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Everest Energy Group

Techno-Economic Study Report for Potential Biomass Power Plant sites in Nigeria

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UNIDO

Executive Summary

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1. Context of the feasibility study

General Context:
UNIDO is implementing a feasibility study under GEF 4 project (mini-grid based Renewable Energy biomass sources) to help augment rural electrification in Nigeria. This study has been developed to assist the government of Nigeria in addressing the existing gap in demand and supply of electricity, as well as enhancing energy access in rural areas through the promotion of mini-grid based renewable energy (RE) sources. The core objective of the study is to promote market-based approaches to RE based mini-grids in Nigeria to augment rural electrification. This study aims at demonstrating techno-economic viability of biomass based mini-grids.

Nigeria has a huge potential of energy generation from wood waste including sawdust. There are around 2,000 saw mills in the country, which generate around 104,000 m^3 of wood waste per day. A previous UNIDO study has identified nine areas with large potential for power generation from biomass waste from saw-mills in Ondo and Ogun state.[1] The current feasibility study executes a techno-economic feasibility studies and business plans for the identified sites.

Economic Context:
The techno-economic study will focus on investigating small scale IPP's (Independent Power Production) projects using locally sourced feedstock. The investigation has a market-based approach (meaning the project needs to create highest value against the lowest cost) with the understanding that:

a. Logistical cost are to be kept minimal and therefore feedstock should not be transported unnecessarily,
b. Developing 2 IPP's separately (one fueled by sawdust and one fueled by wood waste) is Capex intensive and therefore this study focuses on one installation capable of using both input fuels,
c. Capex as opposed to O&M cost and production efficiency needs to be as low as possible. Meaning that the highest efficiency output against the lowest O&M + Capex cost is desired,
d. The previously executed study identified a large volume of available fuel; leading to the assumption that feedstock is available if large(r) plants are desired for efficiency reasons.
e. The steam produced in the process can be a value carrier if this can be utilized by another clients, for example a heat intensive manufacturing process.

Technical Context:
The technological part of the study will focus on the most effective and efficient manner in which feedstock is converted into power and/or thermal energy serving a local/off grid user/set of users. The technological part of the study will be executed within the boundaries of the economic context. The technological boundaries are:

a. Given that sawdust and wood waste are to be converted simultaneously and the consequently produced syngas is incinerated, the installation (incineration bed) has to be able to use both fuel inputs.

[1] Techno-economic studies on biomass gasification power plants in Nigeria, The Energy and Resource Institute, September 2014

b. Given that the physical form of sawdust and wood waste are different, the material is to be uniformed before gasification.
c. The sawdust as well as the wood waste has high moisture content (at origin as well as at a centralized plant). Effective transformation of fuel into syngas requires fuel with low moisture content and therefore thermal energy is desired to pre-dry the fuel before gasification.
d. The power which is to be fed into a mini-grid system needs to be stable and continuous. Therefore the IPP is required to run continuously and with stable operation.
e. In order to fulfill the requirements of stable and continuous power production, feedstock shall be stored on site to be able to guarantee a continuous production cycle even in rainy seasons.
f. As the plant needs to run a stable production load (24/7) the study needs a view of the power balance and variation of the grid during day and night loads. It is un-desirable to run the plant in a start/stop modus.
g. The hooked-up voltage and delivery load has to be in line with the local grid and/or off-grid system.

Research focus:
Given the above mentioned context this study focuses its investigation on the market driven feasibility of > 1 MWe decentralized wood fueled (heterogeneous input streams: wood waste + sawdust) gasification-incineration-steam cycle projects (thermal energy is used for pre-drying fuel wood before gasification) delivering power to cities, villages or local industries.

Within the given regions the study investigates where the largest conglomeration of saw mills are situated in the smallest geographical region.

1.1 General context of biomass based sources to augment rural electrification in Nigeria

In Nigeria, the energy demand is increasing due to the rapid growth in the population (average of 2.7% on annual basis in the last five years)[2] and due to economic development[3]. Also, on account of the atmospheric greenhouse effect, environmental pollution and rapid shortage of fossil fuels encountered currently within Nigeria, the interest in developing renewable energy has received a considerable attention for years. Renewable energy technologies which are being developed include solar, wind, geothermal, hydroelectric, marine and biomass energy[4].

Among these technologies, biomass plays a key role, being the most commonly used source of rural energy in Nigeria[5]. Fuel-wood is a cheap and easily accessible source of fuel in both rural and urban areas. Furthermore, electricity access in Nigeria can be difficult and most rural areas are still not connected to an electricity grid.

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[2] World Bank data on population growth (annual %). http://data.worldbank.org/indicator/SP.POP.GROW
[3] Didem Ozcimen and Filiz Karaosmanoglu. (2003). Production and Characterization of Bio oil and Bio char from Rapeseed Cake. Renewable Energy, 779-787.
[4] Gonçalves da Silva C. (2010). Renewable energies: Choosing the best options. Energy.
[5] Chen W.H. and Kuo P.C. (2010). A study on Torrefaction of Various Biomass materials and its Impact on Lignocellulosic Structure Stimulated by a Thermogravimetry. Energy.

Over 70% of the total population of Nigeria relies on fuel-wood or charcoal as their major source of energy for domestic cooking, heating, and lighting purposes or generating energy through direct combustion[6]. The use of fuelwood entails health and environmental problems such as large scale deforestation and air pollution. To decrease the rate of deforestation and to spur economic development, electricity access is the way forward especially in meeting the needs of people on day to day domestic and industry activities.

Nigeria is endowed with forest resources with diverse fauna and flora, and the forest is been exploited for the benefit of man and production of various goods and services especially energy. The nation has about 9.9% of forest reserve, covering over 9,041,000 ha of land area[7]. Wood, being a major product from the forest, is the most versatile raw material the world has ever known. Throughout history, people have relied on wood for fuel due to availability of forest, forest based industries especially sawmills has been major in the forefront of processing. As a matter of fact, the waste generated by these sawmills is enormous.

Ekpe, (2011) showed in his study that that the conversion efficiency of sawmills available in Nigeria was between 40% and 50% by the 1990s[8]. Also, other reports showed that between 3.6 and 7.2 million m^3 of wood processed in Nigerian sawmills end up as residue[9]. The waste products which is technically referred to as residue are gotten in different categories in forest industries; as delimbs, toppings, branches at the point of harvestings, (saw dust, off-cuts, slabs, trims and shavings at different section of and waste wood) produced at these mills are sawmill. All of these residues are often disposed in the environment or incinerated in the open causing environmental pollution or left to decay. The utilization of these waste residues streams for the generation of electricity can add extra value for the saw mills and forest processing industries in Nigeria; offer off-grid electricity for the residents and industries in the area and reduce environmental pollution, as access to reliable and affordable electricity holds a great lot for the economic development of any country.

1.1.1 Overall appraisal of potentials and challenges of gasification in Nigeria

Nigeria has large feedstock availability in the form of waste wood (including sawdust), rice husk and other biomass products. Feedstock is scattered across the country and as a result there is no high concentration in a single location. Therefore it is preferable to have small on-site power utilizing the available biomass in the region.

For biomass gasification to meet its full potential in Nigeria some challenges arise:

1. High costs of funding due to inadequate knowledge of potential investors.
2. The technical know-how of installing, operating and maintaining is still limited.
3. Gasification is not adequately addressed in the Nigeria Renewable Energy Policy[10].

[6] Chukwu, I.E.W. (2000).). Agricultural Suitability and farmer's Decision at farm level. Proceeding of 6th Scientific workshop of Sub-Saharans Africa Network (SUSAN) Held at International Institute of Tropical Agriculture (IITA) (pp. 23-27). Ibadan, Nigeria: Sagary N.(ed).

[7] Food and Agricultural Organization (FAO). (1997). State of the world's Forests, . Rome:: Food and Agriculture Organisation of the United Nations.

[8] Ekpe, S. (2011). (2011). Comparative Study of activities of Sawmilling Industry on the Environment of two selected locations within Southern Nigeria. . Norderstedt Germany: Demand GmbH, , ISBN 978-3-640-97384-2.

[9] Fuwape, J.A. (Oct. 5-8, 1998). Development in wood based industries in Nigeria. International symposium on Global Concern for Forest Resource utilization. Sustainable use and management. Vol. IIA Yoshimo to and K. Yukutake (Ed).

[10] National renewable energy and energy efficiency policy (NREEEP) – Energy commission of Nigeria – 03/2014

Incineration of the biomass using an boiler and steam turbine to produce electricity can therefore be an alternative for gasification. This technique is less vulnerable for contamination of the feedstock and there is more knowledge about operating and maintaining such a plant. In general the cost of funding is lower because potential investors have more knowledge about this technique.

1.1.2 Status of biomass gasification in Nigeria

In the gasification of sawdust, the sawdust is gasified to produce a gas that can be incinerated. This gas can be used for power and electricity generation with an engine or a boiler with a rankine-cycle.

The Rankine cycle is the fundamental operating cycle of all power plants where an operating fluid is continuously evaporated and condensed. The selection of operating fluid depends mainly on the available temperature range[11]. For most rankine cycles water is used which evaporate into steam.

Due to high availability of liquid fuels in Nigeria gasification has not been utilized on a large scale and therefore there is not much experience with and knowledge of gasification in the country. Nonetheless, due to fuel price variations and increasing environmental awareness, there is a renewed interest in this technology[12].

Biomass gasification and electricity generation can be utilized on a small scale which makes it suitable for the dispersed rural population of Nigeria. Most rural areas in Nigeria do not have access to a reliable electricity grid; access to electricity could give these people a great opportunity for economic development by opening new opportunities like electrical water pumps for irrigation and other electrical machinery.

Research in the past shows that compared to gasified fueled with wood or agricultural residues, charcoal gasifier present less operational problems and are recommended for village level applications. Micro scale gasification systems (1-10 kW) can be used by small and medium farmers for providing power to irrigation systems. The equipment shall be small, cheap, simple and transportable. If firewood is available in sufficient amount without any danger to forest, gasifier can serve as an option for energy supply in remote areas.

It is in the above respect, that successive Federal Government of Nigeria beginning from late 90's began setting up various agencies and dedicated Higher Institution with a mandate to develop closely with private stakeholders to develop a Renewable Energy model that includes Gasification.

One of those agencies is the Energy Commission of Nigeria with six centers having gasification units. In addition, Federal Universities of Agriculture and Technologies are at various level of micro scale sawdust gasification experiment. Furthermore, few entrepreneurs have also demonstrated their interest in this area.

[11] Thermopedia: http://www.thermopedia.com/content/1072/

[12] Fuwape J.A. and Faruwa F.A. (2012). Bio fuel: a renewable source of energy. Paper presented at National short term training on Providing Alternative Watt for All (PAWA) at Wesley University Ondo, Ondo State Nigeria.

1.2 Biomass (sawdust) resources in selected states/cities

With Ogun state total waste wood and sawdust of 86,565 and 46,000 tons per year respectively spread over the local government areas including our Cities of selected project sites. (See biomass potential in Ogun state).
Ondo state also parade a total of 378,000 tons/year of waste wood and 200,000 tons of saw dust spreading across our identified.

1.2.1 Sawdust (wood residue)

Wood residues or waste as it were, are products of both primary and secondary forest industries. They come in form of toppings, delimbs, branches, offcuts, shavings, saw dust, particles, trims etc. They are sources with greater potential for upgraded values and can be used to produce free GHG fuel due to their carbon neutral ability. They are characterized by low energy density/heating values as a result of low fixed carbon when compared to coal, high moisture content (50%), high volatiles matter content (70%), low ash content, more oxygen content(needs less air for stoichiometric combustion, non-uniform in structure.

Sawdust or wood are by-products of wood, grinding, drilling, sanding, or otherwise pulverizing wood with a saw or other wood creating fine particles of wood. It can also be obtained from activities of certain animals, but and inset which live in wood. It is presently used for particle board and of recent being molded in briquette for electricity generation. It has a calorific value of about 7.8 to 8.2 Gj/mt, Gasification of this sawdust produces synthesis gas that further process to produce electricity.

	Wood	Corn stover	Chicken Litter	Black Liquor	IL No. 4 HvBb	Rosebud subB	Athabasca Bitumen
Proximate, wt% as received							
Ash	1.16	4.75	18.65	52.01	12.88	7.82	
Volatile Matter	81.99	75.96	58.21	32.56	37.54	33.32	
Fixed Carbon	13.05	13.23	11.53	6.11	42.04	41.91	
Moisture	4.8	6.06	11.61	9.61	7.54	16.94	
HHV, Dry (kj/kg)	19,496	18,100	14,677	11,563	28,842	27,176	41,635
Ultimate, wt% as received							
Carbon	47.05	43.98	32	32.12	63.43	62.59	83.6
Hydrogen	5.71	5.39	5.48	2.85	5.1	6.27	10.3
Nitrogen	0.22	0.62	6.64	0.24	1.09	1.08	0.4
Sulfur	0.05	0.1	0.96	4.79	4.4	4.36	5.5
Oxygen	41.01	39.1	34.45	0.71	12.98	12.85	0.2
Chlorine	<0.01	0.25	1.14	0.07	0.11	0.11	
Ash	1.16	4.75	19.33	51.91	12.88	12.75	
H/C Atomic Ration	1.45	1.46	2.04	1.06	0.96	1.19	1.47

Table 1: Properties of wood residues and selected biomass (source: Wood pellet association Canada)

PRODUCT SPECIFICATION - COMPARATIVE DATA						
Parameter	**Unit of Measure**	**Wood**	**Wood Pellets**	**Torrefied Pellets**	**Charcoal**	**Fossil Coal**
Calorific value (HHV)	GJ/metric tonne	9 to 12	17 to 20	21 to 24	26 to 30	17 to 30
Moisture	% of weight	30 to 50	4 to 10	1 to 5	1 to 5	10 to 15
Fixed carbon	% of weight db	20 to 25	20 to 25	28 to 35	85 to 87	50 to 55
Volatiles	% of weight db	70 to 75	70 to 75	55 to 65	10 to 12	15 to 30
Bulk Density	kg/m3	200 to 250	650 to 725	700 to 800	180 to 240	800 to 850
Hardgrove Grind ability Index	HGI			> 45		> 50
Deflagration index (Kst)	bar.m/sec	100	140 to 160		> 180	120 to 140
Electrostatic propensity		Low	Moderate	High	Very high	Moderate
Hygroscopic properties		Hydrophilic	Hydrophilic			Hydrophobic
Leaching		Yes	Yes	Yes	Yes	Yes
Self-heating		Moderate	High		Extreme	High
Off-gassing		Extreme	Extreme		Extreme	High
Oxygen depletion		Extreme	Extreme		Extreme	High

Table 2: product specification comparative data (source: Wood pellet association Canada)

1.3 Review of saw dust based gasification in Nigeria

1.3.1 What is gasification?

Gasification is a process that converts any material containing carbon-such as coal, waste or biomass (wood) into a synthesis gas (syngas). Gasification involves the thermal destruction of biomass in a reducing atmosphere of steam or air (or both) to produce a medium- or low-calorific value gas.

If air is present, the ratio of oxygen to biomass is typically around 0.3. It is a thermochemical process, meaning that the feedstock is heated to high temperatures, producing gases which can undergo chemical reactions to form a synthesis gas[13].

[13] E4tech. (2009). Review of Technology for the Gasification of Biomass and Waste. United Kingdom: project funded by DECC, project managed by NNFCC.

The gasification process follows several sequential steps[14], being:

- Drying of biomass materials which takes place around 100°C
- Pyrolysis vaporizes the volatile component of the feedstock (de-volatilization) as it is heated. The volatile vapors are mainly hydrogen, carbon monoxide, carbon dioxide, methane, hydrocarbon gases, tar, and water vapor. Since biomass feedstocks tend to have more volatile components (70-86% dry basis) than coal (around 30%), pyrolysis plays a larger role in biomass gasification than in coal gasification. Solid char and ash are produced.
- Gasification further breaks down the pyrolysis products with the provision of additional heat:
  - Some of the tars and hydrocarbons in the vapors are thermally cracked to give smaller molecules, with higher temperatures resulting in fewer remaining tars and hydrocarbons
  - Steam gasification - this reaction converts the char into gas through various reactions with carbon dioxide and steam to produce carbon monoxide and hydrogen
  - Higher temperatures favor hydrogen and carbon monoxide production, and higher pressures favor hydrogen and carbon dioxide production over carbon monoxide[15]
- The heat needed for all the above reactions to occur is usually provided by the partial combustion of a portion of the feedstock in the reactor with a controlled amount of air, oxygen, or oxygen enriched air[16] Heat can also be provided from external sources using superheated steam, heated bed materials, and by burning some of the chars or gases separately. This choice depends on the gasifier technology
- There are then further reactions of the gases formed, with the reversible water-gas shift reaction changing the concentrations of carbon monoxide, steam, carbon dioxide and hydrogen within the gasifier. The result of the process is a mixture of gases[17].
- All above mentioned process steps, including the combustion of the created syngas, can take place in a special designed incinerator. See chapter 4.

The syngas can be combusted in a boiler or engine to produce electricity or can be used as raw material to produce chemicals, fertilizer, liquid fuels, substitute for natural gas and even hydrogen.

Gasification takes place between 480-1650°C with very little oxygen. Steam may also be added to the gasifier to convert the carbon to syngas. Gasification uses only a fraction of the oxygen that would be needed to burn the material. Heat is supplied directly by partial oxidation of the carbon in the feedstock. Ash or slag remains as a residual[18].

[14] Boerrigter, H. & R. Rauch (2006) "Review of applications of gases from biomass gasification", ECN Research University of Science and Technology thesis.

[15] Haryanto et al. (2009) "Upgrading of syngas derived from biomass gasification: A thermodynamic analysis" Biomass & Bioenergy 33, 882-889.

[16] Juniper (2007) "Commercial Assessment: Advanced Conversion Technology (Gasification) For Biomass Projects", report for Renewables East England Development Agency.

[17] E4tech. (2009). Review of Technology for the Gasification of Biomass and Waste. United Kingdom: project funded by DECC, project managed by NNFCC.

[18] Gasification Technologies Council – www.gasification.org

1.4 Description of the technology

Gasification

Gasification is already being used for more than 60 years in the refining, fertilizer and chemical industries and in the last 35 years for the production of electricity.

The envisioned technology for the utilization of saw dust and waste wood in the state Ondo and Ogun is gasification by means of a boiler. This combination is an efficient way of electricity generation and should also lead to a more stable process than with the use of a gas-engine.

Biomass gasification is basically the conversion of solid fuels like wood and agricultural residues into a combustible gas mixture. In order to produce electricity the gas is used as a fuel in an energy conversion set with a combustion engine or with a boiler and a Rankine-cycle. An engine generally is used for the generation of up to 500 kWe and whereas a boiler can be used for the generation of over 0.5MWe up to several MW's.

The gasification technology in combination with an engine is principally well suited for small power plants ranging from 10 kWe to over 100 kWe. Appropriate gasifier systems with internal combustion engines can produce 1 kWh of electricity from 1.1 – 1.5 kg wood, 0.7 – 1.3 kg charcoal, or 1.8 – 3.6 kg rice husks. Assuming the wood originates from renewable production – regardless of whether planned forestation or natural regeneration – it is a perfect, nearly CO2 neutral, renewable energy source.[19]

In order to define the capacity of the gasification plant and therefore whether to choose for the use of an engine or a boiler, taking into account the amount of available input is of primary and utmost importance.

The gasifier is essentially a chemical reactor that uses wood chips, charcoal or similar carbonaceous materials as fuel and burns them in a process of incomplete combustion due to a limited air supply. In a boiler the biomass is heated and therefore the solid biomass will gasify, this gas is then immediately incinerated in the same boiler.

Products of the gasification process are:

- Solid ashes
- Partially oxidized products like soot (which have to be removed periodically from the gasifier)
- Generator gas.

The main flammable components of the resulting generator gas are:

- Carbon monoxide (CO)
- Hydrogen (H2)
- Methane (CH4)

[19] Gasification Technologies Council – www.gasification.org

Due to its high content of nitrogen (more than 50%) and other incombustible components this producer gas has a low calorific value compared to other fuels. The calorific value of generator gas is only about 5 -6 MJ/kg versus 35-50 MJ/kg for natural gas. This might require a specific engine design or an additional fuel to keep the engine running.

Theoretically, electricity can be produced by various kinds of technical equipment, for example a combustion unit in combination with a steam turbine, a gas turbine, a Sterling engine, or even a fuel cell.

Combustion

Combustion of the wood residues in an stoker that is suitable for biomass/wood waste incineration can also be used as a technique to generate heat and power. When using this technique the biomass is gasified and directly incinerated in an stoker, the heat produced is used to generate steam, the steam is used to operate an turbine to produce electricity.

This technique can use different kinds of biomass and is less vulnerable for contaminations. Electricity production from biomass/wood residues is because of this much more stable using incineration then when using gasification.

1.4.1 The biomass gasifier

Most biomass gasification systems use air instead of pure oxygen for the gasification reactions (which is typically used in large-scale industrial and power gasification plants). Gasifiers that use oxygen require an air separation unit to provide the gaseous/liquid oxygen; this is usually not cost-effective at the smaller scales biomass gasification plants. Air-blown gasifiers use the oxygen in the air for the gasification reactions.

There are different types of gasifier systems in circulation meant for firewood, wood waste or other wood -like materials. While the others are meant for fine biomass materials like rice husk. Biomass may have to be cut to size (as specified by us) and moisture content has to be less than 20% (on wet basis) for woody biomass and 10% (on wet basis) for rice husk.

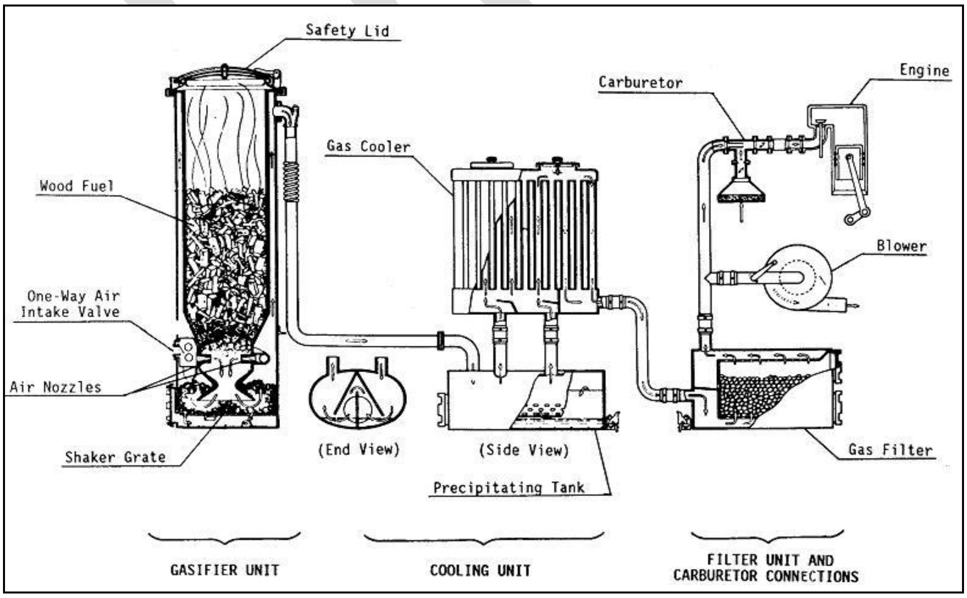

Figure 1: Simplified overview of biomass gasification with the use of an engine (www.lowtechmagazine.com)

Gasification and incineration of biomass in a boiler in combination with a steam turbine might be the most stable and reliable way of gasification. The wood is gasified in the boiler and the gas is thereafter immediately incinerated in the same boiler. Because the gas is burnt in the boiler, the gas has a longer residence time and the tars that are produced in the gasification process are burnt more properly, this gives a higher efficiency and resolves the environmental and technical problems who might be caused by the tar.

When utilizing different streams of biomass (sawdust and waste wood for instance) the input is often heterogeneous and can make the calorific value and chemical composition of the producer gas fluctuate. These fluctuations can represent a threat for the electricity plant as the equipment is vulnerable for the chemicals that are produced during the gasification or incineration of the gas.

The use of a boiler where both the input is gasified and the producer gas is incinerated will reduce these fluctuations and therefore the whole electricity plant will have a longer life span. Also the maximum generating capacity of such a plant is much higher compared to a gasification plant utilizing an engine for the generation of electricity.

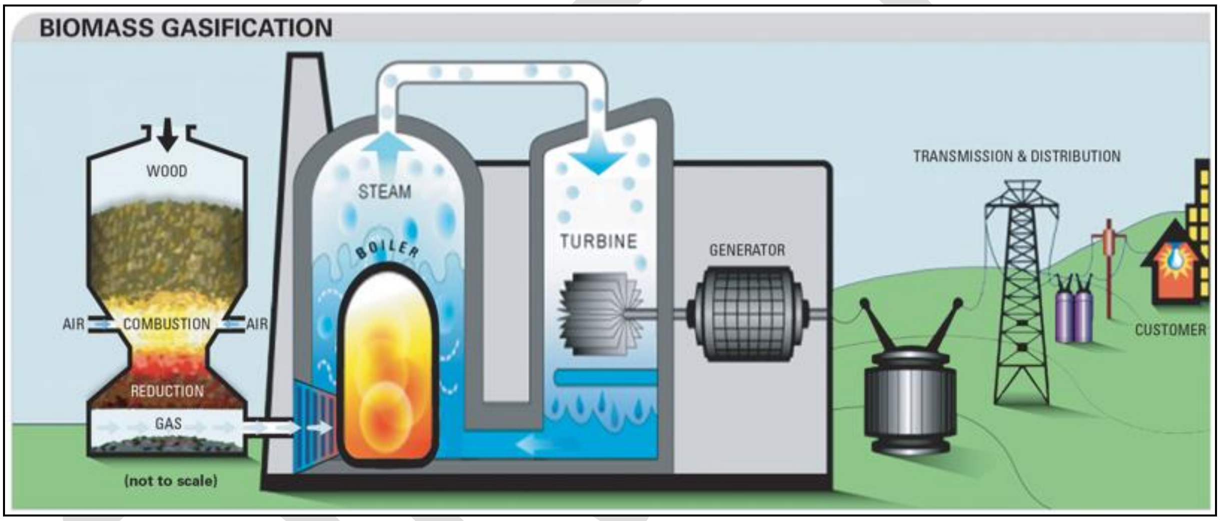

Figure 2: Simplified overview of biomass gasification and electricity production with the use of an boiler (source: www.eai.in)

1.4.2 The gasifier cleaning system

With the gasification of biomass and the combustion of its syngas – as in the combustion of every fuel – several contaminant by-products are produced and should be adequately dealt with in favor of public health, the general environment and efficiency of the whole installation.

For a reliable utilization of the plant, the amount of produced tar is important. When using an engine, especially those who are running at high speeds and have short residence times of the gas in their combustion chambers, have a high percentage of tar in their exhaust gases. These tars will accumulate in the engine and its exhaust and will lower the engines efficiency. Removing these tars will lead to higher maintenance costs and will lower the operating hours per year. The availability of engines with longer residence times in the combustion chambers is limited due to emission legislation.

When using a boiler for the gasification of biomass and combustion of the syngas the residence time of the syngas in the combustion chamber is much longer – up to a few seconds. The longer residence time allows the long carbon molecules (tar molecules) to break into smaller molecules, these smaller molecules are easier and therefore cheaper to extract from the exhaust gases.

Regardless of the amount and type, tar is a universal challenge of gasification because of its potential to foul filters, lines and engines, as well as deactivate catalysts in clean-up systems or downstream processes.

Up to date, no cleaning systems have been developed that can deal with larger amounts of long carbon molecules on an economic viable basis. But for cleaning of shorter carbon molecules there are options available that are economically sound. An specific gas cleaning system has been developed by ECN in the Netherlands but is only available for plants with a higher electrical output above 10 MWe

As defined by the Handbook of Biomass Gasification[20], there are three different types of cleaning systems:

a) Hot gas cleanup;
b) Cold gas cleanup;
c) Warm gas cleanup.

a) Hot gas cleanup (HGC)

Hot gas cleanup has historically focused on removal of particulate matter and tar, with the goal of minimizing maintenance of syngas combustion equipment. With temperatures above 200°C, many syngas applications benefit thermodynamically by cleaning the gas at elevated temperatures. In general, benefits of hot gas cleanup may include reduced waste streams, reduced costs, increased efficiencies or improved syngas conversions with fewer by-products.

b) Cold gas cleanup (CGC)

While HGC processes are 'dry' due to high temperatures, cold gas cleanup is characteristically a 'wet 'process. Liquid adsorbents are typical in CGC processes. A general shortcoming of these first generation cleaning technologies is that the cooler temperatures of CGC also incur thermal penalties on the overall plant efficiency. Treating the scrubbing medium is these wet technologies also incur added expense in order to meet increasing environmental standards. Despite these downfalls, however, CGC techniques will continue to be important gas treatment technologies in the future due to their high efficiency and proven reliability.

c) Warm gas cleanup (WGC)

Several cleanup processes operate at temperatures higher than ambient conditions, but lower than the hot cleanup applications. Although some may be capable of operating at hot cleanup conditions, they are widely employed at more moderate temperatures due to several process advantages. In general, the risks associated with extreme operating conditions as well as higher costs of materials are avoided. These processes all avoid water condensation, but allow some tars, alkalis and chlorides

[20] Biomass Technology Group, Handbook Biomass Gasification, pp: 130-138-145

to be condensed and removed. Maintaining temperatures above the point of water condensation also eliminates water treatment required in CGC.[21]

1.4.3 The engine

Biomass is gasified in a downdraft gasifier, which is then wet-scrubbed to condense tars and reduce syngas temperature for the internal combustion engine. A series of filters is used to reduce particulates before the engine generator. A downdraft gasifier is often employed because it produces the lowest amount of tars of all the gasifier types. This system is simple and has worked to produce power from syngas for many years. However, even after a half-century of development, key techno-economic barriers are yet to be resolved that would make it commercially viable. While downdraft gasifiers produce the lowest amount of tars of all the gasifier types, they still produce tars. These have to be scrubbed out or they eventually plug the piping. The problem is that scrubbing the tars does not get rid of them. It produces a tarry effluent, much like oily water, that must be disposed of[22].

