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POTENTIAL OF BIOMASS GASIFICATION AND COMBUSTION TECHNOLOGY FOR SMALL- AND MEDIUM-SCALE APPLICATIONS IN GHANA

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ABSTRACT

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This research discusses the biomass gasification technology and which potential feedstock is available and their location in Ghana. It further explains which type of distribution network will be appropriate and the target group who will benefit from the technology and how affordable and appropriate it would be to them. The thesis also discusses which policies will be needed to promote this kind of renewable energy for the small and medium scale gasification plants in Ghana.

The method employed in this paper was a desk top research, identifying the potential feed stock in Ghana, given an overview of solid biomass resources in Ghana, describing the gasification technology to generate electricity and the potential for the small and medium scale gasification plants on the Ghanaian market.

The outcome of this paper revels that, there is a great potential for the gasification technology in Ghana when the right polices and measures are put in place.

Keywords: Biomass gasification, feedstock, distribution network and policies.

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1. INTRODUCTION

This research aims to uncover the potential of bioenergy in Ghana and how this form of energy can be sustained and afforded by the local Ghanaian community.

Renewable energy has become one of the strongest alternatives to improve the plight of about two billion people around the world who are living in mostly rural areas and have no access to any form of energy which is considered as modern. It is estimated that about half a billion people also have limited or unreliable access to energy. It must be noted that these people are living in the most remote parts of the world where population growth is on the increase. If there is any difference to be made in the lives of these people, then it must be a way of helping them to get connected to power sources. In spite of development in technology and economic viability of so many applications, renewable energy has been utilized to a small fraction of the total potentials it has. This is because of the presence of so many barriers to the penetration of renewable energy products. The barriers to renewable energy products may differ within technologies across countries. This research focuses on the identification of these barriers and if possible how to overcome them.

Ghana, a country on the West Coast of Africa, is one of the most thriving democracies on the continent. The country's economy is dominated by agriculture, which employs about 40 percent of the working population. Therefore there is a great potential for bio energy since there are a variety of biomass resources. In Ghana, the main energy supply is based on biomass, mainly firewood and charcoal (64%), petroleum (27%), and electricity (9%), Bio energy among the other renewal sources of energy sources has a great potential of improving the energy security of the nation, since Ghana is predominantly renowned in vegetation and agriculture. The considerable amount of biomass resources in the nation combined with the development of other conversion technologies suggest that bio energy will play a significant role in the future of Ghana’s energy sector. (Albert Adu Boahen- 2010)

The development of Ghana's energy sector has been one of the priorities of the Ghanaian government as the world draws closer to an age where fossil fuels like oil, gas and coal may run out and the reality of climate change becomes more apparent and there is need to switch to renewable energy resources to reduce the emission of greenhouse gases becomes more urgent.

The demand for electricity in Ghana has increased in the past years as the population has grown so much and the need to meet the rising demand has become eminent. Reliance on the hydro dam alone cannot solve the high demand for the entire nation.

The development of Ghana's energy system in the context of energy security will rely on energy efficiency and expanded renewable energy. For the past four years the government of Ghana have been putting together regulations and policies to embrace renewable energy into the energy sector and to promote investment in this area of energy which could become an alternative or supplementary source of energy generation for the country and its surroundings.

1.1. Objective of the Research

The following are some aspects in which this research intends to reveal the enormous potential of the gasification technology in Ghana. The objective of this research is to:

- Identify the potential feedstock in Ghana
- Give an overview of solid biomass resources in Ghana.
- Describe the gasification and combustion conversion technologies that utilize solid biomass to generate electricity.
- Access the market potential for small and medium scale gasification and combustion system.

1.2. The Research Questions

This research will look critically into the following questions with respect to implementation of bio energy technology in Ghana whiles considering factors that lead to barriers and drivers behind the Bio energy growth.

1. What is the available feedstock and where is it located in the country?
2. What type of distribution network would be appropriate?
3. Who are the target group and is the technology appropriate and affordable?
4. What are the barriers in the development of biomass gasification in Ghana?
5. What policies are needed to promote small and medium scale gasification plant in the energy sector of Ghana?

1.3. Structure of the Research

The theoretical framework for the research is described in Chapter (-2-) as a literature review, where information on the subject is gathered mainly by desktop research and information gathered from already existing books and article. Chapter (-3-) discusses the methodology adopted in bringing out the researcher's facts and findings. Chapter (-4-) discusses the potential of bioenergy in Ghana and an overview of the potential feedstock available in Ghana, the appropriate distribution network and the target group for this energy. Chapter (-5-) describes critical factors that can affect the bio energy technology implementation in Ghana and some policies that can help boost this type of energy and the role of Gasek. In chapter 6 the conclusion and recommendations are given on how this energy can be well made use of when the right measures are implemented.

2 BIOENERGY AND RELATED TECHNOLOGIES

This deals with the impact of bioenergy, conversion technology and the bioenergy process in general.

2.1 Definition of Bioenergy

Bioenergy is a renewable source of energy that makes use of biomass to produce energy. Biomass is a term used for any organic matter that is derived from plants as well as animals. Biomass resources include wood and wood wastes, agricultural crops and their waste by-products, municipal solid waste, animal wastes, wastes from food processing, aquatic plants and algae. There are competing uses for these resources because of their economic and environmental value. Biomass can be used to generate power, heat and steam, and for the production of transportation fuels. It is also used by the food processing, animal feed, and the wood processing industries. Biomass is composed mainly of cellulose, hemicellulose, lignin, and small amounts of extractives. The suitability of a particular biomass as a potential feedstock for biofuels production depends on various characteristics such as moisture content, calorific value, fixed carbon, oxygen, hydrogen, nitrogen, volatiles, ash content, and cellulose/lignin ratio. Generally, cellulose is the largest fraction, and constitutes about 38–50% of the biomass by weight. Cellulose is a polymer of glucose, consisting of linear chains of (1, 4)-D-glucopyranose units with an average molecular weight of around 100,000. It is the most abundant form of carbon in the biosphere, and a good biochemical feedstock. Hemicellulose, on the other hand, is a polymer of 5-carbon mainly xylose, and 6-carbon monosaccharaides. Xylose is the second most abundant sugar in the biosphere. Unlike cellulose, hemicellulose is a marginal biochemical feedstock. It represents 20–40% of the material by weight. Lignin can be regarded as a group of amorphous, high molecular-weight, chemically related compounds. The building blocks of lignin are believed to be a three carbon chain attached to rings of six carbon atoms, called phenyl–propane. Lignin constitutes about 15–25% of the composition of lingo-cellulosic biomass. It has very high energy content, and also resists biochemical conversion. (Roewell 1984)

2.2 Impact of Bioenergy

Bioenergy energy has quite a lot of impacts that can affect positively the community that utilizes this energy and some of these impacts can be classified as follows:

Social impacts

The current global interest in biomass resource and biofuel production, especially in the area of transportation fuels presents an opportunity for both domestic and foreign investment in Ghana as well as increased export earnings. In Ghana, biomass has a varied effect: it would boost agricultural development and technological advancement and further bring opportunities, such as, releasing women and children from the heavy duty of collecting fuel, creating new employment, thereby improving the quality of life. Also, because biomass resources can be converted to liquid and gaseous fuels, electricity and process heat, they can increase access to modern forms of energy for the population. Moreover, producing biomass resources locally reduces the country's dependence on foreign energy sources, and vulnerability to supply disruptions. Biomass resource cultivation, harvesting, and processing could have a direct impact on rural development. Biomass and biofuels production could improve rural livelihoods by providing new income opportunities to their families. However, biomass production should not conflict with food stability in the country. It should rather positively contribute to increasing the productivity of food crops cultivated by the farmers producing the bioenergy crops. Efforts should be made to avoid human health impacts and risks through regular training and awareness on the impacts of biofuel production and use. (Mohammed 2007)

Environmental impact

Potential environmental benefits to be derived from the local production and use of biomass resources and biofuel production include offsetting GHG emissions associated with burning fossil fuels, waste utilisation, and erosion control. Clearly, biomass technology may benefit the environment while at the same time it may help solve some pressing environmental problems. It is reported that using biomass to produce energy is carbon-neutral because it releases roughly as much carbon dioxide (CO_2) as it takes in. For instance, for every MWh of power generated using biomass, approximately 1.6 tonnes of CO_2 are avoided. Also, the use of biomass resources, managed in a sustainable way, could reduce CO_2 emissions and thus help tackle global warming. Methane, the principal component in biogas, is produced by anaerobic digestion or fermentation of biodegradable materials such as manure. Negative environmental impacts associated with the production_and use of biomass resources include inappropriate land use (deforestation), land availability, land use-conflicts, increased GHG_emission, loss of biodiversity, and soil erosion. Since majority of_Ghana's population relies almost entirely on biomass resources for_their energy needs, using alternative sources of energy is seen to be crucial to forest sustainability. The planting of energy crops, for instance, could increase vegetation coverage, and substantially improve the local environment such as reduction of soil erosion. But, extensive use of tillage, fertilisers and irrigation could lead to the deterioration of the physical and chemical properties of soil, such as reduced soil fertility, accumulation of toxic substances, and reduced organic matter. Residues left on the farms improve the soil by returning the nutrients, and also inhibit weed growth. The development of cellulosic ethanol and pyrolysis oil, however, may cause some of the farmers to remove huge amounts of agricultural crop residues for sale in order to increase their income to the detriment of the soil. (OECD/IEA 2010)

Electricity from Biomass

The generation of electricity from wastes is a technically mature technology even though cost may be relatively high. Additionally, the collection and management of wastes, particularly municipal waste poses a serious limitation. International experiences, however, suggest that the collection and management issues could be surmounted. The utilization of waste for electricity generation could contribute to meeting the power needs of the country in the medium to long term.

2.3 Conversion Technology

There are a number of technological options available to make good use of the vast range of biomass as a renewable energy source. Conversion technologies may release the energy directly in form of heat or electricity or may be converted to another form, such as liquid biofuel or combustible biogas. Some classes of biomass resources may have only one appropriate technology while others may have several options.

There are two main categories of technology that convert solid biomass resources into energy in the form of heat or power or even a combination of both. These technologies are direct combustion or gasification.

