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BIOMASS ENERGY

THE UTILIZATION OF ALTERNATIVE FUELS FOR CEMENT PLANT PYROPROCESSING IN ETHIOPIA: CASE STUDY FOR NATIONAL CEMENT FACTORY

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Executive Summary

More than 40-60% of the production cost to produce cement is due to the fuel used for heat energy required to burn cement raw materials to produce clinker which is also the case in National Cement Plant. Reducing the cost of the major production cost contributor will significantly reduce the production cost of cement which shall put National Cement in a better stand in the current and future Ethiopian cement market's fierce competition. National Cement Share Company is currently using both local coal from Jimma and Imported coal from South Africa which is expensive and foreign currency intensive for its heat energy requirement. In addition to their expensiveness, fossil fuels like coal are believed to have a considerable net Carbon foot print on the environment and are being discouraged worldwide in a bid to fight global warming. Hence taking the above points in consideration National Cement Share Company which has a cement plant with a capacity of 3000ton/day clinker and utilizing 117,000 tons of imported coal annually has initiated an alternative fuel firing project that shall replace 40% of the imported coal by a relatively cheaper and environmentally friendly alternative fuel which can easily be found locally at a reasonable proximity.

Alternative fuels in cement industry are fuels other than the conventional fossil fuels. The conventional fossil fuels include coal, heavy fuel oil, pet-coke and natural gas etc. In Ethiopia, there are different alternative fuels that can be burned in cement plant Pyroprocessing such as Refuse Derived Fuel (RDF) from municipal solid waste, cotton stalk, chat stalk, sesame stalk, used tires, used oil, meat and bone meal (MBM), rice husk and coffee husk. Among the above mentioned alternative fuels, rice husk, sesame husk, MBM have been rejected from the study due to their proximity problem to Diredawa. Chat stalk biomass which can be found in Diredawa, Harer and Aweday towns have been assessed and have been rejected from the study due to its quantity which can only replace 3% of National Cement Plant's heat requirement and due to the fact that the community is using the chat stalk as fuel wood, the same is true with coffee husk.

Refuse Derived Fuel generation from municipal solid wastes from Diredawa and Harar cities have been assessed and based on the data provided by the municipalities of the two cities, in 2013/14 around 20,437 tons of RDF is calculated to be obtained from the municipal solid waste which is expected to cover only 10% of National Cement's heat requirement and is expected to increase to 25,718 tons in 2022/23GC which can only cover 13% of the heat requirement. Therefore for National Cement, it is not worth investing in RDF preparation and Feeding plant as the amount of RDF that can be obtained from the nearby cities (Diredawa and Harar) is very minimal that it can only substitute (10-13%) of the existing heat energy demand.

Unlike the above alternative fuels, ProsopisJuliflora shrub/tree is found abundantly and in relatively close proximity to Diredawa in Afar and Somali regions which are at a distance of 13km (Shinile Zone) and 350-450km(Zone 3 of Afar region), which covers Awash fentale, Amibara, Buremudaytu and Gewane. ProsopisJuliflora is a wild tree/shrub that grows as a weed and it is one of the invasive plant species which is thorny, fast growing, evergreen/semi-evergreen shrub or tree that grows in semi arid areas all over the world,

which produces a large green crown and develops a deep and well-developed lateral root system. Different studies showed that the Prospis juliflora tree has invaded more than 1.1million hectares of land in Zone 3 of Afar region only, 20 million wet tons of ProsopisJuliflora can be obtained from the standing prosopis in Zone 3 of Afar region only which can sustain the supply of biomass fuel for National Cement Plant for more than 100 years on 60% substitution rate or it can sustain the supply of biomass fuel for five similar plants for more than 20 years.

In order to identify the densely Prosopis invaded areas Coverage in Afar and Somali regions and produce detailed map, GIS expert has been hired and has produced the report annexed herein (Annex 16). More than 23,000 hectares of prosopis severely invaded areas(in Zone 3 of Afar region and Shinile Zone of Somali region) have been identified which are suitable for harvesting operation and in a relatively close proximity to Diredawa. Energy value of the prosopis has also been tested in National Cement Plant laboratory. Based on the result, the woody part of the biomass after being dried to 10% moisture content has a calorific value of **4529** kcal/kg which is good and higher than local coal and Ash content of 1.57% which is very low and in favor of smooth operation unlike local coal with higher ash content(more than 40%). Of course the calorific value is expected to decrease down to 4200kcal/kg when the whole biomass including its leaves, branches is being harvested.

Hence due to its availability in significant amount in close proximity to Diredawa, due to its good calorific value and due to the logistics suitability (rail transport from Meiso to Diredawa) and etc, ProsopisJuliflora has been selected as the best alternative fuel for partially substituting the imported coal.

National Cement Share Company is aiming to substitute 40% of the imported coal by ProsopisJuliflora biomass fuel and gradually increase the substitution rate to 60%. For 40% substitution 66,687 dry tons or 100,286 wet tons of ProsopisJuliflora biomass is required annually. This is expected to substitute 46,800 tons of imported coal annually. To obtain the above amount of biomass, around 3761 hectares of land is required permanently on coppicing basis. For 60% substitution, 100,286 dry tons or 150,429 wet tons of ProsopisJuliflora biomass is required and this is expected to substitute 70,200 tons of imported coal annually. To obtain the above biomass amount around 5641 hectares of land is required permanently on coppicing basis. (N.B wet =40%moisture & dry=10% moisture).

Different Prospis Juliflora shrub/tree harvesting and transportation modalities have been assessed thoroughly namely; fully manual method, Semi-manual method, Semi-mechanized method and fully mechanized method. All the above modalities have their own merits and de-merits; and finally the fully mechanized method of harvesting and transportation has been selected to be the best due to its cost effectiveness and its compatibleness with the existing biomass resource area's hot and harsh climatic condition. In the fully mechanized harvesting method all felling(cutting), chipping ,loading to bin and unloading the chipped biomass to tractor trailer is done by one machine (kangaroo type cutter-chipper machine), the chipped biomass shall then be collected at a certain collection center, here at the collection center the chipped biomass shall be fed to the baler by wheel loaders, after passing the baling process, the bales shall be loaded to trucks and then to trains by forklifts and shall be transported to

cement plant for further processing. This system has shorten the harvesting process in such a way that felling, chipping, loading and unloading of the chipped biomass is done by a single kangaroo type cutter-chipper.

The investment cost for (Cutter-Chippers, wheel loaders, forklifts, Tractor trailers and others) required for harvesting, forwarding, baling and transportation operation is estimated to be around 85 million birr.

In the cement plant site, a bale storage is required at least for one month in closed storage and open storage where the storages shall be equipped with fire detection and extinguishing systems, the bales after being un-baled manually shall be fed to a belt conveyor by mini wheel loaders and the bales shall undergo size reduction process by a hammer mill/shredder to get a three dimensional size of 50mm. The shredded biomass shall then be dosed by dosing machines and fed to calciner by bucket elevator, feeding duct and double flap valve with safety shut of valve. The investment cost required for bale storage, conveying system, Size reduction system, dosing system and feeding system is estimated to be around 93 million birr.

The harvesting, baling and transportation operation is expected to create job opportunities to more than 90 skilled and semi skilled person with an overhead cost of 8.6 million birr annually and the whole operation shall be managed by Biomass harvesting, baling and logistics manager. In order to have a smooth and efficient operation, the cutter-chipper operators, maintenance personnel and logistics managers need to be well trained with a skilled technician from the machine supplier at least for one year; in addition to conducting practical training, the skilled technician from the machine supplier need to manage the whole logistics management at least for a year.

The total investment cost of the project is estimated to be around 188 million birr, and its operational cost ranges from 120 million birr/annum in the first year of operation and decreasing annually reaching 78 million in the 10th operational year of operation. And the operational cost per ton also ranges from 1897 birr/ton in the first year of operation and decreasing down annually reaching 1171 birr/ton in the 10th operational year. Annual savings ranges from 61 million birr/annum in year 1 and increasing annually reaching 112 million in the 10th operational year. The project is viable as it gives Net Present Value of 229 million birr and IRR of 42% when discounted with 15%. The project will pay back its investment within 2.34 years which is reasonably very short period of time.

The project's strength has been tested by 20% escalation in operational cost yielding payback period of 2.91 years, NPV of 159 million birr and IRR of 34% and by 20% escalation in Investment cost yielding payback period of 2.79 years, NPV of 191 million birr and IRR of 35% which still shows the strength and viability of the project, moreover the project when tested with both investment and Operational cost escalation by 20% has resulted in Payback period of 3.48 years, NPV of 121 million birr and IRR of 28%. The project shall be even more attractive when rail transport from Awash to Diredawa or Mieso to Diredawa is operational.

The ProsopisJuliflora shrub/tree is shrub/tree which is invading the whole rangeland and grazing land of Afar and Somali regions and is threatening the livelihood of the pastoralist and agro-pastoralist communities of the regions and Hence the Afar National Regional State has issued a regulation to control, manage and eradicate the invasion of Prosopis through utilization, minimization and eradication systems. In line with the regional governments' directive and policies, National cement Share Company is planning to contribute a major role in controlling, managing and eradication program of ProsopisJuliflora through utilization of the biomass for its cement plant thermal requirement in two modalities. In the first modality, National cement shall be responsible for harvesting operation and the regional/federal government shall be responsible for de-rooting operation and make the land ready to the local pastoral community for agriculture or any other economic benefit. In the second modality National cement shall secure a permanent prosopis invaded land which will be fenced and protected from animals,cattle entry; whereby the prosopis biomass can be harvested now and then sustainably and it is also one way of preventing the spread of ProsopisJuliflora.
Therefore upon implementation of this project, the spread of ProsopisJuliflora is prevented in the severely invaded areas whereby National Cement Shall have a Protected and Fenced Land for sustainable biomass supply which is believed to decrease the negative effect of its invasion on the economy and livelihood of the pastoral community. Besides when NCSC, NGO's and the regional governments get involved in the harvesting and de-rooting operation jointly, large productive lands shall be made free of the prosopis shrub and ready for the local pastoral community or private investors which is believed to significantly benefit the economy of the community, the investors and the country as a whole.

A part from this the project is believed to create job opportunities to more than 90 skilled and non skilled employees.
NCSC is currently incurring around 23 million USD for importing coal from South Africa annually. Upon implementing this project, 40% of the above foreign currency (which is around 9 million USD annually) shall be saved from being incurred; and this is believed to ease the foreign currency burden of the Ethiopian Government. In so doing NCSC is utilizing national resources which were previously not useful but rather harmful to the local community. Moreover, up on implementation of this project, the profit/income of National Cement Share Company and its cost competitiveness in the market shall increase due to fuel cost saving which will in effect increase the income tax to the government.

