VAASAN AMMATTIKORKEAKOULU
VASA YRKESHÖGSKOLA
UNIVERSITY OF APPLIED SCIENCES

Gideon Ocquaye

THE ROLE OF BIOMASS GASIFICATION IN RURAL ELECTRIFICATION IN GHANA

Technology and Communication

2012

VAASAN AMMATTIKORKEAKOULU
UNIVERSITY OF APPLIED SCIENCES
International Energy Technology and Management Program

ABSTRACT

Author	Ocquaye Gideon Nii Nortei
Title	The Role of Biomass Gasification in Rural Electrification in Ghana
Year	2012
Language	English
Pages	61
Name of Supervisor	Adebayo Agbejule

Through the years biomass gasification has indeed emerged potentially as a technology choice for rural electrification for Sub-Saharan Africa (SSA) due to the potential of biomass resources in the sub region. Ghana in particular generates and produces in excess biomass materials, such as cocoa, palm kernel, and sugar, which could be sufficiently harnessed into electricity to improve productivity level in the rural areas.

The purpose of the thesis was to analyze biomass gasification technology and its potential, specific barriers, and appropriate policies to promote such technology and finally how it can improve rural electrification in Ghana.

The study employs literature review, and shows that regulatory framework, national support for R&D, education and information, community participation and financial incentives are factors that can promote biomass gasification for rural electrification in Ghana.

Key words: Biomass gasification, Rural electrification, Biomass resources

CONTENTS

LIST OF FIGURES AND TABLES

1 INTRODUCTION

1.1 Background

The demand for electricity for development is still on the ascendency. This request poses a challenge for many African leaders even until now, In spite of the abundance of deposits of fossil fuels and potentials in natural renewable resources. In this connection the title of this paper;: The Role of Biomass Gasification in Rural Electrification, is so crucial to provide some information and technological capabilities to meet most of the demand for energy in rural communities.

There are new enormous technologies for energy production in the market today. But one has to consider actually the economic activity, technical and engineering skills, sociocultural behavior and also the sustainability of the fuel supply etc. before settling on one. It is apparent that Africa has not fully harnessed the available biomass potentials. The role of biomass gasification in rural electrification will go a long way of giving a boost in the social activities in the rural communities to curb the rampant urban migration, since it can be considered as a food basket most of the African countries. On the other hand, having the potentials alone without the specific technology for energy production will not solve the electricity problems in the rural community.

The aim of this research is to provide some solutions to the challenges associated with the present traditional uses of the biomass feed stock in Ghana, and further to provide how gasification for now is the way forward for electricity off the grid in the rural communities. The direct burning for these feed stocks releases more carbon dioxide into the atmosphere. Although, these emissions when compared to what is released by industry are still minimum, but all together contribute to the global warming. Furthermore, the process is also traditional and many times feed stocks are burned directly. The health implications of this practice have to be addressed and subsequent dangers it poses to individuals and occupants. The transfer of this technology into the rural and local communities will not only provide them with the adequate energy they need for their day to day activities, but largely provide them with some employment opportunities either directly or indirectly.

This project will not critically consider the composition of produces gases from Ghana. Because, the chemical composition for various biomass feed stocks might differ from location to location, as well as the moisture content. This actually determines the quality of the fuel and the tar compositions.

With respect to rural electrification it has been estimated that 55% of the population has no electricity connection or supply from the grid. Further proposals have been made for supply to more than 500 communities in the year 2020. This then makes this technology transfer so curtail and significant for electricity in the rural communities. Most of Africa's economy, and Ghana for that matter, can be supported effectively with some adequate power supply when much attention is given to the surplus biomass energy supply. It is still obvious that the supply of fossil fuels has a finite limit. (Panwar, and Athore, 2011)

1.2 Research objectives

The objective of this study was to consider the role of biomass gasification for electricity in rural Ghana. There are plenty of biomass resources available in the rural community, which when harnessed, can solve most of the energy challenges in rural Ghana.

The questions underneath provide the solid foundation, guiding the path of this thesis, it is expected that at the end of thesis all corresponding answers be documented as such for future consumption.

Q.1. What is the potential of biomass gasification in Ghana?

Q.2 What are the barriers of biomass gasification in Ghana?

Q.3 Policies that can promote biomass gasification in Ghana?

Q.4 How biomass gasification can improve rural electrification?

1.3 Outline of the study

Chapter 2 describes the research methodology. Literature review is presented in chapter 3. Biomass gasification technology is described in some details in chapter 4 of this paper, and also takes into consideration some of the types of gasifiers we have with their advantages and disadvantages. In chapter 5, barriers of biomass and gasification are presented in addition with some characteristics of rural settings, and some policies to promote rural electrification in Ghana. Finally chapter 6 presents the conclusion, recommendation and some limitation of this study.

2 RESEARCH METHODOLOGY

2.1 Research design types

There are basically three types of research design (Brown and Suter, 2012). These serve as the framework and a guide throughout the study. Secondly, the design in a way is used to analyze and to collects data. In some scenarios two of these designs can be employed for a particular work. For example, research works may include both descriptive and exploratory. There are three principal three types of these designs:

- **Causal**

This type of research design is used for the establishment of cause-and-effect relationship between available variables. An example of this design is an experiment, to actually help ascertain the causes and effect.

- **Descriptive**

This design is used to describe variables, for example population with respect to some other imperative and significant variables.

- **Exploration**

This research design is largely used to discover ideas and some insight of variables. The design for this paper was the exploratory research. Figure 1 illustrates the link and relationship between these research designs.

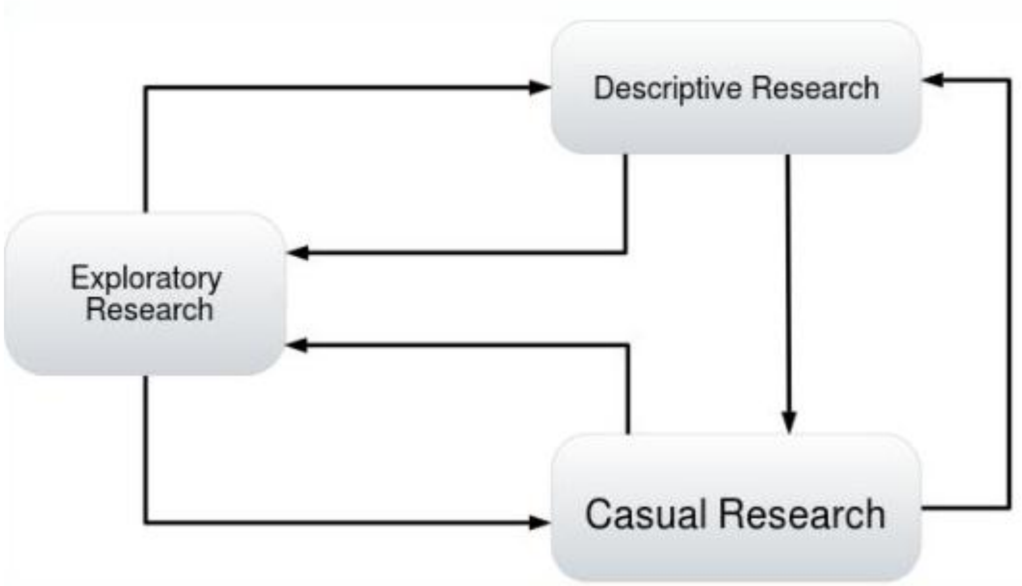

Figure 1. Relationship among research design (Brown and Suter, 2012)

