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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

Techno-economic Studies on Biomass Gasification Power Plants in Nigeria

First progress Report

Prepared for
The United Nations Industrial Development Organization



Prepared by
The Energy and Resources Institute

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Table of contents

List of tables

List of figures

Chapter - 1 Introduction

1.1 Background

Nigeria is a country located in West Africa along the Atlantic Ocean's Gulf of Guinea with a total area of 923768 square km. Nigeria shares land borders with the Republic of Benin in the west, Chad and Cameroon in the east, and Niger in the north. It is the most populous country in Africa and its economy is considered one of the fastest growing in the world. Nigeria is known for being the regional center of West Africa.

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 9th largest natural gas reserves in the world, but due to a lack of infrastructure, Nigeria flares 75% of the natural gas it produces.

Table 1: Key Indicators about the country

Parameter	Unit	Value	Year
Population	Million	170,123,749	2012
Population growth rate	%	2.55	2012
GDP (PPP)	Billion USD	418.7	2011
GDP	Billion USD	238.9	2011
GDP per capital (PPP)	USD	2,6000	2011
GDP growth rate	%	7.2	2011
Energy production	Mtoe	228	2009
Energy consumption	Mtoe	111	2009
Electricity Consumption	TWh	18.62	2009
CO2 emission	Mt of CO2	41.19	2009
Unemployment rate	%	21	2011
Industrial growth rate	%	2.5	2011
Energy production	Billion kWh	20.3	2008

1.2 Primary Energy Distribution in Nigeria

The primary energy supply for the country is majorly contributed by traditional biomass (largely fuel wood) which accounts for the largest share of total energy supply (51%) followed by petroleum products (41%). The distribution of primary energy supply is given in figure 1.

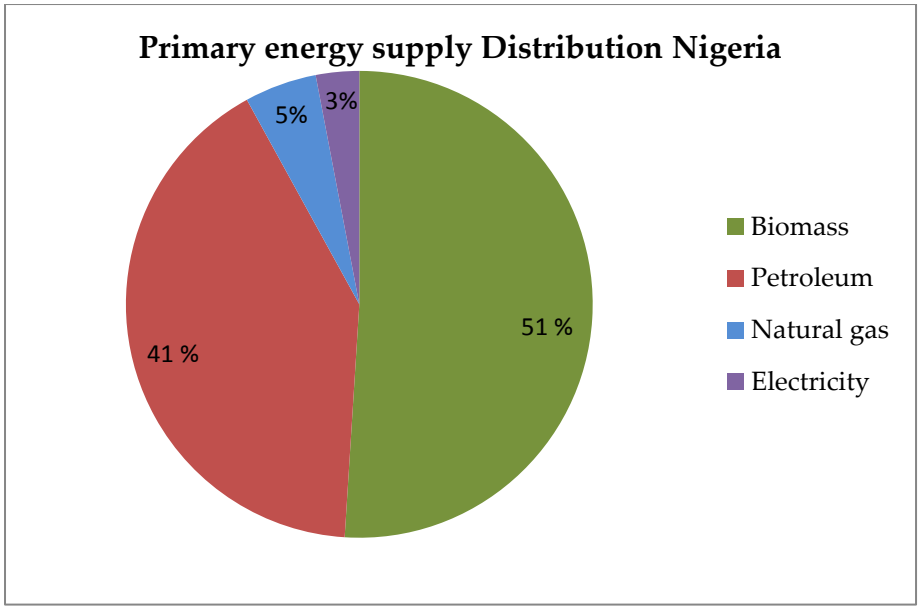

Figure 1: Primary energy supply distribution Nigeria

1.3 Electricity Scenario in Nigeria

In Nigeria, despite the abundance of energy resources, the country is short of electrical power. Population with access to electricity in the country is low about 40% and it is as low as 15% in the rural areas, where 70% of the entire population lives.

