



A RESEARCH REPORT

**THE ECONOMIC SIGNIFICANCE OF USING BAGASSE AS A SOURCE OF RAW MATERIAL
FOR PULP MANUFACTURING: A CASE OF ETHIOPIA.**

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EXECUTIVE SUMMARY

Bagasse which is the fibrous residue that remains after sugar is extracted from sugar cane is used as an alternative source of raw material for pulp and paper manufacturing across many parts of the world. But here in Ethiopia, the ever growing demand of paper and paper products seems to be in quite contrast to the presence of no one pulp mill in the country. It is believed that the scarce availability of pulp raw materials and the requirement of huge capital for investment are the two main reasons why there is no one pulp mill in the country.

On the other hand, the massive new capital investment for new sugar factories and the vigorous expansion of the existing once seems to have a promising and potential source of pulp raw material as this leaves quite huge amount of bagasse that can be used for pulp and paper manufacturing.

In countries like Ethiopia where alternative energy sources such as the hydro- electric power (HEP), wind, and geothermal are relatively cheaper, using bagasse for electric generation is considered low value use for a higher value resource and this was the most important issue that this particular study has tried to address.

This study investigated the economic significance of using bagasse as a source of raw material for pulp and paper manufacturing. The study also compared this issue with the currently undergoing practices of cogeneration, where bagasse is burnt in the sugar mill boilers to produce steam and generate electricity. Operating mills and sugar mill projects that are expected to be realized in the near future were analysed to determine the bagasse pulping potential of the country. Stakeholders and company executives were interviewed to complement the result obtained from mills' operation performances.

The result revealed that using bagasse for pulp and paper manufacturing is economically feasible and more significant than using it for cogeneration. And also, the stakeholders' and executives' opinion survey suggested that using bagasse for pulp and paper manufacturing is economically advantageous and strategic issue for the overall economic growth of the country. This is because bagasse pulping enhances the economic utilization of available resources, and enables the local

production of pulp and paper which further facilitates the development of other strategic sectors such as the education, agriculture and chemical.

As part of its investigation, this study not only investigated the economic significance of producing pulp and paper from the substance bagasse, and that the printing and packaging industry be enhanced and developed to the desired level, but also it promoted the sugar mills so that they can save and sale their bagasse with a price that is better than the price for the equivalent electrical energy which ultimately helps them to remain competitive in the prevailing international sugar market.

Therefore, as the per capita consumption of paper and paper products specifically and the chemical sector development in general directly measures the economic development of a given country, government should promote the sector and show its strategic commitment in creating a conducive working environment for both local and foreign private investors. This in turn helps local and foreign private investors to inject capital investment and transfer technology and management knowhow to the country.

Finally, an integrated effort among all the stakeholders including the government, company executives, the owners of capital, and the community in general is required in order for the country to achieve its Millennium Development Goals where the vision is to build poverty free and medium income earning Ethiopia.

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Finally, I would like to express my deepest appreciation and respect to those closest to me my wife, Hanna and our kid Elbethel, for their support and inspiration during my work to complete this study.

I also thank the countless others that contributed to this thesis.

DEDICATION

This thesis is dedicated to my Dad, I thank him for enriching my life, and to my daughter Bethi, welcome to this world.

“Even though I walk through the valley of the shadow of death, I will fear no evil, for you are with me; your rod and your staff, they comfort me” - Ps 23:4

DECLARATION

The writer of this manuscript, Demelash Tebik Fenta, with student number 71767169, will declare that the work contained in this thesis has not been previously submitted to meet requirement for an award at this or other higher education institution. To the best of my knowledge and belief, the thesis contains no materials previously published or written by another person except where due reference is made.

Signature _____

Date _____

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CHAPTER ONE

INTRODUCTION

1.1 Background Information.

Ethiopia as a developing country has significantly very low paper and paper board consumption per capita of 0.43 kilogram/person/year when compared with the world average of 54.48 kilogram/person/year in 2005 (WRI, 2005). As Ethiopian economy is currently growing consistently with significant amount (11.5% to the average) for the last five years, the per capita consumption of paper (currently 1kg/person/year) is expected to be changed significantly. Besides Ethiopia is targeting to reach to the level of economy of those middle income countries in the coming 20 years there by increasing the per capita consumption of paper to about 83.13kg/person/year (the current annual growth rate of per capita consumption is expected to be changed from 14.36% to 24.47% in order to reach the per capita consumption of paper for middle income countries that is 83.13%).

Further more, the ever increase in price of raw material (pulp) for paper manufacturing and the presence of no one single pulp mill in the country seems to blur the vision to come to the level of the per capita consumption of the middle income countries and there by hinders its economy to grow to the desired level after 10 years. Therefore, in order for the vision to come to reality the industry needs not only to fill the gap between demand and supply of paper and paper products for local consumption but also needs to play a significant role in the export sector and generates foreign currency and keeps the trade balance healthy. In order to do this, Ethiopia, as a strategy towards its vision needs to secure the raw material for paper and paper products manufacturing.

According to the Privatization and Public Enterprises Supervising Agency /PPESA/, with the development of market economy, from 1993 to 2008, the amount of paper and paper board consumption in Ethiopia increased from nearly 28,000 to 90,212 tons to an average annual growth rate of 14.36 percent.

In 2009, paper and paper board consumption in Ethiopia reached 125,742 tones from which the portion that is produced locally is only 11,103 tones or 8.9 percent. The remaining balance is expected to have been imported from Europe or USA.

By 2020 Ethiopia is expected to be categorized under middle income countries where total paper and paper board consumption at that time is expected to reach 1,842,944 tones. From this total amount local production of paper is assumed to cover only 0.81 percent of the consumption if this trend is not changed. The balance is expected to be covered by importation. During that time, with the development of the national economy, the requirement for paper and paper board will increase and per capita consumption of paper is expected to reach 15kg per head in the country, which is considered to be very low when compared to the per capita consumption of middle income countries which at that same time is expected to reach 80.17 kg per head per year (PPESA, 2010).

On the other hand the amount of consumption surpasses that of production in paper and paper board. From 2005 to 2009 for instance, the average annual production of paper and paper board was 11,175 tons per year and the average annual consumption was 106,143 tons so that the deficit was 94,968 tons (some 89.5 percent of consumption). This low local productivity of the sector is mainly due to the following reasons:

- Wearing and tearing of paper manufacturing machines;
- Working capital constraints;
- Shortage in skilled labor power;
- Being inefficient and less competitive with respect to price and quality of paper when compared with the imported ones; and
- Inadequate supply of raw material locally and the requirement of huge amount of foreign currency to purchase from abroad (PPESA, 2010).

Despite the above mentioned limitations paper consumption seems to grow in line with the growth in the economy of the country. Ethiopia is currently growing at an annual average rate of 11.5% and if it continues with this trend, by the year 2020, where Ethiopia is expected to come to the level of the economy of middle income countries, the overall economic growth of the country is expected to show a significant increment. As most paper is used to facilitate some economic activity, having a larger economy, all else being equal, demands a higher level of paper use.

According to the process and rate of paper industry development since the reform and the development of national economy, it is estimated that the demand of paper and paper board will be

predicted to be 188,300 thousand tones in 2010 and will reach 322,069 thousand tons by 2015 (PPESA,2010).

This growth in consumption is attributed to the prospective economic growth of the country which further is facilitated by:

- Establishment of democratic state in the country;
- Favorable investment conditions;
- Development of the education sector, and
- The development of the free press (PPESA, 2010).

Due to such a conducive environment for the expansion of the sector, paper demand seems to grow constantly while the local supply is constrained by so many internal and external factors. Therefore, in order to balance the local supply and demand extra effort must be made so that local production of paper and paper board is enhanced. According to PPESA (2010), this can be done through:

- Motivating economically local manufacturers and improving import substitutions;
- Give protections to the local market and enhancing competitions among them until demand balances supply;
- Producing major input chemicals including pulp locally, and
- Create market opportunity for their products.

Doing this not only increases the local production of paper and paper board but also creates a conducive environment for foreign direct investment where foreign investors can invest in Ethiopia which is considered to be quite vital in the transfer of technology, management know how and efficient marketing activities and strategies.

In contrast to the highly growing demand of paper and paper products, paper production in Ethiopia is at its infant stage where there are only three paper mills producing an annual out put of 15 - 25 thousand tones in aggregate.

The major reason why there are no additional paper mills with better capacity in the country is estimated to be the huge capital investment that paper mills normally require and the significantly high cost of raw material that is imported from different countries of the world (PPESA, 2010).

These makes the local production of paper inefficient and less competitive when compared to other sectors in the industry, which significantly affects the overall economic growth of the country, keeping the per capita consumption of paper for the country well below 1 kg per head per year.

On the other hand the intensive expansion and new green field investments in the sugar industry in the country, now a- days, seems to provide a potential raw material for pulp and paper manufacturing. Bagasse, which is the waste material left after sugar cane is crushed and squeezed in the sugar mills to extract the juice is used as a source of raw material for pulp manufacturing in many countries of the world.

Even though producing bagasse pulp which is a raw material for pulp and paper manufacturing is new experience in Ethiopia, it is a common and feasible practice in the countries such as Brazil, India, China, USA, Thailand, Australia and South Africa. Studies showed that using bagasse for pulp production is not only economically viable but also it is a sustainable alternative to forest products where old growth forests had been cut down for pulp production traditionally (Rainey, 2009).

Further more, the technical-economic relationships which have led to the predominance of wood fibers in many countries do not apply every where. Non wood materials are used in many parts of the world where pulping technology is less advanced, operations are relatively small scale, the discharge of effluents is tolerated (even though of high environmental impact), and where wood is relatively scarce (Rainey & Clark, 2004). According to these authors, non wood fibers are the dominant feedstock in China and India, and world wide, about 10% of paper production is made from bagasse, wheat straw, cotton, hemp, flax, and other materials. Indeed non wood pulping capacity may be increasing further than wood pulping capacity, Rainey and Clark (2004), concluded.

Therefore, thinking about using bagasse as alternative source of raw material for pulp manufacturing in Ethiopia is not something that can not be feasible and achievable from the researcher's point of view, but rather, even if it requires time and extra effort from the stake holders it could be practical and has to be exercised in the country and is the study topic of this research work.

1.2. Overview of Ethiopia's Paper Industry

The Ethiopian paper and packing industry which is mainly comprised of printing, paper converting, paper production and packaging is one of the sectors whose growth is at a fairly early stage and expected to have good future prospects of development. However, the presence of some internal and external constraints will be expected to challenge and hinder its development from the fast growth need of the country.

According to the information obtained from Ethiopian Investment Agency, the total numbers of investors that have received their investment license to invest in the sector for the last 17 years are 534 with total capital of Eth. Birr 2,911,755, 000.00. Among these investors, those who are on operation are 137 and those who are under construction are 59 and the rest 338 (63%) are not yet ready to invest in the sector. With increasing imports to meet the ever growing demand of paper and paper products, the domestic production remains nearly constant (about 10%) and expected to decrease gradually as demand increases unless new local producers come to the industry.

Table 1.1: Investors Registered to Invest in the Pulp and Paper, Printing and Packaging Sectors for the Period of 1992-2009.

Investment type	On operation		Under construction		Registered but not in operation		Total	
	Qty	Capital '000	Qty	Capital '000	Qty	Capital '000	Qty	Capital '000
1 Pulp and paper	-	-	-	-	4	49,975	4	49,975
2 Paper production	5	227,317	5	64,844	48	522,020	58	824,151
3 Paper products and packaging	10	67,327	4	12,023	59	494,750	73	574,100
4 Printing	122	231,844	50	-	227	1,231,655	399	1,463,499
Total	137	526,488	59	76,867	338	2,308,400	534	2,911,755

Source: Privatization and Public Enterprises Supervising Agency /PPESA/, 2010.

As it can be seen from the table above, no one investor has started construction yet, even though 4 have been registered to invest in the pulp and paper sector. This might be attributed to the huge capital investment requirement that the pulp and paper mill requires and the second, probably, the major reasons is the scarce and short supply of raw material for pulp and paper manufacturing.

On the other hand the printing sector seems promising to the investors; this is because 87.8% of those investors who are under construction and operational have invested in this sector. Again this might be attributed to the requirement of relatively low capital investment for printing machines, the sporadic expansion and development of the education sector in relation with text book printing and the possibility of importing paper and paper products of relatively inferior quality with relatively cheap price from abroad.

Following the massive expansion of the education sector and the double digit economic growth of the country for the last five years, the paper, printing and packaging industry is expected to grow with significant percentage if all the constraints and obstacles with in the sector are going to be alleviated. In order for the sector to grow as required, the following opportunities must be exploited:

- Free market economic policy of the country;
- Double digit economic development of the country has helped to improve the disposable income for the citizens of the country and improved purchasing power (or consumption);
- Massive expansion of the education sector;
- Urbanization and ever growing demand of paper, printing and packaging; and
- Availability of small scale efficient technologies on the market (PPESA, 2006).

The sector is also expected to address the following threats that might hinder it to grow to the desired level.

- Technology limitations;
- Raw material shortage;
- Foreign currency problem;
- Working capital constraints; and
- Sharp print quality requirements by donors and a trend to outsource text book publishing to the foreigners.

Thus, in order for the sector to grow as required and to attain the goals and vision of the country, that is, to grow the economy to the level of middle income countries, this import dominated sector

needs to address the threats that the sector encounters and exploit the opportunities that help to achieve the Millennium Development Goal of the country. Being a country comprising 75 million inhabitants with per capita paper consumptions of nearly 1 kg, there will be a potential for the sector to grow to the desired level. More over there is huge gap between demand and supply with only three paper mills which show-cased an ample scope for growth in the paper industry (PPESA, 2010).

Finally, this industry which is characterized by slow growth, fairly unattractive to investors, import dominated (nearly only 10% of the total demand is currently covered by local producers), with a huge potential to grow needs a huge effort both from government and other stakeholders to keep it in the development track, so that the sector contributes its own to the overall economic development of the country.

The researcher, being, an employee in one of the government owned paper producing companies, strives to make his own contribution, specifically, by supporting the effort in searching for the source of raw material to make pulp and paper. Bagasse which is the fibrous residue that remains as a waste product from the sugar milling process (Singh, 2004) is the prime candidate to be studied as an alternative source of raw material for pulp manufacturing and thus is the major concern of the researcher through out the research endeavor.