2.2 Exploratory research

As stated earlier the design for this work is the exploratory. This in many times used and conducted when a better understanding is needed in a situation. A researcher using this design provides some hypothesis describing some related variable during their work. It is imperative to note that this design when used in reality does not come out with verdict or final conclusion.

2.3 Exploratory research types

The most well-liked methods of exploratory research are: literature review, depth interview, focus group, and case analysis. Figure 2 shows the familiar and common types of exploratory design.

- Depth interview

This method is basically used to tap relevant information, experience and knowledge from anyone who relates to the topic at a particular time. Interviews sessions are arranged and conducted directly and indirectly with people having knowledge and some specific idea on a subject being investigated. However, this can be very expensive when often conducted.

- Focus group

This methodology is frequently used technique in marketing research. It is said to be overused and from time to time used wrongly. This requires only a targeted and small number of persons, who simultaneously undergo an interview session. This method relies ultimately on group discussions for the collection of data, than directly asking specific questions. Furthermore, for the discussion to be absolutely sound, a moderator is employed to locate the focus group and also steer the interview sessions.

- Case analysis

Many times researches really learn a lot when a specific circumstance is studied cautiously, and this is the reason for a case analysis methodology. This can be conducted in many forms. Sometimes internal records are reviewed; interviews are conducted on individuals, and in addition through a careful observation. One or two varieties are sometimes to analyze a condition a specific time.

- Literature survey

Literature research examines available information and uses it as a guide for researching specific topics. A literature survey may include popular press (newspaper, magazines), academic literature, or published statistics from research firms or government agencies (Brown and Suter, 2012). The literature survey was the type of methodology used for the work. Chapter 3 explains in detail the literature review of the research topic.

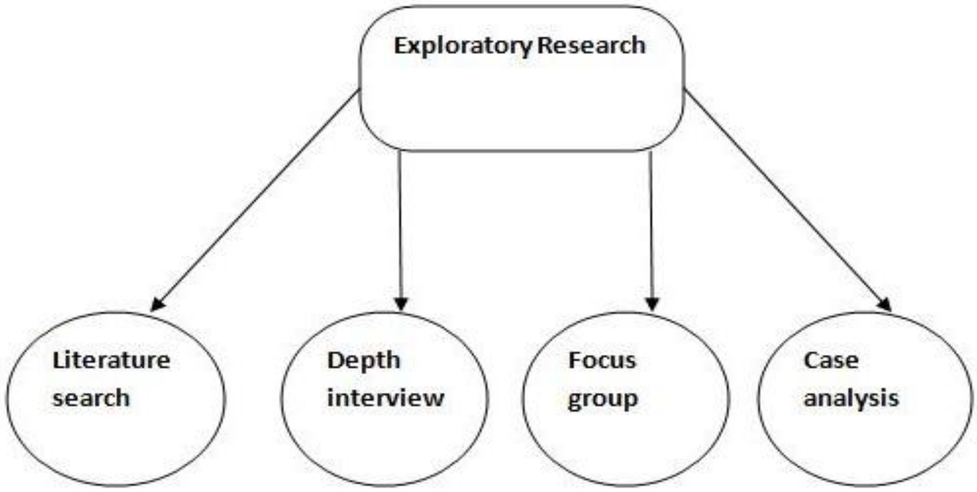

Figure 2. Common types of exploratory research

3 LITERATURE REVIEW

3.1 Definition of biomass

It has been estimated over the years of energy production that the cost for the provision of energy supply by renewable energy source can be determined and known for a consistent projection purposes. Biomass is an inexhaustible renewable energy source which is solar energy stored in organic matter. A terminology is used to describe all organic matter or biological materials, produced by photosynthesis existing on earth –practical action. Not only is biomass an important renewable energy source, but its significances for locally clean energy. It is therefore clear that countries spearheading clean energy will eventually become prominent and economical vibrant. “We know the countries that harness the power of clean energy will lead the 21^{st} century” – President Obama address to congress, February 24^{th}, 2009.

Biomass is presently gaining much publicity and desired attention due to the uncertainties and unpredictability of fossil fuels, not forgetting the reduction of waste accumulation in our localities and the endless agricultural substances available. Irrefutably, the earliest generation used biomass in the form of burning wood for heat in campfires, cooking, lighting, just to mention a few. The use of biomass presently (so-called modern biomass) disregards the traditional uses by the earliest generation as fuel wood. Modern biomass through some specific technologies provides the production of CHP, transportation, just to mention a few. That is, transportation fuels through several processes from agricultural, forest residues and solid wastes (Goldenberg and Coelho 2008).

Last but not the least; biomass is relatively flexible energy source. Unlike some other sources, it can be stored and used as fuel whenever required.

3.2 Kinds of biomass used today

Biomass usage today either for energy production is classified into four categories with respect to its nature. These are solid waste, wood and agricultural products, land fill gas and alcohol fuel.

- Solid waste

Words like trash, garbage or refuse, comes in mind when solid waste is mentioned. All this in a way refers to things we throw and dump away. However, there are two significant terms that have to be considered. They are total solid waste (TSW), waste thrown away daily, And municipal solid waste (MSW), referring to the waste from any household or work place, school thrown away every day. It may include used and old clothing's, broken furniture's, magazines and newspapers, some electric appliances, kitchen and food left overs etc. Basically, there are challenges with this kind of waste specifically, when not managed and controlled properly by the exact municipality and authorities in question.

- Wood and agricultural products

Any agricultural waste can produce bioenergy. But, wood biomass is incontestably the most conventional source for many homes today. Examples of these are wood-sawdust, logs, backs, and chips.