The electricity supply in Nigeria is inadequate and unstable. Even though, the total installed capacity of electricity generation is 6500MW, the actual generated electricity is about 3959 MW. In the country electricity is mainly being generated from petroleum (oil & gas) and hydroelectricity. The distribution of electricity generation from different sources is illustrated in **figure 2.**

1.4 Electricity Crisis

About 60% (that is, 80 million) Nigerians are not connected to the national electricity grid. There is also frequent power outages that can last up to 20 h daily in places connected to the grid .The low amount of electricity produced and the electricity grid problems contribute to the low per capita consumption (≈100 kWh) of electricity in Nigeria in comparison to consumption of over 10,000 kWh in developed countries. Power unreliability and unavailability have prompted industrial firms, households and commercial enterprises to depend on private diesel and petrol fueled generators which have unfortunately resulted in the death of several Nigerians because of health issue such as inhaling of carbon monoxide. The persistent energy crisis in Nigeria has weakened industrialization in the country. This has significantly undermined efforts to achieve sustained economic growth, increased competitiveness of indigenous industries in domestic, regional and global markets as well as employment generation.

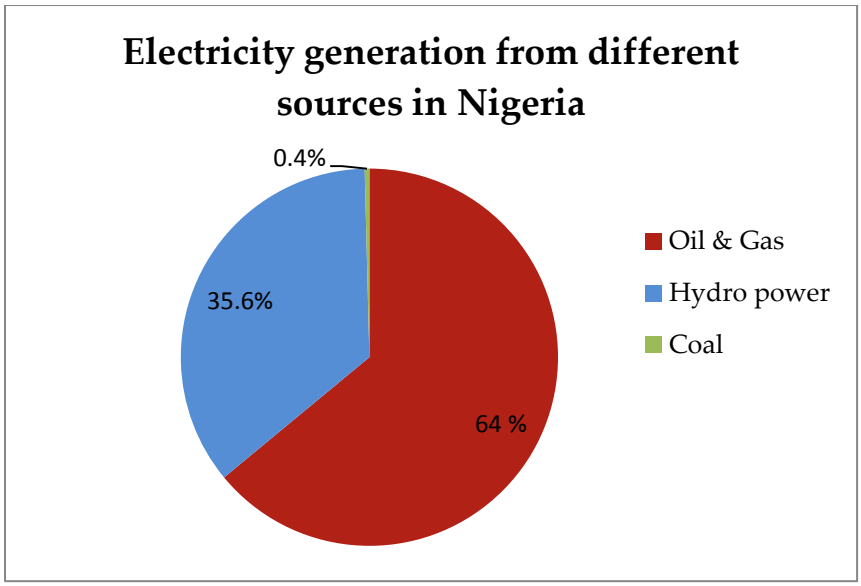

Figure 2: Electricity generation from different sources

1.5 Biomass Resources: Saw dust and wood waste – Potential feedstock for power generation

Nigeria has a huge potential of energy production from wood waste including saw dust. There are around 2000 sawmills in the country, which generate around 104000 m^3 of wood waste per day. By considering 312 working days in a year the total volume of waste wood generated per annum is 32.45 million cubic meters which has a mass equivalent of around 5.2 million tons per year.

Because of lack of better management approaches, currently, wood wastes particularly sawdust are disposed along road sides and rivers, or openly combusted. Many sawmills, especially those located at the banks of river particularly in Ogun, Lagos and Edo states often disposed waste wood into water bodies, which negatively impact the water quality.

As the country is challenged with twin problems of wood waste management and insufficient power generation, Nigeria is looking for solution which can tackle both the problems together. By considering the several advantages of utilizing wood waste for energy purposes, Nigeria plans to establish a 1MW wood gasification plant at Odogbolu, Ogun state and Pategi, Niger state and has invited companies to submit project proposals. As of now Nigeria has not got any experience in the installation and operation of a wood based gasifier power plant. ***(Ohimain 2012, Journal of waste conversion, Bio products and Biotechnology).***

Other than saw dust, considerable quantities of agricultural residues are also available in the country. The details of biomass availability in the country are given in table 2.