Another issue is that the syngas has high nitrogen dilution when air is used for the gasification process. This reduces the energy content to approximately 4098.5 Kj/M^3. Most modern engine generators are rated for 11,177– 37,258 Kj/m^3. Trying to operate the engine generator on 4098.5 Kj/M^3 de-rates the engine by more than 75 percent. This means a 100-kilowatt (kW) engine generator will produce only approximately 25 kW when run on syngas alone. It also significantly reduces the reliability of the system[23].

Any drop in syngas quality will shuts down the generator and will then, require manual restart. This requires an operator to constantly watch the system, which significantly increases the operating costs of a distributed-power system. One method to overcome this latter barrier is to embark on co-generation with engine generator using fuel. When this is done, both engine reliability and power increase. However, the economics must now account for the cost of fuel, and the overall system is not as “green” as it would have been with just biomass alone[24].

1.5 Existing experience in different countries

Gasification of biomass or coal is a relatively old technology. Town gas in Western European cities was produced by the gasification of coal before natural gas became widely available. By 1850, large parts of London had gas lights powered by the gas produced from gasifiers using coal and biomass. With the increasing availability of other energy sources and electrification the technology lost its importance. In the early years of the 20th century, gasifier systems to power stationary engines and trucks were demonstrated but did not gain general acceptance.

The technology reappeared only after petroleum fuels became scarce during World War II. Almost one million gasifier-powered vehicles were in use during that time. However, with increasing availability of diesel and gasoline, this rather inconvenient technology was again abandoned. The

[21] Biomass Technology Group, Handbook Biomass Gasification
[22] P. Hutton, Powering an engine generator with a biomass gasifier, Biomass power & heating March 2011, p 12
[23] P. Hutton, Powering an engine generator with a biomass gasifier, Biomass power & heating March 2011, p 12
[24] P. Hutton, Powering an engine generator with a biomass gasifier, Biomass power & heating March 2011, p 12

energy crisis of the 1970s and 1980s again triggered interest in gasification technology. By the 1980s about 15 manufacturers were offering wood and charcoal power gasifiers. Amongst others, DGIS, GTZ, and SIDA began financing and running pilot gasifier power systems in several developing countries. Brazil, China, India, Indonesia, the Philippines and Thailand had gasifier programs based on locally developed technologies. In some cases the technology was promoted by local entrepreneurs. However due to frequent technical problems and decreasing petrol prices the interest in this technology again disappeared rapidly.

Only large-scale industrial applications and plants for heat production have achieved some economic success and become fairly common. Biomass gasification is used quite success-fully in Scandinavia, especially using residues of the wood, pulp and paper industry. However, worldwide the development and construction of new small and medium-size gasification plants has once more gained momentum during the last decade parallel to the discussions on climate change. In particular the guaranteed high feed-in tariffs in Germany have triggered the installation of about 50 gasifier power plants.

Example of a success story of this technology comes from Austria with the Biomass gasification based combined heat and power plant in Güssing.

Güssing is a small town located in eastern Austria and well known for its 8 MW biomass gasification plant. Due to lack of connectivity, the energy costs in the town were extremely high. Therefore, the government of Güssing decided to make the town self-sufficient in energy. Since, the biomass is abundant in the town with 40% of the region covered with wood which could provide sufficient raw material for energy generation; a biomass gasification plant was implemented in 2002. The plant has not only resulted in providing energy security but also being a carbon neutral source does not contribute in increasing CO_2 emissions unlike fossil fuels. As a result, Güssing became the first community in the European Union to cut carbon emissions by more than 90 percent[25].

The experience with the gasifier power plants constructed in the last 30 years is the background for this appraisal summary, even if it is very hard to obtain reliable detailed data especially concerning long-term operation. Manufacturers promote their gasifiers with performance figures. However, these rarely seem to be based on practical operation. The projects that use the gasifiers publish their use as success stories, but apparently only rarely collect reliable long-term data. Tracking the operational history of a gasification plant is in many cases almost impossible. It is for that reason that the information provided may contain minor contradictions. Nevertheless, there are some important studies available that relate personal observations by experts and allow for a conclusive statement.

Africa

While in Asia many gasifier plants are or have been in operation, there seems to be little on the ground in Africa. In the early 1990s, a gasification plant based on rice husk was operational in Molodo, Mali. It was the result of a joint cooperation between Mali, Germany, and China. However,

[25] Biomass gasification based combined heat and power plant at Güssing, Austria. http://viainfotech.biz/Biomass/theme5/document/flipbook-pdf-document/Biomass%20gasification%20based%20combined%20heat%20and%20power%20plant%20at%20G%C3%BCssing,%20Austria.pdf

the performance of the plant was rather mixed and a Chinese technician had to supervise it constantly to guarantee smooth performance. This technician was the only person able to fix the very specific technical problems (in particular problems with gas cleaning). Therefore, replicability and long-term sustainability were not achieved.

Since 2011 in Senegal two plants are operational, two others have been gone into operation in Benin. Due to the constant being in place of two local engineers, the Senegal plants seem to have a satisfying outcome.

Some research activities show recent African interest in the gasification technology. For example the Ethiopian Rural Energy Development and Promotion Centre (EREDPC) tested a gasifier as an option to convert Prosodies bushes and trees into energy. The study claims that as little as 1- 1.25 kg solid dry wood can produce 1kWh of electric energy. However, apparently the plans for the system have not yet been implemented in practice."[26]

Nigeria

Gasification Technology in Nigeria is relatively a young sector; hence data(s) for it looks scanty. However, Nigeria Government having obtained the potentials therein has imbibed this technology. This is evidence in their approach which has necessitated their establishment of various agencies in higher institutions collaborating with private groups in demonstrating R&D within the country.

For instance, Nigeria under its University Research Program has pilot Gasification plants in University of Sokoto, Obafemi Awolowo University, University of Agriculture Makurdi and University of Nigeria Nsukka. It has also approved the establishment of a large Gasification plant in Niger and Ogun states. Of note is a private Gasification plant in Zaria, Kaduna state run by Bioplant Nig Ltd. This plant has a dual fuel generator that supplies up to 128kw of electricity to small businesses, farms and household in Gida Wusasa through a local grid spanning about 2km. The plant cost is about Two Hundred Thousand USD. With 90% of the cost spent on Gasifier and generator, while the remaining 10% is on distribution line. Local farmers supply the Biomass and customers are charged 0.15 USD per kWh.

1.6 Drawbacks of gasification

Gasification has some characteristics which make it suitable for decentralized power generation: the generator set is easy to start up or turn off and small gasification and generating sets can be placed at or near locations were the biomass is sourced, resulting in lower transportation costs.

But the technology also has some drawbacks that should be properly addressed.
Gasification is vulnerable for contamination of its feedstock, biomass that is mixed with silica (sand) can plug, jam and even cause irreparable damage to the gasifier or engine, also can contaminated feedstock influence the calorific value of the gas resulting in lower generating capacity of the gen set. Gasification is a delicate process which makes proper maintaining and repairing essential, not correct repaired or maintained gasification sets can result in a gas that has a lower calorific value. If the gas is used in an engine it will produce tars, these should be captured and disposed in an proper way to prevent environmental damage to the environment.

[26]Small-scale Electricity Generation from Biomass – GIZ, 2010

An alternative for gasification can be the direct incineration of the biomass in an combined heat power (CHP) plant which produces electricity and heat with the use of steam and an turbine or generator. This principle is less vulnerable for contamination of the feedstock and therefore also easier to maintain. In general there is more experience in maintaining and repairing these types of power plants because it has the same principles as conventional power generation. An more elaborate description of this principle can be found in chapter 4.

1.7 Objectives of the study

This techno-economic feasibility study will address the technical, economic and financial issues as well as environmental and socio-economic conditions to develop a biomass power plant in Nigeria. the study will focus on 9 Local Government areas identified as potential sites by UNIDO in Ondo and Ogun state and will focus on the utilization of rest wood (sawdust, wood shavings and bark) that is produced at the numerous sawmills in the areas.

With this study there is a basis for an informed decision on the construction and operation of a biomass power plant in the identified areas.

1.8 General information on the project area

Nigeria is the largest economy of Africa and has the biggest and fastest growing population on the African continent. Nigeria is endowed with big oil and gas reserves and is a large exporting country, however, according to the CIA World Fact-book, in 2010 still 70% of the population lived below the poverty line[27].

In Nigeria, still 80 million people have no access to electricity and because of insufficient and unstable generation of electricity those who have access to the national grid often experiences outages. This poor electricity supply puts a hold on the economic growth of the country.

The two states this study focuses on are Ondo and Ogun close to the major city Lagos in the south west of the country. This area has an tropical climate and has a rainy season in the months May, June and July with an average peak rainfall of 386mm in June and an average annual rainfall of 1780mm, the average humidity is between 90% and 100%, The Netherlands has for comparison an peak rainfall in October of 82.3mm and an annual average of 820mm and has an average humidity between 80% and 85%.[28]

The rain and humidity can have a large influence on the moisture content of the sawdust and waste wood and therefore influence the efficiency of the plant.

Key economic data	Unit	Value	Year
Population	Million	173.6	2014
Population growth rate	%	3	2014
GDP	billion US$	568.5	2014
GDP PPP	billion US$	1,049	2014
GDP growth rate	%	6.3	2014
GDP PPP per capita	US$	6,000	2014
Electricity production	billion KWh	25.7	2011
Electricity from fossil fuels	%	67.1	2011
Electricity from hydroelectric plants	%	32.8	2011
Electricity from other renewable sources	%	0	2011
CO2 Emissions from consumption of energy	Mt	86.4	2012
Unemployment rate*	%	8.20%	2014
Commercial bank prime lending rate	%	17	2014

Table 3: Key economic data Nigeria (source: World Bank and CIA World Fact Book)

[27] CIA World fact-book: https://www.cia.gov/library/publications/the-world-factbook/fields/2046.html
[28] http://en.climate-data.org/country/153/#example4

1.8.1 Project locations

Nigeria is a federal republic modeled after the United States of America; this means that the republic is divided into 36 states which share sovereignty with the federal government. The states are further subdivided into Local Government Area's (LGAs), who can be seen as municipalities and have limited legislative power. LGAs can differ a lot in surface area and population. The project locations for this study are defined as LGAs

The project locations in the Ogun state are:

I. Ijebu Ode
II. Ijebu North
III. Abeokuta North
IV. Abeokuta South

The project locations in the Ondo state are:

I. Akure South
II. Akure North
III. Owo
IV. Odigbo
V. Idanre

Figure 3: Map of Nigeria and key project locations (Source: Google Earth)

Ogun State

Ogun State is strategically located; bordered to the east by Ondo State and to the north by Oyo and Osun States. Its border with the Republic of Benin, to the west, makes it an access route to the expansive market of the Economic Community of West African States (ECOWAS), to the south by Lagos, the former Capital of Nigeria, and which still remains the commercial nerve centre of the country and indeed the West Africa Sub-region and also by the Atlantic Ocean.

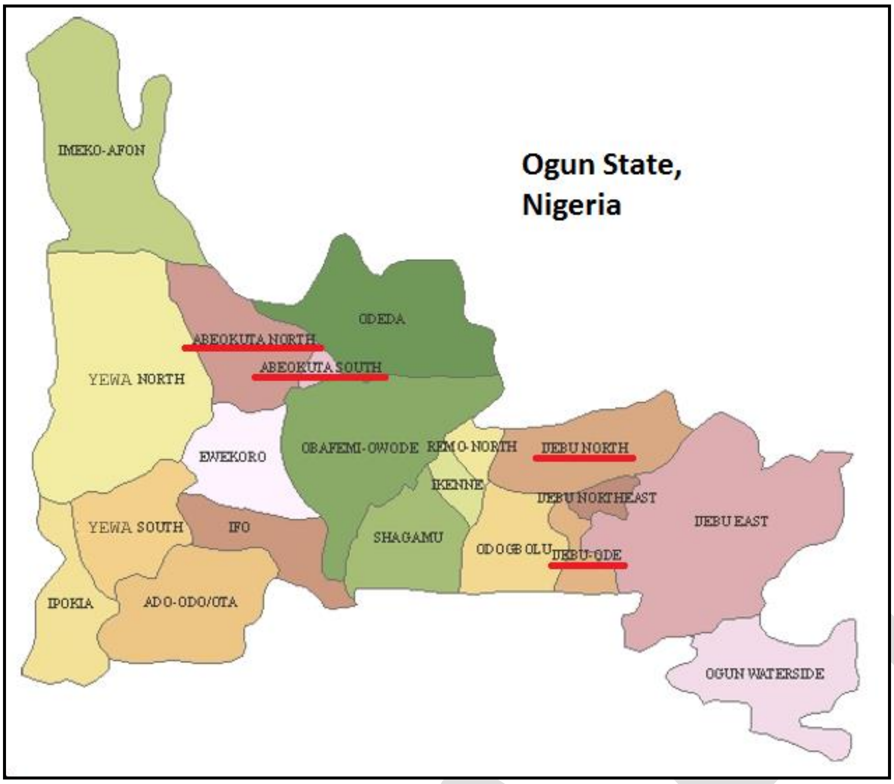

Figure 4: Ogun state, with red underlined are the Project LGAs (Source: www.thenationonlineng.net)

Ondo State

Ondo State lies easterly of Ogun and borders in the south with the Atlantic Ocean. In the west it borders Edo state and in the north it borders the Delta. The state is crossed by two highways who both are East-West orientated. The northerly Expressway runs via Akure through Osun to Ibadan Oyo. The southern expressway runs from Benin in Edo state through Ondo and Ogun towards Lagos.

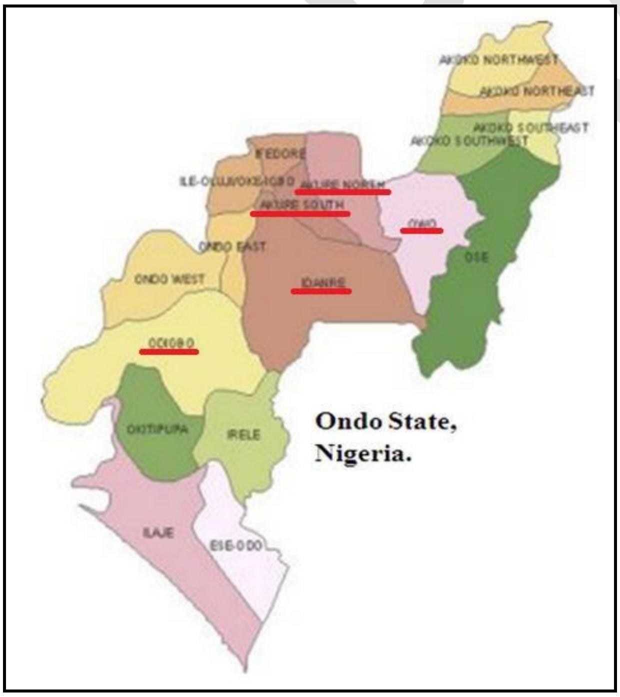

Figure 5: Ondo state, with red underlined are the Project LGAs (Source: www.ondostate.gov.ng)

1.8.2 Accessibility

All foreseen locations are connected with the network of national highways, except for Idanre. Owo which is the most easterly situated city lies at a 5 hour drive from Lagos and the complete route is about 470 km long.

Project locations	Population*	Surface area (km^2)	Express ways	Waterways	Railways
Ogun State					
Ijebu Ode	185,360	192	A121	No	No
Ijebu North	330,840	967	A121	No	No
Abeokuta North	234,360	808	A5	No	Yes
Abeokuta South	295,200	71	A5	No	Yes
Ondo State					
Akure North	151,930	660	A122	No	No
Akure South	418,570	331	A122	No	No
Owo	258,230	994	A122	No	No
Odigbo	269,880	1,818	A121	No	No
Idanre	150,800	1,914	A122	No	No

Table 4: Overview of the project locations population and the accessibility. (*Source: www.citypopulation.de)

Only Abeokuta North and South have rail running through the LGA and none of the investigated areas has navigable waterways that could be used for the transport of the feedstock. All the 9 locations are connected to the expressway system of Nigeria[29].

1.8.3 Supply and demand

Supply

In the pre-feasibility study commissioned by UNIDO[30] in 2014 an estimation on the supply of wood waste and saw dust has been made for selected areas in the states of Ogun and Ondo. For the calculation of the power generation potential a conversion factor of 3.5 ton of wood is equal to 1 MWe of electricity output is used.

<u>Ogun State</u>

Ogun has a total of 86,565 mt/y of wood waste and 46,168 mt/y of saw dust available produced by a total of 229 sawmills. The most sawmills and the largest available feedstock is found in the LGAs; Ijebu Ode (96) and Ijebu North (81).

Project locations Ogun State	Number of sawmills	Waste wood (mt/y)	Saw dust (mt/y)	Power generation potential (MWe)
Ijebu Ode	96	38,016	20,275	2.8
Ijebu North	81	32,076	17,107	2.3
Abeokuta North	40	12,672	6,758	0.9
Abeokuta South	12	3,801	2,028	0.3
Total	229	86,565	46,168	6.3

Table 5: Potential power generation per location and total in Ogun state.

[29] Google maps

[30] Techno-economic studies on biomass gasification power plants in Nigeria, The Energy and Resource Institute, September 2014.

Ondo Sate

In the Ondo State there is an total of 378,624 mt/y of waste wood and 201,934 mt/y of saw dust identified, this is produced by 493 sawmills and with the highest available amount of biomass in Akure North and South.

Project locations Ondo State	Number of sawmills	Waste wood (mt/y)	Saw dust (mt/y)	Power generation potential (MWe)
Akure South	143	109,824	58,573	8.0
Akure North	101	77,568	41,370	5.7
Owo	122	93,696	49,971	6.9
Odigbo	91	69,888	37,274	5.1
Idanre	36	27,648	14,746	2.0
Total	493	378,624	201,934	27.7

Table 6: Potential power generation per location.[31]

Demand

No data is available on the exact demand of electrical power in the project areas; therefore it is estimated using the population of the area and the electrical power use per capita of Nigeria as provided by the World Bank (see Table 7: calculated demand per project location.Table 7).

Project locations	Electrical power use per capita (KWh)[32]	Population	Calculated demand in (MWh)
Ogun state			
Ijebu Ode	156	185,360	28,916
Ijebu North	156	330,840	51,611
Abeokuta North	156	234,360	36,560
Abeokuta South	156	295,200	46,051
Ondo State			
Akure North	156	151,930	23,701
Akure South	156	418,570	65,297
Owo	156	258,230	40,284
Odigbo	156	269,880	42,101
Idanre	156	150,800	23,525

Table 7: calculated demand per project location.

[31] Techno-economic studies on biomass gasification power plants in Nigeria, The Energy and Resource Institute, September 2014 – third progress report.

[32] CIA World fact-book: https://www.cia.gov/library/publications/the-world-factbook/fields/2046.html

To date the waste wood and saw dust are due to lack of better management approaches not utilized and are disposed on the side of roads and rivers or openly incinerated. This shows there is no or very little demand for this type of feedstock and using the feedstock for power generation will put a value on this waste product. This might contribute to the profitability of the sawmills[33].

1.9 Socio-economic information

1.9.1 Population

With a population of more than 180 million[34] Nigeria is most populated country of the whole African continent and the 7th in the world. Highest population densities are found in the south of the country, with the highest density in and around Lagos 4,193 people per km^2[35]– one of the highest population densities in the world – and an average density of 196 people per km^2.
Of the total Nigerian population, 47.8% lives in the urban areas[36].

The population of the two states object of this study is:

- Ondo state: 3,441,024 and
- Ogun state: 3,728,098.

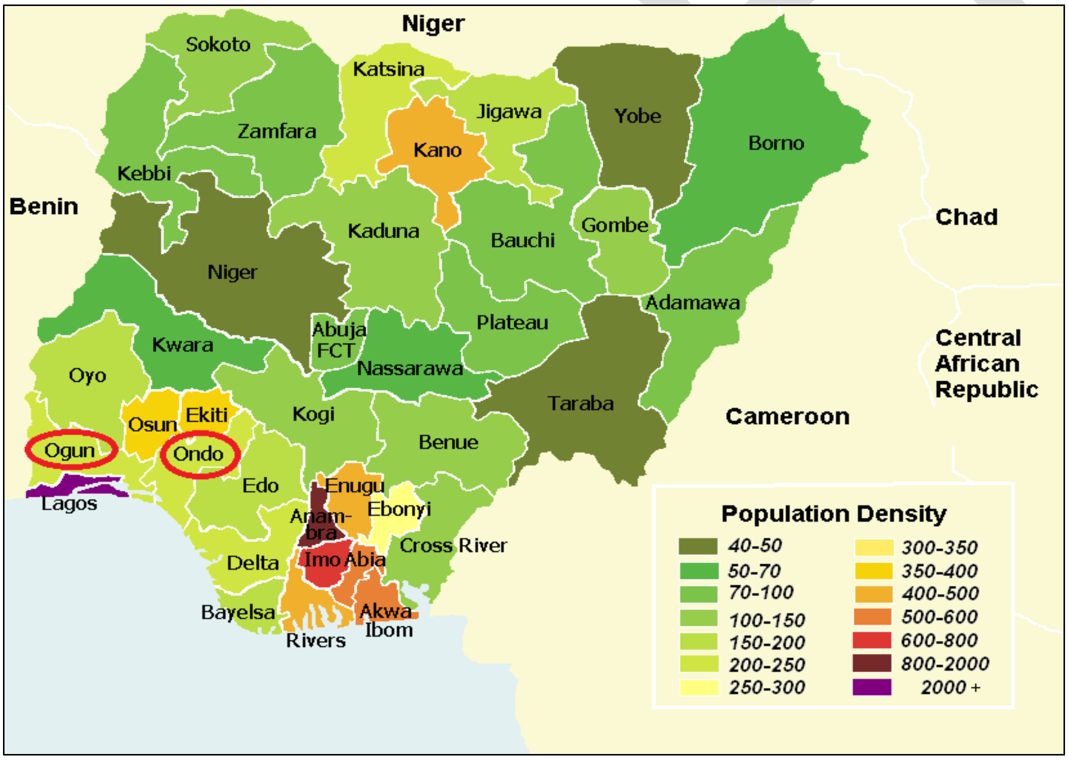

Figure 6: Population density in Nigeria per state (Source: www.newworldencyclopedia.org)

[33] Techno-economic studies on biomass gasification power plants in Nigeria, The Energy and Resource Institute, September 2014 - First progress report – The Energy and Resources Institute
[34] CIA World Fact Book - www.cia.gov
[35] Lagos State - http://www.lagosstate.gov.ng/pagelinks.php?p=6
[36] Databank – World Bank

1.9.2 Existing economic activities

Nigeria is Africa largest economy, with 2014 GDP estimated at $573.7 billion, the country is striving to be one of the largest 20 economies in the world by 2020, but now, take 21st place. However, still 70% of the population lives below the poverty line as defined by the UN[37]
Nigeria is the only oil producing country of West Africa and is a net energy exporting country. The country is the sixth largest crude oil producer and has the 9th largest natural gas reserves in the world, but due to a lack of infrastructure, Nigeria flares 75% of the natural gas it produces. More than 95% of the country's export income is from crude oil and oil based products. Nigeria's income from exports of oil and natural gas are for 80% for the government, 16% is for operational costs and the remaining 4% goes to the investors.

In other economic sectors a lot of challenges are still in existent, human capital is seen as under developed – Nigeria ranked 152 out of 187 countries in the UN human development index 2014 – and according to Transparency International corruption is still a big issue as Nigeria ranks 136 out of 175 countries.

However the Nigerian agricultural sector has suffered from years of mismanagement and poor government policies, still the sector accounts for 20% of the GDP and 70% of employment and has more than 19 million head of cattle, the largest livestock in Africa.

The oil industry is with more than 91% the highest contributor to the export of the country and is responsible for about 83% tot federal governments income. A total of more than 1.8 million barrels a day is produced but only 445,000 barrels per calendar day are refined in the country itself, meaning the oil industry has a limited effect on its employment rate.[38]

The instable electricity network has crippled the service sector. Due to the constant occurring outages, companies are not able to operate in a normal routine and put their profitability under pressure. The service sector accounts for about 25.7% to the GDP and with a total of 313,214 million US$ Nigeria ranks fifth in Africa according to total output of the service sector.

1.9.3 Public institutions

In addition to several Agencies, Nigeria has over 90 universities belonging to federal, state and private organizations. Polytechnics and other Learning institutions are also sizable. For instance, our area of assignment, these are Ogun (6 private and 1 Federal Universities), while Ondo state has (3 private and 1 Federal Universities). Professional institutions with good membership size also abound in this regions.

[37] CIA World Fact Book - www.cia.gov

[38] OPEC - http://www.opec.org/opec_web/en/about_us/167.htm

1.9.4 Access to electricity supply

Compared to other Sub-Saharan African states electrification rates in Nigeria are below average, only 45% of the population have access to electricity. In urban areas this is higher with 84%, but only 24% of the rural population has access to electricity, this still leaves around 100million people in Nigeria without electricity.[39]

GIZ states in their The Nigerian Energy Sector - an Overview with a Special Emphasis on Renewable Energy, Energy Efficiency and Rural Electrification report that: *"The World Bank reports that Nigerian businesses tend to suffer power outages of on average approximately 240 hours a month, and that this is the reason for nearly 7% of lost sales. A recent study by the MAN reveals that in industrial clusters, on average between 7.8 and 8.3 hours per day were lost in 2013 [MAN; 2013]. The World Bank concludes that: "As a result, most private enterprises are forced to resort to self-generation at a high cost to themselves and the economy (about US$0.3–0.5 per kWh as compared to the current grid based tariff of US$ 0.13 per kWh)."* [40]

Due to these outages companies and families spend on average N3.5 trillion annually to power their generating sets with diesel and petrol due to unstable supply of electricity.[41]

Expanding access to renewable energy services in rural and peri-urban areas is associated with a number of challenges, and innovative approaches are being considered for instance by the UN Development Programme.

The UNDP Access to Renewable Energy Programme focuses on increasing the national capacity to invest in and utilize renewable energy resources to improve the access to modern energy services for MSMEs[42]. These are the services many Nigerian MSMEs either lack completely or access erratically through electricity grid which hampers their potential for growth[43].

It also aims to build capacity in the business and financial sectors to incorporate renewable energy in business planning and development, and to support the evolution of renewable energy policy and public planning. It is aimed at building capacity of the following:

- MSMEs to incorporate renewable energy either as a business in and of itself, or as service for business development
- Financial Institutions to better understand and assess the credit and financial risks of renewable energy investments and services
- Government to develop and implement renewable energy policies and regulatory frameworks

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[39] World Bank Databank - http://databank.worldbank.org/

[40] The Nigerian Energy Sector - an Overview with a Special Emphasis on Renewable Energy, Energy Efficiency and Rural Electrification - GIZ

[41] Vanguard media limited, Nigeria - Article: "Nigeria spends N3.5trn annually on power generators", January 16, 2013

[42] MSMEs: micro small medium enterprises.

[43] UNDP, access to renewable energy in Nigeria: http://www.ng.undp.org/content/nigeria/en/home/operations/projects/environment_and_energy/access-to-renewable-energy.html

Within the overall framework of increasing access to modern energy services, the strategy for the Access to Renewable Energy Programme comprise three outcome areas:

1. Foster pro-development energy services by facilitating an expansion of renewable energy services accessible to MSMEs
2. Support renewable energy investments by building up capacity within the financial sector as well as among users and providers of energy services
3. Promote policies and institutional frameworks for an inclusive renewable energy market

2. Analysis of the existing mini-grid business

2.1 Background

Nigeria's electricity generation and distribution network suffers frequent outages. The national grid is currently primarily focused on the main urban areas, with the majority of rural households having no access or very limited access to the national grid.

Mini-grids are a solution to cover these rural areas and together with locally sourced biomass feedstock and power plants this could spur the development of the rural regions. Off-grid licenses cover an electricity capacity of only 305MW of which only 49MW is embedded. The electrification rate of remote rural areas have not been progressing as expected, the main reason for this is the high costs to roll out the national grid and the low consumption in these areas.

