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Techno-Economic Analysis of Biomass Waste Based Pellet Production in Bangladesh

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September, 2016

DECLARATION

This thesis paper has been prepared by me to submit as a requirement for the partial fulfillment of MS in Renewable Energy Technology and it has not been submitted in any previous application for any degree. Exclusively I executed the work, reported within, unless otherwise stated.

…...……….……………………..

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CERTIFICATION

This is to certify that Asad Dullah Al-Saiem, Exam Roll: 528, Registration No.: Ha-302, Session: 2013-2014, student of MS in Renewable Energy Technology in Institute of Energy, University of Dhaka, has successfully prepared this thesis paper entitled **"Techno-economic analysis of biomass waste based pellet production in Bangladesh"** under my supervision and guidance. However, this thesis paper has been prepared and submitted to the Institute of Energy, University of Dhaka, for the partial fulfillment of the requirement for the degree of MS in Renewable Energy Technology.

…………………………

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DEDICATION

To the freedom fighters of Bangladesh liberation war………….

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First and foremost, I would like to thank almighty ALLAH, the Almighty without whom I would not has been here and I thank for his unconditional love.

Secondly I would like to thank Dr. S. M. Nasif Shams, my supervisor, he found very helpful and supportive through out my research.

I further extend my heartfelt gratitude to my mom whose words of advice, care and support have brought here and whose love has kept me going.

Special thanks to all my friends and family for their support, advice and encouragements.

Last but not least, my heart goes to our organization Institute of Energy, University of Dhaka for making my dreams come true. Thank you once again.

ABSTRACT

This thesis involves with the techno- economic analysis of biomass waste pellet production in Bangladesh. As an agricultural country along with a larger population we have lots of biomass waste. 75% of energy comes from biomass in rural area we found that agricultural waste and residues are used in a non-efficient and non-hygienic way. Mainly this energy consumption is happened in rural indigenous cooking system with only 8-12% efficiency. The main problem with that biomass is less density and moisture content. By palletizing we can solve those problems. In this thesis, it has been put some statistical data and analysed the data reflecting the possibility of establishing power generation unit using biomass waste pellet.we also introduced a new raw material mix, caddies with saw dust. Our test production was successful. We tested our experimental pellet and found very suitable as a fuel with calorific value 4235.4 kcal/kg and density index 0.96. The pellet production also found economically feasible. By using pellet we can solve our energy crisis, assuring hygiene in rural cooking and save the entire environment.

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Chapter 01

1. Introduction

Bangladesh is a developing country with 157.9 million of population [1]. Like other developing country Bangladesh also faces energy crisis. She is a tiny developing country with very limited energy resources. Per capita Consumption of energy in Bangladesh is one of the lowest in the world. Present consumption of electricity in the country is about 371 KWh/year [2]. About 74% of the population has only access to electricity [6]. Among the renewable energy sources, biomass is found to be the most effective and utilizable in Bangladesh. Potential electricity generation from biomasses is 312,608 terra watt hours (TWh), where only 43.52 terra watt hours (TWh) is utilized [7]. Wood, animal wastes and crop residues are estimated to account for 65% of the country's energy consumption [8]. In recognition of the importance of energy in socio-economic development, the Government of Bangladesh has formulated and approved the National Energy Policy (NEP) in which two different projections of energy and electricity were made covering the time horizon up 2020 aiming at sustainable development. 5% (800 MW) of total energy production will be from RE by 2015.10% (2000 MW) of total energy production will be from RE by 2020.we have a lots of agricultural activities .As a thumb rule each ton of cereal produce 1.5 ton of biomass. This agro waste and residues is used in a non-efficient and un-hygienic way in domestic cooking and other heating purposes, some portion is use as fodder and Dwelling place materials.. To make sure the proper and efficient use biomass can be converted to pellet and can be used in direct electricity generation, cooking, refractory, boiler brick field and dryer heating. Among the various biomass energy conversion techniques, pelletization is easy and less costly for solid materials .The Bangladesh government energy policy targeted 5% of total energy mix attains from renewable sources within 2015 and 10% of total energy mix from renewable sources by 2020. Bangladesh government policy is to shift energy dependency from natural gas powered power plant to coal fired power plant.

As pellet can be used with coal in a coal fired power plant up to 25% the importance of pellet also increased with this government's policy. Bangladesh is an agricultural country with dense population and this ensures a huge amount of biomass availability. So the scoop of renewable energy study is increasing day by day. As a master's student of IE, DU I was encourage to conduct a thesis on the techno- economic analysis on biomass waste pellet in Bangladesh under the supervision of Dr. S. M. Nasif Shams, Assistant professor, IE, DU. Many researches were done on biomass briquette but not on biomass pellet. So we took it as our research matter.

1.1 Thesis Objectives

The following research goals were set up at first. They are-

a. Study the availability of raw materials for biomass pellet production.
b. Possible raw materials mix.
c. Study the regional advantages of pellet plant establishment with specific raw materials.
d. Manufacturing process according to available raw materials.
e. Financial analysis of a pellet manufacturing plant.
f. Produce some pellet with desired raw material mix by available technology and test the fuel quality.

Chapter 02

2. Literature review

2.1 Biomass as a renewable energy

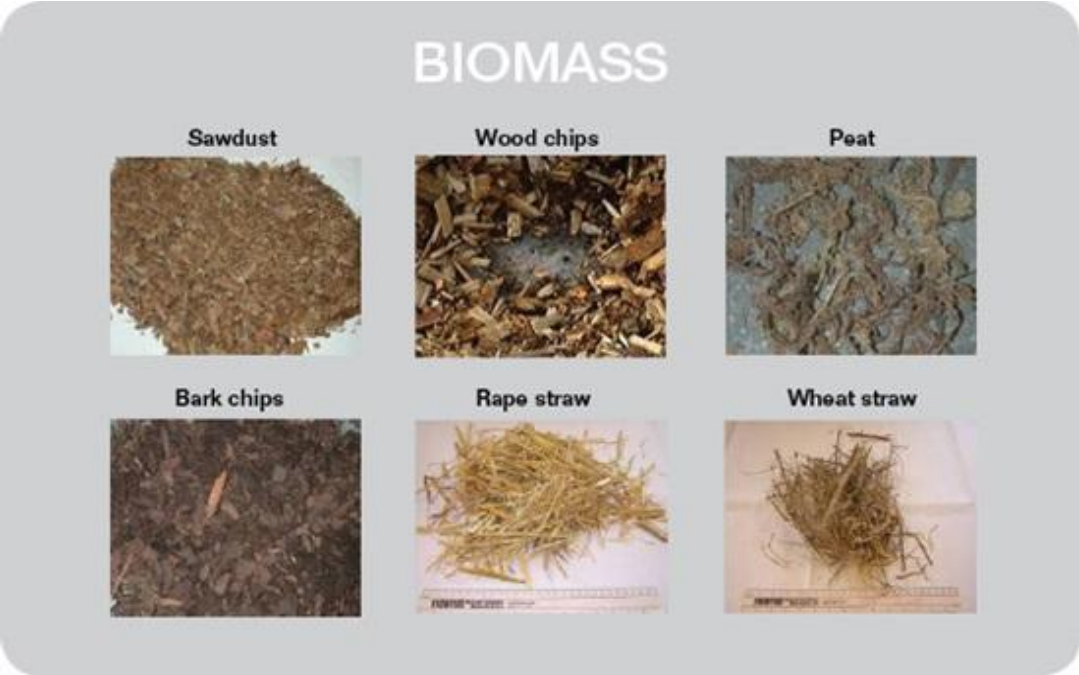

Fig 2.1: Various kinds of biomasses.

Biomass is organic matter derived from living, or recently living organisms. Biomass can be used as a source of energy and it most often refers to plants or plant-based materials which are not used for food or feed are specifically called lignocelluloses biomass. As an energy source, biomass can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of bio-fuel. Conversion of biomass to bio-fuel can be achieved by Different methods which are broadly classified into thermal, chemical and biochemical methods. Currently bio-energy is the second largest commercial renewable energy source. Current total biomass energy usage ranges around 10% of world total primary energy consumption, mainly in traditional applications like cooking in developing nations like India, Bangladesh, Pakistan and Nepal etc. Also the usage of wood for heating purposes is increasing day-today. Normal domestic wood-burning appliances include fireplaces, pellet stoves and burners, central heating furnaces and boilers for wood logs and wood pellets [1].

Biomass is considered a renewable energy source because the carbon in biomass is treated as part of the natural carbon cycle: trees take in carbon dioxide from the atmosphere and convert it into biomass and when they die, it is released back into the atmosphere. Whether trees are burned or whether they decompose naturally, they release the same amount of carbon dioxide into the atmosphere. The idea is that if trees harvested as biomass are replanted as fast as the wood is burned, new trees take up the carbon produced by the combustion, the carbon cycle theoretically remains in balance, and no extra carbon is added to the atmospheric balance sheet, so biomass is considered "carbon neutral." Since nothing offsets the CO_2 that fossil fuel burning produces, replacing fossil fuels with biomass supposedly results in reduced carbon emissions. In fact, the reality is a lot more complicated. Whether or not biomass is truly carbon neutral depends on what type of biomass is used, the combustion technology, which fossil fuel is being replaced, and what forest management techniques are employed where the biomass is harvested. The combustion of both fossil fuels and biomass produce carbon dioxide. When short-term biomass is burned, such as annual crops, the amount of carbon generated can be taken up quickly by the growing of new plants. But when the biomass comes from wood and trees, not only can the re growing and thus the recapture of carbon take years or decades, but also, the carbon equation must take into consideration carbon the trees would have naturally stored if left untouched. A group of prominent scientists wrote to US Congress in May 2010 explaining that the notion that all biomass results in a 100% reduction of carbon emissions are wrong. Biomass can reduce carbon dioxide if fast growing crops are grown on otherwise unproductive land; in this case, the re-growth of the plants offsets the carbon produced by the combustion of the crops. But cutting or clearing forests for energy, either to burn trees or to plant energy crops, releases carbon into the atmosphere that would have been sequestered if the trees had remained untouched, in addition to producing carbon in the combustion process, resulting in a net increase of CO_2. Nevertheless, all types of biomass energy are currently considered renewable and carbon neutral and thus qualify for many tax credits, subsidies, and incentives. These include Renewable Energy Credits wherein every megawatt-hour of electricity generated by biomass earns a credit that can be sold to utilities required to purchase a certain amount of renewable energy.

2.2 Sources of biomass

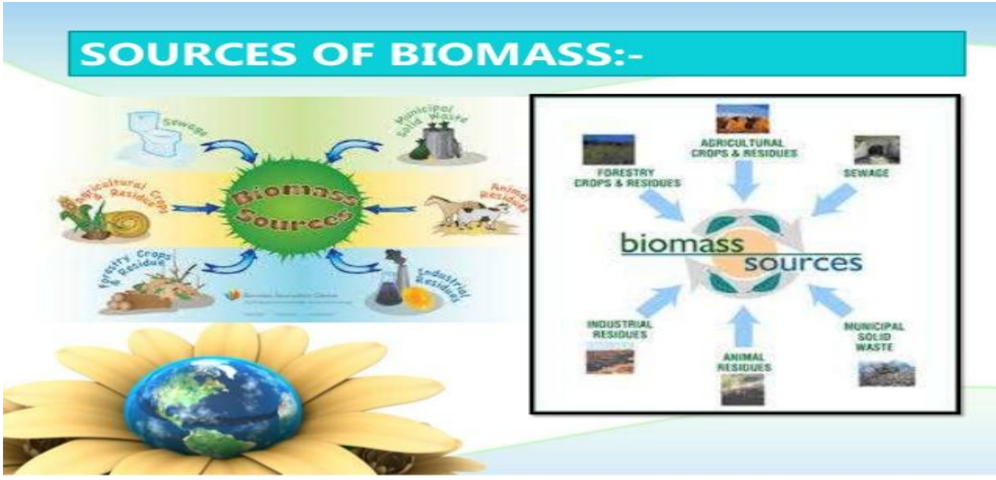

Fig 2.2: Sources of biomass

Sources of biomass are-

- # Energy crops
- # Forest residues
- # Agricultural residues and wastage
- # Animal wastage
- # Human waste
- # Municipal solid Waste
- # Industrial waste and residues

2.3 Useable energy forms of biomass

Biomass has most diversified use. It is the most ancient type of energy source that came into use. Biomass can be converted into various energy forms. Different conversion methods result different energy forms. The forms may be solid, liquid or gaseous. Those forms are useful for different purposes. The following table shows types of biomass with their useable form with various conversion methods.

Table 2.1: Biomass sources and their uses according to the suitable energy forms

Biomass sources	**Conversion method**	**Useable form**	**Consumption sector**
Oil crops	Trans esterification	Liquid bio-fuel (Methyl ester)	Transport/ Electricity generation
Sugar and starch plant	Extraction >hydrolysis> fermentation	Liquid bio-fuel (Ethanol)	Transport/ Electricity generation
Solid biomass	Pyrolysis	Liquid bio-fuel (Pyrolytic oil)	Transport/ Electricity generation
	Gasification	Fuel gas	Heating/Electricity generation
	Densification (Pellet/Briquette)	Heat	Heating
	Direct combustion		
Wet biomass	Anaerobic fermentation	Biogas	Heating/Electricity generation

2.3.1 Biomass pellet

Fig 2.3: Biomass pellet

Processing biomass and shaping it into pellets allows converting organic matter into a standard form of fuel, which can be easily obtained, transported and used. The types of biomass used in the production of pellets are quite varied, which affects the physicochemical properties of the final product. The most desirable are the pellets produced from biomass with high content of cellulose and lignin, which are extracted, among others from wood (including chips from the acquisition and care of forest trees or energy crops like willow from dedicated plantations), bark, straw, grasses (energy crops such as Miscanthus sp., Panicum virgatum, Phalaris arundinacea, Bambus sp.), litter meadows and rushes, husks (as production waste from rice, tamarind, coffee, cotton), pips and seeds (such as olive, corn), shells (including nuts), maize cobs (Grover and Mishra, 1996, University of Vermont in 2011) and caddis. A large variety of raw materials used to produce pellets, forced attempts to unify the products patterns in individual national markets. The most common forms of certification standards and guidelines are one referring to wood pellet characteristics. The main characteristics that determine the quality of pellets are the energy value, the emission of combustion gases (sulphur oxides, nitrogen oxides, hydrogen chloride, volatile dust) and factors that affect proper functioning of furnace (Hiegl et al. 2009). Level of sulphur, chlorine and nitrogen are particularly relevant to the individual recipients, because of the health aspects of consumers and the longevity of heating systems, which are exposed to excessive [8].