Table 2: Agricultural residues available in Nigeria

Sl no	Crop Residue	Quantity (million metric tons)	State with Highest Generation
1	Cassava Stalks	31.9	Benue
2	Maize Stalks	15.4	Kaduna
3	Sorghum Stalks	14.2	Kano
4	Millet Stalks	6.2	Sokoto
5	Rice straw	6.8	Kaduna
6	Rice Husk	0.9	Kaduna
7	Groundnut Stalk	7.6	Niger
8	Cowpea Stalk	3.7	Benue

1.6 Scope of wood based gasification for energy production in Nigeria

Nigeria has a huge potential for energy production from wood waste. In the present situation, only a small fraction of this wood waste is being utilized for cooking purposes in the rural areas and the remaining quantity is being dumped at different locations. Therefore, Biomass gasification offers a credible alternative for the utilization of wood waste for the production of power, heat and biofuels. The use of biomass to generate heat and power is crucial in achieving energy independence and increasing the use of renewable energy sources, thus increasing the renewable share of the nation's electricity mix. In the transition to renewable energy, gasification could play a major role in large part.

Potential Challenges for wood gasification in the country

- The country is forced for the purchase and installation of turnkey plant , adequate capacity building is required to ensure sustainable operation of the plant
- Lack of policy framework for the effective and sustainable operation of bioenergy projects.

1.7 Status of gasifier based power systems in the project sites

As such, biomass based power generation systems are yet to be introduced in the proposed project area. Nigeria have/had plans to join the League of Nations producing bioelectricity using wood as fuel source by installing 1 MW wood gasification electricity power plant in Ogun state and Niger state. Experience gained from the installation and operation of these two plants will either encourage or disfigure the expansion of biomass to electricity projects in Nigeria. Installation, capacity building and demonstration of biomass power plants in the proposed sites will result in large scale adaptation of the technology for power generation.

Chapter - 2. Biomass resources in the three states, Ondo, Ogun and Benue

The present study focuses on biomass availability and feasibility of biomass gasification for power generation in three selected states of the country which are Ondo, Ogun and Benue. As a preliminary step, a field visit has been conducted in these three states and collected information about the biomass availability over there. Ondo and Ogun states are having largest number of wood based industries (sawmills) in the country and hence there is a huge availability of saw dust and related wood waste in these two states. The three sites of project area are illustrated in Figure 3.

2.1 Biomass resources in the Ondo State

Ondo state is located in southwestern Nigeria with a total area of 14606 square kilo metres. The state shares its boundaries with Edo and Delta States in the East, Osun and Ogun states in the West, Ekiti and Kogi states in the North and Atlantic Ocean in the south. Akure is the head quarter of the state.

