Oando

PRE-FEASIBILITY ASSESSMENT

WASTE TO ENERGY IN NIGERIA

Abridged version

Introduction

As the world actively pursues deliberate paths toward the creation of a more sustainable future, there is an increased emphasis on the role of state and non-state actors, corporate bodies and individuals in realizing the climate goals we have set ourselves. There is overwhelming evidence that the environmental damage caused by one country, industry, or a person affects all, to which effect we must all act together by taking responsibility for the creation of a greener planet. And there are rallying calls through the likes of the Sustainable Development Goals and the Paris Agreement, for all to step forward and act now.

Today, petroleum meets over 95% of global transportation demands; however, a sustainable world means the future of Energy companies will increasingly be based on a diversified portfolio that must include renewable energy in various forms, as oil and gas become less fashionable to investors and future workforce.

We are already witnessing a significant shift, across the world, in institutional investments, with some of the world's largest investment management firms and banks boldly reducing business dealings with or completely divesting from companies that do not have active plans to improve their Environmental, Social and Governance (ESG) metrics.

It is against this backdrop that Oando has made it's first foray into renewable energy, as the journey begins for the redefinition of the future of our business and our role in the achievement of a carbon neutral world.

This document presents a pre-feasibility study assessment of opportunities within the Waste to Energy (WTE) Value Chain in Nigeria. It encompasses preliminary research to analyze, determine and select the most technically and economically viable business scenarios for further studies and adoption.

As a company that has always been invested in how Nigerians can through collaboration move the economy forward, we have taken the step of sharing this preliminary research of Nigeria's renewable energy space with the general public.

Our belief; if as a nation we are to pivot substantially into renewable then we must start to create platforms that will enable the growth and diversification of sector players. One of the ways we can do this is via knowledge sharing. Our objective in sharing this pre-feasibility assessment is to act as the first stage of research for interested individuals and businesses to determine and select the most technically and economically viable space they can play in.

WASTE TO ENERGY

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Executive Summary

Nigeria & Oando

Unstable global oil prices, climate change and global warming have resulted in an evolution of global and local polices in favor of "cleaner" energy sources and a consequent shift in financiers' interest to renewable energy. This shift accelerated the need for oil and gas companies, inclusive of Oando PLC to explore a portfolio diversification strategy towards renewable energy.

As the world transitions from fossil fuels into more renewable sources of energy (Wind, Solar, Hydro and Biomass.), energy providers in the fossil fuel space must rapidly evolve to adapt to a new market reality or face disruption. A key part of that evolution is making deliberate efforts to gain an early understanding of the renewable energy value to determine opportunities and strategies for success.

Leveraging on the abundance of waste, growing financier interest in funding renewable energy projects in Africa as well as the FGN's interest in developing and executing solar power projects for rural and institutional electrification there are abundant opportunities for interested private actors to commit to an environmental sustainable Nigeria. Waste-derived energy raises unique interest because of the magnitude of benefits to environmental protection and socio-economic advancement.

Introduction

Nigeria is the largest country in Africa. With an estimated population of 200million as at 2019 and an annual growth of 2.6% based on world bank data, Nigeria's estimated waste per capita stands at 0.63-0.65Kg/capita/day leading to an average of up to 41,000 tonnes of waste generated daily and 42 Million tonnes of waste annually.

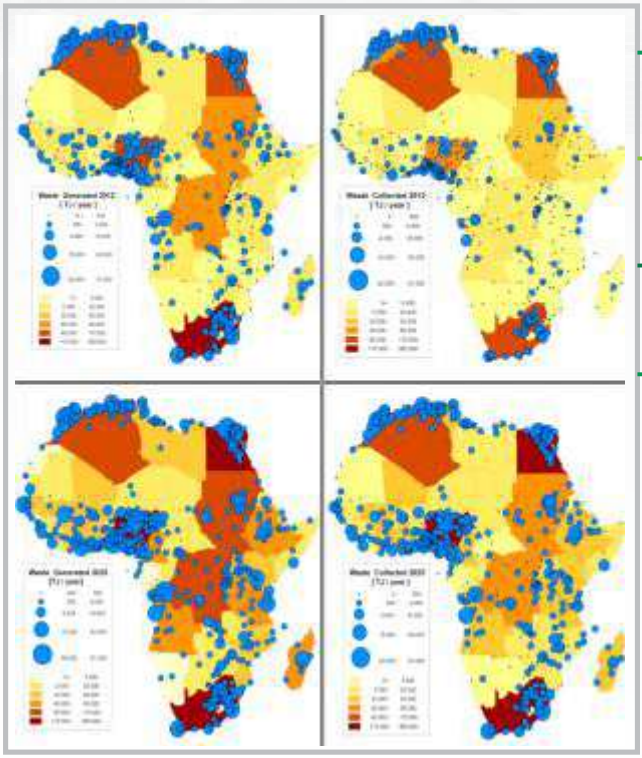
Lagos state which is located in Nigeria is the most populous and most commercial city in Africa. With a population of 14 million, it contributes approximately 25% of the total waste generation in country and suffers from a poor disposal system with many overflowing dumpsites which emit greenhouse gases.

Nigeria's power demand is 24MW, however the current generation is 12.522MW from mainly Hydro and Gas, of which only 40% is utilized, which leaves most of the population in Nigeria without power.

Given the amount of waste generated in Nigeria, the presence of overflowing dumpsites, the power supply gap in Nigeria and the absence of commercial waste to energy plants in the country, the company, Protecosyst seeks to install a 250,000 ton/annum capacity Anaerobic Digestion (AD) plant on a dumpsite conversion site in the urban-rural municipality of Lagos.

Opportunity Description

Energy Potential from Waste



12,522MW Installed power Generating Capacity (Mainly Hydro and Gas)

~5,000MW Actual Generation Utilized

~24,000MW Estimated Actual Demand Required for Consumption

~12,000 - 19,000MW Opportunity for Electricity Generation

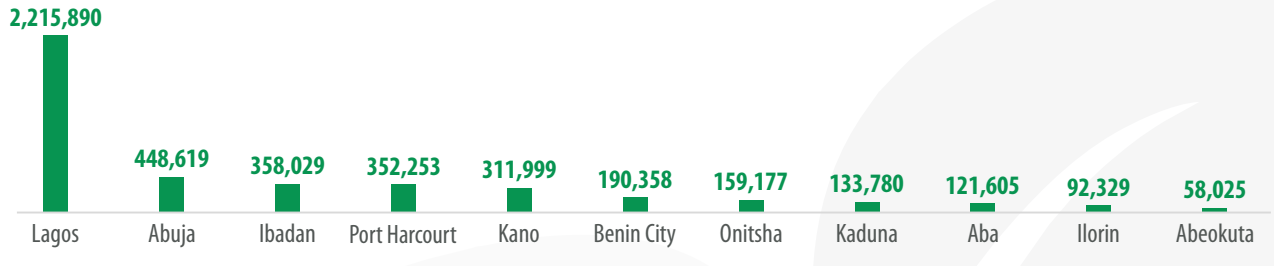
POWER SUPPLY GAP IN NIGERIA

BIOMASS RESOURCE IN NIGERIA

Biomass Resource	Quantity (billion kg/year)
Crop Residues	153.76
Perennial Crop Residues	2.35
Forest Residues	19
Municipal Solid Wastes	4.51
Animal Wastes	17.69
Human Wastes	2.87
Overall Total	200.18

- The quest for reliable and adequate power supply in Nigeria has brought about a surge of interest in renewable energy generation, particularly from wind, solar, hydro and biomass resources including municipal solid waste (MsW).
- Waste-derived energy raises unique interest because of the magnitude of benefits to environmental protection and socio-economic advancement.
- The successful operation of Waste-to Energy (WtE) facilities in Nigeria requires continuous supply of solid waste.
- Estimated at 200 billion kg/year of biomass, such waste is in abundant supply however illegally dumped in open spaces and poorly managed with enormous environmental consequences.
- According to Somorin et al, Nigeria's annual electricity generation potential from Municipal Waste is estimated to be 26744 GWh/year if well collected.
- However, with current realities such as poor collection efficiencies, Nigeria's exploitable WtE capacity from MSW stands at 3800 GWh/year.
- Given the opportunity for on-site power generation such as dedicated power station for industrial estates and corporate users which WtE brings, protecocyst seeks to play in this space helping to transform waste to energy.

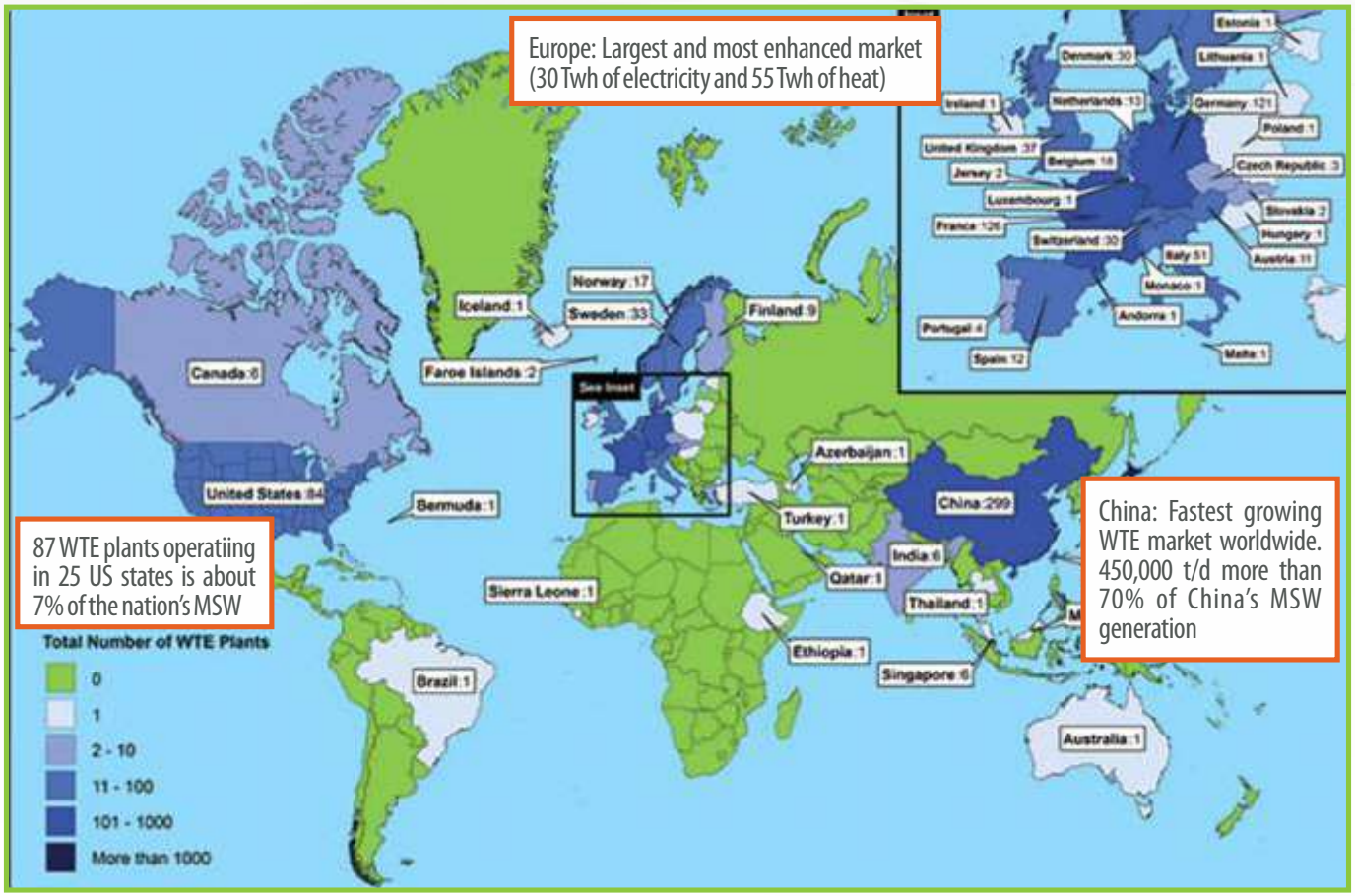
ANNUAL ORGANIC WASTE GENERATED ACROSS STATES IN NIGERIA (TONNES)



Source: Mwangomo EA (2018) Potential of Waste to Energy in African Urban Areas. Adv Recycling Waste Mgt.