2.4 Biomass energy conversion technologies

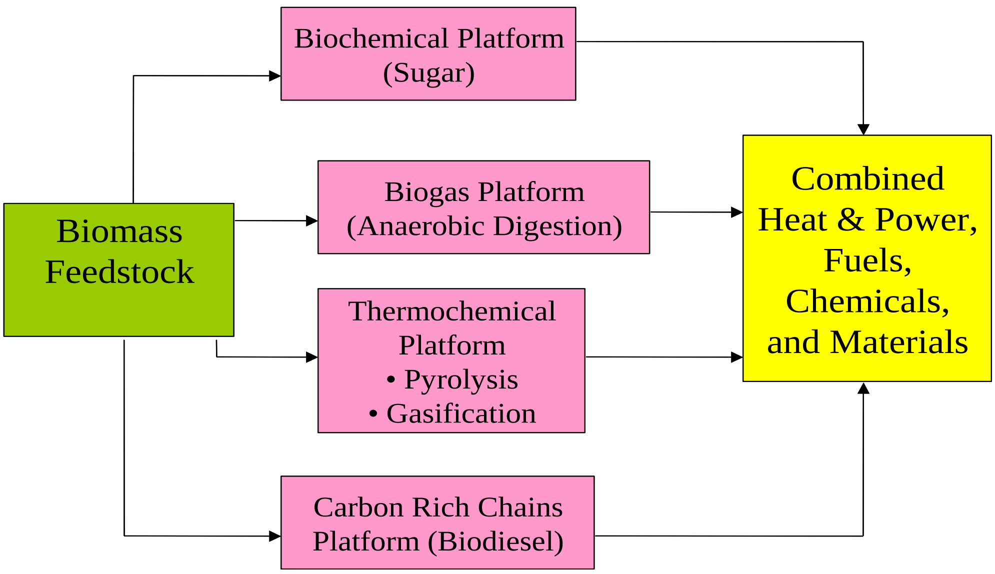

Fig 2.4: Biomass energy conversion technologies

2.4.1 Thermal Conversion of Biomass

A wide range of technologies exists to convert the energy stored in biomass to more useful forms of energy. These technologies can be classified according to the principal energy carrier produced in the conversion process. Carriers are in the form of heat, gas, liquid and/or solid products, depending on the extent to which oxygen is admitted to the conversion process (usually as air). The major methods of thermal conversion are combustion in excess air, gasification in reduced air, and pyrolysis in the absence of air.

2.4.1.1 Combustion

Conventional combustion technologies raise steam through the combustion of biomass. This steam may then be expanded through a conventional turbo-alternator to produce electricity. A number of combustion technology variants have been developed. Underfeed stokers are suitable for small scale boilers up to 6 Mwth. Grate type boilers are widely deployed. They have relatively low investment costs, low operating costs and good operation at partial loads. However, they can have higher NOx emissions and decreased efficiencies due to the requirement of excess air, and they have lower efficiencies. Fluidized bed combustors (FBC), which use a bed of hot inert material such as sand, are a more recent development. Bubbling FBCs are generally used at 10-30 Mwth capacity, while Circulating FBCs are more applicable at larger scales. Advantages of FBCs are that they can tolerate a wider range of poor quality fuel, while emitting lower NOx levels.

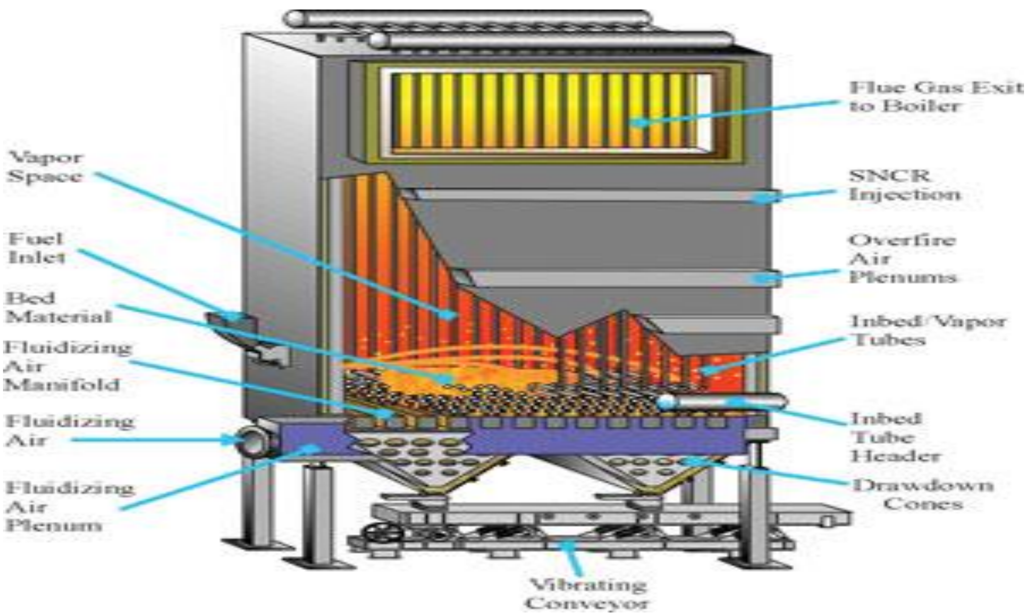

Fig 2.5: Fluidized bed combustors (FBC)

2.4.1.2 Gasification

Gasification of biomass takes place in a restricted supply of oxygen and occurs through initial de volatilization of the biomass, combustion of the volatile material and char, and further reduction to produce a fuel gas rich in carbon monoxide and hydrogen. This combustible gas has a lower calorific value than natural gas but can still be used as fuel for boilers, for engines, and potentially for combustion turbines after cleaning the gas stream of tars and particulates. If gassifiers are 'air blown', atmospheric nitrogen dilutes the fuel gas to a level of 10-14 percent that of the calorific value of natural gas. Oxygen and steam blown gassifiers produce a gas with a somewhat higher calorific value. Pressurized gassifiers are under development to reduce the physical size of major equipment items .A variety of gasification reactors have been developed over several decades. These include the smaller scale fixed bed updraft, downdraft and cross flow gassifiers, as well as fluidized bed gassifiers for larger applications. At the small scale, downdraft gassifiers are noted for their relatively low tar production, but are not suitable for fuels with low ash melting point (such as straw). They also require fuel moisture levels to be controlled within narrow levels.

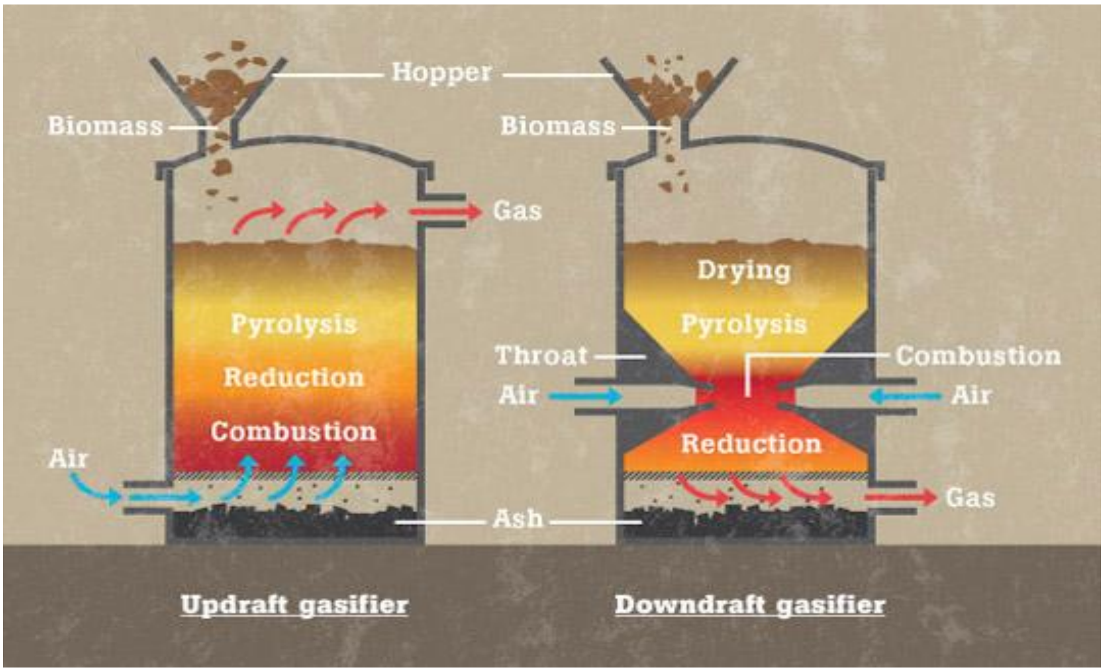

Fig 2.6: Up draft and Down draft gassifier.

2.4.1.3 Pyrolysis

Pyrolysis is the term given to the thermal degradation of wood in the absence of oxygen. It enables biomass to be converted to a combination of solid char, gas and a liquid bio-oil. Pyrolysis technologies are generally categorized as "fast" or "slow" according to the time taken for processing the feed into pyrolysis products. These products are generated in roughly equal proportions with slow pyrolysis. Using fast pyrolysis, bio-oil yield can be as high as 80 percent of the product on a dry fuel basis. Bio-oil can act as a liquid fuel or as a feedstock for chemical production. A range of bio-oil production processes are under development, including fluid bed reactors, ablative pyrolysis, entrained flow reactors, rotating cone reactors, and vacuum pyrolysis.

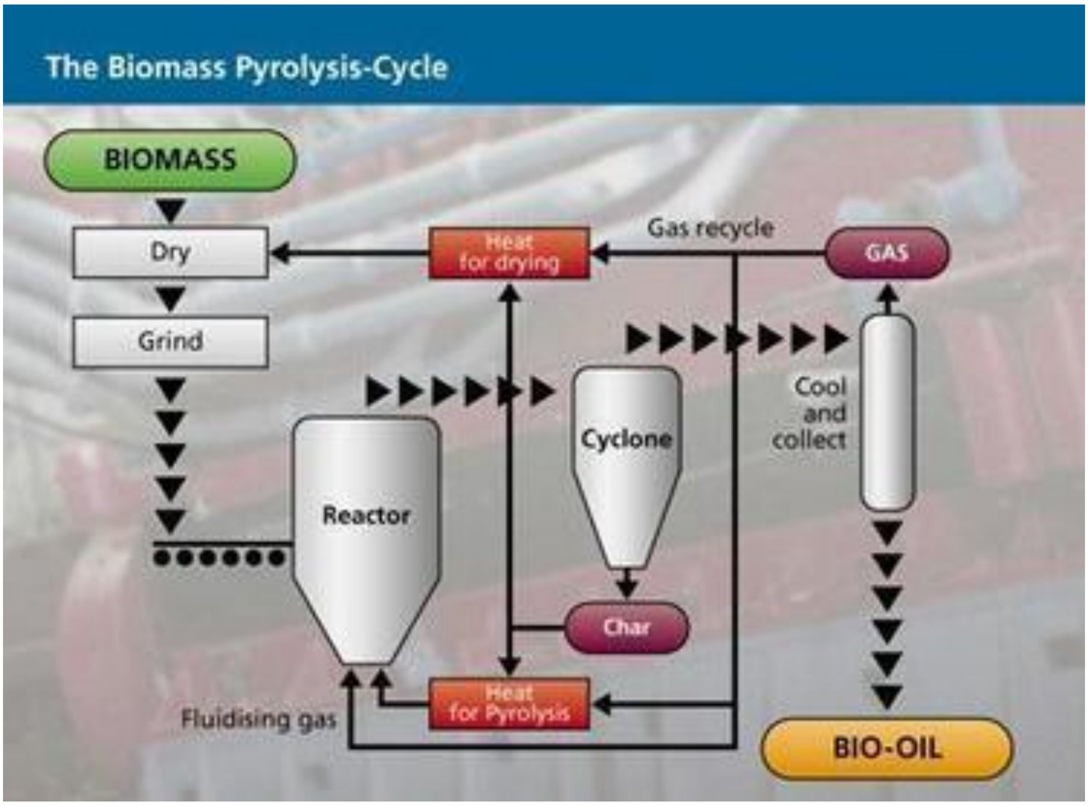

Fig 2.7: Pyrolysis cycle.

2.4.2 Chemical conversion

A range of chemical processes may be used to convert biomass into other forms, such as to produce a fuel that is more conveniently used, transported or stored, or to exploit some property of the process itself. Many of these processes are based in large part on similar coal-based processes, such as Fischer-Tropsch synthesis, methanol production, olefins (ethylene and propylene), and similar chemical or fuel feed stocks. In most cases, the first step involves gasification, which step generally is the most expensive and involves the greatest technical risk.] Biomass is more difficult to feed into a pressure vessel than coal or any liquid. Therefore, biomass gasification is frequently done at atmospheric pressure and causes combustion of biomass to produce a combustible gas consisting of carbon monoxide, hydrogen, and traces of methane. This gas mixture, called a producer gas, can provide fuel for various vital processes, such as internal combustion engines, as well as substitute for furnace oil in direct heat applications. Because any biomass material can undergo gasification, this process is far more attractive than ethanol or biomass production, where only particular biomass materials can be used to produce a fuel. In addition, biomass gasification is a desirable process due to the ease at which it can convert solid waste (such as wastes available on a farm) into producer gas, which is a very usable fuel. Conversion of biomass to bio-fuel can also be achieved via selective conversion of individual components of biomass. For example, cellulose can be converted to intermediate platform chemical such as orbitol, glucose, hydro xymethyl furfural etc. These chemical are then further reacted to produce hydrogen or hydrocarbon fuels.

Biomass also has the potential to be converted to multiple commodity chemicals. Halo methanes have successfully been by produced using a combination of A. fermentans and engineered S. cerevisiae. This method converts NaX salts and unprocessed biomass such as switchgrass, sugarcane, corn stover, or poplar into halomethanes. S-adenosylmethionine which is naturally occurring in S. cerevisiae allows a methyl group to be transferred. Production levels of 150 mg L-1H-1 iodomethane were achieved. At these levels roughly 173000L of capacity would need to be operated just to replace the United States' need for iodomethane. However, an advantage of this method is that it uses NaI rather than I2; NaI is significantly less hazardous than I2. This method may be applied to produce ethylene in the future. Other chemical processes, such as converting, straight and waste vegetable oils into biodiesel is trans esterification.

2.4.3 Biochemical conversion

As biomass is a natural material, many highly efficient biochemical processes have developed in nature to break down the molecules of which biomass is composed, and many of these biochemical conversion processes can be harnessed. Biochemical conversion makes use of the enzymes of bacteria and other microorganisms to break down biomass. In most cases, microorganisms are used to perform the conversion process: anaerobic digestion, fermentation, and composting.

2.4.4 Electrochemical conversion

In addition to combustion, bio-mass/bio-fuels can be directly converted to electrical energy via electrochemical oxidation of the material. This can be performed directly in a direct carbon fuel cell, direct ethanol fuel cell or a microbial fuel cell. The fuel can also be consumed indirectly via a fuel cell system containing a reformer which converts the bio-mass into a mixture of CO and H2 before it is consumed in the fuel cell.