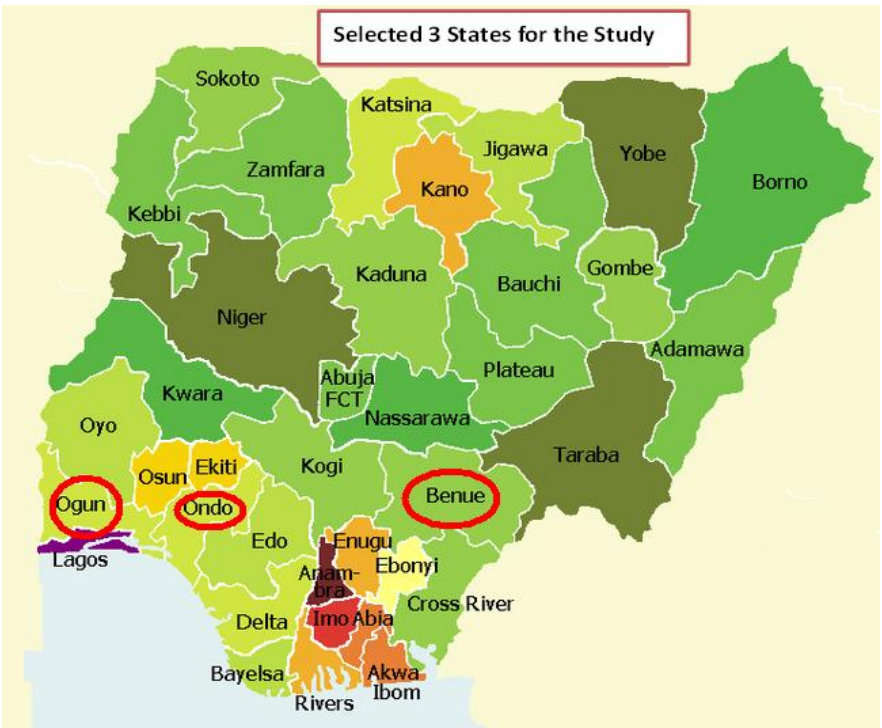

Figure 3: Selected three states for study in Nigeria

A large number of wood based industries are located in Ondo state. Out of total 18 local government area (LGA) /districts in the Ondo state, sawmills are concentrated in 12 LGAs. The numbers of sawmills in each LGA is given in table 3. The highest number of sawmills is located in Akure cluster (Akure North and Akure South), altogether it constitute 244 sawmills. Followed by Akure cluster, Owo cluster consists of 122 sawmills. The distributions of sawmills in different clusters in Ondo state are shown in figure 4.

ndo State

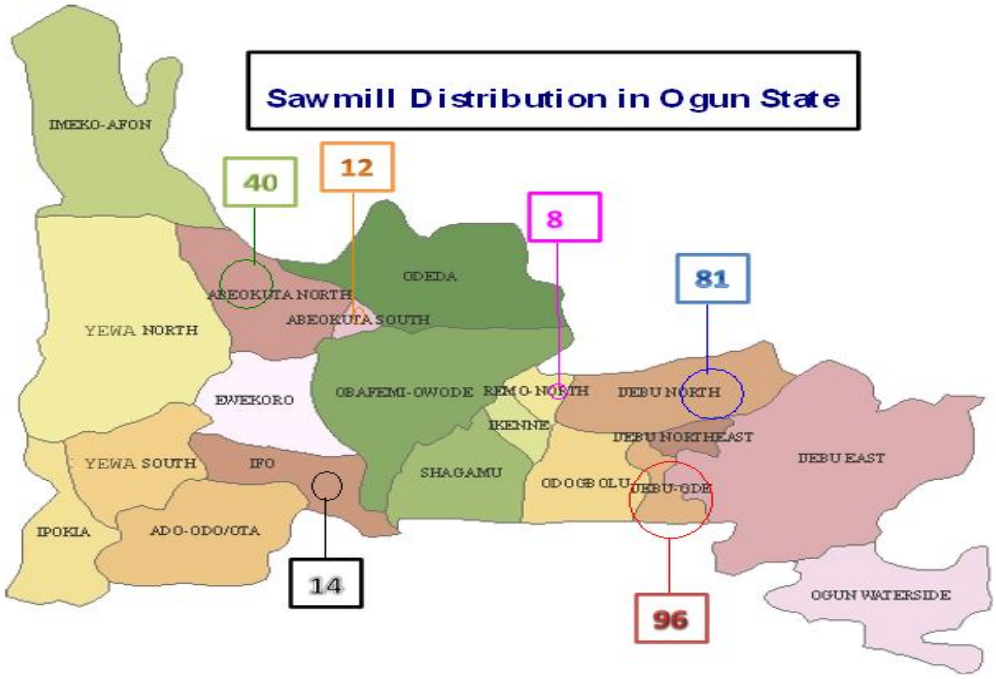

Figure 4: Sawmill Distribution in Ogun State

Table 3: Number of Sawmills in Ondo State

Sl.NO	Local Government Area	Number of Sawmills
1	Akure South	143
2	Akure North	101
3	Owo	122
4	Odigbo	91
5	Idanre	36
6	Ondo West	21
7	Akoko South West	21
8	Akoko North West	16
9	Akoko North East	8
10	Ondo East	4
11	Ileo Obuji	2
12	Irele	2
Total		**567**

From table 3, it may be noted that, Akure, Owo and Odigbo have more than 400 sawmills. The number of sawmills is small in rest of the areas, considering the biomass collection and transportation, the above said three locations may be considered for installation of large scale biomass power plants.

2.2 Biomass resources in the Ogun State

Ogun state is located in southwestern Nigeria with a total area of 16,980 square kilometres. The state shares its boundaries with Lagos State to the South, Oyo and Osun states to the North, Ondo State to the east and the republic of Benin to the west. Abeokuta is the capital and largest city in the state.