2.3.1 Direct Combustion

In Ghana and some parts of the world, direct combustion is the method mostly practiced to convert biomass resource into heat or power. In the direct combustion system, biomass is burnt to generate hot flue gases, which is either used directly to provide heat or fed into a boiler to generate steam. In the boiler system, the steam can be used for industrial purposes or space heating or even to drive turbines to generate electricity.

This technology employs two main principles in the direct combustion boiler system which are the fixed bed (Stocker) and the fluidized-bed system. In a fixed-bed system, the biomass is fed onto a grate where it combusts as air passes through the fuel, releasing the hot flue gases into the heat exchanger section of the boiler to generate steam. A fluidized-bed system instead feeds the biomass into a hot bed of suspended, incombustible particles (such as sand), where the biomass combusts to release the hot flue gas. The manufacturers of fluidized-bed systems claim that this technology produces more complete combustion of the feedstock, resulting in reduced SO2 and NOx emissions and improved system efficiency. Fluidized-bed boilers can also utilize a wider range of feedstock. Fluidized-bed systems, however, have greater parasitic loads than stokers. Given proper emissions-control technology, both systems can meet stringent emissions limits. Direct combustion biomass facilities that produce electricity through a steam turbine have a conversion efficiency of 15% to 35%, depending upon the manufacturer; a CHP system can have an overall system efficiency of as much as 85%. The efficiency of a direct combustion biomass system is influenced by a number of factors including:

(1) Moisture content of the biomass;

(2) Combustion air distribution and amounts;

(3) Operating temperatures and pressures;

(4) Fuel feed handling, distribution, and mixing; and

(5) Furnace retention time.

Although most direct combustion systems generate power utilizing a steam-driven turbine, a few companies are developing direct combustion technologies that use hot, pressurized air or another medium to drive the turbine. (Peterson and Haase 2009)

2.3.2 Gasification

Biomass gasification or combustible gas production from carbonaceous feed stock is an already existing ancient technology, sometimes called dry distillation or pyrolysis. An attempt was made in 1795 and 1805 to first practice commercial processes, by Philippe Lebon and William Murdoch in France and in England respectively. But in 1812 a London established company began the actual commercialization of this technology. Thereafter, many more commercial production pro-cesses emerged in Europe and America.

Gasification systems, -instead of directly burning the fuel to produce heat, -convert biomass into a low-Btu to medium-Btu content combustible gas, which is a mixture of carbon monoxide, hydrogen, water vapor, carbon dioxide, tar vapor, and ash particles. In a close-coupled gasification system, the produced gas is burned directly for space heat or drying, or burned in a boiler to produce steam.

Gasification is basically a thermo-chemical conversion of organic materials at increased temperature with partial oxidation. In gasification, the energy in biomass or any other organic matter is converted to combustible gases (mixture of CO, CH4 and H2), with char, water, and is condensable to minor products. Initially, in the first step called pyrolysis, the organic matter is decomposed by heat into gaseous and liquid volatile materials and char (which is mainly a nonvolatile material, containing high carbon content). In the second step, the hot char reacts with the gases (mainly CO2 and H2O), leading to product gases namely, CO, H2 and CH4. The producer gas leaves the reactor with pollutants and therefore, requires cleaning as seen in Figure 1 below, to meet requirements for engines.

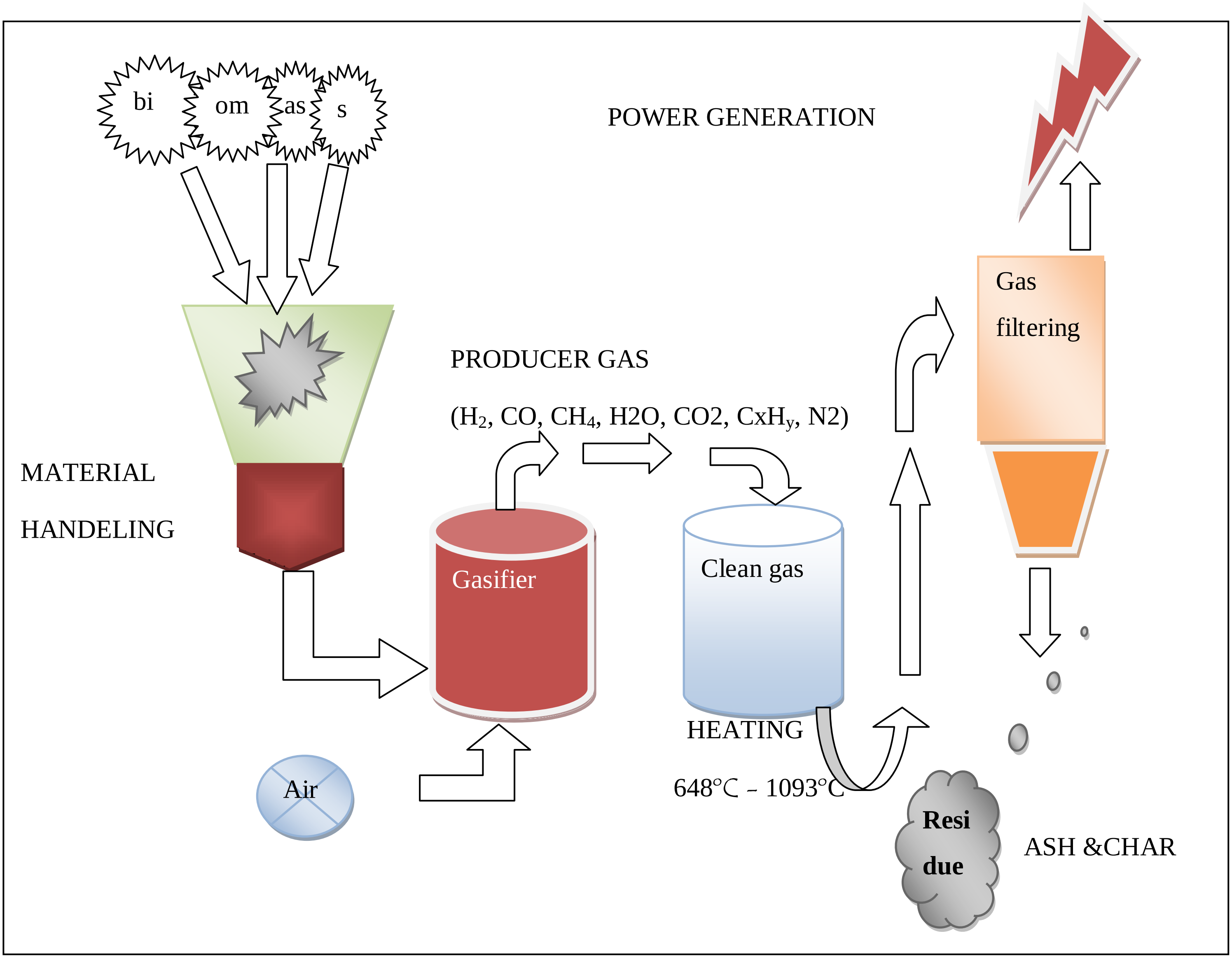


Figure 1. Example of two-stage gasification diagram

(www.frontlinebioenergy.com)

Mixed with air, the cleaned producer gas can be used in gas turbines (in large scale plants), gas engines, gasoline or diesel engines. As shown in the figure above producer gas is a combination of carbon monoxide, hydrogen and methane, together with carbon dioxide, nitrogen and other incombustible gases. Depending on the carbon and hydrogen content of the biomass and the properties of the gasifier, the heating value of the producer gas, ranges between 4 to 20 MJ/m3. The heating value also depends on the type of gasifier agent or the oxidant. The oxidant used can be air, pure oxygen, steam or a mixture of these gases. Air-based gasifiers typically produce a producer gas containing a relatively high concentration of nitrogen with a low heating value between 4 and 6 MJ/m3. Oxygen and steam based gasifiers produce gas containing a relatively high concentration of hydrogen and CO with a heating value between 10 and 20 MJ/m3.Biomass gasification offers certain advantages over directly burning the biomass. Unlike, power generation with direct burning of biomass in a boiler, gasification can be used for very small scale decentralized power generation projects up to 20 kW. A gas producer is a simple device consisting of usually cylindrical container with space for fuel, air inlet, gas exit and grate. It can be made of fire bricks, steel or concrete and oil barrels. Since gas is produced first, some of the problematic and poisonous chemical compounds can be cleaned and filtered before it is burned.

The gasifier alone is of little use. The complete gasification system consists of fuel conditioning units, gasifier, gas cleaning units and gas utilization units. The basic processes that take place in the biomass gasification plant and supporting equipment are shown in the Figure 1 above. Fixed bed and fluidized bed are the main categories of gasification conversion using similar types of equipment as that used in direct combustion systems.Among these categories are some varying designs which determine the type of gasifier they are and their suitability.

Five major types of classification are used in the gasification system shown in Figure 2 below, which are fixed-bed updraft, fixed-bed downdraft, fixed-bed cross draft, bubbling fluidized bed, and circulating fluidized bed gasifiers. These classification describe how the fuel and heat source is introduced into the gasifier and the direction of the flow of both fuel and oxidant. (Peterson - 2009)