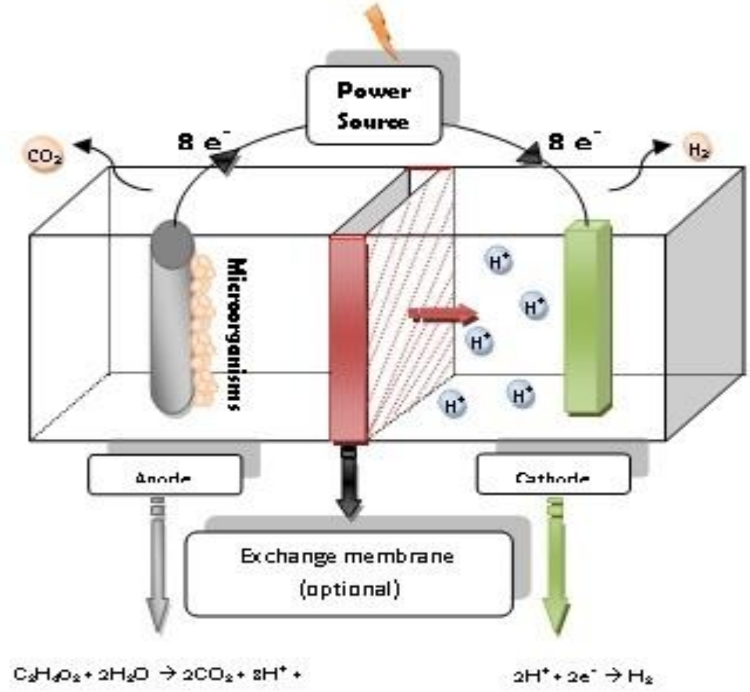

Fig 2.8: Fuel cell

2.5 Global biomass sources and uses

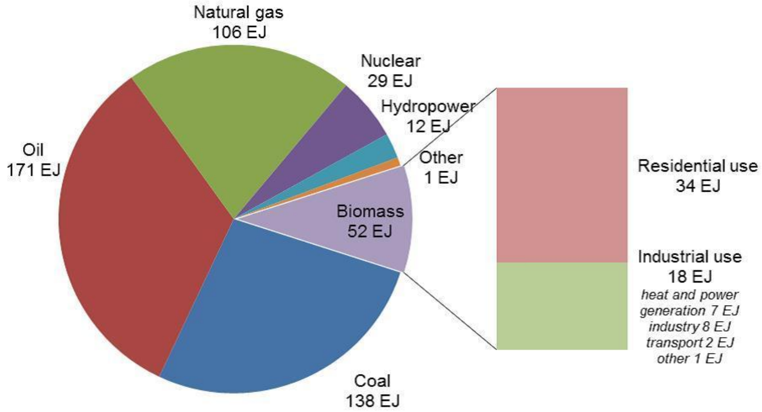

Fig 2.9: Global Energy mix and Biomass using sectors, September 19, 2013. Courtesy: International energy agency.

A new report from the International Energy Agency takes a global overview of biomass use in the industrial and transport sectors, identifying leading countries and the top 15 production companies in each sector. The IEA's Bio-energy Task40 report, "Large Industrial Users of Energy Biomass," was released in early September. Currently biomass covers approximately 10 percent of the global energy supply, of which two-thirds is used in developing countries for cooking and heating. In 2009, about 13 percent of biomass use was consumed for heat and power generation, while the industrial sector consumed 15 percent and transportation 4 percent. The global consumption of bio-fuels in transportation equaled 2 percent of the transport sector total. Excluding residential use, the top countries utilizing all sources of biomass for energy were Brazil, the U.S. and India. Brazil leads the list at 18 percent of the total industrial use globally in 2009. The U.S. and India each had a 16 percent share of global industrial biomass use for energy, with Nigeria, Canada, Thailand and Indonesia trailing far behind in the next group, each having about a 4 percent global share. In Brazil, 21 percent of the energy used in industry came from sugarcane bagasse in 2010, with the food and beverage sector getting 75 percent of its energy from bagasse. The industrial sector in Brazil gets a significant amount of energy from wood as well. In the U.S., most of the biomass used in the industrial sector is derived from the forest, and more than half is black liquor. In the transportation sector, the U.S. has far the largest share of the global consumption of bio-fuels at 43 percent in 2011, of which ethanol is 94 percent of the U.S. total. Brazil bio-fuel usage is also dominated by ethanol, at 94 percent of its total, with the country accounting for about 25 percent of global usage. The EU27 comes in at 23 percent of total global use, with bio-diesel dominating EU bio-fuels with a 76 percent share. Canada and China trail far behind, each having a 2 percent share of global use. Thailand and Belarus each have a 1 percent share and all other counties combined total 3 percent. In reviewing the top plants utilizing biomass resources, the pulp and paper industry accounts for nearly a quarter of global industrial use of biomass for energy. Globally, there are about 630 recovery boilers in use in chemical wood pulp mills. Next in line for global biomass utilization capacity is ethanol, with the U.S. having the largest capacity by far, followed by Brazil? Global bio-diesel production capacity is slightly smaller than ethanol capacity, but the utilization rate is low at about 35 percent. Bio-diesel is third in capacity, although its current rate of utilization compared to capacity is much lower. Among the plant types using solid biomass for energy, pellet mill capacity is nearly one-third of its liquid bio-fuel totals, followed by plants using three different boilers types for industrial plants and power generation. Torrefaction, pyrolysis and gasification applications were discussed, but not charted, as the total global plant capacity is comparatively small.

The report also examined the top 15 plants in different sectors, in part to determine the influence of the largest producers. The 15 largest pulverized firing boilers co-firing biomass cover up to 43 percent of the biomass co-firing capacity. For other boilers as well as wood pellet, bio-diesel, and ethanol production, the share of the 15 largest plants is around 10 to 20 percent of the sector's capacity. Actual use of biomass in the 15 largest plants exceeds 20 percent of the sector's use for bio-diesel plants, pulverized fuel boilers and circulating fluidized bed boilers, while for other categories, it is close to 10 percent.

The report also notes whether the biomass used in the largest plants was sourced locally or imported, finding that most aware local biomass feeds. Imported biomass is used primarily in bio-diesel plants and pulverized firing boilers, and most imported biomass is used in Europe. While the use of raw biomass will likely remain local, the trade of refined bio-fuels such as bio-ethanol, bio-diesel and wood pellets will likely continue to increase in the near future [9].

Table 2.2: Share of Biomass on total energy consumption [10]

Name of country	Percentage (%)
Nepal	95%
Malawi	94%
Kenya	75%
Bangladesh	65%
India	50%
China	33%
Brazil	25%

2.6 Biomass Pellets Basics

Biomass pellets are compressed fiber biomass sources. They are about 30% denser than whole wood and are a renewable energy source that is manufactured using an established and proven production process. The pellets have a cylindrical form and are typically 6-10mm in diameter and 30-50mm long. The thumb rule is that length=4X Diameter. They are an easily managed, free-flowing, and dust-free fuel. The average biomass pellet made from woods has an energy content of about 4000-4200 kcal/kg.

The basics of biomass pelletization are:

a. The wood pellet moisture content should not be more than 10% because it affects the calorific value of pellet.
b. The fineness of raw materials assures better combustion and internal bonding..
c. Proper bonding is important.
d. The biomass fiber is extruded in pellet mills and made into pellets. There are no additives because the wood lignin softens under temperature and pressure to become the binding agent.

2.6.1 Why pelleting?

Actually pelletization does not add extra energy to biomass but make it easy to handle. We prefer pelletization because-

Biomass is low density substance thus not easy to handle. Densification improves the handling capacity.
Densification improves the combustion capacity of biomass.
Densification reduces moisture content and thus improves the calorific value of biomass.
Pellet is less smoky than loose biomass.
Pellet requires fewer places to store and handle.
Pellet is more hygienic than biomass.

2.6.2 Global pellet production

Global wood pellet production in 2015 is 28 million ton, 15 million ton produced to meet heating demand and other 13 million ton produced to meet industrial demand.

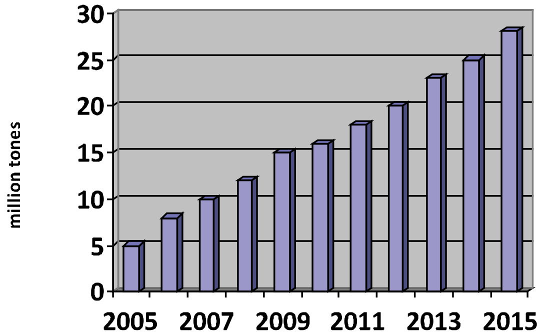

Fig 2.10: Year wise global pellet production [33].

From the above figure it is obvious that the demand is increasing day by day.

2.6.3 Global demand

Global pellet demand is categorized by two sectors. Demand for room heating and industrial demand. The scenario for heating pellet demand is stated bellow with bar chart.

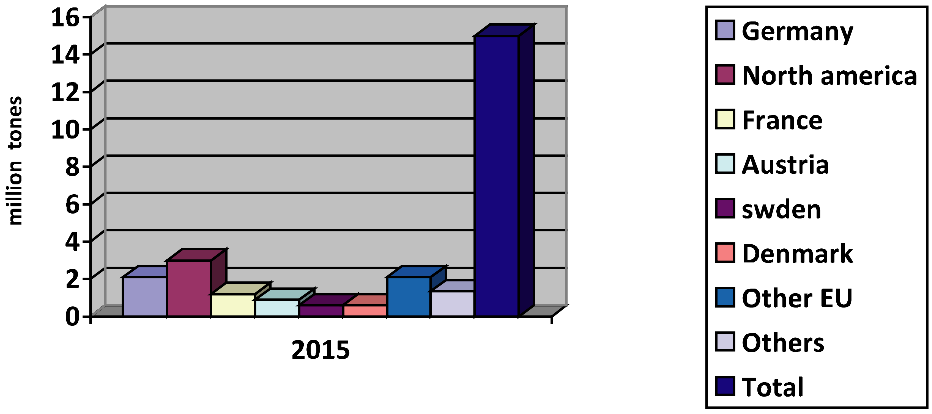

Fig 2.11: World demand for heating pellet [34]

Bellow the scenario for industrial pellet demand

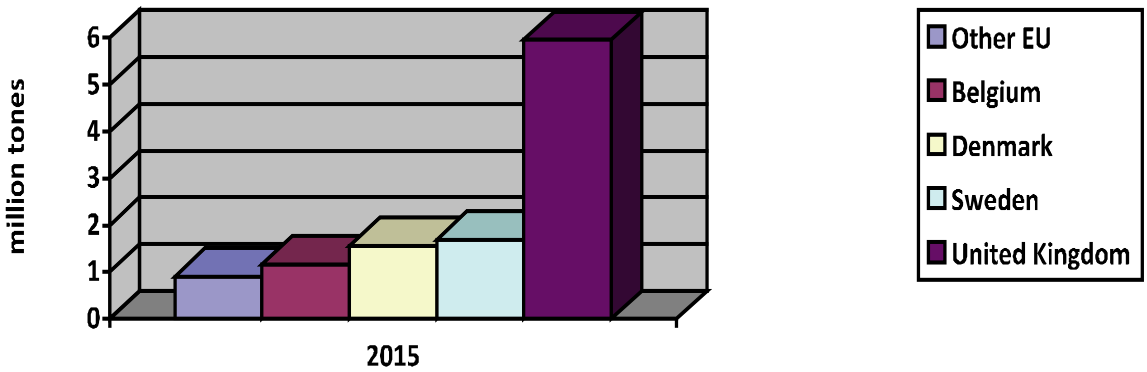

Fig 2.12: World demand for industrial pellet [35]

Analyzing previous data, it is obvious that the increasing demand for industrial pellet exceeding the heating pellet demand.

2.6.4 Global Pellet standard

Standardization aims at removing trade and application barriers by establishing unification (of concepts, procedures and products) within a national or international community of concerned stakeholders. Standards increase economization, compatibility, user-friendliness and security in the application and exchange of products and services [36].

Various European countries set up their standard for biomass pellet according to their uses. Typical use of pellet in small scale room heating and for industrial purpose such as electricity generation, district heating etc. Quality is a central issue for the further development of pellet markets. Especially the residential heating sector depends on reliable fuel quality since it is crucial for a reliable and economic use of small-scale pellet heating systems. The importance of quality standards and assurance became obvious in the last years in Germany and Austria where the early introduction of pellet-related standards and certification systems certainly was a stimulating factor for the dynamic development of residential pellet heating markets. However, standards alone are not sufficient. Certification and the control of products and of the whole supply chain are desirable. Existing national and international certification systems such as DINplus contributed a lot to quality assurance and to gaining consumers´ confidence. However, they all have certain drawbacks and none of them covers the whole supply chain within one system. Based upon the new European standards, the German Pellet Association (DEPV), together with other partners, is currently developing a new certification system with a European scope and a more holistic approach. The system claims the potential to replace the other existing certificates that are partly well accepted by stakeholders such as boiler manufacturers and end-consumers.

2.6.5 Quality issues on biomass pellets

Chemical and physical properties of solid bio-fuels have manifold effects on their thermal utilization. Besides the energy content, end-consumers are mainly concerned with two problem areas: Emissions and boiler/stove function.

Emissions relevant for small-scale wood combustion are mainly NOx, SOx, HCl, PCCD (polychlorinated dibenzo-p-dioxins) and fly ash. The amount of NOx and SOx emissions correlates directly with N and S contents in the fuel. Fuels with N contents below 0.6 % and S contents below 0.2 % usually do not cause emission problems and problematic HCl (and PCCD) emissions are characteristic for bio-fuels with chlorine contents above 0.1 %. However, much lower thresholds are recommended. In countries with demanding NOx emission thresholds, N contents below 0.3 % are preferable. Newer findings also show that corrosion problems in chimneys can already occur with chlorine contents as low as 0.01 %. Therefore, this is the recommended threshold.

The formation of inorganic fly ash increases with higher contents of elements such as K, S and Cl while the formation of organic fly ash usually only occurs independently from fuel quality when old combustion technology is used or when pellet appliances are poorly installed or controlled.2 The combustion of clean wood fuels generally does not produce problematic emissions of any kind since contents of critical elements are very low. Raw materials containing larger amounts of bark or herbaceous raw materials on the other hand have higher ash contents and therefore cause higher emissions.

Besides problematic emissions, low-quality bio-fuels can also cause harmful effects on combustion equipment such as slagging, corrosion and interference with process control. The ash that is not emitted as fly ash (see above) deposits in the combustion chamber. The melting point of this deposited ash is an important fuel characteristic. Ca and Mg usually increase the melting point, while K and Na decrease it.2 During the combustion of fuels with unfavorable ash composition (such as straw) and therefore low ash melting temperature, high temperatures in the combustion chambers can lead to melting and sintering of deposited ashes.

Corrosion of metal parts of the boiler/stove is usually caused by chloride salts and HCl derived from high Cl contents in the fuel. Finally, the content of fine particles in the fuel can disturb the regulation of highly automated heating systems or interrupt automated fuel feeding. In addition, fine particles burn quicker and the resulting higher temperatures can favor ash melting. The content of fine particles depends on the mechanical durability and on logistics and storage issues. As already said, clean wood (and especially soft wood) pellets contain very low amounts of the problematic elements mentioned above, so that most of the problems described above (except problems related to fine contents) are not relevant for high quality wood pellets. However, with increasing use of bark, forest residues, SRC wood or herbaceous biomass, the described problems gain relevance.

2.6.6 Pellet quality

Standards and certification Several European countries such as Austria (ÖNORM M 7315), Sweden (SS 187120) and Germany (DIN 51731) have introduced pellet-related standards in the past, but experiences in these countries showed that standards need to be accompanied by a control system that certifies pellet production and minimum pellet quality. In Austria, for example, the pellet standard is connected to a certification label ("ÖNORM tested") that certifies pellet producers and guarantees unproblematic pellet usage for the end-consumer. This did not work in Germany where production in agreement with DIN standards is usually certified by the "DIN tested" label. However, this label is granted without external controls at the production site. Furthermore, the minimum requirements of DIN 51731 are not always strict enough for unproblematic pellet combustion in small scale applications. This standard also lacks a threshold for mechanical durability. This led to the development of the standard-independent certification scheme DIN plus for wood pellets by DIN CERTCO which combines features of the German and the Austrian standard, including external controls and strict quality requirements. Today, it is the best known certification label for wood pellets in Europe and worldwide. The situation will change largely after the introduction of European standards for solid bio-fuels (EN 14961). National standards have to be adapted or taken back. Therefore, they will lose their relevance soon and will not be addressed in detail in this report. Existing certification schemes do not have to comply with the new standards but the certification bodies acting in a unified European framework will still face the necessity to adapt their requirements. Both end-consumers and appliance manufacturers will look for a certification system that ensures the compliance of pellet quality with European standards. Wood pellet specification Norms and standards Quality marks ÖNORM M 7135 DIN 51731 SS 187120 others CEN ISO Influence Basis for new quality mark schemes Wood pellet specification Norms and standards Quality marks ÖNORM M 7135 DIN 51731 SS 187120 others CEN ISO Influence Basis for new quality mark schemes.