There are a lot of wood based industries located in Ogun state also. Out of total 20 local government area (LGA) /districts in the Ogun state, sawmills are concentrated in 8 LGAs. The numbers of sawmills in each LGA of Ogun state is given in table 4. The highest number of sawmills is in Ijebu Ode cluster, which constitute 96 sawmills. Followed by Ijebu Ode cluster, Ijebu North cluster, which is lying adjacent to Ijebu Ode, consists of 81 sawmills. The distributions of sawmills in different clusters are shown in figure 5. Out of 256 sawmills in the state, Abeokuta and Ijebu clusters have 229 sawmills. As these two clusters have more than 50% of the total sawmills, these are the potential site for installation of large scale power plant. The saw dust and waste wood can be transported to a common location for power generation. The power generation potential and selected technology will be worked out in the forthcoming periods of the project.

Table 4: Number of Sawmills in Ogun State

Sl.NO	Local Government Area	Number of Sawmills
1	Ijebu Ode	96
2	Ijebu North	81
3	Abeokuta North	40
4	Abeokuta South	12
5	Ifo	14
6	Rem O North	8
7	Ikenne	3
8	Yewa South	2
Total		**256**

2.3 Biomass resources in the Benue State

Benue state is located in the middle belt of Nigeria with a total area of 33 955 km² and derives its name from River Benue which is the second largest river in Nigeria. The state shares its boundaries with five other states namely: Nassarawa to the north, Taraba to the east, Cross-River to the south,

Enugu to the south-west and Kogi to the west. The State also shares a common boundary with the Republic of Cameroun on the south-east. Makrudi is the capital and major city of the state.

Benue state is endowed with abundant agricultural resources. About 80% of the total population depends on agriculture for their sustenance and livelihood. The major crops grown in the state are cassava, yam, rice, soya beans, sesame, maize citrus, mangoes and sugarcane. As agriculture based state there is a huge availability of biomass resources in the state in the form of agricultural residues. The availability of agri-residues against each major crop in the Benue state is given in table 5.

Table 5: Agricultural residues available in Benue state

Sl no	Crop Residue	Quantity(1000 metric tons)
1	Cassava Stalks	2733
2	Maize Stalks	294
3	Sorghum Stalks	392
4	Rice straw	435
5	Rice Husk	58
6	Groundnut Stalk	744
7	Groundnut Husk	112
8	Cowpea Stalk	30

Chapter - 3 Biomass potential in selected clusters- assessment during the field visit

3.1 Potential sites in the selected states

The team visited various potential sites of the selected three states for the primary data collection related to biomass potential and possible technology for power generation. The team also made observations about the process and the existing power supply and management. The potential clusters visited during the field study are presented in table 6.

Table 6: List of Project Sies

Sl.NO	Name of the state	Name of the site
1	Ondo	Akure South
2		Akure North
3		Owo
4	Ogun	Ijebu Ode
5		Ijebu North
6		Abeokuta North
7		Abeokuta South
8	Benue	Makrudi
9		Otukpo

3.2 Biomass potential in Ogun state

The team visited the ministry of forest to obtain the status and capacity of sawmills in Ogun State (Figures 6&7). During the discussion with the officials from Ogun state the key points emphasized were clean environment, sustainable development tree planting and regeneration of biomass. During the field visit, the team visited the sawmill cluster and met the members of sawmill association at Ijebu clusters (Figures 8&9). Each sawmill process about 400-500 cft per day, which is equivalent to one truck load. Sometime, during the rainy season the processing capacity falls down to 250 cft/ day. The mills are functioning about 8 hours per day. Sometime they operate for two shifts per day and process 1000 cft of wood logs. On an average it may be considered that these sawmills process about 400 cft per day per machine

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Figure.5 Meeting with the officials in Ogun state

Figure 6-Officials participated in the meeting

Generally, sawmills are functioning 5 days in a week. The sawmills have two to three machines. Each machine is operated by using the Motors with the capacity of 25 to 40 hp. The electricity charges are about 17000 N/month. In addition the sawmill uses about 50-80 liter of Diesel to operate their genset during the period, when the grid power is absent. Each sawmill have a diesel genset with a power generation capacity of 125 kW. Cost of Diesel is about 155 to 170 N per liter.