Because of recurrent blackouts on the national grid, a lot of businesses and a large part of the population have installed their own generators. It is estimated that about 60% of the total electricity production in the country comes from individual power sources, most often in petrol or diesel generators. In 2009 it was estimated that about 6,000MW was generated by these generators.

In Ogun state 27.9% of the households has no access to electricity and in Ondo 33.7%.[44]

2.2 Electricity generation

The Nigerian electricity regulatory commission (NERC) issued 20 licenses for off-grid (self) generation as of 2011. A license is only needed when more than 1MW is generated[45].

Nine of these off-grid generators are in the Ogun State and only one is in the same local government area this study focuses on. This off-grid generator is Tower Power Abeokuta limited and is situated in Abeokuta South. According to the Private Infrastructure Development Group "*The project consists of the construction and operation of a 12.5MW power plant, situated in close proximity to the Expressway Industrial Corridor in Abeokuta. It is designed to be a CHP station fueled by Natural Gas feedstock in which Waste Heat Recovery technologies are employed to recover systemic heat wastes and thereby increase the total power output. The power will be sold to industrial off takers under long-term off take contracts. Due to the efficient power generation of the power plant, the electricity cost for these industrial off takers will be reduced with at least 25%. The Project will also remove potential off takers from the grid, thus relieving some of the stress from the sub-standard national grid and transmission network.*"[46]

Off-grid electrification using fossil fuels dates back to the 1970s, when the Government decided to electrify all off-grid local government areas headquarters with off-grid diesel powered generators.

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[44] The Nigerian Energy Sector - an Overview with a Special Emphasis on Renewable Energy, Energy Efficiency and Rural Electrification - GIZ
[45] Nigerian Electricity Regulatory Commission – www.nercng.org
[46] http://www.pidg.org/what-we-do/projects/nigeria/tower-power-abeokuta-limited - Private Infrastructure Development Group

Company	Site location	Capacity (MW)
African Oxygen & Industrial Gases limited	Ikorodu, Lagos State	19
Akute Power limited	Lagos State	13
CET Power Projects	Tinapa, Cross River State	20
CET Power Projects	Iganmu, Lagos State	5
ContourGlobal Solutions	Ikeja, Lagos state	10
ContourGlobal Solutions	Apapa, Lagos State	4
Coronation Power and Gas	Sango Otta, Ogun State	20
Ilupeju Power Limited	Ilupje, Lagos State	2
Income Electrix Limited	River State	6
PZ Power Company Limited	Abia State	4
Wedotebary Nigeria Limited	Kuru, Jos State	5
CET Power Projects (Ewekoro)	Wapco Ewekoro, Ogun State	6
CET Power Projects	Saagamu, Ogun State	7
DIL Power Limited	Cement factory, Ogun State	114
Energy Company of Nigeria	Agbara, Ogun State	3
Ewekoro Power Ltd	Ewekoro, Ogun State	12.5
Shoreline Power Company Limited	Sagamu, Ogun State	9
Tower Power Abeokuta Limited	Abeokuta, Ogun State	20
Tower Power Utility Limited	Ota, Ogun State	20
Unipower Agbara Limited	Agbara, Ogun State	6
Total:		**305.5**

Table 8: Off-grid licensed power generators >1MW (Source: www.nercng.org)

Renewable energy as a source for off-grid electricity production up to now primarily focused on the utilization of photovoltaic cells. A survey carried out by the Nigerian Energy Support Programme in 2015 including 55 companies stated that these companies have installed about 2,033kW of off-grid photovoltaic combining mini-grids and stand-alone systems.

2.3 Power demand

Data from the International Energy Agency (IEA) shows that energy consumption in Nigeria is 23,487 GWh in 2013 of which the largest part is utilized for residential use[47].

Energy consumption by sector	Electricity consumption (GWh)
Industry	3,899
Residential	13,458
Commercial and public services	6,130
Total consumption	**23,487**

Table 9: Energy consumption by sector (Source: www.iea.org)

In 2008 the Energy Commission Nigeria (ECN) together with the atomic energy agency projected a demand of 15,730MW for 2010 and 119,200MW for 2030 using a reference scenario of 7% yearly economic growth. This means at this moment the demand is about three times higher than the supply. Other research done by the World Alliance for Decentralized Energy and the Power Holding Company of Nigeria have shown the same gap in demand and supply is 3:1 and that it will become more entrenched under a business as usual scenario.[48] Present statistics from NERC show a demand of 19,000MW and a supply of 6,000MW.

2.4 Electricity distribution

On-grid:

There are 11 electricity distribution companies (DISCOS) in Nigeria. The coverage areas of these 11 Companies are indicated in the map below. The project sites of Ondo and Ogun state falls under Ibadan Distribution Company and Benin Distribution Company respectively.

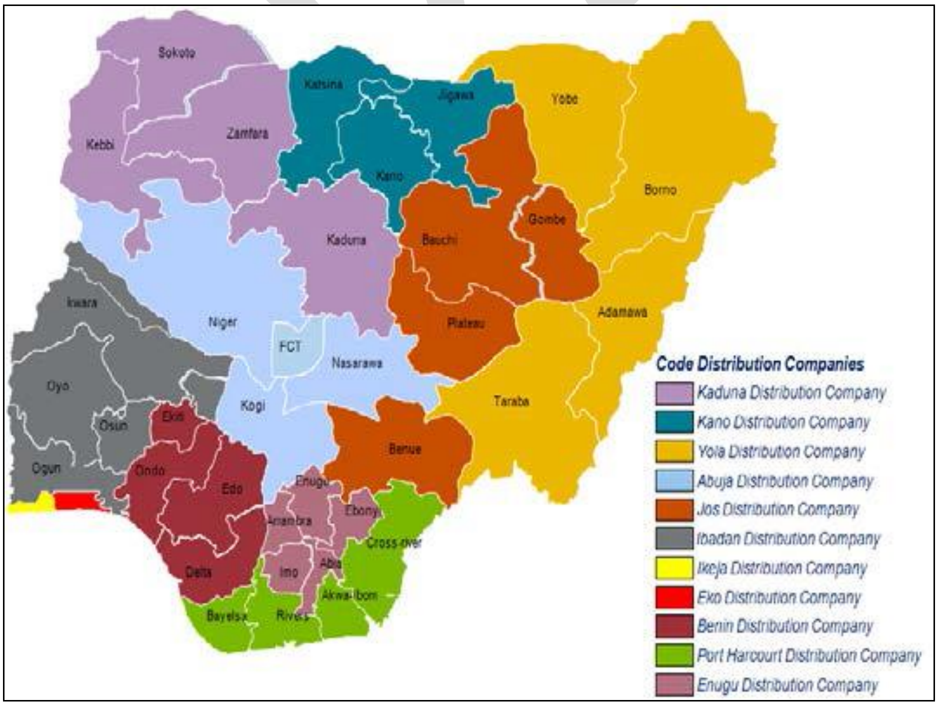

Figure 7: Distribution companies in Nigeria and operating areas.(Source: Guide to the Nigerian power sector, KPMG 2013)

[47] https://www.iea.org/statistics/statisticssearch/report/?country=Nigeria%20&product=electricityandheat

[48] https://energypedia.info/wiki/Nigeria_Energy_Situation - Energypedia

Because of the high costs and low revenue of connecting rural areas, the national grid has a low level of connections to these areas of the country, but is mainly focused on the largest cities like Lagos, Benin City and Abuja. Therefore the rural population (63% of the total national population) often does not have access to on-grid electricity.[49]

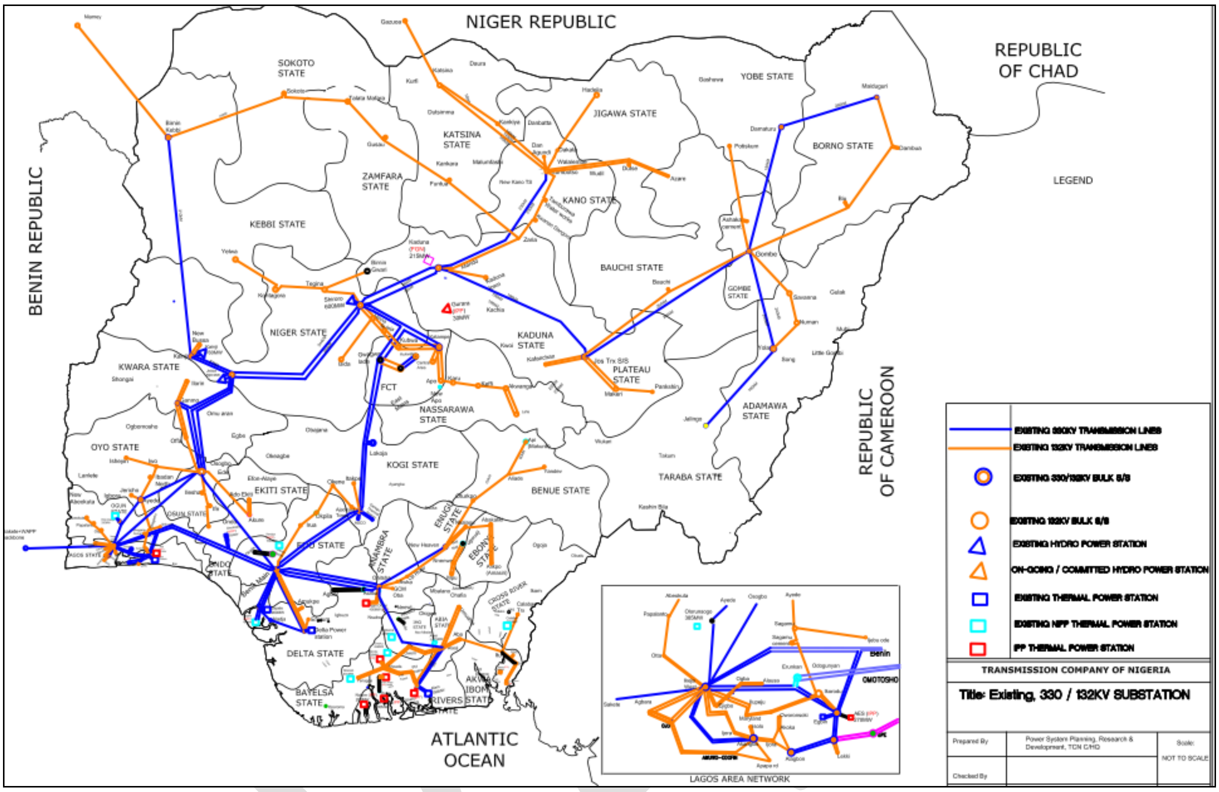

Figure 8: The national electricity grid of Nigeria (Source: GIZ)

Mini-grid

Currently, Off-grid and mini-grid licenses cover a production capacity of only 305 MW; with embedded generation capacity represents 49 MW. Electrification trends, particularly for rural remote areas, have not progressed as fast as they have been expected. In addition to the high demographic pressure, the strong focus on main-grid extension of the Federal and State Government's electrification programs is raising substantially. Project costs for low density and remote areas with low consumption and capacity to pay are often regarded as reasons for this remote progress.

Intra- and inter-community conflicts have also resulted in delays in the country's electrification program. However; Rural Electrification Agency of Nigeria has a program to connect all Local Government Headquarters to electricity by year 2016. Another program that is ongoing under mini-grid is the Nigeria Energy Support Program targeting private sector with its pilot's scheme now in operation. It is expected that the National rollout will be done in 2017.[50]

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[49] https://energypedia.info/wiki/Nigeria_Energy_Situation- Energypedia

[50] The Nigerian Energy Sector - an Overview with a Special Emphasis on Renewable Energy, Energy Efficiency and Rural Electrification - GIZ

2.4.1 Business management

Prior to approvals and permits, it is critical to ascertain ability and or willingness of customers to pay and understand issues related to Power Generation System, logistics for distribution as well as organizational model for operating and selling of the electricity in an economically viable manner. Having understood this, your choice of technology leading to ownership is also crucial. Ownership can be divided into three segments

- initial capitalization and development of the power system;
- generation capacity and the grid;
- running operation (maintenance and revenue collection).

2.4.2 Clientele

One of our areas of focus, Abeokuta North LGA is the only one that has a licensed off taker agreement on supply of electricity production to Industrial, commercial/public, and residential groups within this cluster that form the bulk of the clients and this should act as a model to clientele development.

2.4.3 Electricity tariff

On-grid

The Nigerian Electricity Regulatory Commission (NERC) is the governing body who developed a Multi-Year Tariff Order (MYTO[51]) in which the commission sets out the pricing principles used for calculating the electricity tariffs per consumer and per DISCO.

The MYTO provides a 15 year tariff path for the electricity industry, with limited minor reviews each year in the light of changes in a limited number of parameters (such as inflation and gas prices) and major reviews every 5 years, when all of the inputs are reviewed with stakeholders.

The MYTO sets out the tariffs for generation and distribution, transmission and system operations. The commission has adopted three basic principles in the determination of an appropriate methodology. These principles require that a regulatory methodology:

a. Produces outcomes that are fair
b. Encourages outcomes that are efficient in that involves the lowest possible costs to Nigeria and encourages investment in electricity generation
c. Is simple, transparent and avoids excessive regulatory costs.

Energy charges are reported in Naira per kWh.
Naira is the local Nigerian currency. The currency exchange with Euro and USD are respectively[52]:

- 1.00 NGN = 0.00502792 USD
- 1.00 NGN = 0.00449817 EUR

[51] Multi-Year Tariff Order (MYTO) – Nigerian Electricity Regulation Commission
[52] XE Currency converter: http://www.xe.com/currencyconverter/ - retrieved on 16/02/2016

Energy charges N /kWh				
	2015	2016	2017	2018
Residential				
Life-Line (50 kWh)	4.00	4.00	4.00	4.00
Single and 3-phase	18.00	17.36	19.60	17.93
LV maximum demand	28.82	27.79	31.38	28.70
HV maximum demand (11/33 KV)	28.82	27.79	31.38	28.70
Commercial				
Single and 3-phase	19.06	18.38	20.76	18.99
LV maximum demand	26.79	25.83	29.17	26.68
HV maximum demand (11/33 KV)	26.79	25.83	29.17	26.68
Industrial				
Single and 3-phase	21.61	20.84	23.53	21.53
LV maximum demand	28.08	27.08	30.57	27.97
HV maximum demand (11/33 KV)	28.08	27.08	30.57	27.97
Special				
Single and 3-phase	20.69	19.95	22.53	20.61
LV maximum demand	20.69	19.95	22.53	20.61
HV maximum demand (11/33 KV)	20.69	19.95	22.53	20.61
Street lightning				
Single and 3-phase	15.89	15.32	17.30	15.82

Table 10 Energy charges Ibadan DISCO (Source: Nigerian Electricity Regulatory Commission)

The NERC is required to balance the interests of all parties and considers that the objectives of both stakeholder groups (suppliers and consumers) are joined by the common need to ensure that the electricity supply system is viable, adequate and safe. This type of regulation is known as incentive-based regulation. The Nigerian electricity supply industry needs to improve performance on a number of levels and this of regulation provides incentives to do so. The regulated entities have an incentive to do better than the projected performance levels built into the tariff path.

There are three standard building blocks used in this approach:

a. The allowed return on capital – being the return necessary to achieve fair rate of return on the necessary assets invested in the business;
b. The allowed return on capital – associated with recouping the capital over the useful lives of assets
c. Efficient operating costs and overheads

At commencement of the MYTO all prices will be regulated, but this will be reduced over time as competition increases in the market and electricity supply is sufficient to meet requirements.

Energy charges N /kWh				
	2015	2016	2017	2018
Residential				
Life-Line (50 kWh)	4.00	4.00	4.00	4.00
Single and 3-phase	18.46	17.02	18.23	15.23
LV maximum demand	26.52	24.45	26.19	21.88
HV maximum demand (11/33 KV)	26.52	24.45	26.19	21.88
Commercial				
Single and 3-phase	20.72	19.10	20.46	17.09
LV maximum demand	24.65	22.73	24.35	20.34
HV maximum demand (11/33 KV)	24.65	22.73	24.35	20.34
Industrial				
Single and 3-phase	19.89	18.34	19.64	16.41
LV maximum demand	25.84	23.83	25.52	21.32
HV maximum demand (11/33 KV)	25.84	23.83	25.52	21.32
Special				
Single and 3-phase	19.04	17.56	18.80	15.71
LV maximum demand	19.04	17.56	18.80	15.71
HV maximum demand (11/33 KV)	19.04	17.56	18.80	15.71
Street lightning				
Single and 3-phase	19.62	18.09	19.37	16.19

Table 11: Energy charges Benin DISC (Source: Nigerian Electricity Regulatory Commission)

2.4.4 Connection fee

To operate a generator capacity above 1MW in Nigeria a generator license is needed. This license can be obtained by an application done at the NERC, for the application and for the license a fee has to be paid. The fees differ for operations connected to the transmission grid and operations not connected to the transmission grid or embedded generation[53].

For operations not connected to the transmission grid or embedded generation, the fees for a generation capacity between 1 and 10 MW are:

- Processing fee for application, 50.000- Naira
- License fee, US$10,000.-
- Renewal Fee, 25,000- Naira
- 1.5% of tariff charge/kWh

For operations connected to the transmission grid, the fees for a generating capacity between 1 and 10 MW are:

- Processing fee for application, 70,000.- Naira
- License fee, US$5,000.-
- Renewal Fee, 35,000- Naira
- 1.5% of licensee's charges/kWh

[53] Licence and operating fees regulation – Nigerian Electricity Regulatory Commission

2.4.5 Billing/invoicing

The current status of billing and invoicing is that pay as you go. However, this is gradually giving way to pre-billing and invoicing system. This is by means of using automated meters with cards that are agrees with the tariff, thereby giving no room for debt.

2.4.6 Punishment

Offences such as tempering and canalization will attract punishment such as suspension or prosecution.

3. Field study results

3.1 Initial project concept and site identification

For this report, nine potential locations for a biomass gasifier have been assessed; out of these nine sites three sites have been shortlisted for a more extensive field visit. The sites are selected based on:

- The total feedstock availability (sawdust and waste wood) and potential in MWh per year gasifying the sawdust and waste wood;
- The average potential plant capacity in MWe and MWth and plant capacity for drying in MWth;
- The surface area in km^2 of each LGA and the average number of sawmills per km^2;
- The number of available ways of transportation (road, water and rail);

State	LGA	Feedstock	Feedstock availability mt/y	Total Supply (waste + saw-dust) mt/y	Potential MWhe/y (Gross)	Ops. Hours (y)	Plants cap MWe (Gross)	Plants cap MWth (Gross)	Plants cap for drying MWth	Surface area in km2	Nr of mills per region	Nr of mills per km2	Average Biomass available mt per sawmill	Available Logistics (road, rail, waterway)	Ranking Biomass available mt per region	Ranking Biomass available mt per sawmill	Ranking Saw mills per km2 in region	Ranking Availbale Logistics	Total Score	Rank Total
Ondo	Akure South	Waste wood	109,824	168,397	48,113	7,000	6.87	24.55	11.78	331.0	143.0	0.4	1177.6	1.0	100.0	100.0	86.4	50.0	336.4	1
		Saw dust	58,573																	
	Akure North	Waste wood	77,568	118,938	33,982	7,000	4.85	17.34	8.32	660.0	101.0	0.2	1177.6	1.0	70.6	100.0	30.6	50.0	251.2	3
		Saw dust	41,370																	
	Owo	Waste wood	93,696	143,667	41,048	7,000	5.86	20.94	10.05	1509.0	122.0	0.1	1177.6	1.0	85.3	100.0	16.2	50.0	251.5	2
		Saw dust	49,971																	
	Odigbo	Waste wood	69,888	107,162	30,618	7,000	4.37	15.62	7.50	1818.0	91.0	0.1	1177.6	1.0	63.6	100.0	10.0	50.0	223.6	5
		Saw dust	37,274																	
	Idanre	Waste wood	27,648	42,394	12,113	7,000	1.73	6.18	2.97	1914.0	36.0	0.0	1177.6	1.0	25.2	100.0	3.8	50.0	178.9	6
		Saw dust	14,746																	
Ogun	Abeokuta North	Waste wood	12,672	19,430	5,551	7,000	0.79	2.83	1.36	808.0	41.0	0.1	473.9	2.0	11.5	40.2	10.1	100.0	161.9	8
		Saw dust	6,758																	
	Abeokuta South	Waste wood	3,801	5,829	1,665	7,000	0.24	0.85	0.41	71.0	12.0	0.2	485.8	2.0	3.5	41.2	33.8	100.0	178.5	7
		Saw dust	2,028																	
	Ijebu North	waste wood	32,076	49,183	14,052	7,000	2.01	7.17	3.44	967.0	81.0	0.1	607.2	1.0	29.2	51.6	16.8	50.0	147.5	9
		Saw dust	17,107																	
	Ijebu Ode	Waste wood	38,016	58,291	16,655	7,000	2.38	8.50	4.08	192.0	96.0	0.5	607.2	1.0	34.6	51.6	100.0	50.0	236.2	4
		Saw dust	20,275																	

Table 12: Ranking of the 9 locations (0 to 100 scale with 100 being the best).

These parameters have been standardized on a 0-100 scale, with a 100 score for the best performer and no weighing factor for the different parameters. Using this method the LGA's **1) Akure South, 2) Owo and 3) Akure North** have the highest potentials.

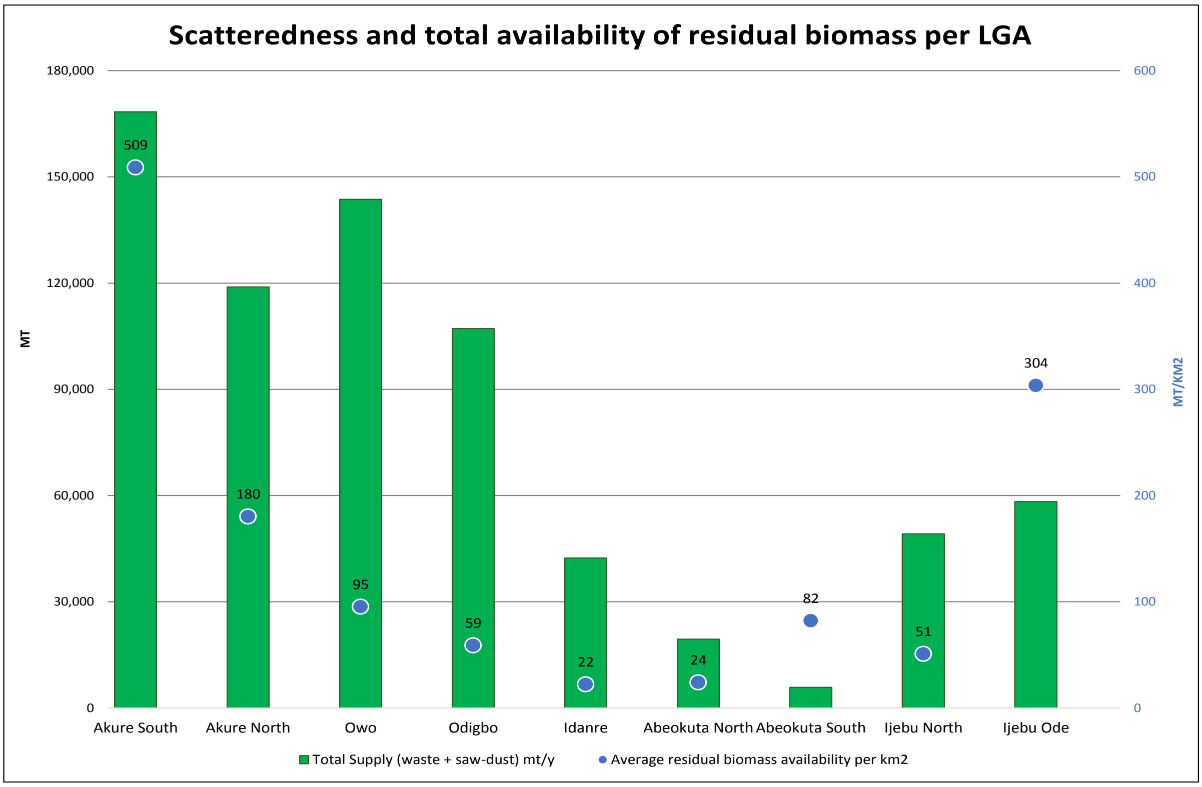


Figure 9: Scatteredness and total availability of residual biomass per LGA

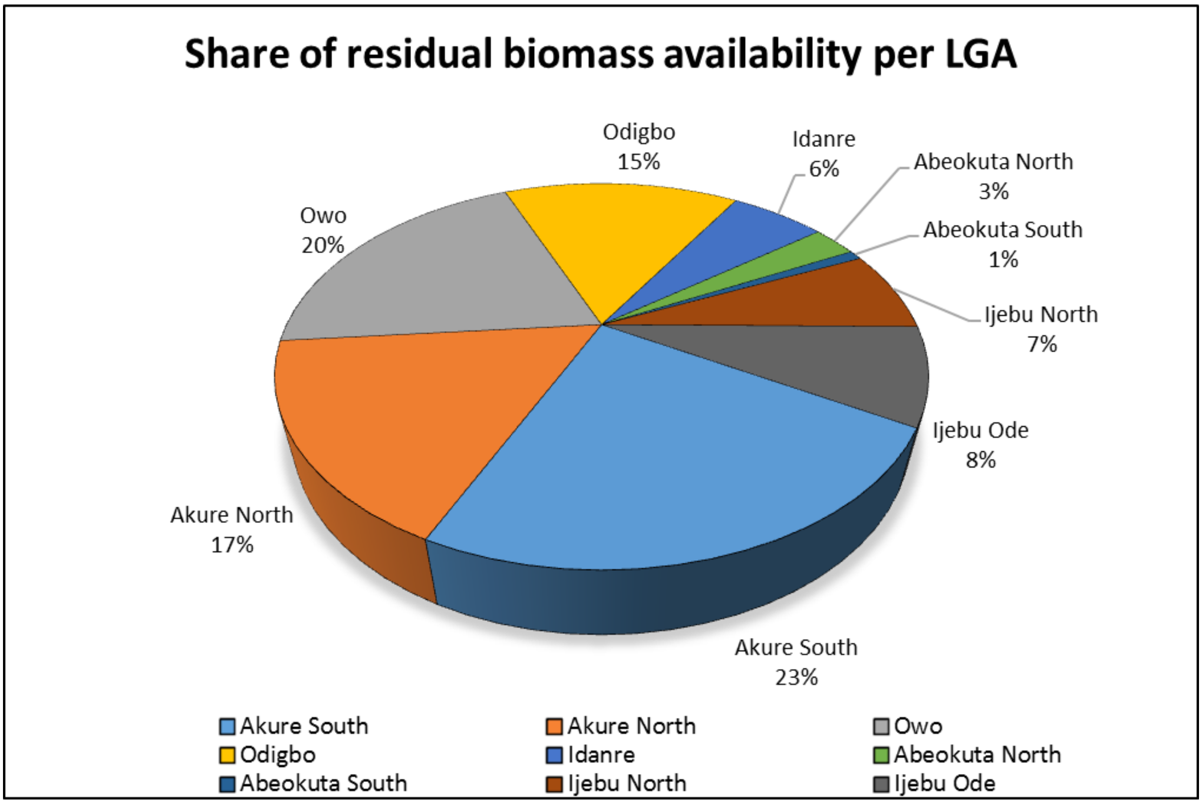


Figure 10: Share of total residual biomass available per LGA.

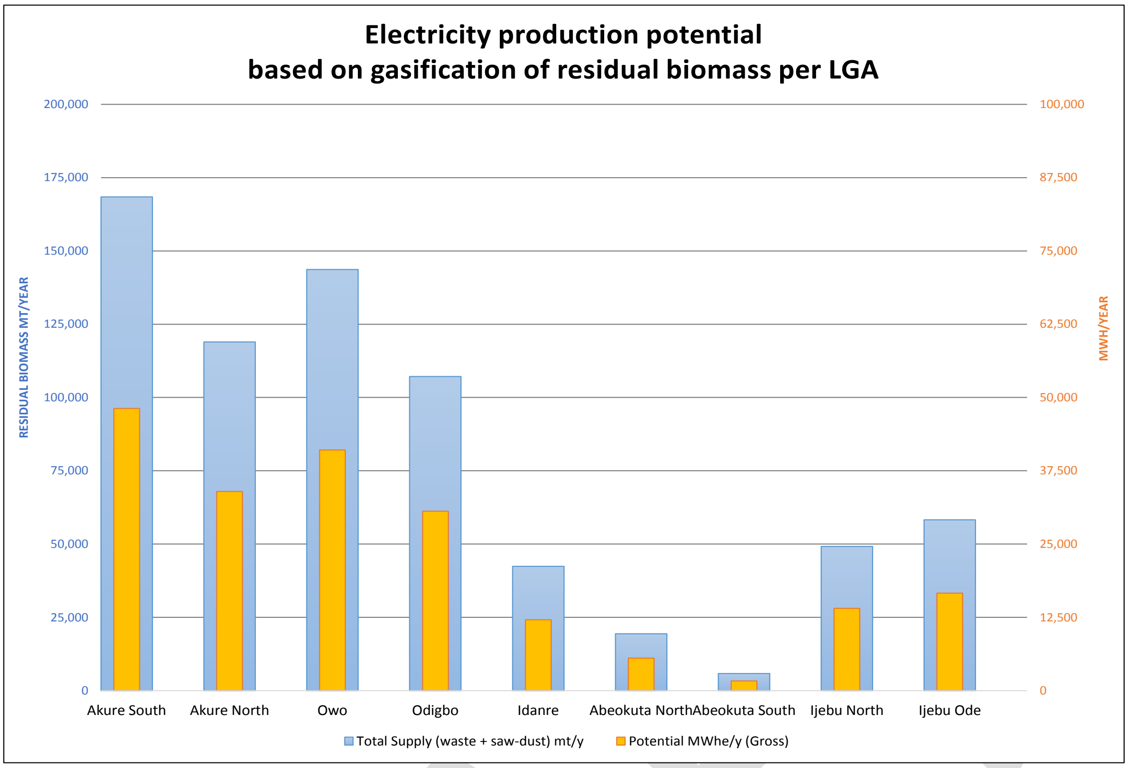


Figure 11: Total residual biomass availability per LGA and relative potential in MWhe/year.