While burning Prospis Juliflora biomass in our Pyroprocessing system the overall emission effect is almost zero since the CO2 emitted after burning the ProsopisJuliflora biomass in our Pyroprocessing will be absorbed back by the ProsopisJuliflora shrub/tree when re-growing again, only there will be CO2 emission from the cuter-chipper harvesters, tractors, loaders, forklifts and trucks fuel usage which is relatively very small and negligible. Therefore around 131,040 tons of CO2 annually shall be saved from being emitted to the environment upon the implementation of this project. Hence this project is believed to play its own role in reducing the main green house gases like CO2 in the environment which are responsible for the current global warming problem. And there is also a possibility for NCSC to earn carbon credit finance by selling the above CO2 emission amount that shall be saved from being emitted.

Utilization of ProsopisJuliflora biomass as an alternative fuel to partially substitute the existing imported coal is expected to benefit the company by cutting its energy costs, the environment by reducing the net CO2 emissions, the society by improving the livelihood of the pastoral community and creating job opportunity and the country and the government as a whole by easing the scarce foreign currency shortage which makes the game Win-Win-Win-Win. It is also believed to help NCSC in its bid to decrease its production cost to be able to be competitive in the fierce Ethiopian cement market where several new entrants are coming forth and existing big cement plants are there. The financial analysis results (IRR=42%, NPV=228,662,780 birr, Payback period =2.34 years) show that the project is viable and even under extreme conditions like increase in investment cost ,increase in operational cost and increase in both operational and investment cost at the same time, the project is strong enough and is worth investing. Therefore it is recommended for National Cement Share Company to invest in this project as fast as possible which shall make the company's financial position strong and firm.

List of Acronyms and Abbreviations

NCSC	National Cement Share Company
RDF	Refuse Derived Fuel
MBM	Meat and Bone Meal
NGO	Non-Governmental Organization
CO2	Carbon Dioxide
IRR	Internal Rate Of Return
B/C	Benefit-Cost Ratio
NPV	Net Present Value

1. BACKGROUND

1.1 Country over View

Ethiopia is a country located in the horn of Africa. It has a land area of about 1.1 million square kilometers and a population of 87.95 million people out of this 44.20 male and 43.75 female, and the annual population growth rate is about 2.7% (CSA, 2014).

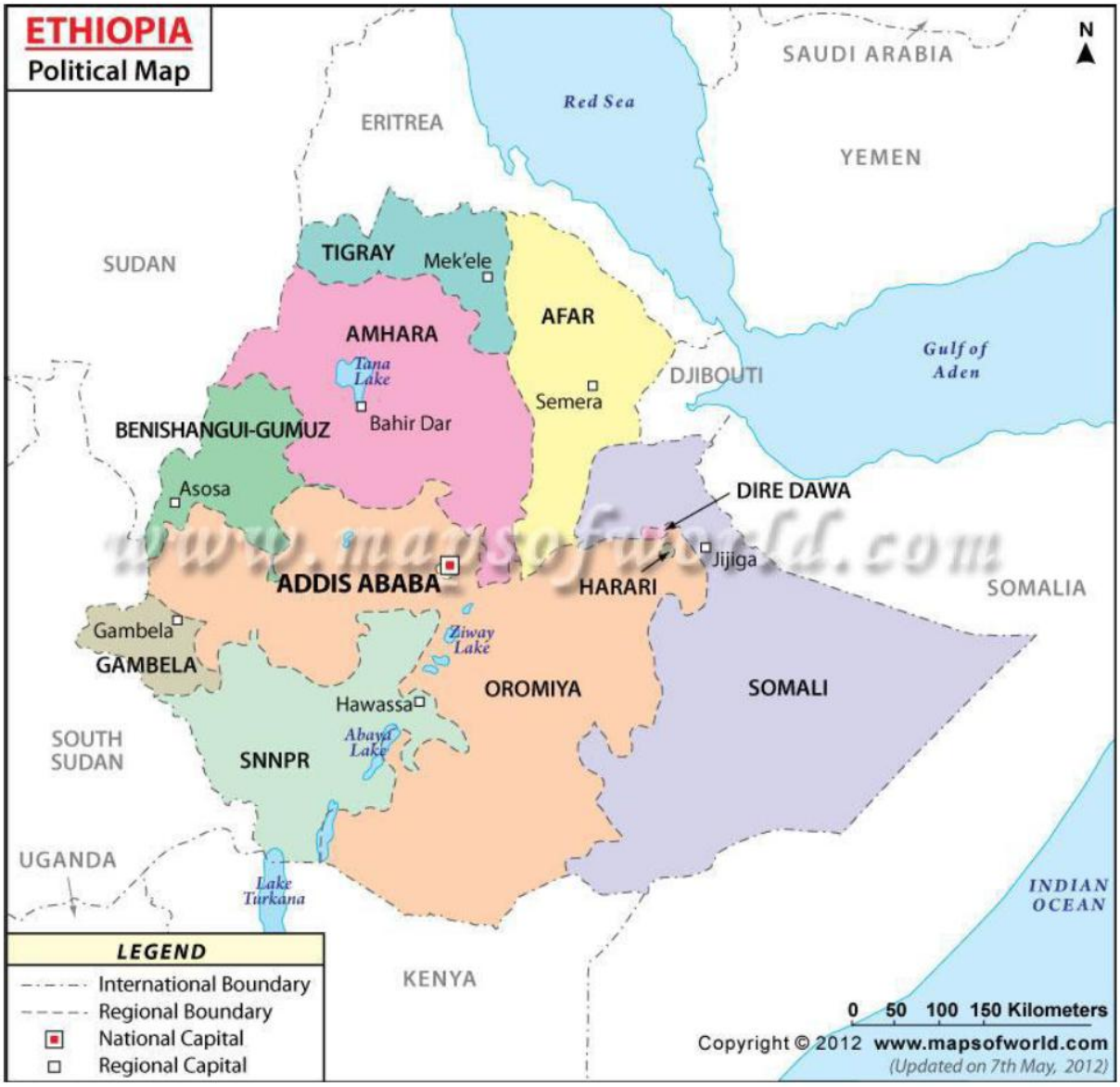

Figure 1:Ethiopia Political Map

Ethiopia has a federal country composed of nine regional states. The country has a bicameral parliamentary system, and government headed by a prime minister. Addis Ababa is the capital of the country, and is the seat of many international and regional organizations, like the African Union, and the UN ECA (Economic Commission for Africa).

The National energy policy of the country emphasizes the need for equitable development of the use of energy in parallel with other social and economic developments. Specific policy lines include the attainment of self-sufficiency through the development of indigenous resources with minimum environmental impact and equitable distribution of electricity in all regions. The policy envisages the development of hydro, geothermal, natural gas, coal, wind and solar energy resources based on their techno-economic viability, social and environmental acceptability.

1.2 Background History National Cement Share Company (NCSC)

National Cement Share Company (NCSC) was established in 2006 by acquiring the state-owned Dire Dawa Lime and Cement Factory, which was originally set up and built in 1936 by the Italians, as the first cement plant in Ethiopia. It was established through a joint venture of East Africa Mining Corporation, the Federal Democratic Republic of Ethiopia's privatization and public enterprises supervising Agency in which 80% share of the factory was owned by East African Mining Corporation, and the 20% was by the government. Over the next few years, government shares were bought out by East African Mining Corporation. Since July 2010, it is a fully privatized company under the share of East African Mining Corporation, &a global partner called the Schulz Global Investment /SGI/ joined the company as foreign investor. Immediately after takeover, the old plant was converted from a long semi-wet manufacturing process to a suspension pre-heater kiln system, and the production capacity was upgraded from the original capacity of 36,000 tons per annum (TPA) to 150,000TPA or 500 TPD. By taking in consideration the increased capacity of the newly inaugurated 3000 TPD plant, Economy of scale and environmental issues influenced the decision to have the old plant mothballed. Currently a project to convert the old plant to a Lime and Gypsum (Plaster of Paris) Plant is on the final stage and will start commercial product soon.

In line with the company's vision and continuous efforts to position itself as a prominent player in the development and industrialization of the country, and to respond to the growing cement demand, NCSC aggressively embarked on the construction of a Greenfield Cement Plant with a capacity of 3,000TPD (1 Million tons Clinker per annum) or 1.4 Million tons Cement per annum& built by Chinese contractor named NHI.

The project started in 2009 and started preliminary operations as of January 2013. Commercial production started on March 1, 2013. The plant is located in Dire Dawa city, 515 km east of the Ethiopian capital, Addis Ababa,at 09.35N latitude and 41.45E longitude near the old plant about six kilometers far from the city center on the Dire Dawa - Addis Ababa highway. Currently, 1287 total number of employees are found and working in the factory. 154 employees are female and the rest 1133 are male workers based on the current employee's data.

The new 3000TPD plant is a Modern Integrated Plant with a Reclaimer-Stacker System to promote Pre-homogenization of raw materials, Raw Grinding VRM, a Coal Grinding VRM, In-Line Calciner (ILC) Kiln, 2 Cement Ball Mills and 4 Rotary Packers each with two

loading bays. Additional features are the facility provisions for Bulk Cement withdrawals. On-going project is also to put a facility for the use of 1 tonner or Jumbo Bags.
Operation and Process Control of the plant is highly automated with the *Advanced Siemens' SIMATIC PCS7 Distributed Control System (DCS).*Primary fuel used is coal, and is now starting to bank on the use of *local coal* from a sister company and then soon with Alternative Fuels. The Quality Control and Laboratory is set up according to EN 197-1 which is equipped with XRF Spectrometer by Panalytical of Philips.

Environmentally, the plant is equipped with the latest Bag house Technology for the Main Waste Gas Stack which can deliver particulates emission below 50 mg per Nm3 of gas. However the company is environmental friendly, the company extends its commitment for corporate social responsibility by contributing one birr from each quintal sales for environmental protection and social development. With regards to Safety Culture and Practices, National Cement had been serious on its implementation, benchmarking the Best Practices from global companies with respect to Behavioral Safety, Safety Standards and Safe Systems of Work. It is the ultimate goal of the company to be fully Integrated Management System Certified (IMS) by 2015.

The major raw material inputs are limestone, clay, gypsum and pumice/rhyolite. Limestone deposit is identified in two sites with a total reserve of 93,728,250 tons which is sufficient for 80 years. Similarly, the amount of reserve for clay, gypsum and pumice is 13,852,800 tons, 2,534,410 tons and 8,698,122 tons sufficient for 28 years, 33 years and 20 years respectively
The total land holding of the 3,000tpd plant is 95.82 hectares held by lease agreement including the limestone mining land with the Diredawa Administration. The lease agreement is effective for 80 years.

National cement share company quarry sites are located in four regional states namely: Dire Dawa Administration, Somali Regional state, Oromia and Amhara regional states. Limestone, clay, weathered Basalt (substitute of Clay) and Rhyoite (substitute of Pumice) are extracted from Dire Dawa administration while Gypsum and weathered basalt are from Somalia regional state and pumice is from both Amhara and Oromiya regional states. See the detail of quarries and exploration sites status in table below. Currently National cement Share Company producing two types of cement namely PPC (Portland PozzlanaCement) and OPC (Ordinary Portland cement).