Application Insights

The technology advancement and deployment globally provides an opportunity to explore WTE for commercial and socio-economic purposes. There are over 2000 WTE plants converting Municipal Solid waste to Energy and heat globally.



WTE IN AFRICA				
Name	Technology	**Location**	**Generation**	**Status**
Reppie Plant	Combustion	Ethiopia	20 MW	Active
Climate Neutral Group-Joburg	Combustion	South Africa	19 MW	Development
Gorge Farm	AD	Kenya	2.4 MW	Commissioning
Ikorodu WTE	Combustion	Nigeria	12 MW	Inactive
Ikosi Biogas Plant	AD	Nigeria	-	Inactive
Ebonyi	Gasification	Nigeria	12 MW	Active

Operations Overview

Waste-to-Energy includes processes such as incineration, gasification, pyrolysis that thermally treat solid waste and directly recover energy in the form of electricity and/or heat.

It also include bio-chemical processes such as landfill gas recovery and anaerobic digestion that converts the chemical energy in solid waste to yield products of high energy value e.g. methane.

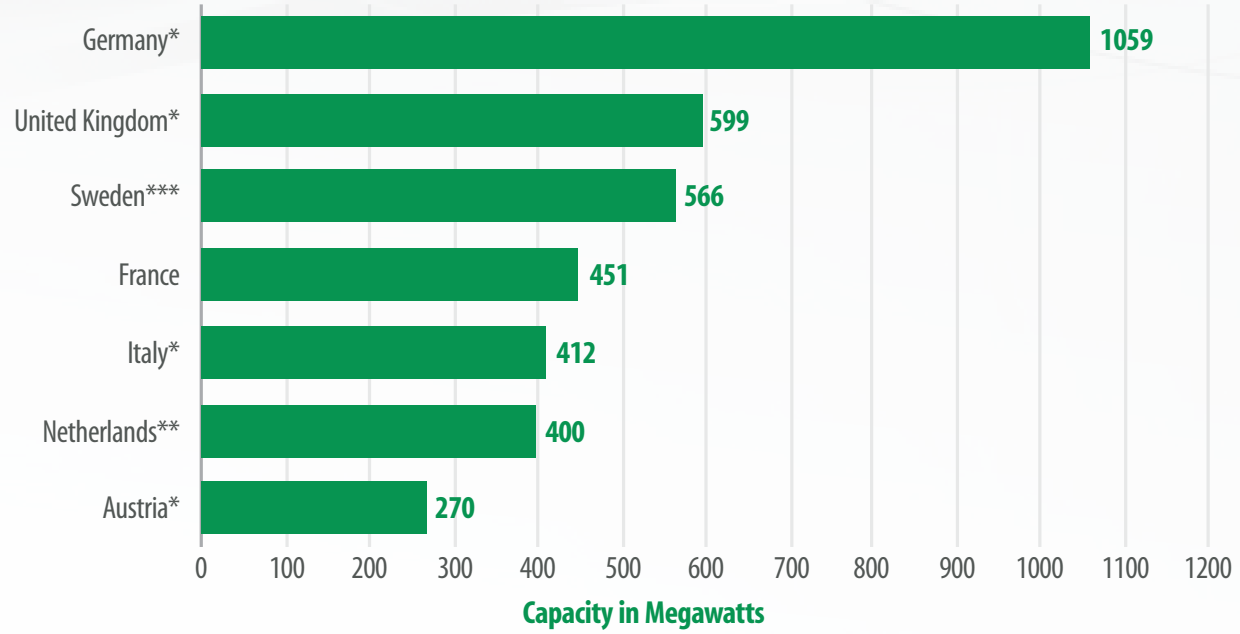
In ranking the various technologies within the Waste To Energy space, various factors were considered:

- Electricity Generation: The technologies must provide for energy recovery in the form of electricity.
- Processing Capacity: A technology must be capable of processing adequate MSW
- Technology Maturity: The waste processing technologies should be proven on a commercial scale
- Operational Requirements: Handling of available type of waste and running of facility
- Environmental Issues and Human Factors: The technology should not adversely affect community and its environment

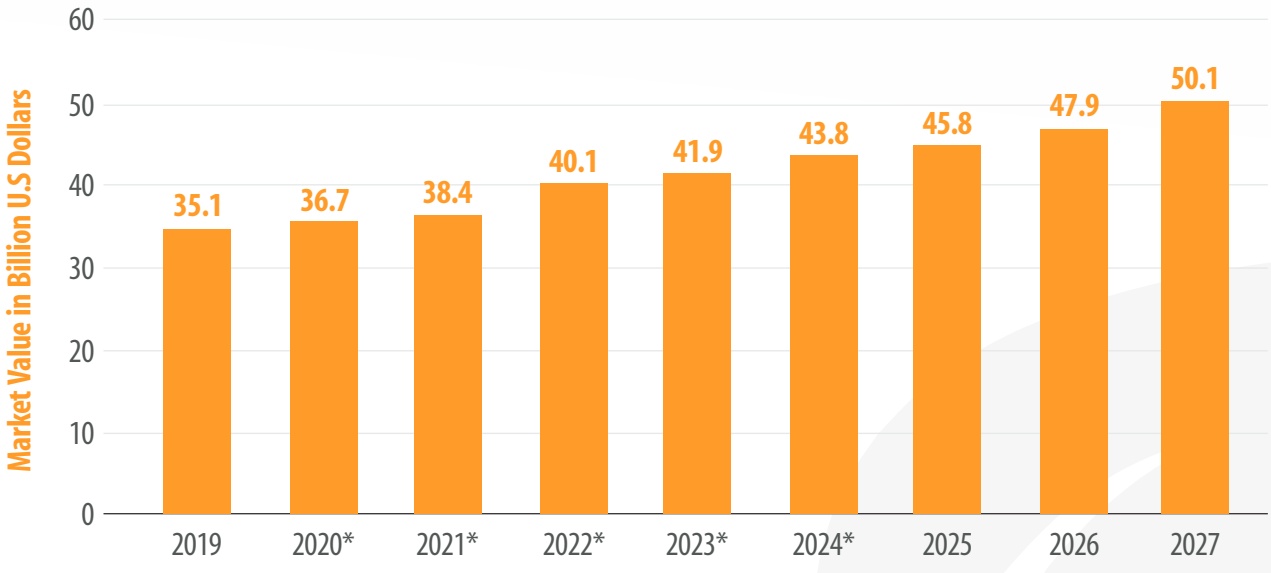
Guiding Principle	Combustion (Mass Burn Incineration)	Pyrolysis	Gasification	Anaerobic Digestion
Electricity Generation	1	2		3
Technology Maturity	1	2		1
Operational Reqt.	2	3		1
Environmental issues	2	2		1
Human Factor	2	2		2
Overall Rank	2	3		1

Global Market

CUM. INSTALLED CAPACITY OF MUNICIPAL WASTE TO ENERGY PLANT IN EUROPE (MW)



PROJECTED WASTE TO ENERGY MARKET VALUE WORLDWIDE (IN BILLION U.S. DOLLARS)



Market Assessment

WTE (AD Siting) & Revenue Assessment

There are a total of 7 dumpsites in Lagos state, Nigeria. 2 of the biggest sites are located in Ojota and Lasu Iba within 10km radius to a community.

The Lagos state government plans to carry out dumpsite conversions of some of the dumpsites one of which is the Solous 3 which will accommodate a Waste to Energy plant to power the General Hospital and the College of Nursing.

The conversion works include levelling of the refuse, slope stabilization, soil covering, grading as well as rolling and landscaping, rebuilding drainage and road network within and outside the site. The company will carry out facilitation of these works with the government.

DUMPSITE CONVERSION		
Location	Ojota, Lagos	Lasu-Iba rosd., Lagos
Capacity	2,100,000 T/yr	820,000 T/yr
Area	43 hectares	8 hectares
Residents	5million in 10km radius from the site Proximity to Various industries	200meters from the nearest dwellings, 4 4million people live within 10km radius Proximity to the General Hospital


Risk
Assessment

Risks and Mitigation Measures

TECHNICAL

Key Risk Indicators	Mitigation Measures
• Limited local technical expertise – need to promote the development of domestic WtE technology capabilities (anaerobic digestion and/or thermal combustion technologies)	• To promote development of domestic WTE anaerobic digestion technology capabilities, seek working partnerships and technical alliances with renowned international players and equipment suppliers in this sector. This is to augment local skill sets, gain new competitive skills and eventual technology and knowledge transfer that will have a lasting effect on the brand's product market positioning
• Non availability of components locally - need to source for high quality components/equipment from industrialized countries	

FEEDSTOCK RESOURCE

Key Risk Indicators	Mitigation Measures
• Limited or non existent waste management/disposal practices in Nigeria and impact on sourcing, collection and aggregation of waste for a commercial venture. Researchers estimate that in Nigeria only 20-30% of waste disposed is collected, the rest are left to litter the environment or end up in arbitrary dumpsites constituting serious health, environmental and infrastructural hazards	• Where and if applicable drive policy changes in this sector especially as it relates to the collection, aggregation and segregation (recycling) of waste as this opportunity would not only provide electricity but also help to address the problem of solid waste management, especially in urban clusters around the country
• Limitations in WtE treatment alternatives as a result of Nigeria's poor waste management practices i.e. poor waste segregation at source/ recycling, inefficient transportation of waste	• Consider a highly efficient mass burn incineration/combustion process, based on the waste management landscape in Nigeria, as it requires minimal waste pre-treatment such as recycling and composting – this also comes with it's own risk factors such as low efficiency from wet waste and generation of toxic ash as a final product

COMMUNITY

Key Risk Indicators	Mitigation Measures
• Anaerobic Digestion Facility location assessments - For specific agricultural feedstock – the AD facility needs to be situated close to the feedstock/biomass source or a collection process implemented to optimize feedstock collection and ensure steady supplies.	• Perform location assessments for optimal location of these facilities