Hence, waste wood, cardboard, waste pallets and straw represents forestry produce of wood biomass. In the case of agricultural products for bioenergy, the suitability of technology is vital, owing to, its vast availability. Examples of agricultural products are palm nuts, palm kernel shell, cocoa shells**,** corn cobs, fruit pits, coconut husk, sugarcane, miscanthus and many more

- Land fill gas

The payback period for gas harvesting in a proposed land fill can take some time. Presently, a landfill for gas stands potentially viable as sources of energy.

Often we see dumping sites as land fill. Usually an open hole is created in the ground for garbage burial. This practice in nature calls the attention of many animals. For example; mice, rats, and all kinds of birds.

A landfill can structurally be engineered both in the ground and on top of the ground. With the principal objective to eliminate and prevent the trash from any hydraulics or water correlated. Either from the ground or the atmosphere, and also preventing it from air. The buried gas with respect to time produces methane gas.

The security of every landfill depends on these four systemic foundations:

- Bottom liner
- Leachate collecting system
- A cover
- The natural hydrological settings

This setting appears to be a natural phenomenon which stands to decrease the probability of waste discharge to the ground. (Basics of landfills 2001)

- Alcohol fuel

Methanol, ethanol, propanol, and butanol (difficult to produce) are some of the commonly known alcohol fuels. Notwithstanding, the leading role of fossil fuels for energy in the world market today, the factual usage and consumption of this fuel cannot be contravened. They are high synthesized chemically (blended) with other fuels like gasoline. On the other hand, one major advantage for alcohol fuel is their extraordinary octane rating, which eventually promotes fuel efficiency.

3.3 Fermentation

This is simply the process whereby carbohydrates are converted to alcohol. An example of biomass fermentation is biodiesel and bioethanol. In bioethanol production, the sugar in the biomass feedstock through some specific process is transformed into ethanol. Barley, wheat, potato, corn and some energy crops can be used for the same production as well. But, the proficient sources are the beet and sugar cane.

3.4 Pros and cons

Although alcohol fuels are considerably efficient, it is estimated that the price for a barrel of oil should be twice before contending with ethanol as fuels for transportation, making it very expensive to produce. (Earth science project 2008)

- Pros (ethanol)

In addition to ethanol being a renewable source of energy, it can also be produced domestically and considered to have a high octane number. But when needed to be used as fuel for modern and present day cars, fewer changes are required and would to be considered.

- Cons (ethanol)

There are also a number of challenges and disadvantages with respect to ethanol. Some of these may be related to the fact that it is heavily subsidized due to the refinery processes. There are problems associated with starting in cold weathers. It is also considered as a toxic product, but not as severe as methanol. In addition it is difficult to transport via pipes and corrodes the plastics and metal components in various occasions. Ethanol when used as fuels covers less mileage than gasoline.

- Pros (methanol)

One of the pros of methanol is its high octane number when use as fuel. Methanol also burns cleaner than diesel in engine. Unlike ethanol, which in a way requires some fewer changes for compatibility in present day cars, methanol in some way compatible to existing engines?

- Cons (methanol)

There also a number of cons associated with methanol. It has a dangerously invisible flame as E100 (100% methanol). Generally, it has poor cold weather starting characteristics and is primarily imported. This in a way deepens and increases fuel dependency. Furthermore, it has a lower energy contents with high cost. Just like ethanol, methanol is highly corrosive to plastics and metals. With respect to emission and toxicity, it is easily absorbed through the skin.

3.5 Sub-Saharan Africa

This is a term used geographically to describe a specific part of the continent located south of the Saharan desert. This eventually comprises most of the African countries. Countries located north of the regions of Sudan, Chad, Mali, Mauritania, and Niger are excluded, and also, countries at the north, which are largely considered to be part of the Arabic world. Figure 3 shows the map of Africa and the shaded blue portion indicates Sub-Saharan Africa.

In Sub-Saharan Africa, agricultural residues provide another important source of biomass, amounting to about 5 tonnes of dry matter per hectare of sorghum, 4 tonnes of straw and 2.5 tonnes of bran per hectare of rice, 2 tonnes of tops per hectare of groundnut and cowpea, and 10 tonnes of stubble per hectare of maize. In some countries, using these residues as substitutes for fuel wood is an important first step.

In Guinea Bissau, for example, biomass residues represent an estimated 65% of the cashew tree, providing a potential of 67,000 m3 of residue per year. This is equivalent to 12,000 tonnes of charcoal.

