Alternative of Conventional Solid Fuels: Renewable Energy from Fields

Mr. Maulin Yogesh Raval

***Abstract*— This paper mainly deals with the production of renewable energy from agricultural waste products, highlighting the usefulness and efficiency of 'Bio-Coal', while improving the finances of Indian farmers and declining the usage of lesser efficient coal and other conventional fuels. White coal, which can be named as 'Fuel From Fields' can be generated out of agricultural wastes, rather be it a waste of any kind. The densification of biomass into briquettes brings up many advantages to industries as a capable fuel, and to farmers as proper disposal of agro-waste, which is the ultimatum this paper highly focuses on. This paper will also put a light on the other aspects of briquetting, like the raw materials required, technology used for the purpose, possible applications of such a fuel, for example, cogeneration, as well as few statistical dimensions of 'Briquetting.**

***Index Terms*— Renewable Energy, Bio-Coal, Bio-Energy, Briquetting, Agricultural Waste**

I. INTRODUCTION

India is the country of villages. There are total 6,40,867 villages in India. Indian economy is basically dependent on agricultural products. The economic input of agriculture to India's Gross Domestic Product is steadily lowering with the country's heavy economic progress. Yet, agriculture is demographically the widest economic sector of the country that it plays a significant role in the general socio-economic fabric of India. Though, India has shown extraordinary progress in recent years and has obtained self sufficiency in food staples, the production of Indian farms for the same crop is much low compared to farms of Brazil, France, the United States and many other nations. For example, Indian wheat farms produce only about one third of wheat per hectare per year compared to wheat farms in France. But India is having a very large farming area available, where most of it is left unaltered and unused. If India could implement technologies and improve its infrastructure, a number of studies suggest India could eradicate malnutrition and hunger within India, and be a chief source of food for the world. Having such a big farming area in our country, farmers of our country face a major problem of disposal of agricultural waste.

Actually, this agricultural waste, if used properly, can be one of the sources of income for farmers, and it also helps to produce one of the most important sources of energy, which is called 'Bio-Energy'.

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Agricultural waste, which would include both natural and non-natural wastes, is a common term used to describe waste generated on a farm by various farming activities. These may include but are not restricted to horticulture, dairy-farming, seed growing, livestock breeding, nursery plots, market gardens, and woodlands also. Agricultural and food industry remains, refuse and wastes represent a fine proportion of world wide agricultural production. It has been estimated that these wastes can even account for more than 30% of total world wide agricultural productivity.

According to El-Saeidy (2004) and Kaliyan and Morey (2009), 86 % of energy being consumed all over the world is from fossil fuels[5][6].

Production of bio-fuel can bring down usage of fossil fuel and can reduce the fuel crisis up to considerable extent.

II. WASTE PRODUCTION IN AGRICULTURE

The potential agro-residues which do not pose collection and drying problems, normally associated with biomass are rice husk, groundnut shells, coffee husk and coir waste (obtained by dry process) [1].

The types and quantities of wastes vary between farms.
Common agricultural wastes include:

- Saw dust
- Ground nut shells
- Custer shell
- Cotton stalk
- Dry grass
- Sugarcane bagasse

Other less common wastes include unused pesticides and veterinary medicines, horticultural plastics. Now, as many farmers in India, are unaware of waste management and the use of agricultural waste in making manures, biogas and fertilizers, they simply burn the waste. This causes air-pollution and is one more reason for global warming. Figure-1 shows percentage of different types of wastes produced globally.

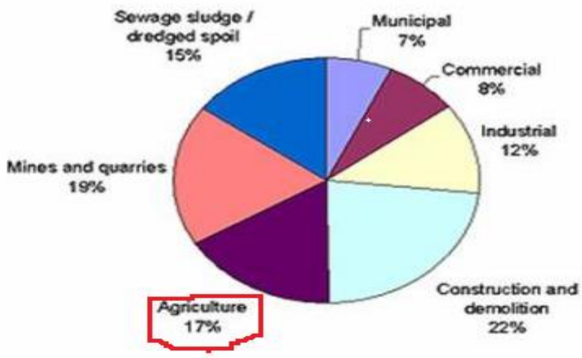

Figure-1: Percentage of waste produced globally

Now, as the waste production in agriculture is thrown a light upon in the above article, another issue is that farmers tend to burn the waste produced. As they lack literacy of proper waste disposal and management, they tend to burn it, causing pollution on one hand, and an overall loss to the energy sector due to loss of renewable energy that could have been produced from it. It is not a matter of a few kilograms, but thousands of tones of waste is burnt every year, blending at least 1 million kilograms of pollutants in the air annually. The open, uncontrolled burning of agricultural waste is no longer acceptable. Farmers can, register an exempt activity for either the burning of plant tissue in the open, e.g. for burning brash, or for burning other wastes, such as card board, in a drum incinerator. This can be carried out but requires to be registered on notification forms available from local offices. In accordance with the PEPFAA Code burning of plastics, rubber tires or other material which may produce black smoke should be avoided.