OUTPUT AND END USE

Key Risk Indicators	Mitigation Measures
• End user sensitization - End users have not fully embraced the concept of renewable energy	• Sensitization efforts to significantly drive adoption

Risks and Mitigation Measures

ECONOMICS AND FINANCING

Key Risk Indicators	Mitigation Measures
• Financial capabilities of project sponsor	• Research to identify applicable intervention funds and grants
• Eligibility to access identified funds and grants	• Perform thorough assessment of all identified funds / grants eligibility criteria and strategically position company to access same • If there are any time or experience-based barriers for fund/grant prequalification, consider partnership/technical alliances with companies that meet the set criteria
• Alternative funding barriers	• Ensure project economics model shows the viability of the project
• Perceived high cost of doing business in Nigeria and impact on value creation potential of this investment.	• Development of a business model that seeks to optimize the commercialization of the energy/power output with a focus on cost optimization and profitability

GOVERNMENT AND REGULATORY

Key Risk Indicators	Mitigation Measures
• Absence of long term WtE policy programmes locally and the impact on this opportunity specifically limited policy support and private sector investment levels	• Investor confidence can be gained by a robust and stable policy framework and long-term national objectives and targets, backed-up by sound market forecasts • Seek to drive the implementation of appropriate legal, policy, regulatory, and institutional frameworks to promote newer and more sustainable energy recovery options from waste

Conclusive Information

Available Funding from the World Bank

The World Bank announced in June 2020, that it has approved the sum of $750 million as a loan to Nigeria's power sector after years of negotiations over long term reforms in the sector. The loan, which has been approved by Bretton Wood Institution, is for Power Sector Recovery Operation (PSRO) to improve the reliability of electricity supply, achieve financial and fiscal sustainability, and enhance accountability in the power sector in Nigeria.

The World Bank would likely disburse this loan through the Federal Government of Nigeria in line with specifications and requirements set by the World Bank.

Carbon Credits in Nigeria

Introduction

- Developed under the Kyoto Protocol;
- Establishes the Clean Development Mechanism ("CDM") applicable to developing countries
- The CDM allows Annex B Countries to execute/finance emissions reduction projects, including renewables (such as a solar power project, waste to power) in developing countries. Such projects can earn them saleable certified emission reduction ("CER") credits.

Eligibility

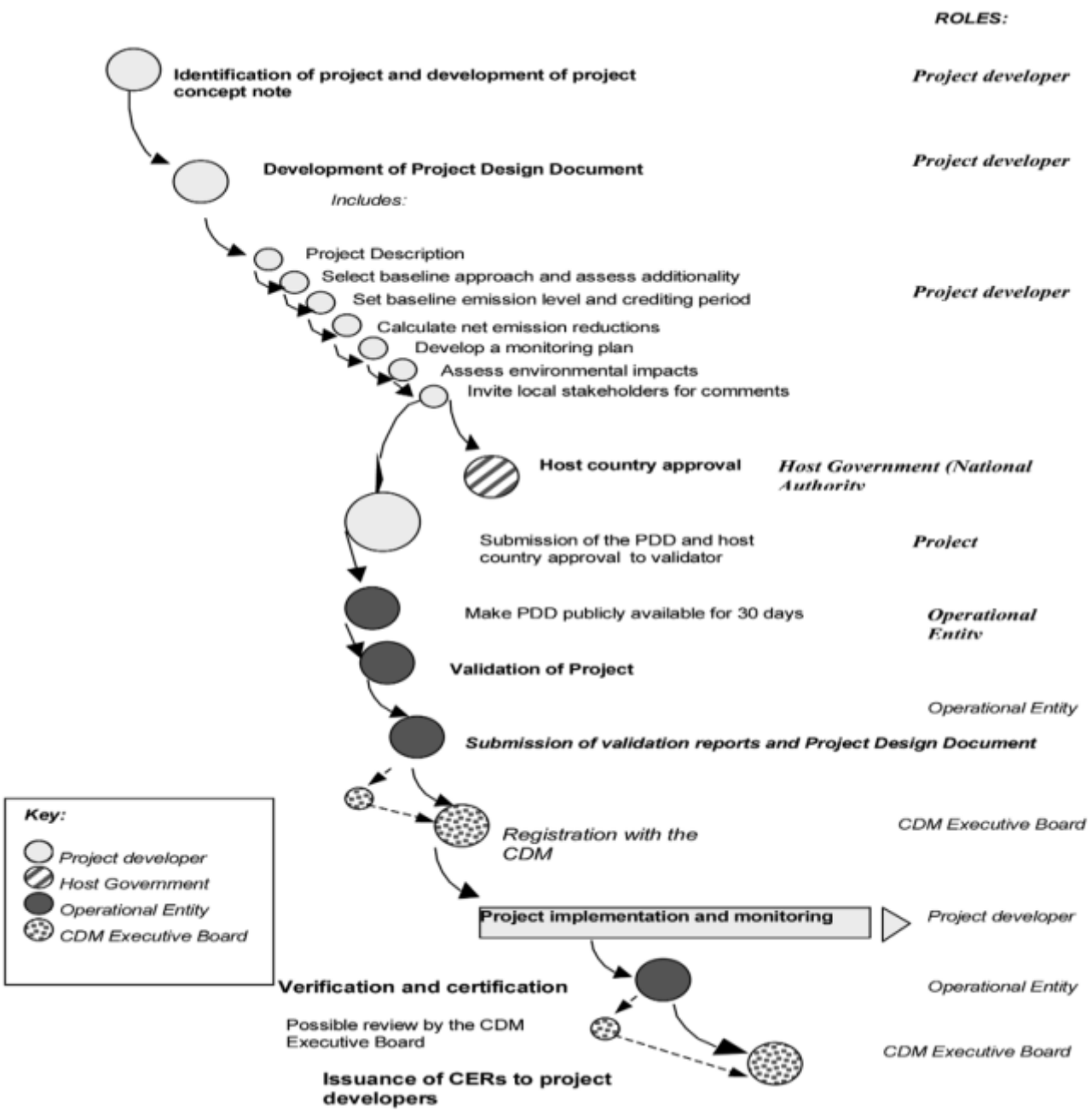
CDM project must:

- Have long term climate change benefits
- Achieve Reductions in emissions that are additional to any that would occur in the absence of the CDM project

Administration

- Presidential Implementation Committee for CDM, which was established under the auspices of the Federal Ministry of Environment;
- Companies creating projects, in developing countries, which actively reduce GHG emissions become eligible for carbon credits and then can raise funds, by selling them to a company exceeding its allowance on an exchange.
- Income from Carbon credit trading are tax exempt.
- Carbon credit prices are affected by forces of demand and supply, risks – project, sovereign, credit, etc

CDM Process flow



CBN Intervention Fund - Other Strategic Subsectors

Introduction

- Set up by the CBN in January 2016
- Funding for the agriculture, manufacturing, mining, solid minerals and other strategic subsectors
- For green and brown (expansion) projects - priority for local content, fx earnings and for job creation
- Trading activities shall not be accomodated

Other Key Points - Upstream

- Types – (i) Term Loan for acquisition of plants and machinery and (ii) Working Capital
- Tenor - Maximum of 10 years (1 year for Working Capital on a 1 year roll-over basis)
- Interest rate – 9%
- Moratorium – 1 year
- Eligibility – Borrower must be registered under CAMA

Real Sector Support Facility (initially for N300bn)

Appendix

Technical

Waste to Energy Overview

Waste-to-Energy (WTE) or Energy-from-Waste (EFW)

Generating energy in the form of electricity and/or heat from the primary treatment of waste, or the processing of waste into a fuel source.

Bio-Energy

Bioenergy is renewable energy made available from materials derived from biological sources.

It the main source of renewable energy in the world today, **contributing to energy used in Heat, Electricity and Transport**

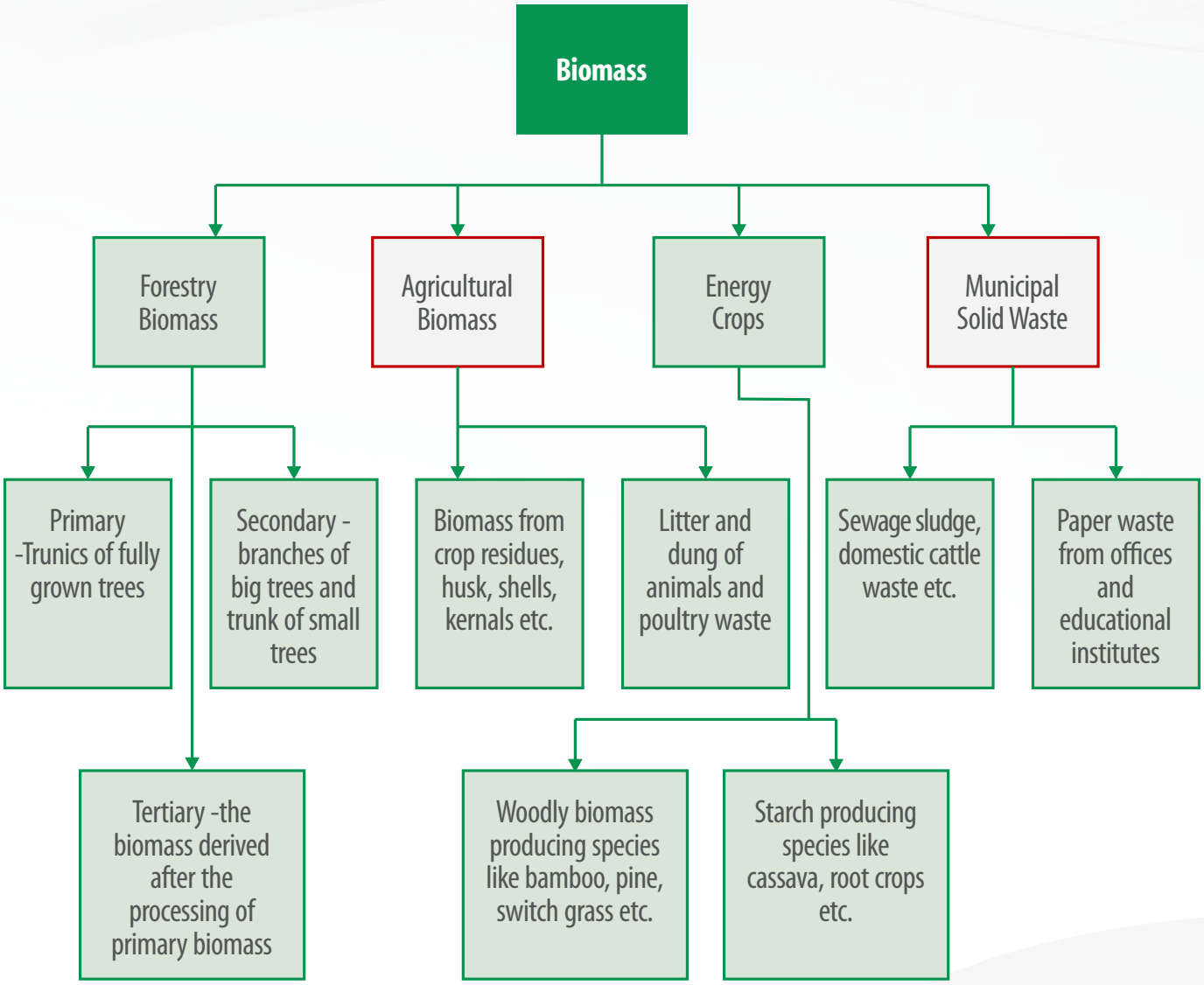
Biomass/Bio-Energy Feedstock

Biomass is the plant or animal material used for energy production. It is renewable organic material that comes from plants and animals. Biomass contains stored chemical energy from the sun.