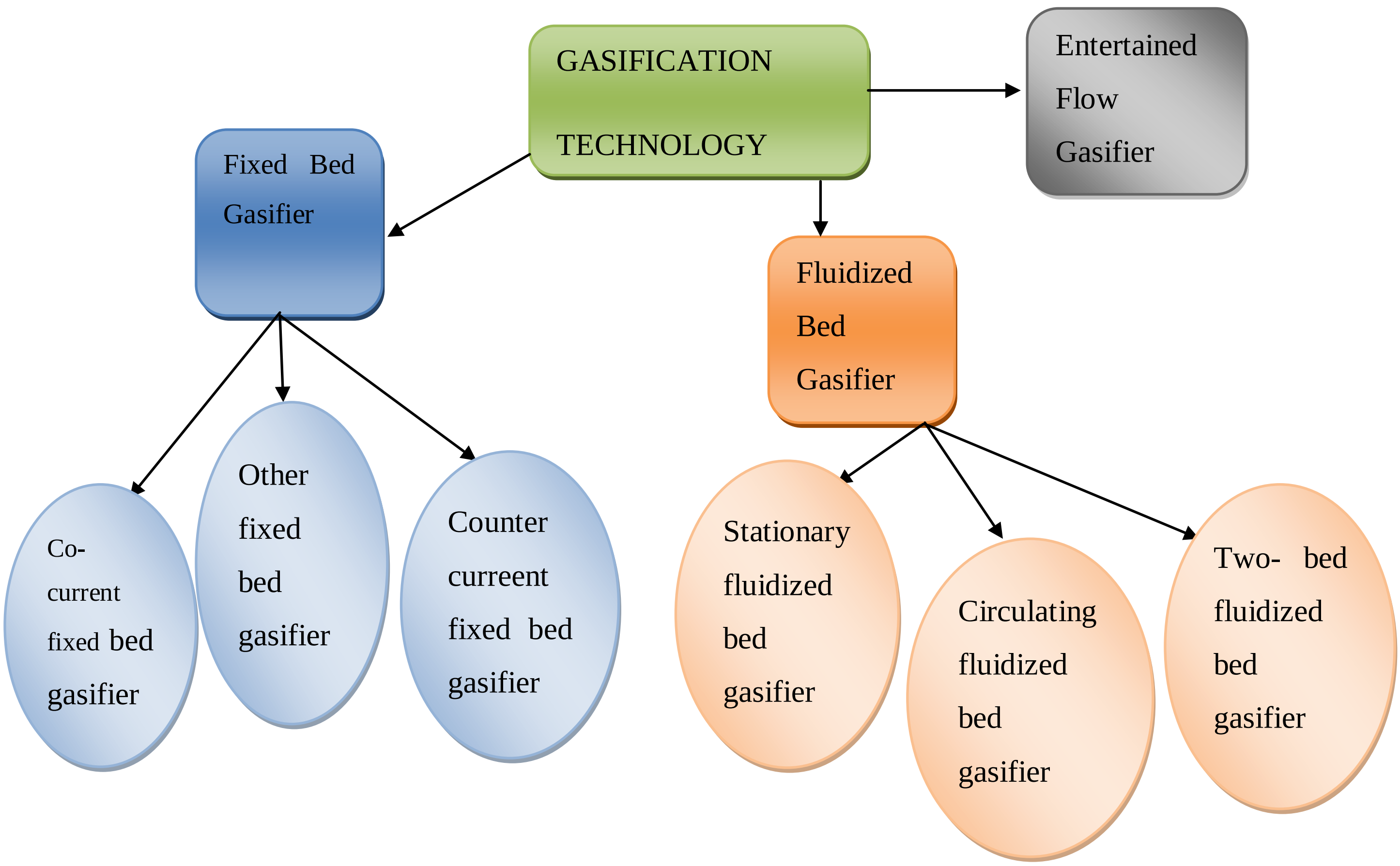
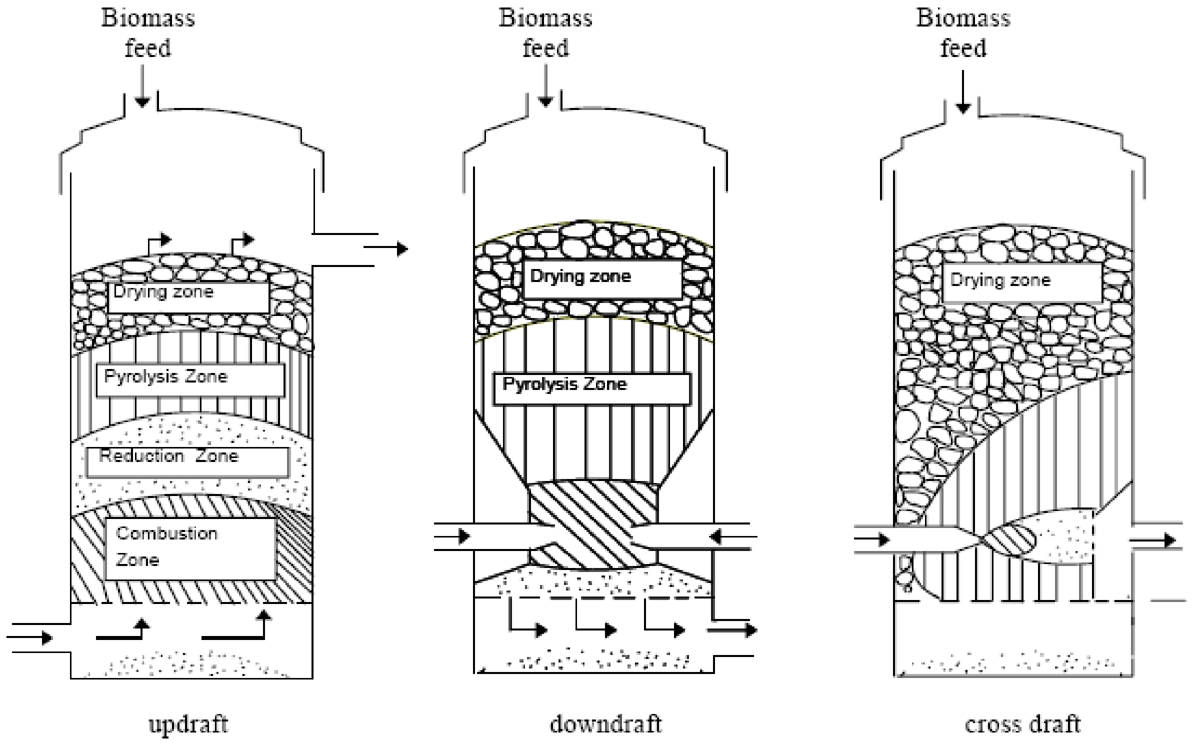


Figure 2. Overview of the different gasification technologies

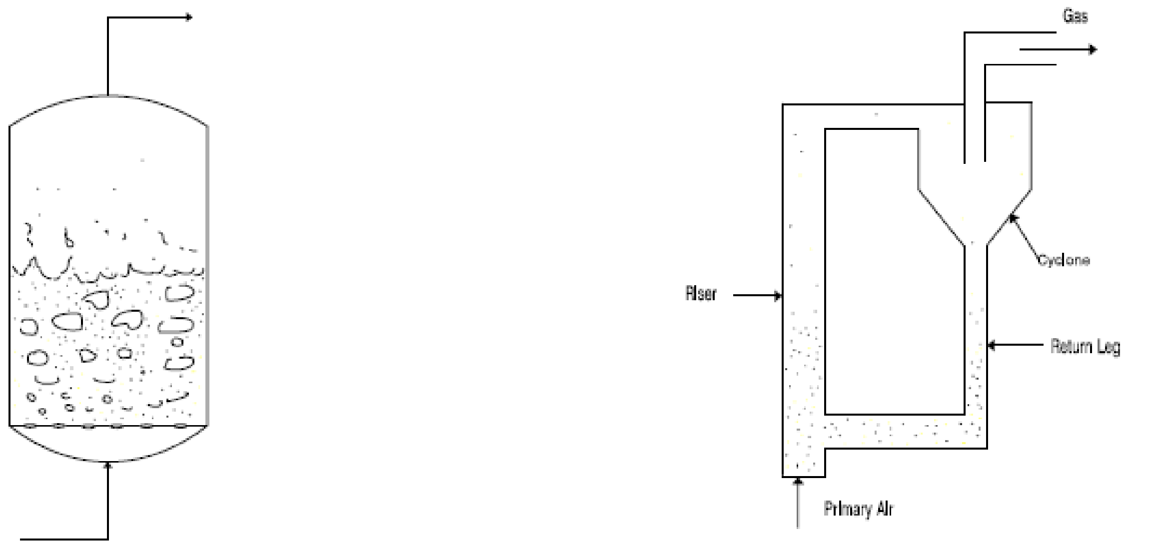
(Salam, Kumar and Siriwardhana, 2005)

In the **fixed bed gasifier** system the feedstock (fuel) is fed into the gasifier from the top onto a grate in the gasifier chamber. This technology has proven to be simpler in construction and less expensive. The down side of this system is that it produces a gas with low heat content.

In the **fluidized-bed gasifier** system the feedstock is fed into a hot bed of suspended inertia material which generates the flue gas with a higher heating value. This system is a bit complicated and expensive.The updraft, down draft and cross draft show how the air is fed into the system and how the producer gas leaves the chamber as illustrated in Figure 3 below. The circulating and bubbling bed system has almost the same operation function as the ones described above.



i) Fixed Bed Gasifiers



a) Bubbling Fluidized Bed **b) Circulating Fluidized Bed**

ii) Fluidized Bed Gasifiers

Figure 3. Illustration of the various gasification systems. (Bhattacharya and Salam, 2006)

Table 1 below clarifies some of the strengths and weaknesses of the conversion technologies that is usually used in solid biomass conversion.

Table 1. Comparison of direct combustion and gasification technology

Technology	**Strengths**	**Weaknesses**
Direct Combustion	•Proven, simple, lower-cost technology • Equipment is widely available, complete with warranties • Fuel flexibility in moisture and size •Lenders comfortable with technology	•Greater NOx, CO, and particulate emissions •Inefficient conversion process when generating power alone—some advanced designs are improving efficiency •Requires water if generating power with a steam turbine
Gasification	•Lower NOx, CO, and particulate emissions •Potential for more efficient conversion process when generating power •Virtual elimination of water needed if generating power without a steam turbine (close-coupled systems excluded)	•Technology is in the development and demonstration phase (closecoupled systems excluded) • Need fuel of uniform size and with low moisture content

Adopted from D. Peterson - 2009

The type of gasification preferred over the other is dictated by fuel, size, moisture content, ash content and its final available form. Table 2 below depicts some of the strengths and weaknesses of the main gasification categories.

Table 2. Pros and Cons of the gasification technologies

Gasifier	Advantages	Disadvantages
Bubbling fluidized bed	Large-scale applications Feed characteristics Direct/indirect heating Can produce higher heating value gas	Medium tar yield Higher particle loading
Circulating fluidized bed	Large-scale applications Feed characteristics Can produce higher heating value gas	Medium tar yield Higher particle loading
Updraft fixed bed	Mature for small-scale heat applications Can handle high moisture No carbon in ash	Feed size limits High tar yields Scale limitations Low heating value gas Slagging potential
Downdraft fixed bed	Small-scale applications Low particulates Low tar	Feed size limits Scale limitations Low heating value gas Moisture-sensitive

(EPA-CHP, 2007)

3 RESEARCH METHODS

In the research method of any thesis, there can be diverse ways of going round a research to bring out the findings of your results. This is a framework that makes your thesis look much easier to write as it also serves as a guide. There are several methods that one can use to decide to use in a thesis working depending on the form of his/her thesis structure. In this study, the research method used is explained the framework below.