In Ijebu Igbo cluster there are about 40 functional sawmills. These mills are having a total number of 100 machines functional. Generally each sawmill is equipped with 2 or 3 machines. Around the Ijebu Ode cluster there are about 65 sawmills (160 machines) are functional.

Figure.7- Meeting with members of sawmills association at Ijebu Igbo, ogun

Figure.8- Meeting with sawmill owners Ijebu ode, in Ogun state

3.2 Finished product and biomass waste

The sawmill industry produces finished timber wood from wood logs. Each machine is capable of processing 400-500 cft per day. The waste products from the sawmills are bark, defective wood/waste wood and saw dust. From the field study it was observed that, out of the total wood log processed, 40 % is the finished product, 40 % is waste wood and bark. The remaining 20 % of the log is turned in to saw dust. A view of the sawmill along with saw dust is shown in Figure 12. The view of the fuel wood and saw dust available for biomass power plant is shown in Figures 10&11. A view of sawdust collected and dumped in open space is shown in Figures 13&14.

Figure.9- A view of the wood waste in sawmills

Figure.10- A large pile of wood waste available for power generation

Figure.11 - Saw dust and wood waste available at the location of the sawmill

Figure.12 - View of saw dust available for power generation (Ogun state)

Figure.13- View of saw dust available for power generation (Ondo state)

3.3 Power generation potential at Ijebu clusters

From the field study it was observed that about 260 machines are functioning at Ijebu north and Ijebu Ode clusters of Ogun state. A centralized biomass power plant can be installed, using waste wood and saw dust available in this cluster. There is a potential for installation of about 10 MW biomass power plant using the wood waste available from Ijebu north and Ijebu Ode clusters. The saw dust available from these mills can supply fuel to a 5 MW biomass power plant. A detailed study including the capacity to be considered at the beginning and technology to be adopted will be analyzed during the forthcoming phases of the project.

3.4 Biomass potential in Ondo state

The team met the officials from Ondo state to understand the sawmill status and biomass potential (Figure 15). The sawmills are operated by a cooperative. The team had a meeting with the members of the sawmill cooperative along with the permanent secretary (Figure 16). Ondo state has 16 functional forest resources spread over 3000 sq. km. The secretary and the members of the sawmill cooperative in Ondo state are interested to have biomass power plants. A small portion of the fuel wood (less than 25%) is consumed locally and majority of the waste wood and saw dust is available for power generation.

Figure.14 - Officials participated in the meetings during the visit to Ondo state

Figure.15 - Meeting with members of the sawmill association in Ondo state

Similar to Ogun state, the sawmills at Ondo state also uses diesel genset to meet their power requirement. There are few large sawmills at Ondo state they are having 4-5 machines. Most of the time, the sawmills have to rely on captive power produced from the diesel genset. Sometime the sawmills are operated using the diesel genset for the en tire week. These sawmills have 450 kVA diesel gensets and consume about 150 liter of diesel per day. Depending up on the load the sawmills are operated 6 days in a week. 400 cft of wood log is processed by a machine per day. Hence, the process rate of wood log per machine is similar, as in Ogun state.

3.5 Potential for power generation

From the field study it was observed that about 450 machines are functioning in three clusters (Akure North, Akure south and Owo) of Ondo state. Centralized biomass power plants can be installed, using waste wood and saw dust available from these clusters. There is a potential for installation of about 20 MW biomass power plants using the wood waste available from these clusters. The saw dust available from the sawmills can supply fuel to a 10 MW biomass power plant. A detailed study including the capacity to be considered at the beginning and technology to be adopted will be analyzed during the forthcoming phases of the project.

3.6 Rice husk potential in Benue state

The team has met the official in charge of the rice mills in Benue state (Figure 17). In Benue state, almost 80% of the area is cultivated one crop per year, through rain fed. At some areas, rice is cultivated twice in a year. Number of crops cultivated is according to the availability of water source. There are small rice mills operators at Gboko, Otkpo and Kazinaaca clusters. There is one large mill operating at Markudi. In most of the cases the rice husk burnt in open atmosphere. Markudi and Otukpo were found to be potential clusters to start with installation of biomass power plants.