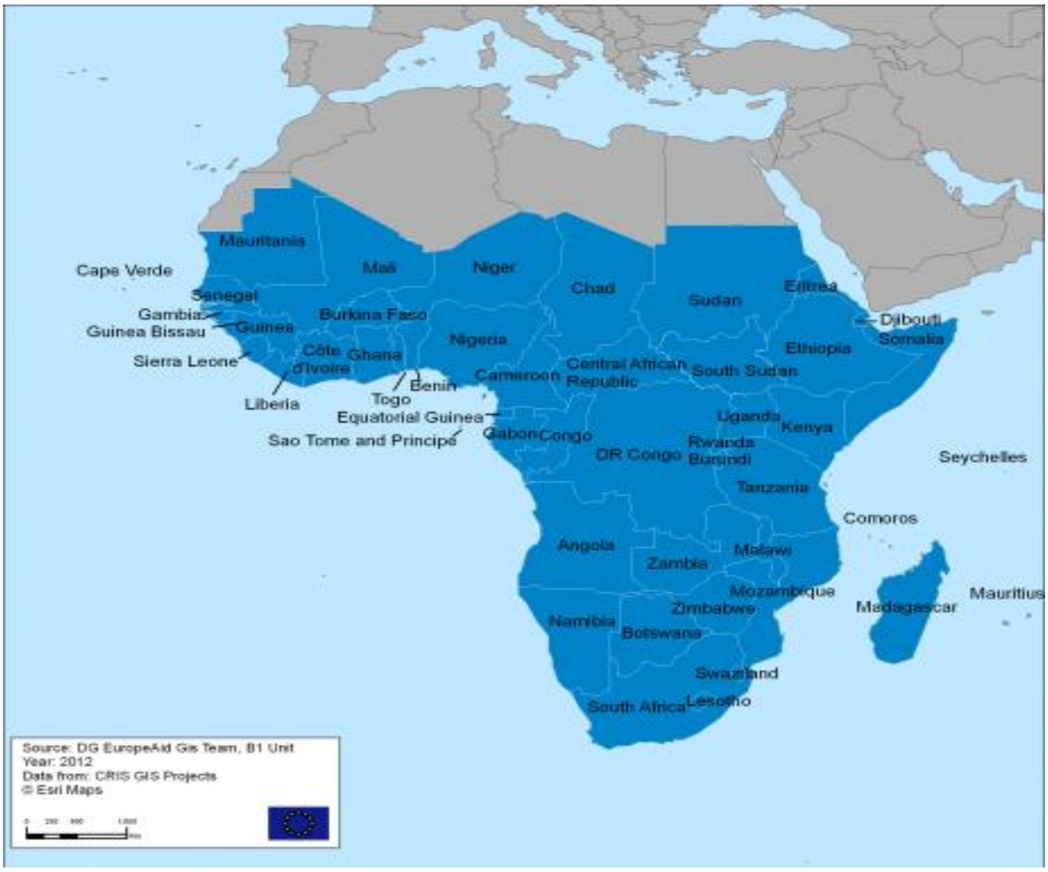

Figure 3. Map of Africa

The geographical location of the continent (SSA), both in the tropical zones and having access to the Sahara, has substantially endowed it with immense wealth and considerable amount of renewable energy resources. These, when harnessed and managed appropriately will aid solving most of the energy problems and challenges. Currently the population of Sub-Saharan Africa is 870 million after quintupling since 1950. This is estimated to double by 2050. (Lipton 2012).

Most of the region's challenges are as a result of inadequate amount and lack of energy, especially in the rural areas. Economic development and poverty reduction will greatly manifest should sustainable renewable energy supply is considered paramount. However, a stagnant energy supply will often amounts to a stagnant economy. Hence, a vigorous sustainable energy policy will have a bearing completely on all segments of the economy. That is, providing electricity for industries, commerce, agricultural, transportation, and other imperative social services like education and health. In SSA the dependency on biomass for both energy supply and consumption is estimated 75%. With respect to the developing countries biomass accounts for 35% of the total energy supply. (Atakora 1999) About 50% of Africa is said to be rural, and having no access to electricity. Those with such facilities are considered to be privileged. Owing to these prevailing developments biomass gasification in the rural communities becomes laudable and gets much attention.

3.6 Biomass potential in Ghana

Undeniably, Africa is endowed immensely with renewable energy potentials and Ghana is an example. But, unfortunately these potentials are not evident in the supply of energy as the demand for energy really appreciates.

There are two forms of forest resources in Ghana. The first is the open (savanna) zone which is estimated to cover total area of 9.6 million hectares and the second is the closed (high forest) zone, also estimated to cover an area of 8.2 million hectares. This estimated land area reveals the biomass that can be harnessed in the agricultural and the timber industry. Some of these biomass resources or feedstock includes the following: Agriculture residues, wood processing residues and wood chips, just to mention a few. Figure 4 shows the map Africa with the arrow and the flag of Ghana. The size area is 238533 square kilometers, which is about 92,098 square miles and according to the statistical service of Ghana, the population has hit over 24 million (Population and housing census 2010).

This study in addition demonstrates that Ghana is most ready and endowed with resource for biomass gasification for rural electrification.

On the other hand countries with a stronger electricity network arguably have to some extent minimum amount of waste (biomass) deposits due to the availability of modern conversion technologies for bio-waste to energy production.

.

Figure 4. African map showing Ghana (http://www.rogerreierson.blogspot.com)

The report of the energy commission in 2006 actually presented a higher demand for energy. It is also estimated that Ghana poverty level will decline, and gradually move to a middle income economy by 2015. This, however, increases the present energy demand from 6900 GWh to about 18,000 GWh in 2015. Therefore, other sustainable and renewable energy technologies should be employed to support the national grid to make this a reality and also to mitigate some energy challenges at the moment.

Biomass generally accounts for 64 % of the total energy consumed in the country as illustrated in figure 5. Considering all the bio-materials and residues, wood specifically gains dominance in usage as an energy source both directly and indirectly. The remaining resources, for example palm kernel shell, cocoa pod, maize cobs, millet stalks etc. should be tapped if biomass gasification will be a success in Ghana. (Energy commission Ghana, 2006)

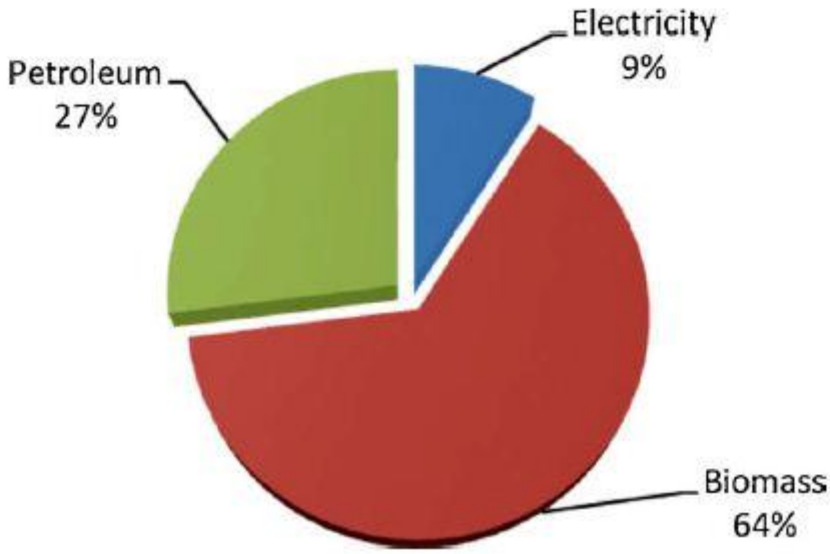

Figure 5. Ghana energy balance

It is also for a fact that the country has even until now some other rich minerals. For example manganese, bauxite, diamond, and gold just to mention a few (see Figures 6-9).

- Residues and waste from agriculture

Agriculture is a sector in Ghana's economy that cannot be neglected since the socio-economic development of the country depends on it. It provides employment for high percentage of the population. However, large amount of agricultural crops are cultivated and some residues such as the following can be beneficial for the biomass industry:

Figure 6. Palm Kernel shell

Figure 7. Cocoa pod

Figure 8. Maize cobs

Figure 9. Millet stalks

- Wood processing residues and wood chips

The timber industry is also an area that has seen considerable changes in the past to ensure it remains to play a pivotal role in the economy of Ghana. Therefore, there is a recommended annual allowable cut of timber from Ghana forest for both export and domestic consumption, about 1.0 x 10^6 m^3. This figure does not include the immeasurable amount of wood left in the forest such as tree branches, stumps, fallen parts of standing trees and defective logs.

The wood off-cut, barks, edging, slab and the above listed left in the forest are often considered as free fuel and in some cases as an opportunity for money and are sold as domestic or industrial fuel. Furthermore, the wood processing sector generates a huge amount of by-products which is usually considered to be waste material as shown in figures 10 and 11.