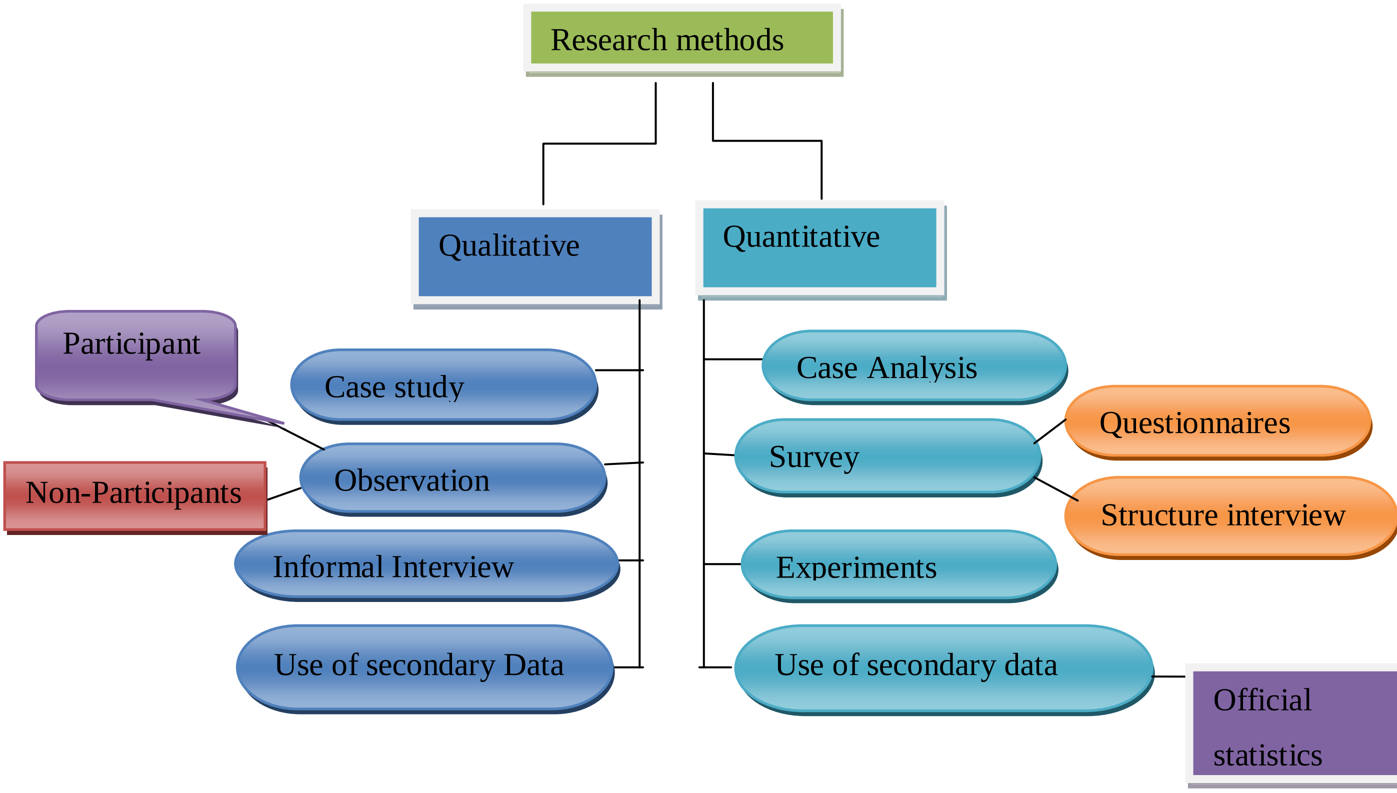


Figure 4. Research method diagram. (http://www.researchconsultation.com)

The diagram above (figure 4) is a basic description of how a research can be done successfully when the steps or blocks are understood well. As can be seen there are two main branches, and these branches have their individual ways or approach of going about them.

The research method employed in this thesis is a desktop research, this was due to lack of finance to go to Ghana for the field study.

Qualitative research

This seeks to bring out an in-depth reasoning to how and why certain things are done the way they are done, not just focusing on the what , where, when since there will also be a need to focus on smaller data samples.

Under this stream you can have the following types or methods of data collection of qualitative research which are:

- Case study
- Use of secondary data
- Informal interviews.
- Observation.

Case study research was made about Gasek taking detailed account and analyzing their operations. Various methods of data collection an analysis were used but this typically includes desk top research, observation and public records

Use of secondary data

This led to the discovery of certain vital information acquired from the net, library and from other sources that were relevant to the information being sort for. This method can also be referred to as the deck top research.

Informal interviews

This is a method of gaining information from others or a particular group without any pre-arranged process or procedure but has a well formed way of coming out with the desired or expected results.

Observation- Monitoring the operational life cycle of a component or systems and gathering data over a period of time revels the evidence of how an input in an earlier stage will result in the outcome of a later stage of a system.

4 BIOENERGY POTENTIAL IN GHANA

Obviously the desire of any nation is to realize the use of environmentally-sound and cost-competitive bio energy on a sustainable basis so that substantial contribution to meeting future energy demand will be provided. The issues are those of providing a clean and reliable source of energy as economically as possible. All sources of energy have both pros and cons.

Biomass is the major source of energy in Ghana. There are various types and forms of bioenergy resources which include wood fuels, sawmill residues, agro-fuels and municipal solid waste and may even be in the form of non-plantation resources, this covers about 20.8million hectares of land in Ghana.

This chapter seeks to address some of the major aspects that obstruct the progress of the development and utilization of bioenergy in Ghana. It also continues to describe some of the economic benefits, social benefits and environmental benefits.

It also seeks to describe where in Ghana we can find various types of biomass feedstock in abundance that will be suitable for the stable production of electricity for that community

Forestry land use or traditional farming, competition with other energy sources, national energy policies, and the local/opinion constitute great problems to increased bioenergy use. Biomass, is a low-risk, clean source of energy, it is only that its production is limited today by economic factors. Social, economic and political situation will also have to change if barriers to its use are to be surpassed.

4.1 An overview of Biomass Feedstock in Ghana

Ghana’s agricultural sector is dominated by a large number of scatted small-scale producers, using manual cultivation techniques and dependent on rain-fed, with little or no purchased inputs but yet providing over 90% of the food needs of the country. Farming systems vary with the six agro-ecological areas.

However, certain general features are discernible throughout the country. According to the World Trade Organization (WTO), low yield of crop production in Ghana is a result of land misuse, improper field development, use of low-yield varieties, lack of organized seed production and distribution systems, and inadequate storage structures. Major crops cultivated include maize, rice, sorghum, cassava, yams, plantain, groundnuts, cowpeas, cocoa, oil palm and coffee as listed in Table 3 below. Aside the commercial plantations such as cocoa, rubber, palm oil, and coconut production, and to a lesser extent, rice, maize and pineapples, about 90% of farms in the country are less than 2 hectares in size.

Table 3. Over-view of major crops grown in Ghana (FAOSTAT. Crop production Ghana, 2008)

Product	Production (1000 tons)	Yield of crop (Hg/ha)	Area harvested (ha)
Oil palm fruits	1,900	6,333	300,000
Coconut	316	5,6936	55,500
Cocoa beans	700	4000	I,750,000
Sugarcane	145	2,544,385	5,700
Maize	1,100	104,615	750,000
Rice	242	20.166	120,000
Sorghum	350	10,294	340,000
Coffee, green	1.5	1650	10,000
Cassava	9650	120,625	800,000
Seed cotton	2	8,000	25,000

Soya beans	n.a	n.a	n.a
Groundnut	4289	9317	460,000

Table 4 below shows the production of industrial crops grown in Ghana

Table 4. Production of industrial crops (Mt) (. COCOBOD, 2. Oil palm Plantation companies)

Year	Cocoa	Coffee	Rubber	Sheanut	Oil Palm
1997	322,490	2,880	n.a	21,504	955,505
1998	409,360	8,370	n.a	34,886	1,022,010
1999	397,675	3,965	n.a	17,465	1,031,919
2000	436,364	1,956	11,080	30,771	1,066,426
2001	389,591	1,379	9,784	19,882	1,586,500
2002	340,562	1,464	10,240	27,160	1,612,700
2003	496,846	338	10,942	n.a	1,640,100
2004	736,975	477	12,347	n.a	1,686,800
2005	599,318	270	13,619	n.a	1,712,600
2006	740,458	164	13,618	n.a	1,737,900
2007	6174,5532	304	15,318	n.a	1,684,500
2008	680,800	2,024	14,132	698	1,896,760
2009	710,638	516	19,132	31,386	2,103,600

2010	903,646	n.a	n.a	n.a	2,004,300
2011	1,024,600	n.a	n.a	n.a	n.a

The estimated energy from agricultural residue in Ghana is also shown in Table 5 below.

Table 5. Estimated energy from agricultural residue

Regions	Maize Cobs & stalks	Rice straw	Rice husks	Millet straw	Sorghum stalks	Cassava stalks	Yam Straw	Cocoyam straw	Gnuts haulms	Gnuts shells	Regional total
western	2053215	465616	76935			5040205	709999	1806443			10152415
Central	5962540	117679	19444			14185774	120328	653409			21059176
Eastern	7434338	433625	71649			20856922	4890550	2910677			36597763
G.Accra	73150,4	65421	10809			457666					607047
Volta	1928915	1073112	177314		49320	9663456	2507592	3695379			15705038
Ashanti	4840900	258583	42726			8581152	2766461	2649700	1263300	189495	21637999
Brong Ahafo	10661165	11760	19408			17725596	13947595				45120926
Northern	3490914	2576236	245680	793296	988090	4309031	7706324		2950780	442617	23682970
U. West	1462293	254847	25585	712380	1020320				3391720	508758	7275904
U. East	1012827	2110327	348696	820344	1251770				1796200	269430	7609595
Total	38920262	7372910	1218251	232602	3309500	8081980	326488	1202093	940200	1410300	189448

				0		3	52	8	0		838

(Energy Commission 2009)

Based on the various feedstocks shown in the tables above the solid biomass feedstock that can be used in the gasification technology in Ghana can be found in the table 6 below.