2.6.7 Existing national certification schemes for pellet

There are many National standards for biomass pellet but DIN plus (Germany) and ÖNORM M 71356(Austria) are most followed.

2.6.8 DIN plus (Germany) and ÖNORM M 713569 (Austria)

In 1996, the DIN 51731 on compressed wood was introduced in Germany. As already said, the usability of this standard for the small-scale pellet heating sector is limited. Main reasons for this are high maximum ash contents (1.5% ash might already cause combustion problems) and the absence of a maximum for abrasion (Figure 2). Furthermore, the certificate that attests production according to this standard is awarded without external control. That means that end-consumers cannot always be sure that certified pellets actually comply with the requirements of DIN 51731. This system is still in use today (October 2009). However, it is mainly used for briquette production rather than pellet production.

Table 2.3: Some European national standard comparison on biomass pellet [37, 38, 39]

Criteria	DIN Plus	DIN 51731	ÖNORM M 71356
Diameter(D in mm)	4-10	4-10	4-10
Length(mm)	< 5 x D	< 50 mm	< 5 x D
Density(kg/cm3)	> 1.12	1.0 - 1.4	> 1.12
Moisture content (%)	< 10	< 12	< 10
Ash content (%)	< 0.5	< 1.5	< 0.5
Abrasion (%)	< 2.3	-------	< 2.3
Energy content (MJ/Kg)	> 18	17.5-19.5	> 18
Sulfur content (%)	< 0.04	< 0.08	< 0.04
Nitrogen content (%)	< 0.03	< 0.03	< 0.03
Chlorine content (%)	< 0.02	< 0.03	< 0.02
Heavy metal (%)	regulated	regulated	Non-regulated

As the DIN standard did not show to be useful, DIN CERTCO developed the DIN plus certification scheme for high quality wood pellets in 2002. It combines characteristics of both the German DIN 51731 (e.g. testing of heavy metal contents) and the Austrian ÖNORM M 7135 (e.g. high quality requirements in general) (Figure 2). This scheme includes the establishment of internal quality management and annual, external controls without announcement. DIN plus contributed a lot to the promotion of the residential pellet market in Germany and today, it is the most important quality label for high quality wood pellets worldwide. In total, 102 pellet producers are DIN plus certified (October 2009) and 61 of these are based in Germany. Figure 3 shows the countries, where DIN plus is used (Certificates in Germany are not shown). The DIN plus certified producers with known production capacity represent a total capacity of around 3.5 million tons. Considering the other 40 small and medium scale producers with unknown capacity, the total production capacity for DIN plus pellets certainly exceeds 4 million tons [40].

2.7 Important issues from literature review

From previous literature it is obvious that biomass is a good source of renewable energy and pelletization is a popular and effective way to extract energy from biomass. There is no doubt about the worldwide demand for biomass, but pellet production has some issues. They are-

a. Most of pellet produced in western hemisphere from woods and all wood used are soft wood.
b. Transportation of low density agro waste.
c. Moisture, Ash, sulphur, nitrogen and chlorine content.
d. Calorific value and density of pellet.

2.8 Setting up the research goals

From literature review and our primary goal to analyze the techno-economic aspect of biomass waste the essential subject matter that needs to be focused are

a. Types and availability of biomass in Bangladesh.
b. Calorific value of available biomass of Bangladesh.
c. Target market and degree of competition.
d. Set up target area for pellet production.
e. Raw materials mix and production technology.
f. Raw materials drying.
g. Economic analysis.
h. Sample production and test.

Chapter 03

3. Methodology

In this research we collected data from previous research, concern government agencies and field survey.

3.1 Data collection: Quantification of biomass waste

3.1.1 Agricultural residues and wastages

Agricultural residues are the major contributor to the biomass sector of Bangladesh. Crop production generates considerable amounts of residue that can be used as energy source. As a thumb rule 1 ton of cereal production causes 1.3-1.5 ton of biomass production [1]. Crop residues can be distinguished into field residue and process residue. Field residue is left in the field after harvesting, which is scattered over a wide area, and is generally used as fertilizer (sometimes by burning). Process residues are generated during crop processing, e.g. milling. They are available at a central location. Besides being an energy source, crop residues are used for several other purposes such as fodder and raw manufacturing material. Paddy straw, rice husks, maize, wheat, coconut, groundnut, mastered oil tree, beans, vegetables trees, jute, sugar cane etc. are the major agricultural residues.

Table 3.1: Production and Yield Rate of Major Agricultural Crops

Year	Rice tone	Jute tone	Sugarcane tone	Pulse tone	Oil seeds tone
2009-10	31973000	924000	4491000	333000	270000
2010-11	33452000	1523000	4671000	316000	587000
2011-12	33859000	1452000	4603000	279000	657000

Courtesy: Bangladesh Bauru of Statistics, year book 2015.

Agriculture in Bangladesh has grown at 3.2 per cent annually from 1991-2005 and the dominant source of this growth has been the crop sub-sector growing at 2.3 per cent per annum.

3.1.1.1 Paddy Straw

Straw normally contains 14-20% water, which vaporizes during combustion. The dry matter contains of about 50% Carbon, 6% Hydrogen, 42% Oxygen as well as small amounts of Nitrogen, Sulphur, Silicium, Alkali, Chloride and other. When straw is used as fuel, the water content must not exceed 20%. If the water content is higher, there is a risk that the bales of straw become too hard and compact. Similarly, a high water content increases the risk of formation of condensation and corrosion. The presence of Chlorine and Alkali in the flue gas can be a problem at combustion, leading to the development of Sodium Chloride and Potassium Chloride, which are highly aggressive and cause corrosion in boilers and pipes, particularly at high temperatures. The aim is to use straw with a low content of harmful matter, and here the weather plays a significant role. Straw, which has been exposed to a lot of rain after maturing - especially after harvest, and has turned grey, is far less aggressive than yellow straw, which only has been exposed to a limited amount of rain. The ash content can vary between 2-10%, although the average is 4%. Straw from crops that have been cultivated on sandy soil normally has the lowest content of ash, while straw from lowland soils usually has the highest ash content. The heating value is highest with the lowest ash content, so it can be an advantage to use straw from sandy soil for heating purposes. The ash from straw burning can become viscid already at 600 degrees, and this is important for the power plants, where a high steam temperature is envisaged in order to obtain high electricity efficiency. New boiler types and better steel alloys have reduced the problem over time, but power plants still consider straw as a more troublesome fuel than wood. [11]

Fig 3.1: rice straw in field

Table 3.2: Comparison between straw and other materials as energy.

Name of item	Straw	Wood chips	Coal
Moisture content	10-20%	40-50%	12%
Ash content	4%	1%	12%
Carbon	42%	50%	59%
Hydrogen	5%	6%	4%
oxygen	37%	38%	7%
Chloride	0.75%	0.02%	0.08%
Nitrogen	0.35%	0.30%	1.00%
Sulphur	0.16%	0.05%	0.80%
Calorific Value	14.4MJ/KG	10.4MJ/KG	25MJ/KG

3.1.1.2 Rice husk

Rice husk is a unique biomass fuel having good calorific value (heat value: about 14,000 KJ) per kg & is also ‘carbon-neutral’. Bangladesh is a major rice producing country. It produces on average about 40,000,000 MT of paddy and about 8,000,000 MT of husk per year (K Islam 2008). Bangladesh has over 100,000 rice mills [12] all over the country which use both thermal energy (of steam produced by burning rice husk for parboiling of rice) & electric power (from grid) for entire operation of the mill (milling, boiler pumps, lighting etc.) Power generation through biomass gasification/pelletization from rice husks could be a wonderful option in rice mills all over Bangladesh. The production of rice husk is increasing in Bangladesh. The rice milling sector is the main consumer of rice husk energy. About 70% of rice husk energy is consumed by the rice parboiling system [24]. The total amount of recoverable rice residues in Bangladesh in FY 2010–11 was 58,504.07 k ton of which 51.54% and 48.46% were field and process residues respectively 224.73 k ton, of which 428.65 k ton was recovered [13].As a thumb rule 1 ton of Rice paddy produces 220 kg Rice Husk, and1 ton Rice Husk is equivalent to 410-570 kWh electricity. Calorific value of rice husk is 3000 kcal/kg with 8% Moisture content. Actually moisture content ranges from 5 – 12% [14].

Fig 3.2: Rice husk

3.1.1.3 Wheat residues

Wheat straws are generally used as biomass energy source. The total cultivation of wheat has increased from 901.490 k ton (FY 2009–10) to 972.085 k ton (FY 2010–11). But the farming area has decreased from 929,766 acres to 923,470 acres. The total amount of recoverable residues increased from 552.16 k ton to 595.40 k ton[15].The calorific value wheat straw is 2400 kcal/kg in natural state[16].

3.1.1.4 Jute Stick

Bangladesh holds the 2nd position as a Jute producer in the world with the average production of Jute 1.08 m ton/Year.[17].jute tree produce 30% fiber and 70% jute stick. This jute stick is a good source of biomass. In terms of world export of jute fiber, Bangladesh's share is more than 70%, which makes Bangladesh the largest exporter of jute fiber in the world. The global demand for jute and allied products has seen a steady increase driven by afresh comeback for biodegradable fiber as people now look for eco-friendly products replacing synthetics.

Table 3.3: Fuel properties of jute stick [18].

Name	Ash content (%)	Moisture content (%)	Calorific value, kcal/kg
Jute stick	1.59	9.35	4448.8

3.1.1.5 Corn Stover and core

Corn Stover is the leaves and stalks of maize plants that left in a field after harvest and consists of the residue. Stover makes up about half of the yield of a crop and is similar to straw.[1] Corn Stover is a very common agricultural product in areas of large amounts of corn production. It is very bulky with low moisture.

Now maize is widely cultivated in our country. Mainly the north-western part of Bangladesh came under maize cultivation. Total area under maize is 0.313 million hectares (ha), producing 2.183 million tons with yield of 6.98 t/ha during 2013 (DAE, 2013). Maize occupied about 1.92 percent of the cropped area in Bangladesh during 2013 (Table 1). The average area, production, and yield of maize are reported to be the highest in Rangpur and Khulna divisions compared to other divisions (Figure 1). Dinajpur, Rangpur, Chuadanga, Thakurgaon, Lalmonirhat, Manikgonj, Panchagar, Jhenaidah, Rajshahi and Bogra districts are the intensive maize growing areas of Bangladesh. These 10 districts covered more than 75 percent of the total maize area and production in 2013[19].

Table 3.4: Stover as fuel [20, 21and 22]

Name	Ash content	Calorific value	
		Higher MJ/Kg	Lower
Corn stalks/Stover (1,2,6)	4.8%	17,636 - 18,519	16,849 - 17,690

3.1.2. Livestock and poultry residues

At presents the number of livestock and poultry in Bangladesh from FY 2006–07 to FY 2008–09. Table 9 also estimates the cattle heads per household in the rural areas of Bangladesh. From Table 3.5, it is mentioned that the number of livestock and poultry are increasing day by day. Therefore, the extent of manure is also being produced positively. According to the statistics, there were about 22.97 million cattle, 1.30 million buffaloes, 22.40 million goats, 2.87 million sheep, 221.3 million chickens and 41.23 million ducks in FY 2008–09. In FY 2008–09, Total population of livestock and poultry were 49.55 and 262.62 million respectively. The amount of waste produced per day by livestock and poultry is estimated using the generation ratio of neighboring Asian countries. It was taken as 2.86 kg dry matter/animal/day for cattle, 2.52 kg dry matter/animal/day for buffalo, 0.55 kg dry matter/animal/day for goat, 0.33 kg dry matter/animal/day for sheep and 0.02 kg dry matter/poultry/day. The total waste produced in a year is calculated by multiplication of the waste production per year and the number of livestock/poultry

Table 3.5: Bangladesh livestock scenario, 2012 [23].

Name	Number in million
Cattle	22.97
Buffalo	1.3
Goat	22.40
Sheep	2.87
Total Livestock	49.55
Chicken	221.3
Duck	41.23
Total Poultry	262.62

Therefore, in FY 2008–09, about 49.55 million livestock and 262.62 million poultry produced 30,016.61 kton and 1917.12 kton waste, respectively. The residues recovery rate for animal waste and poultry droppings have been assumed as 60% and 50% respectively [24]. Using these ratios, it is approximated that the amount of recoverable animal waste. And poultry droppings in Bangladesh were 18,009.96 kton and 958.56 kton respectively in FY 2008–09.

3.1.3 Industrial residues

3.1.3.1 Jute caddis

The contribution of jute sector to economy of Bangladesh is enormous. Bangladesh produces 5.5-6.0 million (55-60 lakh) bales of raw jute every year of which some 3.2 million (32 lakh) bales are used in the existing 148 jute mills. The country exports 2.4 million (24 lakh) bales of jute. Bangladesh exports 0.46 million (4.60 lakh) tonnes of jute goods, comparing India’s share of 0.285 million (2.85 lakh) tonnes in the international market. Dhaka controls 62 per cent share of the total jute goods market of the world and earn Taka 20.125 billion (2012.5 crore) [25].In Jute fiber processing results 3-4% remain as residues, called jute caddis. caddis contain about 4% batching oil and 1% dust by weight and rest are lingo cellulosic fiber materials.[1]Jute caddies in combination with other agro-residues viz., rice husk, saw dust, jute stick can be pelletize at optimum moisture condition of 10-15%. The gross calorific value of jute caddies briquettes was found to be is 3000-3200 kcal kg^{-1} (Anonymous, 2006). Considering the calorific value of coal as 5200 kcal kg^{-1} and mineral oil as 10,000 kcal kg^{-1}, 1 kg of jute caddies briquette is equivalent to 0.635 kg of coal or 0.33 kg of mineral oil (Nayak et al., 2011)[26]

Table 3.6: Composition of jute caddies [27].

Name of components	% in weight
Fiber (3 mm – 100 mm)	85 (85-86)
Oil and grease	5.00 (3.5-6.5)
Bark & remnants	5.00 (4-6)
Clay and Dirt	4.50 (4-6)
Foreign matter	1.00 (1-1.5)

Table 3.7: Jute caddies as a fuel [28]

Name	Ash Content (%)	Moisture (%)	Calorific value, Kcal/Kg
Jute caddies	9.7	8.84	3923.4

3.1.3.2 Wood industry waste and residues

Recovery rates vary with local practices as well as species (FAO, 1990). After receiving the logs, about 12% is waste in the form of bark. Slabs, edgings and trimmings amount to about 34% while sawdust constitutes another 12% of the log input. After kiln- drying the wood, further processing may take place resulting in another 8% waste (of log input) in the form of sawdust and trim end (2%) and planer shavings (6%). For calculation purposes a yield factor of 50% has been used (38% solid wood waste and 12% sawdust).1.In Bangladesh, Barisal division is famous for wood processing business. In Barisal there are1200 saw mills operating. One third of mills are operating in Swarup kathi–Indurhat region. They produce120000 Ton of saw dust yearly along with 200000 tone of wood chips annually.