Generally the company has a capacity to produce 3000 TPD clinker or 40,000 quintal cement per day, in which the annual production is 1.2 mill tons of cement. The company has more than 120 trucks for cement loading and transporting for the outlets and market centers. The company market destinations are all eastern Ethiopia, south & central Ethiopia, and export market in neighboring countries Djibouti & Hargesa and mainly the company is back bone for the state development by providing quality cement with reliable supply for big public development projects like railway project from DebreZeit to Djibouti, condominium house constructions, sport academies, office & business complexes. Generally the company has a capacity to produce 3000 TPD clinker or 40,000 quintal cement per day, in which the annual production is 1.2 mill tons of cement. The company has more than 120 trucks for cement loading and transporting for the outlets and market centers. The company market destinations

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2. Introduction

More than 40-60% of the production cost to produce cement is due to the fuel used for heat energy required to burn cement raw materials to produce clinker which is also the case in National Cement Plant. Reducing the cost of the major production cost contributor will significantly reduce the production cost of cement which shall put National Cement in a better stand in the current and future Ethiopian cement market's fierce competition. National Cement Share Company is currently using both local coal from Jimma and Imported coal from South Africa which is expensive and foreign currency intensive for its heat energy requirement. In addition to their expensiveness, fossil fuels like coal are believed to have a considerable net Carbon foot print on the environment and are being discouraged worldwide in a bid to fight global warming. Hence taking the above points in consideration National Cement Share Company which has a cement plant with a capacity of 3000ton/day clinker and utilizing 117,000 tons of imported coal annually has initiated an alternative fuel firing project that shall replace 40% of the imported coal by a relatively cheaper and environmentally friendly alternative fuel which can easily be found locally at a reasonable proximity.

While burning Prospis Juliflora biomass in Pyroprocessing system the overall emission effect is almost zero since the CO2 emitted after burning the ProsopisJuliflora biomass in Pyroprocessing will be absorbed back by the ProsopisJuliflora shrub/tree when re-growing again, only there will be CO2 emission from the cuter-chipper harvesters, tractors, loaders, forklifts and trucks fuel usage which is relatively very small and negligible. But the Net Life cycle CO2 emission factor for Coal is around 2.8ton of CO2 per ton of Coal. That means in our case annually =117,000tons of coal x 2.8 tons of CO2/ton of coal=327,600 tons of CO2 is being emitted due to burning of coal. When replacing 40% of the coal by carbon neutral ProsopisJuliflora biomass as it is the case in this project, (0.4 x 327,600) =131,040 tons of CO2 annually is saved from being emitted to the environment. Hence this project is believed to play its own role in reducing the main green house gases like CO2 in the environment which are responsible for the current global warming problem. And there is also a possibility for NCSC to earn carbon credit finance by selling the above CO2 emission amount that shall be saved from being emitted.

3. Description of the project

The Proposed Project is found 530 km from Addis Ababa, eastern part of Ethiopia. Diredawa where National Cement Plant is located we shall only focus on the Afar region which is relatively nearer to Diredawa (300-450km). In Afar region, cotton is produced in Amibara wereda (around Melka werer, Melka Sedi),buremudaytu wereda , Dulessa wereda, Gewane wereda and Dubti Wereda. Since Dubti wereda and Gewane are relatively far away from Diredawa, we shall again make our focus on Amibara Wereda, Buremudaytu and dulecha

wereda. According to the data from Agricultural Bureau of Afar region provided to us in 2014 (Annex 16), around 14,000 hectares of land have been covered by cotton plantations in 2003/4 EC; according to experiences from different. Most of the prosopis invasion; more than 1.1 million hectare is around zone 3 of afar region (Amibara, Gewane, Awash Fentale, Bure mudaytu and Gewane). All the above areas are in close proximity to Diredawa; the nearest being Awash Fentale which is only 292 km away from Diredawa and the distant ones Gewane and Bure mudayto which are only 448 km away from Diredawa.

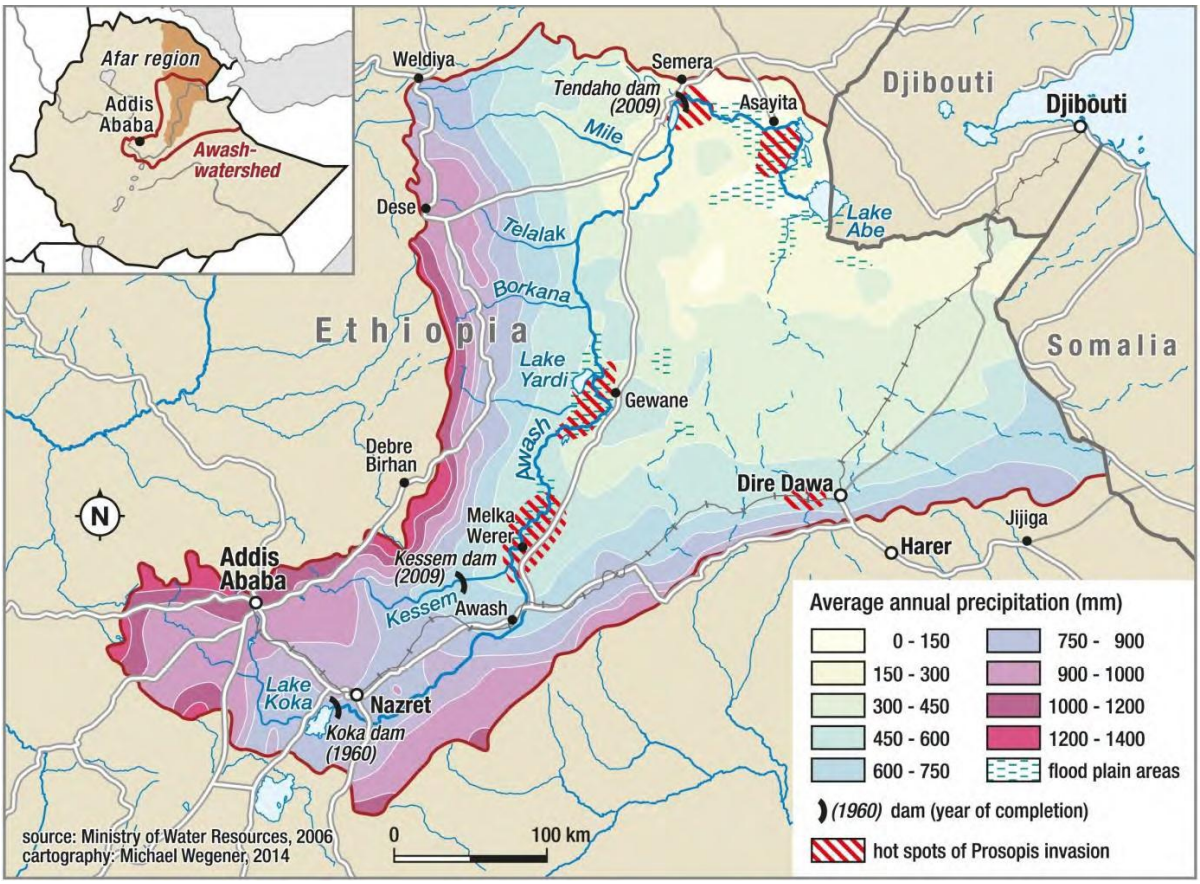

Figure 2:ProsopisJuliflora invaded areas within the Awash Basin

The Proposed Project would include the following elements:

- Cutter -chipper-Collector (AHWI kanagro type harvester)
- Tractor and Trailer
- Wheel loader(mini)
- Fork lift (mini)
- Stationary Baling machine
- Civil engineering cost(collection and Baling Center)
- Big Bag filling machine
- Mobile workshop container

- Mobile Fuel Tanker
- Grinding machine with chipper blade holder
- Used empty 20" container as storage for spare parts

4. Methodology of the study

Different methodologies have been applied to address each objective of this study. Each methodology was selected to undertake this research.

The problem identification involved a literature survey in collecting general information about Prospis Juliflora tree affected area such as geography, climate, population, current condition etc.

A. Available biomass Resources Assessment in the project area

The potential available biomass Resources around Diredawa and surrounding area were assessed. Different types of biomass resource was collected from Diredawa and Harar municipality and other regional state of Ethiopia.
Site visit investigation was conducted to checked the total area covered by Prospis juliflora tree. Moreover; the problem identification involved a literature survey and desktop documents reviewed was conducted .

B. Engineering and Technology Options Identification and Analysis

Different harvesting and transportation options have been assessed and the most appropriate one is selected considering different factors; the most common harvesting and transporting methods practiced all over the world.

C. Conclusion & Recommendation

After detail analysis of the collected data a new alternative solution for NCF. The analysis and Engineering and Technology results was based on its logical relation with inputs the most appropriate one is selected considering different factors; the most common harvesting and transporting methods practiced all over the world and financial and technically feasible option was selected.

5. Biomass resources and data analysis

a. Cotton stalk biomass

In Ethiopia cotton is produced in Afar, Tigray, SNNP, Gambela and Oromiya regions. Afar and Tigray regions are the main cotton producers. Since the other regions are far away from Diredawa where our cement plant is located we shall only focus on the Afar region which is relatively nearer to Diredawa (300-450km).

In Afar region, cotton is produced in Amibara wereda (around Melka werer, Melka Sedi),buremudaytu wereda , Dulessa wereda, Gewane wereda and Dubti Wereda. Since Dubti wereda and Gewane are relatively far away from Diredawa, we shall again make our focus on Amibara Wereda, Buremudaytu and dulecha wereda. According to the data from Agricultural Bureau of Afar region provided to us in 2014 (Annex 16), around 14,000 hectares of land have been covered by cotton plantations in 2003/4 EC; according to experiences from different farms in India and Ethiopia, 3-4 tons of cotton stalks can be obtained per hectare if the land is fed by irrigation & therefore considering the lowest value(3 tons of cotton stalk per hectare of cultivated land), it is estimated that 42,000tons of cotton stalks can be obtained annually; this can only cover around 20% of the annual heat requirement of National Cement Plant's Pyroprocessing. At present, the cotton residues are not utilized but are burnt in the field to control pathogen and insect infestation of the following crops and are then ploughed under

.Hence we can consider cotton stalk as a good candidate for our Alternative Fuel Project although the amount is below NCSC's requirement to replace 40-60% of its coal by an alternative fuel. But it should be noted that the amount may increase or decrease based on the cotton demand and market inside and outside Ethiopia.

b. Chat Stalk/Stem biomass

The availability of chat stalk in Harar, Aweday and Diredawa has been assessed, the amount that could be obtained can only cover around 3% of NCSC's heat requirement; besides the community is using the chat stalk as fuel wood; therefore utilizing the chat stalk for our cement plant may force the community to use the forest wood as fuel wood which could negatively affect the environment. Therefore due to the above reasons, utilizing chat stalk as an alternative fuel at this stage is not feasible.

c. Refuse Derived Fuel(RDF)

Refuse Derived Fuel (RDF) and Sometimes called Solid Recovered Fuel (SRF) is a fuel type which is produced by processing the municipal solid waste (MSW). It is prepared by removing the non-combustible materials like glass, metals etc and also removing the easily bio-degradable wastes like food wastes for compost preparation and sorting out the combustible wastes like plastic, paper, rubber, bones, woody biomass etc.