The disposal of this waste material is a major problem, it causes fire hazards and resources had to be employed to burn them which also cause air pollution to the public or it has to be transported somewhere for disposal. If this vast amount of residue from this sector can be properly harnessed, it will be beneficial to the biomass industry.

Figure 10. Wood processing residues

Figure 11. Wood chips

3.7 Biomass potential in Sub-Saharan Africa (SSA)

SSA energy problems can be solved when much attention is focused on its renewable energy resources and the adequate energy technology systems are used. However, the access to electricity in any economy is considered paramount to development to alleviate poverty.

The access and electrification level of SSA is still well-thought-out to be very little. Paralleled to other developing countries, the electrification rate in SSA is between 23 and 25 % plainly indicating a lower level of electrification, than in the Middle East, China, Latin America, South and East Asia.

Sub-Saharan Africa has adequately renewable energy sources, which include a large quantity of biomass for energy production. A combination of good management and preferred technology would aid to increase the low electrification rates. The access to electricity is 26 % and less than a percentage in the rural communities. Biomass has the large potential as a renewable source. This is evident in the availability of agro residues, waste from wood industry, and forest reserves. Table 1 presents the ration of crop residue that are generated during cereal production and processing (CR Ratio) in Africa. Having a total cereal production of 140Mt, which in conjecture means that if crop residue ratio is 1.0 for the any agro product, then the contribution of these residues to biomass potential is about 140 Mt.

Table 1. Crop to residue ratio

Crop	Residue	CRR	Crop	Residue	CRR
Barley	Stalks	1.30	Paddy	Straw	1.50
Bar seem	Stalks	1.00	Paddy	Husk	0.20
Black pepper	Stalks	0.50	Paddy	Stalks	1.50
Gram	Stalks	1.15	Peas & beans	Stalks	0.50
Groundnut	Stalks	2.00	Potato	Leaves	0.76
Groundnut	Shell	0.30	Potato	Stalks	0.05
Guar	Stalks	2.00	Pulses	Stalks	1.30
Horse gram	Stalks	1.30	Safflower	Stalks	3.00
Jowar	Cobs	0.50	Sannhamp	Stalks	2.52
Jowar	Stalks	1.70	Sawan	Stalks	1.00
Jowar	Husk	0.20	Small millets	Stalks	1.20
Kodo millets	Stalks	1.16	Soyabean	Stalks	1.70
Linseed	Stalks	1.47	Sugarcane	Tops & leaves	0.05
Maize	Stalks	2.00	Sunflower	Stalks	2.00
Maize	Cobs	0.30	Sweet potato	Stalks	0.10
Mustard	Stalks	1.80	Tapioca	Stalks	0.72
Mustard	Husk	0.43	Tea	Sticks	1.00
Niger seed	Stalks	1.07	Tobacco	Stalks	1.00
Oilseeds	Stalks	2.00	Wheat	Stalks	1.50
Onion	Stalks	0.05	Wheat	Pod	0.30

Waste land also can be utilized for bio-energy production. Other sources of SSA biomass potential are the non-valued residues from non- edible oil extractions (bi-odiesel) (Dasappa, 2011).

Most of these resources are scattered and unevenly located across the continent. The forest base, wood biomass, and agricultural residue present a reliable source of energy for SSA. The massive biomass deposits in SSA would need an efficient institution to promote the commercialization of bio-energy on a large scale for electrification. Since, for now the consumption of energy is moreover dominated fossil fuels (combustibles), non-commercials and renewable resources.

Households commonly use biomass (wood) for, cooking, drying, and heating. Besides, biomass accounts for more 30 % of the energy consumed in the continent and more than 80 % in SSA. (Kebede, Kogochi, and Jolly, 2010). Table 2 illustrates the energy composition in SSA, from petroleum, electricity and wood fuel. Wood fuel (biomass) accounts for 70-77 % between 1980-2005, whereas, petroleum and electricity accounts for 28 % of the total energy with respect to the same year interval.

Table 2. Source of energy in SSA

YEAR	**PETROLEUM**	**ELECTRICITY**	**WOODFUEL**
1980	0.23	0.06	0.71
1985	0.23	0.04	0.73
1990	0.24	0.05	0.71
1995	0.19	0.04	0.77
2000	0.22	0.04	0.74
2005	0.23	0.05	0.72

4 GASIFICATION

Biomass gasification or combustible gas production from carbonaceous feed stocks is an already existing ancient technology, sometimes called dry distillation or pyrolysis. An attempt was made in 1795and 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 processes emerged in Europe and America.

Biomass gasification is basically the conversion of organically derived biomass (feedstock) by partial oxidation. Into gaseous components or products, synthesis gas or "syngas This can be air, pure oxygen, steam or a mixture of the two, and consist principally of hydrogen (H_2) and carbon monoxide (CO), but a minimum amount of carbon dioxide (CO_2), water (H_2O), methane (CH_4), higher hydrocarbons (C_2+) and nitrogen (N_2) (Ciferno &Marano 2002)

Air-based gasifiers produce gas having a lower heating value, which is between 4 and 6 MJ/m^3. And the nitrogen concentration is said to be relatively high. Whereas, the combination of oxygen based and steam-based gasification produces gas having a higher heating value which is between 10 and 20 MJ/m^3. The hydrogen and carbon monoxide concentration is also said to be relatively high.

4.1 Classification of Gasifiers

A gasifier classification basically depends on certain specific designs, and these designs also depend on feed fuel, and whether the gasifier will be stationary or portable. Furthermore, the absolute reaction of the oxidant and the feed stock in the gasifier plays an important role in the design subsequently. There are several types of gasifiers which I will be discussing later in this chapter. An overview of biomass gasification is illustrated in figure 12.