1.2 Statement of the Problem

1.3.1. Background to the Statement of the Problem

The ever growing demand of paper and paper products has forced countries of the world to invest a huge amount of money and capital on the industry. As the per capita consumption of paper is directly related to the economic growth of the country, the demand for paper and paper products will grow proportionally as the economy of the country grows. Ethiopia as a developing country has a strong vision to become a middle income country.

According to the Ministry of Finance and Economic Development of Ethiopia (MoFED), the country's vision specifically on the economic sector has set the following goals:

- To build an economy which has a modern and productive agricultural sector with enhanced technology and an industrial sector that plays a leading role in the economy.
- To sustain economic development and secure social justice; and
- Increase per capita income of citizens so that it reaches the level of those in middle income countries in the coming 10 years.

The above stated goals seem to be achievable in the future as the Ministry disclosed that the Ethiopian economy is on a higher growth trajectory (over 11 percent real GDP growth rate during the last 5 years ending in 2008/2009) and provided that this momentum of fast growth needs to be maintained (Gebresilassie, 2010).

Among the sectors that the Ethiopian government has given attention is the paper industry which is required to spend a huge sum of money (usually more than USD 90 million) for imports. The government is also intended to vigorously substitute this import through its import substitution policy.

Even though the Ethiopian government includes the paper and packaging industry in its strategic sector list, the challenges behind this fact are that the sector requires huge capital investment and there is scarcity of raw material, which seems to seriously affect the entrance of the private investment to the sector.

In order to overcome the challenges of the paper industry, a special attention should be given by the government which might include:

- Up grading the currently operating paper mills;
- Creating a conducive investment policy that can motivate private investors to enter to the sector;
- Facilitating the productions of the major raw material (pulp) locally;
- Discouraging importation so that the local manufacturers will be competent enough on the market;
- Granting funds from different sources to local manufacturers; and
- Injecting foreign capital investment in to the sector through privatization with joint venture modalities (PPESA, 2010).

With all these efforts and others, it is possible to invest in an integrated pulp mill (that is pulp and paper) and make the paper industry competitive. Investing in pulp and paper not only make the sector highly competitive but also saves or generates foreign currency for the country.

With regard to the raw material for pulp manufacturing, previous studies showed that the country has huge potential from sugar factories; that is bagasse, which is the bio mass remaining after sugar cane stalks are crushed to extract the juice, is a candidate for this purpose. For example, a feasibility study by Sandwell Swan Wooster Inc. for the construction of a bagasse based pulp mill with a capacity of 22,000 ADt/a (air dry ton per annum), to reduce the amount of imported pulp was completed in 1986. According to the study, bagasse can be obtained from sugar mills of the Ethiopian Sugar Corporation (ESC) through fuel substitution, and boiler efficiency and energy utilization improvements, possibly augmented by also harvesting sugar cane tops and leaves (Sandwell, 1989). Currently the bagasse obtained from sugar factories which are on operation is estimated to produce more than 800,000 tones of short fiber pulp which is in excess of the local demand and be able to be exported to generate foreign currency for the country.

On the other hand, bagasse could also be used for generation of electricity by the process of cogeneration where bagasse is burnt in bagasse firing boilers to produce superheated steam which further generates electricity and help sugar mills so that they can be energy self sufficient and some times, depending on the efficiency of boilers and availability of bagasse, excess energy might be supplied to the national grid for additional revenue. Due to this multi-functionality of bagasse, its effective utilization and economic significance needs to be identified so as to choose the best alternative use of this raw material.

Depending on the economic, social, geographical and political conditions of countries the utilization and economic significance of using bagasse might have different dimensions. For instance, in countries where there are no abundant and potential energy sources, using bagasse for the generation of electricity might be feasible. On the other hand in countries where there are abundant and potential energy sources, using bagasse to generate electricity might be wastage, or a low value use for a higher value resource.

Therefore, even though using bagasse as an alternative source of raw material for pulp manufacturing is not a new phenomena in the paper manufacturing industry across many parts of

the world, here in Ethiopia, the ever growing demand of paper and paper products seems to be in quite contrast to the presence of only three paper mills with limited capacity and no one single pulp mill in the country. It is believed that the scarce availability of raw material and the requirement of huge capital investment that the industry require are the two main reasons why there are very few paper mills and no one pulp mill in the country.

On the other hand, following the massive new green field capital investments and the expansion of the currently operating sugar mills in Ethiopia, this fact is expected to be reversed. And this research has attempted to show whether the use of available and surplus bagasse as an alternative and potential source of raw material for pulp manufacturing is economically significant or not when compared to cogeneration (that is the simultaneous production of heat and electricity), and has also showed its contribution to the over all economic growth of the country.

1.3.2 Statement of the Problem

Resulting from the above mentioned back-ground information the statement of the problem was given in the form of research questions as follows:

- ✚ What is the bagasse pulping potential of the country?
- ✚ What is the economic advantage of pulping bagasse over cogeneration?
- ✚ What must be done to exploit this bagasse pulping potential of the country?

1.4. Objectives of the Study

1.4.1. General Objective

The general objective of this study was to assess and evaluate the economic significance or advantage of using bagasse as an alternative source of raw material for pulp and paper manufacturing over the currently undergoing practice of burning it for cogeneration to generate electricity, and there by alleviating the raw material supply problem of the paper industry in the country.

1.4.2. Specific objectives.

- i. To determine the bagasse pulping potential of Ethiopia.
- ii. To assess and evaluate the economic significance of pulping bagasse over cogeneration.
- iii. To create awareness about the economic significance of bagasse among stakeholders, investors and the government officials and company executives so that they can play a significant role in the overall development of the paper industry in the country.
- iv. To suggest some critical issues toward economic policies with respect to import substitution and investment opportunities in the paper industry.

1.5. Basic Assumptions and Theoretical Value Considerations

- ✚ Regardless of the country of origin, maturity, harvesting method, variety of cane and mill efficiency, bagasse was considered to have the same compositions of fiber, yield, physical and chemical properties.
- ✚ Cost of production and operation of generating electricity per KWh in a modernized sugar mill with reasonable daily milling capacity was taken for granted for all other sugar mills regardless of the country where the mills are located.
- ✚ Sugar cane yield per unit area, sugar and bagasse yields per unit of cane, and energy (electricity) generated per unit of bagasse for a modernized sugar mill of reasonable daily milling capacity was taken for granted for all mills under consideration regardless of the country of origin for the purpose of this study.
- ✚ The following theoretical values were taken into consideration and are the milestones for evaluating cane yield of sugar mills under consideration in this particular study:

1 ton of sugar cane yields:

- ✓ 250 – 300 kg of bagasse.
- ✓ 100 – 121 kg of raw sugar.
- ✓ 100 – 120 kWh of electricity.
- ✓ 85 – 100 kg of bagasse pulp (on dry basis).

1.6. Rationale of the Study.

Even though using bagasse as a source of raw material for pulp manufacturing is not a new phenomenon in many countries of the world, it is quite a new experience for Ethiopia where the country is strongly in short supply for paper making raw material. Behind this fact, Ethiopia could be one of the very few countries in the world who have no one pulp mill for their local paper making.

On the other hand Ethiopia currently produces nearly 300,000 tones of sugar annually and plans to increase its annual production to 4 million tones in the near future, which is considered to be significant when compared to many other sugar producing countries of the world. This significant amount of production leaves approximately 10 million tones of available bagasse which could either burnt inefficiently to produce heat and electricity in the sugar mills or just thrown to the surrounding as a waste and pollutes the environment. But if it is used wisely this amount of bagasse which could be thrown to the surrounding is used to produce approximately 3.4 million tones of pulp which further is used to manufacture 5 million tones (in combination with other soft wood fibers) of paper of different quality as per the specified furnish.

Thus, knowing about the international trend of making pulp and paper from surplus bagasse, one has to question the best alternatives of efficient and economic utilizations of this raw material. In countries like Ethiopia where there is cheap and abundant and unutilized hydro electric potential, evaluating the economic and efficient utilization of bagasse is quite important.

Further more, pulping bagasse helps the sugar mills to have additional income (revenue) that helps to stabilize the vulnerable economic viability due to global sugar price fluctuation and fiercely competitive domestic and global sugar market. Therefore, sugar mills need to configure efficient technologies during the course of making themselves sufficient with energy and save bagasse for pulp and paper industry. Thus, the ability to meet all of the mills' increased energy needs as well as

the promise of additional revenue from the sale of exportable surplus bagasse to pulp and paper mills could become a key factor in securing the sugar industries viability.

Finally, it is the researcher's exclusive interest to make this paper to be not only the source of knowledge and information, but also with all its multidimensional benefits, the paper needs to be applicable and be part of the solution in the whole journey of economic growth that Ethiopia needs to go through.

1.7. Delimitation and Scope of the Study

1.7.1 Delimitation of the Study

- i. The study was not attempted to perform scientific experiments to determine the physical and chemical properties of bagasse fiber.
- ii. The study was not attempted to use advanced mathematical computations and modeling to determine the yield and any property of bagasse fiber.
- iii. The study was not attempted to do feasibility study of bagasse pulp mill and will only be limited to show the economic advantage of using bagasse for pulp manufacturing over (cogeneration).

1.7.2. Scope of the Study

This study intended to evaluate the economic significance of using bagasse as alternative source of raw material for pulp manufacturing and compared it with cogeneration, where bagasse is burnt in bagasse firing boilers to generate heat and electricity. As bagasse is the waste material left after sugar cane juice is extracted in the sugar mills, the amount of bagasse that will be produced in the currently operating sugar mills and the one that will be obtained from sugar mill projects when they will be completed, was taken in to consideration in determining the total available bagasse the country will have for the future. Apart from this, two established mills, Wonji Shewa Sugar Factory (WSSF) and Metehara Sugar Factory (MSF) and Tendaho Sugar Factory (TSF) from projects were selected to determine and evaluate the economic advantage of pulping bagasse over

cogeneration. And finally, this study was done in Ethiopia and so, the results cannot be generalised to other countries.

1.8. Importance of the Study

The study added to the body of knowledge in the economics field and might be of value to policy makers regarding:

- The rationality of their decision making on the effective utilization of the country's available resources; and
- The realization of the import substitution policy of the government in its effort to save foreign currency and there by encouraging the overall economic growth of the local industry.

1.9 Limitations of the Study

To the knowledge of the researcher, the economic significance of using bagasse as a source of raw material for pulp and paper manufacturing when compared with using it for cogeneration had not been formally studied and the question of the economic significances of the two alternatives had not been clearly answered. Therefore, this particular study has limitations with respect to comparing the findings with the previous studies, that is, whether the findings are consistent or inconsistent with previous works of researches. Due to this reason, there might be another limitation regarding the availability of comprehensive and relevant data and literature. Despite all the limitations, the researcher has tried to demonstrate that the problem and research questions for this particular study need to be answered and are worth answering.

1.10 Outline of the Study

This study was divided into five chapters. Chapter one provided an introduction to the study, stating the problem and explaining the purpose, scope delimitations, limitations and rationale or justification of the study.

Chapter Two provided a review of the literature which covers the global view and experience of bagasse pulping and bagasse cogeneration. In addition, bagasse pulping and bagasse

cogeneration potential for the leading countries in this particular industry have been discussed in this chapter.

Chapter three provided the methodology of the study which revealed how data are collected from various sources, how data are integrated and analysed so as to come to sound conclusions and recommendations.

Chapter Four provided the findings of the study where the results of the whole research endeavour are presented. Here, a number of computation and comparisons that justify the economic significances of bagase pulping and bagasse cogeneration have been carried out to reach to conclusion.

Chapter Five, the last chapter of the study, provided the conclusion of the study and summarized the key issues of the policy implications so that the government and stake holders in general should build a strategic commitment to wards developing the chemical industry as a whole.

1.11 Conclusion

Currently, the Ethiopian government has endorsed the second five year development plan to be implemented in every sector of the country including the chemical sector which is comprised of paper printing and packaging industry over the next five years. According to the Federal Government 2010/11-2014/15 Plan and Industry Transformation Program, the double digit economic growth is expected to be maintained and the economy will be made over to take the nation out of poverty ending decades of food aid from donors which is considered as a journey to ward achieving the Millennium Development Goals of the country.

According to the Federal Government Plan and Industry Transformation Program of 2011-2015, the massive expansion of the education sector, followed by a significant increase in student text book ratio from 1.25:1 (2010) to 1:1 (2015), import substitution and foreign currency saving policies, the plan to increase sugar production from 314.4 thousand tonnes (2010) to 2,250 thousand tonnes (2015) all favour the production of pulp and paper locally and the availability of raw material (bagasse) for pulp and paper production (MoFED, 2010).

Therefore, it seems reasonable that producing pulp and paper locally using the available raw material, that is, bagasse, is crucial for the country to meet its Millennium Development Goal, a goal that brings the country to the level of economies of the middle income countries.

A critical evaluation of the related literature against the researcher's contribution on the subject will be pretended in the next section.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1. Introduction.

To the knowledge of the researcher, there are no organized and formally written literature that are related to the economic significance of using bagasse as an alternative source of raw material for pulp manufacturing in Ethiopia, except some pre-feasibility studies of bagasse pulp mill some twenty years back by project contractor Sandwell Swan Wooster and the client of the project Ethiopian Pulp and Paper S.C. Therefore, the researcher intends to review the literature of the global experiences related to the topic and there by assume these experience to be applicable to Ethiopia, as Ethiopia will never be out of the global experiences and trends.

2.2. Paper Making from Non woods

Paper making (defined as being made of pulped cellulose) was invented from non wood materials in China almost 2000 years ago. Textile rags, cereal straw, reeds, grasses, and sugar cane bagasse have been used in pulping and paper making ever since, especially in Asia (Jahan, *et. al.*, 2009). According to Jahan *et al.*, (2009), the invention of industrial printing in the 15th century implied a rapid increase in demand for paper. Yet, it was not until 400 years later, that the use of wood to make pulp had been invented in Germany by Fredrick Gottolb Keller in 1840. The annual production of paper from wood pulp has grown since to a multi-billion dollar industry, concentrated mostly in a few industrialized countries. Today, about 90% of all pulps are being produced from wood.