It can be burned directly for heat or converted to renewable liquid and gaseous fuels through various processes.

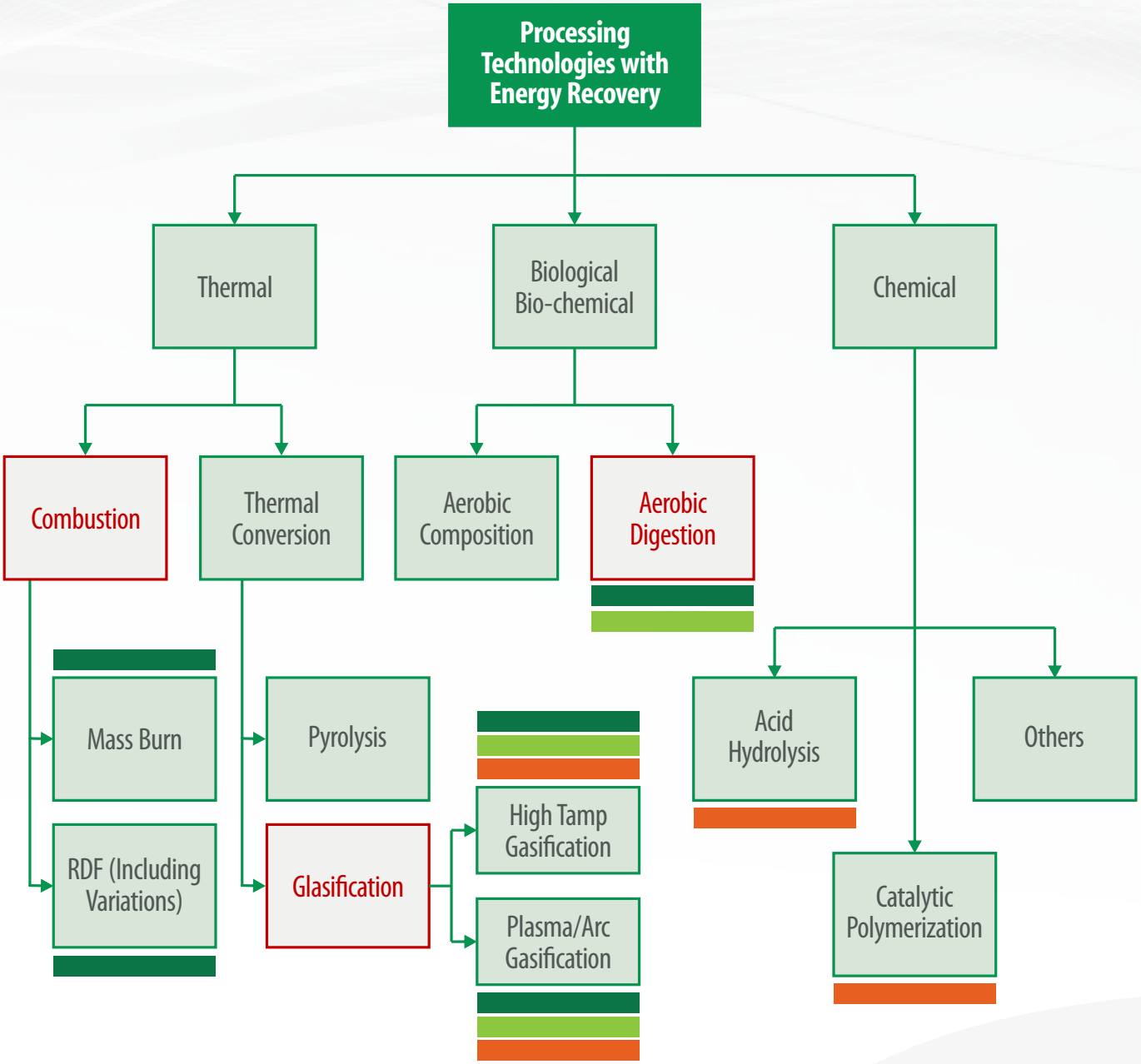
Waste to Energy /Bio-Energy Feedstock

- The type, characteristics, availability of feedstock will determine the type and amount of bioenergy that can be produced and the technology that can be used to produce it.



- Agricultural crop residue and Municipal Solid Waste (MSW) is our focus in this waste to energy analysis

Biomass Waste to Energy Recovery Pathway



Recovered Energy converted to steam/electricity (power)

Gaseous Fuels (Syngas, biogas)

Liquid fuels

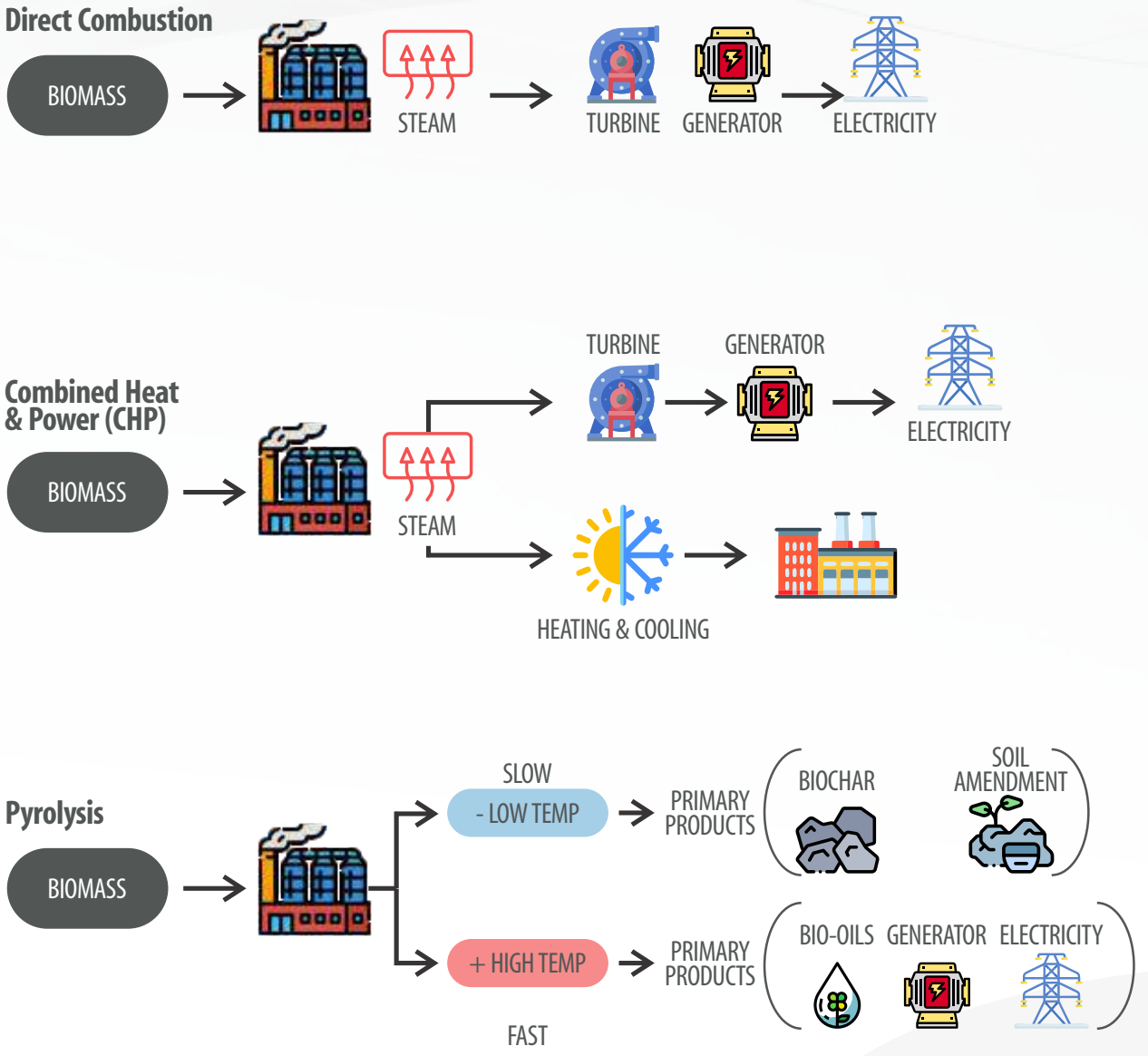
Waste to Energy Recovery Technologies

For the purpose of energy recovery, processing technologies, there are 3 main recovery technology classification.

TECHNOLOGY	DESCRIPTION	MODE OF OPERATION
Combustion	Direct Combustion of feedstock utilizing excess air or oxygen as oxidant to generate heat	Grate Bubbling fluidized bed Circulating fluidized bed
Pryolysis	Thermal Conversion of feedstock in the absence of air or oxygen as oxidant to generate a synthetic gas or fuel and pyrolysis oil.	• Slow (low temp.) or Fast (High temp.) • HorizontalVertical (updraft/downdraft) • Plasma arch
Gasification	Thermal conversion of feedstock in a limited atmosphere of air or oxygen as oxidant to generate a synthesis gas or fuel	• Horizontal stationary • Horizontal rotating • Vertical (updraft/downdraft) • Stationary grate • Bubbling fluidized bed
Anaerobic Digestion	Biological conversion of a feedstock in the absence of oxygen to generate biogas	• Single or double stage • Wet or Dry Process • Mesophilic (77degF - 100degF) or Thermophilic (122degF - 135degF)