If the agriculture waste can be densified and dried, forming dense masses of completely or partially dried called 'Briquettes', which is also famous locally as 'White coal' can be produced. Note that after a certain usage, it is found that briquetting machines, like the infamous Jumbo-90 lose the ability of removing moisture completely from raw material, but it can always remembered that on later stages, these partially dried briquettes can always be solar dried, to obtain fuel completely on non-conventional basis.

Hereby, I present a few practical aspects of using agricultural waste as fuel that have already brought into reality.

III. USE OF AGRICULTURAL WASTE INSTEAD OF PETROLEUM IN A LIME KILN

The project is concerned with the modification of a traditional vertical type lime kiln in order to substitute the fuel oil with agricultural waste and to achieve significant energy saving by recycling the exhaust gases from the kiln. The recovery of the waste heat can increase the productivity and the quality of the lime. In addition, the modifications facilitate the working conditions for the operators and have significant reduction of emissions offering better environmental protection. The majority of the traditional lime industries uses fuel oil. Most of the kilns modified to run on biomass or other solid fuels are equipped with open burners which result in high surface area requirements in the kiln, defective loading and unloading equipment and no recycling of the flue gases for energy savings. This results in energy waste, low quality lime, low efficiency and high production cost.

The objectives of this project were to demonstrate the modifications to closed biomass combustion system, and the energy savings that can be attained by recovering and reusing the waste heat of the flue gases via a heat exchanger. These modifications on the lime kiln are economical and highly efficient. An extensive market study on the complete lime industry in Greece was carried and it concluded that *its conversion to biomass fuels would result in significant environmental and economic benefits for the industry*.

A. *Technical description*

The Vertical kiln is in steel construction with refractory bricks lining, charging and discharging systems that work automatically, and 2 rows of burners in order to have a better temperature distribution in the kiln. The flue gases are removed from the top of the kiln, and after particulates removal in a cyclone the flue gases are supplied to the heat exchanger, in order to transfer the heat to the fresh combustion air. Additional particulates removal is achieved in a bag filter before the flue gases are emitted to the atmosphere. In order to improved the temperature distribution in the kiln and eliminate any cold spots, the kiln is equipped with four biomass burners as shown in the general schematic in Figure 1. The biomass burners are of the closed type without any contact with the atmosphere. This combustion system provides for more accurate and better control of the pressure and temperature in the kiln. One part of the exhaust gases (with very low oxygen concentration) is sent by a fan to the burners in order to protect them (by providing local cooling) and to facilitate the burning process, together with the mixture of fuel biomass and fresh air.