Historically, paper was made from a variety of plant fibers (non wood) and it was after the growth of industrialization in the mid to late nineteenth century did virgin fiber from trees become the primary raw material for pulp and paper manufacturing. Even though the principal raw material used for manufacturing paper pulp is wood, the growing demand in the paper industry, at a time of dwindling forest resources, have compelled the sector to run to other source of raw materials, such as cereal straw, reeds, bamboo or sugar cane bagasse (Guillaume, 2006).

Non wood fiber resources have the potential to complement wood supplies because they are abundant, have short cycles and rapid regeneration, and are of comparatively low price (FAO,

1998). Thus non wood and recycled fiber will play important roles in paper-making and manufacture of artificial panels as substitutes or complement to wood.

Of the common non wood fiber mills, bagasse pulp mills are typically among the largest non wood mills which have been built because large volume of bagasse are available in one spot - the sugar mill (Hurter, 2001). According to him, typically, bagasse pulp is produced in integrated pulp and paper mill, that is, pulp mills supply the slurry pulp that has come out of the pulp mills to the paper mills so that significant amount of energy that has been required for drying the pulp will be saved, and soft wood craft or sulfite pulp is added to provide the strength requirements to the paper.

Hurter (2001) also described that the wide variety of physical and chemical properties offered by non wood plant fibers provides virtually endless opportunities for paper making and that combination of common and specialty non wood pulp will permit the production of virtually any grade of paper to meet any quality requirements demanded in the global market. This is to mean that, adding possible combination which include wood pulp, non wood pulp and recycled waste paper pulp increases the possibilities for developing paper with specific sheet properties designed to meet specific customer's needs.

The use of non wood plants for paper making is also emphasized by World International Property Organization (WIPO, 2009), that depletion of forest cover and pollution of the environment are two major concerns of man kind today. Thus there is great impetus for developing technologies that prevent the cutting down of forests, as well as developing "green technologies" that reduce the quantity of chemicals used in a process. According to the organization, agricultural wastes such as sugar cane bagasse, grain and cereal straws, jute sticks, cotton stalks, etc... are fibrous cellulose materials consisting of cellulose, hemi cellulose and lignin in nearly the same proportion as most wood, and therefore if new technologies replace wood with these materials, they would help preserve many forests and the environment.

The world demand of paper is so great that most fibrous plant based lignocelluloses mater have been identified for pulping by using different processes to produce paper grade cellulose pulp and this is achieved by removing the lignin and hemicelluloses constituent in ways designed to minimize loss and damage to the cellulose fiber. Paper making in general involves cooking or digesting the cellulose plant matter with pulping chemicals at elevated temperature and sufficient

time to cause an acceptable degree of delignification, so as to produce a pulp type of specific characteristics, especially color, strength, gloss and printability (WIPO, 2009).

2.3. Bagasse as a Source of Raw Material for Pulp and Paper Manufacturing

Bagasse, as a non wood fibrous, raw material for paper making is widely used in India, China and many parts of the world where the supply of forest based raw material is not adequate (Kumar and Singh, 2009). According to Kumar, *et. al.*, (2009) bagasse pulps are capable of producing paper with excellent formation, surface, smoothness, and sufficient strength as required in many grades of paper. The relatively low optical scattering power of bagasse pulp which has been considered as a major draw back of bagasse fibers can generally be increased by using more filler in paper, although with usually some reduction in paper strength and stiffness (Kumar *et. al.*, 2009). On the other hand, bagasse, the sugar cane residue is found to be one of the best alternatives because of its low cost, longer fiber than straw, low refining energy consumption, and good sheet formation and paper smoothness, which enable the sugarcane bagasse to meet the quality requirements for news print and fine paper manufacture (Agnihotri, *et. al.*, 2010)

Table 2.1: Recommended Bagasse Furnishes as a Percentage of the Total Fiber Contents of Different Paper Grades

Paper Type	Bagasse pulp (%)		Soft Wood Pulp (%)		Recycle paper (%)	
	Unbleached	Bleached	Unbleached	Bleached	White	Mixed
<u>Printing and writing</u>						
Bond paper		60		30	10	
Bank paper		50		40	10	
Exercise book		65		25	10	
Text book		80		10	10	
Offset		65		25	10	
WF printing		70		20	10	
WF Printing regular		80		10	10	
<u>Wrapping Board</u>						
Bristol		65		25	10	
Manila (White)		65		25	10	
Manila Colored		80		10	10	
Pressing paper	55		10		10	25
Grey board					5	95
Kraft Wrapping	25		40-70		5-10	0-30
Kraft liner	10		80			10
Fluting med.	30		10		10	50
Test liner	30				10	60

Source: *Bagasse Pulp Mill and Paper Machine II Project Feasibility Study by Sandwell Swan Wooster, (1989).*

One of the well known researchers in this particular research area, Thomas Rainey (2009), described bagasse as the fibrous residue that remains after sugar is extracted from sugar cane, is normally burnt in Australia (his country) to generate steam and electricity for the sugar factory. According to him, a study in to bagasse pulp was motivated by the possibility of making highly value added pulp product from bagasse for the financial benefit of sugarcane millers and growers,

and emphasized that bagasse pulp could replace eucalypt pulp which is more widely used in the local production of paper products.

It seems, from the fact discussed above, that using one of the agricultural residues, bagasse, as a source of alternative raw material (fiber) seem to offer advantages over the use of trees for paper making. But as noted above, it is important to carry out careful life cycle analysis of any new raw materials before concluding that they would be preferable both from economical and environmental perspectives and evaluating such an alternative is the main application area of interest for this study.

Historically, the first truly successful utilization of bagasse as a fibrous raw material on a commercial scale was for the manufacture of insulation board in 1920 by the Cellotex Corporation in Marrero, Louisiana and later in 1939, the initial bagasse- based pulp and paper mill operations were carried out in Peru, Taiwan, and the Philippines (Singh, 2007). The use of bagasse in the manufacture of pulp and paper was regularly considered over the last 150 years whenever fiber shortages presented themselves and much research has been done, and still continuous, in the hope of strengthening the role of bagasse in the pulp and paper industry (Singh, 2007). According to this researcher, from all the non wood fiber available to the pulp and paper industry in South Africa, bagasse seems the most favorable to use, since it is a by product of an established industry.

Chiparus (2004) is also in agreement with Singh (2007) that bagasse will be ahead of other crops as a source for the pulp and paper industry and estimated that the amount of bagasse produced annually about 80,000,000 metric tons (MT), from which 25,000,000 metric tons will be used for pulping (13% of the total paper making pulp capacity).

2.4. Properties of Bagasse

Bagasse is the fibrous residue of cane stalk obtained after crushing and extraction of Juice. Each tone of sugarcane can yield 250kg of bagasse. According to WADE (2004), the composition of bagasse varies with variety and maturity of sugarcane as well as with harvesting methods used and efficiency of the sugar mill in processing the cane. The properties of bagasse are outlined in the following table below:-

Table 2.2: Physical Properties of Bagasse.

Properties	Result
Fiber content	43-49%
Water content	46-52%
Soluble solids	2-6%
Average Density	150kg/m ³
Low-heat value	1,780 Kcal/kg
High-heat value	4,000 Kcal/kg

Source: *World Alliance for Decentralized Energy /WADE/, 2004.*

Bagasse is an important fibrous raw material for paper making in many parts of the world where the supply of forest-based raw material is not adequate. Bagasse pulps are capable of producing papers with excellent formation, surface smoothness, and sufficient strength as required in many grades of paper. However, a relatively low optical scattering power has been considered a major drawback of bagasse fibers, which generally can be improved by using more filler in the paper (Kumar *et. al.*, 2009).

Table 2.3 Physical Properties of the Pulps Used from Different Sources

PROPERTIES	BAGASSE	HARD WOOD	SOFT WOOD	WHEAT STRAW
Ash %	0.61	0.66	0.35	1.60
Tensile index Nm/g	58.9	65.6	44.1	45.5
Burst index kPam ² /g	3.73	4.73	5.96	2.66
Tear index mNm ² /g	3.96	5.34	18.5	3.32
Folding endurance	1.39	1.47	2.69	0.62
Brightness	73.5	73.0	74.3	71.4
Scattering coefficient m ² /kg	21.2	36.7	24.0	25.8
Absorption coefficient m ² /kg	0.52	0.73	0.38	0.62

Source: Department of Paper Technology, Indian Institute of Technology Roorkee. India, 2009.

Bagasse is the residue after crushing and processing of sugarcane to remove the sugar juice and its fibers are of 1.0 to 1.5mm length and 20 micro diameter, which is similar to hard wood such as eucalyptus (0.7 to 1.3mm by 20 to 30 micron) (Covey, *et. al.*, 2006). Accordingly, with appropriate manufacturing process, bagasse pulps can be produced of similar quality to pulp from hard wood.

According to Covey, *et. al.*, (2006), there are a number of features of bagasse which require different treatment from the processing of wood chips. Some particularly important considerations are as follows:

Storage: sugar cane is a seasonal crop and the crushing mills operate for only about half the year, so it is usually necessary to store large quantities of bagasse for long period.

Pith: Bagasse typically contains 30-35% pith cells. These are fine, thin walled; low cellulose content cells which do not produce paper making fiber. However, they consume large quantities of chemicals, result in a poor draining pulp and reduce scattering power in mechanical pulps. Therefore, effective depithing is an essential requirement.

Silica: Compared with most other non woods fiber sources, bagasse is quite low in silica, but at 0.5% it is at least twenty times higher than in eucalyptus, and removal or other compensatory methods are essential to a practical mill.

Chemical recovery: silica is a major issue, but the high viscosity of the liquor and the small scale of most bagasse mills also present significant problems.

Finally, bagasse is used commercially to produce chemical, semi-chemical and various types of mechanical pulp in both bleached and unbleached forms. It is most commonly used in countries where other fiber sources are limited and often (but by no means always) in situations where imported pulps are too expensive.

2.5. Alternative Uses of Bagasse

Now a-days bagasse is mainly used as a burning raw material in the sugar cane mill furnaces. The low calorific power of bagasse makes this a low efficiency process (Chiparus, 2004). According to this researcher, the sugar cane mills management encounter problems regarding regulations of “clean air” from the Environment Protection Agency, due to the quality of the smoke released in the atmosphere. In Australia too, despite the large quantity of sugarcane growth in the region, no bagasse is pulped in the country (Covey, *et. al.*, 2006). Covey, *et. al.*, (2006), explained the reason for this to be the presence of an established pulp industry based on the native hard wood resources, however, increasing demand for fiber and the limited availability of additional forest area make bagasse pulping attractive.

According to Covey, *et. al.*, (2006), there are some circumstances that may now make the production of bagasse pulp in Australia more attractive:

- It has become difficult to gain access to sufficient reserves of natural forest to support significant increases in wood pulp capacity. The alternative has been to establish plantations but the increasing minimum economic size for new pulp miller and the long establishment times for plantations make this alternative unattractive in many cases.

- The technology for pulping bagasse has developed so that satisfactory quality pulps of various types are now being produced in many countries.
- Imbalance between supply and demand for fiber in the region is making acceptance of non-traditional pulp source more attractive.
- Compared with establishing timber plantations, bagasse fiber can be available with very short lead-time and with the cost of collection already covered.
- Bagasse paper production can now attract a premium over products made from wood chip because of the perceived environmental benefits.

Even though the above stated facts are specific to Australia, it is believed that they can be applied to the other countries and the following remarks should be given due considerations (Rowell, *et. al.*, 1996).

- While adequate technology exists to convert most agro based fibers such as bagasse in to quality paper and board products, economics will dictate how quickly and how much the use of these raw materials for pulp manufacturing will grow or expand for the coming periods.
- The cost of production, collection, storage and processing coupled with the value of the saleable products must result in a reasonable investment return and be competitive with other fiber sources (wood and recycled paper)
- The mechanization of handling sugarcane bagasse, annual fiber crops and straw /stalk residues is a reality in developed countries and developing countries (e.g. Colombia, Peru, and Indonesia). Machines are slowly replacing hand labor with these crops in other developing countries. High density balers are available that improve the economics of transportation and storage of the bulky fibrous raw materials.

Thus, as it can be seen from the literature review, even though the principal raw material used for manufacturing paper pulp is wood, the growing demand in the paper industry, at a time of dwindling forest resources, have compelled the sector to run to other sources of raw materials such as cereal

straw, reeds, bamboo or sugar cane bagasse. Therefore, the large requirement for fiber and the limited forest resources makes sugar cane bagasse pulping much more appealing.

2.6. Bagasse cogeneration

2.6.1. Cogeneration, Overview

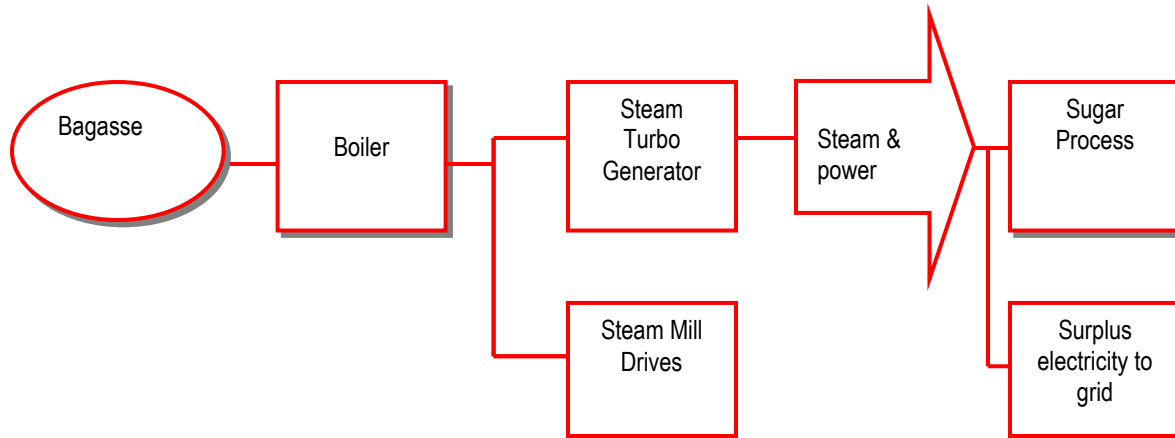


Fig 1: The Bagasse Cogeneration Process

The world energy demand is provided from conventional energy sources, such as coal, oil, natural gas, etc. Since the life of these sources is limited by the present and foreseeable future energy consumption of the world, attention is being turned toward new and renewable sources, such as solar, wind, wave, biomass, etc (Kilicaslan, *et. al.*, 1998). According to these researchers, electricity production based on fossil or nuclear fuels induces substantial social costs, where as it would appear, that the use of renewable energy sources involves far less and lower social costs. Continuous of economic growth and prosperity rely heavily on adequate energy supplies at reasonably low costs.