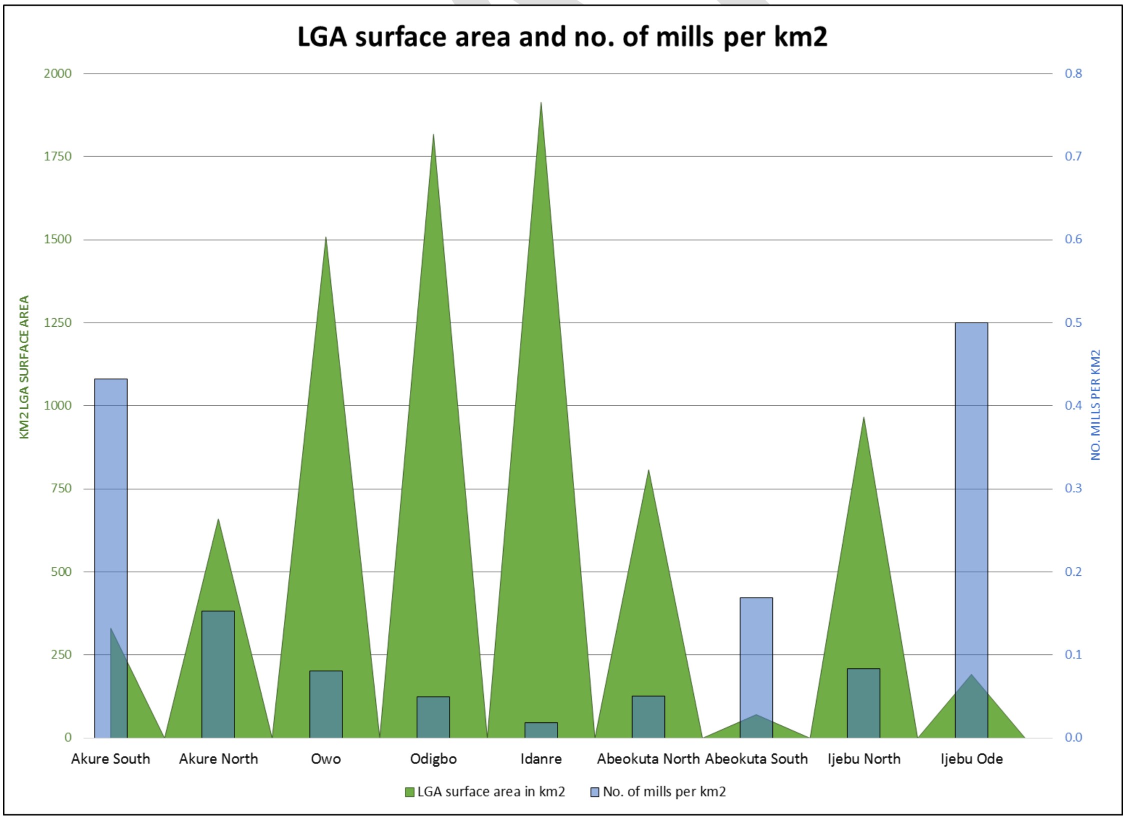


Figure 12: LGA surface area and number of mills per km2.

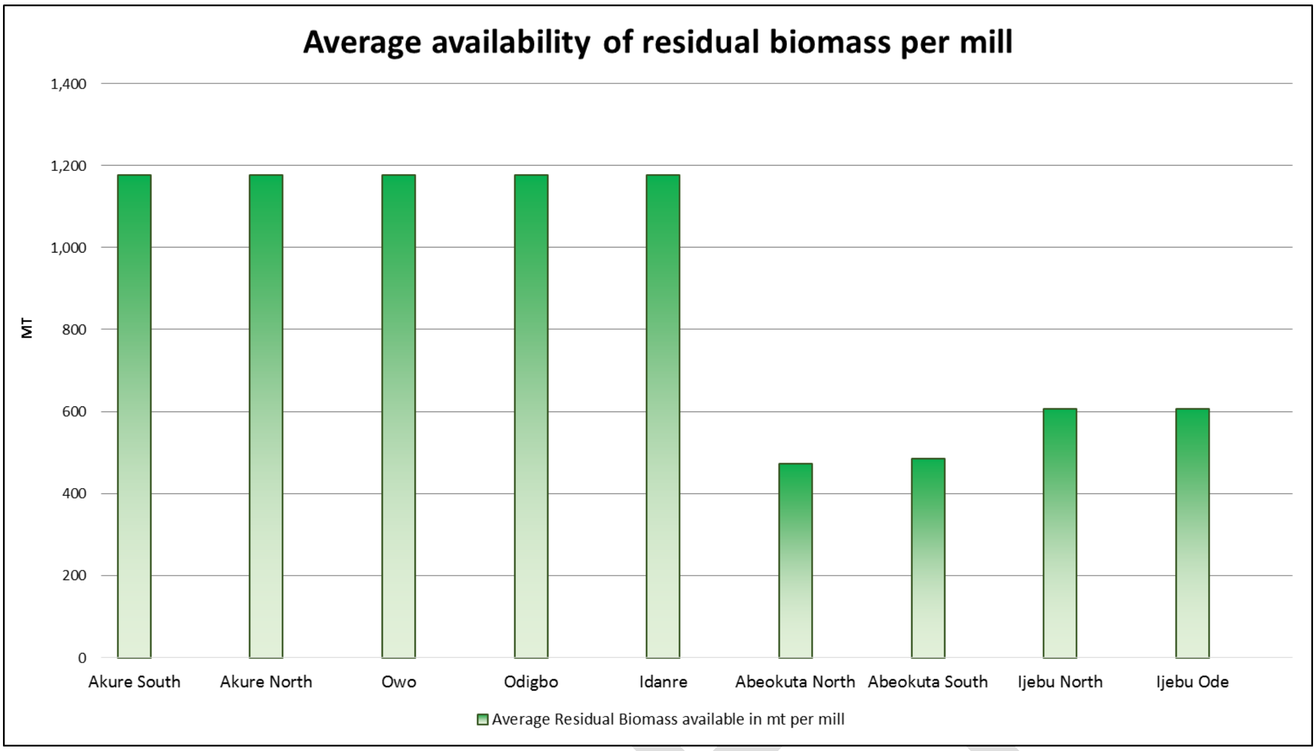


Figure 13: Average availability of residual biomass per sawmill

3.2 Methodology

3.2.1 Location and description

As further probes continues in form of locations visits, Ondo state with the beneath index of investigated LGAs with connections to Southern & Northern highways has upper potentials of Project implementation.

3.2.2 Existing electrical infrastructure

Like other communities that run micro business such as this, main source of power are the national grid or individual/cooperate generating set (usually between the capacity of 150-250KVA). Most some used in our area of focus operates on individual or cooperate electricity generation. Electricity from national grid is connected to a substation using transformers, poles, wires and meters .This same of infrastructures in our area focus.

Figure 14: Left: Electricity poles in Owo LGA. Right: Gen set of the Olukayode sawmill in the Akure South LGA

3.2.2.1 Overview of generating facilities

In Nigeria the present power management will site in national headquarters called National Electricity Power Authority (NEPA). This organization though now privatized is saddled with responsibility of electricity generation and distribution. Existing power generations are mostly from large hydro's and gas. Electricity from these sources is distributed to various cities via cable and pipeline. At local levels, substations are installed to step down or step up available power to the local grid. In addition individual or cooperative generators are installed to cater for in availability of electricity supply. Such generators have a capacity of between 150 - 200KVA

The Nigerian Power Generation sector can be detailed into the following sub-sectors:

(a) Existing Federal Government of Nigeria (FGN) Power Generation facilities.
(b) Independent Power Projects.
(c) National Integrated Power Projects

Also to ensure a system of generation, transmission, distribution and marketing that is efficient, safe, affordable and cost-effective throughout the country; the federal Government of Nigeria did set up a Bureau to develop a strategy.

- To ensure that the power sector attracts private investment both from Nigeria and from Overseas;
- To develop a transparent and effective regulatory framework for the power sector;
- To develop and enhance indigenous capacity in electric power

- To participate effectively in international power sector activities in order to promote electric power development in Nigeria, meet the country's international obligations and derive maximum benefit from international cooperation in these areas

3.2.3 Overview of distribution system

Through cables of varying sizes depending on required demand electricity is sequenced through the switch gear supplies power to residents, commercial and industrial outfit. This cable varies from 0.5kv to 35kv. Power consumption is usually monitored through types of meters on pay as you go system. Individual or cooperate generators mostly on diesel fuel stands as standby.

3.2.3.1 Demand, operation and management

Electricity demand of these LGAs are usually carried out by assessment department of the DISCOs demand rating sheet, be it for residential, Industrial and Public are carried out to enable operation unit evaluate requirement leading to costing and installation. National Grid supplies is manage is run at national, state and local government setups. In it you have the operations that attend to all technical issues while the management handles all the administrative and financial matters.

3.2.3.2 Social characteristics

Sawdust/waste wood power plant would definitely be a boost to the social and economic development of any community and its surrounding area. Its employment generation, during construction in direct and indirect labour is huge. There is also capacity building and technology transfer of projects of this nature. The project also will contribute to Nigerian power supply which in effect will create additional electricity to houses, shops, industries leading to more opportunities.

3.2.4 Load forecast

A typical energy demand assessment is developed to cover the energy requirement of the area of focus using the following index:

1. Residential
2. Industrial
3. Public/Private

This would reveal population of each index, volume of appliances, duration of electricity required/ period required. It may go further to reveal the economic status of each client and thus provide important input to define the load requirements of each LGA in focus.

3.2.4.1 Approach to the load forecast and scenarios

Approach to load forecast will essentially depend on feedstock capacity observed from number of sawmills/milling capacity, yearly saw dust production, power and energy consumption rate.
It will also consider availability/capacity of clients and their energy requirement, source of power and duration of operation.

3.3 Results

The complete field study reports are in annex 1 and 2.

3.3.1 Field research context

This field research is divided into two field missions, the first mission is focused on the three LGA's with the highest potential as identified in Table 12.
The top three LGA's are:

- Akure South;
- Owo and
- Akure north.

First field research
The first mission took place from 16^{th} of February up to the 20^{th} and was attended by 8 representatives of different companies and governmental bodies and was led by Kristiaan Tetteroo who represented Everest Energy and Hussaini Solomon who functions as the local engineer for Everest Energy.

The complete team for the first field research consisted of:

1. Kristiaan Tetteroo (Everest Energy Group)
2. Egnr Hussaini Solomon (Biodiesel NIG LTD)
3. Mr.Faruwa Francis (Biodiesel NIG LTD)
4. Mr. R.A. Adewole (Director of Commerce)
5. Mr. Ehinmitan B.B. (Representative of P.P.P. Ondo State)
6. Mr Ogunmade Ayo(PRO Sawmillers Association)
7. Mr Tope Aladewole(Ministry of Commerce)
8. Oluwatosin Patrick (Ministry of Commerce)

During this mission three sawmills per LGA have been visited.

The sawmills visited are:

1. Akure South Local Government .
   i. Olukayode Sawmill Ondo Road, Akure.
   ii. Akad Sawmill Ondo Road, Akure
   iii. Fabkob Sawmill Ondo Road, Akure

2. Akure North Local Government.
   i. Akinjide Sawmill Ado/Ikere Road, Akure
   ii. Agro Forest Sawmill Ogbese
   iii. Best life Sawmill Ogbese

3. Owo Local Government
   i. Fafunwa Sawmill
   ii. Akinjide Sawmill
   iii. Dapson Sawmill

See Figure 15 for their locations.

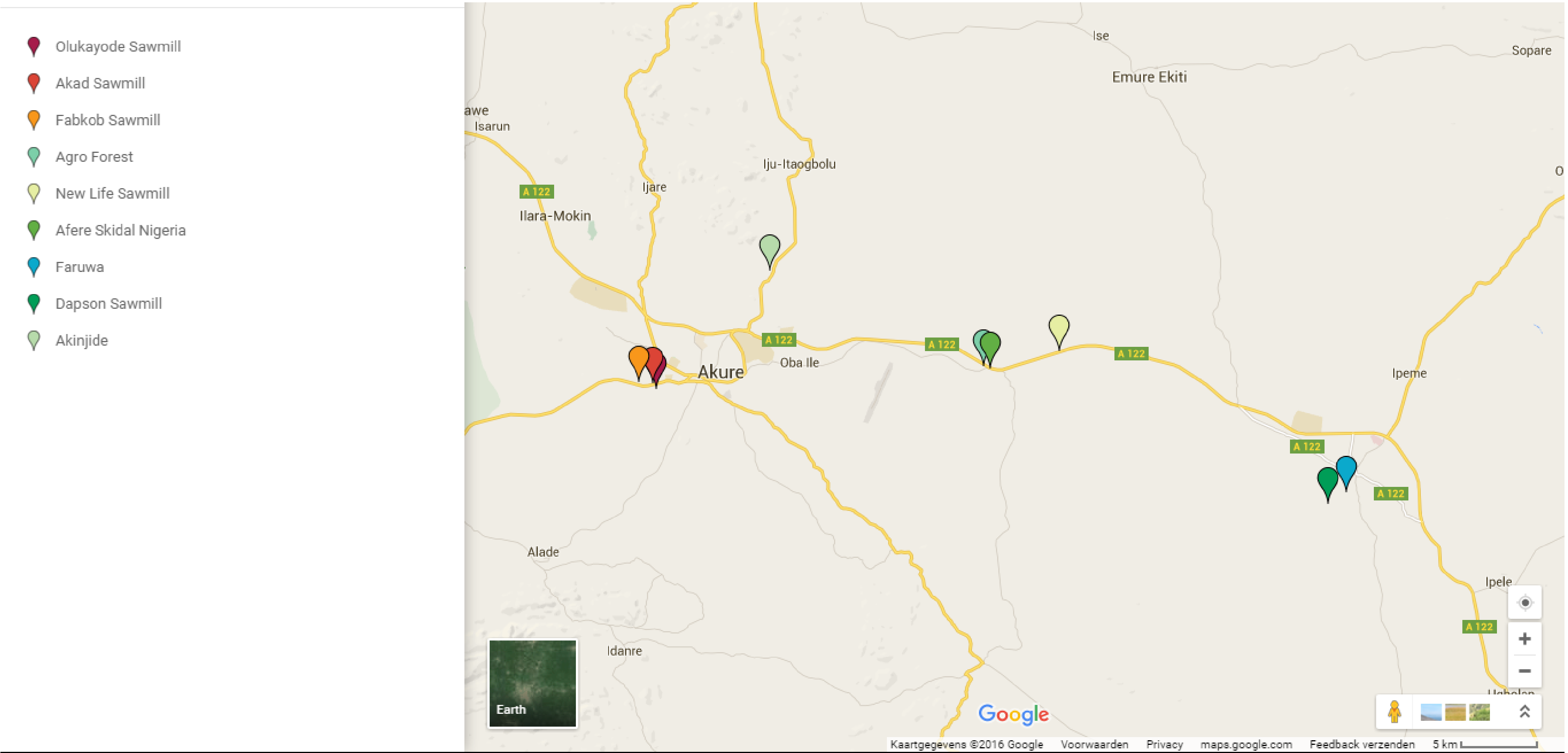


Figure 15: visited sawmills during the first field mission.

Second field research
The second field research is focused on the other LGA's being:

- Odigbo;
- Idanre;
- Abeokuta North;
- Abeokuta South;
- Ijebu North and
- Ijebu South.

This second part of the field research was held on 25 and 26 of February and 3, 4 and 7 March.

The team consisted of:

1. Engr. Hussaini Solomon (Biodiesel Nigeria Limited)
2. Mr.Faruwa Francis (Biodiesel Nigeria Limited)
3. Mr Sam Onagura(Rep Sawmillers Association)
4. Mr Akin Olugbade (Rep Sawmillers Association)

During this mission in every LGA three sawmills have been visited.
The visited sawmills are:

1. Odigbo.
    i. Ore road sawmill
    ii. Alagbede sawmill
    iii. Orita sawmill

2. Idanre.
    i. Sedeco sawmill
    ii. Onikare sawmill
    iii. Mtd sawmill

3. IJEBU ODE
    i. Ejirin
    ii. Adefisan
    iii. Oke Owa

4. Ijebu North
    i. Oke Agbo
    ii. Church
    iii. Sectariat

5. Abeokuta North
    i. Lafenwa oda
    ii. Oke Lafenwa
    iii. Iyana Lafenwa

6. Abeokuta South
    i. Sapon
    ii. Anjorin
    iii. Ago oke

3.3.2 General observations

Unknown potential for generating electricity with biomass
During the visits of sawmills it was noticed that none of the sawmill companies were familiar with the concept of using biomass for energy generation. This causes that all residues are burned in the open to make new space. Only at one sawmill (Agro Forestry) wood residues were collected to make bundles of fire wood. At the other sawmills there is no collecting of wood residues with the purpose to generate extra revenues.

Quality of biomass on the sites
It was observed at the visited locations that the sawdust and the other wood residues are a mixture of different tree species. For this reason it is not possible to acquire qualitative biomass from one mono source. At all mills three types of biomass were found:

- Saw dust;
- Bark (outer part of logs);
- Wood residues in form of small pieces of lumber (planks, wood shavings etc.)

With the fact that none of the sawmill companies is familiar with the concept of biomass for energy generation, the sawmill owners were not able to give answers about biomass quality properties. For this reason it was not possible to get answers about silica content and moisture rate, this might be subject for further investigation. Taken into account the mixture of different wood species, laboratory analyses will be difficult to estimate the exact properties of silica. At all visited sawmills, residual biomass is disposed on the ground and therefore the contamination with silica is expected.

Abundant biomass residues available but not quantified
Although it was not possible to quantify the amount of residual biomass per sawmill it is evident from observations, previous conducted studies for this project and other reports that biomass residual is abundant.

According to a study of the University of Akure at present 45 to 55% from processed logs end up as waste (Olufemi et al, 2012). Furthermore it was observed that for some locations up to one third of the area owned by sawmill was used for the storage and incineration of the residual biomass.
Resulting from the interviews with the saw mill owners there is currently no quantitative administration of biomass residues. The reason for this lack of administration is that the residual biomass currently carries no value.

The supply of wood for saw mills
Logs utilized at sawmills are sourced in the surrounding forests. Some companies are doing the logging activities by themselves while others buy their wood from forestry companies. All the logs are sourced from natural forests and therefore it is impossible to have a fixed mixture of three species supplied.

Willingness of buying electricity
Sawmill owners expressed interest of buying electricity from the potential gasification plant as long costs are lower compared to electricity generation with diesel generators. Various saw mill owners mentioned to spend an annual amount between US$ 40.000 - 80.000 for fuel consumption of the diesel generators. According to interviews with the sawmill owners, around 80-90% of the total operational time saw mills are running on diesel generators.

In general, very large parts of Nigeria are currently dependent for electricity on diesel generators[54].

Power supply of the saw mills

All saw mills have diesel generators at the location. Only three saw mills visited during this field research are connected to the electricity grid, the six other mills are working off the grid. During interviews it is mentioned that only a few hours per day electricity from the grid is available.
During the visits an electricity grid was observed in the vicinity – up to 1 km – of sawmills.

Logistics of the saw mills

All visited saw mills were only accessible by road and no railroads or waterways near the mills were observed. From the nine mills in total only two mills (Akinjide Sawmill and Dapson Sawmill) have no tarmac roads. All other mills were connected to a tarmac road and in general near a village or town.

Railways

In Abeokuta north and South, there is a railway which passes through the area at less than 1 km from the visited sawmills.

Other general observations

In general bigger mills were better organized and biomass residuals and logs were better separated. Only two out of nine sites were protected for burglary by a fence, all other sites were freely accessible.

[54] Interview with ministry officials during the field trip

3.3.3 Field research findings

General information									
LGA	Akure south - AS			Akure north - AN			Owo - OW		
Sawmill no.	1	2	3	4	5	6	7	8	9
Name	Olukayode sawmill - AS	Akad sawmill - AS	Fabkob sawmill - AS	Akinjide - AN	Agro forest - AN	New life sawmill - AN	Afere Skidal Nigeria - OW	Faruwa - OW	Dapson sawmill - OW
Description of location	Urban	Urban	Urban	Semi urban	Rural	Semi urban	Rural	Rural	Rural
Area type	Residential	Residential	Residential	Residential	Industrial	Industrial	Residential	Industrial	Industrial
Coordinates of the sawmill	7.249155, 5.166997	7.24994, 5.165255	7.251202, 5.156857	7.31743, 5.23507	7.259906, 5.363704	7.269419, 5.408188	7.259305, 5.365952	7.185558, 5.57961	7.178818, 5.568638
Size of the mill									
Number of FTEs working at the sawmill	32	16	48	16	48	40	32	40	40
No. of sawing machines	4	2	6	2	6	5	4	5	5
Residual biomass specifications									
Residual biomass available	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Calorific value biomass (mj/kg)	Not known	Not known	Not known	Not known	Not known	Not known	Not known	Not known	Not known
Silica content biomass (%)	Not known	Not known	Not known	Not known	Not known	Not known	Not known	Not known	Not known
Plastic content (%)	0%	0%	0%	0%	0%	0%	0%	0%	0%
Amount of residual biomass available for the gasifier	Not known	Not known	Not known	Not known	Not known	Not known	Not known	Not known	Not known
Opportunities for the gasification plant to deliver heat and electricity									
Connection to the grid	Yes	Yes	Yes	No	No	No	No	No	No
Observed distance to the grid (km)	0	0	0	0.5	0.5	0.1	1	0.5	0.4
Connection capacity to the grid	Not known	Not known	Not known	Not known	Not known	Not known	Not known	Not known	Not known
Possibility for heat delivery	No	No	No	Within 1 km	At own site	No	No	Within 1 km	At own site
Distance from sawmill to the nearest village (km)	0	0	0	0.5	0.5	0	0.5	1	0.5
Willingness to buy electricity from gasification plant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Laws & Regulations									
Availability local emission laws	No	No	No	No	No	No	No	No	No
Regulation on sawdust disposal	No	No	No	No	No	No	No	No	No
Sawmill accessibility									
Road access	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Road conditions	Good	Good	Good	Good	Good	Good	Good	Medium	Poor
Rail access	Not present	Not present	Not present	Not present	Not present	Not present	Not present	Not present	Not present
Waterway access	Not present	Not present	Not present	Not present	Not present	Not present	Not present	Not present	Not present
Current residual biomass buyers									
Current commercial value of residual biomass (USD/mt)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Present buyers of sawdust and bark	No	No	No	No	No	No	No	No	No
Present buyers for waste wood	No	No	No	No	Yes	No	No	No	No
Operating charataristics of the sawmills									
Days in operation per week (week is 7 days)	6	6	6	6	6	6	6	6	6
Working hours per day	12	10	10	12	12	12	12	12	12
Own technical staff	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Spare parts available on site	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Residual biomass storage possibilities	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Figure 16: Research findings first field trip – Akure South, Akure North and Owo

General information									
LGA	Ijebu Ode			Ijebu North			Abeokuta North		
Sawmill no.	10	11	12	13	14	15	16	17	18
Name	Ejirin Rd	Adefisan	Okeowa	Okeagbo	Church	Sectariart	Lafenwa	Oke lafenwa	Lyana lafenwa
Description of location	Urban	Urban	Urban	Semi Urban	Urban	Urban	Urban	Urban	Urban
Area type	Residential	Residential	Residential	Residential	Residential	Residential	Residential	Residential	Residential
Coordinates of the sawmill	6.804865, 3.901862	6.809970, 3.900146	6.835886, 3880748	6.961719, 3.990057	6.9596367, 3.9889694	6.9632078, 3.9915273	7.1590991, 3.3238171	3.15772594,3.3 1604	7.1542044, 3.324479
Size of the mill									
Number of FTEs working at the sawmill	18	16	32	32	32	32	40	20	30
No. Of sawing machines	3	3	4	4	4	4	5	3	4
Residual biomass specifications									
Residual biomass available	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Calorific value biomass (mj/kg)	Not known	Not known	Not known	Not known	Not known	Not known	Not known	Not known	Not known
Silica content biomass (%)	Not known	Not known	Not known	Not known	Not known	Not known	Not known	Not known	Not known
Plastic content (%)	0%	0%	0%	0%	0%	0%	0%	0%	0%
Amount of residual biomass available for the gasifier	Not known	Not known	Not known	Not known	Not known	Not known	Not known	Not known	Not known
Opportunities for the gasification plant to deliver heat and electricity									
Connection to the grid	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observed distance to the grid (km)	0	0	0	0	0	0	0	0	0
Connection capacity to the grid	Not known	Not known	Not known	Not known	Not known	Not known	Not known	Not known	Not known
Possibility for heat delivery	No	No	No	No	No	No	No	No	No
Distance from sawmill to the nearest village (km)	0	0	0	0	0	0	0	0	0
Willingness to buy electricity from gasification plant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Laws & Regulations									
Availability local emission laws	No	No	No	No	No	No	No	No	No
Regulation on sawdust disposal	No	No	No	No	No	No	No	No	No
Sawmill accessibility									
Road access	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Road conditions	Medium	Good	Good	Good	Medium	Medium	Good	Good	Good
Rail access	Not present	Not present	Not present	Not present	Not present	Not present	Yes	Yes	Yes
Waterway access	Not present	Not present	Not present	Not present	Not present	Not present	Not present	Not present	Not present
Current residual biomass buyers									
Current commercial value of residual biomass (USD/mt)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Present buyers of sawdust and bark	No	No	No	No	No	No	No	No	No
Present buyers for waste wood	No	No	No	No	No	No	No	No	No
Operating charataristics of the sawmills									
Days in operation per week (week is 7 days)	6	6	6	6	6	6	6	6	6
Working hours per day	12	12	12	11	12	10	12	12	12
Own technical staff	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Spare parts available on site	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Residual biomass storage possibilities	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Figure 17: Research findings second field trip - Ijebu Ode, Ijebu North and Abeokuta North

General information									
LGA	Abeokuta South			Idanre			Odigbo		
Sawmill no.	19	20	21	22	23	24	25	26	27
Name	Sapon	Anjorin	Ago oko	Sedeco	Onikare	Mtd	Ore	Alagbade	Orita
Description of location	Urban	Urban	Urban	Urban	Urban	Urban	Semi Urban	Semi Urban	Urban
Area type	Residential	Residential	Residential	Residential	Residential	Residential	Residential	Residential	Residential
Coordinates of the sawmill	7.1553396, 3.3452385	7.1546876, 3.346188	7.155159, 3.346783	7.1113119, 5.1102733	7.1096653, 5.11029733	7.1096653, 5.1102273	6.783176, 4.873033	3.7915853, 4.8801789	6.7870334, 4.87334
Size of the mill									
Number of FTEs working at the sawmill	40	20	30	12	19	16	24	20	28
No. Of sawing machines	5	3	4	2	4	4	4	5	5
Residual biomass specifications									
Residual biomass available	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Calorific value biomass (mj/kg)	Not known	Not known	Not known	Not known	Not known	Not known	Not known	Not known	Not known
Silica content biomass (%)	Not known	Not known	Not known	Not known	Not known	Not known	Not known	Not known	Not known
Plastic content (%)	0%	0%	0%	0%	0%	0%	0%	0%	0%
Amount of residual biomass available for the gasifier	Not known	Not known	Not known	Not known	Not known	Not known	Not known	Not known	Not known
Opportunities for the gasification plant to deliver heat and electricity									
Connection to the grid	Yes	Yes	Yes	yes	yes	yes	yes	yes	yes
Observed distance to the grid (km)	0	0	0	0	0	0	0	0	0
Connection capacity to the grid	Not known	Not known	Not known	Not known	Not known	Not known	Not known	Not known	Not known
Possibility for heat delivery	No	No	No	No	No	No	No	No	No
Distance from sawmill to the nearest village (km)	0	0	0	0	0	0	0	0	0
Willingness to buy electricity from gasification plant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Laws & Regulations									
Availability local emission laws	No	No	No	No	No	No	No	No	No
Regulation on sawdust disposal	No	No	No	No	No	No	No	No	No
Sawmill accessibility									
Road access	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Road conditions	Good	Good	Good	Good	Good	Good	Good	Good	Good
Rail access	Yes	Yes	Yes	Not present	Not present	Not present	Not present	Not present	Not present
Waterway access	Not present	Not present	Not present	Not present	Not present	Not present	Not present	Not present	Not present
Current residual biomass buyers									
Current commercial value of residual biomass (USD/mt)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Present buyers of sawdust and bark	No	No	No	No	No	No	No	No	No
Present buyers for waste wood	No	No	No	Yes	Yes	Yes	No	No	No
Operating charataristics of the sawmills									
Days in operation per week (week is 7 days)	6	6	6	6	6	6	6	6	6
Working hours per day	12	12	12	12	12	12	12	12	12
Own technical staff	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Spare parts available on site	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Residual biomass storage possibilities	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Figure 18: Research findings second field trip - Abeokuta South, Idanre and Odigbo