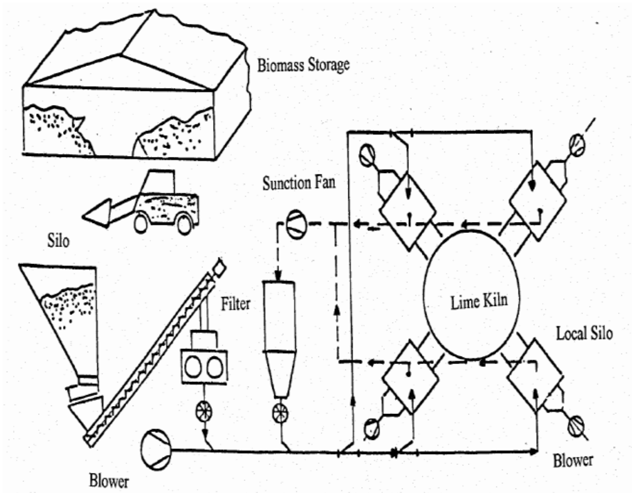

Figure-2: Diagram of Installation

The operation of the kiln is very simple, the calcium carbonate stone (CaCO3) is loaded from the top by a conveyor and a charging system which works automatically. Discharging of the quick lime (CaO) is from the bottom with a feeder and a conveyor. During the process, the stone is moving slowly downwards, passing from-the preheating zone, to the burning zone and finally to the cooling zone. The burners are situated at about 1/3 of the kiln in two rows. Every burner is provided with an independent feeding system and for every two burners there is one blower and one silo. The fresh air is preheated in the heat exchanger increasing its temperature from about 20 °C to about 100 - 120 °C. This process is very innovative comparing to traditional kilns, as it provides for excellent mixture of fuel biomass with air in the burners, and eliminates the possibility that the biomass will burn in the calcium carbonate bed. The utilization of the closed biomass burners resulted in a 40% decrease in the internal diameter of the kiln without any compromise in its output. The ideal biomass fuel is the residue from the olive oil industry of Peloponnese. It has the advantage that the material has a relative small size (< 10mm) which makes it ideal for pneumatic feeding. In addition, the high surface area of the fuel and the still relatively high concentration of oil components result in very good combustion behavior in the kiln. However since it is not possible to guarantee the supply of olive oil residues throughout the year other types of biomass residues (such as olive tree pruning) must be used. For these fuels size reduction must be carried out by a chipper. The biomass is stored under a shed as shown in Figure-2. The shed covers an area of 2,500 m2 and has a storage capacity of 15,000 tons. The construction of the shed was necessary in order to provide big storage capacity, natural drying and storage of different types of biomass.

IV. SOLID FUEL FROM THE FIELDS: COAL FROM AGRICULTURAL WASTE!

2.4 billion people use solid fuels like wood, coal as their cooking fuel on daily basis worldwide. Biomass may account over 70% of cooking fuel in many developing countries. But, burning of biomass in raw form has created many health and environmental hazards. For example, burning of unprocessed biomass leads to indoor air pollution, and it is estimated that over 1.6 million people die each year due to such kind of air pollution; especially women and children are highly prone to it. A team called 'Fuel from the Fields' (FftF) effectively developed a method of generating charcoal from unused agricultural wastes. Charcoal thus provides many advantages over raw biomass fuels, because the process of carbonization lessens the particulate emissions, and lowers the risk of emerging respiratory infections. Another advantage is that, people does not require to buy new stoves or change the way they cook, unlike liquefied petroleum gas (LPG) or compressed natural gas (CNG).

Charcoal making is very traditional across the world – charcoal is an energy dense fuel that can be easily transported from rural to urban environments. It also helps generating employment, for example, in a charcoal industry near Haiti, more than 1,50,000 people are employed.

Three conditions should be satisfied to make charcoal:

• A carbon-rich material

• Heat

• Anaerobic fermentation or anaerobic conditions

Conventionally, charcoal is prepared by wounding down a tree, putting trunk on fire, and covering it with soil then. The tree turns into charcoal over 1 to 3 weeks. The environmental blow is even worsened mainly because hardwood trees (trees that grow very slowly) make the best quality charcoal. The 'Fuel from the Fields' technology comprises of filling a metal kiln with agricultural waste which is a source of carbon. This waste is ignited then, and later sealed in order to create anaerobic conditions and just after two hours, charcoal is formed.

Charcoal can be possibly produced from any agricultural waste. The 'FftF' team encourages the use of biomass that does not have any other value i.e. the biomass unsuitable for animal or human consumption, or even for composting. In Haiti, *bagasse (dried sugar cane)* is an easily available byproduct of sugar manufacturing. In other countries, we might have tested *corn cobs, palm fronds* and *coconut shells,* but other crop wastes can also be used.

Note that 16kg of crop waste can produce about 4kg of charcoal.

V. BRIQUETTING

The process of 'Briquetting' is the physical transformation of loose raw material mostly made of agro waste like rice husks, bagasse, ground nut shells etcetera and other organic materials like municipal solid waste into high density fuel briquettes through a compacting process[9].

Biomass briquetting is a process of compressing bio mass by extrusion, followed by moisture removal. Historically, the process of compressing and densifying biomass was developed in two distinct directions. The United States and Europe developed technique of extruding the biomass briquettes through ram reciprocation, while Japan independently developed the screw press technology. Both the technologies have their own advantages and disadvantages, it is found through brief study that screw pressed briquettes are far superior to ram pressed solid briquettes in storability, combustibility, and low moisture content. In the current scenario, Japanese machines are also being manufactured in Europe nowadays, but worldwide both the technologies are equally used for the sake of briquetting locally available agro-residues. Briquetting technology is yet to build up a strong hold in many developing countries, mainly because of the technical limitations involved and lack of knowledge to adopt
the technology to match local conditions.