Following the increase in demand of energy in the future, the use of conventional energy sources will not by itself be able to solve these problems, and a continuous increase will result in the undesirable consequences. However, the emergence of the alternative energy sources in the form of renewable resources are expected to be parts of the solution of the future energy consumptions, at least in orders to reduce the environmental concerns and impacts with regard to air and water quality, acid rain, global warming etc. Cogeneration is widely recognized world wide as an attractive alternative to the conventional power and heat generating options due to its low capital

investment, short gestation period, reduced fuel consumption and associated environmental pollutions, and increased fuel diversity (Michaelowa, 2007).

Bagasse cogeneration describes the use of fibrous sugar cane waste bagasse to cogenerate heat and electricity at high efficiency in sugar mills (WADE, 2004). WADE's (2004) report indicated that there is abundant opportunity for the wider use of bagasse based cogeneration in sugar cane producing countries and to contribute substantially to high efficiency energy production. According to the report, even though this potential yet remains largely unexploited, the potential to make a meaningful contribution to the energy balance is especially great in Cuba, Brazil, India, Thailand, Pakistan, Colombia, Mexico and the Philippines. Overall, the potential in these countries (which accounts for 70% of global cane production) reaches as high as 25% in Cuba and, as an average a significant 7.45% of total demand of the world.

Table 2.4. Global Market potential of Bagasse Cogeneration

Country	Sugar Cane Production (toner/yr)	Potential for Electricity Production (GWh/yr)	Bagasse Potential as Percentage of Electricity Demand (%)
Brazil	386,232,000	38,623	11.5
India	290,000,000	29,000	5.83
China	93,900,000	9,390	0.72
Thailand	74,071,952	7,407	8.15
Pakistan	52,055,800	5,206	8.36
Mexico	45,126,500	4,513	2.42
Colombia	36,600,000	3,66,	9.19
Australia	36,012,000	3,601	1.95
Cuba	34,700,000	3,470	25.93
USA	31,178,130	3,188	0.09
Philippines	25,835,000	2,584	6.16
Other	244,581,738	24,458	0.32
Total	1,350,293,120	135,029	0.97
Total (Excl. China, Aust, U.S.A, and Others)	944,621	94,462	7.45

Source: World Alliance for Decentralized Energy /WADE/, 2004

Bagasse cogeneration as reported by WADE (2004) has the following benefits:

- Near-zero fuel costs (paid in local currency), commercial use of a waste product and increased fuel efficiency leading to an increase in the economic viability of sugar mills.
- More secure, diverse, reliable and wide spread supply of electricity for local consumers.
- Minimal transmission and distribution (T & D) costs, and reduced network losses, as generation is located near important loads.
- Greater employment for local populations.
- Lower emissions of CO₂ and other gases than from convention fossil fuel generation.

In line with WADE (2004), Restuti and Michaelowa (2007), have emphasized that all countries through out the world are called for efforts to reduce global warming where industrialized countries in particular are required to reduce their Green House Gases (GHG) emissions to 1990 level during the first commitment period 2008/12. Accordingly, Clean Development Mechanism (CDM) is one of the flexible mechanisms defined in the protocol that enables the industrialized countries to reach their legally binding GHG emissions targets in a cost effective way with involvements from developing countries. In parallel to GHG emission abatement, projects under CDM will benefit the host non industrialized (Developing) countries in achieving sustainable development goals as a consequence of financial and technological assistances (Restuti, *et. al.*, 2007).

The amount of energy that can be extracted from bagasse is largely dependent on two main criteria, moisture content and the technology used for energy production (WADE, 2004). That is, the output of electricity from bagasse cogeneration plants is fundamentally dependent on the prevailing electricity market rules; inadequate buy back prices paid to mill owners by the utility company creates a substantial disincentive to size cogeneration plants to meet mill heat demand. Conversely, higher rates can incentivize owners to upgrade their energy facilities to enable maximum on-site efficiency. This is the key to enabling the potential for bagasse based cogeneration to be achieved.

With the same talken, the economic feasibility of cogeneration as reported by Coelho and Velazquez (1996), significantly depends on the current electricity tariffs of a country and show that more efficient cogeneration technologies might not be economically competitive if the current

prevailing electricity tariffs are significantly low that selling prices could not be able to cover the cost of generation.

According to these writers, despite the large benefits from environmental aspects (avoiding carbon emissions reasonable for the greenhouse effect) and despite the advantages of allowing the expansions of electricity offer through private capital, biomass origin cogeneration improvements are not economically feasible. Electricity tariffs are quite low for the industrial sector in Brazil, for instance, especially for pulp/paper industries, and therefore cogeneration costs are not competitive. Also the purchasing price established by the utilities for the electricity surplus is not attractive to encourage this process.

This actually is not always true, because, in countries where electric prices are considerably high and in those where sources of electricity are not abundant, the tariffs for electricity can be significantly high and consequently, biomass origin cogeneration is considered to be feasible.

In order for bagasse cogeneration to achieve the potential benefits, it is important that certain key measures are brought forward. Building on experiences in India, Brazil and else where, WADE (2004) recommends that:

1. Planning and regulatory paths are cleared for the development of enhanced cogenerations facilities in sugar mills. This includes insuring fair and easy access to the grid for both large and small generators as well as guaranteeing that incumbent generators and utilities do not hinder these processes.
2. Financial and tax incentives, in line with other incentives for renewable energy, are provided to boost the initial development of cogeneration facilities in sugar mills. This would allow generators to invest in the necessary equipment and infrastructure to maximize their electricity output whilst making the most effective use of heat and electricity generated onsite. Financial incentives also include the provision, where possible, of renewable energy feed-in-tariffs that reflect the benefits of onsite production and biomass combustions.
3. Where financial and tax incentive are currently unavailable, the CDM should be promoted and developed. The CDM could provide the incentive required for the upgrade or installation of

cogeneration equipment in mills in a cost effective manner whilst facilitating the meeting of Kyoto Protocol commitments by industrialized countries.

4. Further research is carried out in to bagasse gasification to fully explore its potential, so that the best technologies can continue to be promoted and installed to reap the maximum benefits of bagasse cogeneration.

The effectiveness of bagasse cogeneration thus is affected by both internal and external factors.

Internal Factors:

- Process efficiency (that is the efficiency of bagasse firing boilers and the turbo alternator turbines).
- The moisture content of bagasse (when the moisture content of bagasse is relatively higher, its calorific value decreases).
- Fiber characteristics of bagasse (as the fiber content of bagasse varies from country to country and from season to season, bagasse that contains relatively smaller fiber content will be inefficient and its calorific value will be less).
- Skilled man power to operate and handle the high pressure boilers.

External Factors:

- Potential for various sources of electricity that the country has.
- Government policy to motivate private electricity generation, transmission and distributions.
- Ease and compatibility of grid synchronization.
- Regulatory incentives for the utilities to purchase private power

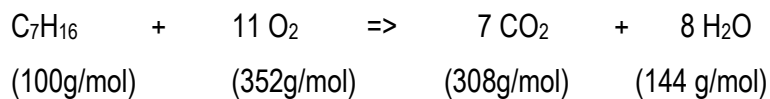
Thus, the stated internal and external factors determine whether bagasse could be used for cogeneration to generate electricity or else it must be used for some other purpose, say, pulp and paper so that its value be maximized.

2.6.2. Environmental Issues

Using bagasse for cogenerations avoids green house gas emissions (GHGE) and the process can help the sugar mills obtain Certified Emission Reduction Earnings. The combustion of any material produces gases. The combustion of biomass is no exception, but there is a fundamental difference between sugar cane biomass combustion and fossil fuel combustion, the first returns to the environment the carbon that was captured from atmosphere in a short period, depending on the kind of vegetal biomass, 1-1.5 years, fossil fuels expel in to the environment the carbon that has been accumulated during several dozen million years (Alonso-Pippo *et. al.*, 2007).

According to Alonso-Pippo, *et. al.*, (2007), from an environmental point of view, thermodynamic balance of sugarcane biomass combustion is innocuous compared to fossil fuel combustions. From the authors perspective there are many gases that contribute to green house effect. NO₂, CH₄, CO, but the most important of them is CO₂ because of the quantities delivered to the environment during the combustion of oil and oil by products.

Theoretically, gasoline combustion can be expressed by the correlation:



Calculating ton/mol ratio for each component in the equation above, it is easy to notice that stoichiometric combustion of gasoline (1st term in the equation) requires 3.52 tones of oxygen (16.35 tones of air) and delivers to the environment 3.08 tones of CO₂ plus 1.4 ton of steam. Thus, it can be further observed that if fuel oil (which is 25 %) consumption of 270 g/KWh is assumed and if a country's potential electricity power cogeneration from sugarcane biomass is taken as 9006 GWh/year, the amount of avoided CO₂ emission from fossil fuel would be 5.4 million ton of CO₂ /year (Alonso-Pippo, *et. al.*, 2007).

Bagasse power development has the advantages that it is environmentally friendly, uses renewable energy and it encourages the use of sugar trash in future (Mbohwa and Fakuda, 2002). These authors also note that sugar factories in future have to cogenerate heat for sugar processing and power normal usage in a factory and for sale if they are to remain viable in light of falling sugar prices at the world market.

To the knowledge of the researcher, cogeneration as specified by the previous authors is not the only option that makes sugar factories remain competitive in the international sugar market; the other option, that is selling bagasse to pulp and paper mills might benefit them more than burning it to generate electricity and supply to the grid, as doing this is more easier said than done. Therefore, the possible alternative uses of bagasse need to be critically assessed and evaluated in order to come to the right decision, and this probably is the reason why the researcher attempted to evaluate the economic significance of alternative uses of bagasse, specifically, in using it as alternative raw material for pulp manufacturing.

2.7. The Economics of Alternative Uses of Bagasse

Sugar mills produce a range of by products including bagasse, filter mud and molasses. A typical sugar cane complex with a capacity of 3,000 tones crushed per day (TCD) can produce 345 tones of refined sugar, 6,000 liters of alcohol (Ethanol), 3 tones of yeast, 15 tones of potash fertilizer, 25 tones of pulp, 15 tones of wax, 150 tones of press-mud fertilizer and 240 MWh of exportable electricity from bagasse (WADE,2004).

Despite the facts stated above, most sugar industries of the world simply burn this valuable resource in low-pressure boilers to generate steam, part of which goes to generate power for internal consumption and as a result the mills run at loss. According to WADE (2004), each tone of sugar cane yield 250 kg of bagasse and the compositions of bagasse vary with variety and maturity of sugar cane as well as with harvesting methods used and efficiency of the sugar mill in processing the sugar cane.

In relations to the energy requirement, WADE (2004) described that the sugar and alcohol production processes are energy intensive, requiring both steam and electricity. Historically sugar mills have been designed to meet their energy requirements by burning bagasse this was seen as an economic means of producing electricity whilst cheaply disposing of bagasse. However, according to the report, as there was little potential for the sale of electricity to the grid, efficiency in the process was a hindrance rather than a bonus.

As it is reported by WADE (2004), the rationale for bagasse cogeneration is its classic win-win for the sugar industries from a financial point of view. This is because, cogenerations, especially at high temperature and pressure configurations, could play an important role in encouraging much more efficient use of resources and ensuring wide spread access to electricity services. Unfortunately, insufficient incentive to supply electricity to the grid because of low or inexistent buy back rates has meant that, until recently, around two thirds of harvested bagasse was wasted. This situation is now set to improve, with the introduction of more effective biomass feed in tariffs in countries such as Brazil and India (WADE, 2004).

To the knowledge of the researcher, burning bagasse, even in high temperature and pressure boilers to generate electricity to the grid should not be considered as the only option that sugar mills need to exploit, but rather, the reverse option that is using electricity from the grid and saving bagasse for some other useful and economical alternatives such as for pulp and paper needs to be considered. Therefore, sugar mills will be much more benefited if they are able to consider the opportunity cost of using bagasse for various alternatives and evaluating these alternatives might preclude from a low value use for a higher value resource.

2.8. Summary of the Literature Review

Literature review has indicated that the biomass, bagasse, which have been left over after sugarcane is crushed in the sugar mills is a non wood fibrous raw material for pulp and paper making and it is widely used in many countries of the world including Brazil, China, India, Cuba, Thailand, South Africa and others, where the supply of forest based (wood) raw materials is not adequate. Singh (2007), for instance indicated that from all the non wood fibres available to the pulp and paper industry in South Africa, bagasse seems the most favourable to use since it is a by product of an established industry which makes its availability easier.

According to Kumar, *et. al.*, (2009), the physical and chemical properties of bagasse fibres are comparable to that of the conventional pulp making wood fibres and are capable of producing papers of excellent formation. Surface smoothness, good printability and sufficient strengths as required in many grades of paper. However, according to Rowell, *et. al.*, (1996), the economics of converting most agro based fibres such as bagasse in to quality paper and board products and the cost of production, collection, storage and processing coupled with the value of the saleable

products must result in a reasonable investment return and be competitive with other fibre sources such as wood and recycled paper.

On the other hand using bagasse for cogeneration that is burning it in the sugar mill boilers to generate heat and electricity both for factory consumption and selling to the national grid (export) is also an international experience commonly practiced in countries like Cuba, Brazil, India, Thailand, Pakistan, Colombia, Mexico and Philippines. According to Michaelowa (2007), cogeneration is widely recognized world wide as an attractive alternative to the conventional power and heat generating options (i.e. fossil fuels coal etc) due to it low capital investment, short gestation period, reduced fuel consumption and associated environmental pollution. However despite all the large benefits from substituting the conventional power sources and the positive environmental aspects, the economic feasibility of cogeneration largely depends on the current electricity tariffs of a country and believed that more efficient cogeneration technologies might not be economically competitive if the currently prevailing electricity tariffs are significantly low that may result in the selling price could not be able to cover the cost of generation (Coelho and Velazquez, 1996).