Refuse Derived Fuel (RDF) is nowadays becoming a popular alternative fuel in different cement plants across Europe, Africa and other continents. In Ethiopia, the RDF that can be obtained from Municipal Solid waste has not been utilized so far although there are some recent moves to utilize the municipal solid waste as energy source to generate electricity in the main capital Addis Ababa.

For the case of National Cement, the RDF (Refuse Derived Fuel) that can be obtained from nearby big cities like Diredawa and Harar has been considered. Based on the data provided by the municipalities of the two cities, it was calculated that in 2013/14GC around 17,097 tons from Diredawa and 3340 tons from Harar which is 20,437 tons of RDF in total can be obtained. This amount is expected to increase in 2022/23GC to around 21,166 tons in Diredawa and to around 4,552 tons in Harar which is 25,718 tons

in total. Considering the Net Calorific Value of the RDF to be 3600kcal/kg, the RDF that can be obtained from both cities (Dirdawa and Harar) in 2013/14GC can only cover 10% of the heat requirement of the Pyroprocessing and in 2022/23GC, it is expected to cover around

13% of the heat required by the National cement plant Pyroprocessing shown in Table 1 below

Table 1:Total RDF amount that can be obtained from Diredawa and Harar Cities

Year(GC)	Total(HH+ Enterprise) RDF in Diredawa	Total (HH+ Enterprise) RDF in Harar	Total (HH+ Enterprise) RDF in Diredawa and Harar (ton/Year)
2013/14	17,097	3,340	20,437
2014/15	17,508	3,457	20,965
2015/16	17,928	3,578	21,506
2016/17	18,358	3,703	22,061
2017/18	18,799	3,833	22,631
2018/19	19,250	3,967	23,217
2019/20	19,712	4,106	23,818
2020/21	20,185	4,249	24,434
2021/22	20,670	4,398	25,068
2022/23	21,166	4,552	25,718

Therefore for National Cement, it is not worth investing in RDF processing and Feeding plant as the amount of RDF that can be obtained from the nearby cities (Diredawa and Harar) is very minimal that it can only substitute (10-13%) of the existing heat energy demand.

d. Used Tires

Used tires do have high calorific value ranging from 7000kcal/kg-8000kcal/Kg. Used tires can be fed to the burning system as whole tire or after being shredded. The availability, price and collection mechanisms shall be studied in the future to be incorporated in the biomass firing plant.

e. ProsopisJuliflora biomass

ProsopisJuliflora is a wild tree/shrub that grows as a weed and it is one of the invasive plant species which is thorny, fast growing, evergreen/semi-evergreen shrub or tree that grows in semi arid areas all over the world, which produces a large green crown and develops a deep and well-developed lateral root system.

ProsopisJuliflora grows as a shrub or tree on average 7 meters and occasionally can reach up to 12 -15 meters in height. It usually has thorns with varying thorn size reaching up to 5 cm. Stems are up to 20 centimeters in diameter.

In afar region the local people call it "Dergi Hara", and in Diredawa and its surrounding it is known by " Yeferenj Biscuit".

Prosopis was introduced to Ethiopia in the 1970s by the Ethiopian Ministry of Agriculture for conservation and shade purposes. It was wrongly introduced to high potential pasturelands and irrigable areas. Local people were not made aware of the invasive nature of the tree and not advised on the management practices to minimize further spread. As a result the shrub rapidly invaded vast areas of agro- and silvo-pastoral lands and affected the biodiversity and socio-economic environment.
Some of the unique characteristics of Prosopis Juliflora are

- It Is drought resistance,
- Withstands adverse growing conditions,
- Adapts to almost all types of soil and widely varying climatic conditions
- Easily invades new regions over great distances (given the ease with which seeds are transported)
- Grows well on both arable and pasture lands.

Merits and de-merits of Prosopis Juliflora in Afar and Somali region

Currently the ProsopisJuliflora is used by the local community for

- Fuel wood and Traditional Charcoal making
- Fencing
- Timber for furniture making
- The seed pods after being milled and mixed with other rations can be used for animal fodder.
- The seed pods after being milled and produce flour can substitute up to 25% wheat, maize or cassava flour in traditional recipes for breads and cakes

According to local communities in afar region, Prosopis invasion has resulted in multiple negative effects on their livelihood and ecology namely;

- Dry season grazing land across the Awash River basin was lost
- Indigenous trees, a significant dry season fodder source, were threatened.
- People and livestock suffer from mechanical injuries from sharp Prosopis thorns.
- Access to roads and watering points were blocked.
- Predator threats to both livestock and humans have increased as predators, such as hyenas, hide in the thicket.
- Livestock feeding on pods exclusively for extended periods, due to lack of pasture, show health problems such as constipation, dental disfiguration and reduced overall productivity
- Agro-pastoralists and private farms spend large amounts of money clearing Prosopis

- Malaria cases were increased due to water pond under the Prosopis tree which created a favorable microclimate for multiplication of mosquitoes in invaded areas.
- The lack of pasture has forced pastoralists to look for other income sources.

Prosopis has many disadvantages and many advantages, some consider it as a blessing and some as a curse and different researchers debate on whether the disadvantage out weights the advantage or vice versa. But Both the Afar regional government and communities declared the invasion a top priority problem and requested for external support to prevent further expansion of the invasion and the restoration of invaded areas. Hence the Afar National Regional State has issued a regulation to control, manage and eradicate the invasion of Prosopis through utilization, minimization, eradication and combination of the above systems.

In terms of coverage, areas most adversely affected nationally include the Afar and Somali Regions in the east and southeast of the country and the area around Dire Dawa City. There are also moderately affected areas in Amhara, Oromia, Southern Nations Nationalities and Peoples (SNNP) and Tigray Regions that is, in the mainly dry lands of Central, East and North Ethiopia.

According to recent studies from Ethiopian Forestry Research Institute, Over 1.1 million hectares of land is invaded by ProsopisJuliflora only in zone 3 of afar region that covers Amibara, Gewane, Awash Fentale, Bure mudaytu and Gewane areas and it is invading some 20 to 50,000 hectares of new land annually. Both the local government and communities declared the invasion a top priority problem and requested for external support to prevent further expansion of the invasion and the restoration of invaded areas.

The quantity of biomass that could be obtained per hectare depends on different factors like soil fertility, moisture and age of the prosopis tree/shrub. Considering experiences from Kenya, India, Namibia, Cuba and physically observing the situation in Ethiopia, we can assume that in Afar and Somali regional states around 40 wet tons of Prosopis Juliflora biomass can be obtained in the densely invaded areas which are shown in the Maps, and (20 wet tons) of Prosospis Juliflroa can be obtained in other areas which are not invaded severely. Considering the lowest biomass per hectare (20wet tons/hectare), it is estimated that more than (1.1 million hectare *20 wet tons/hectare= 22 million wet tones) of Prosopis Juliflora can be obtained from the existing biomass in Zone 3 of Afar regional government only. Moreover it is believed that the Prosopis Juliflora plant re-grows back to its original length within 16-18 months time. This means annually it is possible to obtain (40/1.5) ~ 27 wet tons of Prosopis Juliflora biomass with moisture content of 40% or (27*0.6/0.9) ~ 18 dry tons of Prosopis Juliflora biomass with moisture content of 10% per hectare per annum in the severely invaded areas. This means that from 6000 hectares of densely invaded areas, it is possible to get 162,000 wet tons or 108,000 dry tons of Prosopis Juliflora biomass annually and sustainably. This much amount biomass (108,000 dry tons) is more than enough for 60% replacement of the existing coal by Prosopis Juliflora biomass.

Densely Populated Prosopis Juliflora forest Coverage Study by NCSC

With the objective of

- Knowing the vegetation coverage by "Prosopis Juliflora" tree/shrub around Zone 3 of Afar Region and around Diredawa city.
- Preparing a detailed map of the areas which have been covered by the prosopis tree to be able to estimate the amount of biomass.
- Preparing distance map of the prosopis invaded forest areas from known nearby cities to be able to design economical logistics management.

According to Kenya Forestry research institute, the bulk density of Prosopis Juliflora wood is measured to be around 891 kg/m3 which is very dense but the bulk density of the whole biomass including its leaves and branches after being chipped would be between 200-250 kg/m3.

The woody part of ProsopisJuliflora has high calorific value as can be shown below in the proximate analysis made by Kenya Forestry research institute (Table 2) and National Cement Plant Laboratory (Table3). The calorific value of the whole biomass including its leaves, branches etc is expected to be lower than that of the woody biomass.

Table 2:Proximate Analysis of ProsopisJuliflora Woody Biomass (Kenya Forestry Research Institute)

Moisture Content (%)	Volatile Matter (%)	Ash Content (%)	Fixed Carbon (%)	Calorific Value(Kcal/Kg)
7.3	76.75	1.13	14.82	4952

Table 3:Proximate Analysis of Prosopis Juliflora Woody Biomass (National Cement Plant Laboratory)

Moisture Content (%)	Volatile Matter (%)	Ash Content (%)	Fixed Carbon (%)	Calorific Value(Kcal/Kg)
9.87	72.06	1.57	16.5	4529

As described above most of the prosopis invasion; more than 1.1 million hectare is around zone 3 of afar region (Amibara, Gewane, Awash Fentale, Bure mudaytu and Gewane). All the above areas are in close proximity to Diredawa; the nearest being Awash Fentale which is only 292 km away from Diredawa and the distant ones Gewane and Bure mudayto which are only 448 km away from Diredawa. *(Refer Fig 3). Considering rail transport (150km from Meiso to Diredawa), the total distance shall be even be shorter (between 273 to 420km)*