3.1.3.3 Bagasse

In Bangladesh sugarcane is grown in about 0.38 million acres of land. The annual production of cane is about 5.5 million m tons. It is one of the most important cash crops of the country. There are 15 sugar mills in Bangladesh. These mills use about 60% of the cane produced; rest are supplied to the molasses producers. The by-products obtained from sugarcane include rum, alcohol, fuel, bagasse, livestock feed, and from the stalk residue, paper and wallboard [29]. In BANGLADESH it is grown all over the country; however, the major sugarcane growing district are Rajshahi, kustia, jessore, Dinajpur, Rangpur, Faridpur, Mymensingh, Tangail, jamalpur, and Dhaka.

Table 3.8: Bagasse production in Bangladesh [30]

Year	Quantity in million ton
2011	359
2012	310
2013	359

Table 3.9: Bagasse as a fuel

% of bagasse in sugarcane	Moisture content (%)	Ash content (%)	Calorific Value, Kcal/kg
30	50[31]	1-4	2270[32]

3.1.4 Municipal solid wastes

Municipal solid waste (MSW) is just household waste that is collected by garbage collectors and dumped in for landfill or in selected rubbish dumps. This amounts to millions of tons of household waste per year. The food production industry generates large fruit and volumes of waste product. These waste products include scraps from fruit and vegetables, food that is not of commercial standard and even the water that is used to carry off the waste material. These materials can be used to produce ethanol in a fermentation process or biogas in anaerobic digester. The main cities of Bangladesh are already overburdened with solid wastes from different sources. According to the world Banks study, the rural population generates solid waste only 0.15 kg per capita per day, while their urban counterparts generate 0.4 to 0.5 kg per capita per day [World Bank, 2005].

Figure 3.3: Municipal solid wastes

But attempts have been made to establish private community–bases waste management systems through NGOs. In the capital city of the country–Dhaka, one of the most populated cities in the world with about 10 million inhabitants and area of only 360 km^2, waste disposal system has become one of the major civic projects. It has been estimated by different sources that each day about 300 to 5000 tons of solid waste materials are generated in the city. Recently, waste concern, NGO involved with waste management, has entered into a Memorandum of Understanding (MOU) with the Dhaka City Corporation under which eight new communities based composting plants are being established throughout the city. Waste Concern have demonstrated how creative ventures, in which non-government and private sector organizations support the work of waste disposal authorities, can tackle the serious problems of waste management and generate revenue from a very unconventional source. Their innovative approach has recognized internationally and they are requested to provide technical support to India and Palestine (Waste Concern 2010) [36].

3.2 Primary out comes from previously conducted research and government's data analysis.

a. Bangladesh has lots of biomass
b. The main challenge is to collect them because they are scattered distributed.
c. Small pellet mill is preferable and must situate near the source of biomass.
d. Raw material mix is a good option for pellet production.

Analyzing those data we prepare the following table.

Table 3.10: Regional allocation of pellet raw materials in Bangladesh.

Name of region	**Available biomass**	**Raw materials mix for Pellet production**	**Comments**
Panchaghar Thakurgaon region	Wheat straw Rice straw Rice husk Sugar cane tops Bagasse Saw dust Stover	1. Wheat straw+ Rice straw + bagasse + stover 2. Sawdust+rice husk	Sugar cane tops may use for drying
Dinajpur region	Rice straw Rice husk Saw dust	1. Sawdust + rice husk.	This region is a paddy processing hub.
Kustia region	Rice straw Rice husk Sugar cane tops Bagasse Saw dust Stover	1. Sawdust + rice husk 2. Rice straw + bagasse + maize stalk	This region is a paddy processing hub.
Khulana barishal region	Sawdust Caddies Rice straw Rice husk Sunflower stalk	Saw dust + rice husk + caddies	Caddies can be used in dryer.
Hobigonj –Brahman baria region	Rice straw Rice husk Saw dust	Rice husk + Saw dust	Ashugonj is a paddy processing hub.
Chittagong region	Rice straw Rice husk Saw dust	Rice husk + Saw dust	

Considering the above table we chosen Barisal- Khulna region for field survey.

3.3 Field survey: Cost and quantity assessment of jute cadies and saw dust

3.3.1 Field survey goals

a. Availability of jute cadies and procurement process and cost of jute cadies in Khulna region.

b. Availability and cost of Saw dust in Barisal region.

We visited Khulna several times. There are 48 privates and 8 state own jute mills in Khulna. Khulna is the biggest jut processing hub of Bangladesh. We visited two state own and three private jute mills. They are khalispure , platinum jubilee, khansons jute mill, Nowapara jute mill and Ahad jute spinners ltd. We found that Average 3% cadies is found from raw jute processing. Each of the mill processes average 80 tone of jute every day in season. This season lasts for about four month. So annual average wastages produced by each mill is 500 ton.

Cadies is sold 2-3 BDT/kg in retail market. We can procure caddies from the mill by turnkey basis and the price will be less.

Fig 3.4: Inside of Crescent jute mills, Khulna.

We visited Barisal several times for conduct a survey about the availability of saw dust. This region is famous for wood processing. Swaropkathi and indurhat area is the most prominent saw mill zone in Bangladesh. In Barisal division there are 1245 registered saw mill operating. Other thousands of unregistered saw mill are operating. Each saw mill produces about 50 ton of saw dust and 120 ton of wood chips each year. This wood chips can be crushed into smaller one like saw dust and used to produce pellet.

Fig 3.5: Swarupkathi wood processing zone, Pirojpur.

3.4 Laboratory activities

We collected raw materials from Khulna and Barishal and processed those raw materials in RET lab. IE, DU**.** Laboratory work includes-

a. Moisture measurement of specimen
b. Sizing of caddies to 5mm length size
c. Mixing raw materials in desired ratio

Table 3.11: Moisture content of biomass specimen

Raw materials Name	Collection area	Moisture content (%)
Saw dust	Swarupkhthi,piroj pur	34%
Rice husk	Rajapur, Jhalo kathi	25%
Rice straw	Rajapur, Jhalo kathi	12%
Cadies	Khulna	8%

 Saw dust(Mehegoni tree)	 Saw dust(Raintree)
 Rice husk	 Caddies

Fig 3.6: Biomass specimen

In RET laboratory we checked the moisture content of specimen, cut the caddies into 5mm size and then we prepared a mixture of raw materials for test production.

 Moisture reading	 Cutting of caddies (5mm Size)
 Moisture reading	 Specimen

Fig 3.7: laboratory work

We prepared one set of raw materials mix.

Mixture (Mehegoni saw dust 40%+Raintree saw dust40%+cadies 20%)

3.5 Development of a new pellet

We done our experimental pellet production with the help of Eco-Fuel industry ltd, Shukursi galakatapul, Sarulia, Demra, Dhaka. Eco fuel is a small pellet factory with 500Kg/Hr capacity. They have one impact pelleting machine with a local made rotary drum dryer.

As our raw materials had 30% moisture content we need to dry it first. But it is not feasible to dry so little amount of raw materials with a rotary drum dryer, so we used conventional method by a cooking stove. The moisture was reduced to 12%.then sample pellet is made.

Fig 3.8: Eco fuel’s premises and dryer

Experimentally produced pellet

Pellet with documents

Fire in pellet mill

Pellet mill

Fig 3.9: pellet production

3.6 Fuel characteristics of our pellet

We sent our pellet specimen to the institute of fuel research and development (IFRD).The findings are stated bellow in a table.

Table 3.12: Fuel parameters test of biomass pellet specimen

Name of test	results
Moisture Content ,% (w/w)	10.09
Ash Content, % (w/w)	4.05
Density, Tone/M^3	0.95
Calorific Value, kcal/kg	4235.4

The test report is attached to the appendix A.

3.7 Bangladeshi pellet and world standard

Bangladesh is a small country. We got only 8% of our land covered by forest. We don't have enough wood for pelleting. More than that, we have to import logs to mitigate our need for wood. Moreover, in our forest we only have hard wood and imported wood also hard wood. We have many saw mills and wood industries but their residues also full of minerals as they workout from hard wood logs. So our pellet can comply with standard size, moisture content, density and calorific value but cannot comply with ash content criteria. Typically we got 2-4% ash in our pellet that fully manufactured from saw dust, if we mix agro waste with sawdust the resultant ash content will be more. More than that bark also get dust while cutting the logs and mix with saw dust. Our saw mill process does not follow debarkation. But no need to worry we have a larger domestic market full of crisis with cooking fuel.

3.8 Scope of biomass pellet business in Bangladesh

Bangladesh with a high potential for biomass pellet business because we have a lots of agro waste is ready to be used in a proper way. In our rural area 60% energy come from biomass specially for heating purpose. As population growth is rapid in Bangladesh the energy demand is increasing day by day. Most of the biomass available is used for cooking. The problem is the way they used, only 10-12% efficient. More than that in rainy season the situation becomes more severe. Pellet will be favorable in urban and city also, because pellet emits only a minimum smoke. Now many lucrative and energy efficient pellet stoves are available in market .more than that government already decided to stoop Natural gas supply to household, so biomass pellet must attain a good alternative for cooking.

Fig 3.10: Traditional Rural cooking stove

More than 5000 brick field is operating in Bangladesh along with hundreds illegal seasonal brick field. It is important to note that the major air pollutants are vehicles (55.8 per cent), followed by the brick manufacturing industry (28.8 per cent).

Fig 3.11: Damaging the environment by brick field with coal as fuel.

And the primary source of NOx (nitrogen oxides) pollutants are also vehicles (54.5 per cent) and the brick manufacturing industry (8.8 per cent). About 8,000 brick fields were set up in the country without any clear environmental guidelines, resulting in loss of fertility of farmlands. Also nearly 25 to 26 per cent of the country's wood is used for burning bricks every year, causing deforestation. The unauthorized brick fields in different parts of Bangladesh are using firewood for burning bricks. The coastal forests are bearing the brunt of it.

These forests are under threat of losing the environmental and ecological balance. Under the related laws, the owners of brick fields are to pay license fees, VAT and land development tax at the commercial rate, but the government is being deprived of such taxes due to the unauthorized manufacturing of bricks. The use of firewood in kilns of bricks fields is prohibited under the brick burning control ordinance of 1992. But many brickfield owners in Bangladesh are burning bricks with firewood. As a result, a large number of trees like Keora, Chaila, Sundari, Mehgini, Bain etc. are being felled indiscriminately in different districts. The dishonest brickfield owners collect the firewood from different forests with the help of their agents. It is observed that the task force concerned turns a blind eye to it while the administration frequently takes money from the unscrupulous brickfield owners. The Department of Environment has found that the four thousand brick kilns in the country burn nearly 20 lakh or 2.0 million tons of coal and another 2.0 million tons of wood every year [41].Biomass pellet will be an excellent fuel for brick field and add zero carbon to the environment. Biomass pellet can be used in industrial sector for heating purpose. Biomass boiler can be used instead of diesel boiler and can operate industry in an economic and sustainable way.

Fig 3.12: Boiler operating by biomass pellet.

Biomass pellet can be used for electricity generation by operating a steam turbine. Biomass pellet can be used with coal in a coal fired power plant without changing technology up to 25%. Bangladesh government’s energy road map to shifting from natural gas to coal based power plant and share up to 70% opens a good scope for biomass pellet business.

Fig 3.13: Drax was once Britain's biggest coal-fired power station. It now burns millions of tons of wood pellets each year, and is reputed to be the UK's biggest single contributor towards meeting stringent EU green energy targets [42].

Chapter 04

4. Technical analysis of biomass waste pellet production in Bangladesh

4.1 Available technology

A pellet machine operates by two distinctive ways. Impact pelleting and ring dye methods. In an impact pelleting machine no more than 5mm long biomass is impacted by a piston and forced to come out through a die. Then the pellet is cut with a cutter according to desire length.

On the other hand a required size biomass is conditioned before enter into a ring die machine. The raw materials are fed between ring die and roller. Roller pressure provides enough heat to bind the cellulose without binder. This later process is widely used through the world for large scale pellet manufacturing.

The same kind of technology is used for poultry feed manufacturing. This type of machineries is usually imported from China, Europe and Taiwan.

4.2 Availability of technical personnel

Same kind of machineries have been using in Bangladesh for last two decades. So a group of technical personnel are working there for long time. They can be deployed to operate the pellet mill. So availability of technical person is not a problem.

4.3 Manufacturing process and machineries

4.3.1 Wood Crusher

Fig 4.1: Wood Crusher

Wood crusher convert logs, branches, and wood chips into wood dust.

4.3.2 Pre-grinding and size reduction of raw materials

Raw material supplied as wood chips and crushed wood in sizes of approx. 100+ mm requires size reduction in a chipper and a hammer mill prior to the subsequent drying process. The Optimal hammer mill is intended for high capacity and optimum particle size distribution by means of an energy-efficient rotor design and replaceable wear liners in the grinding chamber.

4.3.3 Raw materials drying

Fig 4.2: Rotary drum dryer

Sawdust The drum drying system dries the raw material before the fine-grinding process. To ensure an evenly dried product, the raw material is conveyed pneumatically by a stream of hot gases and dried in a convective process until it reaches a residual moisture content of approx. 10%.

Drying can be done by solar dryer also in Bangladesh. Or both dryer can be used for more financial benefits risk free business. The solar drying is almost free and 10% raw materials used in Drum dryer.

Fig 4.3: Solar tunnel dryer

4.3.4 Fine grinding

It is recommended to grind raw materials in a hammer mill to achieve homogeneous pellets. The large surface and open fibers of ground products facilitate steam absorption in the cascade mixer. Steam and high temperature in the cascade mixer soften the lignin in the wood, after which pelleting can take place without the addition of binders. The Multi mill hammer mill operates with an airflow that optimizes the grinding process and carries the wood meal on to a cyclone or filter for separation.

4.3.5 Conditioning

For better pelleting and less corrosion of pellet mill a steam conditioning is necessary.

4.3.6 Pelleting

The pellet mill ensures high output and efficient control of the pellet quality. The pellet mill is dimensioned for large forces and provided with exchangeable wear parts. The efficient process control ensures high flexibility and optimum energy utilization. The energy consumed to operate the pellet mill and heat the steam corresponds to 2.5-3% of the wood energy content.

4.3.7 Cooling

A cooler is provided for wood pellets prior to packing and storage. The friction generated in the die during the pelleting process develops additional heat in the pellets, which has to be removed before sifting and storing the pellets. The pellets are cooled by air taken from the surrounding area, thus the pellet temperature will always be 5 to 10 °C above room temperature. The cooler retention time and the wood pellet diameter are decisive for dimensioning the cooler.

4.3.8 Final sifting

Finally, the pellets pass through a sifter for removal of crumbs and dust, which are re circulated to the process.

4.3.9 Packaging

Final product is then packed into a 25 kg or 50 kg package. For bulk materials pelletizer may use.