Therefore, according to WADE (2004), in order for bagasse cogeneration to achieve the potential benefit certain key measures must be taken by both the government and the generators such as insuring fair and easy access to the grid for both large and small generators and the provision of financial and tax incentives to boost the initial development of cogeneration facilities in the sugar mills.

Thus, using the biomass bagasse either for pulp and paper manufacturing or cogeneration seems to depend on several factors such as the potential for various sources of electricity that the country has, the government's policy to motivate private electricity generation, transmission and distributions, ease and compatibility of grid synchronization, regulatory incentives for utilities to purchase private power and the generators process efficiency, skilled man power.

Therefore, research has to be carried out in order to determine and to fully explore the potential for either bagasse pulping or bagasse cogeneration so that the maximum benefit from this high value resource is obtained which is the key question that needs to be answered in this particular research endeavour.

The research design and methodology employed to address the research problem or research questions are presented in the next chapter.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.1. Introduction

Even though studying about bagasse pulping and bagasse cogeneration seems to involve laboratory experiments and advanced computations, and categorized best under scientific research, the researcher has made the best of his effort to reduce the technicality of the paper and adjust it to show the economic significance of pulping and cogenerating bagasse and viewed the topic from the economic point of view.

The study has adopted both qualitative and quantitative (mixed) research design by using a case study approach that has been conducted in two established sugar mills (Wonji Showa Sugar Factory and Metehara Sugar Factory) and one project (Tendaho Sugar Factory). The selected sugar mills were expected to be representative of the rest as there are few sugar mills and projects in the country. The aim was to get mills performance data and to draw conclusions about the bagasse pulping and bagasse cogeneration potential of the country and to show the economic significance of using bagasse for pulp and paper production and compare it with cogeneration.

To compare the estimated cost of cogeneration with the estimated cost of power production from other sources, data were collected from Ethiopian Electric Power Corporation (EEPCo). The data obtained were compared with the cost of cogeneration of sugar mills in order to determine whether using bagasse for power production is economically feasible or not. Finally, based on the research findings, conclusions and sound recommendations were given in congruent with leaving an opportunity for further research areas.

3.2. Research Design

Based on the nature and type of data to be collected to address the topic, the researcher employed both qualitative and quantitative research approaches where data were collected through pre designed interview schedules and observations which finally help to draw conclusions. In this particular study, data were collected from three sugar mills located at different sites of the country. The stakeholders and executives' opinion regarding the economic utilization of bagasse was collected using interviews. The collected data were used to determine whether using bagasse for

pulp manufacturing is economically significant or not. By integrating the results obtained from the comparison and executives opinion survey interviews, the one that has supposed to be done was recommended.

Wonji Shewa Sugar Factory /WSSF/ has been in operation since 1954, located some 112 km South East from the capital Addis Ababa. The mill operates 24 hours per day during the harvesting season, which is normally 220-250 days per annum from October to June inclusive with a daily crushing capacity of 3,000 TCD. The mill currently produces 740,000 quintals of sugar per annum which is 23.5% of the current total production of the county. Bagasse is burnt in the bagasse firing boilers to generate heat and electricity for the process energy requirement of the mill and currently, there is no extra power supply to the national grid. After capacity expansion to 8,500 TCD, the mill intends to generate and sale 18 MW of power to the national grid.

Metehara Sugar Factory /MSF/ has been in operation since 1968, located 200 km east of the capital Addis Ababa. The mill operates 24 hour per day during the harvesting season, which normally ranges from 220-250 days per annum based up on the availability of matured sugar cane in the agricultural fields, with a daily crushing capacity of 6,000 TCD. The mill produces 1,300,000 quintals of sugar per annum which is 41.4% of the current total production of the country. Bagasse is burnt in bagasse firing boilers to generate heat and electricity for the process and residential energy requirement of the factory and currently there is no extra power supply to the national grid.

These two established mills have been selected in this particular study because these mills cover almost 65% of the country's total annual sugar production and also it is believed that it is possible to obtain adequate and reliable data for better representation and analysis.

Tendaho Sugar Factory /TSF/ located some 600 km North East of the capital Addis Ababa is one of the mega sugar projects that will be realized in the near future with daily crushing capacity of 26,000 TCD expected to produce 6,000,000 quintals of sugar per annum. TSF is also designed to generate 105 MW power by cogeneration from which 38 MW will be available for internal consumption and the remaining balance that is 67 MW, will be for sale to the national grid.

Like the established sugar mills selected before, Tendaho Sugar Factory project has also been selected because it is a well-running mega project which is expected to be completed in the near

future, and believed to have been a good representative of all other projects in the country with respect to technology, process efficiency and overall management knowhow and decision making capability.

3.3. Sources and Types of Data to be Collected

In order to have reliable and valid study, three different sources of data were employed. These were data collected from mills' operation performances and those collected from Ethiopian Electric Power Corporation /EEPCo/, where both of them were secondary data. The other data source was the one obtained by interviewing the executives using the openion survey interview schedule, which actually was a primary data.

3.3.1 Mills Performance Data, (Appendix A)

Two years performance data (where appropriate) with respect to the following parameters had been collected through the pre designed format presented to them during the survey that were conducted at the site visits.

Mills' performance data with respect to the following parameters were collected from selected mills and projects /WSSF, MSF &TSF/.

- Land developed (Hectare)
- Cane produced (T/a)
- Crushing rate (TCD)
- Sugar produced (T/a)
- Bagasse Available (T/a)
- Bagasse for internal consumption (T/a)
- Surplus Bagasse (T/a)
- Boilers (T,P steam)
- Turbo alternators. kV, rmp, type)
- Installed capacity (MW)
- Internal consumption (MW)
- Power supply to Grid (MW)
- Estimated cost of power generation (US\$/kWh)
- Steam production (TPH)
- Process steam requirement (TPH)
- Steam production per tone of Bagasse (tons)
- Process steam requirement per ton of sugar produced (tons)

The collected data were analyzed and used to determine the following variables:

- I. Total available bagasse (bagasse potential) in the country.
- ii Bagasse that has been used for internal consumption by the mills to be energy self sufficient.
- iii. Surplus bagasse that can be used for pulping or used to generate additional electricity to the grid.
- iv. Bagasse pulping potential for the country based on basic assumptions and theoretical value considerations.
- V Bagasse cogeneration potential for the country based on basic assumptions and theoretical value considerations.

Vi Comparison (Arithmetic) of the market value of electricity for 1 kWh with the market value of bagasse pulp that will be generated/produced from the same amount of bagasse based on theoretical and practical findings.

3.3.2. Data from Ethiopian Electric Power Corporation /EEPCo/, (Appendix B).

The following data were collected from EEPCO:-

- Hydro Electric potential (HEP) of the country(MW);
- Five years strategic plan with respect to power generations, transmission and distribution;
- Cost of generation and selling price of energy per kWh;
- Power purchase plan from sugar mills if any;
- Feed in tariff issues if any;
- Costs of Grid connection energy tariff per kWh;
- Demand and supply, short term, medium term and long term;
- Electricity act of the country;

From data sources Appendix A and Appendix B, the market value of electricity for 1 kWh were compared with the market value of pulp that can be produced from the same amount of bagasse used to generate 1kWh, that is, whether using bagasse as an alternative source of raw material for pulp manufacturing is economically significant or not was determined. That is, the market value of bagasse pulp was compared with the market value of electricity for 1 kWh, where both are produced (or generated) from the same quantity of bagasse in order to determine the economic significance of pulping bagasse over cogeneration. Alternatively, the production cost of 1kWh electricity from bagasse was compared with the production cost of the same quantity of electricity from another energy sources such as the HEP in order to determine the economic significance of pulping bagasse over cogeneration.

3.3.3 Data from Executive's Opinion Survey Interview Schedule, (Appendix C).

Stakeholders' opinions were collected and summarized with the research findings so as to reach the final conclusions. Recommendations were given and advices were made to policy makers and

investors so that they can realize the economic significance of pulping bagasse over cogeneration and act accordingly.

The stakeholders' (or executives') opinion survey had helped the researcher to know the feelings and awareness level of the executives regarding the topic under consideration and triggered them to think of the issue of bagasse pulping and bagasse cogeneration. The opinion survey interview schedule also had motivated the stakeholders or executives so that they can have the desire to know the final out put and finding of this research paper and possibly act inline with it.

3.4. Sampling

Even though Ethiopia currently employs three established sugar mills and 6 projects of different project execution status from both the public and private sectors, all of them were included in the over all potential contribution for the country, The three mills (Two from established and one from projects) were randomly selected- using the simple random sampling method and taken as a sample to be used in the study. The selected mills were Wonji Shewa Sugar Factory (WSSF) and Methara Sugar Factory (MSF) from established mills and Tendehe Sugar Factory (TSF) from projects.

As a complement to the samples from operating sugar mills and projects, a total number of 30 stakeholders, company management members, and government executives (Directors and Commissioners) who were believed to be particularly knowledgeable about the issue were purposively selected and invited for the interview from which 27 had attended the interview using pre-designed semi-structured interview schedule.

3.5. Instruments of Data Collection

Appropriately formatted interview schedules were developed to collect mills performance data (Appendix A). The formatted schedules were presented to the respondents during site visits at the sugar mills that had been selected. An opinion survey interview schedule (Appendix C) was also presented to the Executives (Management members and higher officials) physically and their opinion regarding the research topic was collected. A pre designed format was also used to collect data from EEPCo in order to have the data required as specified in (Appendix B). The expected

data sources for this study were individuals, performance reports of mills, past records, and observations during site visits.

3.6. Data Analysis Strategies

Collected data (Appendix A) were summarized by using the excel spreadsheet of the windows computer software and was integrated with (Appendix B) to determine:

- The bagasse pulping potential of the country
- The surplus bagasse used for either pulping or generating electricity.
- Estimated cost of generating electricity per KWh and the bagasse pulp price equivalent of this kWh, or the rate of bagasse consumption per kWh, based on theoretical values.
- Based on the current market price of electricity and theoretical values, whether using bagasse as an alternative source of raw material for pulp manufacturing is economically significant or not was evaluated and determined, that is, the value of energy (electricity) equivalent of bagasse was compared with the market value of its bagasse-pulp equivalent.

3.7. Validity and Reliability

In the process of organizing data to information and evidence, some sort of interpretation is required. However, when interpretation is reinterpreted, some distortion of the original is inevitable (Pierce, 2007). According to this author, some distinctions, criteria, and tests are useful to weed out distortions and 'untruths'. The distinctions adopted are between primary and secondary sources of information and the criteria used are validity, reliability, and accuracy. The main test adopted is triangulation.

In this particular study both primary and secondary data sources and also both qualitative and quantitative data were employed. Quite representative samples from sugar mills and purposive sampling of the executives and stake holders for opinion survey interviews were used so that the data obtained and the conclusion drawn are dependable and trust worthy.

3.8. Data Analysis.

i. Research question 1

- ✓ Bagasse pulping potential of the country were determined by calculating the total available bagasse of sugar mills through out the country including projects and converting it to its pulp equivalent quantity based on basic assumptions and theoretical value considerations.

ii Research question 2

- ✓ Data collected from the selected sugar mills (Appendix A) were used to calculate the rate of bagasse consumption per kWh (bagasse/kWh). This further helped to determine the amount of bagasse consumed to generate 1 kWh of electricity.
- ✓ Data collected from EEPCo (Appendix B) were used to determine the market price (US\$) of 1 kWh in the country.
- ✓ This was equivalent to bagasse cogeneration price (per kWh), which further was compared to the currently prevailing market price (US\$) of bagasse pulp which would further helped to determine the economic significance of bagasse pulping over cogeneration.

iii Research question 3

- ✓ By integrating research findings obtained from Appendixes A and B above with Appendix C, sound recommendations with respect to raw material potential, awareness creation, policy issues, investment opportunities, and potential benefits from economic and social perspectives were given.

3.9. Ethical Considerations

Even though the degree of being a social science research for this particular study is minimal, the commitment of the researcher was expressed by a covering letter to the participants (Appendix D) that respondents were kindly requested for their consent to participate in the survey. And also the

letter had disclosed that all the information provided by participants will be kept strictly confidential and individual respondents will never be identified in reporting survey findings.

3.10. Research Findings and Presentations

Research findings obtained from the analysis results were presented in the form of tables and numerical values based on the data sources collected from sugar mills and projects (Appendix A and Appendix B). Results from stakeholders' and executives' opinion survey interview (Appendix C) were presented in the form of interview summaries and were integrated with the results of mills and projects so as to reach to the final conclusions and recommendations.

Finally, based on the results and findings, the economic advantage or significance of pulping bagasse over cogeneration, pulp and paper manufacturing and exporting potentials of the country, foreign currency saving potential, and the macro economic and social impacts associated were thoroughly discussed and well addressed in the next consecutive chapters of this study.

CHAPTER FOUR

RESEARCH RESULTS

4.1. Biographic Profile of the Respondents.

4.1.1. Sugar Mills.

Among the established mills of the country, Wonji Shewa Sugar Factory and Methara Sugar Factory have been selected and studied to determine and evaluate the economic significance of using bagasse as a source of raw material for pulp and paper manufacturing and to compare it with cogeneration. And Tendaho Sugar Factory, which is the mega Sugar Factory project of the country was also included in the study to evaluate and forecast the projects intention and plan in considering the issue under study during their planning and implementation phases.

Wonji Shewa Sugar Factory (WSSF) has been in operation since 1954, located at some 112 km south East from the capital Addis Ababa with a daily crushing capacity of 3000 tonnes of cane per day and producing 80,000 ton of sugar per year. The mill intends to expand it capacity currently to 6,250 TCD in the short run and then to 8,500 TCD and further to 12,500 TCD in the future. Currently, bagasse is burnt in the bagasse firing boilers to generate power for internal consumption only and plans to produce and export 18 MW, 30 MW and 40 MW in its expansion phases respectively.

Metehara Sugar Factory (MSF) has been in operation since 1968, located 200 km East of Addis Ababa with a daily crushing capacity of 5,000 tonnes of cane per day producing 1,300,000 quintals of Sugar per annum. The mill intends to expand its capacity to 6000 TCD creating an additional capacity of generating 12 MW of power for internal consumption.