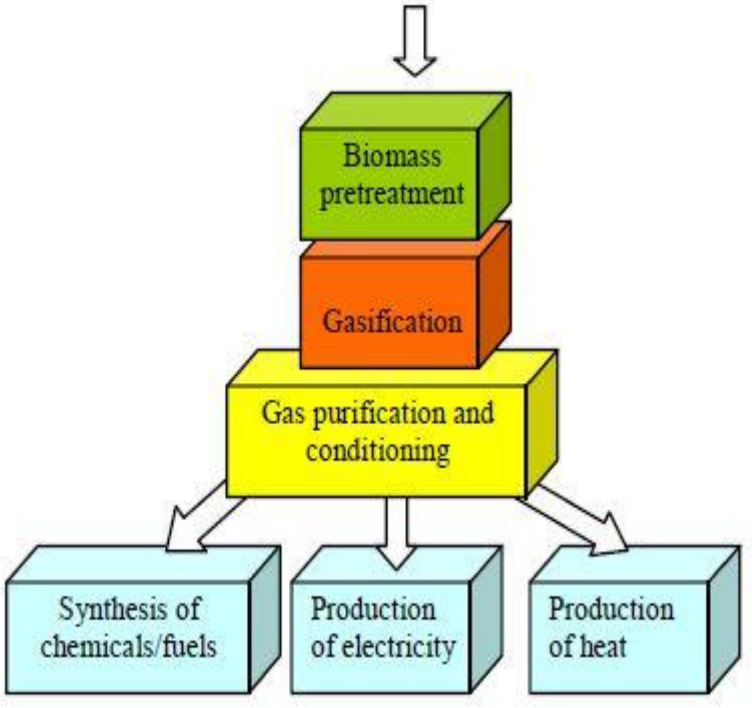

Figure 12. Biomass gasification overview

4.2 Processes of gasification

There are quite a few processes related to the combustion of any carbonaceous feed stock. These thermal processes have to be monitored and controlled. In so doing, it enhances and increases the result associated with gasification. In general, the processes involved in gasification are thermochemical processes and very difficult to comprehend. All these reaction processes take place at various points and concurrently in the reactor. These processes are: Drying, Pyrolysis, Oxidation and Reduction. To categorize these precise processes into stages would help one appreciate and understand gasification in general. Figure 13 illustrates the steps in gasification.

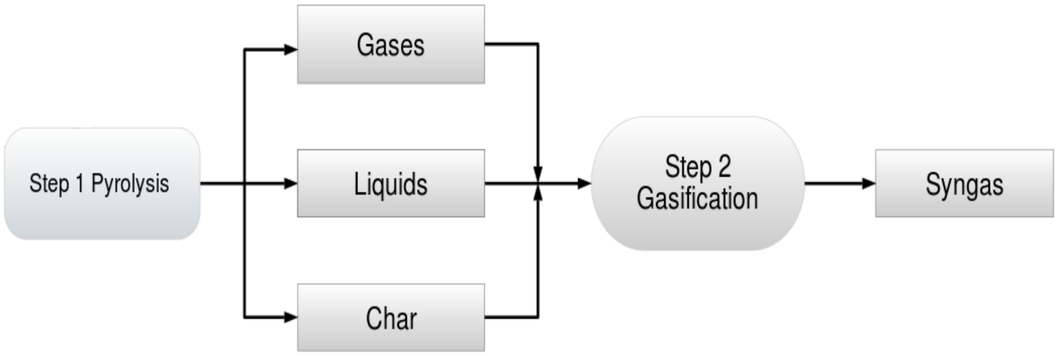

Figure 13. Steps in gasification process

- Drying stage

This stage is very critical in the entire gasification process. This is where water and any form of moisture are removed from the feed stock in the reactor by evaporation. There is an amount of water or moisture content in all carbonaceous feed stocks varying from between 5 and 35 % specifically. The feed stock in itself in this process does not experience or undergo decomposition in anyway. The temperatures in this process are between 100 and 160 ^{0}C.

- Pyrolysis stage

In this stage, temperatures which are lower sufficiently initiate this pyrolysis process to enable the generation of hydrocarbons or tars. Immediately after a thorough drying process in the reactor, volatile gases are in the long run released from the feed stock. Also in this stage of the process decomposition occurs thermally without the presence of air. There are three various types of products released in this process: solid charcoal, liquid tar, and. and volatile gases. The type of end-product depends on the type of feed stock in use and operating standards or the condition of the reactor. This process is also called devolatilization.

- Oxidation stage

Immediately after the pyrolysis stage, the oxidization process initiates within the temperatures of 700 and 1400 ^{0}C specifically. An oxidant (air) is introduced into the process. At this stage of the process this particular oxidant comprises of nitrogen as well as oxygen and water vapor. It is expected not to have any form of reaction on the fuel.

- Reduction stage

Some of the foremost reduction reactions in this stage are bouduard reaction, water gas reaction, and shift reaction. This is particularly where reactions take place chemically in an extremely high temperature, about 1100 ^{0}C. Hydrogen and carbon oxide (combustible gases) are form when the water vapor reacts with the carbons.

- Cleaning the gas

After all these various stages of the production process, the next stage is the cleaning of the gas before consumption. This is because the syngas comes with some other unwanted impurities. The initial ash particles are removed by a cyclone and further go through several kinds of filtering process.

4.3 Advantages of gasification

Gasification process in itself is a difficult and very challenging. Nonetheless, the existence of fossil fuels as a source of energy is predictably limited, not forgetting the instability which is evident in its economical distribution over the world. This apprehension makes gasification development convincing and much beneficial. Predominantly, most of the fuels used for the production of energy have to be imported and transported. This practice is avoidable, just for the fact that biomass feed stock (fuel) for the process, be it energy production can be delivered and generated locally in the neighborhoods. And this by far makes the fuel potentially economical.

The syngas from the gasification process can be used for the production of so many chemicals, which are commercially looked-for at the industry. Additionally, not only is it needed in the industry, but also in the transportation sector, for the production of synthetic fuels. Gasification can be associated with energy production system whereby an integrated gasification combine system (IGCS) is employed where the consumption of the product gases is used to fire a gas turbine and further using the exhaust gases from this same system to generate steam as a driving force for an alternative turbine concurrently.

Biomass gasification for that matter has its own peculiar stumbling blocks. Critical examination of this process entirely and the production of gases for the generation of combined heat and power (CHP), the production of the various industrial chemical, fuels for the transportation sector, a cleanup syngas without pollution during combustion in combined cycles are the obvious advantages of gasification. Figure 14 shows the benefits of biomass gasification process.

Again, try to eliminate the white space here.