Table 6. Potential crops for gasification in Ghana

Product	Production (1000 tons)	Yield of crop (Hg/ha)	Area harvested (ha)
Oil palm fruits	1,900	6,333	300,000
Coconut	316	5,6936	55,500
Cocoa beans	700	4000	I,750,000
Sugarcane	145	2,544,385	5,700

Ghana has ten main regions and among these regions, some have various feedstock potentials that can be used to generate energy or electricity for some communities in their individual regions. Nevertheless some regions have predominantly more resources than others. Here the potential feedstock that will be looked at in this section are the type of feed stock with high calorific value of heat stored in it to produce much of the energy. Nonetheless almost all the biomass resources in Ghana can also be used in bioenergy generation but not for this specific technology in question.

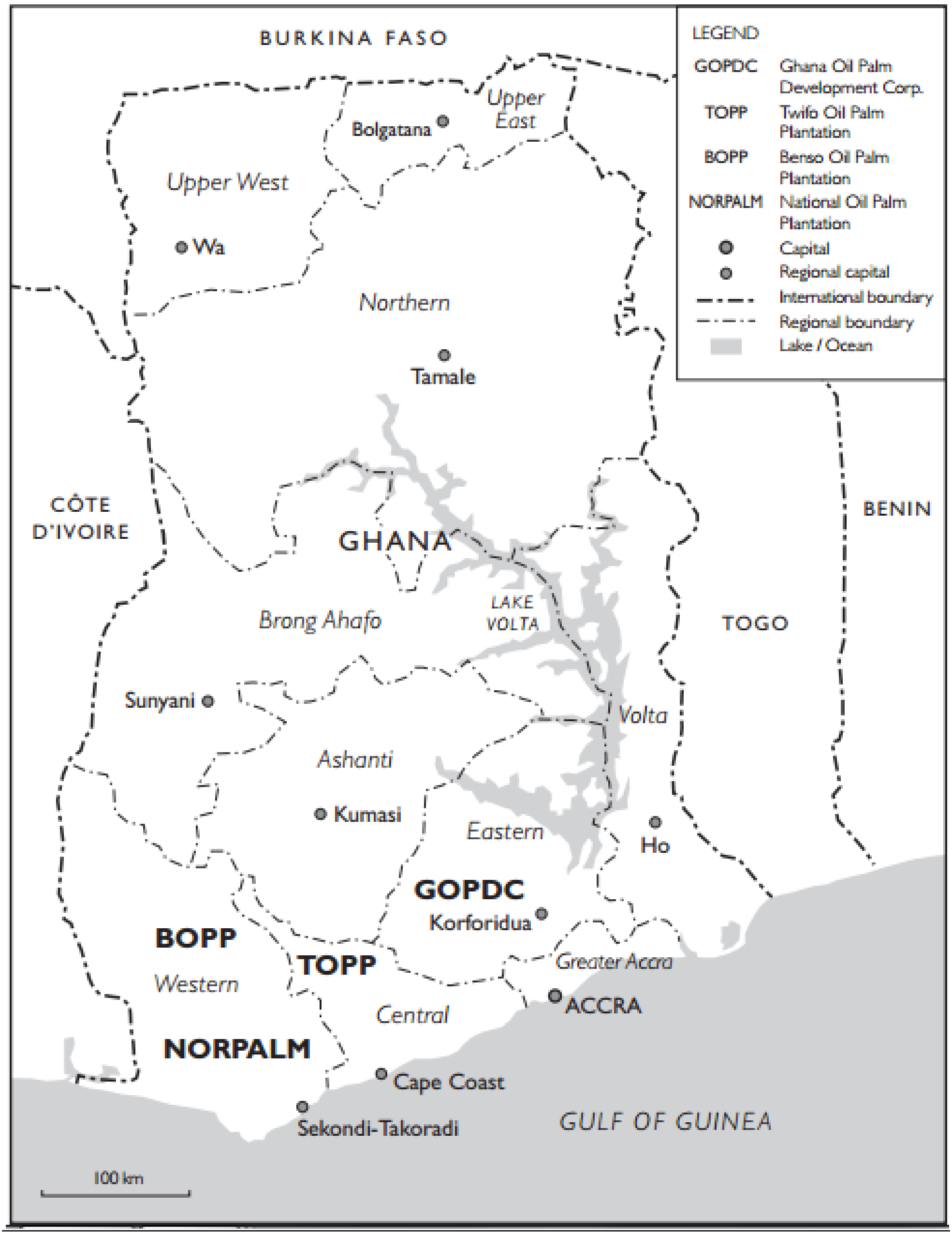


Figure 5. Regional map of Ghana showing the four large oil palm estates.

(Huddleston and Tonts 2007)

The ten regions which have their regional capital listed as seen in the figure 5 above. Among these ten regions, three of these regions have in enormous quantities of some major crop produce that can be used as feedstock for bioenergy generation. Tables 7 below depict the total land areas of the regions and potential feedstock for biomass gasification in Ghana.

Table 7. Land area by region

Region	Area (000 sq. km.)	% of Total	Feedstock type
Northern	70.38	29.5	-
Brong-Ahafo	39.56	16.6	Cocoa
Ashanti	24.39	10.2	Cocoa, wood residue, coconut
Western	23.92	10.0	Palm kernel, coconut
Volta	20.57	8.6	Palm kernel, coconut
Eastern	19.32	8.1	Palm kernel, cocoa, coconut
Upper West	18.48	7.7	-
Central	9.83	4.1	Coconut, sugar cane
Upper East	8.84	3.7	-
Greater Accra	3.24	1.5	-
Total	238.53	100.0	

Own elaboration.

As it can be seen in table 7 above, coconut, palm kernel, cocoa and sugar cane are common sources biomass found in most of the regions. Tables below 8 and 9 show some of the potential gasification feedstock in Ghana and where they can be located in Ghana.

Table 8. Coconut plantation in Ghana

Regions	Area in ha	Production in ton/year
Eastern	1000	6000
Western	24000	90000
Volta	1000	6000
Central	3000	12000
Ashanti	1500	6000

(Ministry of food and Agriculture 2010)

Table 9. Sugar cane plantations in Ghana

Location	Area (ha)	Production (tons)
Mfantsiman Municipal	30.5	1525
Cape Coast	35.2	1760
Abura asebu Kwamankese	56.3	2815
Gomoa East	140.4	7020
Agona West	24.4	1220
Assin South	124.4	6220
Agona East	35.2	1650
Komenda Edina Eguafo Abrem (KEEA) Municipal	24	1200
Total	470.4	23410

(Ministry of food and Agriculture 2010)

Table 10 below describes a selection of the tree crops in Ghana. As seen in this table the potential feedstock is the oil palm tree followed by cocoa which has a high production capacity in Ghana.

Table 10. Selected tree crops grown in Ghana.

CROP	AREA CROPPED(HA)	YIELD RATE.MT/HA	PRODUCTION (MT)
Cocoa	2,000	1.0	2,000
Citrus	168	10	1680
Oil palm	876.5	4.8/yr	4,207.5
Cashew	550	1.0	550

(Ministry of food and Agriculture 2010)

The table 11 below shows the type of practice the proposed feedstock cultivated and how much can be harvested in a year.

Table 11. Farming methods and average output / hectare

Crop	Current practice	Current output (ton/ha)	Recommended practice	Recommended output (ton/ha)
Cocoa	Mono	0.48 tonne	Mono	1.562 tonnes
Oil palm	Mono	4-8 tons/ha/yr	Mono	12-15 tons/ha/yr

(Ministry of food and Agriculture 2010)

The table 12 below gives a summary of the harvest of oil palm production in the eastern region, this shows that eastern region might be a good area that might benefit from biomass gasification.

Table 12. Oil Palm productions in the eastern region for the year 2000-2009

	NUMBER OF FARMERS/FARMS	AREA CROPPED (HA)	HARVESTABLE AREA (HA)	YIELD (MT/HA)	OUTPUT (MT)
West Akim	1,182	1,976.6	1,218.0	11.8	-
East Akim	403	643.0	383.2	19.7	-
Suhum-Kraboa-Coaltar	827	1,098.3	561.5	9.3	18.5
Kwahu South & East	410	541.5	162.0	8.8	-
Kwahu West	462	629.2	271.3	9.2	-
Afram Plains	68	98.8	50.9	7.9	1.5
Fanteakwa	423	755.4	373.9	7.3	-
Kilo Krobo	-	-	-	-	2,500.0
Upper& Lower Manya Krobo	-	-	-	-	800.0
Atiwa	295	361.0	205.7	9.2	-
New Juabeng	124	173.2	101.3	6.5	-
Akwapim South	475	966.0	744.7	10.2	-
Akwapim North	111	285.0	125.0	22.1	7,901.0
Birim South & Central	1,101	1,451.0	1,001.7	8.5	-
Birim North	394	766.4	592.3	11.0	-
Kwaebibirem	1,173	3,682.0	2,018.0	8.7	-
Asougyaman	91	125.9	66.4	8.3	152.8

TOTAL/ AVERAGE	**7,539**	**13,553**	**7,876.0**	**10.2**	**11,373.8**

(SRID and MOFA**)**

A survey conducted on the Average Crop production & yield from 2000-2009 (metric tons/ha) shows that in 2006 and 2007 the production capacity of oil palm was bountiful with figures from 11169mt and 18377mt respectively. **(**Dadu Agona Ahanta-MOFA**)**

4.2 Potential feedstock for Biomass Gasification in Ghana

The most important criteria for choosing a specific feedstock depends on the properties which it possess and how much energy content it has. The under listed properties listed below are what should be considered when selecting a gasification feedstock Table 9 below shows that palm kernel shells, coconut shells, and cocoa pods have quiet good properties.

- Moisture content
- Calorific value
- Proportion of fixed carbon and volatility
- Ash/residue content
- Alkali metal content
- Cellulose/lignin ratio

The two main forms of moisture content that play a major role in biomass gasification are

1. **Intrinsic Moisture**: The moisture content of the material without the weather influence on it and
2. **Extrinsic Moisture:** the influence of the weather on the biomass feedstock during harvesting.

In reality, extrinsic moisture content is the main issue that needs to be dealt with well in this area whiles intrinsic moisture is only detected when the material is sent to the lab for testing.