Tendaho Sugar Factory (TSF) project located some 600 kms North East of the capital Addis Ababa with a daily crushing capacity of 26,000 tonnes of cane per day (TCD) is one of the mega projects of the country which is expected to produce 6 million quintals of Sugar per year. The mill is designed to produce 105 MW power by burning bagasse in the bagasse firing boiler (cogeneration) from which some 67 MW will be planned to supply to the national grid for sale.

4.1.2 The Ethiopian Electric Power Corporation /EEPCo/

The Ethiopian Electric Power Corporation (EEPCo) was named in 1997 after serving in the name of Ethiopian Electric Light and Power Authority which was established in 1956. EEPCo is responsible for generation, transmission, distribution and sale of electric energy through out the country.

The corporation has two electric power supply systems: the interconnected system (ICS) and the self contained system (SCS). The main energy source of ICS is hydro power plants and for SCS mini-hydros and diesel power generators allocated in various areas of the country. EEPCo previously generators 843.3 MW from ICS and, 36.21 from SCS with a total generating capacity of 875.41 MW as of 2008/09, currently EEPCo produces nearly 2000 MW of power mainly from the new entrants Tekeze, Gilgel Gibe II and Tana Beles completed projects (EEPCo, 2010).

4.1.3 Stakeholders', Management Members', Executives' and Directors' Opinion

Various Stakeholders, company Executives and Management members and Agency Directors who are supposed to have a stake in the issue were interviewed by using a pre designed semi-structured interview schedule. The qualitative data collected are summarized and presented in the next section of this chapter.

Corporations and Ministries that were visited during the interview were listed below:

1. Wonji Shewa Sugar Factory
2. Metehara Sugar Factory
3. Tendaho Sugar Project
4. Ethiopian Pulp and Paper S.C.
5. Anmol Products Ethiopia PLC.
6. Privatisation of Public Enterprises Supervising Agency (PPESA).
7. Ethiopian Sugar Development Agency (ESDA)
8. Ethiopian Electric Power Corporation (EEPCo).
9. Ministry of Trade and Industry.

A minimum of two or three representatives of the above institutions and a total sum of 30 individuals were invited for the interview from which 27 of them had fully attended the interview.

4.2. Research Results

4.2.1. The Bagasse Pulping Potential of the Country

The bagasse pulping potential of the country was determined by calculating the total available bagasse of sugar mills throughout the country including the net irrigable land and projects that will be realized in the near future. The bagasse pulping potential further indicated the amount of paper and paper products that can be produced here locally based on the theoretical value considerations.

Table 4.1, Crushing Capacity, Land Available and Cane Production Potentials of Sugar Mills and Projects

Sugar Mills / Projects	Crushing Capacity (TCD)	Land Available (Hectare)	Cane Production Potential (Tons)
Wonji Showa Sugar Factory	12,500	22,000	2,293,988
Metehara Sugar Factory	6,000	11,000	1,203,249
Finchaa Sugar Factory	13,000	27,586	2,640,000
Al-Habesha Sugar Factory	8,000	15,000	1,435,488
Tendaho Sugar Factory	26,000	60,000	5,617,237
Hiber Sugar Factory	12,500	25,000	2,363,636
Kesem Sugar Factory	10,000	20,000	1,390,909
Other projects	80,000	200,000	20,000,000
Total	168,000	380000	36,944,467

Source: Ethiopian Sugar Development Agency /ESDA/.

Bagasse production potentials for the sugar mills and projects were calculated from the following table.

Table 4.2, Calculated Bagasse Production Potentials of Sugar Mills and Projects

Sugar Mills / Projects	Land Available (Hec)	Cane Production Potential (tons/yr)	* Bagasse Prod. Potential (tons/yr)
Wonji Showa Sugar Factory	22,000	2,293,988	661,357
Metehara Sugar Factory	11,000	1,203,249	346,897
Finchaa Sugar Factory	27,586	2,640,000	761,112
Al-Habesha Sugar Factory	15,000	1,435,448	413,840
Tendaho Sugar Factory	60,000	5,617,237	1,619,449
Hiber Sugar Factory	25,000	2,363,636	681,436
Kesem Sugar Factory	20,000	1,390,909	400,999
Projects (Diff. Phases)	200,000	20,000,000	5,766,000
Total	380,586	36,944,467	10,651,090

Source: ESDA

Note that:

1. Bagasse available in tons is calculated and determined based on the assumptions and theoretical value considerations, that is:

$$*Bagasse \text{ Prod. Pot.} = \left[\text{cane produced (tons)} * 0.2883 \right]$$

2. All data are based on the expandable capacity of the sugar mills and projects expected to be realized with in the coming five to ten years.

As it can be seen from the computation above, the total bagasse production potential of the country is **10,651,090** tons per year.

Sugar production potentials for the respective mills and projects were calculated from the following table.

Table 4.3, Calculated Sugar Production Potentials of Sugar Mills and Projects

Sugar Mills / Projects	Cane Produced (tons/yr)	Bagasse Available (tons/yr)	*Sugar Production Potential (tons/yr)
Wonji Showa Sugar Factory	2,293,988	661,357	252,338
Metehara Sugar Factory	1,203,249	346,897	132,357
Finchaa Sugar Factory	2,640,000	761,112	290,400
Al-Habesha Sugar Factory	1,435,448	413,840	157,899
Tendaho Sugar Factory	5,617,237	1,619,449	617,896
Hiber Sugar Factory	2,363,636	681,436	260,000
Kesem Sugar Factory	1,390,909	401,000	153,000
Projects (Diff. Phases)	20,000,000	5,766,000	2,200,000
Total	36,944,467	10,651,090	4,063,890

Source: ESDA

Note that:

1. Sugar production potential for the country is calculated and determined based on the assumptions and theoretical value consideration. That is:

$$*Sugar\ Production\ Potential = \left[\text{cane production potential} * 0.11 \right]$$

2. All data are based on the expandable capacity of the sugar mills and projects expected to be realized in the coming five to ten years.

✚ As it can be seen from the computation above, the total sugar production potential of the country is **4,063,890** tons per year.

Bagasse pulping potentials for sugar mills and projects were calculated from the following table.

Table 4.4, Calculated Bagasse Pulping Potentials of Sugar Mills and Projects

Sugar Mills / Projects	Cane Produced (tons/yr)	Bagasse Available (tons/yr)	*Bagasse Pulp Production Potential (tons/yr)
Wonji Showa Sugar Factory	2,293,988	661,557	217,928
Metehara Sugar Factory	1,203,249	338,112	114,309
Finchaa Sugar Factory	2,640,000	761,133	250,800
Al-Habesha Sugar Factory	1,435,448	431,851	136,368
Tendaho Sugar Factory	5,617,237	1,619,449	533,638
Hiber Sugar Factory	2,363,636	681,436	224,545
Kesem Sugar Factory	1,390,909	401,000	132,136
Projects (diff. Phases)	20,000,000	5,766,000	1,900,000
Total	36,944,467	10,651,090	3,509,724

Source: ESDA

Note that:

1. Bagasse pulping potential for the country is calculated and determined based on the assumptions and theoretical value consideration. That is:

$$*Bagasse\ Pulp\ Prod.\ Pot = \left[\text{cane production potential} * 0.095 \right]$$

2. All data are based on the expandable capacity of Sugar Mills and projects expected to be realized with in the coming five to ten years.

✚ As it can be seen from the computation above, the total bagasse pulp production potential of the country is **3,509,724** tons per year.

From the information given above, the total bagasse pulp production (or bagasse pulping) potential of the country is nearly 3.5 million tons. If 70% bagasse pulp furnish is used to produce a particular fine grade paper, the paper production potential for the country from local resources will be 5 million tons per year, assuming 30% other fibre sources. This quantity of pulp and paper is far more than the local demand and a significant quantity of it can be used for export to generate foreign currency and contributes a lot for the overall economic growth of the country.

The other important point that has to be considered here is that it is up to the sugar mills either to replace their energy requirement obtained fully or partially with electric energy that has to be supplied from the national grid. A detailed feasibility study regarding the energy replacement options has to be carried out so that sugar mills will remain competitive in the prevailing international market.

4.2.2. The Economic Benefits of Pulping Bagasse over Cogeneration

4.2.2.1. The Rate of Bagasse Consumption per MWh (Bagasse/MWh)

Generally speaking, the current trend of the sugar industry in the world is towards reducing the consumption of steam and power through the development of energy efficient systems (or equipments) and exporting as much power as possible or the other alternative, save bagasse for pulp and paper manufacturing. The Ethiopian sugar industry is no exception to implement this scheme if it is to remain competitive and this derives the need to upgrade and expand the currently existing non energy efficient sugar mills to a better efficiency and capacity.

Below were the summary the data collected from selected sugar mills and projects with respect to their energy efficiency and capacity (Mills Performance Data, Appendix A).

Table 4.5, Mills' Performance Data

Parameters to be measured	WSSF		MSF		TSF
	Existing	Expansion	Existing	Expansion	Project
Land Available (Ha)	7,022	22,000	11,000	-	50,000
Cane produced (T/a)	672,000	2,293,988	1,203,249	-	5,617,237
Crushing rate, TCD	3,000	12,500	6,000	-	26,040
Sugar produced (T/a)	76,000	252,338	120,035	-	600,000
Bagasse available (T/a)	201,600	761,357	338,112	-	1,623,019
Bagasse for internal consumption (T/a)	201,600	642,102	314,445	-	1,617,550
Surplus Bagasse (T/a)	-	19,255	32,452	-	5,469
Boilers (T.P steam)	340°C, 21bar	515°C, 66bar	380°C, 21bar	-	510°C, 66bar
Turbo alternators KV,rpm, type	11Kv, 3,000	11Kv, 6,000	3Kv, 1,500	-	2x20 MW 2x40 MW
Installed capacity (MW)	3.2	60	9.9	-	105
Internal consumption (MW)	3.2	18	7.5	-	30.10
Power supply to Grid (MW)	-	42	-	-	77.64
Estimated cost of power generation (US\$/KWh)	-	0.030	0.030	-	0.030
Steam production (TPH)	58.1	326	120	-	650
Process steam requirement (TPH)	58.1	248	110	-	463.6
Steam production per tone of bagasse (Tons)	1.5	2.57	1.85	-	2.56
Process steam requirement per tone of sugar (TPH)	4.24	4.43	5.2	-	4.27

Source: Wonji Shewa, Metehara and Tendaho Sugar Factories and Projects.

Note that the expandable capacity of the established sugar mills and projects were taken into consideration in determining the rate of bagasse consumption per MWh, (Bagasse/ MWh) which further was used to determine the amount of bagasse consumed to generate 1 MWh of Electricity. Note also that a tolerable variation exists between data collected directly from mills and the one obtained by computation.

I. **Wonji Showa Sugar Factory (WSSF).**

- Bagasse available = 661,357 Tons
- Bagasse for power generating = 642,102 tons
- Surplus bagasse = $[661,357 - 642,102 \text{ Tons}] = 19,255 \text{ ton}$
- Power installed capacity = 60 MW
- Gross operating time, power plant = 220 days
- Energy production (MWh) = $60 \times 5,280 = 316,800 \text{ MWh}$
- Rate of bagasse consumption per MWh:

$$= \frac{\text{Bagasse for internal consumption (tons)}}{\text{Energy production (MWh)}}$$

$$= \frac{642,102 \text{ tons}}{316,800 \text{ MWh}}$$

$$= \mathbf{2.03 \text{ tons/MWh}}$$

- Bagasse Pulp Equivalent of 2.03 tons of Bagasse:
 - = Bagasse * 0.34
 - = 2.03 tons * 0.34
 - = **0.69 tons** of Bagasse Pulp.

(Note that 0.34 is the Bagasse Pulp Equivalent of raw or whole green bagasse).

If this amount of pulp is imported with the currently prevailing price, that is, US\$ 1,128 CFR Djibouti, the specified amount of bagasse pulp (0.69 Tons) costs \$778.32, which is significantly higher than the mill's selling price of the equivalent energy (MWh) which is only \$30 for 1MWh.

If the same amount of bagasse pulp is produced locally and if manufacturing cost is estimated 50% of total cost, considering a high cost manufacturing scenario, the bagasse pulp equivalent of the specified energy (MWh) will be \$ 389.16 which again is significantly higher than the energy price as settled by sugar mills, which is only US\$ 30 per MWh.

II. Metehara Sugar Factory (MSF):

- Bagasse available = 338,112 tons
- Bagasse for power generation = 314,445 tons
- Surplus bagasse = $[338,112 - 314,445 \text{ tons}]$
= 23,667 tons
- Power installed capacity = 9.9 MW
- Gross operating time, power plant = 220 days
- Energy production (MWh) = $9.9 \text{ MW} * 5,280 \text{ h}$
= **52,272 MWh**
- Rate of bagasse consumption per MWh (t/MWh)
= Bagasse for power generation
Energy production (MWh)
= 314,445 tons
52,275 MWh
= **6.02 tons/MWh**

Bagasse Pulp Equivalent 6.02 tons of bagasse:

= Bagasse * 0.34

= **2.05 tons** of Bagasse Pulp

If this amount of pulp is imported with the currently prevailing prices of pulp, that is US\$ 1,128 CFR Djibouti, the specified amount of bagasse (i.e. 2.05 tons) costs US\$ 2,312.4 which is significantly higher than the mills selling price for the equivalent energy (MWh) which is only US\$ 30 for 1 MWh.

If the same amount of bagasse pulp is produced locally and if manufacturing cost is estimated to be 50% of the total cost, considering a high cost manufacturing scenario, the bagasse pulp equivalent of the specified energy (1MWh) will be US\$ 1,156 which again is significantly higher than the energy price set by sugar mills and project which is only US\$ 30 per MWh.