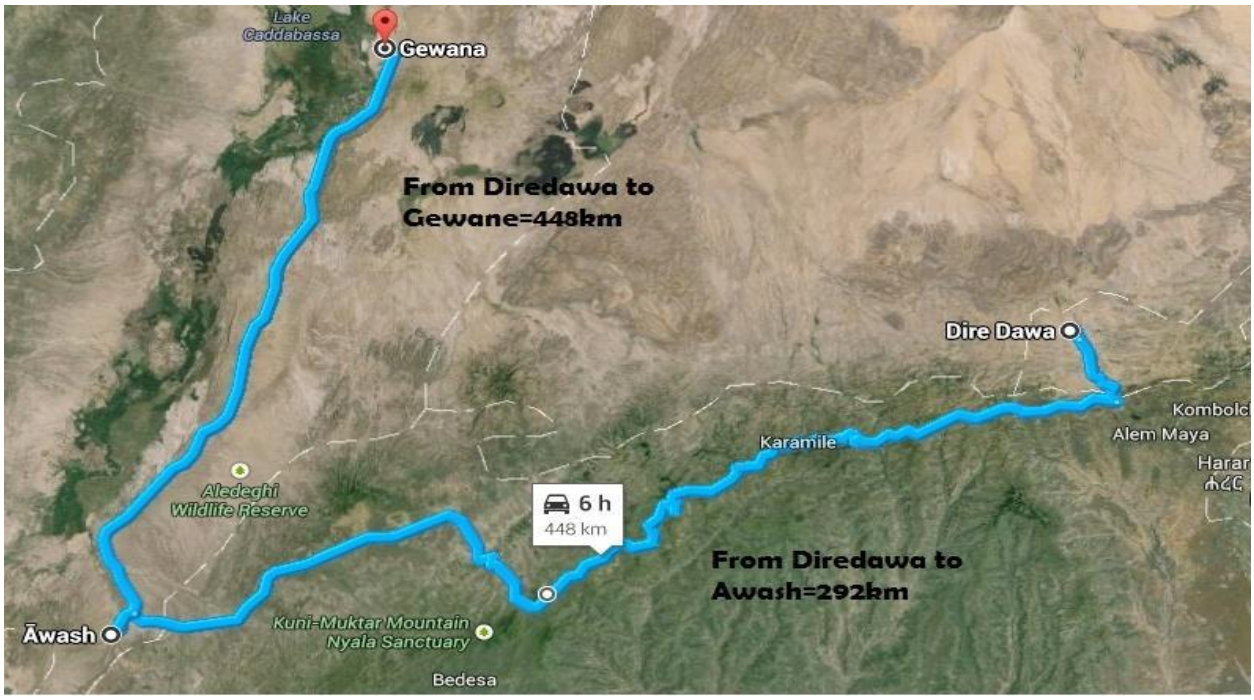

Figure 3:Google Maps that shows the proximity of Zone 3 of Afar to Diredawa

In Somali regional government, there is also considerable area of land invaded by prosopis around Shinile Zone which is 13km away from Diredawa. Please refer annex17; a study report on coverage of prospis juliflora in Afar and Somali regional governments.

Therefore Prosopis Juliflora is considered to be the best candidate alternative fuel for NCSC Pyroprocessing due to its availability, its physical and chemical properties, proximity of the invaded areas to Diredawa and etc. Hence the following chapters shall focus on the utilization of Prosopis Juliflora as an alternative fuel to partially substitute 40% the existing imported South African coal.

6. Technical Analysis

a. Alternative Fuel Firing plant Capacity determination

The following table calculates and summarizes the tonnage of Prosopis Juliflora required, hectare of land covered by Prosopis and tonnage of imported coal and local coal to be replaced at different replacement percentages considering basic data and assumptions as basis for the calculation.

For instance for 40% substitution rate;

$$\frac{(3000\ \text{ton/day} * 300\text{days/annum} * 780\text{kcal/kg} * 0.4)}{4200\text{kcal/kg}} = 66{,}857$$ dry tons of PJ biomass per annum is required.

For 40% substitution rate,

$$\frac{(3000\ \text{ton/day} * 300\text{days/annum} * 780\text{kcal/kg} * 0.4)}{6000\text{kcal/kg}}$$ =46,800 tons of Imported Coal per annum can be replaced

OR

$$\frac{(3000\ \text{ton/day} * 300\text{days/annum} * 780\text{kcal/kg} * 0.4)}{3800\text{kcal/kg}}$$ = 73,895 tons of Local Coal per annum can be replaced

and

$$\frac{(66,857)}{17.78} = \mathbf{3761}$$ hectares of land covered by Prosopis is required.

Table 4:Tonnage of Prosopis Juliflora required, hectares of land required, tonnages of imported coal and local coal to be replaced

Basis for Calculation(Data and Assumptions)					
	Kiln Capacity	*3000*	*ton/day*		
	Running days	*300*	*days/annum*	*Dry Prosopis*	*10*
	Specific Heat Consumption of	*780*	*kcal/kg*	*Wet Prosopis*	*40*
	Calorific Value of Prosopis Juliflora whole dry biomass	*4200*	*kcal/kg*		
	Calorific Value of Imported	*6000*	*kcal/kg*		

	Calorific Value of Local Coal	*3800*	*kcal/kg*		
	Prosopis growth rotation rate	*1.5*	*years*		
	Productivity of Prosopis	*40*	*wet tons/hectare/rotation*		
	Productivity of Prosopis	*26.67*	*wet tons/hectare/year*		
	Productivity of Prosopis	*17.78*	*dry tons/hectare/year*		
	Bulk Density of chipped	*200.00*	*kg/m3*		
Fuel replacement %	**ProsopisJuliflora biomass**	**ProsopisJuliflora biomass (wet tons)**	**Required Hectare of Land covered by Prosopis**	**Equivalent Imported Coal to be replaced**	**Equivalent Local Coal to be replaced**
10%	1	25,071	940	11,700	18,474
20%	3	50,143	1,880	23,400	36,947
30%	**5**	**75,214**	**2,821**	**35,100**	**55,421**
40%	**6**	100,286	3,761	**46,800**	**73,895**
50%	**8**	125,357	4,701	**58,500**	**92,368**
60%	**1**	**150,429**	**5,641**	**70,200**	**110,842**
70%	1	175,500	6,581	81,900	129,316
80%	1	200,571	7,521	93,600	147,789
90%	1	225,643	8,462	105,300	166,263
100%	1	250,714	9,402	117,000	184,737

b. Technologies and Engineering required in /near the biomass farm

i. Selection of Harvesting technologies ,Economic transport logistics design for the Prosopis Juliflora biomass

Different harvesting and transportation options have been assessed and the most appropriate one is selected considering different factors; the most common harvesting and transporting methods practiced all over the world are as follows;

Option A: Fully Manual Method: In this method the process chain (flow) is as below; Manual Cutting of the Prosopis tree using axes, trimming the tree manually and collect the stem (woody) part of the biomass manually, transport it by community animals (donkey,

camels) to collection center, load the tree after cutting it into some 1m length, load it to truck and transport to the cement plant. The above process flow can be summarized in the following process flow diagram.

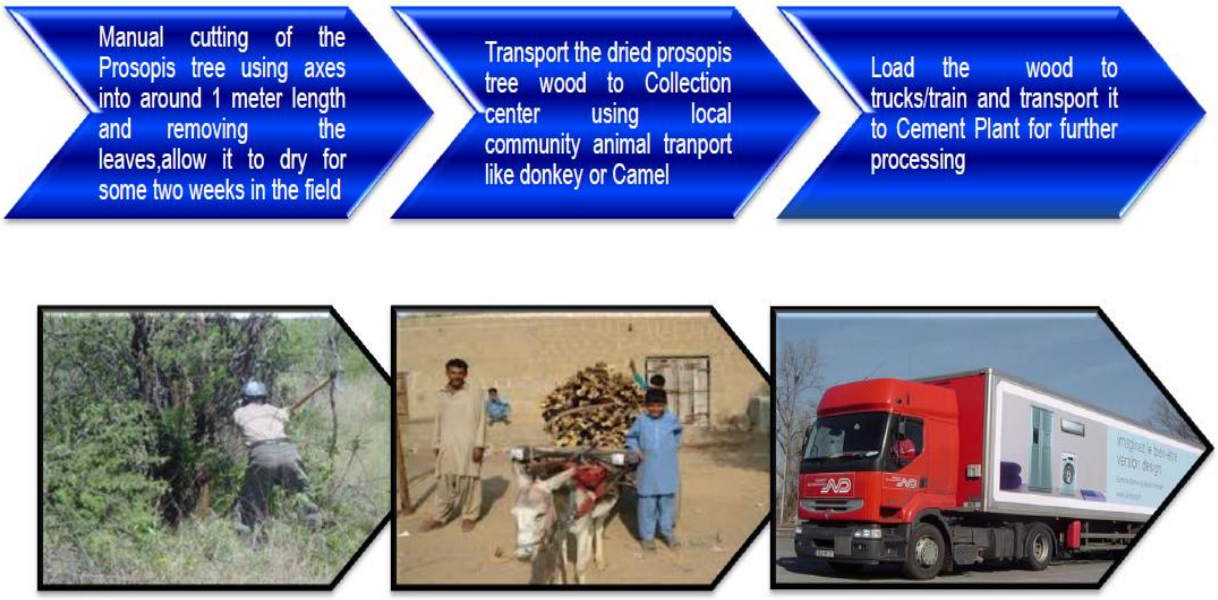

Figure 4:Process Flow Diagram for the Fully Manual Method of Harvesting and Transportation

The advantage of this system is:

- As can be clearly seen in the process chain (flow) diagram of the fully manual system of harvesting and transporting, it is going to involve many labor forces in cutting the trees, in loading to tractor trailer and transporting it to collection center and in loading to trucks; hence this mode of harvesting and transporting is expected to create job opportunities to more than 1000 people.
- ProsopisJuliflora forest areas found in gorges and non-plain field which are difficult to be accessed by machines can be easily accessed by human being and get harvested.
- The soil is not disturbed while harvesting
- The investment cost is the lowest of all the systems indicated here in this document.
- Selective harvesting of the ProsopisJuliflora bush only can be done easily which protects the native trees from being cut.

The disadvantage of this system is:

- The productivity of this system is very low as it depends on the productivity of persons.
- Because of the thorny nature of the Prosopis Juliflora, the harvesting job is very difficult and challenging.

- Because of the hot temperature in the harvesting areas, it will be a big challenge for human beings to work at day time exposed to sunlight and hot temperature; besides possibility of being bitten by snakes is there which makes the harvesting operation challenging and complicated.
- The operation cost of this system is the highest of all the options mentioned below(Option B, C and D)

Because of the above difficulty and challenges (labor productivity by nature is lower than machines, extreme temperature, the thorny nature of the prosopis, possibility to be bitten by snakes etc), the total productivity of the system shall be lower than mechanized or semi-mechanized systems which makes this system not efficient economically and not recommended for large scale operations like ours although it has its own advantages as mentioned above.

Option B: **Semi-Manual Method**: Manually Cutting the ProsopisJuliflora tree using manually operated machines like chainsaw or brush cutter, allow the felled tree to dry for some two weeks, collect the felled biomass and feed it to the mobile chipper, chip the tree by the mobile chipper and transport it to collection center; The biomass chips shall be fed to a baler by wheel loader and the baled biomass shall be loaded to truck by forklift and finally it shall be transported to cement plant for further processing.

The above process flow can be summarized in the following process flow diagram

Figure 5:Process Flow Diagram for Semi-Manual Method of harvesting, baling and transportation

The advantage of this system is:

- As can be clearly seen on the process chain(flow) diagram, this method takes relatively less number of labor as compared to option A; but still the cutting operation, loading the cut biomass into tractor trailer, feeding the chipper require a direct labor involvement and is expected to create some job opportunities.

