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IMPROVED BIOMASS COOKING STOVE

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Abstract – *Cooking is done by using chulha in villages and LPG burner in cities. In developing countries like India, cooking is mainly considered as responsibility of women. Biomass resources are found in the world with less effort in its quantum usage for cooking and heating since the origin human civilization. It was concluded that cook stove yields reduced combustion product concentration as well as faster cooking resulting in giving better energy efficiency.*

Key Words: *Biomass, Thermal efficiency, cook stove, water boiling test*

1. INTRODUCTION

The depletion of fossil fuels (i.e. natural gas and oil) and the need to reduce greenhouse gas (GHG) emissions to levels that will avoid dangerous levels of human-induced climate change have resulted in the increasing use of biomass for heat and power production. Bioenergy accounts for roughly 10% (50 EJ) of the world's total primary energy supply today [1]. Most of this is consumed in developing countries for cooking and heating, using very inefficient open fires or simple cook stoves, with considerable impact on health (indoor air pollution) and on the environment [2–3].

Attempts to overcome the poor handling properties of biomass, i.e. its low bulk density and inhomogeneous structure, have led to increasing interest in the development of biomass densification technologies, such as palletization and briquetting [4–8]. When compared to other types of bioenergy, the pellet sector is one of the fastest growing. In 2013, 22 million tons (Mt) of pellets were produced worldwide in approximately 800 plants with individual capacity of over 10,000 tons [9]. The annual growth of biomass pellet production has been close to 20% over the last decade [10], and has increased dramatically in recent years, mainly due to the demand created by policies and bioenergy-use targets in Europe [11]. The need for mitigating carbon dioxide (CO2) emissions is an important reason behind the policies in Europe. Bioenergy is also being discussed as an important technology in the de-carbonization of future global electricity production. Global bioenergy production could increase to 180 EJ in 2050 (compared to 50 EJ under BAU) under a 2.6 W/m2 climate policy scenario with the imposition of a carbon tax on both the fossil-fuel and land-use sectors [12].

1.1 PELLETS PRODUCTION PROCESS

The biomass is reduced to small particles of not more than 3 mm before it is fed into the pellet mill. Size reduction is done by grinding, using a hammer mill equipped with a screen of size 3.2 to 6.4 mm. If the feedstock is quite large, it is put through a chipper before grinding. The next—and the most important— step is palletization where the biomass is compressed against a heated metal plate (known as a die) using a roller. The die has holes of fixed diameter through which the biomass is passed under high pressure. Due to the high pressure, frictional forces increase, leading to a considerable rise in temperature. The high temperature causes the lignin and resins present in the biomass to soften, which acts as a binding agent between the biomass fibers. In this way, the biomass particles fuse to form pellets. The rate of production and the amount of electrical energy used in the palletization of biomass are strongly correlated to the type of raw material used and to the processing conditions such as moisture content and feed size. The average amount of energy required to pelletize biomass is roughly 16 to 49 kWh/t [29]. During palletization, a large fraction of the process energy is used to make the biomass flow into the inlets of the press channels.

Binders or lubricants may be added in some cases to produce higher quality pellets. Binders increase pellet density and durability. Wood contains natural resins which act as a binder. Similarly, sawdust contains lignin which holds the pellet together. However, agricultural residues do not contain much resins or lignin, and so a stabilizing agent needs to be added in this case. Distillers dry grains or potato starch are some commonly used binders. The use of natural additives depends on the biomass composition and the mass proportion between cellulose, hemicelluloses, lignin, and inorganics. Excess heat is produced by the friction generated in the die. Thus, the pellets produced are very soft and hot (about 70 to 90oC). They need to be cooled and dried before they are stored or packaged. After they have cooled, they are packaged in bags or stored in bulk. Pellets can be stored indefinitely, but they must be kept dry to prevent deterioration.

1.2 GLOBAL BIOMASS TRADE

In 2014, global production of biomass pellets rose by 8% to just over 24 Mt (Figure 2) as compared to 2012, continuing a strong upwards trend. The main biomass pellet-producing regions continued to be Europe (roughly 62%) and North

America (roughly 34%). The top producers were the United States (26%), Germany (10%), Canada (8%), Sweden (6%), and Latvia (5%). The United States had an estimated 184 plants producing biomass pellets in 2014.