III. Tendaho Sugar Factory (TSF):

- Bagasse available = 1,623,019
- Bagasse for power generation = 1,617,550
- Surplus bagasse = $\left[1,623,019 - 1,617,550 \text{ tons} \right]$
= 5,469 tons
- Power installed capacity (MW) = 105
- Gross operating time, power plant = 270
- Energy production (MWh) = 105 MW x 6,480 h
= **680,400 MWh**
- Rate of bagasse consumption per MWh:
 - = $\frac{\text{Bagasse for power generation (tons)}}{\text{Energy production (MWh)}}$
 - = $\frac{1,617,550 \text{ tons}}{680,400 \text{ MWh}}$
 - = **2.83 tons/MWh**

- Bagasse Pulp Equivalent of 2.38 tons of bagasse:
 - = Bagasse (tons) * 0.34
 - = 2.38 * 0.34
 - = **0.81 tons** of Bagasse Pulp

If this amount of pulp is imported with the currently prevailing price of pulp, that is US\$ 1,128 CFR Djibouti, the specified amount of bagasse pulp (i.e. 0.81 tons) costs \$ 912.78 which is significantly higher than the mills selling price of the equivalent energy (MWh) which is only nearly \$ 30 for 1 MWh.

If the same amount of bagasse pulp is produced locally and if manufacturing cost is estimated to be 50% of the total cost, considering a high cost manufacturing scenario, the bagasse pulp equivalent of the specified energy (MWh) will be US\$ 456.39, which again is significantly higher than the energy price set by sugar mills, which is only US\$ 30 per MWh.

Therefore, from the above analysis, it is an easy task to understand that the economic value of pulping bagasse is much higher than its value in using it for cogeneration to generate electricity in the selected sugar mills and projects. And thus, using bagasse for energy production is not economically feasible and is considered as a low value use for a higher value resource.

4.2.2.2. Ethiopian Electric Power Corporation's (EEPCo's) Cost of Power Generation, Corporate Data

The following data were collected and analysed to determine the cost of power generation (Birr/KWh), which later were converted to US\$/MWh, and compared with the energy selling price of the sugar mills and projects

Table 4.6, EEPCo's Five Years Power Generation Costs

Description	For the Ending Year					
	2004/05	2005/06	2006/07	2007/08	2008/009	2009/10
Installed capacity, (MW)	-	-	-	814	874	2060
Generated Energy, (GWh)	2,587	2,890	3,332	3,531	3,728	3,981
Energy consumed ,(GWh)	2,095.00	2,408.00	2,966.00	3,131.26	-	-
Sales of electric energy (000's birr)	1,066,001.20	1,327,412.18	1,744,505.88	1,874,463.00	1,749,173.15	-
Number of employees	10,582	11,354	11,725	12,687	12,292	12,446
Number of customers (000's)	953	1,126	1,396	1,677	1,830	1,962
Transmission line (KM)	6,633.00	7,754.00	8,745.85	8,867.85	8,867.55	8,723.55
Distribution line (KM)	24,555.34	33,000.00	65,518.00	75,174.00	77,640.52	126,038.00
Generation cost (000's)birr	571,900.00	719,003.00	760,964.00	1,046,968	1,627,057	-
Number of customer (000's)	953	1,126	1,396	1,677	1,891	2,600

Source: Ethiopian Electric Power Corporation /EEPCo/

From the above table power generation unit costs (Birr/KWh) can be calculated as follows: (Note also that the foreign currency exchange rate used is: US\$ 1 = Birr 16.50)

Generation Unit cost

$$\text{(Birr/KWh)} = \frac{\text{Birr x 1,000}}{\text{Generated Energy (GWh) x 1,000,000}}$$

$$\begin{aligned}
 2004/05 &= \frac{571,900 \times 1000 \text{ (Birr)}}{2,587 \times 1000,000 \text{ (KWh)}} \\
 &= 0.22 \text{ Birr/KWh} \\
 &= \mathbf{\$ 13.33/MWh}
 \end{aligned}$$

$$\begin{aligned}
 2005/06 &= \frac{719,003 \times 1000 \text{ (Birr)}}{2,890 \times 1000,000 \text{ (KWh)}} \\
 &= 0.25 \text{ Birr/KWh} \\
 &= \mathbf{\$ 15.15/MWh}
 \end{aligned}$$

$$\begin{aligned}
 2006/07 &= \frac{760,964 \times 1000}{3,332 \times 1000,000} \\
 &= 0.23 \text{ Birr/KWh} \\
 &= \mathbf{\$18.94/MWh}
 \end{aligned}$$

$$\begin{aligned}
 2007/08 &= \frac{1,046,968 \times 1000}{3,531 \times 1,000,000} \\
 &= 0.30 \text{ Birr/Kwh} \\
 &= \mathbf{\$18.18/MWh}
 \end{aligned}$$

$$\begin{aligned}
 2008/09 &= \frac{1,627,047 \times 1000}{3,787.78 \times 1,000,000} \\
 &= 0.44 \text{ Birr KWh} \\
 &= \mathbf{\$26.67/MWh}
 \end{aligned}$$

As it can be seen from the above power generation cost computation, the 2008/09 highest ever power generation cost, that is, \$ 26.67/MWh is even lower than the energy selling price of the sugar mills and projects, which is \$30/MWh. Thus, as EEPCo is not a non profit making organization, power purchase agreement with a price higher than its generation cost is not expected.

4.2.3 Conclusions

The analysis of data obtained from mills performance and cost computations from EEPCO showed that:

- ✓ Whether bagasse pulp is imported or produced locally, the economic value of bagasse is much higher than its corresponding value when it is used to generate electricity by cogeneration.
- ✓ Power generation cost of EEPCo from hydro power is significantly lower than the cost of power generation by cogeneration in the sugar mills and project.
- ✓ Thus, for the two reasons mentioned above, pulping bagasse has greater economic advantage than burning it in the boilers of sugar mills to produce electricity (i.e. Cogeneration)
- ✓ Note also that currently EEPCo has no plan to purchase power from sugar mills and also there is no signed contract for power purchase agreement between EEPCo and the sugar mills and projects, Thus, unless there is an appropriate policy in place regarding the issue and a pre-hand signed power purchase contractual agreement between the sugar mills and EEPCO, sugar mills will never be in a position to sell their energy (or power) and bagasse cogeneration might not be attractive and feasible for sugar mills.

4.2.4. Stakeholders' and Executives' Interview Summaries

4.2.4.1. General

- ✓ The main purpose of the interview schedule was to complement the analysis and findings obtained from mills performance data and EEPCo's power generation cost estimates. By integrating the analysis result obtained from mills performance data and EEPCo's power generation potential, cost of production, and its future plan with the stakeholders' and relevant higher officials interview transcript results, sound judgement and recommendation with respect to raw material potential, import substitution policy issues, investment

opportunities, and potential benefit from economic, social and environmental perspectives were given.

- ✓ A pre designed semi structured interview schedule was used to take extensive notes as much as possible during the interview. Even though it required the ability to write at a fast pace to take notes, to be able to hear what is being said and record information in a manner that is both legible and faithful to the respondent was also critical and was given attention for the task.
- ✓ Notes were reviewed and reports were written at the end of every day of interviewing that helps to summarize and interpret the information obtained.
- ✓ Recursive abstraction method where data sets are summarized and re-summarized was employed in presenting and analysing data from interview transcripts. And great care has been taken so that the final conclusions were not removed from the underlying data, which is the common criticism of the method.
- ✓ Detailed interview summaries are given in the Appendix C part of Appendixes.

4.2.4.2. Conclusions

By counting the number of times a reason (or issue) was given by respondents - so that the one with more counts would be more important than the one with less, the majority of the respondents agreed that using bagasse for pulp and paper manufacturing is a strategic issue to Ethiopia for the following four major reasons:

- ✓ Effective and economic utilization of available resource.
- ✓ Local production of pulp and paper which further enhances the development of other strategic sector such as the education, agriculture and chemical.
- ✓ Import substitution and foreign currency saving
- ✓ Employment opportunity, management know how and transfer of technology.

Therefore, the stakeholders' and relevant higher officials' opinion towards pulping bagasse was quite positive and it's also in congruent with the previous findings that using bagasse for pulp and paper manufacturing is economically more significant than using it for cogeneration.

Based on all the findings, sound recommendations with respect to raw materials potential, awareness creation, policy issues, investment opportunities and potential benefit from economic, social, and environmental perspectives were given in the next chapter.

CHAPTER FIVE

DISCUSSIONS, CONCLUSIONS, RECOMMENDATIONS, AND POLICY IMPLICATIONS

5.1 Discussions and Conclusions

Due to steadily rising standards of living in all countries, the production of pulp and paper from sugar cane bagasse is of increasing importance, especially in countries with limited pulp wood resources and considerable sugar cane cultivation. So, bagasse for practical purpose is the sole source of fibrous raw material that can easily be available within a very short harvesting time period, especially in sugar cane growing countries (Hurter, 2001). On the other hand following the increase in demand of energy in the future, the use of conventional energy sources such as coal, oil, natural gas, etc, will not by itself be able to satisfy the energy requirement of the society (Michalowa, 2007). However, other alternative and renewable energy source such as bagasse seem to have been used as an alternative to conventional energy sources through cogeneration.

The purpose of this study was, therefore, to explore the economic significances of either using bagasse for pulp and paper manufacturing or the other alternative, which is using it for cogeneration where bagasse is burnt in bagasse firing boilers to generate heat and electricity. As there was no as such a comprehensive research study as to compare and determine the best alternatives with respect to both economic and social issues, the researcher tried to address the issue through out the whole journey in finalizing this research study.

In going through this research study, respondents from various sources, such as the sugar mills, the Ethiopian electric power corporation /EEPCo/, company management members, Chief executives, Directors and Ministers participated. Mills performance data from the selected sugar mills, potential, capacity, cost and efficiency data from EEPCo, and stakeholders and Executives opinion data through pre-designed and semi-structured interview schedule were collected.

The amount of cane produced and available bagasse in the sugar mills and projects all over the country are used to determine the bagasse pulping potential of the country which is nearly 3.5 million tons per year. This shows that the country has very large potential for pulp manufacturing which further enables the country to export and generate foreign currency.

With regard to the economic advantage of pulping bagasse over cogeneration, the analysis result showed that the value of the bagasse that is used for cogeneration is much more less than the value of the same amount of bagasse if it is used for pulp manufacturing. That is the price of the energy that is produced from certain amount of bagasse is much more less than the price if the bagasse could have been used for pulp manufacturing. This further shows that the economic significance of pulping bagasse is much better than the other alternative which is using it for cogeneration.

The cost computations and analysis result from the Ethiopian Electric Power Corporation /EEPCo/ cost data sheet showed that, the average power generation cost of EEPCo is much lower than the selling price of the sugar mills which suggests that EEPCo will not come to buy power from sugar mills with a price higher than its generation cost. The result was again consistent with the previous one and thus bagasse cogeneration has much lower economic value than bagasse pulping.

Moreover, the stakeholders and executives opinion interview schedule showed that pulping bagasse has more economic advantage than using it for cogeneration, however, some respondents have expressed their concern that bagasse which is used for generating energy in the sugar mills has a great role as a source of revenue for sugar mills and a detailed feasibility study has to be carried out to clearly show whether the benefit from pulp can compensate the benefit from cogeneration.

Overall, the analysis of data from both the sugar mills and stakeholders opinion interview showed that using bagasse as an alternative source of raw material for pulp manufacturing has a much more economic significance than using it for cogeneration to generate heat and electricity in the sugar mills. This result is consistent with Rainey (2009), who demonstrated that using bagasse for pulping production is not only economically viable but also it is a sustainable alternative to forest products where old growth forests had been cut down for pulp productions traditionally. And also the finding was in a quite agreement with him that, using bagasse for cogeneration is a low value use for a higher value resource.

On the other hand, in contrast to this research finding, from the many new entrants and projects that are coming to the sugar industry, it was found that the majority of them have planned to generate electricity and to supply it to EEPCo at a pre - set energy price for additional revenue. But it was found that EEPCo has no formal contractual agreement to purchase power from sugar mills (that is no power purchase agreement yet) and there is no appropriate policy in place regarding this issue. Even if EEPCo plans to purchase power from this sugar mills to fulfill its demand during peak hours or any sort of energy deficits created for various reasons, the pre – set energy prices by sugar mills are not attractive and the sugar mills might have been forced to sale their energy at a price that is considerably less than their energy generation costs. This further has negative influence on the revenue that would have been generated and seriously affect the competitiveness of these sugar mills and projects.

Therefore, sugar mills and projects which are on the way to come to the industry need to have critically evaluated the best possible alternative for the economic and efficient utilization of their resources – that is bagasse, before they move to investments on power generation facilities.

5.2 Policy Implications and Recommendations

The Ethiopian government has endorsed the second five year development plan to be implemented in every sector of the country over the next five years. The new growth and transformation plan is designed not only to achieve the millennium development goals of the country which was the core of the previous Plan for Accelerated and Sustained Development to End Poverty (PASDEP) but also entering a new phase of economic development where the industry will have to take over the precedence from the agriculture sector by 2020.

The Growth and Transformation Plan is undertaken by the Ethiopian incumbent to repeat the double digit growth rate (11.5% to the average) of the past five years in the economic, social development, health and every major sector. Not only is the plan to repeat the successes of the past years, but also to venture in and realize a grand achievement in all the sectors and particularly in industry. The growth and transformation plan makes the incumbent's endeavor and commitment to pull Ethiopians out of poverty and deprivation and lead them on the end towards a better future.

According to the estimates made by the incumbent, there is expected a 14.9% economic growth coupled with the expected double growth in agricultural productivity. Moreover, the plan is targeted

at increasing the efficiency of the industrial sector and finalizing work that enable the latter take the leading role in the economy. Hence, the Ethiopian economy shall be ready to be transformed in to an industry-led one.

The other aspect, which probably is the most important, is that the growth and transformation plan is a plan that changes or transforms the country from foreign investment dependent strategy to a locally driven economy, and mainly focused on the strategic sectors such as the infrastructure, health and education services, and the chemical industry including pulp and paper (MoFED, 2010).

For all the reasons discussed above using bagasse for pulp and paper manufacturing is strategic and in congruent with the five years growth and transformation plan of the country. This can be justified by the following issues:

- ✓ Revising the coverage and quality of education demands the production of pulp and paper locally.
- ✓ The import substitution policy of the government facilitates the local production of raw material for pulp and paper manufacturing.
- ✓ Boosting power generation form 2,000 MW to 8,000 MW, and further to 10,000 MW, shows the governments commitments in the infrastructure and the presence of potential source of energy other than bagasse. [The country has more than 45,000 MW hydro, 5,000 MW Geothermal, and 10,000 MW wind electric energy potential (EEPCo, 2009)]
- ✓ Boosting sugar production from 314.5 thousand tons to 2,250 thousand tons. This further leaves nearly 5.9million tons of bagasse which further has a potential to produce 2.0 million tons of bagasse pulp.