- As compared to option A, the productivity is better as it is using better cutting tools(chainsaw, brush cutter), better transport mechanism(Tractor),better biomass handling processes(chipping and baling)
- ProsopisJuliflora forest areas found in gorges and non-plain field which are difficult to be accessed by machines can be easily accessed by human being and get harvested.
- The soil is not disturbed while harvesting
- The investment cost is very low in comparison to fully mechanized and Semi-mechanized systems
- Selective harvesting of the ProsopisJuliflora bush only can be done easily which protects the native trees from being cut.
- The operation cost is lower than Option A

The disadvantage of this system is:

- The productivity of this system is very low as compared to fully mechanized and semi-mechanized systems.
- Because of the thorny nature of the ProsopisJuliflora, the harvesting job is very difficult and challenging although the challenge is a little bit better than the fully manual system.
- Because of the hot temperature in the harvesting areas, it will be a big challenge for human beings to work at day time exposed to sunlight and hot temperature; besides possibility of being bitten by snakes is there which makes the harvesting operation challenging and complicated.
- The operation cost is higher than Option C and D

In conclusion although this system is better than option A (fully manual method), it still suffers from low productivity and hence it is not recommended for high scale harvesting and transporting Operations like ours.

Option C: Semi-mechanized Method: In this method skid steers are used to fell the tree, the felled Prosopis tree shall be collected and stored manually by laborers and shall be fed to a mobile chipper, the chipped biomass shall then be collected at a certain collection center, here at the collection center the chipped biomass shall be fed to the baler by wheel loaders, after passing the baling process, the bales shall be loaded to trucks by forklifts and shall be transported to cement plant for further processing. This system except the first felling process which is done by skid steer machine, the remaining step is the same with Option B (Semi-manual method).

Figure 6:Process Flow Diagram for Semi-Mechanized way of Harvesting, Baling and Transportation

The advantage of this system is;

- Productivity of this system is better as compared to option A and B since it is using Skid steer machine for felling the trees
- The thorny nature of the Prosopis, the possibility of being bitten by snakes is not a challenge for this method as it uses advanced skid steer machines for harvesting operation.
- The skid steer machine operator can have a good air conditioned environment inside his cabin and can work effectively.
- The investment cost is lower than Option D below
- The operation cost is relatively lower than Option A and B

The disadvantage of this system is:

- The productivity of this system is lower as compared to Option D (fully mechanized) as it still involves man power higher in number than fully mechanized system (Option D) but less man power as compared to Option A and B.
- The soil is more disturbed by skid steer machine than option A and B while harvesting
- Selective harvesting is not as easy as Option A and B.
- It involves less number of human labor than Option A and B and hence less job opportunity.
- The investment cost is relatively higher than Option A and B
- The operation cost is relatively higher than Option D

In conclusion we can say that this system is better than option A and B in productivity although it creates less number of employment opportunity than Option A and B and hence this kind of system can be considered as a good method of harvesting for large scale operations like our project.

Option D: Fully mechanized Method: In this method all felling(cutting), chipping ,loading to bin and unloading the chipped biomass to tractor trailer is done by kangaroo type cutter-chipper machine, the chipped biomass shall then be collected at a certain collection center, here at the collection center the chipped biomass shall be fed to the baler by wheel loaders, after passing the baling process, the bales shall be loaded to trucks by forklifts and shall be transported to cement plant for further processing. This system has shorten the harvesting process in such a way that felling, chipping, loading and unloading of the chipped biomass is done by a single kangaroo type cutter-chipper.

The above process flow can be summarized in the following process flow diagram

Figure 7:Process Flow Diagram for Fully Mechanized System of Harvesting, Baling and Transportation

The advantage of this system is;

- Productivity of this system is superior to all the harvesting options mentioned above(Option A, Option B, Option C)
- The thorny nature of the Prosopis, the possibility of being bitten by snakes is not a challenge for this method as it uses advanced kanagaro type cutter-chipper-collector
- The cutter-chipper-collector operator can have a good air conditioned environment inside his cabin and can work effectively.

- The operation cost of this system is lowest of all the above options (Option A, Option B, Option C)

The disadvantage of this system is:

- The soil is more disturbed by cutter-chipper as compared to option A,B and C
- Selective harvesting is not as easy as Option A and B.
- It involves less number of human labor as compared to Option A, B and C and hence less job opportunity.
- The investment cost is relatively the highest of all the other options mentioned above (Option A, Option B and Option C).

In conclusion we can say that this system is the best since it has the highest productivity and the lowest overall operation cost as compared to the other options (A,B and C) although it creates the smallest number of employment opportunity than the remaining options(A,B,C). Hence this kind of system can be considered as the best and appropriate method of harvesting for large scale operations like our project.

N.B. Baling is required in order to decrease the transport cost of the biomass from biomass site to Diredawa which is in the range of 350-450km. However if it is always the case to get enough empty trucks of National cement returning from Nazareth or Addis on their way back to Diredawa, there is no need to have baling operation; the chipped biomass can be transported after being packed by big bags which requires relatively less investment and technology. So in order not to be standstill when the baling system fails, the big bag filling system is incorporated as an option as it only requires filling funnels which can easily be made locally. Therefore, the investment cost shall include both the baling system and the bag filling system.

6.1 Proposed Equipment, machineries, manpower requirement and their respective investment cost for the project

The following machineries and equipments are required and their respective investment cost is also included in the following table for 40% substitution rate.

Table 5:Harvesting, Baling and Transportation Operation Investment Cost

A. Harvesting ,baling and Transportation Operation(Biomass Site)						
S.No	Equipment Name	Capacity	Qty	Unit Price(birr)	Total Price(Birr)	source
1	Cutter -chipper-Collector (AHWI	11 wet ton /hour, bin storage capacity is	4	14,560,000	58,240,000	Prinoth-AHWI

2	Tractor and Trailer	Trailer volume 50m3	8	1,285,000	10,280,000	Alibaba quotation
3	Wheel loader(mini)	Bucket volume 1.5m3	3	650,000	1,950,000	Alibaba
4	Fork lift (mini)	1 ton	2	650,000	1,300,000	Alibaba
5	Stationary Baling	10t/h	3	1,060,000	3,180,000	Alibaba
6	Civil engineering cost(collection and Baling Center)		1	200,000	200,000	Estimation
7	Erection/Installation cost for the		1	200,000	200,000	Estimation
8	Big Bag filling machine	30t/h	1	150,000	150,000	Estimation
9	Mobile workshop container		1	1,059,552	1,059,552	Prinoth-AHWI quotation
10	Mobile Fuel Tanker	5000liter	1	400,000	400,000	
11	Wear and Spare part		1	6,156,722	6,156,722	Prinoth-AHWI quotation
12	Grinding machine with chipper blade holder		1	403,000	403,000	Prinoth-AHWI quotation
13	Used empty 20" container as storage for spare		1	91,000	91,000	Prinoth-AHWI
14	Pickup double cabin		2	750,000	1,500,000	
15	Minibus car 12 seat		1	300,000	300,000	
16	Office furniture and		1	45,000	45,000	
17	Walky Talky Radios		10	10,000	100,000	
	Grand Total A				***85,555,274***	

Machineries and Equipments required in the Cement Plant Facility

In the cement plant site, a bale storage is required at least for one month in clothed storage and open storage where the storages shall be equipped with fire detection and extinguishing systems, the bales after being unbaled manually shall be fed to a belt conveyor by mini wheel loaders and the bales shall undergo size reduction process by a hammer mill/shredder to get a three dimensional size of 50mm. The shredded biomass shall then be dosed by dosing machines and fed to calciner by bucket elevator, feeding duct and double flap valve with safety shut of valve.

The following machineries and equipments are required and their respective investment cost is also included in the following table for 60% substitution rate.(N.B here the cement plant machineries are designed for 60% substitution rate as there is a plan to gradually increase from 40% and reach to 60% substitution).

Table 6:Bale Storage, Size reduction, Dosing and Feeding Operation Investment Cost

B. Bale storage, size reduction, dosing and feeding Operation(Plant Site)				
S.No	Item description	qty	Unit price(birr)	Total Price(birr)
1	Bale Storage	1	4,000,000	4,000,000
2	Fork lift (for bale unloading)	1	650,000	650,000
3	Transportation system	1	15,000,000	15,000,000
4	Bale size reduction system	1	50,000,000	50,000,000
5	Biomass Dosing System	1	5,000,000	5,000,000
6	Biomass Feeding System	1	4,000,000	4,000,000
7	Civil engineering cost	1	4,000,000	4,000,000
8	Control and automation/instrumentation	1	4,000,000	4,000,000
9	Erection/Installation	1	4,000,000	4,000,000
10	Test and Commissioning	1	2,000,000	2,000,000
	Grand Total B			**92,650,000**

The process flow diagram of the whole process from harvesting to feeding to the calciner burner is shown in the schematic diagram below.

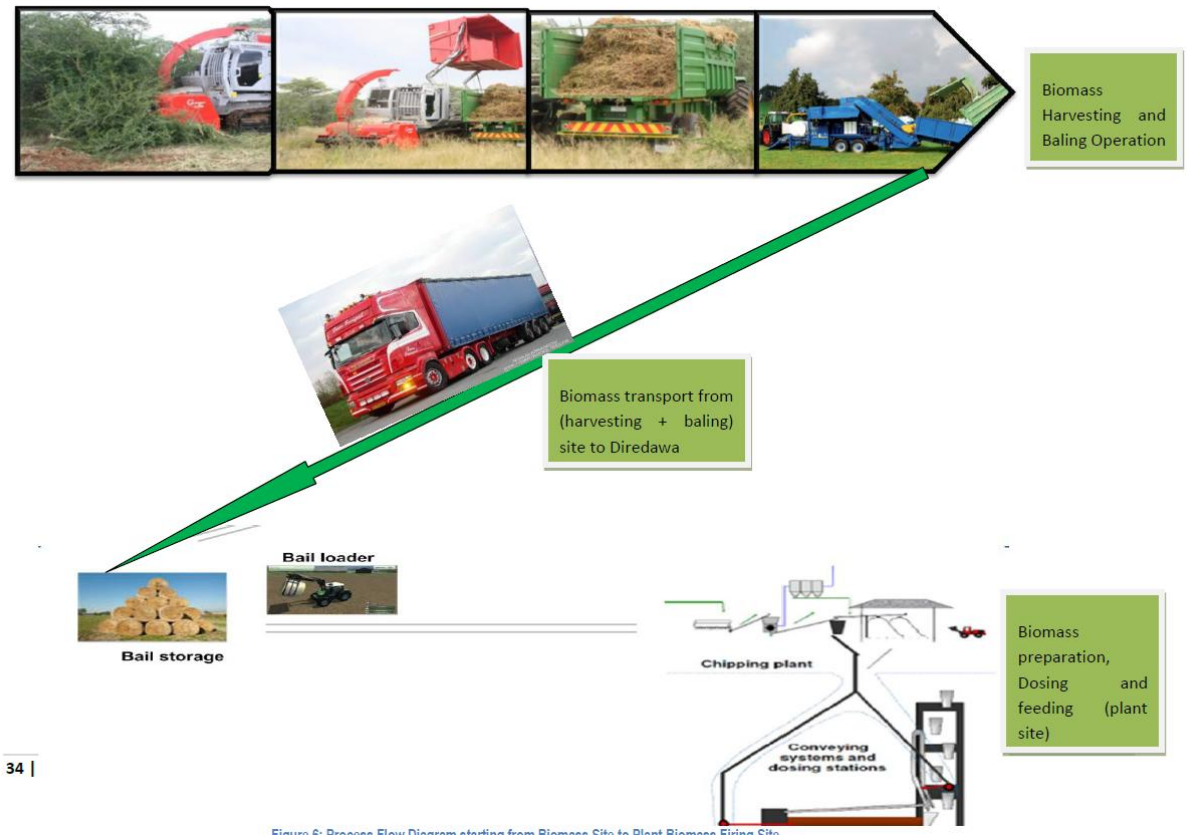

Figure 8:Process Flow Diagram starting from Biomass Site to Plant Biomass Firing Site