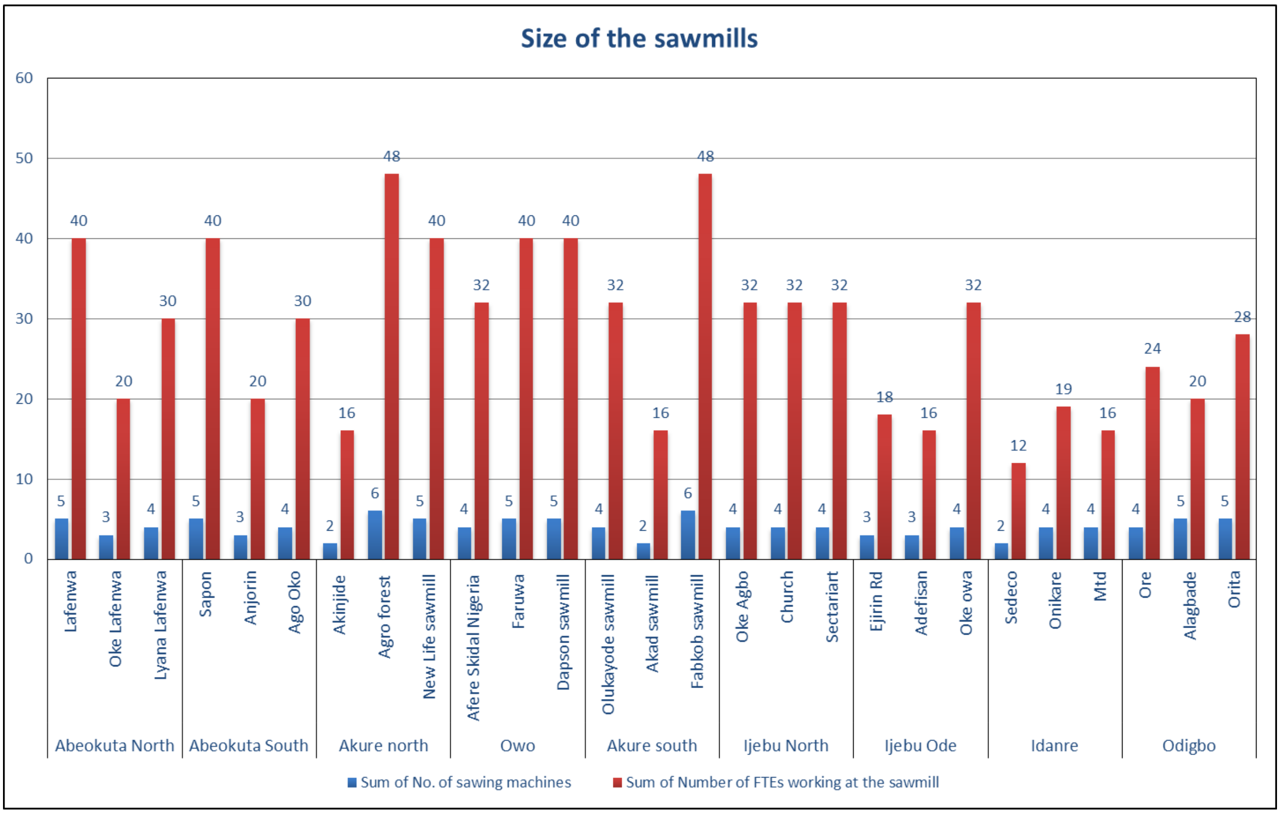


Figure 19: size of the sawmills according to number of sawing machines and FTEs working at the sawmill.

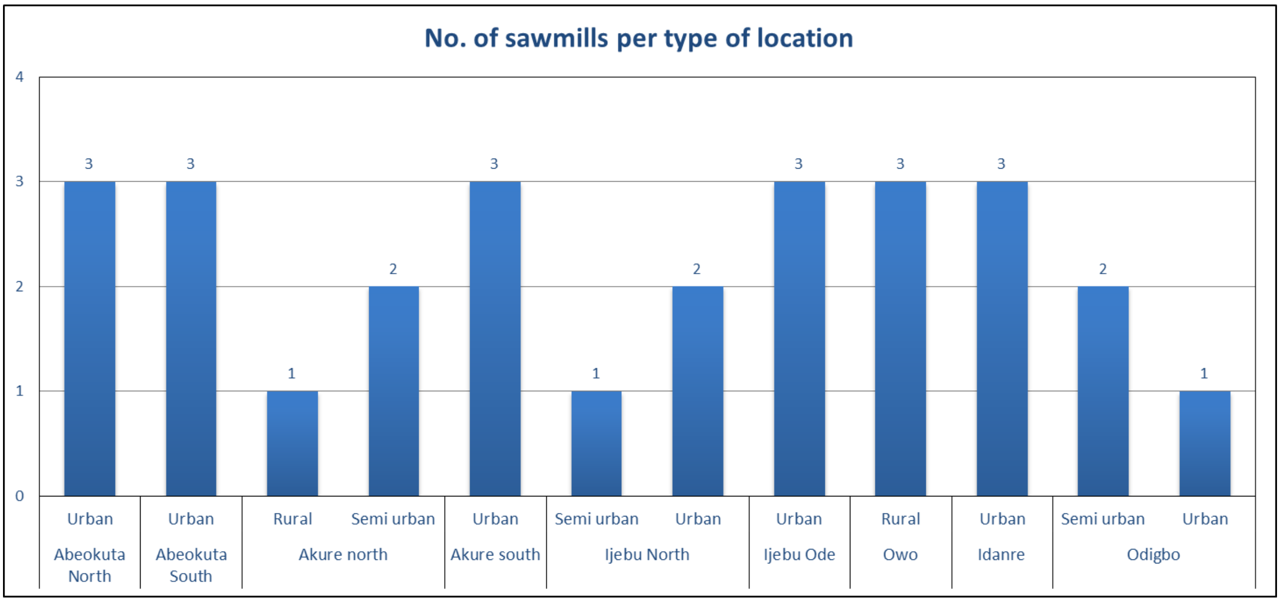


Figure 20: Number of sawmills per type of location.

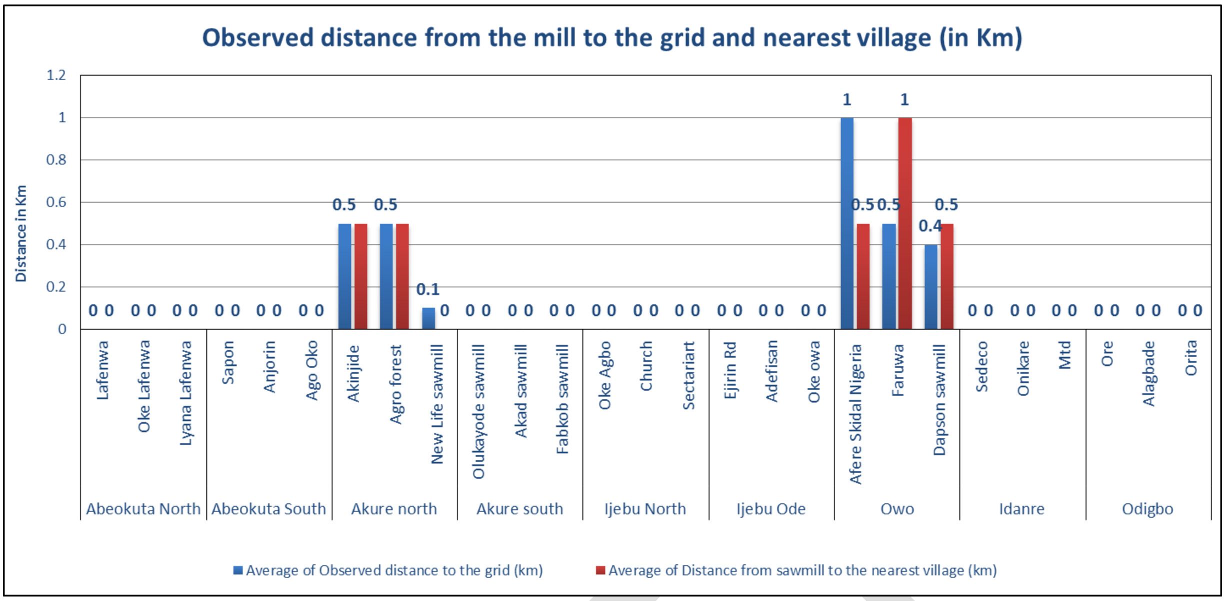


Figure 21: Observed distance from the mill to the grid and nearest village (in Km)
Note: 0=connected to the grid and/or in the village.

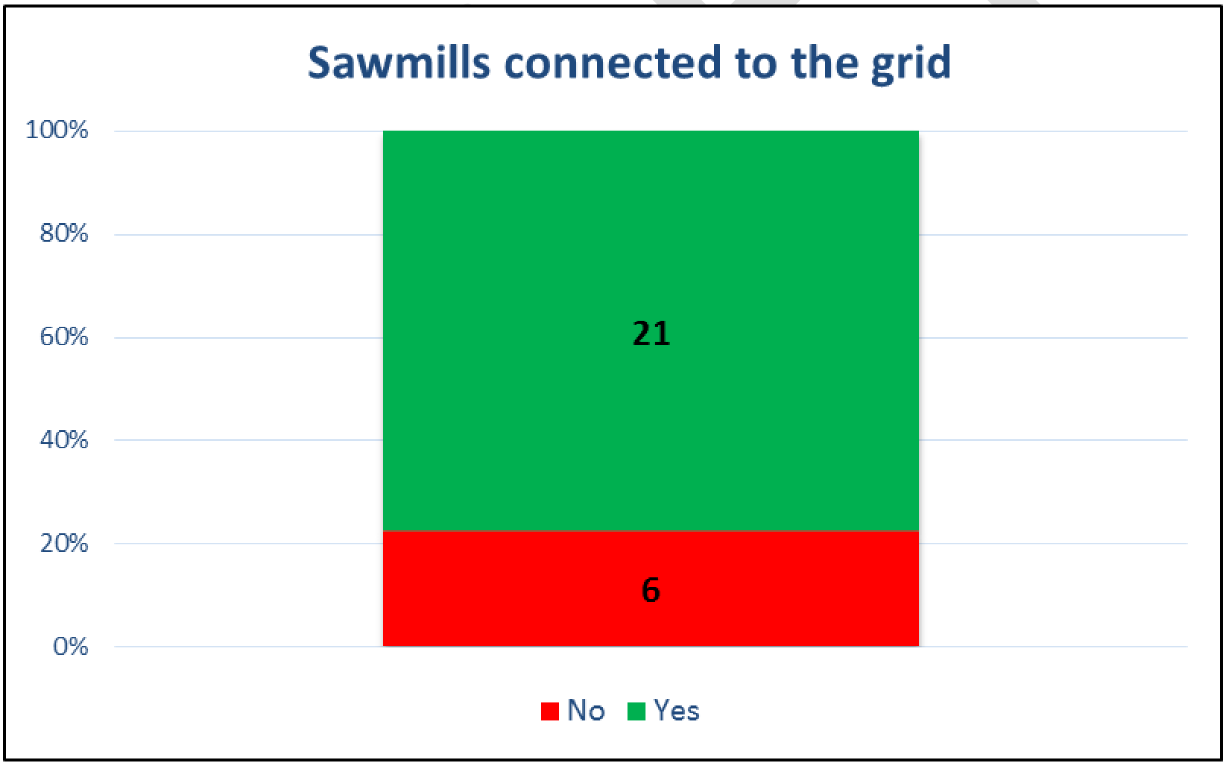


Figure 22: Number of sawmills connected to the grid

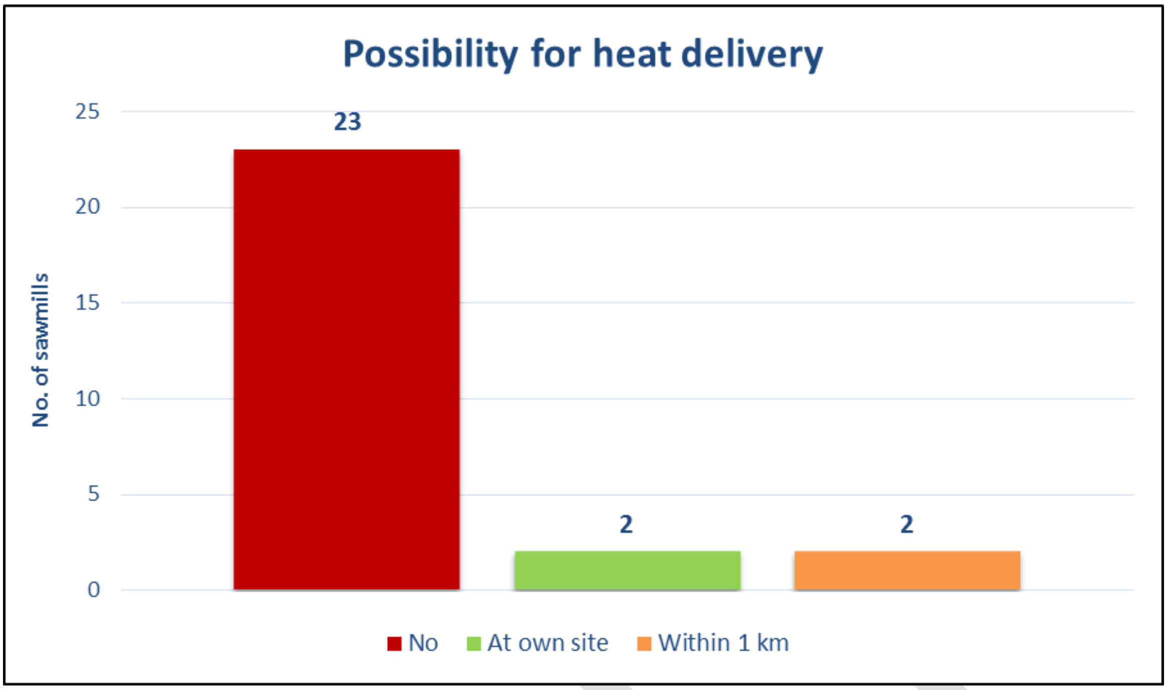


Figure 23: Possibilities for heat delivery.

4. Technical design

Due to complications with the gasification of heterogeneous and contaminated biomass/wood residues and the circumstances the wood residues are handled at the visited sawmills the selected technique of electricity generation is the complete combustion of the biomass with an boiler and steam turbine.

Complete gasification system consist, due to the different dimensions of the fuel particles to be burned, of: a mixing device to mix the different wood streams (wood chips and saw dust) in order to provide a homogeneous fuel mixture. This mixture is led into the combustion chamber of a boiler where it is burned at a high temperature. This high temperature provides a complete breaking of the long carbon hydrogen strings and therefor fore comes a clock-up of plant components. The gasses caused by the incineration of the fuels is then cooled down by water/ steam tubes within the boiler. This heat causes the water, in these tubes, to boil and eventually produces steam. The produced steam is used to drive a steam turbine which is connected to a generator. The generator is connected to the mini grid. Any excess electrical power what is not used by the electrical consumption of the saw mill can be sold to other users.
Key to design is properties and thermal behavior of fuel fed into the boiler. Knowledgeable and skilled operators are demanded in operation and maintenance.
On generation of electricity, load assessment demand of community would be a great parameter in power distribution design.

4.1 Power generation system

The power generation is built out of a steam driven turbine in which the produced steam expands from boiler pressure to the condenser pressure. Most likely a single stage, simple design turbine will be the best option due to its proven and easy operation. This turbine is connected, by means of a gearbox, to the generator. Depending on the local electrical grid requirements the generator voltage and power can be selected. The generator lead will be connecting to an existing low voltage distribution which is already operated by the present owners or when required a new system needs to be installed to distribute the generated electrical power to the users. For emergency reasons, if the power plant needs to be shut down for any reason, the present available diesel generator can be upgraded to an emergency generator to allow the plant to be ran down to a safe mode. The suggested incineration principle is shown in the drawing on the next page.

Point of attention for this plant suggestion is the big difference of electrical consumption between day and night operation. The incineration combination with boiler and steam turbine lacks the flexibility to be run up and down in the load in a short time. Start-stop operation, as normally performed with a diesel driven gen-set, is more complicated. Sudden load changes will need to discussed and the plant needs to be fine-tuned to be able to cope with them. These issues are depending on location of the plant and the surrounding facilities which need to be fed with this plant.

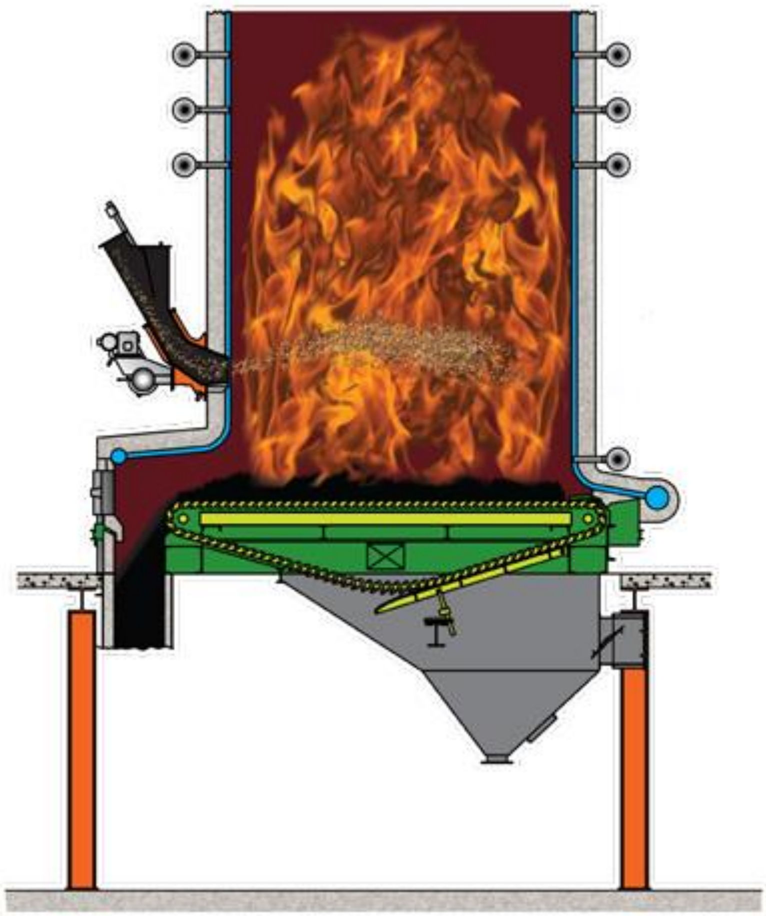


Figure 24: Suggested incineration principle

4.2 Feedstock supply (sawdust/ wood waste)

Sawdust as major feedstock can easily be obtained from sawmills which has already been discussed in our previous findings. However the pollution of the existing feed stock by i.e. silica forces us to look for an incineration process which is not affected by this pollutant. The, up till now favoured, gasification process in combination with a gas engine is not a feasible solution for the following reasons. Feedstock upgrading due to the differences in size and different pollutants will add a substantial amount of money to the CAPEX. The chosen gasification process in combination with a gas engine is not yet considered as a proven technology, where it concerns uninterrupted operations for a longer period of time . The required gas-cleaning techniques have been developed but for power plant with electrical outputs of above 20 MWe. This type of gas-cleaning, is for smaller plant applications a too high increase on the CAPEX and makes the business case not viable.

4.3 Storage

All Biomass system requires storage space to ensure sufficient available feed stock, proper handling and control. A typical wood chips, sawdust or pellets would require the use of a bunker or silos for short term storage and an outside storage area for proper drying and equipment use. A less labor intensive option is to use automated stackers to build piles, which would later be moved to the bunker or silos. As we are planning to burn at least two different materials at the same time, saw dust and wood waste, the required proportions of each individual fuel is of importance. Therefor a separate storage facility is requested for each fuel type (saw dust and wood waste) These two fuels will be led into a small bunker at the incinerator and a speed driven dosing screw will feed the material into the combustion chamber. Both fuels will ignite simultaneously and provide a proper and complete combustion of the components.

4.4 Operation and maintenance of the plant

O & M cost of biomass plant are essentially the cost of fuel, maintenance and labourers. Since operation is continuously, the plant will be shut down to execute the required maintenance. During this period the existing diesel gen set can be used to keep the saw mill in operation. Therefore these related costs of maintenance activities, purchase of spare parts, storage of fuel and the work force is to be assessed into the overall Project cost.

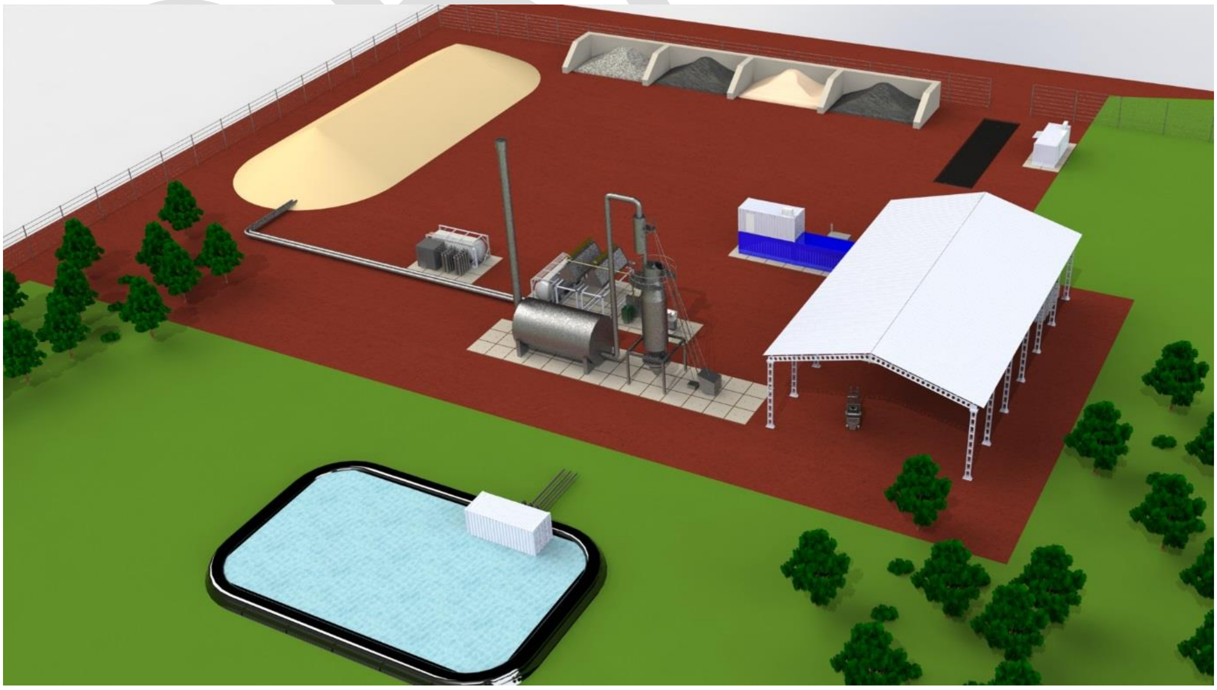
4.5 Incinerator and Gen-set sizing

The Incinerator, boiler and gen size is to be determined based on the overall feed stock availability and energy demand assessment. Meaning the size of the projects incinerator, steam boiler and the generator size will be a result of these two fundamentals.

4.6 Power distribution system

Generated power may be transported to point of consumption via underground or overhead cables. Consumption rate, quantity of required energy, rate and duration would be laid down in a Power agreement between the operator and the user.

4.7 Scheme layout



4.8 Cables and transformer sizing

Cables sizing will be defined in accordance to the requirements as pending per country. Basic is the amount of energy which need to fed into the different sub stations. The choice is based on areal conditions and the power take-off during the day and night cycle. Since the incinerator/ power set can be scaled down in performance till approx. 60 % of the nominal load a certain load needs to delivered to keep the plant operational during low load operations. If the local consumption drops below this point alternative heat or electrical consumers need to be developed. This can be heat storage or battery loading operations.

4.9 Electrical poles and cables

It is suggested to build an above ground power transfer net since the amount of electrical power to be transferred is limited in most case around 200 to 500 kW. Such can be easily transported in an above ground cable run. The further distribution to the users in the neighbourhood needs to studied into a greater depth.

4.10 Earthing system and safety mechanism

The complete will be safely grounded and earthed such in accordance will pending local and international standards. Short circuiting calculations will be performed for each and every individual site. The required protection equipment will be part of the scope of delivery of the projects

4.11 Bill of quantities and costing

The BoQ should capture the name of executing company, project location, power generating capacity from what feedstock. And assumption and result data should also be generated showing general data, tariff, energy plan data, investment cost, annual operation cost, economic data and project performance. This financial analysis will bring out all required items as bill of quantity and costing. It could come in form of a table as an annex.

4.12 Environmental and social impact assessment

The energy policy for Nigeria was formulated in 2007, but recently high oil prices and need for energy security have become more urgent drivers for alternative energy. This may call for re-assessment and update of the policy and strategy. For Nigeria, high oil prices and the need to increase overall energy per capita supply are strong motivators for development of alternative forms of energy. Transportation fuels remain the most emotive of all energy segments, especially when prices are going up, as this is where lifestyles and livelihoods are visibly impacted. Alternative energy is not only focusing on economics alone, but also looks at security of supply, environmental and their social economic benefits to the country.

4.12.1 Law on environmental protection and natural resources management

Three key legislations that have been in application all addressing the commercial energy sub sector on Biomass:

- Electrical Power Act of 1997 currently under review
- Biomass Act Cap 116 – regulates importation, transportation and storage
- Renewable Energy Act – prior to the deregulation of the petroleum sub-sector, this was the legislation that the government used to control pricing of electricity products

In addition to these, there are other legislations relevant to operations within the energy sector:

- Licensing Act – for licensing of operators in for instance in the petroleum and electricity sectors
- Standards Act
- Environment management and coordination Act
- Local Government Act
- Physical Planning Act
- Weights and measures Act
- Monopolies Act

The relevant policy and legal framework for solar energy in Kenya includes:

- Session Paper No. 4 on Energy of Nigeria
- Nigeria rural electrification master plan
- Nigeria Vision 2020
- Nigeria National Climate Change Response Strategy

4.12.2 Summary of potential environmental impact of biomass gasification

Biomass gasification for development is a major avenue for development of varieties of bio fuel. The benefit of biomass gasification and carbon sequestration and storage alone or with other feedstock is significant; similarly capturing CO_2 from its process is also a mitigation option. This project has the potential to address key barriers that constrain the use renewable technology for power and head generation given the high cost of generating electricity based on fossil fuel and its attendant environmental hazards.

4.12.3 Summary of potential social impact of biomass gasification

Expected to be initially maintained and operated by an expert transfer of technology would be a social benefit to the community. Also in a country where management of gasification feedstock does not exist it will this time become a sellable item thereby encouraging future economic potential of sawdust. In addition, direct and associated employment generation in gasification technology will spring up. There is also a possibility of job creation for genders (women) at the power plant in feedstock refilling and loading.

4.12.4 Environmental mitigation measures proposed

Biomass produces low sulphur fuel hence the Project reduces the carbon dioxide emission assault with the normal methods of electricity generation from direct generator/engines. It is CO_2neutral and environmentally friendly. The laws of Nigeria requires that Greenfield mini-grid projects, regardless of their size, obtain approval of the Environmental Impact Assessment by the National Environment Management Authority (NEMA).Based on the Sustainability Guideline (Technical Note no. FI059), for the project, this requirement determines the need to conduct in-depth environmental impact assessment.

4.12.5 Social mitigation measures

As regards overall impact assessment, the project is classified as Category C–minor impact
During construction and normal operation, the project is expected to have either positive or minimal negative impact on land use, water use and CO_2 emissions. The relatively minor use of diesel (5%-7%) is noted in this regard. An analysis of CO_2 emissions indicates the following net savings will be made over the assumed 20 year life of the projects. The levels of savings in the three schemes are insufficient to warrant applying for Certified Emission Reduction credits under the Programmatic Clean Development Mechanism.

5. Costing, economic and financial analysis

5.1 Parameters and modeling assumptions

Parameters and modeling assumptions hereby included are divided according to the key building-blocks of project development. The analysis is executed in USD currency and over a 10 year time.