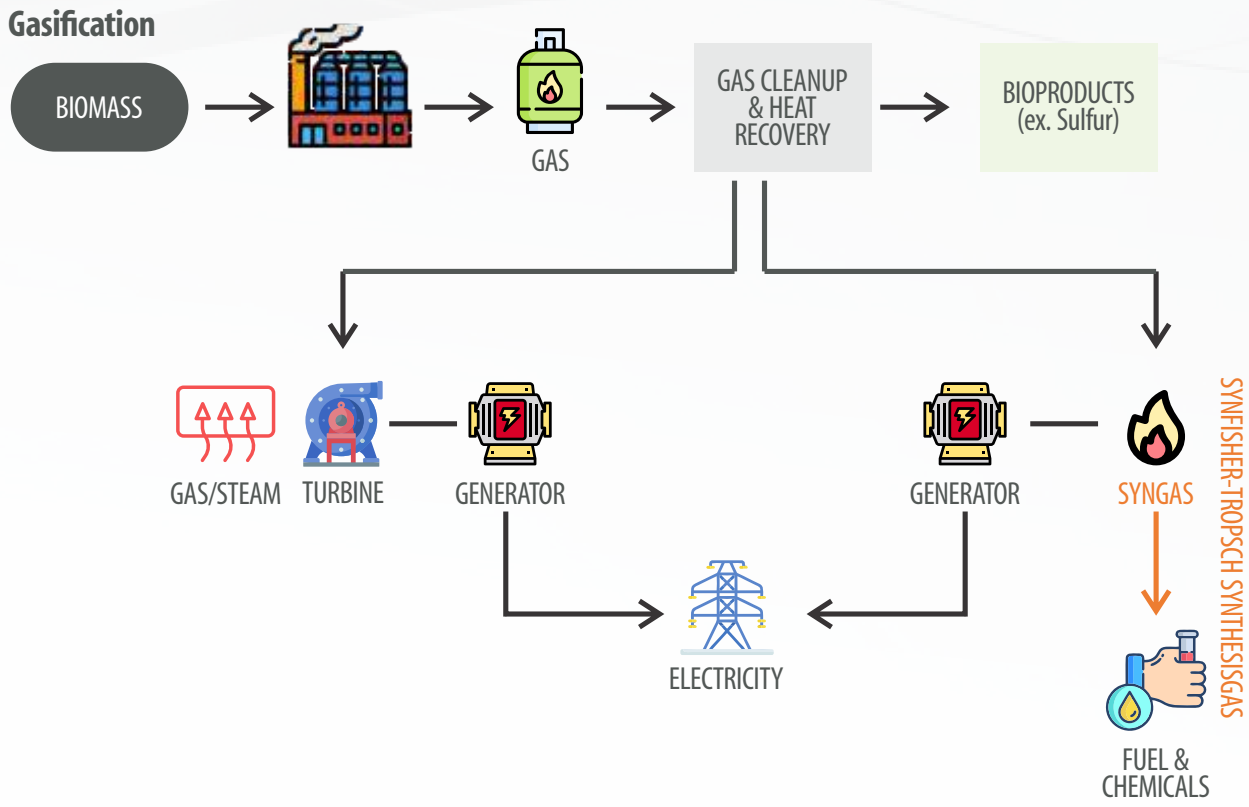
Combustion and Pyrolysis

THERMAL CONVERSION



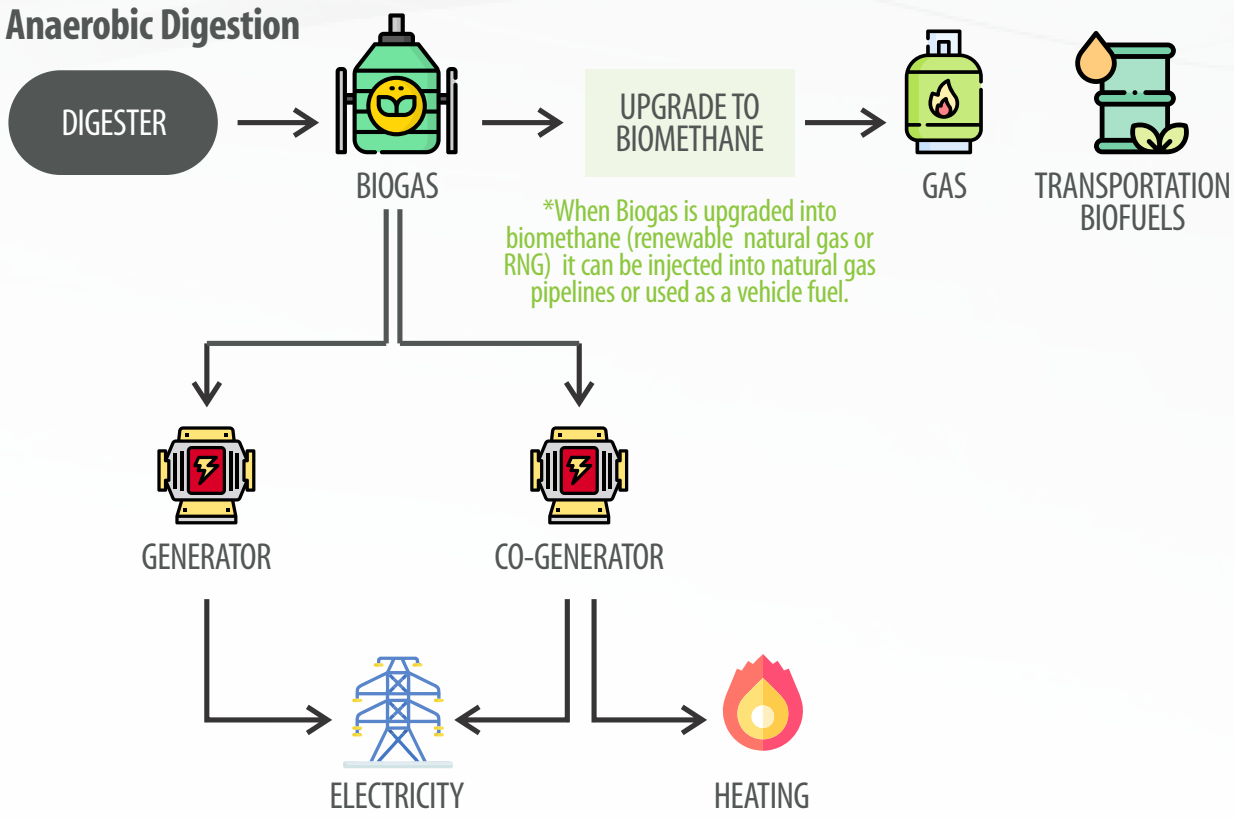
Gasification

THERMOCHEMICAL CONVERSION



Anaerobic Digestion

BIOCHEMICAL CONVERSION



Technology Comparison

CRITERIA	COMBUSTION (MASS BURN INCINERATION)	PYROLYSIS	GASIFICATION	ANAEROBIC DIGESTION
State of Technology Maturity	Widely deployed	Early market deployment	Early market deployment	Widely deployed
Types of Solid Waste	Unsorted waste	Specific type of waste	Unsorted waste	Sorted organic waste, animal or human excreta, feedback
Final Products	Heat, Co2, H2O, Ash	Pyrolysis oil, Syngas, Ash char	Heat, Syngas, Ash Char	Digestate, Biogas
Adverse Impacts	Pollution from air emission toxic gases	High energy consumption during operation, Noise and air pollution	High energy consumption during operation, Noise and air pollution	Problem of leakage of methane gas
Air Pollution	High	High	Medium	Low
Solid Waste Generation due to Rejects	Low	Low	Low	Low
Volume Reduction of Waste	75 - 90%	75 - 90%	75 - 90%	45 - 50%
Contribution to Energy/ Efficiency	Power Generation 20 -30% Net electrical efficiency	Power Generation, Pyrolyis oil used as raw material 13 - 24% Net electrical efficiency	Natural gas replacement Power Generation 14 - 20% Net electrical efficiency	Natural gas (if upgraded), Power Generation from Biogas.
Contribution to Industry	Construction industry (Building Materials, roads)	None, high contamination	None	Agriculture industry (Digestate) as compost for cultivation

Organic Waste for Anaerobic Digestion

Various organic feedstock and can be used for Anaerobic Digestion, they can also be co-digested.

	LIVESTOCK MANURE	AGRIC. CROP RESIDUE	SEWAGE (HOUSEHOLD HUMAN WASTE)	ORGANIC MSW (OR FOOD WASTE)
Feedstock Quality	Lower biogas energy potential. Co-digestion may be required.	Good energy potential without co-digestion. Co-digestion may not be required.	Lower energy content. Co-digestion may be required. Steady and reliable stream. The flow of this feedstock is guaranteed.	High energy content and is a desirable feedstock. Co-digestion with other waste may not be required.
Advantage	In continuous supply. Potential to meet 100% energy needs of agriculture. Significant to the energy security of farms which are often off the grid.	Support to the energy security of farms.	Steady and reliable stream. The flow of this feedstock is guaranteed.	In continuous supply. In rural areas, large capacities possible for generation of electricity and heat or upgrade to biomethane. Stabilization allows for continued generation of energy.
Disadvantage	Proximity of recovery technology to rescue is recommended.	Crop residue is not in continuous supply (seasonal). Storage required for a steady supply throughout the year. Pre-treatment required to allow for faster digestion and higher biogas yields.	Decentralized system mostly applies especially in rural setting. Special Infrastructure needs to be set up to collect the waste. Quality of the sludge based digestate may not be safe (pollutants and pathogens).	Complicated digestion of food waste - one batch of food waste can vary significantly from the next so stabilization is required. In stabilizing (mixing with other substrates maybe required) and it reduces the energy generated. Separate food waste collection required or searation from MSW