Manpower requirement and related costs

Total human resource requirement for the operation of the plant is around 90. The manpower requirement and its related salary and wage costs are shown below;

Table 7:Manpower requirement and Related Costs

Job Title	Qty	Monthly Salary (birr)	Total Annual Salary (Birr)	Remark
Cutter-Chipper Operator	8	8,000	768,000	2 person per one machine
Tractor-Trailor Operator	16	4,000	768,000	2 person per one machine
Baling machine Operator	6	4,000	24,000	2 person per one machine
Maintenance Mechanic	8	6,000	576,000	2 per each harvester and related machines
Electrician	8	6,000	576,000	2 per each harvester and related machines
Maintenance Engineer	4	20,000	960,000	1 per each harvester and related machines
Wheel loader Operator	6	4,000	288,000	2 persons per one machine
Forklift Operator	4	4,000	192,000	2 persons per one machine
Guard	12	1,500	216,000	at harvesting, collection/baling and train bale storage
Harvesting Site Coordinators	4	5,000	240,000	1 for each harvester and related machines
Collection and baling center coordinators	2	4,000	96,000	2 persons per site
Biomass Harvesting ,Baling and logistics Manager	1	25,000	300,000	1 person for all operation
Secretary	1	4000	48,000	1 person for all operation
Finance and Administration manager	1	15,000	180,000	1 person for all operation
Cashier	1	3,000	36,000	1 person for all operation
Accountant	1	5,000	60,000	
Fuel Man	2	3,000	72,000	2 for the whole operation
Store man	1	3,000	36,000	1 person for the whole operation
Translator	1	2,000	24,000	1 person for the whole operation
Car driver	3	3,000	108,000	1 person for each car
Pension			501,120	9% is assumed
Medical expenses			55,680	1% is assumed
Safety clothes ,shoes and sun protecting hats			234,000	
Hardship (Kolla) allowance			2,227,200	40% is assumed
Grand Total -D	90		**8,586,000**	

Training requirement and related costs

As the harvesting machines are new in kind for our country, the local operators and maintenance personals should be well trained; therefore the trainings shown below shall be given with the given cost.

Table 8:Training Cost

	Training Topic	Birr
1	Training(skill transfer) and harvesting operation logistics management for one year	3,744,000
2	Biomass preparation and feeding System(local training)	200,000
	Grand Total C	**3,944,000**

7. Financial Analysis

7.1. Assumptions are made for the financial analysis

The following assumptions are made for the financial analysis;

- **Plant Life**: Construction period of the project shall not exceed 1 year (which is estimated to be 7 -9months) starting from machine suppliers/EPC contractors selection and contract agreement to final test and commissioning. For the calculation of the financial analysis 10 years plant operational life is considered which means the costs and benefits are calculated for 11 consecutive years.

Depreciation : the following depreciation rates are applied to depreciate the assets of the project:

- Buildings and associated Civil works : 5% and in straight line method
- Plant and Machinery : 20% and using declining balance method
- Vehicles and harvesting machineries: 20% and using declining balance method
- Office furniture and equipments: 20% and using declining balance method.
- Pre-production Expenditure: 10% and in straight line method

- **Working Capital:** As this project is a project aiming to substitute some 40% of the existing coal by biomass fuel, no new working capital is required; it only requires shifting some of the working capital from the coal procurement.

- **Discounting:** The total investment and equity capital of the project are discounted at 15 per cent over the life of the project.

- **Source of Finance:** The initial total investment cost is envisaged to be covered 30% by equity and 70% by bank loan. The type of loan is further assumed to be a constant principal bank loan, with a loan repayment period of 5 years after starting operation. One year for construction of the plant is considered as grace period; the annual interest rate including the various fees is taken to be 12%.

- **Capacity of the plant: The** plant shall operate at 95% of its capacity in the 1st year and 100% from 2nd year onwards.

7.2. Financial Results and Analysis

a. Investment cost estimation

The total investment cost is summarized as below in two ways;

Table 9:Total Investment Cost of the project

Total Investment Cost		
S.No	Cost Item	Cost(Birr)
A	Harvesting and Transportation Operation(Biomass Site)	85,555,274
B	Bale storage, size reduction, dosing and feeding Operation(Plant Site)	92,650,000
C	Training Cost	3,944,000
D	Project Implementation Cost	1,824,780
E	Consultancy and study Costs	450,000
F	Freight and Inland transport Cost	3,101,476
	Total Investment Cost	187,525,530

	Total Investment Cost	
S.No	Cost Item	Cost(Birr)
1	Pre-production Cost	11,320,256
2	Fixed capital Costs	176,205,274
3	Working Capital Costs	0
	Total	187,525,530

b. Operational Cost Estimation

The operational cost of the harvesting, baling and transportation operation includes costs for fuel, lubricants, maintenance, transport, interest costs, insurance costs. The interest cost is calculated as per the following assumptions and disbursement schedules

Table 10:Capital Expenditure Finance Source

Capital Expenditure Finance Source			
S.No.	**Source**	**Amount (Birr)**	**Percentage Share (%)**
1	Equity	56,257,659	30%
2	Debt	131,267,871	70%
	Total	187,525,530	

Table 11:Loan Disbursement Schedule

Loan disbursement Schedule				
Year	Disbursement	Repayment	Debt Balance	Interest Payable
0	131,267,871.00	0	131,267,871.00	0
1	0	26,253,574.20	105,014,296.80	15,752,145
2	0	26,253,574.20	78,760,722.60	12,601,716
3	0	26,253,574.20	52,507,148.40	9,451,287
4	0	26,253,574.20	26,253,574.20	6,300,858
5	0	26,253,574.20	0	3,150,429
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0
Total	**131,267,871.00**	**131,267,871.00**	**0**	**47,256,433.56**

The operational cost of the harvesting, baling and transportation operation ranges from 120 million birr/annum in the first year of operation and decreasing down yearly and reaching 78 million in the 10th operational year. And the operational cost per ton also ranges from 1897 birr/ton in the first year of operation and decreasing down yearly reaching 1171 birr/ton in the 10th operational year.
The summarized annualized operational cost is depicted here in Table15 below.

Table 12:Summary of Operational Costs for the whole operation (Harvesting, Baling and Transportation)

Year	Harvesting and Baling Operation Cost(Birr/annum)	Transportation Cost (Birr/annum)	Land lease Cost (Birr/annum)	Manpower overhead Cost (Birr/annum)	Stationary and Telephone costs (Birr/annum)	Depreciation Costs (Birr/annum)	Financial Costs (Birr/annum)	Total Operational Costs without depreciation (Birr/annum)	Total Operational Costs including depreciation (Birr/annum)	Cost per ton including depreciation (Birr/ton)	Capacity
0	0	0	0	0	0	0	0	0	0	0	0
1	27,728,805	32,178,739	1,071,804	8,586,000	22,420	35,143,080	15,752,145	85,339,913	120,482,993	1,897	95%
2	29,188,216	33,872,357	1,128,214	8,586,000	23,600	28,422,869	12,601,716	85,400,105	113,822,972	1,702	100%
3	29,188,216	33,872,357	1,128,214	8,586,000	23,600	23,046,701	9,451,287	82,249,677	105,296,375	1,575	100%
4	29,188,216	33,872,357	1,128,214	8,586,000	23,600	18,745,766	6,300,858	79,099,249	97,845,011	1,463	100%
5	29,188,216	33,872,357	1,128,214	8,586,000	23,600	15,305,018	3,150,429	75,948,821	91,253,834	1,365	100%
6	29,188,216	33,872,357	1,128,214	8,586,000	23,600	12,552,419	0	72,798,393	85,350,806	1,277	100%
7	29,188,216	33,872,357	1,128,214	8,586,000	23,600	10,350,341	0	72,798,394	83,148,728	1,244	100%
8	29,188,216	33,872,357	1,128,214	8,586,000	23,600	8,588,678	0	72,798,395	81,387,065	1,217	100%
9	29,188,216	33,872,357	1,128,214	8,586,000	23,600	5,770,017	0	72,798,396	78,568,404	1,175	100%
10	29,188,216	33,872,357	1,128,214	8,586,000	23,600	5,488,151	0	72,798,397	78,286,538	1,171	100%

7.2.1 Cost Benefit analysis, Payback period, IRR,NPV(*South Africa Coal vs Prosopis Juliflora*)

Cost Benefit Analysis and Payback Period The cost of imported coal at Diredawa Cement factory gate (which includes purchasing price, freight and inland transport, loading and unloading) is around 4073 birr per ton having calorific value of 6000kcal/kg; And considering 4200kcal/kg calorific value of Prosopis Juliflora biomass and gate price of this biomass ranging from 1897 birr/ton in the first year and decreasing yearly reaching 1171 birr/ton in the 10th operational year, the cost benefit analysis is shown in the following tables (Table 13 and Table 14).