Biomass densification has been practiced for many years in many developed countries. At present two high pressure technologies, i.e. screw extrusion and ram or piston press machines are used for the purpose. Screw extrusion technology was invented in Japan in 1945. Then the research and development continued, as can be seen from execution of the technology, that till April of 1969, 638 plants in Japan were already engaged in producing 'Saw dust Briquettes'. Briquettes can be manufactured with a density of 1.2 g/cm^3 from loose biomass of average density of 0.1 to 0.2 g/cm^3. With a view of improving the scene in India, Indian Renewable Energy Development Agency (IREDA) has financed many briquetting projects, where all of them uses the piston or ram press. In other Asian countries, briquetting cannot be seen on large basis, which is a downside thing. In many countries, research and development is undertaken on this field. Technically, there are lots of advantages of briquettes over conventional charcoal. Few of the advantages of briquttes are mentioned as follows:

- Eco-friendly and renewable energy fuel
- Cheaper than other solid fuels
- High thermal calorific value of approximately 4000 kcal/kg
- Pollution free and non-hazardous
- Low ash content (2 to 5%) and no fly-ash while burning
- Consistent high burning efficiency
- High density and high fix carbon value
- Easy transportation, feeding and combustion
- Combustion is uniform
- Co-generation with other conventional fuels is possible.
- There is no sulfur in the white coal, therefore no toxic gases.

Groundnut shell, Sugarcane bagasse, Saw dust and Wood chips, Rice husk, Tea and Tobacco waste are few of the premium agro-residues very commonly used in briquetting. In the regions, where production of a certain crop, e.g. sugarcane is very high, residues of that crop can be totally used up. For example, in many plants of Tamil Nadu, only sugarcane bagasse are used as raw material. Sugarcane bagasse is having high calorific value, which is very advantageous.

Calorific Values of Organic Samples								
	Bagasse Try 1	Bagasse Try 2	Bagasse Briquette (Compressed Bagasse with possible binder)	Bagasse Pith	Sawdust	Sawdust/ binder (Kerala briquette)	Sawdust/ Paper/ Cardboard (Haiti briquette)	Waste paper/ coffee husks (Bangladesh briquette)
Weight (dry) [g]	0.9252	0.966	0.99901	1.0101	1.0365	1.02261	1.02	1.02
Temperature Change [°C]	1.644	1.6389	1.88255	1.7409	2.0532	1.8457	2.0532	1.78
Calorific Value [MJ/kg]	18.1	17.3	19.2	17.6	20.2	18.4	20.5	17.8

Table 1: Calorific Values of organic samples

VI. AVAILABILITY OF RAW MATERIAL: SUGARCANE BAGASSE

India is the second major sugarcane producing country in the world after Brazil. Tamil Nadu is one the biggest Sugarcane producing states in India, and Pondicherry also has many sugarcane plantations of its own. The main waste product of sugarcane production is a substance known as 'bagasse'. Surplus bagasse presents a disposal problem for many sugar factories.

The average tonnage of excess bagasse produced per year can be over 24000 tons[8].

The fibrous substance that remains in large amount upon the crushing of sugarcane in order to remove sugar juices is called bagasse. About 300 kg of bagasse is redeemed for each tonne of sugarcane crushed. Because of large amount to bagasse that can be redeemed, many sugarcane factories in India operates on co-generation, where about 50% of sugarcane produced are used to power the factory itself. The other half that remains is sold to paper mills to make paper as it is also an alternative to wood-pulp. One of the world's largest bagasse based paper mills is situated in Tamil Nadu. Bagasse produced can also be used in briquette-making, apart from eco-friendly papers. Briquettes can also be made from wheat and rice husks and many other agricultural wastages.

VII. 'BRIQUETTE AS BIOMASS'

Briquettes can be uses in many thermal applications like a commercial fuel. Some of them are Gasifier system applications, Ceramic and Refractory industries, Spinning mills, Leather and Rubber industries, Brick making and Dying units etc.

Biomass briquettes are finished from agricultural waste and are a substitute for fossil fuels, and may be used to heat up boilers of modern power plants. Biomass briquettes are a renewable resource of energy and avoid adding up fossil carbon to the atmosphere (though, in some cases, we also go for co-firing). Many Indian companies have switched from furnace oil to briquettes to save expenses on boiler fuel. The use of biomass briquettes is major in south India, where furnace oil and coal are being substituted by biomass briquettes. Many units in Maharashtra (India) are using biomass briquettes the same as boiler fuel. Biomass briquettes' use helps in earning 'carbon credits' for lowering emissions in atmosphere. Lanxess India and a many other big companies are already using biomass briquettes in order to earn Carbon Credits by changing their boiler fuel.