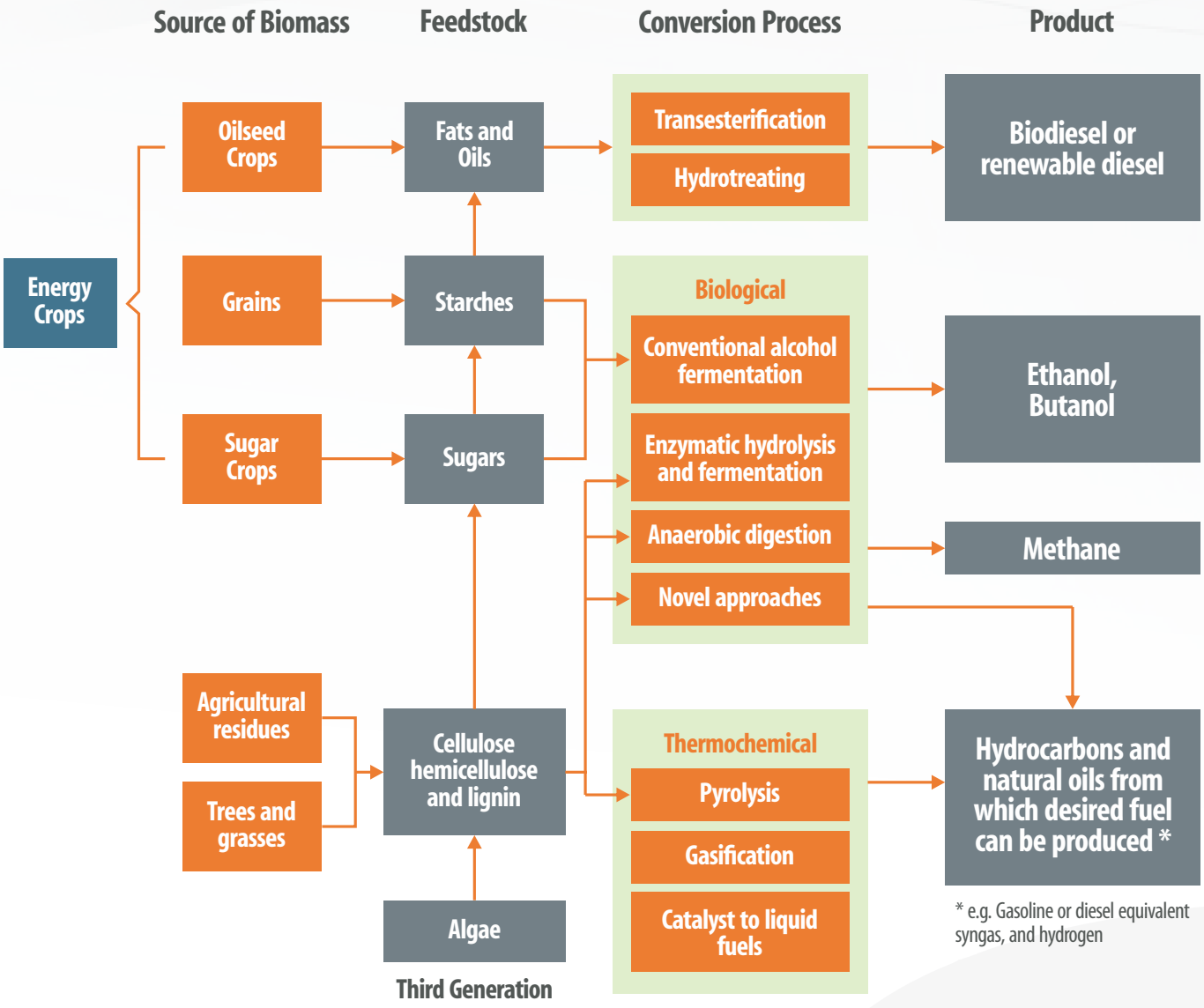
Biogas Yield from Organic Waste

Biogas Yield for Various Waste Material			
INPUT DIGESTION	**Nm^3CH_4/raw ton**	**Biogas (m^3/t)**	**Biogas (ft^3/t)**
Biowaste + Garden waste	50 - 60	80 - 90	2,800 - 3,200
Biowaste + Low level of Cardboard	65 - 75	104 112	3,700 - 4,000
Biowaste + Cardboard + Garden Waste	65 - 75	104 - 112	2,700 - 4,000
Biowaste + Cardboard	75 - 85	112 - 136	4,000 - 4,800
MSW	75 - 90	112 - 144	4,000 - 5,100

Typical Biogas Composition from the Anaerobic Digestion of Source Separated Food Waste				
BIOGAS COMPOSITION		**AVERAGE**	**MINIMUM**	**MAXIMUM**
Methane	Vol. %	65	52	70
Carbon dioxide	Vol. %	35	30	48
Hydrogen sulphide	ppm		50	1,800
Total Chlorine	mg/m^3	0.6	0.02	1.2
Total fluorine	mg/m^3	< 0.1	< 0.03	0.2

Biofuel Pathway (Transport Fuel)

The biomass/feedstock can be from purposely grown energy crops, forest residues or agricultural residue



Transport Fuel Production in Nigeria

- Biofuels used for transportation are blended into traditional petroleum fuel sources such as gasoline and diesel.
- **Bioethanol** is the most widely used biofuel and is a fuel additive for petroleum gasoline / petrol, the majority of which is produced using **fermentation.**
- **Biodiesel** can be produced in a process known as **transesterification.**
- **Biogas** can be converted to biomethane by **upgrading the biogas generated from AD**, through removal of the unwanted gases, particularly carbon dioxide, hydrogen sulphide and water. The purified or upgraded gas is called biomethane or renewable natural gas (RNG).
- By utilizing the syngas produced from **gasification** after impurities have been removed, hydrocarbons produced can be refined to produce a wide variety of fuels and chemicals.
- **In 2007 NNPC was mandated to create an environment for the take-off of a domestic fuel ethanol industry (Automotive Biomass Programme). In 2011 the Nigeria Export and Import Bank (NEXIM) granted loans to companies to commence commercial production of biofuel, most of their projects – both state government and private sector owned – are still in the planning phase.**

Biofuel	Potential Raw Material	Inudustrial Feasibility in Nigeria	Proposed Use	Main Advantage	Land Use	Water Use
Bioethanol	Sugarcane, sweet sorghum, cassava	Developing	Transportation	Reduced pollution, diversification of fuel mix	Sizeable	Sizeable
Biodiesel	Jatropha, oil palm, soy beans	Under investigation	Transportation	Diversification of fuel mix	Depends on crop	Depends on crop
Biogas	MSW, Manure, Sewage	Good	Indoor Combustion	Reduce deforestation, improved indoor air quality	None	Limited

Waste Generation in Nigeria

- Proximity to the resource and end-user is key for siting a Waste to Energy Combustion plant or an Anaerobic Digestion plant.
- Based on a regional analysis of Nigeria, states identified. Lagos, Abuja, Ibadan, Port Harcourt, and Kano provide the best opportunity.
- Residual waste generated in other cities can be moved, the additional waste will ensure sufficient, reliable and increased amount of waste to fuel the plant or smaller capacity plant installed

Regions	Population	Cap/Person /Day (kg)	Daily MSW (t)	Avg. Monthly Waste (t)	Annual Waste (t)	Organic Waste (%)	Annual Organic (t)	Potential States Plant location
Northeast								
Northwest	3,999,000 1,130,000	0.56 0.58	2,239.44 655.40	60,465 17,696	725,579 212,350	43% 63%	311,998.78 133,780.25	Kano Kaduna
Northcentral	949,886 3,278,000	0.5 0.66	474.94 2,163.48	12,823 58,414	153,882 700,968	60% 64%	92,328.92 448,619.21	Ilorin Abuja
Southeast	1,081,000 1,415,000	0.56 0.56	605.36 792.40	16,345 21,395	196,137 256,738	62% 62%	0 121,604.72 159,177.31	Aba Onitsha
Southwest	14,368,000 3,552,000 533,000	0.7 0.51 0.56	10,057.60 1,811.52 298.48	271,555 48,911 8,059	3,258,662 586,932 96,708	68% 61% 60%	2,215,890.43 358,028.81 58,024.51	Lagos Ibadan Abeokuta
Southsouth	1,727,000 3,020,000	0.63 0.6	1,008.01 1,812.00	29,376 48,924	352,515 587,088	54% 60%	190,358.23 352,252.80	Benin City Port Harcourt

Dumpsites in Lagos

- There are various locations that can provide potential plant locations, proximity to Biomass, end user, land availability, required facility scale and capacity need to be considered.

DUMP CONVERSION						
	Olusosun	**Solous 2*3**	**Epe**	**Awotan (Apete)**	**Lapete**	**Eneka**
Location	**Ojota, Lagos**	**LASU-Iba rd, Lagos**	**Lagos**	**Ibadan**	**Ibadan**	**Port Harcourt**
Year	1992	2006	2010	1998	1998	
Estimated Capacity	Largest dumpsite in Nigeria 2.1million t/yr	820,000 t/yr	12,000 t/yr	36,000 t/yr	9,000 t/yr	45,600 t/yr
Area	Area: 43hectars, 18m deep	8 hectares	80 hetares	14 hectares	20 hectares	5 hectares
Residents	5 million in 10km radius from the site	200 meters from the nearest dwellings, 4 million people live within 10km radius from the site. Proximity to the Alimosho General Hospital.	2km away from Osogbo River and 7km away from Lekki Lagoon.	200 meters away from nearest settlement. Close to Eleyele Lake (2.5km away) and IITA Forest Reserve (4.5km away).	2km away from nearest settlement 9km away from IITA Forest Reserve. Surrounded by vegetation.	1.2 million people living around 10km radius from the site (closest building is 200 meters away). Igwuruta/Eneka road and 9km from Okpoka River and Otamiri River.
Issues	Health problems - reported by residents living around 3km radius from the site.	Contamination of ground water	Waterway pollution	Groundwater contamination	Ground water and food crops contamination	Dumpsite flooded almost all year round (+/- 2,500mm per annum) ground water, surface water, and soil contamination.

	MARKET	**ABATTOIR**	**SAW MILL**	**BREWERY**	**FARMS**
Biomass	Keri, Mile 12, Oshodi, Itire, Ojuwoye (Mushin), Ajayi (Ikeja), Pako (Okokomaiko).	Lagos state government modern abattoir	Coconut saw mill (Ebute meta)	Guiness Nigeria PLC (Ikeja), Nigeria Breweries	Various

There are 3 other main dumpsites to consider in Lagos. For dumpsite conversion, rehabilitation works will be carried out:
Leveling of the refuse, slope stabilization, soil covering, grading as well as rolling and landscaping, rebuilding drainage and road network within and outside the site.

This can be done in partnership with the state government. The state is planning dumpsite conversion for *solous 3 to accommodate a Material Recovery Facility and WtE plants to power the General Hospital and the College of Nursing.

Typical Combustion and AD Facility

ANAEROBIC DIGESTER	DESCRIPTION
Combustion Plant	Waste is either stored on site or received weekly (The Waste bunker should be able to hold at least 1 week of MSW) The Plant layout typically is typically split into 4 main systems. • Furnace/boiler System Energy recovery • Flue gas treatment • Ash/residue handling According to WTERT, WTE overall availability is 330, 24-hr days per year.

ANAEROBIC DIGESTER	DESCRIPTION
Waste sorting site/central system Anaerobic Digestion	Waste Management company delivers to waste on plant location The AD system should operate 52 weeks per year, six (6) days a week, and two shifts (16 hours) per day. **The AD site should be accommodate :** • Material intake and digester facility • Separation and gas storage facility

Supply Chain of Recovered Energy Pathway

In the Supply chain process, there are 3 streams of Logistics involved in running a AD process:

LOGISTIC 1: DELIVERY OF FEEDSTOCK TO LOCATION

Partnership with one of the 364 LAWMA licensed waste collectors and environmental agency is required.

The material collection, processing facility should be located on site of the Waste to Energy facility if possible.

A Controlled and Well Managed Waste Management System is Required

Primary Collection	Transportation	Transfer Station and Processing Site	WTE Processing Plant/Site
Collection includes from markets, abattoir, sawmill brewery, farms	Waste collection bins transported to either transfer station or processing facility	Bio Degradable Waste (composting, vermicomposting) Non Bio Degradable Waste (recycle market, Waste to Energy Process)	

LOGISTIC 2: DISTRIBUTION SYSTEM FOR BY-PRODUCT

Composted Digestate (AD) or Bottom Ash	Buyers (Agric/Construction) offtake from WtE facility (to avoid any logistics f or company)

LOGISTIC 3: POST ENERGY GENERATION - ELECTRICITY DELVIERY TO END USER

Electricity Generated	Connect to Grid	Electricity Transmitted by TCN (not applicable for off-grid connection)	Electricity Delivered to Disco	Consumer

WTE Projects in Africa and Nigeria

To date, only one WTE developer of note has successfully constructed and started operating a major waste-fed power project in Africa

- The $120m Reppie plant in Ethiopia. Developed by Cambridge Industries and commissioned in 2018. The facility is designed to convert 1,400 tonnes of waste per day from the Koshe landfill site in south-east Addis Ababa into 185 GWHr of electricity per year.

Other African municipal solid waste (MSW)-fed plants are at various stages of development, including;

- Climate Neutral Group's Joburg Waste to Energy Offset Project, intended to produce 19MW of energy from landfill gas.
- Tropical Power's 2.4MW Gorge Farm Anaerobic Digestion Power Plant in Naivasha, Kenya, which runs on vegetable waste.

NREEP pilots projects

- The waste-to-energy plant that is proposed for Ikorodu Industrial Estate and surrounding areas in Lagos State and the 12 MW (no details)
- Biogas plant was installed for the ikosi fruit market in 2013 by government and Midori Environmental Solutions (MES). Project is no longer active.