Table 13:Cost Benefit analysis of Replacing 40% South African Coal by ProsopisJ uliflora Biomass(Basis)

Cost Benefit Analysis of Replacing 40% of south african coal by Prosopis Juliflora						
S.No	Type of fuel	Avg.Calorific Value kcal/kg	Cost of fuel (Birr/ Ton)	Annual Fuel requirement for 100% replacement (tons)	Annual Fuel requirement for 40% replacement (tons)	Cost for 40% (birr/annum)
1	South African Coal	6000	4073.95	117,000	46,800	190,660,860
2	Local Coal	3800	2403.95	184,737	73,895	177,639,253
3	Prosopis Juliflora biomass	4200	refer the annual cost	167,143	66,857	refer the annual cost

Table 17: Cost Benefit Analysis of Replacing 40% South African Coal by Prosopis Juliflora Biomass (Annualized Comparison)

Table 14:Cost Benefit Analysis of Replacing 40% South African Coal by Prosopis Juliflora Biomass (Annualized Comparison)

Year	Annual South African Coal Cost (Birr/annum)	Annual Prosopis Juliflora Biomass Cost (Birr/annum)	Annual Saving (Birr/annum)	Depreciation (Birr/annum)	Income tax	Net Cash Flow (Birr)	Accumulated Cash Flow(Birr)	Capacity
0	0	0	0	0	0	(187,525,530)	0	0
1	181,127,817	120,482,993	60,644,824	35,143,080	(18,193,447)	77,594,457	77,594,457	95%
2	190,660,860	113,822,972	76,837,888	28,422,869	(23,051,366)	82,209,391	159,803,848	100%
3	190,660,860	105,296,375	85,364,485	23,046,701	(25,609,346)	82,801,840	242,605,689	100%
4	190,660,860	97,845,011	92,815,849	18,745,766	(27,844,755)	83,716,860	326,322,549	100%
5	190,660,860	91,253,834	99,407,026	15,305,018	(29,822,108)	84,889,936	411,212,485	100%
6	190,660,860	85,350,806	105,310,054	12,552,419	(31,593,016)	86,269,457	497,481,942	100%
7	190,660,860	83,148,728	107,512,132	10,350,341	(32,253,640)	85,608,833	583,090,775	100%
8	190,660,860	81,387,065	109,273,795	8,588,678	(32,782,139)	85,080,334	668,171,109	100%
9	190,660,860	78,568,404	112,092,456	5,770,017	(33,627,737)	84,234,736	752,405,845	100%
10	190,660,860	78,286,538	112,374,322	5,488,151	(33,712,297)	84,150,176	836,556,021	100%
	Payback Period				2.34	Years		

From the above table 14, we can see that the annual saving ranges from 61 million birr in year 1 and increasing annually and reaching 112 million birr in the tenth year of operation, the initial investment value 188 million birr lies between 160 million of year 2 and 243 million of year 3 which when extrapolated will be around 2.34 years. Therefore we can say that this project shall return its investment within 2.34 years which can be regarded as a quick return.

Internal rate of Return and Net present Value ***The internal rate of return (IRR)*** is the annualized effective compounded return rate that can be earned on the invested capital, i.e., the yield on the investment. Or in other words, the internal rate of return for an investment is the discount rate that makes the net present value of the investment's income stream total to zero. It is an indicator of the efficiency or quality of an investment. A project is a good investment proposition if its IRR is greater than the rate of return that could be earned by alternate investments or putting the money in a bank account. Accordingly, the IRR of this project is computed to be **42%** indicating the viability of the project. ; This is clearly shown on Table-18 below.

Table 15:Internal Rate of Return (IRR) and Net Present Value (NPV) Calculation

			Discounting rate	15%
Year	Capacity	Net Cash Flow(Birr)	Discounting Factor (@15%)	Discounted Cash Flow (Birr)
0	0%	(187,525,530)	1.0000	(187,525,530)
1	95%	77,594,457	0.8696	67,473,441
2	100%	82,209,391	0.7561	62,162,110
3	100%	82,801,840	0.6575	54,443,554
4	100%	83,716,860	0.5718	47,865,387
5	100%	84,889,936	0.4972	42,205,301
6	100%	86,269,457	0.4323	37,296,667
7	100%	85,608,833	0.3759	32,183,531
8	100%	85,080,334	0.3269	27,812,912
9	100%	84,234,736	0.2843	23,944,769
10	100%	84,150,176	0.2472	20,800,637
			NPV	228,662,780
			IRR	42%

Net present value (NPV) is defined as the total present (discounted) value of a time series of cash flows. NPV aggregates cash flows that occur during different periods of time during the life of a project in to a common measuring unit i.e. present value.It is a standard method for using the time value of money to appraise long-term projects. NPV is an indicator of how much value an investment or project adds to the capital invested. In principle a project is accepted if the NPV is non-negative. Accordingly, the net present value of the project at 15% discount rate is found to be Birr **228,662,780** which is acceptable. (This is clearly shown on Table15 above).

7.2.2 Sensitivity Analysis(South African coal vs Prosopis Juliflora biomass)

A sensitivity analysis on selected cost components has been further conducted to test the strength and viability of the project. In view of this, extreme conditions like cost escalation on investment and operation cost due to various factors have been therefore examined. Accordingly, the sensitivity of the project towards 20% operational cost escalation is shown in Annex12 and Annex 13 and it shows that the project is still viable having payback period of **2.91 years**, **NPV of 159 million birr** and **IRR of 34%.** And its sensitivity towards an increment in 20% investment cost is also shown in Annex14 and Annex 15 which shows that the payback period shall increase to **2.79 years** and IRR and NPV shall decrease to **35% and 191 million birr** respectively and still viable. Moreover the project when tested with both investment and Operational cost escalation at the same time by 20% has resulted in Payback period of **3.48 years**, **NPV of 121 million birr** and **IRR of 28 %.(** Refer annex16and17). The above sensitivity analysis can be summarized as below:

Table 16:: Financial results and sensitivity analysis summary (Imported coal vs Prosopis Juliflora)

	Project's financial Result	20% escalation in Operational cost	20% escalation in Investment cost	20% escalation in both Operation and Investment cost
Pay back (years)	2.34	2.91	2.79	3.48
NPV(Birr)	228,662,780	158,966,586	191,157,674	121,461,480
IRR	42%	34%	35%	28%

7.2.3 Cost benefit analysis, IRR,NPV and Sensitivity analysis for (Local Coal vs ProsopisJuliflora biomass

The economic benefits that can be obtained by replacing 40% of the local coal by ProsopisJuliflora biomass has also been compared considering the calorific values of the local to be 3800kcal/kg and that of the Prosopis Juliflora biomass 4200kcal/kg. The result shows that an annual saving ranging from **48 million** birr in the first year and increasing annually and reaching **99 million** in the 10th operational year can be obtained which is very considerable amount although it is not as much as the case with the imported coal. The project's financial results also show that the project is feasible even when compared with the local coal as is shown in the following table including the sensitivity analysis.

Table 20: Financial Results and sensitivity analysis summary (Local coal vs Prosopis Juliflora biomass)

Table 17:Financial Results and sensitivity analysis summary (Local coal vs Prosopis Juliflora biomass)

	Project's financial Result	20% escalation in Operational cost	20% escalation in Investment cost	20% escalation in both Operation and Investment cost
Pay back (years)	2.62	3.37	3.14	4.03
NPV(Birr)	183,312,385	113,616,192	145,807,279	76,111,086
IRR	37%	29%	30%	23%

8. Socio-Economic Benefits

The Prosopis Juliflora shrub/tree as it is **discussed in chapter 3** in detail is shrub/tree which is invading the whole rangeland and grazing land of Afar and Somali regions and is threatening the livelihood of the pastoralist and agro-pastoralist communities of the regions and Hence the Afar National Regional State has issued a regulation to control, manage and eradicate the invasion of Prosopis through utilization, minimization and eradication systems. In line with the regional governments directive and policies, National cement Share company is planning to contribute a major role in controlling, managing and eradication program of Prosopis Juliflora through utilization of the biomass for its cement plant thermal requirement in such a way that;

- National Cement SC shall be responsible to harvest the Prosopis Juliflora biomass in Afar and Somali regions; for this operation NCSC shall invest on mechanized harvesting machines; after the harvesting operation the regional/federal and/or different NGO's shall be responsible for de-rooting operation; NCSC shall provide technical support in the de-rooting operation as NCSC is now having a close relationship with a European company that supplies the harvesting machines and the de-rooting machines who have already done the same job in the same prosopis tree in Sudan. After de-rooting the land shall be made ready for the local pastoral community or private farmers for cotton plantation, sesame plantation, forage production and other.

- In order to get the Prosopis biomass sustainably, continuously and economically there should be a permanent source of biomass that can be harvested again and again in the nearest areas possible to Diredawa. For this to happen NCSC need to secure a permanent prosopis invaded land which will be fenced and protected from animals, cattle entry; in this way the spread of the ProsopisJuliflora by animals and cattles can be prevented and NCSC shall get a sustainable and continuous source of biomass

Therefore upon implementation of this project, the spread of Prosopis Juliflora is prevented in the severely invaded areas whereby National Cement Shall have a Protected and Fenced Land for sustainable biomass supply which is believed to decrease the negative effect of its invasion on the economy and livelihood of the pastoral community. Besides when NCSC, NGO's and the regional governments get involved in the harvesting and de-rooting operation jointly, large productive lands shall be made free of the prosopis shrub and ready for the local pastoral community or private investors which is believed to significantly benefit the economy of the community, the investors and the country as a whole.

NCSC is currently incurring around 23 million USD for importing coal from South Africa annually. Upon implementing this project, 40% of the above foreign currency (which is around 9 million USD) shall be saved from being incurred; and this is believed to ease the foreign currency burden of the Ethiopian Government. In so doing NCSC is utilizing national resources which were previously not useful but rather harmful to the local community.

Moreover, up on implementation of this project, the profit/income of National Cement Share Company and its cost competitiveness in the market shall increase due to fuel cost saving which will in effect increase the income tax to the government.

9. Environmental Benefits

While burning Prospis Juliflora biomass in our Pyroprocessing system the overall emission effect is almost zero since the CO2 emitted after burning the Prosopis Juliflora biomass in our Pyroprocessing will be absorbed back by the Prosopis Juliflora shrub/tree when re-growing again, only there will be CO2 emission from the cuter-chipper harvesters, tractors, loaders, forklifts and trucks fuel usage which is relatively very small and negligible. But the Net Life cycle CO2 emission factor for Coal is around 2.8ton of CO2 per ton of Coal. That means in our case annually =117,000tons of coal x 2.8 tons of CO2/ton of coal=327,600 tons of CO2 is being emitted due to burning of coal. When replacing 40% of the coal by carbon neutral Prosopis Juliflora biomass as it is the case in this project, (0.4 x 327,600) =131,040 tons of CO2 annually is saved from being emitted to the environment. Hence this project is believed to play its own role in reducing the main green house gases like CO2 in the environment which are responsible for the current global warming problem. And there is also a possibility for NCSC to earn carbon credit finance by selling the above CO2 emission amount that shall be saved from being emitted.

10. Conclusion and Recommendation

Utilization of Prosopis Juliflora biomass as an alternative fuel to partially substitute the existing imported coal is expected to benefit the company by cutting its energy costs, the environment by reducing the net CO2 emissions to the environment, the society by improving the livelihood of the pastoral community and creating job opportunity and the country and the government as a whole by easing the scarce foreign currency shortage which makes the game Win-Win-Win-Win. It is believed to help NCSC in its bid to decrease its production cost to be able to be competitive in the fierce Ethiopian cement market where several new entrants are coming forth and existing big cement plants are there. The financial analysis results (**IRR=42%, NPV=228,662,780 birr, Payback period =2.34 years**) show that the project is viable and even under extreme conditions like increase in investment cost ,increase in operational cost and increase in both investment and operational cost at the same time, the project is strong enough and is worth investing. Therefore it is recommended for National Cement Share Company to invest in this project as fast as possible which shall make the company's financial position strong and firm.

11. Bibliography

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