Therefore, in order for the country to achieve its millennium development goals and the growth and transformation plan in the coming five years due attention must be paid for the chemical sector especially for the printing and packaging industry. Government officials, Directors, Chief Executives, Company managers and stakeholders in general should come together and work for the overall economic growth of the country.

As the per capita consumptions of paper specifically and the chemical sector development in general measures the economic development of a country, government should promote the sector and show its strategic commitment to wards both local and foreign private investors so that they can inject capital, transfer management know how and technology to the sector.

Finally, this study was not only about making the paper, printing and packing sector be enhanced and developed by motivating the government and the individual private investors to play their vital role in the sector but it also promoted sugar mills so that they can save and sale their bagasse with a price that is better than the price of equivalent electrical energy that bagasse would produce; and this will help the sugar mills to remain competitive in the prevailing international sugar market. Thus, pulping bagasse is like a double edged sword that can benefit both the pulp and paper and the sugar industries so that they can reduce manufacturing costs and generate additional revenue, which will help the country to meet its double target; the five years growth and transformations plan and the millennium development goals where the ultimate goal is to build a poverty free and medium income earning Ethiopia.

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Appendixes

Appendix A:

Mills' Performance Data

Parameters to be measured	WSSF		MSF		TSF
	Existing	Expansion	Existing	Expansion	Project
Developed land (Ha)	7,022	22,000	11,000	-	50,000
Cane produced (T/a)	672,000	2,293,988	1,203,249	-	5,617,237
Crushing rate, TCD	3,000	12,500	6,000	-	26,040
Sugar produced (T/a)	76,000	252,338	120,035	-	600,000
Bagasse available (T/a)	201,600	761,357	338,112	-	1,623,019
Bagasse for internal consumption (T/a)	201,600	642,102	314,445	-	1,617,550
Surplus Bagasse (T/a)	-	19,255	32,452	-	5,469
Boilers (T.P steam)	340°C, 21bar	515°C, 66bar	380°C, 21bar	-	510°C, 66bar
Turbo alternators KV,rpm, type	11KV, 3,000	11KV, 6,000	3KV, 1,500	-	2x20 MW 2x40 MW
Installed capacity (MW)	3.2	60	9.9	-	105
Internal consumption (MW)	3.2	18	7.5	-	30.10
Power supply to Grid (MW)	-	42	-	-	77.64
Estimated cost of power generation (US\$/KWh)	-	0.030	0.030	-	0.030
Steam production (TPH)	58.1	326	120	-	650
Process steam requirement (TPH)	58.1	248	110	-	463.6
Steam production per tone of bagasse (Tons)	1.5	2.57	1.85	-	2.56
Process steam requirement per tone of sugar (TPH)	4.24	4.43	5.2	-	4.27

Source: WSSF, MSF and TSF Project

Appendix B:

Data from Ethiopian Electric Power Corporation

1. Hydro Electric potential of (HEP) of the country (MW),	45,000.00
1.1 Current (MW)	2,060.00
1.2 Short term (MW)	4,633.00
1.3 Medium term (MW)	5,988.00
1.4 Long term (MW)	8,000.00

Remarks: ***Wind and geothermal energy sources are included.***

2. Five years plan with respect to power generation transmissions and distribution.	
2.1. 2010 (MW)	2,060.00
2.2. 2011 (MW)	$2060 + 1050 = \mathbf{3,110.00}$
2.3. 2012 (MW)	$3110 + 1,523 = \mathbf{4,633.00}$
2.4. 2013 (MW)	$4633 + 280 = \mathbf{4,913.00}$
2.5. 2014 (MW)	$4913 + 4,075 = \mathbf{5,988.00}$
3. Cost of production and selling price per kWh	
3.1. Production (US\$)	0.027
3.2. Selling price (US\$)	0.031

4. Power purchase plan from Sugar Mills if any:

No formal power purchase plan from sugar mills

5. Feed in tariff plans if any;

NA

6. Costs of grid connections energy tariff per kWh (US\$)

NA

7. Demand and supply of power (MW)

Power(MW)	Short Term	Medium Term	Long Term
Demand	4,433	5,288	6,800
Supply	4,633	5,988	8,000
Export	200	700	1,200

Source: EEPCo

8. Plans to acquire additional energy from different sources other than HEP

8.1. Coal **Not yet**

8.2. Geothermal **5,000 MW**

8.3. Wind **10,000 MW**

8.4. Biomass **Not yet**

8.5. Other **N/A**

9. Electricity Act of the Country:

1. *To run the operation of generation, transmission, distribution and Sell of electric energy.*

2. *Engages in the construction of electricity generation, transmission, distribution and control facilities of varying types and standard including feasibility studies, consultancy, design and survey there of. It may procure local or international consultant from outside in the event of it inability to conduct these activities.*

10 Additional remarks if any:

No additional remarks were given.

Appendix C:

Stakeholders' (Executives') Opinion Survey Interview Schedule on the Alternative Benefits of Bagasse and Cogeneration.

Interview Summaries:

- Have you ever thought of the substance bagasse? If so what is bagasse?
 - ✓ Bagasse is the fibrous material left after the juice (sugar) has been extracted from sugar cane stock either in the milling or diffuser plant.
- If you know about bagasse, what do you think are the alternative uses of bagasse?
 - ✓ Heat and electrical energy generation
 - ✓ Pulp and paper manufacturing
 - ✓ Cheap wood and plain board manufacturing
 - ✓ As a cattle feed
 - ✓ Production of ethanol and others
- Do you know that Bagasse can be used for pulp and paper manufacturing?
 - ✓ Yes
- If your answer is yes, what is the possible reason why there is NO ONE single pulp mill in Ethiopia?
 - ✓ Less bagasse availability from sugar mills
 - ✓ High replacement cost for energy
 - ✓ Lack of strategic consideration
 - ✓ Lack of awareness and poor investment promotion in the sector
 - ✓ The requirement for huge capital investment.
 - ✓ Lack of skilled professionals in the sector
- Do you think that using Bagasse for pulp and paper manufacturing is useful and strategic to Ethiopia?
 - ✓ Yes

- If your answer is yes, what must be done in order for bagasse to be used for pulp and paper manufacturing in Ethiopia?
 - ✓ Using the bagasse from expanded and new sugar plants as a source for pulp and paper production.
 - ✓ Consider the issue as a strategic commitment.
 - ✓ Increase the awareness of stake holders and the government and show the economic and social benefits.
 - ✓ Promote the sector and secure the capital for investment.
 - ✓ Conduct a detail feasibility study to show the economic significances of pulp production from bagasse.

- What do you think are the potential benefits if bagasse is used for pulp and paper manufacturing here in Ethiopia?
 - ✓ Possible to produce short fibre pulp which can be used for paper production of various grades,
 - ✓ Save foreign currency which otherwise would be used to import pulp.
 - ✓ Import substitution, substituting the imported paper by producing it locally.
 - ✓ Satisfy the ever growing demand of paper in the country.
 - ✓ Development in local pulp and paper and chemical industries.
 - ✓ Enhancement of employment opportunity.
 - ✓ Market opportunities for newly emerging strategic and basic chemical industries.
 - ✓ Additional revenues for sugar factories.
 - ✓ Good quality paper with reasonable price will be available to the public.

- Have you ever thought of the concept cogeneration? If so, what is cogeneration?
 - ✓ Producing two kind of energy from one source and be able to take advantage of them.

- ✓ The simultaneous generation of process steam and extra power to the grid/national network.
- Do you think that cogeneration is the only and appropriate mechanism for using or avoiding bagasse in the sugar factories?
 - ✓ No
- If No, Why?
 - ✓ It can also be used for pulp and paper production.
 - ✓ Under our circumstances, it is cheaper to use hydropower than using energy generated from bagasse.
 - ✓ Bagasse can be used for diversified other uses such as pulp and paper.
 - ✓ Power generation from bagasse has no comparative advantage.
 - ✓ Need further research.
- Is using bagasse for pulp and paper manufacturing more feasible and has more multidimensional economic and social benefits than using it for cogeneration?
 - ✓ Yes
- If Yes, why?
 - ✓ Efficient and economic utilization of available resource.
 - ✓ Lower costs of manufacturing
 - ✓ Saving/increasing foreign reserve and enhancing employment opportunity.
 - ✓ The presence of relatively cheaper and abundant hydro electric power potential in the country.
 - ✓ Cheap electric tariff and other dependable energy sources such as wind and geothermal.
- If your answer is No, why?
 - ✓ It depends on whether the benefits from pulp compensate the benefits from cogeneration.

- If your answer is yes, in your opinion, what must be done in order for bagasse to be effectively utilised as an alternative source for pulp manufacturing to be excised here in Ethiopia?
 - ✓ Awareness must be created among the stake holders.
 - ✓ A detailed feasibility study must be conducted in order for the policy makers to make a sound decision.
 - ✓ Government should encourage and incentives private investors so that they can invest in the sector.
 - ✓ Take deliberate policy position to dedicate bagasse for pulp and paper production.
 - ✓ Develop the skill and create more professionals in the sector.
 - ✓ Working in collaboration with foreign investors and facilitate a means to transfer management know how and technology.

- If using bagasse for pulp manufacturing is not as such feasible when compared with using it for cogeneration, what are the potential benefits of cogeneration when compared with other sources of energy in the country?
 - ✓ The difference is based on cost benefit derived from cogeneration and other sources of energy.
 - ✓ Cost of energy in sugar industries in contemporary way is negligible.
 - ✓ If, for instance, cogeneration is substituted by electrical energy, a number of electrical boilers must be erected, more skilled labourers are required to manage the boilers, spare parts for new machines must be stocked and refilled, cost of electrical energy consumption to run the boiler, factory, agriculture and for residence houses requires a huge sum of money every month.

- Who do you think are responsible for effective and economic utilization of bagasse in the country?
 - ✓ The government, as represented by the Ministry of Trade and Industry.
 - ✓ The private investors
 - ✓ The management, that is, the management body of any institution has a great responsibility to use the resources available economically in order to maximize the profit margin and to keep the firm strong in the market field. In fact knowledge is a key factor for wise management of resources and a knowledge gap can increase the blind area in a business transactions. So, regarding bagasse, it is the management who has the right and responsibility to explore various ways, to see which way is adding a better value to the company they are leading and decide the best.

- If you have any comments on important issues that were not covered in the interview schedule and you think are relevant, please mention some of them.
 - ✓ Following the double digit growth in the economy of the country for the last five years the country's paper and paper products demand is expected to increase at a higher rate than before for the coming years.
 - ✓ To satisfy this demand the country has to encourage private and other investors to invest on the pulp and paper production sector.

 - ✓ The country has a great potential to fulfil its demand and even there is a potential to export and generate foreign currency. Therefore, great concern should be given by government to encourage and even to invest itself in establishment of pulp and paper mills that use bagasse as an input

 - ✓ In fact planting trees for pulp takes many decades and our country's geographical situation being in tropical region is not comfortable like

Scandinavian countries. But to think about planting sugar cane or other similar cane or grass plants which require short harvesting time can be a good idea. Such idea seems feasible; because land for agriculture can be easily secured from the prevailing government or plants can be available through business negotiation with farmers union. Capital investment is also open according to Ethiopia's five years plan for development and transformation as such a project is directly related to agriculture.

Appendix D:

Cover Letter for Interview Schedule

“The Economic Significance of Using Bagasse as an Alternative Source of Raw material for Pulp Manufacturing: A case of Ethiopia.”

Date: _____

Participant's Name and
Address: _____

Telephone No: _____

Dear Participant,

The purpose of this research study is to evaluate the economic significance of using Bagasse as an alternative source of raw material for pulp manufacturing and to compare it with the currently undergoing practice, that is, cogeneration. I am doing this study because in countries like Ethiopia where there are abundant and potential energy sources, such as the hydro electric power (HEP), using Bagasse for energy production might not be economically feasible and might be considered as a low value use for a higher value resource.

Enclosed is an interview schedule that I am asking you during the interview session.

Please be assured that all information you provide will be kept strictly confidential. Your name or other identifying information will not appear on any study report – all results from the study will be reported as statistical summaries only.

Do not hesitate to call me office or mobile if you have any questions or concerns about the interview schedule or any aspect of the study. Your participation represents a valuable contribution to this particular research, and I would like to thank you again for your cooperation.

Sincerely Yours,

Demelalsh Tebik Fenta

Ethiopian Pulp and Paper S.C

Production Manager.

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Appendix E: Pulp Prices and Trends in the PPI Markets

<i>Month/Year</i>	<i>Fluff -US southern Kraft to Northern Europe 1</i>	<i>NBSK - Canadian/Nordic to Northern Europe 2</i>	<i>Eucalyptus - to Northern Europe From Brazil and Liberia 2</i>	<i>BCTMP (aspen) - Canadian to Northern Europe 2</i>
	USD	USD	EUR	EUR
	Max	Max	Max	Max
May-08	900	920	540	800
Jun-08	900	920	540	800
Jul-08	930	900	540	800
Aug-08	930	890	540	800
Sep-08	940	860	580	790
Oct-08	930	780	570	690
Nov-08	930	710	520	620
Dec-08	900	670	500	580
Jan-09	850	620	440	520
Feb-09	820	600	425	510
Mar-09	800	580	415	480
Apr-09	770	580	380	450
May-09	770	600	350	460
Jun-09	770	630	360	460
Jul-09	770	660	370	510
Aug-09	770	690	370	540
Sep-09	780	730	410	580
Oct-09	810	760	440	620
Nov-09	830	800	465	660
Dec-09	840	800	476	660
Jan-10	880	830	504	690
Feb-10	895	860	554	690
Mar-10	940	890	578	730
Apr-10	990	940	627	800
May-10	1020	940	870	860
Jun-10	1060	960	900	870
Jul-10	1060	980	900	870
Aug-10	1060	980	870	870
Sep-10	1060	980	870	820

Source: <http://www.risiinfo.com>

Appendix F: Pulp Price Trends Graphical Presentation

