdraft gasifiers are very similar to updraft gasifiers (Fig. 9.2), except that the feedstock and oxidizer in downdraft gasifiers both enter from the top of the gasifier. The gas passes though the hot zone combusting the tars and leaving the reactor from the bottom. Some of the advantages of this design are that it has a fairly simple design and is low cost, and it produces a relatively cleaner gas with very low tar formation. Some of the disadvantages are that the system requires low moisture and ash feedstock, can only use feedstocks within a limited particle size range (between 1-30 cm), and it has low efficiency because the product gas leaves the gasifier at higher temperatures, which requires an additional cooling system as compared to an updraft gasifier.

Four distinct processes take place in a gasifier as the fuel makes its way to gasification. They are:

a) Drying of fuel b) Pyrolysis

c) Combustion d) Reduction

a) Drying of fuel

The first stage of gasification is drying. Usually air-dried biomass contains moisture in the range of 7-15 %. The moisture content of biomass in the upper most layers is removed by evaporation using the radiation heat from oxidation zone. The temperature in this zone remains less than 120 °C.

b) Pyrolysis

The process by which biomass loses all its volatiles in the presence of air and gets converted to char is called pyrolysis. At temperature above 200°C, biomass starts losing its volatiles. Liberation of volatiles continues as the biomass travels almost until it reaches the oxidation zone. Once the temperature of the biomass reaches 400°C, a self-sustained exothermic reaction takes place in which the natural structure of the wood breaks down. The products of pyrolysis process are char, water vapour, Methanol, Acetic acid and considerable quantity of heavy hydrocarbon tars.

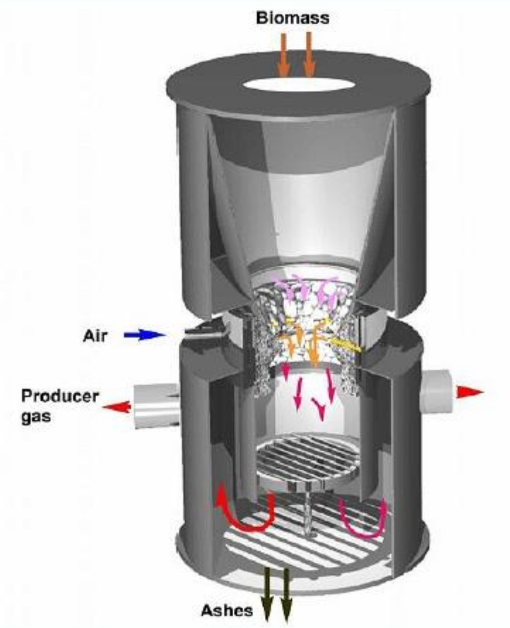

Fig. 9.2 Downdraft gasifier model

c) Combustion

The combustible substance of a solid fuel is usually composed of elements carbon, hydrogen and oxygen. In complete combustion carbon dioxide is obtained from carbon in fuel and water is obtained from the hydrogen, usually as steam. The combustion reaction is exothermic and yields a theoretical oxidation temperature of 1400 °C. The main reactions, therefore, are:

$$C + O_2 = CO_2 \ (+\ 393\ MJ/kg\ mole) \qquad (1)$$

$$2H_2 + O_2 = 2H_2O \text{ (- 242 MJ/kg mole)} \qquad (2)$$

d) Reduction

The products of partial combustion (water, carbon dioxide and un-combusted partially cracked pyrolysis products) now pass through a red-hot charcoal bed where the following reduction reactions take place:

$$C + CO_2 = 2CO \text{ (- 164.9 MJ/kg mole)} \qquad (3)$$

$$C + H_2O = CO + H_2 \text{ (- 122.6 MJ/kg mole)} \qquad (4)$$

$$CO + H_2O = CO + H_2 \text{ (+ 42 MJ/kg mole)} \qquad (5)$$

$$C + 2H_2 = CH_4 \text{ (+ 75 MJ/kg mole)} \qquad (6)$$

$$CO_2 + H_2 = CO + H_2O \text{ (- 42.3 MJ/kg mole)} \qquad (7)$$

Reactions (3) and (4) are main reduction reactions and being endothermic have the capability of reducing gas temperature. Consequently the temperatures in the reduction zone are normally 800-1000˚C. Lower the reduction zone temperature (~ 700-800˚C), lower is the calorific value of gas.[10]

X. CONCLUSION

1. By the use of bagasse as a fuel in three different form of energy result in a sustainable production and power generation can solve the vital issues of atmospheric pollution, energy crisis, wasteland development, rural employment generation and power transmission losses. The energy requirement of any countries can be fulfilled by different form of bagasse without emission of GHG and pollutant substance in the atmosphere. Bagasse provides both, thermal energy as well as reduction for oxides. It is renewable, widely available carbon-neutral and has the potential to provide significant employment in the rural areas. Also reduce dependency on other countries for energy sources requirement.

2. From this paper can be said that *Bagasse is a Non-conventional source of energy*.

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