There have been numerous attempts in industrialized and developing countries to briquette agricultural and forestry residues for fuel. Not all of them were successful. Until today, fuel from agricultural and forestry wastes plays only a minor role in worldwide supply of energy and heat[3].

. Also note that biomass briquettes provide more calorific value/kg and save about 30-40 percent of conventional boiler fuel costs (economical) as they are comparatively cheap. A typical briquetting plant would extrude out a log that can replace firewood from raw materials. It is a process similar to forming a wood pellet but on a superior scale. None of the binders are involved in this process, but rather the lignin present in the wood binds the particles together to form a solid. Burning a wood briquette is much more efficient than firewood. Moisture content of a biomass briquette can be as low as 4%, whereas that of a green firewood may be as high as 65%.

Although large quantities of charcoal briquettes have been produced, there is lack of a readily available market to motivate more production[7].

It is the main reason why governments are providing subsidies on such projects and encouraging their production and usage.

Table 2: Comparison of coal and fuel briquettes properties

Combustion gas properties	*Eco-fuel briquette*	*Coal*
Gross calorific values	18.9	25.9
Specific gravity	0.71	0.86
Carbon w/w%	22.5	61.2
Hydrogen w/w%	0.71	4.3
Oxygen w/w%	43.8	7.4
Sulphur w/w%	0.0020	3.9
Nitrogen w/w%	0.0010	1.2
Ash w/w%	28.4	12.0
Water w/w%	10.9	10.0
Carbon dioxide: volume%	19.7	15.0
Oxygen: volume %	13.4	3.7
% Excess air	12.8	20.0
$Nm^3/GJ:8MJ/1.14m^3$	142.5	293.6

VIII. TECHNICAL ASPECTS BRIQUETTING: JUMBO-90 MACHINE

Jumbo-90 briquetting machine, shown in Figure-4 is very commonly used for briquette manufacturing. First of all, raw material is inserted through a conveyor belt. Then raw material is crushed and extruded. Input raw material may vary from 2 mm to 20 mm in size. Finished products are of diameter 90 mm and length may vary from 1 m to 0.1 m. The production capacity of Jumbo-90 plant is 1500 kg/Hr. which may vary 15% depending on the bulk density of raw material. The plant can run continuously round the clock. The proportion of raw material used is not fixed and can be varied as per requirement and availability, for example, briquettes in Tamil Nadu are made of 100% sugarcane bagasse, but approximately following proportion of raw materials is used:

- Groundnut shell: 85%
- Custard shell: 7%
- Cotton seed: 6%
- Saw dust: 2%

It is not mandatory to use raw material in above proportion, but ideally it is just an ideal suggestion. Also it is seen that, many Indian briquetting plants use 'tire-dust' in little amount, i.e. around 0.05 to 0.05% of total raw material. The main reason for adding tire-dust is that, it helps in smooth motion of raw material inside the plant, as tire-dust would act as a solid lubricant, and also, the briquettes formed so can be ignited easily.

Following are few of the parameters, based on which raw materials can be quantified and performance of briquette as a fuel can be predicted:

$$\text{(i) Density Ratio} = \frac{\text{Relaxed Density}}{\text{Maximum Density}} \quad (1)$$

$$\text{(ii) Relaxation Ratio} = \frac{\text{Maximum Density}}{\text{Relaxed Density}} \quad (2)$$

$$\text{(iii) Compaction Ratio} = \frac{\text{Maximum Density}}{\text{Initial Density}} \quad (3)$$

Formulas for quantifying raw-materials [4]

From the above, we can find the average density of raw materials and obtain density ratio, relaxation density and compaction ratio. The higher the compaction ratio, more is the calorific value and briquettes are considered of 'Better Quality'. High relaxation ratio ensures transportation of briquettes without breakage.

A. Briquetting Process

With the successful development of the new briquetting technique for raw biomass under room temperature, the space requirement, energy consumption, and running cost of biomass briquetting have been reduced significantly. With optimized system operation, small volume and low energy cost, this technique will make practical mobile biomass collecting and processing units. This will turn biomass into a promising alternative energy source for coal in the near future[2].

Figure-3 demonstrates steps of the modern white-coal production system.