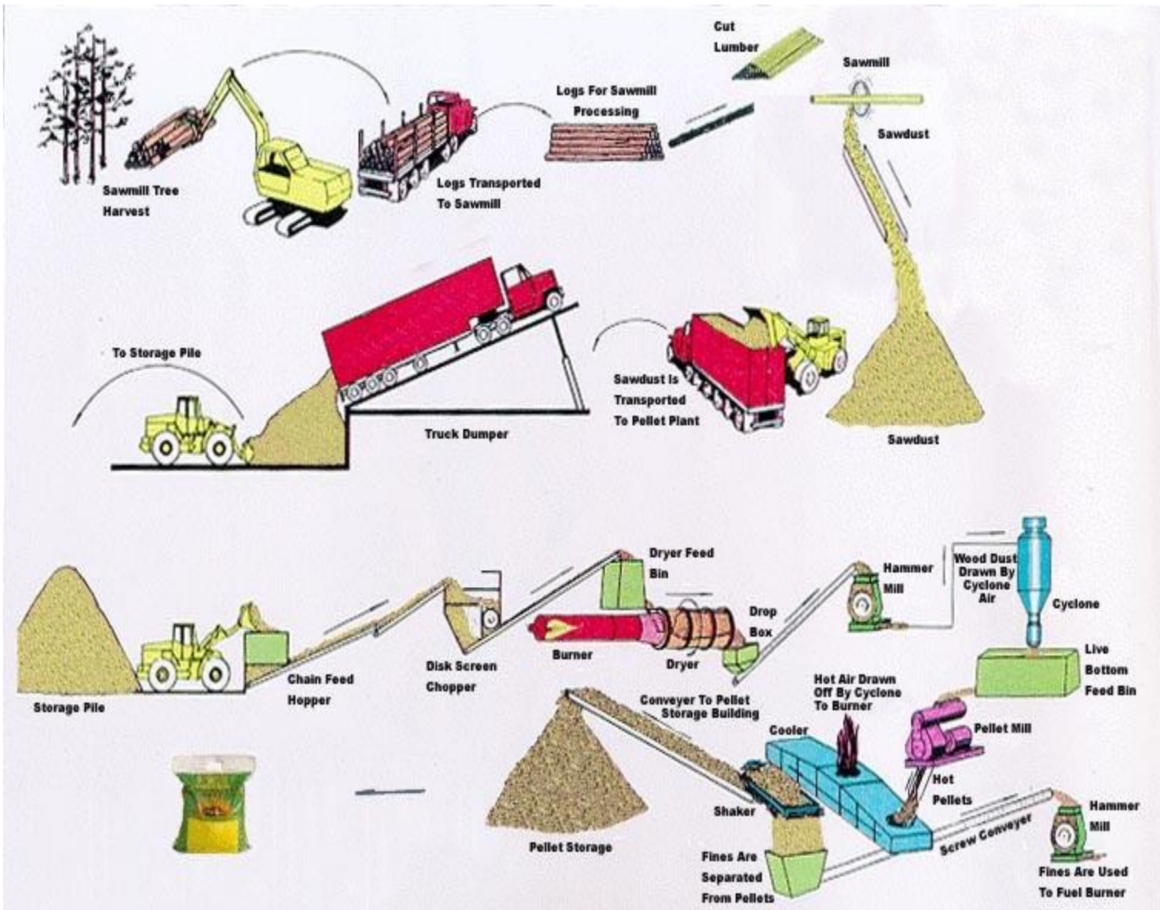

Fig 4.4: pellet manufacturing process

4.4 Process flow-chart

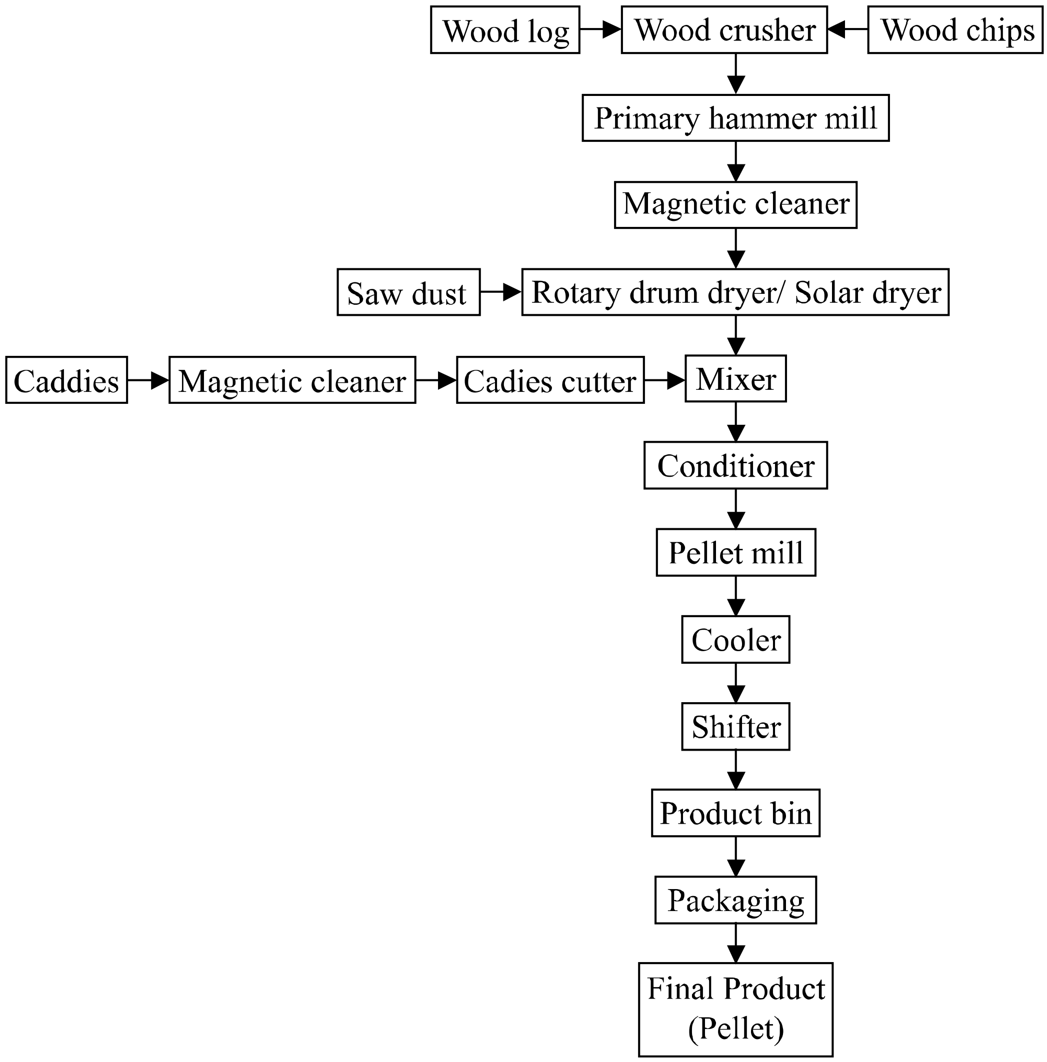

Fig 4.5: pellet manufacturing flow chart

Chapter 05

5. Economic analysis of biomass pellet manufacturing in Bangladesh

5.1 Financial analysis

5.1.1 Optimal Sizing of the Project

Given the current demand in the region, the expected growth in demand over the next 10 years, and the sensitivity of the regional saw and jute mill activities (availability of feed stock), the project should be modestly sized to manufacture about 12,000 tons per year of pellets. This is 75% of the nameplate capacity of the system evaluated. The facility is expected to operate at a rate of 3 tons per hour and produce up to 12,000 tons of pellets per year, operating two shifts per day, and 6 days per week.

This sizing will have a negligible impact on the regional wood basket and therefore will have an insignificant impact on regional wood pricing. The operation will have to source about 30,000 tons per year of sawdust and 15,000 tons of jute cadies. The total capital cost for the project is estimated to be BDT **193,337,552.00.** This includes all process equipment, buildings, engineering, construction, and working capital needs. Details of the estimate are show in Tables below. The project financing assumptions used in the analysis include: 60% debt + 40% equity, a loan term of 10 years, and a 15.5% interest rate.

Raw material Mix=80% Saw dust +20% Cadies

Estimated cost of raw materials

Saw dust final cost 5 BDT/kg (including transportation and moisture loss)

Cadies final cost 4.5 BDT/Kg (including transportation and moisture loss)

Pellet selling price 16 BDT/kg

5.1.2 Financial Estimation

Details of the analysis is attached to the appendix. Only gist is stated bellow:

Table 5.1: Total cost of project

Fixed cost	169,713,115.00
Working capital(1st year)	23,624,437.00
Cost of project	**193,337,552.00**

Table 5.2: Sales Estimation

Description	**Y-1**	**Y-2**	**Y-3**
Value of Quantity estimated to be sold in BDT	**196,650,000.00**	**274,200,000.00**	**410,025,000.00**

Table 5.3: Manufacturing Expenses

Item	**Y-1**	**Y-2**	**Y-3**
Total	**44,624,476.83**	**55,185,719.65**	**71,922,230.07**

Table 5.4: Distribution & Selling Expenses

Item	**Y-1**	**Y-2**	**Y-3**
Total	**24,697,000.00**	**29,203,600.00**	**51,137,700.00**

Table 5.5: Financial Expenses or Non-Operating Expenses

Item	**Y-1**	**Y-2**	**Y-3**
On fixed cost	14,503,109.04	13,392,607.53	12,137,740.83
On working Capital	2,315,194.83	3,549,175.18	5,699,399.14
Total	**16,818,303.87**	**16,941,782.71**	**17,837,139.97**

Table 5.6: Preliminary & Startup Expenses

item	**Amount in BDT**
Total	**5,211,690.00**

Table 5.7: Contingencies

Item	percentage	Amount in BDT
Total		5,911,325.00

Table 5.8: Imported & Local Machineries

Item	Cost in BDT
Total Imported machineries	51,800,000.00
Total Local machineries	45,500,000.00

Table 5.9: Break even analysis

Sales revenue in 1st year 196,650,000.00	
Total cost in 1st year	160535342.14
Particulars	**Cost in BDT**
Profit volume ratio	
Break-even point (unit)	6,843,885.60
Break-even point (sales)	104,027,061.08
Margin of safety	47%
Break even capacity(rated)	19%
Break even capacity(assumed)	25%

Table 5.10: Payback period & IRR

Amount to be paid back(Project cost)		169,713,115.00
Year	Cash Flow	Cumulative Cash flow
0	-169,713,115.00	- 169,713,115.00
1	24,621,293.09	- 145,091,821.91
2	40,768,377.65	-104,323,444.26
3	71,918,938.72	-32,404,505.54
4	68,424,060.55	36,019,555.01
5	68,286,664.12	104,306,219.12
6	66,335,733.93	170,641,953.06
7	64,084,969.18	234,726,922.24
8	61,626,691.64	296,353,613.88
9	70,485,417.25	366,839,031.13
10	79,996,578.51	446,835,609.63
Payback period		**3.450569852 Years**
IRR		29%

5.2 Economic analysis

Table 5.11: Economic Aspects

Employment Generation		**76Persons**
Cost per job		**1,824,872.20**
Contribution to GDP:		
A. Sales(1st year)		**196,650,000.00**
B. Inter Firm transaction:		
Raw materials	66,203,595.00	
Store & Spares	1,946,000.00	
Tax & insurance	848,565.58	
Repair & maintenance	973,000.00	
Utilities	23,342,960.00	
Telephone, Tlx & Postage	100,000.00	
Legal & Audit Exp.	50,000.00	
Printing & Stationary	80,000.00	
Transport ,conveyance & D/A	200,000.00	
Sales Commission	19,665,000.00	
Advertisement	4,000,000.00	
Miscellaneous Expenses	100,000.00	
Total		**117,509,120.58**
Total Contribution to GDP(A-B)		**79,140,879.43**

Selling price of pellet per tone 16000 BDT.

5.3 Discussion

We found that Bangladesh has lots of agro and industrial residues and waste to set up mid capacity (2-3 ton/Hr) pellet mill in various regions of the country. The most common raw materials are rice husk and saw dust. But considerable amount of saw dust only can be procured from Chittagong, Barisal and Dhaka. But in Dhaka saw dust has many alternative uses. We have to use wood crusher along with pellet mill because saw mill produces wood waste that is three times of saw dust. Only a crusher can handle wood cuttings and chips. In financial analysis we consider Barisal for the potential factory site. We collected raw materials and satisfactorily produced pellet. The calorific value of the pellet is 4235.4 kcal/kg with 0.95 densities. The payback period is 3.45 years and IRR is 29%. Both the result is very positive to start the business. The estimated GDP contribution will be BDT **79,140,879.43** and are quite satisfactory.

Chapter 06

6. Conclusion

Bangladesh is very much potential for pellet production. As an agricultural country we have the comparative advantages for biomass pellet production. But we can not achieve the European standards because out biomass content more ash. On other hand European pellet are manufactured from soft wood which content fewer minerals. Further study should be conduct focusing biomass pellet potentiality for electricity generation. We know already it's a common practice to use pellet for power generation in western country with coal. More ash content causes slogging and corrosion in the burner of boiler. Further chemical base study may open the true scenario. But out pellet is very much useful in cooking and brick making

6.1 Further research scope

Our energy policy's main phenomenon is to shift natural gas dependency to coal dependency as pellet can be used with coal up to 25% in a coal fired power plant without changing the system, the pellet production along with quality maintenance is very important. Research need to conduct on desired quality of pellet for power plant use. How to reduce ash content is the main target. As our pellet made from saw dust that comes out from hard wood our pellet contain more ash than European pellet. European pellet usually made from soft wood and content less minerals.

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Appendix – A

Fuel criteria test report of experimentally manufactured bio-mass waste pellet

Science for Life

INSTITUTE OF FUEL RESEARCH & DEVELOPMENT (IFRD)
Bangladesh Council of Scientific & Industrial Research (BCSIR)
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Ref. No. IFRD/Adhoc-215(part-1)/Ad-67/16 **Date: 06.10.2016**
Analytical Service Cell No. Fu-76, Date: 06.10.2016

Subject: Test report of supplied fuel pellet sample

The test result of fuel pellet sample supplied by Asad Dullah Al-Saiem, Exam. Roll: 528, Reg. No.: Ha-302, M.S in Renewable Technology Institute of Energy, University of Dhaka. Ref. No.: Nil of dated 06.10.2016 is as follows:

Test Result

Sl. No.	Name of the Test	Result
1.	Moisture Content ,% (w/w)	10.09
2.	Ash Content, % (w/w)	4.05
3.	Density, Tone/M^3	0.95
4.	Calorific Value, kcal/kg	4235.4

6.10.16
(Dr. Md. Abdur Rouf)
Analytical Service In-charge
IFRD, BCSIR
Dr. Mohammad Abdur Rouf
Principal Scientific Officer
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for. 06.10.16
Research Coordinator
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Badhan Saha
Scientific Officer
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6/10/16
(Mahfuza Khanam)
Director
IFRD, BCSIR
Mahfuza Khanam
Director
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Dhaka-1205

Asad Dullah Al-Saiem
Exam. Roll: 528,
Reg. No.: Ha-302
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Appendix – B

Financial Analysis

Fixed cost summary

Item	Specifications	Worth in BDT
Land& development	150 decimal	8,590,000.00
Building & Civil work		34,877,500.00
Imported machinery		51,800,000.00
Local machinery		45,500,000.00
Installation & local fabrication		9,280,000.00
Furniture and fixture		2,000,000.00
Duty, clearance and insurance		5,542,600.00
Preliminary and startup		5,211,690.00
Contingency		5,911,325.00
Internal Freight		1,000,000.00
Total		**169,713,115.00**

Land value to total project cost5.061482726%

Total cost of project

Fixed cost	169,713,115.00
Working capital(1st year)	23,624,437.00
Cost of project	**193,337,552.00**

Debt-Equity ratio on fixed cost

Item	Percentage	Amount in BDT
Bank loan	60%	101,827,869.00
Sponsor's Equity	40%	67,885,246.00
Total	**100%**	**169,713,115.00**