The Ebonyi State Government took over this project from the United Nations Industrial Development Organization (UNIDO)

- Demonstration biomass **gasifier power plant** located at the UNIDO Mini -industrial cluster .The power plant is to generate 5.5 Megawatt energy using rice husk and other available waste materials available.

Potential WTE Technical Partnerships

USA companies for potential partnerships, these companies can enhance opportunity for US grants and funding.

Company	Contact	Service Offering
1. EISENMANN USA	Eisenmann Corporation 150 E. Dartmoor Drive Crystal Lake, IL 60014. T (825) 455-4100	Technology, Consulting & Concept Design; Sale of Capital Equipment (AD Technology); Installations, Commissioning of Turnkey Systems.
2. BIOWORKS ENERGY LLC	4652 Beecher Rd, Flint, Michigan 48532, United States. T: 7409722499	Engineering & Process Evaluation, Feedstock /Waste Stream Screening, Evaluation, Process Laboratory Evaluations and Research.
3. ANAERGIA INC.	Pacific Ridge Corporate Center, 5870 Fleet Street, Suite 310, Carlsbad, California 92008 United States. T: +1760-436-8870	Consulting and Concept Design, Sale of Capital Equipment, O&M Service.

European companies below can enhance opportunity for European grants and funding

Company	Contact	Service Offering
1. STEINMULLER BABCOCK ENVIRONMENT GmbH	Fabrikstraße 1; 51643 Gummersbach info@steinmueller-babcock.com/en/energy; +49 (0) 2261 85-0 https://www.steinmueller-babcock.com/en/energy	Technology, Consulting & Concept Design; Sale of Capital Equipment (AD Technology); Installations, Commissioning of Turnkey Systems.
2. AEB	Australiehavënweg 21, 1045 BA Amsterdam, Postbus 58292, 1040 HG Amsterdam info@aebamsterdam.ni, (+37)-020-5876299	Technology, Sale of Capital Equipment (AD Technology), Installation & Commissioning of Turnkey Systems.

Partnership opportunity for European grant and funding focused on

Company	Contact	Service Offering
1. PARTNERS FOR INNOVATION B.V.	Partners for Innovation B.V Withoedenveem 8, 1019 HE AMSTERDAM, the Netherlands +31 (0) 20 620 05 11. info@partnersforinnovation.com Partner for Innovation Niger Sarl Boulevard Bawa Djangorzo Avenue Niamey Nyala BP 577 NIAMEY, Niger +227 2035 1058 r.gazibo@partnersfor innovation.com	Technology, Consulting & Concept Design; Sale of Capital Equipment (AD Technology); Installations, Commissioning of Turnkey Systems.

Anaerobic Digestion Global Deployment

The biogas industry may be analyzed in 3 broad categories.

Micro-Digesters Using Biogas (Very small scale – >=100 KW)

- Family Scale or household biogas plants.
- Important in rural communities (integral part of farming, waste management and energy security). Biogas is used in cooking stoves and lighting.
- Feedstock is usually from household or family small farms.

+/-50 million micro-scale digesters operating around the globe

42 million in China, 4.9 million in India, 700,000 biogas plants are estimated in rest of Asia, Africa and South America.

Scale Digesters Generating Electricity (Small, Medium, Large scale)

- Produces heat and/or electricity
- Can utilize one or many suitable feedstock (Co-digestion – Large scale)
- It is estimated that there is a total of around **132,000 small, medium or large-scale digesters operating in the world.**
- China 110,448 plants
- Europe 17,783 plants
- (Germany has the most installation, others: Sweden, UK, France and Netherlands)
- USA 2,200 plants with capacity of 977MW
- 196 MW installed capacity in canada
- India 180 plants with 300MW capacity

Scale Digesters Producing Biomethane (Medium -Large scale)

- Upgrading of biogas to biomethane is relatively new but now a proven technology.
- While some plants upgrade biogas to be used as vehicle fuel, others inject it into the local or national grids.

Estimated that 700 plants upgrade biogas to biomethane globally.

- 540 upgrading plants in Europe
- 50 in the USA
- 25 in China
- 20 in Canada
- A few in Japan, South Korea, Brazil and India.

African Market Analysis

Country	Cape Verde	Egypt
Population	**550,000 residents (10 islands)**	**100.4 million**
Waste Generation	Cape Verde potentially have a waste collection coverage rate of 85% nationwide.	**95 million tonnes waste produced/yr** 55.2% household's solid waste is collected by private companies 44.8% of the households dispose their waste by dumping it onto the street.
Renewable Focus	257.6 MW and 314.5 MW for wind and solar photovoltaic sources.	Solar, Wind. WTE (Incineration of MSW - 20 35 % target)
Current Electricity Capacity	Per capita electricity consumption is circa 828 kWh/yr per capita Sub-Saharan Africa average of 488 kWh per person per year.	It is Continent's Top Electricity Producer with about 55.21 MW per day in 2017/2018 to around 58,000MW Installed capacity as at end 2019
Electricity Prices	US$0.26 - 0.32	Renewable tarrif: The Egyptian Cabinet has approved the Waste-to-Energy tariff at EGP 1.4/Kwh. The approval was issued by virtue of Decree no. 41 of 2019 (the "Decree"). The tariff shall be applicable until reaching the maximum contractual capacity of 300 MW. Thereafter, the Cabinet will reconsider the tariff.
Current Electricity Capacity	No renewable energy pricing Small population with potentially small waste generation and organic waste is only 17%. Government focus is on waste management and recycling plan as more 10% of the waste make up is recyclable. Transportation of goods and services cost is very high Capable human resources is lacking.	Potential Strict control by the Governorate via PPA (plant shall be located for a period of 25 years and control of the plant shall be by the Waste Management Regulatory Authority (WMRA), together with Egypt ERA for regulatory rules and technical requirements for the connection of the plant to the electricity grids may be a challenge).

African Market Analysis

Country	Namibia	South Africa
Population	**2.5 million**	**59.62 million**
Waste Generation	Extrapolated from a domestic waste sample of Windhoek, Waste gen/year included 123,000tons of recyclable. But only a fraction of less than five percent was exported to South Africa for recycling each year.	**About 54,2 million tonnes of general (municipal, commercial, and industrial) waste per year,** a maximum of only 10% recycled or recovered for other uses, 90% is landfilled or dumped.
Renewable Focus	Non-electricity off-grid renewable energy projects-micro wind driven water pumps in farms (30,000) to be replaced by solarSolar, wind and biomass generation. Invade bush is widely spread in the country's northern parts, which allows a large scale bioenergy-based production capacity.	Primary sources of renewable energy - solar, wind, hydroelectric, and biomass. The first large-scale WTE plant in Africa in cape town converts municipal solid waste into renewable, clean energy using technology from the Anaergia group of companies. Biomass is currently the largest renewable energy contributor in South Africa with 9-14% of the total energy mix.
Electricity Potential	Around 1 million Namibians lack access to electricity- almost half of the country is without access at all (~53% has access & ~47% has no access.	Demand growth at about 1%.
Current Electricity Capacity	Average consumption rate is around 1677kwh/yr per capita. Its generation capacity is about 1305 GWh/year.	Average consumption is 3,591 kwh/yr per capita 54GW installed generation capacity. Access at 86.1%, , peak demand of 34.5GW.
Electricity Price	**Household 0.131 $/Kwh.** **No renewable price.**	**Household 0.140$/kWh and Business 0.068$/kWh.** **Renewable Tarrif Biomass solid 0.12 €/kWh, Biogas 0.10 €/kWh.**

African Market Analysis

Barriers/Resistors	No policies, population and households structures are sparse, lack of knowledge/ exposure by people – potential infrastructure vandalization. Potential unaffordability of renewable energy power by the people. There is a supply gap, covered by importing power from South-Africa, Zambia, and Mozambique". The government of Namibia and NamPower have committed to making Namibia energy self-sufficient.	Lack of political stability and capacity, marginalization, corruption, poverty, and environmental degradation. The high initial capital required to employ renewable energy is a large constraint the sector experiences. National Grid connection challenges – all connections go through the grid for now and is controlled by ESKOM. All renewable energy power generators under the REFIT will require a generation licence Power Purchase Agreement (PPA). The Independent Power Producers Procurement Programme (REI4P) exists to support renewables power projects hort-to-medium and long-term targets to help set the pace of renewable energy production in place by government with a focus to increase access to electricity in rural areas because of its suitability for off-grid and small-scale solutions.

Economics

Economics of Waste to Energy

A Controlled and Well Managed Waste Management System is Required

Revenue for Combustion

- Energy Sale
  - Electricity
  - Heating
- Recovered materials (recycling, metals)
- Government Subsidies
- Gate fee

Revenue for AD

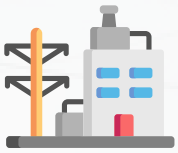
- Energy Sale
  - Electricity (driven by heat produced)
  - Heating/cooling
  - Biomethane (when biogas is upgraded)
- Digestate sale
- Government Subsidies
- Gate fee

- The business model and the facility revenue of the WTE project is highly influenced by waste mix
- The more waste that is combustible, the hotter the furnaces burn, the higher the caloric value (CV) produced and more electricity to sell
- For AD, the technology/system deployed can influence the retention time of waste and the biogas production in a shorter time
- Economics of scale is evident in the capital costs
- Normalized CAPEX is typically lower for dry AD, higher for Combustion and highest for advanced thermal system
- The local electricity price is key to determine the revenues and return on investment
- Additional income can be made from recovery of ash residues (combustion) or digestate (AD)
- Optimizing maintenance costs strongly influences Opex

Electricity Generation Capacity (Combustion)

WASTE TO ENERGY

1 Tonne of Waste → **0.60 - 0.75MWh 600 - 750KWh**



Average throughput for Lagos 10,000.
2,469 tonne/815,000 tonne/yr (using 25% of residual waste)

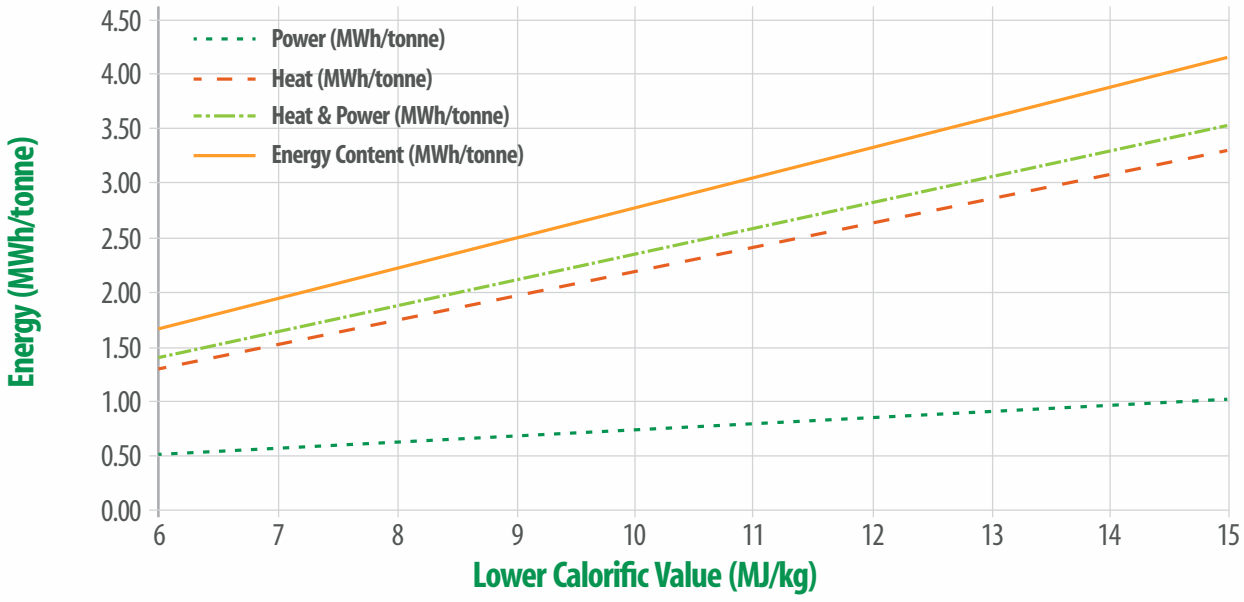
Design assumptions: 1T = 750Kwh; 2469T/day; 25% plant capacity

Electricity Gen capacity: **1,851,750 KWh/day @ 25% plant capacity** (net electrical eff.)