2. BIOMASS PELLET GLOBAL PRODUCTION

In the global perspective, in 2013, the EU was the largest consumer and producer of wood pellets, manufacturing 12 Mt pellets, with Germany, Sweden, Latvia, and Portugal as the top producers (Figure 3a). Similarly, Europe ranked at the top in biomass pellet consumption in 2013, with a demand of 10 Mt of wood pellets for domestic heat production and 9 Mt of wood pellets for industrial use. Europe was followed by North America and Asia, with wood pellet consumption of 4 Mt and 1 Mt respectively (Figure 3b).

A dramatic shift in the trading patterns and export routes for biomass pellets was observed in 2014. The largest international trade flows are from North America (the United States and Canada) to the EU. In 2014, shipments of biomass pellets from Canada to Europe declined to 2011 volumes, whereas Canadian shipments to Asia (notably South Korea) increased significantly. While the volume of biomass pellets shipped to Asia is increasing, the primary supplies for Asian markets continue to be sourced either domestically or from within the region—for example, South Korea imports from Vietnam.

In the wood pellets global trade, Europe met its growing demand mostly through imports. In 2013, Europe imported about 6.4 Mt of biomass pellets, with around 75% of total imports from North America, a 55% increase compared with 2012, and the rest was almost all from Russia and Eastern Europe. Table 1 presents statistics of the biomass pellet global trade.

Table -1: Biomass pellets global trade

BIOMASS PELLETS GLOBAL TRADE			
Exporter	Importer	Volume(kt) 2013	2014
United states	EU-27	2,776	3,924
Canada	EU-27	1,963	1,166
Russia	EU-27	702	821
Ukraine	EU-27	165	137
Belarus	EU-27	117	126
Bosnia and Herzegovina	EU-27	171	178
Serbia	EU-27	70	71
Australia	EU-27	31	0
Norway	EU-27	48	18
Egypt	EU-27	17	20
Other	EU-27	23	33
EU-27	Switzerland	87	89
EU-27	Norway	30	27
EU-27	Japan	6	6
Canada	South Korea, japan	250	503

The rise in pellet consumption has resulted in a wider variety of materials used for pellet manufacture. Thus, the pellet industry has started looking for a broad range of alternative materials, such as wastes from agricultural activities, forestry, and related industries, along with the combination thereof. In the results section, we present our estimates for the biomass surplus from agriculture, forestry, and wasteland, the potential for biomass pellet-based electricity generation, and its financial viability. This section lays out the methodology for the same.

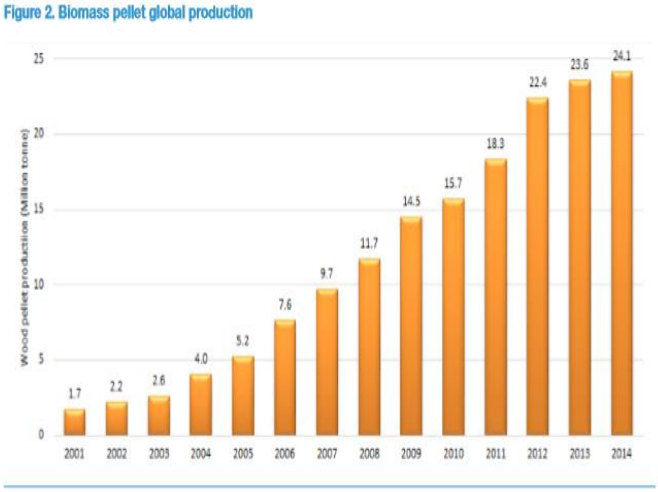

Chart -1: Biomass pellet global production

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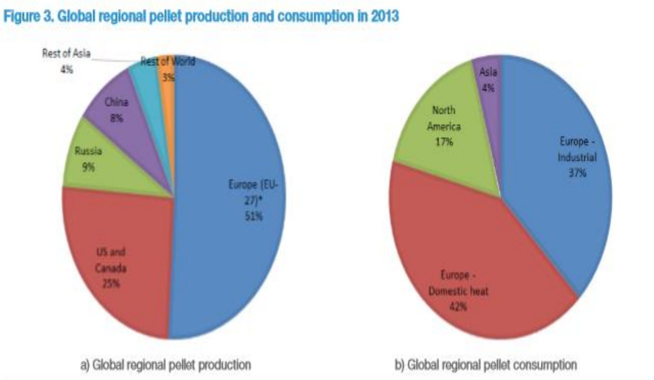

Fig -1: Global regional pellet production and consumption in 2013

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2012, and the rest was almost all from Russia and Eastern Europe. Table 1 presents statistics of the biomass pellet global trade.