Working Capital Estimation

Item	Days	Y-1	Y-2	Y-3
Capacity utilization		**38%**	**50%**	**75%**
Raw materials	90	16,550,898.75	22,220,865.00	31,191,547.50
Store & spares	90	364,875.00	608,125.00	729,750.00
Receivable on sales (50%)	30	8,193,750.00	11,425,000.00	17,084,375.00
Diesel	90	517,500.00	201,250.00	258,750.00
Lubricant	90	125,000.00	200,000.00	300,000.00
Current assets		**25,752,023.75**	**34,655,240.00**	**49,564,422.50**
Less: Depreciation		13,441,951.25	13,441,951.25	13,441,951.25
Current asset after adjustment		12,310,072.50	21,213,288.75	36,122,471.25
Cash expenses	30	2,825,246.67	3,534,846.67	4,830,785.00
Stock in hand(FG)	15	8,550,000.00	11,550,000.00	17,325,000.00
Total:		**23,685,319.17**	**36,298,135.42**	**58,278,256.25**
Quantity of Margin		7,105,595.75	10,889,440.63	17,483,476.88
Working Capital Loan		**16,579,723.42**	**25,408,694.79**	**40,794,779.38**

Fund Allocation on Fixed cost

Item	Debt (%)	Equity (%)	Debt	Equity	Total
land &development		100%		8,590,000.00	8,590,000.00
Building & civil work	60%	40%	20,926,500.00	13,951,000.00	34,877,500.00
Imported machinery	93%	7%	48,174,000.00	3,626,000.00	51,800,000.00
local machinery	50%	50%	22,750,000.00	22,750,000.00	45,500,000.00
Contingency	100%		5,911,325.00		5,911,325.00
Furniture and fixture	50%	50%	1,000,000.00	1,000,000.00	2,000,000.00
Installation & local fabrication	33%	55%	3,066,044.00	6,213,956.00	9,280,000.00
Preliminary and start up		100%		5,211,690.00	5,211,690.00
Duty, clearance and insurance		100%		5,542,600.00	5,542,600.00
Internal Freight		100%		1,000,000.00	1,000,000.00
Total			**101,827,869.00**	**67,885,246.00**	**169,713,115.00**

Loan Utilization

Items	Debt Coverage	L/C	F/C	Total
Buildings & Civil Work	60%	20,926,500.00	-	20,926,500.00
Purchase of imported M/C	93%	-	48,174,000.00	48,174,000.00
Purchase of local M/C	50%	22,750,000.00	-	22,750,000.00
Contingency	100%	5,911,325.00	-	5,911,325.00
Furniture & Fixture	50%	1,000,000.00	-	1,000,000.00
Installation & fabrication	33%	3,066,044.00	-	3,066,044.00
Total		**53,653,869.00**	**48,174,000.00**	**101,827,869.00**

Earning forecasting

Description	**Y-1**	**Y-2**	**Y-3**
Capacity utilization	38%	50%	75%
Annual sales revenue	196,650,000.00	274,200,000.00	410,025,000.00
a.Net sales revenue	196,650,000.00	274,200,000.00	410,025,000.00
b.Cost of goods sold	**103,322,071.83**	**142,896,179.65**	**194,358,620.07**
c.Gross profit(a-b)	93,327,928.18	131,303,820.35	215,666,379.93
d.Admin & General Exp.	7,142,000.00	7,703,600.00	8,329,190.00
e.Distribution & Selling Exp.	24,697,000.00	29,203,600.00	51,137,700.00
f.Operating Profit(c-(d+e))	61,488,928.18	94,396,620.35	156,199,489.93
g.Financial Expenses	16,824,270.32	16,949,824.80	17,849,009.94
h.Net Profit(f-g)	44,664,657.86	77,446,795.55	138,350,479.98
i.Income Tax	16,749,246.70	29,042,548.33	51,881,429.99
Net profit after tax	**27,915,411.16**	**48,404,247.22**	**86,469,049.99**
Gross profit to sales	47%	48%	53%
Operating Profit to sales	31%	34%	38%
Net profit to sales after tax	14%	18%	21%

Sensitivity analysis of earning
5% increase in cost of production

Description	**Y-1**	**Y-2**	**Y-3**
Capacity utilization	38%	50%	75%
Annual sales revenue	196,650,000.00	274,200,000.00	410,025,000.00
a.Net sales revenue	196,650,000.00	274,200,000.00	410,025,000.00
b.Cost of goods sold	108,488,175.42	150,040,988.64	204,076,551.08
c.Gross profit(a-b)	88,161,824.58	124,159,011.36	205,948,448.92
d.Admin & General Exp.	7,142,000.00	7,703,600.00	8,329,190.00
e.Distribution & Selling Exp.	24,697,000.00	29,203,600.00	51,137,700.00
f.Operating Profit(c-(d+e))	56,322,824.58	87,251,811.36	146,481,558.92
g.Financial Expenses	16,824,270.32	16,949,824.80	17,849,009.94
h.Net Profit(f-g)	39,498,554.27	70,301,986.56	128,632,548.98
i. Income Tax	14,811,957.85	26,363,244.96	48,237,205.87
Net profit after tax	24,686,596.42	43,938,741.60	80,395,343.11
Gross profit to sales	45%	45%	50%
Operating Profit to sales	29%	32%	36%
Net profit to sales after tax	13%	16%	20%

5% decrease in sales price

Description	Y-1	Y-2	Y-3
Capacity utilization	38%	50%	75%
Annual sales revenue	186,817,500.00	260,490,000.00	389,523,750.00
a.Net sales revenue	186,817,500.00	260,490,000.00	389,523,750.00
b.Cost of goods sold	103,322,071.83	142,896,179.65	194,358,620.07
c.Gross profit(a-b)	83,495,428.18	117,593,820.35	195,165,129.93
d.Admin & General Exp	7,142,000.00	7,703,600.00	8,329,190.00
e.Distribution & Selling Exp	24,697,000.00	29,203,600.00	51,137,700.00
f.Operating Profit(c-(d+e))	51,656,428.18	80,686,620.35	135,698,239.93
g.Financial Expenses	16,824,270.32	16,949,824.80	17,849,009.94
h.Net Profit(f-g)	34,832,157.86	63,736,795.55	117,849,229.98
i. Income Tax	13,062,059.20	23,901,298.33	44,193,461.24
Net profit after tax	21,770,098.66	39,835,497.22	73,655,768.74
Gross profit to sales	45%	45%	50%
Operating Profit to sales	28%	31%	35%
Net profit to sales after tax	12%	15%	19%

Sales Estimation

Description	Y-1	Y-2	Y-3
Capacity Utilization rate	38%	50%	75%
Maximum production(75% of rated capacity)	415,800,000.00	415,800,000.00	415,800,000.00
Actual production	205,200,000.00	277,200,000.00	415,800,000.00
Add:Opening stock of WIP	0	0	0
Total Work in progress	205,200,000.00	277,200,000.00	415,800,000.00
Less:Closing WIP	0	0	0
Finished Goods	205,200,000.00	277,200,000.00	415,800,000.00
Add: Opening Stock of F/G	0	8,550,000.00	11,550,000.00
Value of quantity available for sell	205,200,000.00	285,750,000.00	427,350,000.00
Less:Closing Stock of F/G	8,550,000.00	11,550,000.00	17,325,000.00
Value of Quantity estimated to be sold	**196,650,000.00**	**274,200,000.00**	**410,025,000.00**

Cost of goods sold

Particulars	Y-1	Y-2	Y-3
Raw materials consumed	66,203,595.00	88,883,460.00	124,766,190.00
Factory wages/Direct wages	1,044,000.00	1,827,000.00	3,445,200.00
Prime cost	**67,247,595.00**	**90,710,460.00**	**128,211,390.00**
Manufacturing expenses	44,624,476.83	55,185,719.65	71,922,230.07
Factory cost	**111,872,071.83**	**145,896,179.65**	**200,133,620.07**
Opening stock of WIP	-	-	-
Work in progress	111,872,071.83	145,896,179.65	200,133,620.07
Less :Closing stock of WIP	-	-	-
Total cost of goods	111,872,071.83	145,896,179.65	200,133,620.07
Opening stock of finished goods	-	8,550,000.00	11,550,000.00
Goods available for sell	111,872,071.83	154,446,179.65	211,683,620.07
Less :closing stock of FG	8,550,000.00	11,550,000.00	17,325,000.00
Cost of Goods sold	**103,322,071.83**	**142,896,179.65**	**194,358,620.07**

Administrative Expenses

Item	Y-1	Y-2	Y-3
Administrative salary	5,532,000.00	5,628,600.00	5,729,190.00
Depreciation on Furniture	400,000.00	400,000.00	400,000.00
Stationary & Printing	80,000.00	90,000.00	100,000.00
Telephone, Fax & Postal	100,000.00	150,000.00	200,000.00
Conveyance, T/A and D/A	200,000.00	300,000.00	400,000.00
Legal & Audit Fees	50,000.00	55,000.00	60,000.00
Office Rent	480,000.00	480,000.00	540,000.00
Entertainment	200,000.00	400,000.00	600,000.00
Miscellaneous	100,000.00	200,000.00	300,000.00
Total	**7,142,000.00**	**7,703,600.00**	**8,329,190.00**

Manufacturing Expenses

Item	Y-1	Y-2	Y-3
Indirect wages	2,472,000.00	2,633,400.00	2,765,070.00
Repair & Maintenance	973,000.00	1,459,500.00	1,946,000.00
Tax & Insurances	848,565.58	852,808.40	895,448.82
Store & Spares	1,946,000.00	2,432,500.00	2,919,000.00
Raw materials carrying	2,000,000.00	4,000,000.00	6,000,000.00
Depreciation	13,041,951.25	13,041,951.25	13,041,951.25
Utility	23,342,960.00	30,765,560.00	44,354,760.00
Total	**44,624,476.83**	**55,185,719.65**	**71,922,230.07**

Distribution & Selling Expenses

Item	Y-1	Y-2	Y-3
Advertisement	4,000,000.00	700,000.00	9,000,000.00
Sales commission (10%)	19,665,000.00	27,420,000.00	41,002,500.00
Salary to sales Personnel	1,032,000.00	1,083,600.00	1,135,200.00
Total	**24,697,000.00**	**29,203,600.00**	**51,137,700.00**

Year wise Repayment

Item	Y-1	Y-2	Y-3	Y-4	Y-5
Interest	14,503,109.04	13,392,607.53	12,137,740.83	10,719,741.44	9,117,402.15
Principle	8,542,319.32	9,652,820.82	10,907,687.52	12,325,686.91	13,928,026.20
Total	**23,045,428.36**	**23,045,428.35**	**23,045,428.35**	**23,045,428.35**	**23,045,428.35**

Y-6	Y-7	Y-8	Y-9	Y-10
7,306,758.74	5,260,731.69	2,948,721.13	514,900.97	0
15,738,669.61	17,784,696.67	20,096,707.23	11,007,813.21	0
23,045,428.35	**23,045,428.36**	**23,045,428.36**	**11,522,714.18**	**-**

Financial Expenses or Non-Operating Expenses

Item	Y-1	Y-2	Y-3
On fixed cost	14,503,109.04	13,392,607.53	12,137,740.83
On working Capital	2,315,194.83	3,549,175.18	5,699,399.14
Total	**16,818,303.87**	**16,941,782.71**	**17,837,139.97**

Utility

Item	Rate	Y-1		Y-2		Y-3	
		Quantity	Worth, BDT	Quantity	Worth, BDT	Quantity	Worth, BDT
Electricity	8 BDT/KWh	2596620KWh	20,772,960	3443820KWh	27,550,560	5006220KWh	40,049,760
Diesel	69BDT/LTR	30000LTR	2,070,000	35000LTR	2,415,000	45000LTR	3,105,000
lubricant			500,000		800,000		1,200,000
Total			**23,342,960**		**30,765,560**		**44,354,760**

Preliminary & Startup Expenses

Item	Amount in BDT
Security for electrical connection and others	3,500,000.00
Legal charge & Feasibility Study	1,211,690.00
Trial Production loss	500,000.00
Total	**5,211,690.00**

Contingencies

Item	Percentage	Amount in BDT
On machinery	5%	4,865,000.00
On Building & Civil work	3%	1,046,325.00
Total		**5,911,325.00**

Break even analysis

Sales revenue in 1st year196,650,000.00				
Total cost in 1st year				160535342.14
Particulars	**Fixed cost**	**Variable cost**	**Sub Total**	**Cost in BDT**
Raw materials		66,203,595.00		**66,203,595.00**
Direct labor		1,044,000.00		**1,044,000.00**
Administrative salary	5,532,000.00		5,532,000.00	
Depreciation on Furniture	400,000.00		400,000.00	
Stationary & Printing	80,000.00		80,000.00	
Telephone, Fax & Postal	100,000.00		100,000.00	
Conveyance, T/A and D/A	100,000.00	100,000.00	200,000.00	
Legal & Audit Fees	50,000.00		50,000.00	
Office Rent	480,000.00		480,000.00	
Entertainment	200,000.00		200,000.00	
Miscellaneous	50,000.00	50,000.00	100,000.00	
Administrative expenses				**7,142,000.00**
Indirect Wages	2,472,000.00		2,472,000.00	
Utilities	1,867,436.80	21,475,523.20	23,342,960.00	
Repair &Maintenance	973,000.00		973,000.00	
Taxes and Insurances	848,565.58		848,565.58	
Stores & Spares	194,600.00	1,751,400.00	1,946,000.00	
Raw materials carrying		2,000,000.00	2,000,000.00	
Depreciation on machinery& Building	13,041,951.25		13,041,951.25	
Manufacturing expenses				**44,624,476.83**
Advertisement	4,000,000.00		4,000,000.00	
Sales commission		19,665,000.00	19,665,000.00	
Salary to sales person	1,032,000.00		1,032,000.00	
Sales Expenses				**24,697,000.00**
Financial Expenses	14,503,109.04	2,321,161.28		**16,824,270.32**
Total	**45,924,662.67**	**114,610,679.48**		**160,535,342.14**
Profit volume ratio				
Break-even point (unit)				6,843,885.60
Break-even point (sales)				104,027,061.08
Margin of safety				47%
Break even capacity(rated)				19%
Break even capacity(assumed)				25%

Cash flow Statement

Item	Y-1	Y-2	Y-3	Y-4	Y-5	Y-6	Y-7	Y-8	Y-9	Y-10
Net profit after tax	27,915,411.16	48,404,247.22	86,469,049.99	84,392,171.21	85,857,114.07	85,716,827.29	85,512,089.60	85,365,822.62	85,135,654.21	83,639,002.26
Non cash adjustment										
Add: Depreciation	13,441,951.25	13441951.25	13441951.25	13441951.25	13441951.25	13441951.25	13441951.25	13441951.25	13441951.25	13441951.25
Deduct: Receivable on sales	8,193,750.00	11,425,000.00	17084375	17084375	17084375	17084375	17084375	17084375	17084375	17084375
A/C Payable	0	0	0	0	0	0	0	0	0	0
Cash Flows from operating activities:	**33,163,612.41**	**50,421,198.47**	**82,826,626.24**	**80,749,747.46**	**82,214,690.32**	**82,074,403.54**	**81,869,665.85**	**81,723,398.87**	**81,493,230.46**	**79,996,578.51**
Cash flow from investment	0	0	0	0	0	0	0	0	0	0
Cash flow from financial activity										
Principal repayment	8,542,319.32	9,652,820.82	10,907,687.52	12,325,686.91	13,928,026.20	15,738,669.61	17,784,696.67	20,096,707.23	11,007,813.21	-
Net cash flow	**24,621,293.09**	**40,768,377.65**	**71,918,938.72**	**68,424,060.55**	**68,286,664.12**	**66,335,733.93**	**64,084,969.18**	**61,626,691.64**	**70,485,417.25**	**79,996,578.51**
Supplemental information										
Cash paid for Interest amount	16,824,270.32	16949824.8	17849009.94	16431010.55	14828671.26	13018027.85	10972000.8	8659990.243	6226170.083	0
Cash paid for Income tax	16,749,246.70	29042548.33	51881429.99	50635302.72	51514268.44	51430096.38	51307253.76	51219493.57	51081392.53	50183401.35