EGC = **463,000 KWh/day/152,769,375KWh/year**

If only electricity is produced and energy output will be approximately 0.60 – 0.75 MWh per tonne of waste with a calorific value of 11 MJ/kg.

- Assuming supply to consumers at N23 per kWh via distribution company for grid connection; 10 million naira/day
- Assuming supply to consumers at N56 per kWh for off grid solution; 26 million naira/day

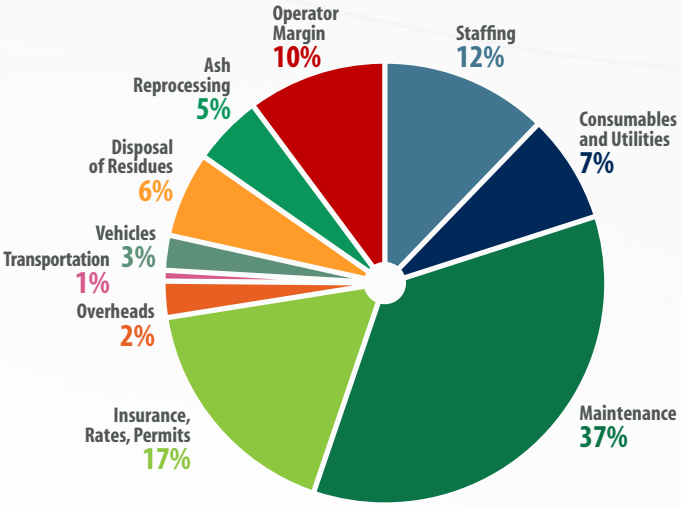


WTE Plant Investment Costs

OPEX (excluding Finance costs)	**Operations and Maintenance**
Combustion $ '000	**Typically 5 - 7% of Capital cost**

Investment cost have in general been seen in the magnitude of;
300 – 400 USD/yearly tonnage for Lower income.
400-600 USD/yearly tonnage capacity for middle income.
600-900 USD or even higher per yearly tonne capacity in European countries and in North America.

2H Land will Typically be Required for 100k TPA Plant



Mid-Large Scale (2010):

Country:	Waste tonnage (annual):	Capital Investment:	OPEX:	Annual Electricity Generated:
Uruguay	640,000 tonnes/yr	$440million	$22million (34.4/tonne)	400GWh energy

Mid Scale (2010):

Country:	Waste tonnage (annual):	Capital Investment:	OPEX:	Annual Electricity Generated:	Revenue:
Philippines	200,000 tonnes/yr	$198million	$50-$70 per tonne of waste	106,700,000Kwh/ 106,700MWh	$90/tonne of waste ($18MM)

Low Scale (2015):

Country:	Waste tonnage (annual):	Annual Electricity Generated:
Isle of Man	480,000 tonnes	24,000,000Kwh/24,000MWh

Anaerobic Digestion Plant Costs

1m3 of biogas contains 6 kWh of calorific energy.

For biogas converted to electricity, in a biogas powered electric generator:
1m3 biogas will typically generate around 2 kWh of useable electricity (depending on the technology, retention type, waste type etc)

Tech. Owner	Location Deployed	Year	Waste Type	Capacity	Reported Biogas Generated m3/ton	Energy Gross kwh/yr	Electricity Net kwh/yr	Cost ($'000)	Land
ISKA	Sydney, Australia	2006	MSW (dry)	175,000	50	17,500,000	2,556,180	55,000	7.4 acres
Valorga	Varennes, France	2001	MSW (wet, 25days ret.)	110,000	154	34,000,000		42,000	9 acres
Valorga	Geneva, Switz'land	2000	Green waste (24-30 days ret.)	13,200		435,000	356,700	5,000	1.2 acres
Linde	Barcelona, Spain	2002	MSW (wet, 22days ret.)	150,000	87	36,000,000	18,000,000		
Entec	Lucknow, India	2003	MSW	200,000		5,000,000	115,000 Kwh/day	17,000	
Entec	Kogel, Germany	2003	Food waste	40,000		1,400KW	1,250KW	6,5000	

One of the larger scale (UK onsite digester) is a 3MW plant, Processes 50,000 tonne of waste and est to power 6000 homes and generate 46,750 tonnes fertilizer. UK capital costs for 1-3MW off-farm Anaerobic digester plants is around $6.5 - $10 million.

Typical AD Operating costs are around 7%

Legal and Regulatory Framework

Applicable Laws and Regulatory Institutions: WTE

Electric Power Sector Reform Act, No. 6 of 2005 ("EPSRA")

Nigerian Electricity Management Services Agency Act

Nigerian Electricity Regulatory Commission (NERC)	The regulator of the electricity industry and generally responsible for enforcement of the EPSRA and such other related or incidental matters
Nigerian Electricity Management Services Agency (NEMSA)	Carries out electrical inspectorate services in Nigeria's electricity supply industry and ensures that all major electrical materials and equipment used in Nigeria are of the right quality and standards, among other powers
Standard Organisation of Nigeria (SON)	Issues the Mandatory Conformity Assessment Programme ("MANCAP") Certificate for all locally manufactured products in Nigeria to ensure they conform to the relevant Nigerian Industrial Standards (NIS) before being presented for sale in Nigeria or exported Also issues the Standards Organisation of Nigeria Conformity Assessment Programme ("SONCAP") Certificate for all products imported into Nigeria. The SONCAP Certificate will be required for components or equipment imported for use in installing power systems in Nigeria
National Office for Technology Acquisition and Promotion (NOTAP)	Registers contracts for the transfer of foreign technology to Nigerian parties as well as every agreement in connection with the use of trademarks, use of patented inventions, supply of technical expertise, the supply of basic or detailed engineering, and the supply of machinery and plant, among others

Licenses Based on WTE Technology Deployment

Tech.	Available Tech. Opitons	Recommendations	Industrial Processes	End-Products	Potential Off-takers	Possible Licences
WTE	Combustion	Option recommended based on technical	Mixed Municipal to Steam to Electricity	Electricity only	Private Distribution Company (DISCOs), Private, EKDC Transmission Company of Nigeria (TCN)	Generation licence, IEDN licence; Embedded licence, EIA approval, Building permit, Factories licence, NESREA
	Anaerobic Digestion	Option recommended based on technical	Organic waste to Biogas	Electricity	Private Distribution Company (DISCOs), Private, EKDC Transmission Company of Nigeria (TCN)	Generation or IEDN licence; Embedded licence, EIA Building Permit, Factories licence, NESREA
			Organic waste to biogas to biomethane	Transportation fuel *(Only if biogas is upgraded to Bio-methane by removing impurities)*	Downstream companies (for Fuelling stations) NNPC	EIA, Building permit, Factories licence, NESREA
				Digestate (which is a by product - used as soil nutrient)	Business that sell fertilizer (Agriculture industry)	EIA, Factories licence, Nil.
	Pyrolysis	In early market development				
	Gasification	In early market development *(Opportunity to explore this is in future*				

Licence Regime: WTE

S/N	Type of Licence	Description
1	Generation Licence	Required for electricity generation capacity (excluding captive power generation) exceeding 1 Megawatt (MW). Issued in respect of a specific site
2	Distribution Licence	Entitles the licensee to construct, own, operate and maintain a distribution system and facilities
3	Mini-Grid Licence	Issued for integrated off-grid local generation and distribution systems with installed capacity below 1 MW. For projects below 100 Kilowatts (Kw), only a simple registration with NERC is mandatory
4	Captive Generation Permit	Issued for generation of electricity exceeding 1 MW for the purpose of consumption by the generator, and which is not sold to a third-party. NERC's consent is required before supplying surplus power not exceeding 1MW to a third party
5	Embeded Generation Licence	Enables the generation of electricity that is directly connected to and evacuated through a distribution system which is connected to a transmission network operated by the Transmission Company of Nigeria
6	Independent Electricity Distribution Network Licence	Enables distribution of electricity through a network not directly connected to a transmission system and is issued where: (i) there is no existing distribution system within the geographical area to be served by the proposed IEDN; and (ii) where the infrastructure of an existing DISCO is unable to meet the demand of customers in the area

Other Authorization or Institutions that May be Applicable: WTE

Authorization	Purpose	Issuing Authotiry
Environmental Impact Assessment (EIA) certificate	Confirms that an EIA of the mining activity have been adequately done and provisioned for **Threshold for conduct of EIA for power projects is 10MW**	Federal Ministry of Environment
NEMSA Certificate	Persons undertaking electrical installation work and contractors looking to engage in the business of electrical installations. The NEMSA certificate has therefore become one of the compulsory tender documents for contractors looking to bid for power projects in Nigeria	Nigerian Electricity Management Services Agency
Building & Construction Permits	Required where construction would be carried out in relation to the Project	Various land and physical planning agencies of various states
Factories licence	Where any premises is occupied as a factory	Director of Factories, Ministry of Labour
NESREA	Required for importing new electrical/electronic equipment and waste generation	National Environmental Standards Regulation Enforcement Agency
NOTAP Registration	Required for agreements with foreign partners for technology transfer, such as, use of trademarks, patented inventions, technical/management, technological expertise, etc	National Office for Technology Acquisition and Promotion
Import Related Permits	Where the company would import goods for use in the business	Central Bank of Nigeria; Standards Organisation of Nigeria
Import Clearance Certificate	The importation (and clearing from the ports) of fully assembled generators, knocked-down parts imported for domestic assembling or spare parts	Nigerian Customs Service (NCS)

CBN Intervention Fund

Mini Grid Developers

Types – (i) Term Loan and (ii) Working Capital

- **Term Loan**
  - Tenor – 7 years
  - Obligor limit – Max of 70%
  - Moratorium – 2 years

- **Working Capital**
  - Obligor limit – maximum of N500 million
  - Tenor – 3 years max;
  - Interest rate – 10%
  - Eligibility – pre-qualification under World Bank Nigeria Electrification Program; Nigerian companies (min of 70%)

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