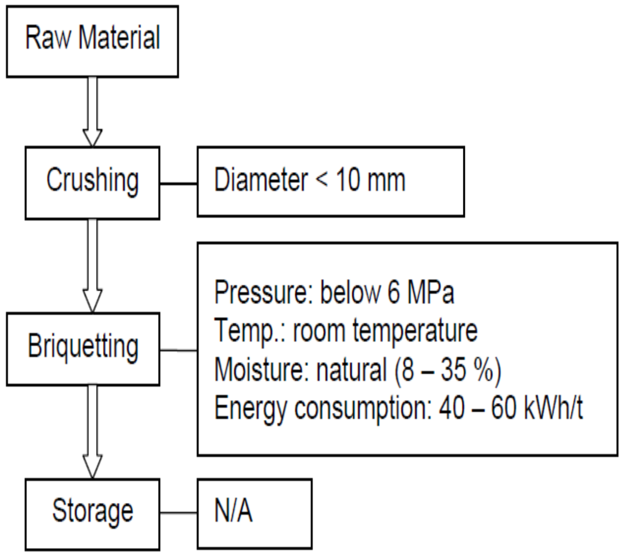

Figure-3: Bio-mass Briquetting Technique [2]

On setting up the plant, government in many countries provides subsidies and benefits of tax-reduction also, as the project is about renewable energy. The man power required is less, and only one skilled operator and five unskilled workers are required per plant. The plant can be run in two shifts in order to assure continuous running and management of the plant. The project is totally pollution-free and technology is completely binder-less. The suitable land requirement in order to set up a briquetting plant would be 20 by 30 feet with 12 feet height and for raw material procurement, it requires 1 acre of land. So, the location and land for the plant should be selected accordingly. For raw material, nearby farmers can be contacted, and should be promised good returns on agro-wastes. Note that the so formed cylindrical briquettes can be stored for a long time, only that they must not make contact with fire and water. The converting cost of briquettes is approximately 6.7 US $ per meter length of 90mm diameter briquettes, including power, labor, wear and tear of parts, maintenance and other miscellaneous expenses. Jumbo-90 plant requires a connected load of 90 HP but utilization load is 75 HP. In the plant, there are basically 4 types of electric motors of various capacities, which are:

- Main electric motor- 75 HP
- Feeding kupy motor- 7.5 HP
- Conveyor electric motor- 5 HP
- Lubrication electric motor- 3 HP
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Every plant can be accomplished or synchronized with a hammer mill. Basically, a hammer mill is used to crush raw material that is bigger in size. After it is converter to smaller size, it is fed in the conveyor belt through a worm to a feeder-box.

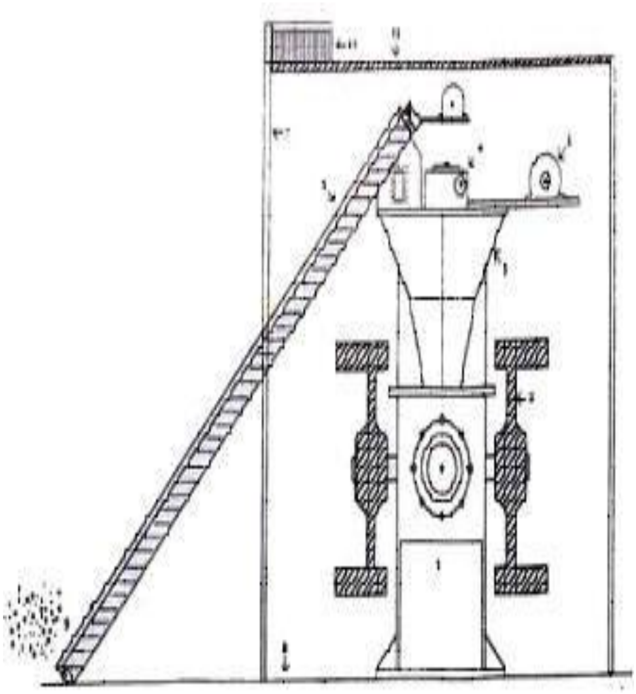

Figure-4: A sketch of Jumbo-90 type briquetting plant

IX. CONCLUSION

It can be concluded from the paper that the question of utmost importance, of production of bio-energy from agro-residues can be achieved, simultaneously solving the problem of it's proper disposal as well. It can be stated for sure that the production of briquettes is possible with any type of agro-waste is any region. This will be beneficial for farmers as well, as they can sell and dispose the waste, and from the energy production point of view, renewable energy is always constructive. So the idea would be advantageous in all the aspects.

ACKNOWLEGMENT

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