Figure.16- Obtaining an introduction about the rice mill clusters in Benue

Rice mill at Markudi

One of the large capacity rice mills is in operation at Markudi (Figure 18). The team met the workers and officials involved in managing of the rice mill operations (Figure 19). The rice mill at Markudi produces about 96 tonne of boiled rice per day. The mill operates 24 hours a day and about 240 days in a year. The rice husk produced is burnt in a boiler to produce steam at 10 bars for parboiling of paddy. In addition to consumption of rice husk the mill also use fuel to compensate their process heat requirement. The rice mill has a target to process 25 000 Metric tonne of parboiled rice per year. The rice mill is having three diesel genset working on diesel. The total capacity of the genset works out to be 1 MW. (2 x 250 and 1 x 500). There is a potential to install a 1 MW biomass fired co-generation plant to meet their electricity and heating requirement. Detailed technology option will be worked out during this project.

Figure.17 - A large scale rice mill at Makurdi in Benue

Figure.18- Members participated in the meeting at the rice mill in Makurdi, in Benue state

3.7 Rice mills at Otukpo

The Team visited the rise mill cluster at Otukpo (Figure 20).In the rice mill cluster at Otukpo, the team met the rice mill owners and interacted to obtain the detailed information about the energy consumption and rice milling process (Figure 23). There are about 136 machines in operation. Each rice mill has 4 machines. Hence, there are about 34 rice mills are functional in Otukpo cluster. Four machines together produce 140 bags of rice per day. Each bag weighs 100 kg. Hence, the total production of rice per mill is about 14 tonne per day. This is corresponding to a daily production of rice husk at the rate of 4 tonne per day per rice mill. 34 mills together will be able to produce about 136 tonne of rice husk per day. Based on the rice husk availability in Otukpo cluster there is potential to install a 2 MWe biomass power plant. The power generated from rice husk can be pumped to grid. A view of the rice husk dumped in open space is shown in Figure 21.

Figure.19- A large quantity of fuel wood is used for parboiling the paddy

Figure.20- A view of the heaps of unutilized rice husk at Otukpo cluster

3.8 Fuel wood used for parboiling

Presently the rice mills at Otukpo is being operated using a diesel engine. The capacity of the diesel engine is in the range of 25-30 hp. Each mill owner spends about 2000 N to process one tonne of rice (for diesel). In addition to diesel they spend about 4000 N to process one tonne of rice, in the parboiling process (fuel wood). In total 6000 N per tonne of rice is spent on energy. Presently parboiling is done through conventional stoves of three stone fires. Generally the three stone fire stove works at low efficiency to the order of close to 10%. These stoves can be replaced with high efficient burning devices like improved cook stoves or centralized par boiling unit using biomass gasifiers. Achieving an efficiency of above 20% can reduce the fuel wood consumption to 50%. Thus, the fuel wood saved can be used for biomass power plant. The heaps of fuel used for parboiling and the three stone stove are shown in Figure 22.

There is a large scope to reduce the fuel wood consumed in the parboiling process and use them for power generation. Total fuel wood consumption in the cluster would be about 14 tonne per day. By having an efficient and centralize devices for par boiling, the fuel wood saved can lead for an additional power generation capacity of 5 MWe.

Figure.21- Parboiling of paddy using fuel wood, in Otukpo

Figure.22- Interaction with the rice mill owners at Otukpo in Benue state

Chapter -4 Conclusions

The expert team from TERI (India) and UNIDO (Nigeria) visited the state offices dealing with forest biomass and agriculture sector. The team met the government officials and other stack holders to obtain the primary and secondary data related to biomass potential assessment in selected states of Nigeria (Ogun, Ondo and Benue). Ondo and Ogun are having a large potential for installation of biomass based power plants using wood waste and saw dust. Benue state has rice husk as biomass resource for power generation. It also observed the rice mill clusters in Benue state has large scope to reduce the fuel wood consumed in parboiling process and the fuel wood saved could be used for power generation. In the present study biomass potential available for power generation in selected clusters were identified. A detailed analysis on individual plant capacity and technology could be adopted will be carried out in the forthcoming phases of the project.