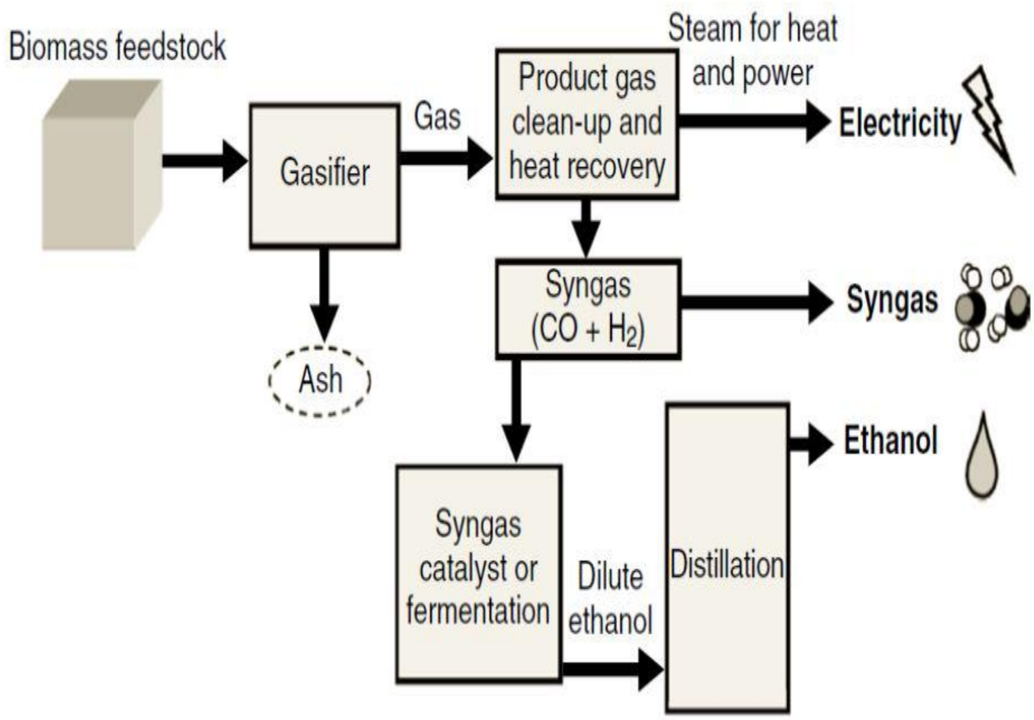

Figure 14. Benefits of gasification

4.4 The updraft gasifier

This is one of the oldest and simplest form of gasifier with a fixed bed, also known as the counter-current gasifier (the biomass flows successively to the gas). This is still in existence in some coal gasification processes.

As indicated in figure 13, the carbonaceous feed stock (biomass) is fed at the top of the reactor and the oxidant (air) is introduced at the bottom. The gas exits at the top.

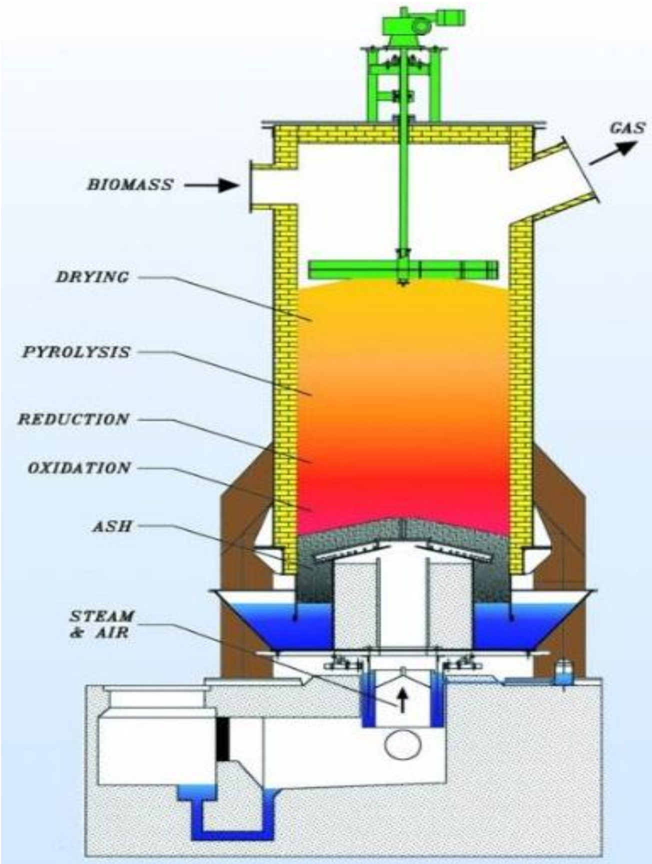

Figure 15. The updraft gasifier

- Advantages of the updraft gasifier

The major advantage of this gasifier is its simplicity and the low cost processes. It also has the ability to handle fuels having a higher moisture contents. Because incoming biomass feed stocks are dried by at the top of the gasifier. Finally, the technology for the updraft gasifier has been proven to have a higher efficiency.

- Drawbacks of the updraft gasifier

One of the foremost drawbacks for this type of gasifier is that the syngas requires clean up before it use because of about 10 to 20% weight of tar. But, this eventually is of less or no little importance when the gas application is direct. (Ciferno and Marano, 2002).

4.5 The downdraft gasifier

With the downdraft gasifier the feed stocks or the fuel is fed into the reactor at the top. The oxidant (air) is introduced sometimes at the top or at the side of the reactor. The syngas exits at the bottom. This type of gasifier is also known as the co-current-flow. The technical alignments are just like the counter-flow (countercurrent). But the difference is the introduction of the oxidant (air) and how the gas exits the reactor.

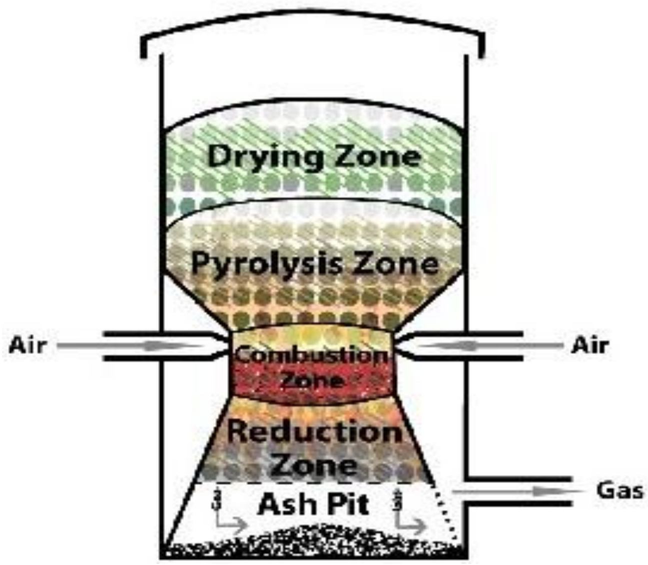

Figure 16. The downdraft gasifier

- Advantages of the downdraft gasifier

One of the most important advantages is that, almost all the tar formation in the reactor is consumed. Therefore, little cleanup gas is required before its application; this also minimizes the cyclone use, because the minerals remain in the gas during the production. The overall cost for this type of gasifier is low and simple with respect to construction as well.