5.2 The gasification plant

Based on the results of the previous chapters of this feasibility study, the biomass gasification plant will have a thermal capacity of 3.25 MWth.
Taking into account an efficiency of 33%, the electrical capacity of the plant is 1.08 MWe.

5.2.1 CAPEX

The Capital Expenditure (CAPEX) envisioned for such plant is estimated at USD 3,600,000[55].
In addition, the investment required to purchase 4 hectares of land (based on the price of the industrial area of the Ogun state) is estimated at USD 80,000[56].

As a result, the total CAPEX of the installation is envisioned to be USD 3,680,000.

5.2.2 Mass and energy balance

The gasification plant will have a maximum utilization of 7,000 hours per year.
For the economic analysis it is assumed that the plant will be running at 50% of its maximum capacity in the first year and at 100% afterwards.

Maximum utilization (full capacity)	7,000	hours/year	
Realized utilization	year 1	3,500	hours
	year 2	7,000	hours
	year 3	7,000	hours
	year 4	7,000	hours
	year 5	7,000	hours
	year 6	7,000	hours
	year 7	7,000	hours
	year 8	7,000	hours
	year 9	7,000	hours
	year 10	7,000	hours

Two different inputs can be utilized for the gasification plant:

- Sawdust;
- Wood waste.

[55] World Energy Perspective Cost of Energy Technologies, World Energy Council 2013. https://www.worldenergy.org/wp-content/uploads/2013/09/WEC_J1143_CostofTECHNOLOGIES_021013_WEB_Final.pdf
[56] Nigeria institute of estate surveyors and valuers.

The following two tables illustrate the characteristics of these two input materials and the quantity of each material that would be needed to run the gasification plant at full capacity each year.

Sawdust		
Quantity input material per year	10,000.00	mt
Calorific Value input material[57]	8.2	Gj/mt
Quantity input material per hr	1.43	mt/h
Calorific Value total input	82,000.00	Gj
Conversion MWh to Gj	3.60	
Thermal capacity	3.25	MWth
Efficiency	33%	
Electrical capacity	1.08	MWe
Hours Utilization per year	7,000.00	hrs
Electricity produced per year	7,592.59	MWh

Wood residues		
Quantity input material per year	9,647.00	mt
Calorific Value input material[58]	8.5	Gj/mt
Quantity input material per hr	1.38	mt/h
Calorific Value total input	81,999.50	Gj
Conversion MWh to Gj	3.60	
Thermal capacity	3.25	MWth
Efficiency	33%	
Electrical capacity	1.08	MWe
Hours Utilization per year	7,000.00	hrs
Electricity produced per year	7,592.55	MWh

5.2.3 Feedstock

The gasification plant will make use of both sawdust and wood residues. The percentage of each one is assumed based on the total availability of each one of the two feedstock materials over the sites object of this study. The price of both inputs is now set at zero as these input materials are currently disposed or burned.

Input 1 - name:	Sawdust
Quantity per year (at full capacity)	3,500.00 mt
Price per unit	0 USD/mt
% Sawdust over total input	35%
Input 2 - name:	Waste wood
Quantity per year (at full capacity)	6,270.55 mt
Price per unit	0 USD/mt
% wood residues over total input	65%

[57] Net calorific value wet based (48% m.c.) sawdust. Source: Ministry of Agriculture and Forestry Ibadan
[58] Net calorific value wet based (48% m.c.) bark. Source: Ministry of Agriculture and Forestry Ibadan

5.2.4 Sales

The biomass gasifier is estimated to have a capacity of approx. 1MWe. Running for 7,000 hours per year the amount of electricity that will be produced equals 7,592.55 MWh.

The electricity shall be sold according to the feed-in tariff defined by the Nigerian Electricity Regulatory Commission. The table below illustrates the feed-in tariffs for different renewable energy sources for 2014-2015 and 2016[59].

Technologies	2014 (N/MWh)	2014 (USD/MWh)	2015(N/MWh)	2015 (USD/MWh)	2016(N/MWh)	2016 (USD/MWh)
Large Hydro	5,715	35	6,174	38	6,671	41
Small Hydro	27,456	168	29,643	182	32,006	196
Wind	28,641	176	30,943	190	33,433	205
Solar	79,116	486	85,401	524	92,192	566
Biomass	32,000	196	34,572	212	37,357	229
Exchange rate as at the 9th of June 2014, 162.95 Naira to 1 USD						

Figure 25: Feed-in Tariffs (FIT) for Renewable Energy generation in Nigeria. Source: IRENA

In 2016 the feed-in tariff for biomass is 37,357 Naira per MWh.
Given the currency exchange rate of 0.005 Naira to USD, the feed-in tariff for the electricity produced by the gasifier is set for the first year at 186.79 USD/MWh.
From year two onwards the feed-in tariff utilized in the model is increased according to the yearly inflation. Inflation utilized in the financial modeling uses World Bank data and is set at 8.1%[60].

5.2.5 Logistics

The sites of the gasification plants are assumed to be in the middle of the LGA's and of the 10 sourcing locations 4 are assumed to be on the furthest distance possible, three are at half the maximum distance and 3 are ate 0.3 times the maximum distance. All the distances are the driving distance from the gasification site to the sourcing site.

The following table illustrates the cost per metric ton per kilometer calculation employed for the logistics modeling[61].

Transportation cost by Truck (27ton)		
Fixed cost	18	Eur
Variable cost	0.11	Eur/km
Fuel consumption (avg)	0.28	Eur/km
Total cost (27ton)	18.39	Eur/km
Total cost per ton	0.68	Eur/km/ton
Total cost per ton	**0.76**	**USD/km/ton**

[59] The Nigerian Electricity Regulatory Commission (NERC) has put in place Feed-in Tariffs (FIT) for Renewable Energy generation in Nigeria since June 2012.
http://community.irena.org/t5/The-Market/Renewable-Energy-Generation-Investor-Guide-Nigeria/td-p/455
[60] http://data.worldbank.org/indicator/FP.CPI.TOTL.ZG
[61] Source: Development of a tool to model EU biomass trade (UU, University Wien en Vito), 2011

Three scenarios have been constructed in order to identify the sensitivity of the model to different logistics situations:

1- In the first scenario the available biomass is equally divided over the sourcing locations with the average of biomass that is available per location;
2- In scenario two 60% of the biomass is sourced at the three closest sourcing locations and the other 40% is equally divided over the other locations; and
3- In scenario three 60% is sourced from the four farthest locations and the other 40% is sourced at middle and short range.

5.2.6 Owo

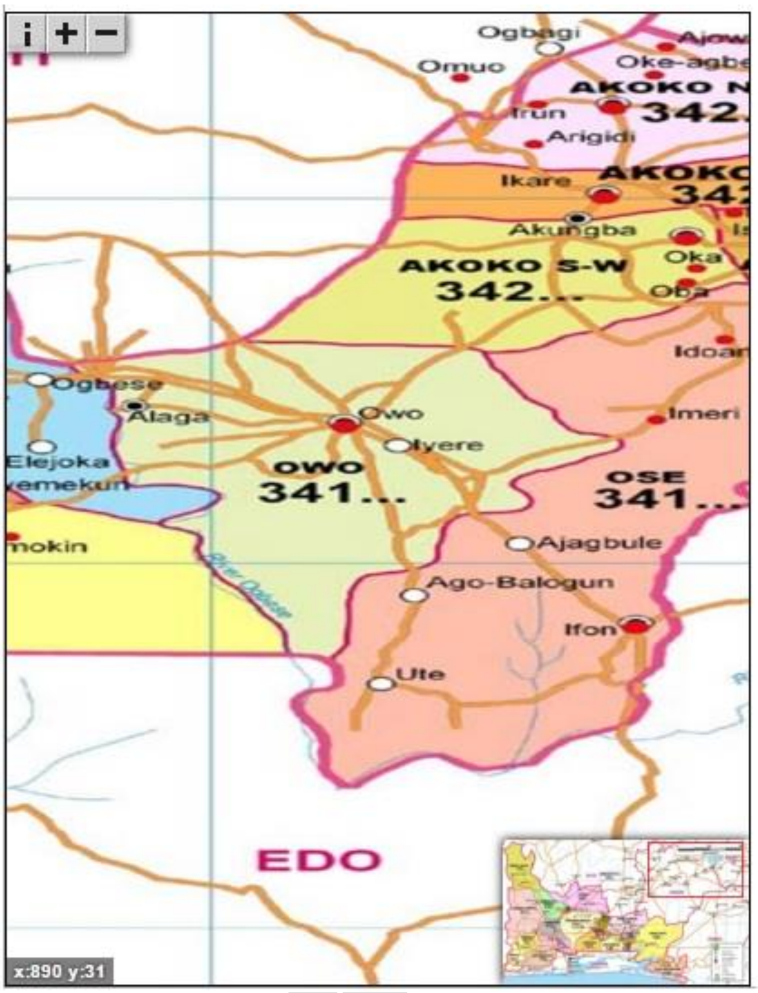


Figure 26: Local government are Owo.[62]

The maximum travel distance within the Owo in Ogun state is 80km from north to south. Assuming the plant will be in the middle of the LGA the maximum distance one can drive to source their biomass is 50km.

[62]http://web.archive.org/web/20091007011423/http://www.nipost.gov.ng/PostCode.aspx

No.	Distance from the project site (MT)	Sawdust availability	Waste Wood availability (MT)	Quantity sawdust to be supplied from the site (MT)	Quantity waste wood to be supplied from the site (MT)	Logistics cost from each site
1	15.00	410.00	768.00	410.00	768.00	$ 13,479.46
2	15.00	410.00	768.00	410.00	768.00	$ 13,479.46
3	15.00	410.00	768.00	410.00	768.00	$ 13,479.46
4	25.00	410.00	768.00	410.00	768.00	$ 22,465.77
5	25.00	410.00	768.00	410.00	768.00	$ 22,465.77
6	25.00	410.00	768.00	410.00	768.00	$ 22,465.77
7	40.00	410.00	768.00	410.00	768.00	$ 35,945.23
8	45.00	410.00	768.00	410.00	768.00	$ 40,438.38
9	45.00	410.00	768.00	220.00	126.55	$ 11,896.37
10	50.00	410.00	768.00	-	-	$ -
Total		**4,100.00**	**7,680.00**	**3,500.00**	**6,270.55**	**$ 196,115.67**

Table 13: Logistics costs for the Owo site, if all input is equally divided over the sawmills

No.	Distance from the project site	Sawdust availability	Waste Wood availability	Quantity sawdust to be supplied from the site	Quantity waste wood to be supplied from the site	Logistics cost from each site
1	15.00	700.00	1,254.11	700.00	1,254.11	$ 22,360.23
2	15.00	700.00	1,254.11	700.00	1,254.11	$ 22,360.23
3	15.00	700.00	1,254.11	700.00	1,254.11	$ 22,360.23
4	25.00	200.00	358.32	200.00	358.32	$ 10,647.78
5	25.00	200.00	358.32	200.00	358.32	$ 10,647.78
6	25.00	200.00	358.32	200.00	358.32	$ 10,647.78
7	40.00	200.00	358.32	200.00	358.32	$ 17,036.45
8	45.00	200.00	358.32	200.00	358.32	$ 19,166.01
9	45.00	200.00	358.32	200.00	358.32	$ 19,166.01
10	50.00	200.00	358.32	200.00	358.30	$ 21,294.80
Total		**3,500.00**	**6,270.57**	**3,500.00**	**6,270.55**	**$ 175,687.31**

Table 14: Logistics costs for the Owo site, when 60% of the feedstock is sourced at the shortest distance.

No.	Distance from the project site	Sawdust availability	Waste Wood availability	Quantity sawdust to be supplied from the site	Quantity waste wood to be supplied from the site	Logistics cost from each site
1	15.00	233.00	418.00	233.00	418.00	$ 7,449.18
2	15.00	233.00	418.00	233.00	418.00	$ 7,449.18
3	15.00	233.00	418.00	233.00	418.00	$ 7,449.18
4	25.00	233.00	418.00	233.00	418.00	$ 12,415.29
5	25.00	233.00	418.00	233.00	418.00	$ 12,415.29
6	25.00	233.00	418.00	233.00	418.00	$ 12,415.29
7	40.00	525.00	941.00	525.00	941.00	$ 44,733.20
8	45.00	525.00	941.00	525.00	941.00	$ 50,324.85
9	45.00	525.00	941.00	525.00	941.00	$ 50,324.85
10	50.00	527.00	941.00	527.00	939.55	$ 55,937.48
Total		**3,500.00**	**6,272.00**	**3,500.00**	**6,270.55**	**$ 260,913.78**

Table 15: Logistics costs for the Owo site, when 60% of the feedstock is sourced at the longest distances.

5.2.7 Akure North

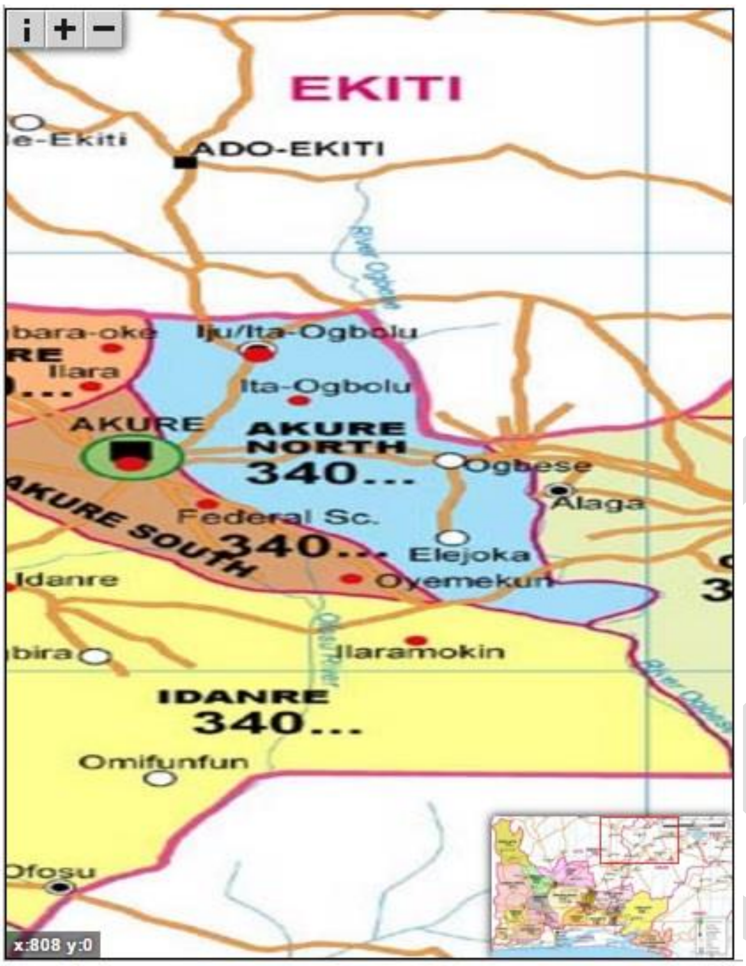


Figure 27: Local government are Owo.[63].

The maximum travel distance within Akure North is 70km form the North to the south. Assuming the plant will be in the middle of the LGA the maximum distance one can drive to source their biomass is 35km.

No.	Distance from the project site	Sawdust availability	Waste Wood availability	Quantity sawdust to be supplied from the site	Quantity waste wood to be supplied from the site	Logistics cost from each site
1	10.50	410.00	768.00	410.00	768.00	$ 9,435.62
2	10.50	410.00	768.00	410.00	768.00	$ 9,435.62
3	10.50	410.00	768.00	410.00	768.00	$ 9,435.62
4	17.50	410.00	768.00	410.00	768.00	$ 15,726.04
5	17.50	410.00	768.00	410.00	768.00	$ 15,726.04
6	17.50	410.00	768.00	410.00	768.00	$ 15,726.04
7	30.00	410.00	768.00	410.00	768.00	$ 26,958.92
8	30.00	410.00	768.00	410.00	768.00	$ 26,958.92
9	35.00	410.00	768.00	220.00	126.55	$ 9,252.73
10	35.00	410.00	768.00	-	-	$ -
Total		**4,100.00**	**7,680.00**	**3,500.00**	**6,270.55**	**$ 138,655.56**

Table 16: Logistics costs for the Akure North site, if all input is equally divided over the sawmills.

[63] http://web.archive.org/web/20091007011423/http://www.nipost.gov.ng/PostCode.aspx

No.	Distance from the project site	Sawdust availability	Waste Wood availability	Quantity sawdust to be supplied from the site	Quantity waste wood to be supplied from the site	Logistics cost from each site
1	10.50	700.00	1,254.11	700.00	1,254.11	$ 15,652.16
2	10.50	700.00	1,254.11	700.00	1,254.11	$ 15,652.16
3	10.50	700.00	1,254.11	700.00	1,254.11	$ 15,652.16
4	17.50	200.00	358.32	200.00	358.32	$ 7,453.45
5	17.50	200.00	358.32	200.00	358.32	$ 7,453.45
6	17.50	200.00	358.32	200.00	358.32	$ 7,453.45
7	30.00	200.00	358.32	200.00	358.32	$ 12,777.34
8	30.00	200.00	358.32	200.00	358.32	$ 12,777.34
9	35.00	200.00	358.32	200.00	358.32	$ 14,906.90
10	35.00	200.00	358.32	200.00	358.30	$ 14,906.36
Total		**3,500.00**	**6,270.57**	**3,500.00**	**6,270.55**	**$ 124,684.76**

Table 17: Logistics costs for the Akure North site, when 60% of the feedstock is sourced at the shortest distance.

No.	Distance from the project site	Sawdust availability	Waste Wood availability	Quantity sawdust to be supplied from the site	Quantity waste wood to be supplied from the site	Logistics cost from each site
1	10.50	233.00	418.00	233.00	418.00	$ 5,214.42
2	10.50	233.00	418.00	233.00	418.00	$ 5,214.42
3	10.50	233.00	418.00	233.00	418.00	$ 5,214.42
4	17.50	233.00	418.00	233.00	418.00	$ 8,690.71
5	17.50	233.00	418.00	233.00	418.00	$ 8,690.71
6	17.50	233.00	418.00	233.00	418.00	$ 8,690.71
7	30.00	525.00	941.00	525.00	941.00	$ 33,549.90
8	30.00	525.00	941.00	525.00	941.00	$ 33,549.90
9	35.00	525.00	941.00	525.00	941.00	$ 39,141.55
10	35.00	527.00	941.00	527.00	939.55	$ 39,156.23
Total		**3,500.00**	**6,272.00**	**3,500.00**	**6,270.55**	**$ 187,112.96**

Table 18: Logistics costs for the Akure North site, when 60% of the feedstock is sourced at the longest distances.

5.2.8 Akure South

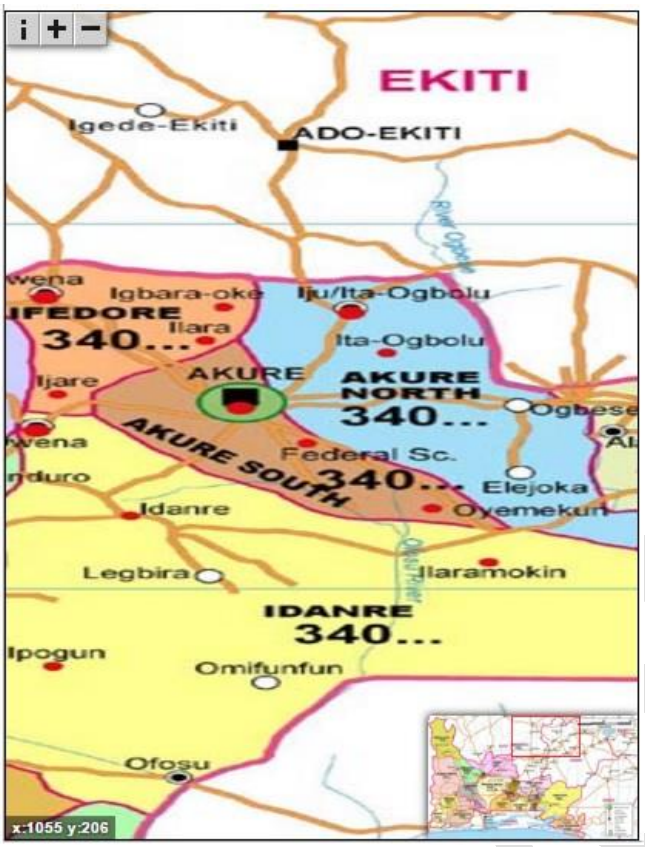


Figure 28: Local government area Akure South[64]

The maximum distance one can drive from one side to the other is 55km form North-West to South-East. Assuming the plant will be in the middle of the LGA the maximum distance one can drive to source their biomass is 27.5km.

No.	Distance from the project site	Sawdust availability	Waste Wood availability	Quantity sawdust to be supplied from the site	Quantity waste wood to be supplied from the site	Logistics cost from each site
1	8.25	410.00	768.00	410.00	768.00	$ 7,413.70
2	8.25	410.00	768.00	410.00	768.00	$ 7,413.70
3	8.25	410.00	768.00	410.00	768.00	$ 7,413.70
4	13.75	410.00	768.00	410.00	768.00	$ 12,356.17
5	13.75	410.00	768.00	410.00	768.00	$ 12,356.17
6	13.75	410.00	768.00	410.00	768.00	$ 12,356.17
7	20.00	410.00	768.00	410.00	768.00	$ 17,972.62
8	20.00	410.00	768.00	410.00	768.00	$ 17,972.62
9	27.50	410.00	768.00	220.00	126.55	$ 7,270.00
10	27.50	410.00	768.00	-	-	$ -
Total		**4,100.00**	**7,680.00**	**3,500.00**	**6,270.55**	**$ 102,524.86**

Table 19: Logistics costs for the Akure South site, if all input is equally divided over the sawmills.

[64] http://web.archive.org/web/20091007011423/http://www.nipost.gov.ng/PostCode.aspx

No.	Distance from the project site	Sawdust availability	Waste Wood availability	Quantity sawdust to be supplied from the site	Quantity waste wood to be supplied from the site	Logistics cost from each site
1	8.25	700.00	1,254.11	700.00	1,254.11	$ 12,298.13
2	8.25	700.00	1,254.11	700.00	1,254.11	$ 12,298.13
3	8.25	700.00	1,254.11	700.00	1,254.11	$ 12,298.13
4	13.75	200.00	358.32	200.00	358.32	$ 5,856.28
5	13.75	200.00	358.32	200.00	358.32	$ 5,856.28
6	13.75	200.00	358.32	200.00	358.32	$ 5,856.28
7	20.00	200.00	358.32	200.00	358.32	$ 8,518.23
8	20.00	200.00	358.32	200.00	358.32	$ 8,518.23
9	27.50	200.00	358.32	200.00	358.32	$ 11,712.56
10	27.50	200.00	358.32	200.00	358.30	$ 11,712.14
Total		**3,500.00**	**6,270.57**	**3,500.00**	**6,270.55**	**$ 94,924.37**

Table 20: Logistics costs for the Akure South site, when 60% of the feedstock is sourced at the shortest distance.

No.	Distance from the project site	Sawdust availability	Waste Wood availability	Quantity sawdust to be supplied from the site	Quantity waste wood to be supplied from the site	Logistics cost from each site
1	8.25	233.00	418.00	233.00	418.00	$ 4,097.05
2	8.25	233.00	418.00	233.00	418.00	$ 4,097.05
3	8.25	233.00	418.00	233.00	418.00	$ 4,097.05
4	13.75	233.00	418.00	233.00	418.00	$ 6,828.41
5	13.75	233.00	418.00	233.00	418.00	$ 6,828.41
6	13.75	233.00	418.00	233.00	418.00	$ 6,828.41
7	20.00	525.00	941.00	525.00	941.00	$ 22,366.60
8	20.00	525.00	941.00	525.00	941.00	$ 22,366.60
9	27.50	525.00	941.00	525.00	941.00	$ 30,754.07
10	27.50	527.00	941.00	527.00	939.55	$ 30,765.61
Total		**3,500.00**	**6,272.00**	**3,500.00**	**6,270.55**	**$ 139,029.26**

Table 21: Logistics costs for the Akure South site, when 60% of the feedstock is sourced at the longest distance.

Among the three LGAs, Akure South is the area where costs of logistics are smaller in all three scenarios (see figure 13). Akure South has a surface of 331km^2 compared for instance to a larger LGA like Owo (994km^2). The maximum driving distance in these scenarios is 50km for Owo, whereas for Akure South is almost half with 27.5km.

These scenario's show that the location of the gasification site in comparison with the sawmills can have a large influence on the logistics cost. It might therefore be favourable to build the gasification plant near a cluster of sawmills with large amounts of sawdust and waste wood available to reduce the cost of logistics.

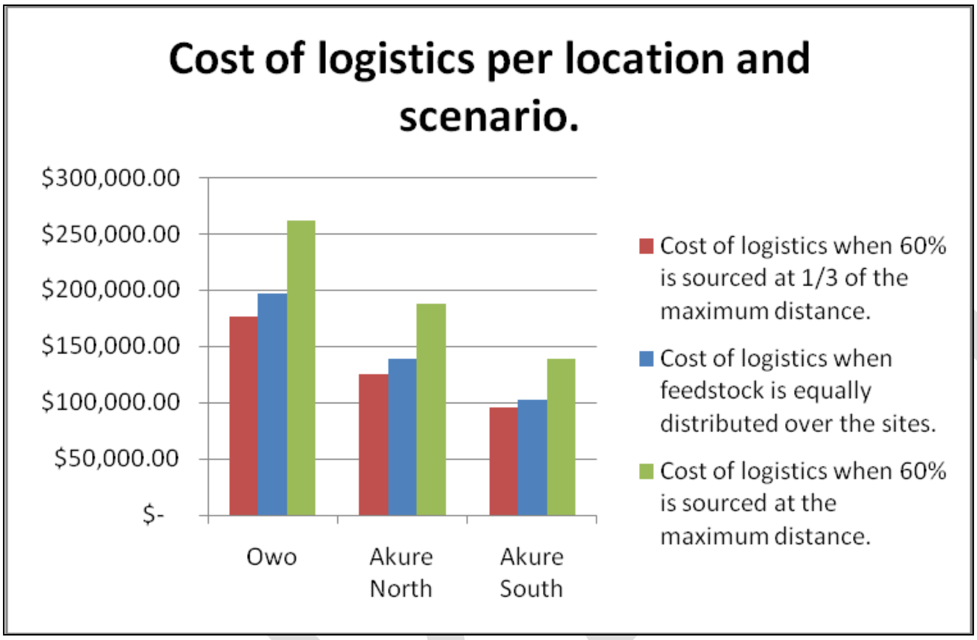


Figure 29: overview for the cost of logistics per location and scenario per year.

Figure 14 illustrates the link between driving distance and cost of logistics if all feedstock is sourced at one location and assuming a linear increase, thus no economies of scale.

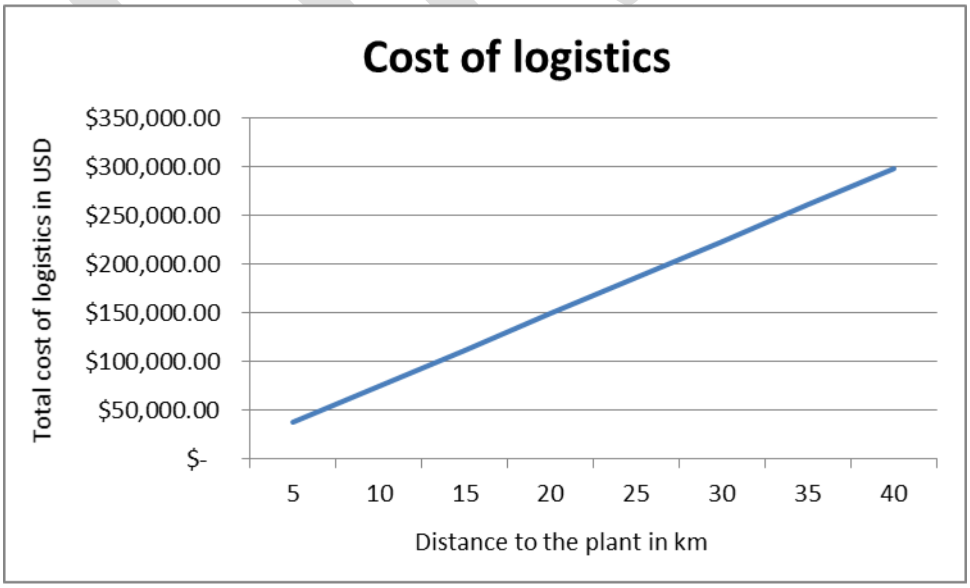


Figure 30: The cost of logistics if all feedstock is sourced at the same driving distance of the plant.

5.2.9 Personnel cost

For the personnel costs the following data and assumptions are employed.
The minimum wage by law in Nigeria is 20,000 Naira per month[65] which corresponds to 100 USD. The gasification plant will be running on three daily shifts and will require the following personnel.