Principles of gasifier stove:

The operation of inverted down-draft or the top lit up-draft (T-LUD) gasifier system has been presented in an earlier chapter of this thesis (chapter-II). Gasifiers are essentially devices that enable converting solid fuel to gaseous fuel by a thermo-chemical conversion process. This process involves sub-stoichiometric high temperature oxidation and reduction reactions between the solid fuel and an oxidant – air in the present case. This is arranged such that air and the gas passes through a fixed packed bed.

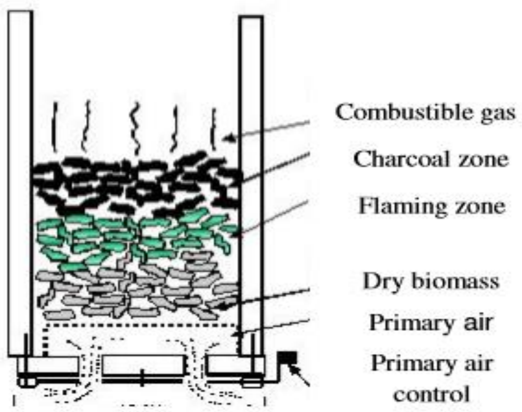

Fig. Schematic of a gasifier stove with gasification air flowing from bottom to top

When a packed bed of solid biomass like wood chips is lit on the top (say by introducing a flaming match stick by sprinkling small amount of liquid fuel, such as kerosene or alcohol) allowing air to flow from the bottom, one would get combustible gases that will burn above the top surface with ambient air or with additional air supplied towards the top. Such a configuration, termed as reverse downdraft gasifier, constitutes a gasifier stove. The rise in temperature due to initial ignition at the top of the fuel bed causes de-volatilization of the biomass giving off combustible gases, which in turn burns readily, but not completely, due to lack of oxygen owing to inadequate supply of primary air. This process is repeated in subsequent layers of biomass feed to establish a flame front which propagates into the fuel bed against the air stream leaving behind a hot char zone at the top of the bed. The product gases when pass through the hot char zone react with the hot chars before they exit at the top of the bed as relatively clean energy rich gas. These gases coming out of the bed typically possesses a temperature of 800-1000 K and contains 16% CO, 12% H2, 3% CH4, 12% H2O (as gas), some higher hydrocarbons (5-6%) and remaining being N2 (Varunkumar et al., 2011.a). These gases when allowed to mix with near-stoichiometric secondary air leads to peak combustion temperature of the product gases; it is this temperature that influences the heat transferred to the vessel within the limited bottom area available. An important consequence of this mode of operation is that the gas exiting from the top of the packed bed bears a fixed ratio (1.5 for biomass) to the amount of air introduced for gasification. The reduction reactions following the oxidation limit the amount of fuel to be consumed due to the endothermic nature of these reactions (Mukunda et al., 2010). The interesting feature is that the relative amounts of fuel consumed and air introduced remain the same and increased amount of solid is consumed when primary air flow rate increases. Thus the power of the stove is proportional to the primary air flow rate.

3. CONCLUSIONS

The current literature review studies the literature available on cook stove through articles, reviews related to it from a lay man's perspective, compendiums of cook stoves with their drawings and constructional details; and testing protocols etc. in order to identify certain gaps in the field of cook stoves, which need to be addressed through future research efforts. The following are the some of the points which can be summarized:

Cook stove design and development: The literature has clearly shown the improved cook stove with high performance however; there is a need to focus on reduction in the manufacturing cost through innovative designs and by exploring an alternative locally available material. The design of process should involve study of factors in order to improve durability of a cook stove through

better choice of materials, with an ease of operation and maintenance. • Cook stove modeling: The parameters assigned during cook stove modeling and parameters of real performance do vary and it may cause variation of performance for designed model during actual testing. But cook stove modeling can prove an effective tool during conceptualization during its design phase. • Testing protocols for cook stoves: It has been observed that, the performance of cook stove during laboratory test and in the field is not same and efficiency calculations during standard test do not reflect its performance at both maximum and minimum power output levels. So there is a need to develop testing protocols which are not only dependent on few efficiency measures but also region wise which will consider food interests or habits of that region for developing cook stove characteristics rather than count of an efficiency. The range of operating parameters during testing a cook stove, like fuel burning rate, feed rate, and quantity of air circulated during its combustion, shape and size of the pot, quantity of water etc. could be standardized in order to get actual picture of stove performance.

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