Table 13 below shows the various properties that led to the selection of a particular type of feedstock for biomass gasification.

Table 13. Properties of proposed feedstock

Raw material	FC %	VM %	ASH %	C	H	O	N	S
Coconut shell	20.58	79.07	0.35	-	-	-	-	-
Palm Kernel	10.66	83.38	4.22	46.53	5.85	42.32	0.89	0.12
Cocoa shells	23.80		8.25	48.23	5.23	33.19	2.98	-

(2009 International Conference on Energy and Environment Technology, Energy Conservation & Management. Vol. 42, issue 18, Dec, 2001

Another property that is considered in the choice of feedstock is the crop to residue ratio and energy which is shown in the Table 14 below.

Table 14. Residues produced during agricultural processing.

Types of Residue	Ratio of residue to crop volume(t/t)	Energy from residue(Mj/kg)
Maize (cobs & Stalks)	1.5	17.65 – 18.77
Cassava	0.5	14.24
Yam straw	0.5	14.24
Cocoyam straw	0.5	14.24
Rice straw	1.5	.16.28
rice husk	0.25	16.14
Groundnut shells	0.3	10.00 – 17.00
Groundnut haulms	2	10.00 – 17.00
Oil palm shells	0.45	10.00 – 17.00
Sorghum stalks	1	10.00 – 17.00
Millet straw	1.2	10.00 – 17.00
Sugar cane	1.2	9.6

Coconut	1	9

(Karath and Larson. 2000)

Some exhibits of potential agricultural residue in Ghana for biomass gasification are shown in Figure 6 below. These types of feedstock, as can be seen in Table 9 above, have got good calorific value of heat that can give out quiet a good amount of energy when gasified. Though they may have different ash content levels which in this case is the most pressing issue in gasification, the technology has the means of handling it. Figure 6 shows the different types of feedstock's that can be recommended for biomass gasification in Ghana. These types of feedstock are much preferred due to their cultivation level as they can be harvested three to four times in a year as most of these tree crops are located around the rain belt of Ghana and do not require so much irrigation to be done by the farm owners.

Figure 6 Proposed feedstock

According to the FAO statistics, Ghana is among the top 20 countries in palm kernel production in the world and is in the 19 position with an annual production of 36000metric tons. This statistics can be seen in Table 15 below.

Table 15. Palm Kernel productions from 2009- 2011

Rank	Area	Production (Int $1000)	Flag	Production (MT)	Flag
1	Indonesia	1507414	*	5840000	*
2	Malaysia	1107846	*	4292000	F
3	Nigeria	250587	*	970820	F

4	Thailand	73796	*	285900	F
5	Colombia	54721	*	212000	*
6	Brazil	53921	*	208900	F
7	Guatemala	42667	*	165300	Fc
8	Papua New Guinea	31490	*	122000	F
9	Ecuador	25811	*	100000	*
10	Côte d'Ivoire	24263	*	94000	*
11	Honduras	20907	*	81000	*
12	Cameroon	17552	*	68000	*
13	China	13938	*	54000	F
14	Guinea	13680	*	53000	*
15	Democratic Republic of the Congo	12776	*	49500	F
16	Costa Rica	10841	*	42000	
17	Togo	10582	*	41000	
18	Benin	10066	*	39000	*
19	Ghana	9292	*	36000	F
20	Philippines	6711	*	26000	*

(*: Unconfirmed, F: FAO Estimate, Fc: Calculated data)

(FAO 2011)

When it comes to coconut production this is also well placed so coconut production also cannot be left out either since its production is also enormous in the country and is a great potential feedstock to be considered for gasification in Ghana (seen in table 16 below).

Table 16. Coconut productions for the year 2011

Rank	Area	Production (Int $1000)	Flag	Production (MT)	Flag
1	Indonesia	1935027	*	17500000	*
2	Philippines	1663727	*	15244600	
3	India	1238417	*	11200000	F
4	Brazil	325488	*	2943650	
5	Sri Lanka	168354	*	1522560	*
6	Papua New Guinea	136918	*	1238260	Im
7	Viet Nam	131449	*	1188800	
8	Thailand	116689	*	1055320	
9	Mexico	112453	*	1017010	Im
10	Malaysia	63872	*	577647	

11	United Republic of Tanzania	60815	*	550000	F
12	Myanmar	46440	*	420000	F
13	Solomon Islands	45113	*	408000	*
14	Vanuatu	44074	*	398604	Im
15	China	35875	*	324452	F
16	Ghana	33171	*	300000	F
16	Jamaica	33171	*	300000	F
18	Mozambique	29415	*	266029	Im
19	Nigeria	23773	*	215000	F
20	Fiji	23611	*	213538	Im

(*: Unconfirmed, F: FAO Estimate, Fc: Calculated data)

(FAO 2011)

According to the FAO statistics and the Ministry of Food and Agriculture as seen in the Tables 11 above, Ghana produces quite an extensive amount of the required feedstock in the designated regions and their location as shown on the map of Ghana. This could easily meet the demand of any gasification plant situated around these area. The four major production companies of palm oil are located around these areas, which are the Eastern region, the Central region and the Western region. Among these regions there are some communities with higher yields of the required feedstock for example, Wassa Amenfi district in the western region that has a lot of the cocoa pods and palm kernel shells. The Twifo district in the central region also has a good production capacity of palm kernel that can support the activities of the gasification plant when sited in any of the towns from these districts in their respective regions.

4.3 Gasification Technologies in Ghana.

There are quite a number of gasification technologies being tried out in Ghana on pilot bases to find out how some of these technologies can be well adopted to the Ghanaian system. Among these technologies there are three main types mainly adopted by most companies who are into biomass conversion or using biomass to generate energy. These technologies are: boiler, pyrolysis and gasification. The biomass boiler is a device in which the feedstock is put in to be combusted to generate heat to serve the purpose of direct heating on homes or indirect heating which might be for the use of heating water. There are three main types of boiler:

•***Log boilers*** - Some log-fired boilers are fairly basic, simple, cheap, and sometimes least efficient form of biomass boiler but others are highly efficient and sophisticated systems. A log burning boiler will need to be manually filled and lit, and the heat from the combustion process is generally stored in large, well-insulated hot water tanks – so that you can then draw it off over a period of time.

•**Pellet boilers** - Wood pellets burn evenly as they do not contain much moisture.

•**Wood chip boilers** - These are most suitable for medium and large scale installations. A combustion device is like a stove which burns the feedstock fed to it, producing heat to meet its demands. This could be fully automated or manually operated. It could have an inbuilt storage capacity that can store its fuel (feedstock) for days

Pyrolysis is a chemical conversion process of organic materials which is transformed into gas by heat in the absence of oxygen. This process typically occurs under pressure and at operation temperature above 430°C .During this process a small amount of liquid and solid residue containing carbon and ash are formed. Particular removal equipment is also required. Pyrolysis is also the first step that occurs in both gasification and combustion processes. There are essentially two different pyrolysis modes: slow pyrolysis (also called carbonization) and fast pyrolysis or flash pyrolysis, with significantly different process conditions and outputs. The product distribution obtained from different modes of pyrolysis and gasification is summarized in Table 17 below. Several types of pyrolysis units are available, including the rotary kiln, rotary hearth furnace, and fluidized bed furnace. These units are similar to incinerators except that they operate at lower temperatures and with less air supply. In Ghana, only a single pyrolysis project has been reported. This project was implemented jointly by the Building and Road Research Institute, the Technology Consultancy Centre of the Kwame Nkrumah University of Science and Technology (KNUST) Kumasi and Georgia University of Technology, USA. It aimed to determine the feasibility of using pyrolysis as an alternative process for power generation. The pyrolysis plant, which had a capacity of 6 tones, utilized sawdust as feedstock to provide an alternative fuel for a brick kiln. Char and oil yields were projected at 25% and 18%, respectively. Unfortunately, the plant had to be shut down following low yields which ranged between 6% and 13% that were obtained, in addition to poor supply and drying of feedstock and utilization of manual process controls. A few feasibility studies have also been conducted on the potential for co-generation from wood residues. These include feasibility study on Letus Power Plant, and case study on the potential for co-generation from wood residues in three cities in Ghana. A co-generation plant with approximately 6 MW capacity has been installed using sawmill and oil palm wastes as feedstock. This plant serves as a source of electric power for some industries and surrounding communities without grid electricity. There is high potential for co-generation in Ghana, but this potential is hindered by factors including the availability of cheaper power supply from grid electricity, lack of financial or fiscal incentives, and lack of regulatory requirements that would encourage investors to generate and sell electricity to the grid .Currently, a few industries use co-generation, including the SAMATEX Ltd. located at Samreboi in the Western region, and STP in Kumasi. The Table 17 below shows some companies in Ghana using the gasification technology to power up their equipment's and derive heat at the same time. (Wilmar - 2012).

Table 17. Biomass-fired co-generation plants in Ghana

Name	TYPE	INPUT	TECHNOLOGY	OUTPUT
SAMARTEX LTD	Operational	Forest residue	CHP plant, Biomass boiler	Heat and electricity
Benso oil palm	Operational	Agricultural Resources	CHP Plant, Biogas	Heat and Electricity

Twifo Oil Palm	Operational	Agricultural resources	CHP plant, Biogas	Heat and electricity

(Ghana Energy Commission, 2010)

This shows that there is a potential for the biomass gasification in Ghana since there are enough feedstock for gasification, and that there is a need for distribution network and policies that might improve this technology in Ghana.

4.4 Potential Distribution Network

The distribution network a vital role in the energy generation from biomass as the network should be well linked to ensure a constant supply of the energy being demanded.

Five (5) main steps are discussed here to come out with a suitable distribution network to satisfy all partners involved in making this development successful (see Fiure7 below)

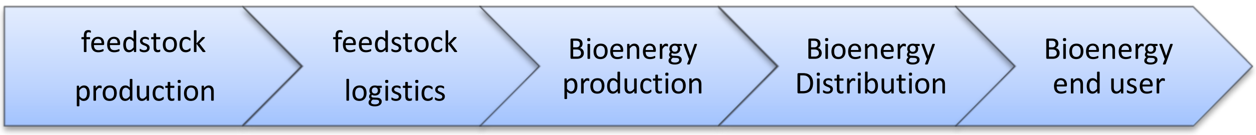


Figure 7. Supply Chain of distribution network.