Personnel	No. FTEs	Yearly Salary USD
Plant manager	2	38,400.00
Supervisors	6	28,800.00
Plant workers	12	28,800.00
Wood preparation	6	14,400.00
Total (FTEs and salaries)	26	110,400.00

The monthly salary of plant workers and wood preparation workers is assumed to be double the minimum salary by law. Supervisors are estimated to receive a salary which is four times the minimum wage by law and the two plant managers are foreseen to receive a monthly salary which is 16 times the minimum wage.

5.2.10 Other cost

The following table summarizes the other operational cost of the project.

Selling, General & Administrative	USD	15,000	Value per year at full capacity
Insurances	USD	50,000	Value per year at full capacity
Output logistics	USD	-	Value per year at full capacity
Permits and licences[66]	USD	23,000	Value per year at full capacity
Maintenance and spare parts	% (CAPEX)	4.0%	
Contingency	%	8.0%	

5.2.11 Financial input

The project is assumed to be financed with a gearing equity/debt of 50/50 %.
As a result both the equity need and the debt required are USD 1,840,000.

Debt is assumed to have an interest rate of 12% with tenure of 10 years.
Equity owners are assumed to require a return of 25%.

The Weighted Average cost of capital (WACC) utilized for the calculation of the Net Present Value (NPV) of the project is 16.7% and it does not take into account any tax deductibility of interests.

The asset (except for land) is depreciated linearly in 12 years with a residual value of 10%.
Corporate tax rate is 30%[67] and a tax rebate of 100% is assumed for the first five years of the project[68] as long as the profit is ploughed back in the company.

[65] Federal Ministry of labour and productivity
[66] Source: Nigerian Electricity regulatory commission
[67] Source: KPMG Fiscal guide of Nigeria 2014. https://www.kpmg.com/Africa/en/KPMG-in-Africa/Documents/2014%20Fiscal%20Guides/Fiscal%20Guide%20Nigeria.pdf
[68] As independent power generation utilizing renewable energy according to Nigerian Government law: http://www.nipc.gov.ng/index.php/invest-in-nigeria/investment-incentives.html

5.3 Financial statements

Profit & Loss Statement

REVENUES	Units	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y10 %
Revenues: Electricity	USD	709,091	1,533,055	1,657,233	1,791,468	1,936,577	2,093,440	2,263,009	2,446,313	2,644,464	2,858,665	100%
Total revenues	**USD**	**709,091**	**1,533,055**	**1,657,233**	**1,791,468**	**1,936,577**	**2,093,440**	**2,263,009**	**2,446,313**	**2,644,464**	**2,858,665**	**100%**
COST OF GOOD SOLD												**Y10 %**
Cost of good sold	**USD**	-	-	-	-	-	-	-	-	-	-	
GROSS MARGIN												**% of Y10 revenues**
Gross Margin	**USD**	**709,091**	**1,533,055**	**1,657,233**	**1,791,468**	**1,936,577**	**2,093,440**	**2,263,009**	**2,446,313**	**2,644,464**	**2,858,665**	**100%**
PROJECT EXPENSES												**Y10 %**
Selling, General and Administrative (SG&A)	USD	-7,500	-16,215	-17,528	-18,948	-20,483	-22,142	-23,936	-25,874	-27,970	-30,236	**3%**
Maintenance and spare parts	USD	-73,600	-159,123	-172,012	-185,945	-201,007	-217,288	-234,889	-253,915	-274,482	-296,715	**26%**
Personnel	USD	-55,200	-119,342	-129,009	-139,459	-150,755	-162,966	-176,166	-190,436	-205,861	-222,536	**19%**
Logistics (input and output)	USD	-98,058	-212,001	-229,173	-247,736	-267,803	-289,495	-312,944	-338,292	-365,694	-395,315	**34%**
Insurance	USD	-25,000	-54,050	-58,428	-63,161	-68,277	-73,807	-79,786	-86,248	-93,234	-100,786	**9%**
Other Expenses	USD	-7,500	-16,215	-17,528	-18,948	-20,483	-22,142	-23,936	-25,874	-27,970	-30,236	**3%**
Contingency	USD	-21,349	-44,885	-47,250	-49,806	-52,570	-55,557	-58,786	-62,277	-66,051	-70,130	**6%**
Total Project Expenses	**USD**	**-288,206**	**-621,832**	**-670,929**	**-724,003**	**-781,377**	**-843,398**	**-910,442**	**-982,917**	**-1,061,262**	**-1,145,954**	**100%**
EBITDA												**% of Y10 revenues**
EBITDA	**USD**	**420,885**	**911,224**	**986,304**	**1,067,465**	**1,155,200**	**1,250,043**	**1,352,567**	**1,463,396**	**1,583,201**	**1,712,712**	**60%**
Depreciation	USD	-	-270,000	-270,000	-270,000	-270,000	-270,000	-270,000	-270,000	-270,000	-270,000	**-9%**
Interest Expenses	USD	-220,800	-220,800	-198,720	-176,640	-154,560	-132,480	-110,400	-88,320	-66,240	-44,160	**-2%**
Net Taxes	USD	-60,025	-126,127	-155,275	-186,248	-219,192	-254,269	-291,650	-331,523	-374,088	-419,565	**-15%**
Taxes exemptions	USD	60,025	126,127	155,275	186,248	219,192	-	-	-	-	-	**0%**
NET PROFIT / LOSS												**% of Y10 revenues**
Net Profit / Loss	**USD**	**200,085**	**420,424**	**517,584**	**620,825**	**730,640**	**593,294**	**680,517**	**773,553**	**872,873**	**978,986**	**34%**
Cumulative Net Profit / Loss brought forward	**USD**	**200,085**	**620,508**	**1,138,092**	**1,758,917**	**2,489,557**	**3,082,851**	**3,763,368**	**4,536,921**	**5,409,794**	**6,388,780**	

Balance Sheet

ASSETS	Units	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	% Y10 of total assets
FIXED ASSETS												
Land	USD	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000	1%
Net Fixed Assets (non-land)	USD	3,600,000	3,330,000	3,060,000	2,790,000	2,520,000	2,250,000	1,980,000	1,710,000	1,440,000	1,170,000	14%
Total fixed assets	**USD**	**3,680,000**	**3,410,000**	**3,140,000**	**2,870,000**	**2,600,000**	**2,330,000**	**2,060,000**	**1,790,000**	**1,520,000**	**1,250,000**	**15%**
CURRENT ASSETS												
Cash	USD	200,085	706,508	1,310,092	2,016,917	2,833,557	3,512,851	4,279,368	5,138,921	6,097,794	7,162,780	85%
Total Current Assets	**USD**	**200,085**	**706,508**	**1,310,092**	**2,016,917**	**2,833,557**	**3,512,851**	**4,279,368**	**5,138,921**	**6,097,794**	**7,162,780**	**85%**
TOTAL ASSETS												
TOTAL ASSETS	**USD**	**3,880,085**	**4,116,508**	**4,450,092**	**4,886,917**	**5,433,557**	**5,842,851**	**6,339,368**	**6,928,921**	**7,617,794**	**8,412,780**	**100%**

EQUITIES & LIABILITIES	Units	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	% Y10 of total liabilities
CAPITAL AND RESERVES												
Retained Earnings	USD	200,085	620,508	1,138,092	1,758,917	2,489,557	3,082,851	3,763,368	4,536,921	5,409,794	6,388,780	76%
Equity provider	USD	1,840,000	1,840,000	1,840,000	1,840,000	1,840,000	1,840,000	1,840,000	1,840,000	1,840,000	1,840,000	22%
Total capital and reserves:	**USD**	**2,040,085**	**2,460,508**	**2,978,092**	**3,598,917**	**4,329,557**	**4,922,851**	**5,603,368**	**6,376,921**	**7,249,794**	**8,228,780**	**98%**
LONG TERM LIABILITIES												
Debt provider	USD	1,840,000	1,656,000	1,472,000	1,288,000	1,104,000	920,000	736,000	552,000	368,000	184,000	2%
Total Long term Liabilities	**USD**	**1,840,000**	**1,656,000**	**1,472,000**	**1,288,000**	**1,104,000**	**920,000**	**736,000**	**552,000**	**368,000**	**184,000**	**2%**
CURRENT LIABILITIES												
Short term liabilities	USD	-	-	-	-	-	-	-	-	-	-	0%
Total Current Liabilities	**USD**	-	-	-	-	-	-	-	-	-	-	**0%**
TOTAL EQUITY & LIABILITIES												
TOTAL EQUITY AND LIABLITIES	**USD**	**3,880,085**	**4,116,508**	**4,450,092**	**4,886,917**	**5,433,557**	**5,842,851**	**6,339,368**	**6,928,921**	**7,617,794**	**8,412,780**	**100%**

Delta	USD	-	-	-	-	-	-	-	-	-	-

Discounted Cash Flow Model

Project IRR calculation

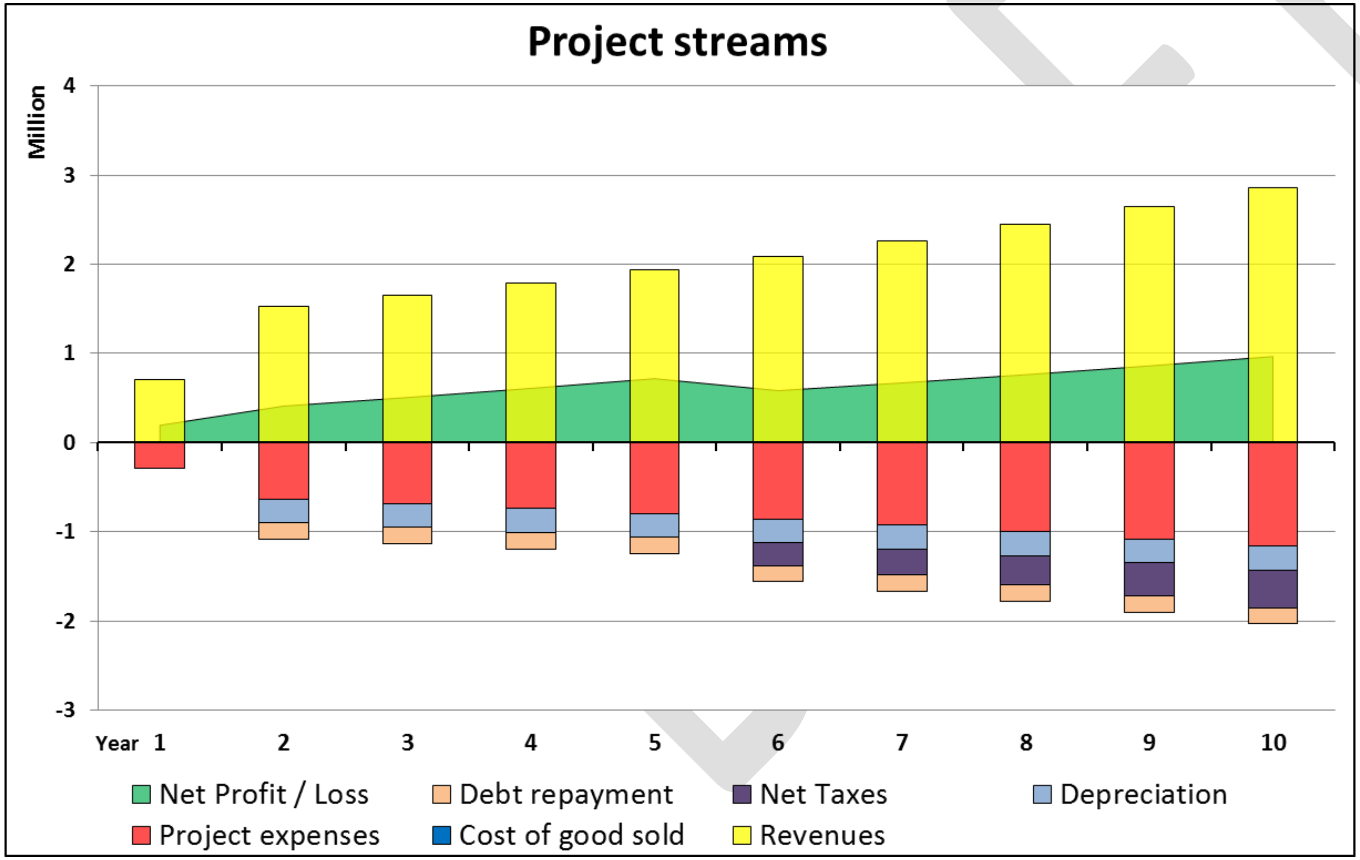
	Units	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
EBITDA	USD	416,564.74	901,883.80	976,207.21	1,056,550.83	1,143,402.28	1,237,288.69	1,338,779.90	1,448,491.90	1,567,090.58	1,695,295.74
Net Taxes	USD	-	-	-	-	-	-250,442.61	-287,513.97	-327,051.57	-369,255.17	-414,340.72
Capex	USD	-3,680,000.00	-	-	-	-	-	-	-	-	-
Changes in working capital	USD	-	-	-	-	-	-	-	-	-	-
FREE CASH FLOW											
Free Cash Flow	**USD**	**-3,263,435.26**	**901,883.80**	**976,207.21**	**1,056,550.83**	**1,143,402.28**	**986,846.08**	**1,051,265.93**	**1,121,440.33**	**1,197,835.40**	**1,280,955.02**
Cumulative Free Cash Flow	**USD**	**-3,263,435.26**	**-2,361,551.46**	**-1,385,344.25**	**-328,793.42**	**814,608.86**	**1,801,454.94**	**2,852,720.87**	**3,974,161.20**	**5,171,996.61**	**6,452,951.63**
Project IRR - overall		**27.97%**	-72.36%	-29.77%	-5.00%	9.15%	16.23%	20.93%	24.13%	26.37%	27.97%
Debt Service Coverage Ratio	**DSCR**	**4.28**	2.23	2.55	2.93	3.38	3.91	4.55	5.32	6.26	7.43
Discounted Free Cash Flow	USD	**-3,263,435.26**	**772,822.45**	**716,803.80**	**664,779.82**	**616,475.23**	**455,926.82**	**416,185.99**	**380,434.75**	**348,201.23**	**319,077.50**
Net Present Value	**USD**	**1,427,272.32**									

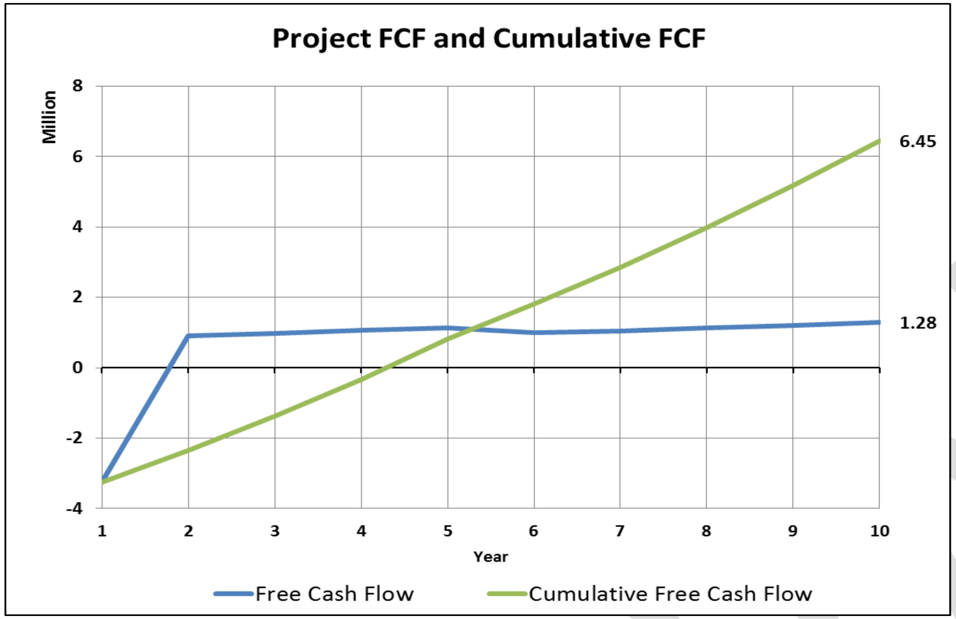
Equity IRR calculation

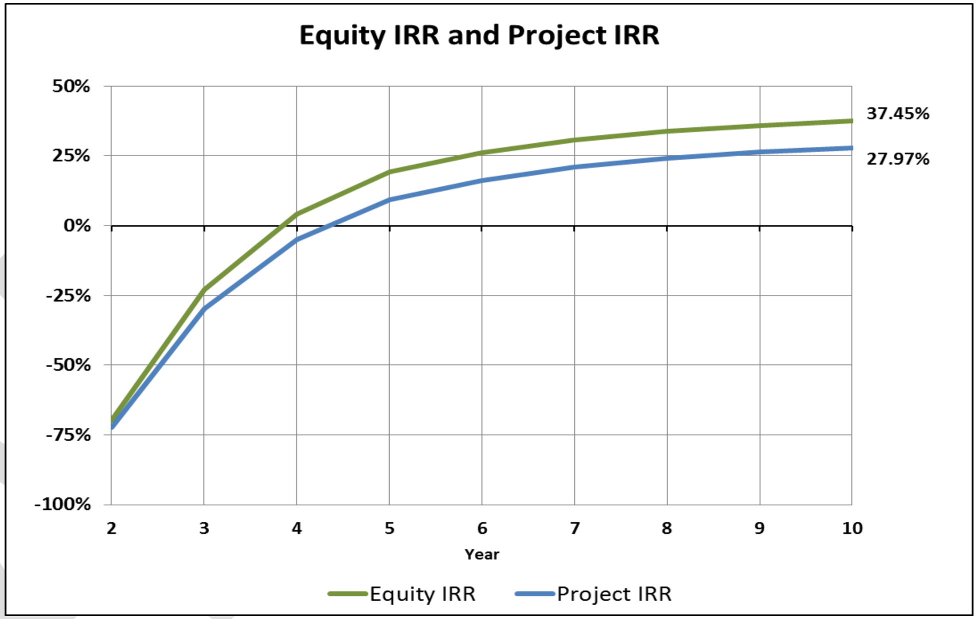
	Units	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Equity injection	USD	-1,840,000.00	-	-	-	-	-	-	-	-	-
EBITDA	USD	416,564.74	901,883.80	976,207.21	1,056,550.83	1,143,402.28	1,237,288.69	1,338,779.90	1,448,491.90	1,567,090.58	1,695,295.74
Debt repayment	USD	-	-184,000.00	-184,000.00	-184,000.00	-184,000.00	-184,000.00	-184,000.00	-184,000.00	-184,000.00	-184,000.00
Interest on debt	USD	-220,800.00	-220,800.00	-198,720.00	-176,640.00	-154,560.00	-132,480.00	-110,400.00	-88,320.00	-66,240.00	-44,160.00
Net Taxes	USD	-	-	-	-	-	-250,442.61	-287,513.97	-327,051.57	-369,255.17	-414,340.72
Changes in working capital	USD	-	-	-	-	-	-	-	-	-	-
FREE CASH FLOW TO EQUITY											
Free Cash Flow to Equity	**USD**	**-1,644,235.26**	**497,083.80**	**593,487.21**	**695,910.83**	**804,842.28**	**670,366.08**	**756,865.93**	**849,120.33**	**947,595.40**	**1,052,795.02**
Cumulative Free Cash Flow to Equity	**USD**	**-1,644,235.26**	**-1,147,151.46**	**-553,664.25**	**142,246.58**	**947,088.86**	**1,617,454.94**	**2,374,320.87**	**3,223,441.20**	**4,171,036.61**	**5,223,831.63**
Equity IRR - overall		**37.45%**	-69.77%	-22.93%	4.03%	19.20%	26.07%	30.66%	33.78%	35.94%	37.45%

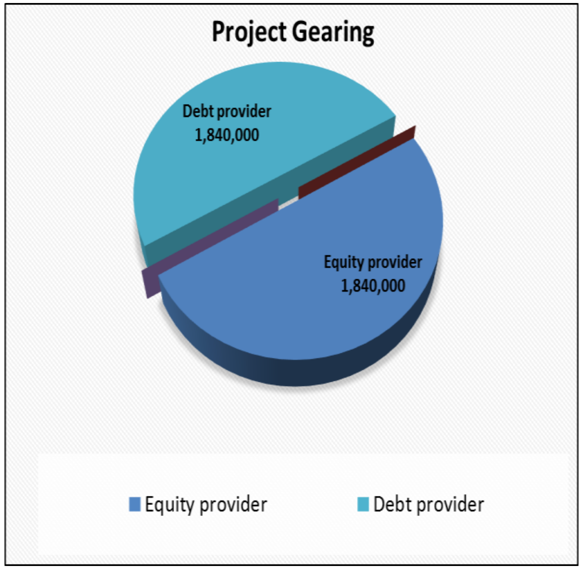
5.4 Key Financial Indicators and Financial graphs

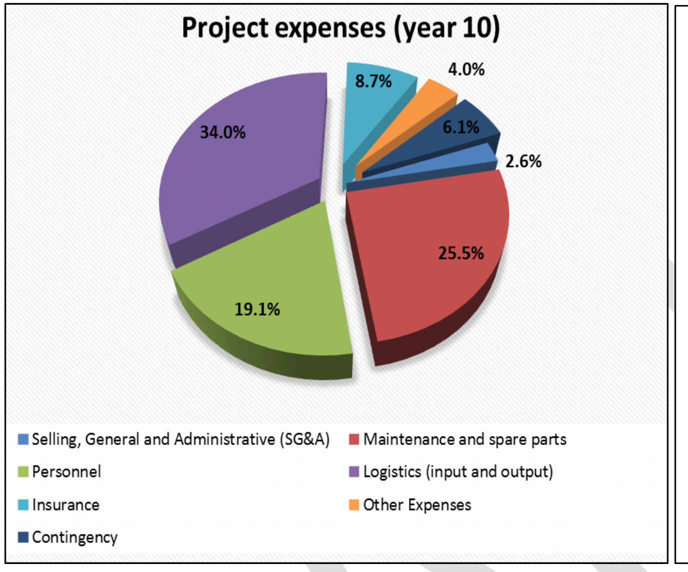
			Project Key financial indicators					Investment
Scenarios	Equity IRR	Project IRR	Cumulative profit	Cumulative FCF	Avg. EBITDA	NPV	DSCR	payback (yrs)
Baseline Scenario	37.45%	27.97%	6,289,831.63	6,452,951.63	1,178,155.57	1,427,272.32	4.28	5

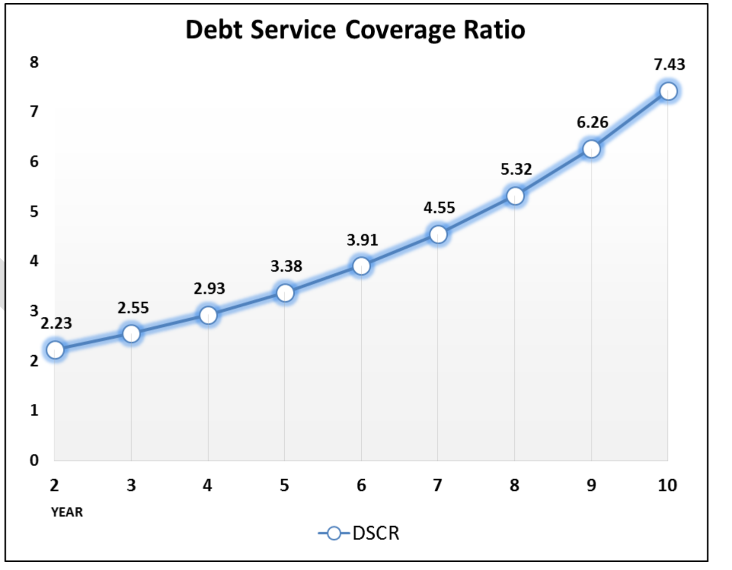


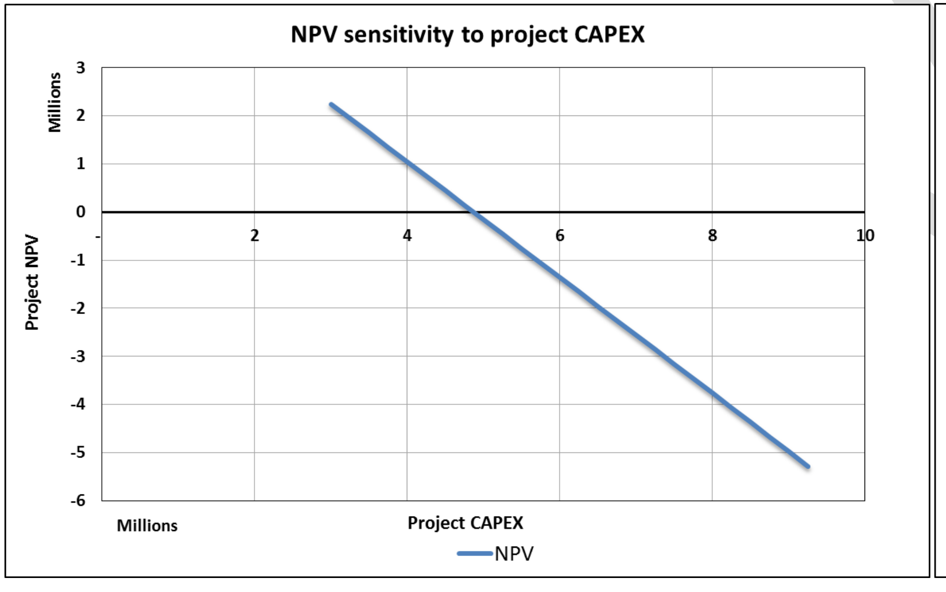

Project FCF and Cumulative FCF
Million
8
6
4
2
0
-2
-4
1 2 3 4 5 6 7 8 9 10
Year
6.45
1.28
Free Cash Flow
Cumulative Free Cash Flow

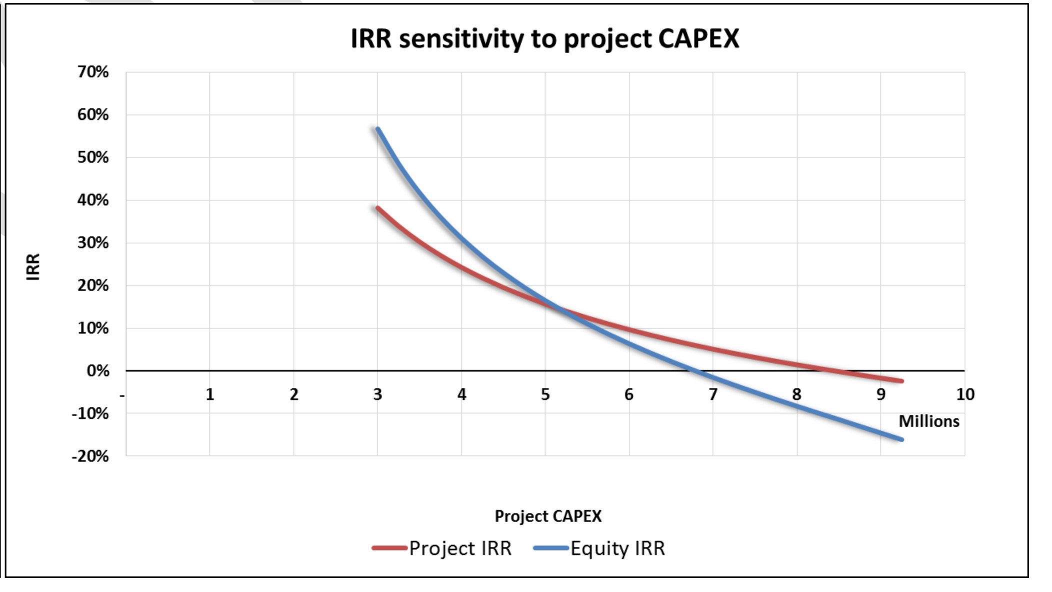

Equity IRR and Project IRR
50%
25%
0%
-25%
-50%
-75%
-100%
2 3 4 5 6 7 8 9 10
Year
37.45%
27.97%
Equity IRR
Project IRR


Project Gearing
Debt provider
1,840,000
Equity provider
1,840,000
Equity provider
Debt provider


Project expenses (year 10)
8.7%
4.0%
6.1%
2.6%
34.0%
25.5%
19.1%
Selling, General and Administrative (SG&A)
Maintenance and spare parts
Personnel
Logistics (input and output)
Insurance
Other Expenses
Contingency


Debt Service Coverage Ratio
2.23
2.55
2.93
3.38
3.91
4.55
5.32
6.26
7.43
YEAR
DSCR