Fund Flow Statement

Sources of Fund	Y-0	Y-1	Y-2	Y-3
Equity-Fixed capital	67,885,246.00			
Equity-Working Capital		7,105,595.75	3,783,844.88	6,594,036.25
Net Profit Before Tax & int.		61,488,928.18	94,396,620.35	156,199,489.93
Long term loan	120,119,427.51			
Increase in bank Borrowing		16,579,723.42	8,828,971.38	15,386,084.58
Depreciation		13,441,951.25	13,441,951.25	13,441,951.25
increase in other C. liabilities				
Decrease in current asset				
Total fund	**188,004,673.51**	**98,616,198.59**	**120,451,387.85**	**191,621,562.01**
Application of fund				
Capital expenditure	169,713,115.00			
increase in current asset		33,659,523.75	12,144,466.25	20,526,682.50
Repayment of term loan		8,542,319.32	9,652,820.82	10,907,687.52
Decrease in bank borrowing				
Decrease in other C. liabilities				
Interest	18,291,558.51	16,824,270.32	16,949,824.80	17,849,009.94
Investment in Bond				
Income Tax		16,749,246.70	29,042,548.33	51,881,429.99
Total fund utilization	**188,004,673.51**	**75,775,360.08**	**67,789,660.20**	**101,164,809.96**
Fund Surplus/Deficit	-	22,840,838.51	52,661,727.65	90,456,752.05
Opening balance	0	0	22,840,838.51	75502566.15
Total Fund flow	**0**	**22,840,838.51**	**75,502,566.15**	**165,959,318.21**

Projected balance sheet

Asset:	Y-0	Y-1	Y-2	Y-3
Land	8,590,000.00	8,590,000.00	8,590,000.00	8,590,000.00
Building & Civil Work	35,923,825.00	34,127,633.75	32,331,442.50	30,535,251.25
Machinery	98,207,600.00	88,386,840.00	78,566,080.00	68,745,320.00
Transport vehicles	9,500,000.00	7,600,000.00	5,700,000.00	3,800,000.00
Furniture & Fixture	2,000,000.00	1,600,000.00	1,200,000.00	800,000.00
Total Fixed asset	**154,221,425.00**	**140,304,473.75**	**126,387,522.50**	**112,470,571.25**
Intangible Asset	33,783,248.51	27,026,598.81	20,269,949.11	13,513,299.40
Cash Balance	0	22,840,838.51	75,502,566.15	165,959,318.21
Receivable	0	8,193,750.00	11,425,000.00	17,084,375.00
Inventory	0	26,108,273.75	34,780,240.00	49,805,047.50
Others current asset	0	14,996,469.01	23,579,870.22	31,908,886.63
Total current Asset	33,783,248.51	99,165,930.08	165,557,625.48	278,270,926.74
Total asset	**188,004,673.51**	**239,470,403.83**	**291,945,147.98**	**390,741,497.99**
Capital & liabilities	67,885,246.00	74,990,841.75	78,774,686.63	85,368,722.88
Retained Earning	0	27,915,411.16	76,319,658.38	162,788,708.37
Worth	**67,885,246.00**	**102,906,252.91**	**155,094,345.00**	**248,157,431.24**
WPF				
Income tax reserve				
Long term loan	120,119,427.51	119,984,427.50	111,442,108.19	101,789,287.37
Commercial bank borrowing		16,579,723.42	25,408,694.79	40,794,779.38
Total current liabilities	**120,119,427.51**	**136,564,150.92**	**136,850,802.98**	**142,584,066.75**
Total Liabilities	**188,004,673.51**	**239,470,403.83**	**291,945,147.98**	**390,741,497.99**

Amortization schedule

Rate of interest					13%
Construction period					1 year
Grace period (including construction period)					1.5 years
Amount of loan					101,827,869.00
Capitalized principle					120,119,427.51
Repayment period					10 years
Capital recovery factor					
Payment Every Quarter					5,761,357.09
Total Interest					75,901,713.52
	Due month	Beginning Balance	Interest	Principal	Ending Balance
1.00	21	119,984,427.50	3,722,635.02	2,038,722.07	117,945,705.43
2.00	24	117,945,705.43	3,659,381.66	2,101,975.43	115,843,730.00
3.00	27	115,843,730.00	3,594,165.80	2,167,191.29	113,676,538.72
4.00	30	113,676,538.72	3,526,926.56	2,234,430.53	111,442,108.19
5.00	33	111,442,108.19	3,457,601.15	2,303,755.94	109,138,352.25
6.00	36	109,138,352.25	3,386,124.85	2,375,232.23	106,763,120.02
7.00	39	106,763,120.02	3,312,430.94	2,448,926.15	104,314,193.86
8.00	42	104,314,193.86	3,236,450.59	2,524,906.50	101,789,287.37
9.00	45	101,789,287.37	3,158,112.88	2,603,244.21	99,186,043.16
10.00	48	99,186,043.16	3,077,344.66	2,684,012.42	96,502,030.73
11.00	51	96,502,030.73	2,994,070.54	2,767,286.55	93,734,744.18
12.00	54	93,734,744.18	2,908,212.75	2,853,144.34	90,881,599.84
13.00	57	90,881,599.84	2,819,691.13	2,941,665.96	87,939,933.88
14.00	60	87,939,933.88	2,728,423.05	3,032,934.04	84,906,999.84
15.00	63	84,906,999.84	2,634,323.28	3,127,033.80	81,779,966.04
16.00	66	81,779,966.04	2,537,303.98	3,224,053.11	78,555,912.93
17.00	69	78,555,912.93	2,437,274.56	3,324,082.53	75,231,830.40
18.00	72	75,231,830.40	2,334,141.62	3,427,215.46	71,804,614.93
19.00	75	71,804,614.93	2,227,808.89	3,533,548.20	68,271,066.73
20.00	78	68,271,066.73	2,118,177.08	3,643,180.01	64,627,886.72
21.00	81	64,627,886.72	2,005,143.83	3,756,213.26	60,871,673.46
22.00	84	60,871,673.46	1,888,603.61	3,872,753.47	56,998,919.99
23.00	87	56,998,919.99	1,768,447.62	3,992,909.47	53,006,010.52
24.00	90	53,006,010.52	1,644,563.68	4,116,793.41	48,889,217.11
25.00	93	48,889,217.11	1,516,836.11	4,244,520.98	44,644,696.12
26.00	96	44,644,696.12	1,385,145.66	4,376,211.43	40,268,484.70
27.00	99	40,268,484.70	1,249,369.39	4,511,987.70	35,756,497.00
28.00	102	35,756,497.00	1,109,380.53	4,651,976.56	31,104,520.44
29.00	105	31,104,520.44	965,048.38	4,796,308.71	26,308,211.73
30.00	108	26,308,211.73	816,238.18	4,945,118.91	21,363,092.82
31.00	111	21,363,092.82	662,810.99	5,098,546.10	16,264,546.72
32.00	114	16,264,546.72	504,623.58	5,256,733.51	11,007,813.21
33.00	117	11,007,813.21	341,528.25	5,419,828.84	5,587,984.37
34.00	120	5,587,984.37	173,372.72	5,587,984.37	-

Production forecasting

	Y-1		Y-2		Y-3	
Items	**Quantity**	**Worth, BDT**	**Quantity**	**Worth, BDT**	**Quantity**	**Worth, BDT**
Capacity utilization	37.5%of rated capacity		50% of Rated capacity		75% of Rated capacity	
Saw Dust	4900.5MT	19,602,000.00	6534MT	26,136,000.00	9801MT	39,204,000.00
Wood Chips	6534MT	19,602,000.00	8712MT	26,136,000.00	10368MT	31,104,000.00
Caddice	4050MT	16,200,000.00	5400MT	21,600,000.00	8100MT	32,400,000.00
Bark/Chips(fuel for dryer)	1332MT	3,995,595.00	1980MT	5,939,460.00	2817MT	8,450,190.00
Bag	567000	6,804,000.00	756000	9,072,000.00	1134000	13,608,000.00
Total Raw materials		**66,203,595.00**		**88,883,460.00**		**124,766,190.00**
Pellet	8100MT	129,600,000.00	10800MT	172,800,000.00	16200MT	259,200,000.00
Briquette	5400MT	75,600,000.00	7200MT	104,400,000.00	10800MT	156,600,000.00
Total Finished goods	**13500MT**	**205,200,000.00**	**18000MT**	**277,200,000.00**	**27000MT**	**415,800,000.00**
Max. Attainable capacity = 75% of rated capacity						

Land & Land Development

Particulars	**Area**	**Rate**	**Cost in BDT**
Land	150 Decimal	40000BDT/Decimal	6,000,000.00
Sand Filling	261600 Cubic Foot	8BDT/Cubic Foot	2,090,000.00
Canal side protection		LS	500,000.00
Total			**8,590,000.00**

Building & civil work

Description	**Area(Square foot)**	**Length (Feet)**	**Rate BDT/Unit**	**Cost in BDT**
Factory shade	7000		1080	7,560,000.00
F. Goods warehouse	3500		900	3,150,000.00
R.Material Ware house	7000		900	6,300,000.00
Office Building	1500		1600	2,400,000.00
Store & Lab	1000		1600	1,600,000.00
Security Dorm & Club	1000		800	800,000.00
Substation and Boiler room	600		1600	960,000.00
Loading Unloading Shade	5000		500	2,500,000.00
Machine Pit	1200		1200	1,440,000.00
Road & Pavement	5000		800	4,000,000.00
Boundary Wall		1000	2200	2,007,500.00
Drainage		800	1200	960,000.00
Tube well & Pump	L/S			200,000.00
Water S & D. System	L/S			400,000.00
Main Gate	L/S			350,000.00
Rain Water disposal	L/S			250,000.00
Total				**34,877,500.00**

Imported Machineries

Item	Specification	Cost in BDT
A.Complete Pellet mill.	3M/HR	35,000,000.00
B. Wood crusher with hammer	4MT/HR	5,000,000.00
Truck scale(60MT)	60MT	1,600,000.00
D. Baling machine	4MT/HR	3,000,000.00
E. Boiler	300KG	1,200,000.00
F. Impact briquette machine	2MT	5,000,000.00
G. Lab Equipment's	LS	1,000,000.00
Total Imported machineries		**51,800,000.00**

Taxes & others Charges on imported machineries

Particulars	Rate (%)	Cost in BDT
Pre Shipment inspection	0.5	259,000.000
Marine Insurance	0.7	362,600.000
Import duty,Surcharge & Others	8	4,144,000.00
L/C Charge	0.75	388,500.0000
Clearing & Forwarding	0.75	388,500.0000
Total	**10.7**	**5,542,600.000**

Local Machineries

Item	Specification	Cost in BDT
Structure, support & Storage bins		6,500,000.00
Rotary Dryer system	3MT/HR	7,000,000.00
Solar tunnel Dryer	15MT/Day	4,500,000.00
Saw mill		1,500,000.00
Central control panel(PLC)		7,000,000.00
Power sub-station	1000KW	5,000,000.00
Cables & Wiring		4,500,000.00
Tractor		1,500,000.00
Pickup(Double cabin)		4,500,000.00
Bulk head(open type)	4000 cubic F	3,500,000.00
Total local Machineries		**45,500,000.00**

Wages & Salaries

Items				Y-1		Y-2		Y-3
	Number	Salaries	Benefits	Annual	Number	Annual	Number	Annual
Administrative salaries								
Directors' Remuneration				3,600,000		3,600,000		3,600,000
General manager	1	30,000	15,000	540,000	1	567,000	1	595,350
Chief accountant	1	20,000	10,000	360,000	1	378,000	1	396,900
Asst. accountant	1	9,000	4,000	156,000	1	163,800	1	171,990
Driver	2	10,000	5,000	360,000	2	378,000	2	396,900
Orderly	2	5,000	2,500	180,000	2	189,000	2	198,450
Master	1	10,000	4,000	168,000	1	176,400	1	184,800
Deck helper	2	5,000	2,000	168,000	2	176,400	2	184,800
Total	**10**			**5,532,000**	**10**	**5,628,600**	**10**	**5,729,190**
Indirect salaries								
plant manager	1	20,000	10,000	360,000	1	378,000	1	396,900
shift in charge	2	12,000	5,000	408,000	2	428,400	2	449,820
operator	4	8,000.00	3,000	528,000	4	554,400	4	582,120
Foreman	1	10,000	5,000	180,000	1	189,000	1	198,450
Technician(Elec)	1	8,000.00	4,000	144,000	1	151,200	1	158,760
Technician(Mech	1	8,000.00	3,000	132,000	1	138,600	1	145,530
Guard	6	6,000.00	4,000	720,000	6	756,000	6	793,800
Total	**16**			**2,472,000**	**16**	**2,633,400**	**16**	**2,765,070**
Direct Salaries								
Skilled labor	3	5,000.00	3,000	288,000.00	5	504,000	9	950,400
Semiskilled labor	6	4,000.00	2,000	432,000.00	10	756,000	18	1,425,600
Unskilled labor	6	3,000.00	1,500	324,000.00	10	567,00	18	1,069,200
Total	**15**			**1,044,000**	**25**	**1,827,000**	**45**	3,445,200
Sales Wages								
Sales Manager	1	20,000	10,000	360,000	1	378,000	1	396,000
Sales executive	4	10,000	4,000	672,000	4	705,600	4	739,200
Total	**5**			**1,032,000**	**5**	**1,083,600**	**5**	**1,135,200**
Total manpower generation is 76 persons.								
Wages & salaries are assumed to be increased 5% per year.								

Payback period & IRR

Amount to be paid back(Project cost)		169,713,115.00
Year	Cash Flow	Cumulative Cash flow
0	-169,713,115.00	- 169,713,115.00
1	24,621,293.09	- 145,091,821.91
2	40,768,377.65	-104,323,444.26
3	71,918,938.72	-32,404,505.54
4	68,424,060.55	36,019,555.01
5	68,286,664.12	104,306,219.12
6	66,335,733.93	170,641,953.06
7	64,084,969.18	234,726,922.24
8	61,626,691.64	296,353,613.88
9	70,485,417.25	366,839,031.13
10	79,996,578.51	446,835,609.63
Payback period		**3.450569852 Years**
IRR		29%

Appendix – C

Section-IV

Economic Aspect

Employment Generation		**76 Persons**
Cost per job		**1,824,872.20**
Contribution to GDP:		
A. Sales(1st year)		**196,650,000.00**
B.Inter Firm transaction:		
Raw materials	66,203,595.00	
Store & Spares	1,946,000.00	
Tax & insurance	848,565.58	
Repair & maintenance	973,000.00	
Utilities	23,342,960.00	
Telephone,Tlx& Postage	100,000.00	
Legal & Audit Exp.	50,000.00	
Printing & Stationary	80,000.00	
Transport ,conveyance & D/A	200,000.00	
Sales Commission	19,665,000.00	
Advertisement	4,000,000.00	
Miscellaneous Expenses	100,000.00	
Total		**117,509,120.58**
Total Contribution to GDP(A-B)		**79,140,879.43**