4.4.1 Feedstock Production.

This chapter tells how the feed stock is received in the first place, the most available and appropriate feedstock whether it's going to be derived from the farms of the local farmers or it is going to be cultivated by some contracted group of people, who in this case are the target group to gather the feedstock at designated locations on the site for easy collection. The choice of feedstock is decided by the availability of feedstock around and its quantity not forgetting the sustainability aspect as well since a regular supply of feedstock will be required for continuous power generation. For example taking into consideration a town like Ylio Krobo in the eastern region where palm kernel shell can be found in available quantities. It would be appropriate to have the gasification plant sited there. A piece of land could be acquired to cultivate the desired feedstock for a medium or long term plan as the short term plan could be the negotiationswith the land owners or farmers to supply with their feedstock in exchange for electricity.

4.4.2 Feedstock logistics

Transportation in bioenergy production is the key to the productivity of the day to day running of the bioenergy power plant as the collection of the feedstock might be scatted and might need to be brought to a central point where it will be finally sent to the treatment site for storage. Companies can use their own medium of transport to convey the feedstock to a designated site or contract the services of a logistics company to gather the required feedstock. In Ghana, the road network to the site might have to be considered and feedstock location as well, as this could be a major hurdle when not addressed well. Most of the road network in these areas may not be well developed and especially in the raining season when some of these roads are almost inaccessible.

The storage of the feedstock is also a very important matter in the production process. Feedstock must be stored in a well-ventilated place but enclosed, to allow the moisture to be taken out by circulating air and also to be protected from the harsh conditions of the weather. It should not be stored in excess or under demand though it may be better to have them in excess but that might increase the inventory cost. This problem could be solved by having vantage collection where the feedstock might be gathered and later brought to the central storage close to the where a required amount can be kept for regular feeding into the gasification plant.

4.4.3 Bioenergy production

Once the feedstock has been brought to the storage site, it further undergoes a certain process to make it suitable for the efficient use of the feedstock. The feedstock has to be purified or cleaned which is by means of separating the unwanted materials that might have found its way into the feedstock should be taken out. Depending on the desired feedstock, drying may be necessary to reduce the moisture content from it as moisture tends to reduce the amount of heat or power required to be derived from the feedstock, for example coconut shells, cocoa pods and palm kernel shells. After these processes have been done and the feedstock stored in its rightful storage place, can it then be fed into the gasifier to produce the syngas needed to produce the required energy.

The generation of the electricity cannot be done without the supply of efficient equipment and technology. The core of the technology is Gasek's patented gasification reactor, which ensures emission free combustion and an exceptional reliability of the process. The technology is based on 30 years of development, which has resulted in transforming problems, traditionally associated with wood gasification, into emissions-free and environment friendly energy generating power plant solutions.

There is high potential for co-generation in Ghana, but this potential is hindered by factors including the availability of cheaper power supply from grid electricity, lack of financial or fiscal incentives, and lack of regulatory requirements that would encourage investors to generate and sell electricity to the grid .Currently, a few industries use co-generation, including the SAMATEX Ltd. located at Samreboi in the Western region, and STP in Kumasi.

4.4.4 Bioenergy Distribution

Once the desired energy is generated or produced which in this case is electricity, it can be put onto the main grid to be distributed or a small mini grid can be built to supply electricity to the households around the generation site. In 2012 the grid coverage over the nation was 74% and the installed capacity is to produce electricity is about 2,170MW which is to be distributed throughout the whole nation and even to supply some of our neighboring countries. This is clearly insufficient for the nation as a whole. A decentralized system in this case would be very much appropriate as the government have put in measures to promote this sector. This system of having a mini grid to supply electricity without connecting to the national grid or main grid is called Off-Grid Electrification. Ghana has got quite a good grid network which is still being improved but even with its good grid network, some portions of Ghana are not linked or not covered by the grid and these areas are those with good resources for bioenergy generation.

Looking at the grid connection of Ghana (as seen in figure 8 above) and how the intended technology will play a major role in the expansion of the electrification project of Ghana, it would be much appropriate to consider an off-grid electrification system which will be much beneficial to the rural communities in the western, Eastern and Central regions.

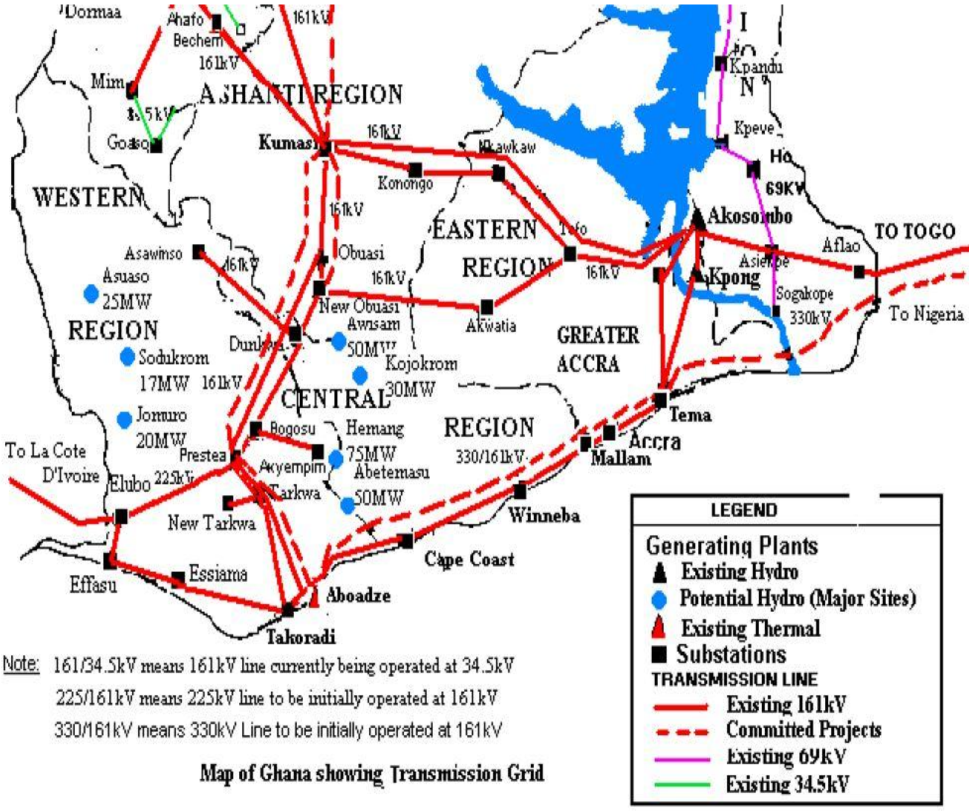


Figure 8. Transmission grid of the targeted Area

4.4.5 Bioenergy End User

The target group for the energy produced here would be the rural communities who have much of these resources that can be used to produce electricity for them. The end users are the health post or clinic, school and inhabitants in the rural communities who might not be on the national grid but are located near the plant. The energy supplied to the health post in the rural community would enable them to powered equipment’s to patients and preserve some inventory that needs to be kept in the refrigerator. The schools can have lights electricity to power their computers to teach IT to the school children. A typical house hold set up in the village might have a radio, fan, lightening system for the bed room, toilet/bath room and living room, and probably a television and a small refrigerator in some cases. This energy provided to the targeted rural community can help improve the living standards of the community by creating jobs or the locals in some skilled professions like a barbering salon, dress making shop and even motivating people to go into the production of the desired feedstock thereby boosting the Agro industry as well.

5 BARRIERS TO GASIFICATION TECHNOLOGY IN GHANA

Gasification as a technology has got certain down sides that need to be well taken care of to make it more efficient and attractive to the market since the reduction of greenhouse gases has to be met by all energy producing companies in accordance with the establishment of Kyoto agreement.

The barriers of biomass gasification technology can be divided into three main categories:

- Socio-technical Barriers
- Economic barriers
- Crosscutting barriers

Socio-technical barriers refers to the resource base, what, where and how the resources for this technology are going to be achieved and the technicalities of the technology being provided such as-like ash handling, gas cleaning, tar minimization and cleaning, Moisture content and Limited technical expertise. Its environmental friendliness also has to be taken into consideration, especially with the feedstock production, whether it is going to be competing with food production or if the process involved in producing the feedstock might destroy land fertility. The emissions the system is going to emits and the social benefits the community is going to gain from this development has to be considered as well e.g. benefits gained by the target group (productive use of electricity). In Ghana we lark some of these technicalities in the area of handling which will really need some attention.

Economic barriers deal with the marketing of the product incentives to encourage commercial development, the cost and benefit of the technology to both manufactures and end users not forgetting the financing part of the project which is support from the government, private sectors and donor agencies and the creation of financial schemes. Ghana has got the ability to really excel in this area since we have financial institutions that have been set-up to promote and support such developments, e.g. Apex bank, Agric Development Bank (ADB), etc.

Crosscutting deals with the flow of information from all areas needed and institutions that will support the project in terms of training, financing, technical knowhow and the like and policies that will enhance the involvement of investors to have stakes in this section of energy production. As stated earlier in the study a collaborative effort will be needed from both public and private sectors and the various stakes involved. This means that effective communication should be employed.

5.1 Bioenergy Policies

Policy implementation plays a vital role in the establishment of any firm or in this case the commercialization of the technology. Some of the bioenergy policies are listed below in the bioenergy draft of Ghana that can promote this technology when properly implemented and also attract investors into this sector.

- Sustainability and regulatory framework

This particular policy when implemented will go a long way to protect investors and entrepreneurs with some kind of security for their investment in this technology. This policy should also noticeably define issues related to distribution, power generation, sustainability criteria pricing (including feedstock pricing) etc. In addition, there should also be regulatory frameworks to critically ensure that the energy production from biomass gasification meets social and environmental standards (UN-Energy, 2011).

- Intensify national support for Research and Development

Governments, on the other hand, should provide essentially any infrastructure and spearheading the institutions for research and development. Seemingly, R&D is an expensive exercise but, notwithstanding provides the platform for commercialization of any technology on a large scale. This with time helped some earlier bio-energy technologies to be acceptable globally although, not a panacea for biomass gasification. It will in a sense bring all stake holders together, including manufactures with the necessary information for a large scale commercialization.