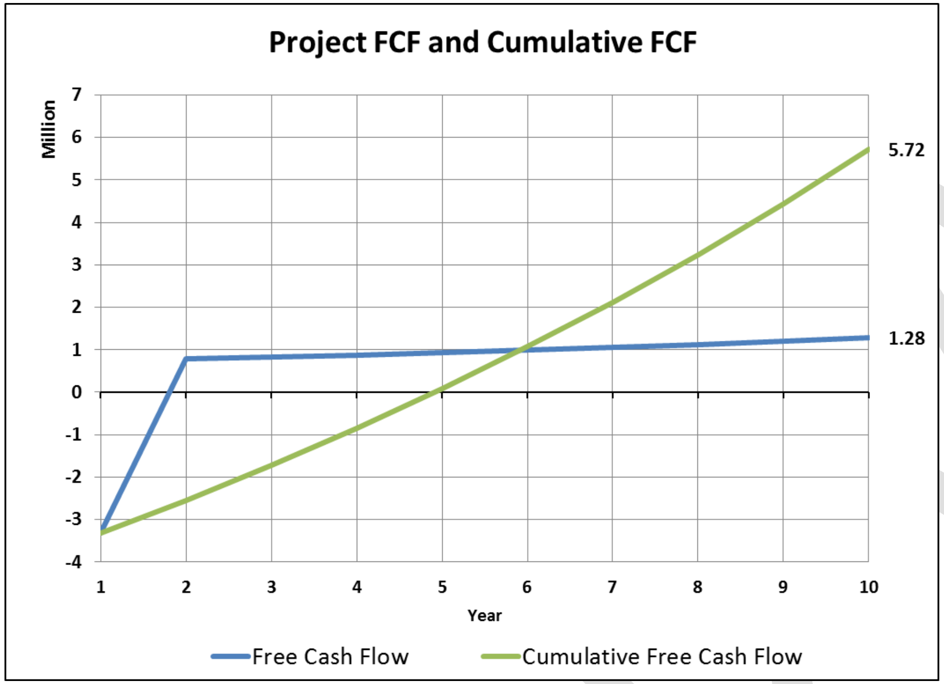

NPV sensitivity to project CAPEX
Millions
Project NPV
Millions
Project CAPEX
NPV

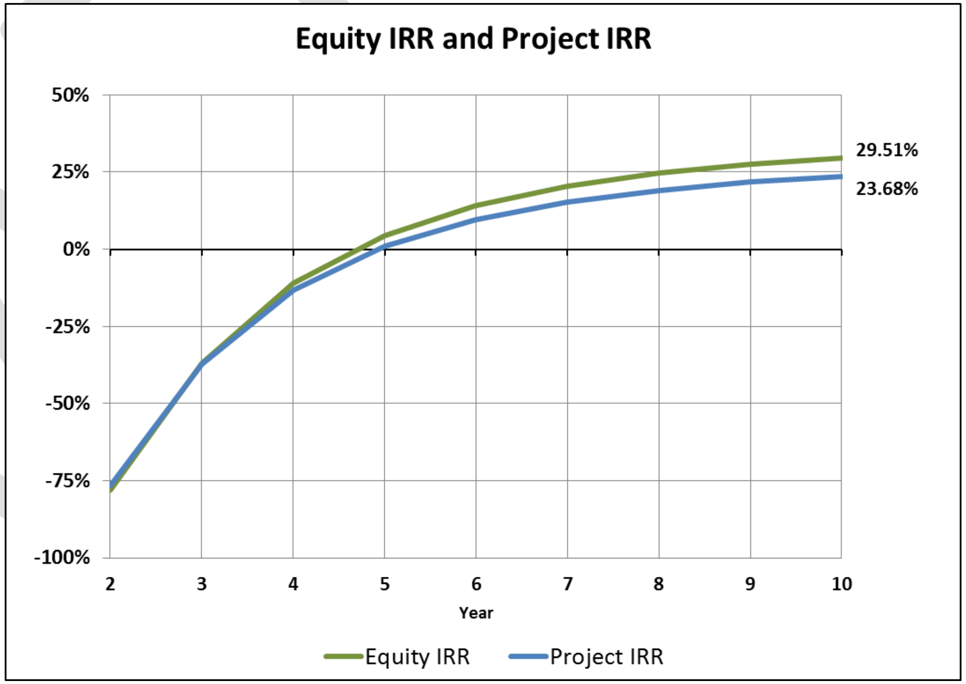

IRR sensitivity to project CAPEX
IRR
Millions
Project CAPEX
Project IRR
Equity IRR

5.5 Sensitivity analysis

Scenario 1: no tax exemption is given to the project, instead of 100% tax exemption for 5 years

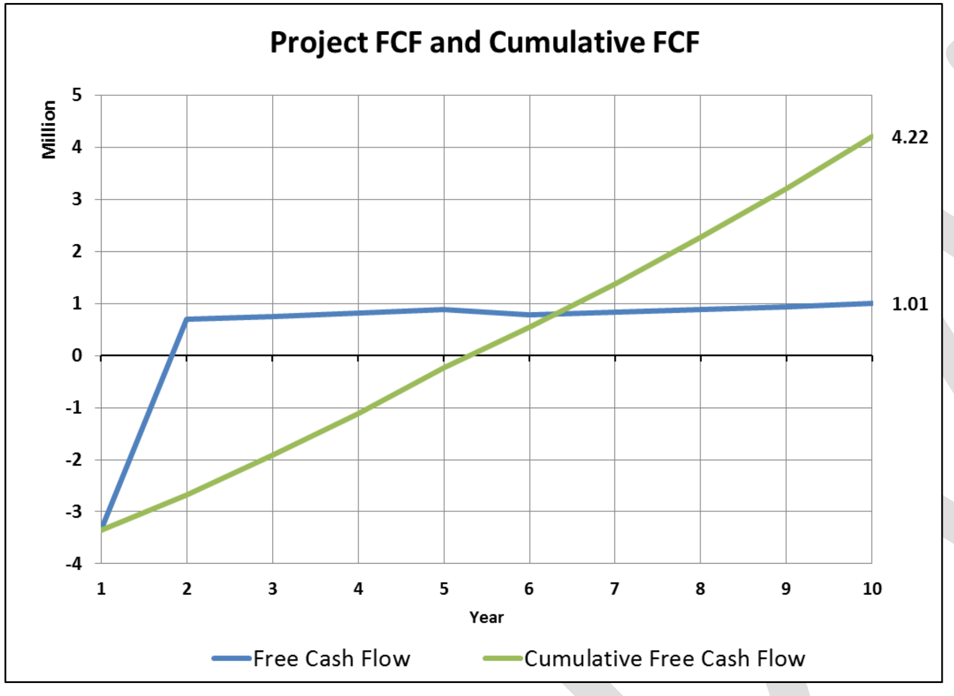
		Project Key financial indicators					Investment payback (yrs)
Equity IRR	Project IRR	Cumulative profit	Cumulative FCF	Avg. EBITDA	NPV	DSCR	
29.51%	23.68%	5,556,904.97	5,720,024.97	1,178,155.57	919,677.96	4.28	5

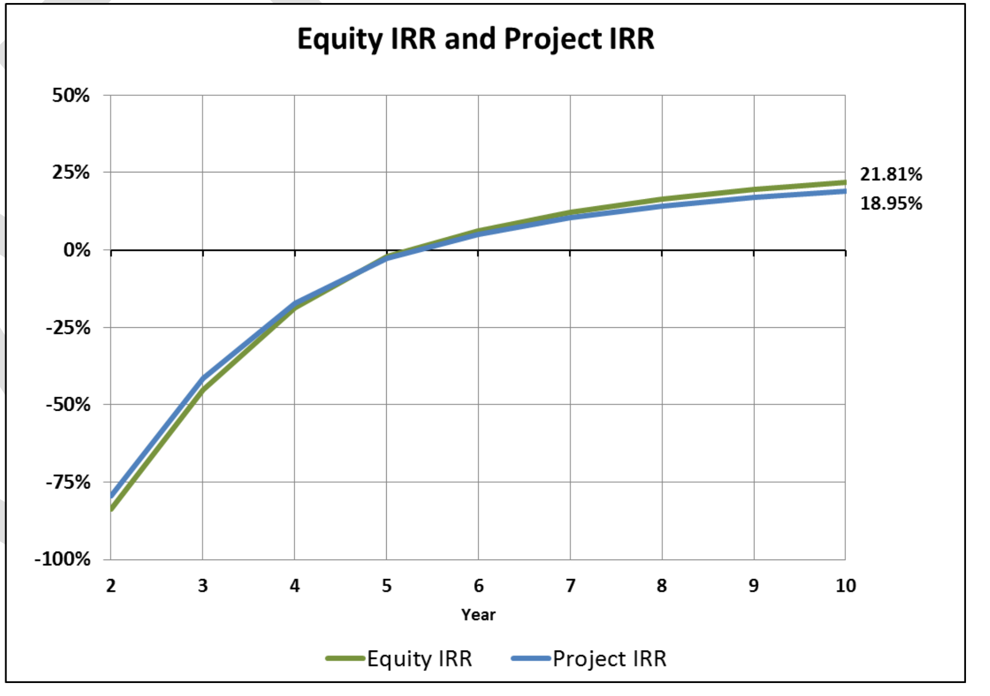




Scenario 2: cost of feedstock (both sawdust and wood residue) is 20 USD/mt and it increases according to yearly inflation of 8.1%, instead of being 0 USD/mt

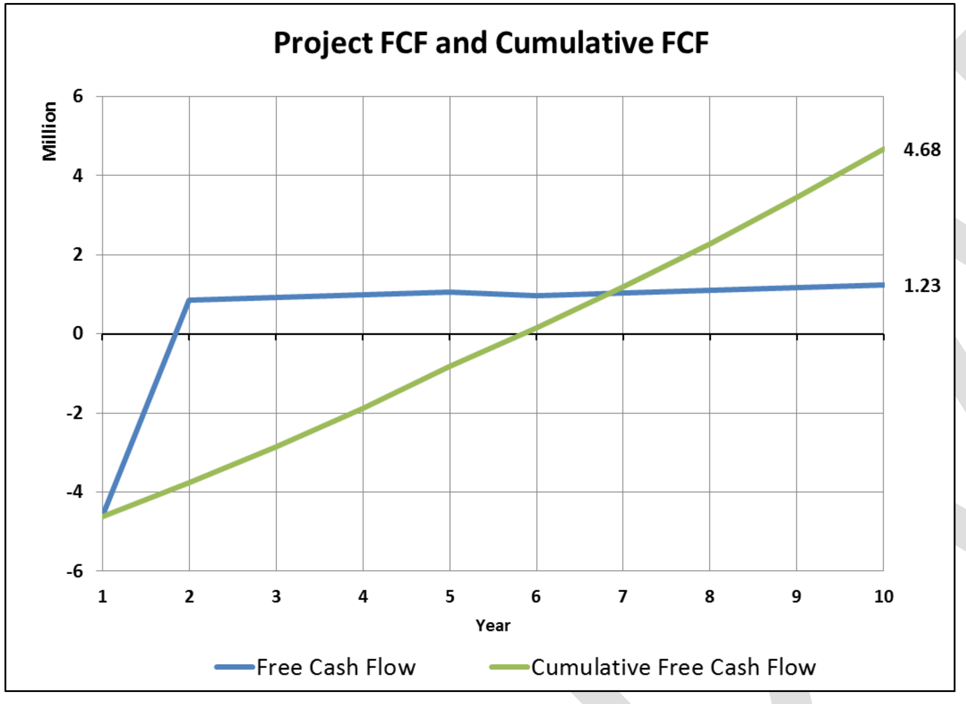
		Project Key financial indicators					Investment
Equity IRR	Project IRR	Cumulative profit	Cumulative FCF	Avg. EBITDA	NPV	DSCR	payback (yrs)
21.81%	18.95%	4,051,912.68	4,215,032.68	903,494.90	279,129.48	3.29	6

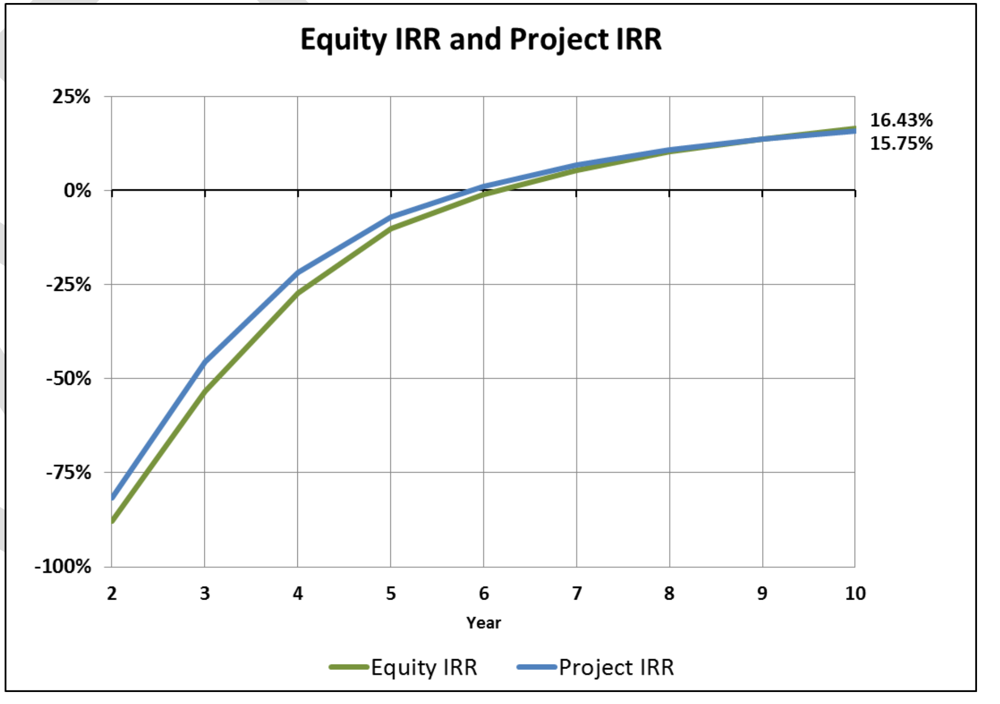




Scenario 3: CAPEX is USD 5,000,000, instead of USD 3,680,000

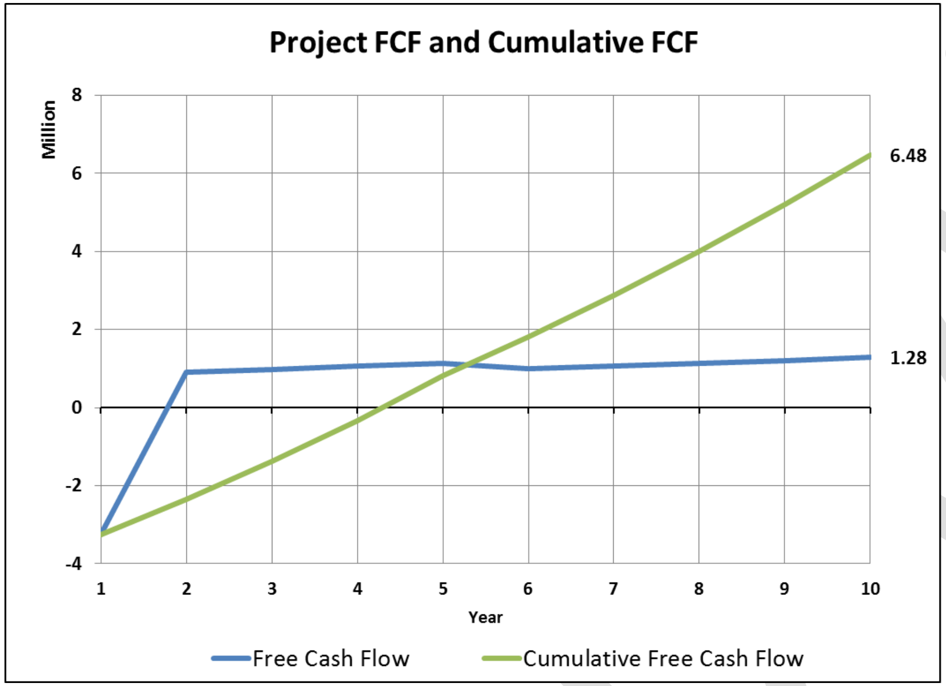
		Project Key financial indicators					Investment payback (yrs)
Equity IRR	Project IRR	Cumulative profit	Cumulative FCF	Avg. EBITDA	NPV	DSCR	
16.43%	15.75%	4,434,911.72	4,675,911.72	1,098,005.27	-158,417.99	2.94	6

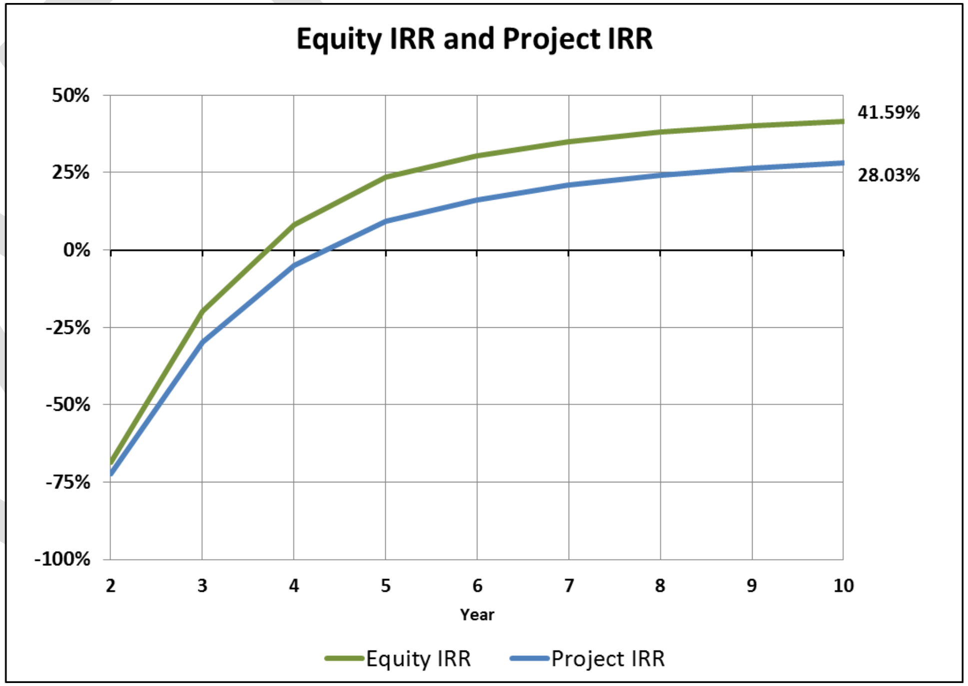




Scenario 4: Debt/equity gearing is 60/40 %, instead of 50/50 %

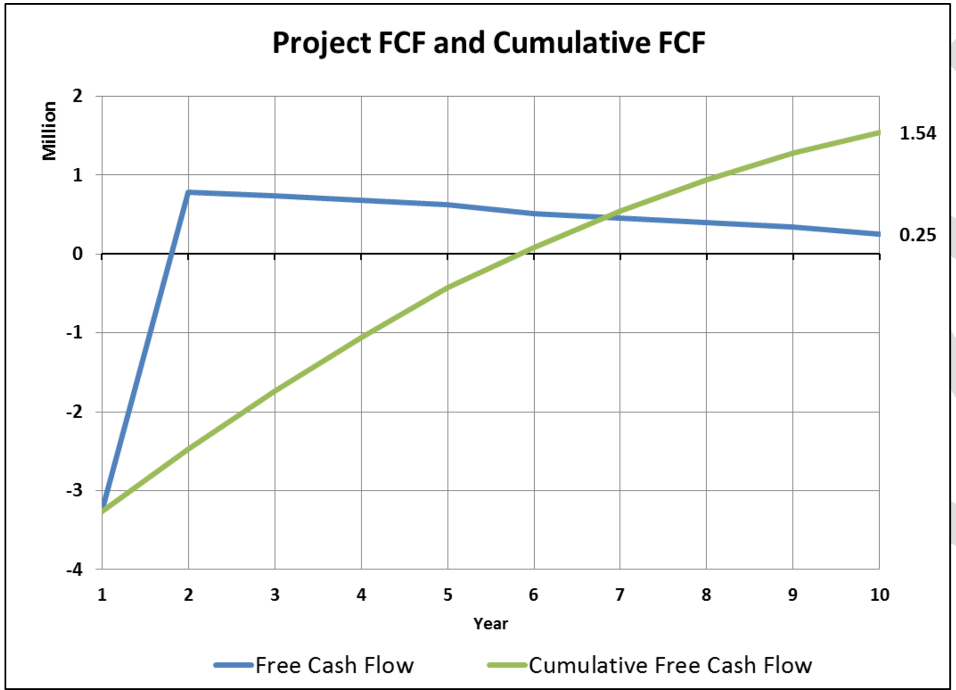
		Project Key financial indicators					Investment
Equity IRR	Project IRR	Cumulative profit	Cumulative FCF	Avg. EBITDA	NPV	DSCR	payback (yrs)
41.59%	28.03%	6,033,703.63	6,479,447.63	1,178,155.57	1,733,195.70	3.57	5

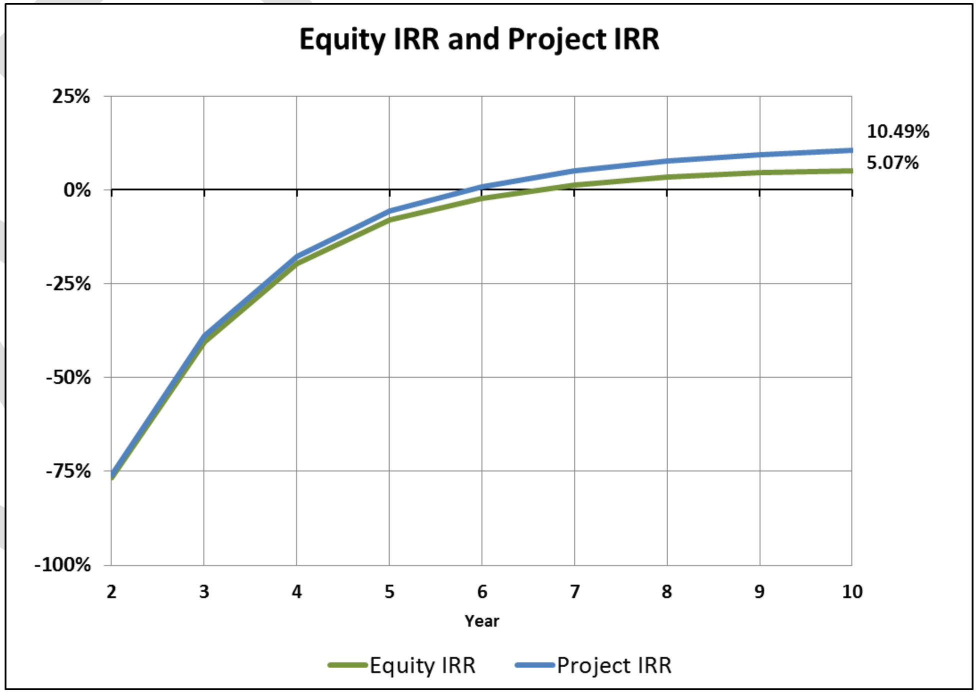




Scenario 5: Price of electricity sold (Feed-in Tariff) remains constant for the ten years at 186.79 USD/MWh, instead of increasing with a 8.1% yearly rate

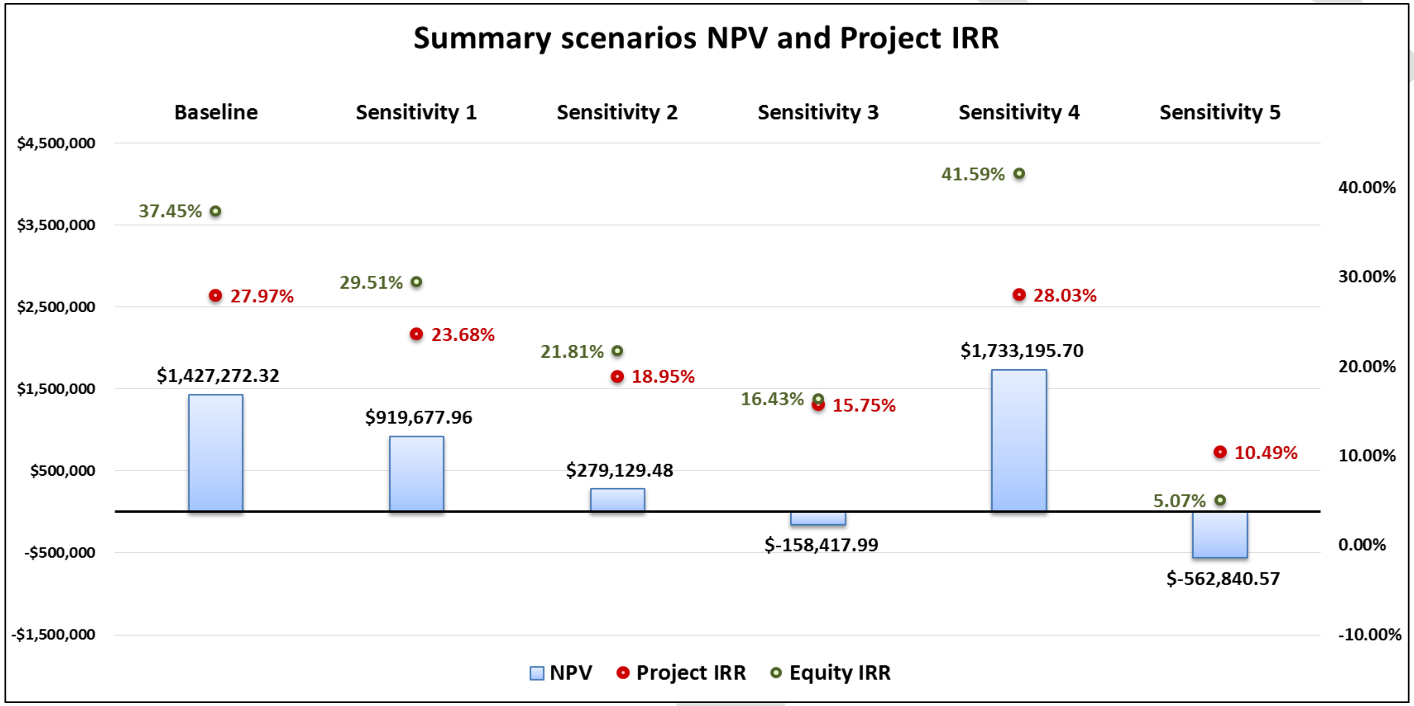
		Project Key financial indicators					Investment
Equity IRR	Project IRR	Cumulative profit	Cumulative FCF	Avg. EBITDA	NPV	DSCR	payback (yrs)
5.07%	10.49%	1,375,937.94	1,539,057.94	532,097.25	-562,840.57	1.68	6





5.6 Summary table of sensitivities

			Project Key financial indicators					Investment
Scenarios	Equity IRR	Project IRR	Cumulative profit	Cumulative FCF	Avg. EBITDA	NPV	DSCR	payback (yrs)
Baseline	37.45%	27.97%	$ 6,289,831.63	$ 6,452,951.63	$ 1,178,155.57	$ 1,427,272.32	4.28	5
Sensitivity 1	29.51%	23.68%	$ 5,556,904.97	$ 5,720,024.97	$ 1,178,155.57	$ 919,677.96	4.28	5
Sensitivity 2	21.81%	18.95%	$ 4,051,912.68	$ 4,215,032.68	$ 903,494.90	$ 279,129.48	3.29	6
Sensitivity 3	16.43%	15.75%	$ 4,434,911.72	$ 4,675,911.72	$ 1,098,005.27	$ -158,417.99	2.94	6
Sensitivity 4	41.59%	28.03%	$ 6,033,703.63	$ 6,479,447.63	$ 1,178,155.57	$ 1,733,195.70	3.57	5
Sensitivity 5	5.07%	10.49%	$ 1,375,937.94	$ 1,539,057.94	$ 532,097.25	$ -562,840.57	1.68	6



Sensitivity 1	no tax exemption is given to the project
Sensitivity 2	cost of feedstock (both sawdust and wood residue) is 20 USD/mt and it increases according to yearly inflation of 8.1%
Sensitivity 3	CAPEX increases to USD 5,000,000
Sensitivity 4	Debt/equity gearing is 60/40 %
Sensitivity 5	Price of electricity sold (Feed-in Tariff) remains constant for the ten years at 186.79 USD/MWh

Out of the five scenarios illustrated by means of sensitivity analysis, only scenario 4 (when the debt/equity gearing changes from 50/50 to 60/40), shows better returns compared to the baseline analysis. The project NPV and IRR increase thanks to the lower cost of debt compared to the cost of equity (12% vs 25%). On the other hand the cumulative profit and free cash flow decrease due to the higher amount of interests to be paid on the debt share.

6. Conclusions

For all the visited sites, biomass properties will greatly vary as different species are being used. Also the moisture content is not known and will vary depending on humidity, therefore, in choosing appropriate technology; the following is Suggested:

Two major technologies are globally identified: Gasification and Combustion.

In Gasification of Sawdust, critical factors to be considered are Moisture content and Calorific values. While in Combustion, a system where feedstock is combusted in a boiler to produce steam which is passed through a steam turbine to produce electricity, moisture content and calorific value are less important.
It is observed on all sites visited different species of logs, thereby making its moisture and calorific values unquantifiable (but can be subjected to further laboratory tests).

7. Recommendations

We are therefore recommending direct combustion; which in our views is less cumbersome for this Project.

8. Annex

1. Field research 1 Akure North+South and Owo
2. Field research 2 Ijebu Ode_Ijebu North_Abeokuta North+South
3. Field research 2 Idanre and Odigbowind guru