- Education and Information

As mentioned earlier, biomass gasification is an old technology but still lack the skills and adequate engineering and technical expertise it required for both maintenance and servicing. However, this technology would be successful in Ghana if the government particularly provides and spells out policies with respect to education and information about the technology. The public and the rural communities should also be integrated in this policy to speed the acceptance of such an important technology for rural electrification.

- Integration

Biomass gasification more or less competes with other technologies, if not for the same resources and financial subsidy. And in this light, the government together with all stake holders should provide a policy that will easily influence the integration of this technology with any other existing ones, e.g. hydro power. This would gradually guarantee its acceptance and soon to a large scale commercialization. The policy will also ensure energy security, reduction in over dependence on imported oil and decreasing the oil import bill. Biofuels development also provide for wealth creation through employment and revenue generation, increase in export earnings and climate change mitigation.This policy is critical, owing to the fact that it would similarly ensure that both infrastructural and opportunity present for energy production are equally employed for greater energy efficiency.

- Financial incentives

This policy will certainly help the promotion of biomass gasification for rural electrification in Ghana. However, financial aid in any form would not directly address and warrant the sustainability of this technology. This is only seen very effective in a short term, to improve its delivery mechanisms and acceptance. Furthermore, reducing initially to a minimum some kind of risks (Sarkar and Singh, 2010)

This policy should specifically extrapolate clearly the required and available incentive scheme that would be appropriate financially, for the success of biomass gasification technology, for example increasing the prices of competing energy sources and reducing the cost of bio-energy. Presently, bio-energy has a minimum profit and actually not competitive with fossil. In spite the enormous potentials of biomass in SSA, and in Ghana particularly, the problems are still recurring. (Dalili, 2009)

On the other hand the existing schemes available in Ghana and commercially operated are in the urban communities and not in the rural areas. And they are actually characterized by unsuitable lending conditions. This is the most importantt reason why the government has issued such policies, to attract investors to help promote biomass gasification for rural electrification. (Derrick, 1998)

5.2 Stakeholders of Bioenergy in Ghana

Bio energy as one of the renewable energy sources which is gaining great publicity in the world is not that well utilized in Ghana to generate the required output in the country. A few companies in Ghana have been making use of some of the biomass resources to generate power to feed their own industries. The general use of the biomass resources in Ghana has been the conventional way of using it to cook e.g. Wood fuel which is most common in the rural areas and is sometimes converted to charcoal which is transported to some urban areas to be used domestically. There are but a few companies who are known in this area. Various R&D activities on biomass resource and biofuels development in Ghana have over the past years been focused primarily on the development of first-generation biofuels, particularly biodiesel and bioethanol, together with analyses of various biofuel feedstocks. Among the major institutions that have been engaged in these R&D activities are the Institute of Industrial listed in Table 18 below.

The prospects of gasification are very high and therefore its challenges in the commercialization and implementation are also high. The production of the desired feedstock in large quantities should be well developed for sustainability of the bioenergy generation process in Ghana. This can be achieved when all stakeholders of the bioenergy industries and the energy sector in Ghana work hand -in- hand to help to boost this technology in the country by implementing the right policy to make this industry attractive.

Table 18. Palm Oil estates in Ghana.

Research insttitution/Universities	Research and Development topics
CSIR-Institute Of Research(CSIR-IIR), Accra	Second generation technology development, biogas technology, laboratory studies on biofuels.
CSIR-Forest Research Institute In Ghana(CSIR-FORIG)	Development of improved Jatropha Curcas plant and seed production: collection and handling viability testing
CSIR-Savannah Agricultural Research Institute(CSIR-SARI)	Development and control of improved sweet sorghum
CSIR-Crop Research institute(CSIR-CRI)	Improved maize species development.
Faculty of renewable natural resources, CARN, KNUST, Kumasi	Development of second generation technologies
Dept. Of Mechanical, chemical Agricultural Engineering,KNUST,Kumasi	
University of Ghana. Legon	Plant design and Fabrication: Laboratory testing and trans-esterification of local feedstock.
University of Development studies, Tamale	Behavior of Jatropha curcas plant under different agro-ecological zones
University of cape coast	Jatropha plant improvement
Biotechnology and Nuclear Agricultural Research institute	Screening of plant species for production of Biodiesel
	Plant tissue culture, sugar cane research

(M.H. Duku 2011)

5.3 The Potential of GASEK in Ghana

Gasek is a young Finnish energy technology company established in 2008 whose objective is to provide energy solutions for its end user-customers. This company's technology is based on 30 years of development of some issues associated with the gasification technology which has yielded positively in transforming traditional problems, associated with wood gasification, into emissions-free and environment friendly energy generating power plant solutions. The core of our technology is the patented gasifier, which produces pure gas from mixed wood chips.

Gaseks provides a possibility for independent power and heat generation, and their power plants can be linked to national grids. Within these years of establishment, Gasek has risen through the ranks to become one of the best gasification technology providers here in Finland and making the waves on the international market. This is due to how efficient and well-designed products they have on the market and based on a customer's specification a design can be modelled for a function or specific purpose. The core of the technology is the company's patented gasification reactor, which ensures emission free combustion and an exceptional reliability of the process. Aside wood gasification, Gasek is still exploring other types of solid biomass feedstock's that can be gasified and solving problems associated with these feedstocks. Their products come in different ranges and sizes and one unique thing about their products is the possibility to have all in one compact package and can be mobile as well based on the specification of the customer. The mobile plant allows one to move the power production plant to any preferred location where the desired feedstock is available and the need for energy to meet the customer demand. GASEK's CHP (Combined Heat and Power) plant is a combined unit for generating electricity and heat, which is well suited, for instance, for small and medium sized businesses as well as for energy generation in remote communities.

The GASEK wood gas, generated as the end-result of the gasification process, contains very low quantities of emissions and microparticles, which are hazardous for the environment. After the cleaning process the particle concentration of the product gas is virtually non-existent. The remaining micro particles burn in the motor or in the burner in heat generation. Exhaust gas primarily consists of carbon dioxide and water vapour. The Gasek technology can be utilised at any locations where gaseous fuel and clean-burning gas are needed. GASEK manufactures Gas Production Units (GPU) used for generating wood gas adjusted to the customer's needs out of wood chips. The GASEK GPU (as shown in Figure 9 and 10 below) is a key component of many CHP plants, where it produces clean wood gas for heat and power production units by different manufacturers.

A future study of the market analysis of the Gasek technology would be required to determine its potential and role in biomass gasification in Ghana.

Figure 9. CHP 150 gasifier encapsulated (Gasek)

Source: (http://www.gasek.fi)

Figure 10. CHP power plants (based on GASEK technology are available also in GASEK's partners' brand name.) (Gasek)

The motive behind purchasing any product will depend on the benefits' derived from it. Gasek's gasification technology has very good benefits which motivated to study about their technology and recommend it for Ghana. Some of the benefits are mentioned below:

Compact: The engineers of this technology have designed it in such a way that the complete gasification and power generation unit can fit into a 40 feet container.

Mobile: It can be moved from one place to the other depending on the availability of feedstock.

Extremely short burner reaction time: It can be run almost like an oil burner.

Extremely quick gas production start-up and shutdown: The equipment starts and stops within a few dozen seconds.

The favorable fuel can be utilized to the fullest extent: Wood chips are gasified and completely incinerated in the gasifier. The gas is transferred and combusted while hot, thereby fully utilizing the energy contained in wood.

6 CONCLUSION

The success of any gasification plant will depend on the type of feedstock and availability of the feedstock. This plays a major role in the gasification technology as it is the key to bioenergy production. In this research, it has been established that Ghana has enormous available feedstock that can be utilized in the gasification technology and these feedstock can be found in almost all parts of the country but most specifically in the eastern, central, western and Ashanti regions.

The appropriate distribution network will have to involve all the stakes involved in the bioenergy generation process, right from the feedstock production to the end user. This will call for the involvement of both public and private sector to collaborate in making the supply chain an effective one.

The use of biomass as a source of energy generation in Ghana will play a major role in the combat against global warming and its effect on the environment. This can also have a drastic impact in the rural areas where the grid coverage is not available where it can also improve the living standards of the people living in the rural communities as they gain access to an improved form of energy that can be utilized in many ways. All these and more can be attained when the technology is well explained to the target group who in this case are the feedstock providers and end uses of the energy generated.

As an accepted form of renewable energy, biomass can help to reduce the amount of carbon dioxide in the atmosphere as it is used up by plants .This can also have a drastic impact in Ghana since we will also be contributing to the generation of green energy . When the needed policies are put in place, biomass gasification will be one of the most attractive forms of energy generation in Ghana.

6.1 Recommendation

Further research has to be done in all aspects of bioenergy production or energy from biomass to minimize the barriers on this type of energy production. This field of bioenergy which has got a great potential to meeting the demand of energy in Ghana since there is enough feedstock to support the biomass gasification technology. What is needed is investors.

Policies that need to be enacted to enhance the development of green energy in this way should be enforced to make the production of these feedstock more accessible and readily available for the market. These policies should not only target the international market but also the local market and be flexible for local investors to be able to have an opportunity to be part of this green energy production not only in the area of feedstock production but in the energy generation as well in Ghana.

Development of viable domestic biomass feedstock production systems will require combined public and private efforts. The government's role includes helping to define national energy goals and to provide appropriate policies and support where needed. The actions recommended in this report should be integrated with the work of the Production, Conversion, Distribution Infrastructure, and Sustainability Interagency Working Groups to help ensure sustainable production and management systems for delivering biofuel feedstocks to bio refineries. Further research will depend on the feedstock type; regional and site characteristics; and the goods, services, and values required to develop and maintain reliable biomass logistics supply systems.

Financial institutions setup to promote green energy should provide the necessary assistance and incentives to the parties involved. Whether they are financial assistance, investment plans, sensitization of potential benefits in this area for both investors and financial institution, they should be well clarified and amplified to all stakes involved to know where to get assistance when needed. In Ghana there are quite a number of financial institutions that are responsible for these activities and services.

Logistics that will be needed to make the supply chain effective should be well developed to make this cycle of energy production continuous. In Ghana one of the areas that really larks attention is in the logistics section, but with the appropriately structured implementation the flow of the production system will be made efficient.

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APPENDIX

LIST OF FIGURES AND TABLES

TABLES