- Drawbacks of the downdraft gasifier

After the production, the syngas collects some amount of dust. This is because it has to pass through the oxidation stage or zone. The feed stocks or fuel entering the reactor should be sized consistently between 4cm to 10cm to prevent any form of blocking. (Quaak, Knoef and Stassen 1999). This drawback eventually makes pelletization an obvious process for the fuel intake, and must have low moisture content. Moreover, the efficiency for this gasifier is low, due to the exit of high temperature of flue gases.

4.6 The fluidized bed gasifiers (bubbling fluidized bed & circulating fluidized bed)

These BFB and CFB gasifiers are very much appropriate for larger capacities. They were originally designed and developed to take care of the problems and challenges associated with the fixed bed gasifiers (updraft and the downdraft) with a higher ash contents. Relatively, the temperature required for gasification is much lower than that of the fixed beds, approximately 750 – 900 ^{o}C, and 1200 – 1500 ^{o}C for the fixed bed gasifiers respectively.

The feedstock or fuel is introduced into a hot suspended sand either bubbling or circulating fludized bed. This bed in the reactor acts like a fluid associated with a higher turbulence. This therefore causes the fuel to speedily mix with the fuel (bed material) and this eventually produces a spontaneous pyrolysis (Ciferno, 2002).

- Advantages of fluidized bed

Some of the advantages of this technology include its low ash melting point because the temperature for the reaction is basically low. Moreover, the constructions for this type of gasifiers are considered to be compact due to the appropriate mixing of the fuel in the bed. Also, this gasifier can handle both materials with higher ash content and a lower bulk density at the same time.

- Drawbacks of fluidized bed

The operation of this reactor is extremely complicated. Particularly, control oxidant (air or steam) and the fuel are needed at the same time during the production. In most cases some amount of power is also necessary and required for the gas stream compression. The carbon burn out in a FBG is mostly incomplete, and the product gases have a high dust and tar content. Figure 15 shows a fluidized bed gasifier. See Tables 3 and 4 for advantages and disadvantages of BFB and CFB respectively.

Table 3. The advantages and disadvantages of BFB

Advantages	**Disadvantage**
The product gases from the gasifier and the distribution of temperature are uniform during the cost of production.	Gas bypassing the bed occurs due to large bubbling signs.
The acceptance of different sizes of fuel particles.	
The heat transfer concerning the inert materials, fuel and the gas is high.	
Conversion is possibly high with unconverted carbons and a low tar.	

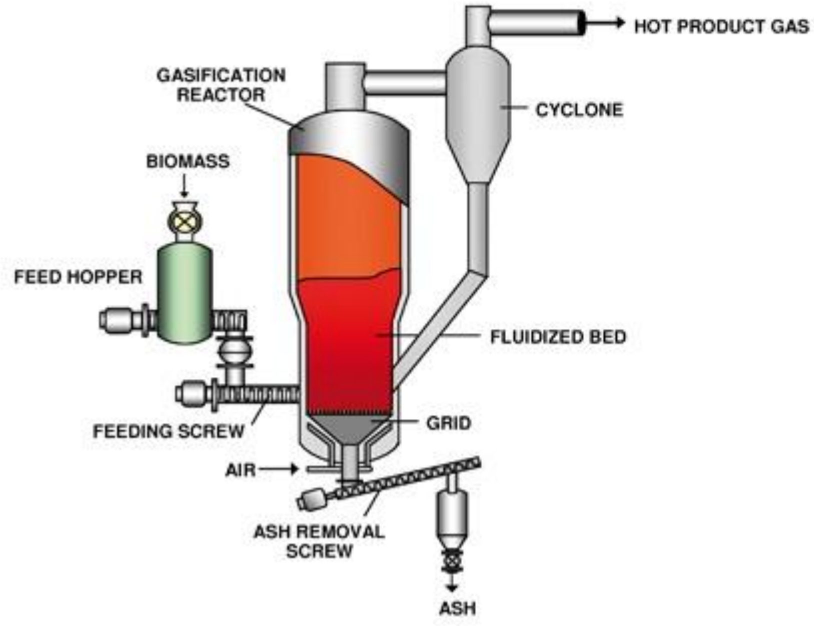

Figure 17. Bubbling fluidized bed gasifier

Table 4. The advantages of the CFB

Advantages	**Disadvantages**
The transfer rate for the heat are feasible owing to the fact that bed materials have a high heat capacity	With CFB the heat exchange is less efficient than the BFB
Probably high rate of conversion with an unconverted carbon and a low tar	The size of the fuel into the gasifier determines the actual velocity however higher velocity might cause erosion in the equipment
Very appropriate for rapid reaction.	The occurrences of temperature gradient to the direction of the solid fluid

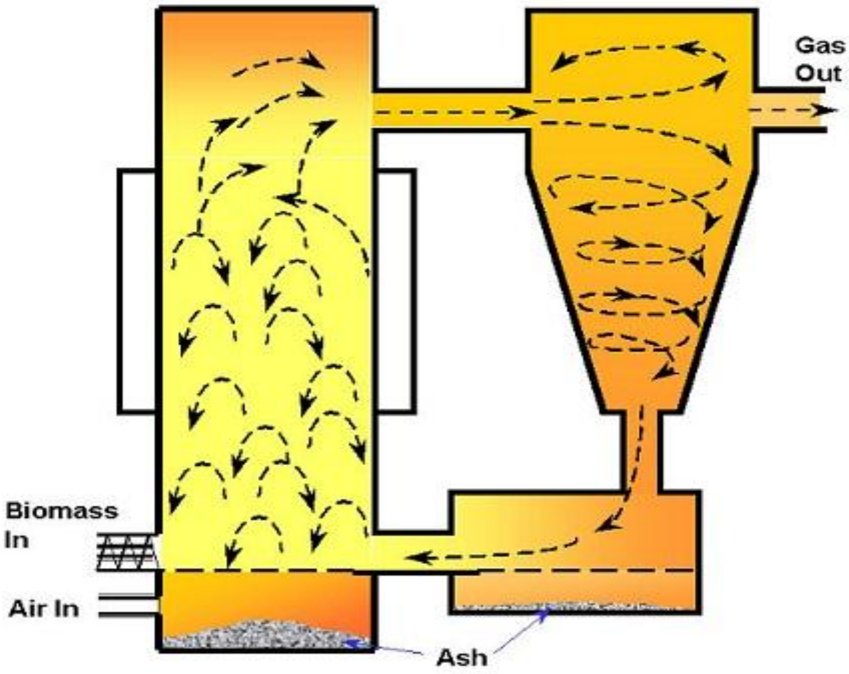

Figure 18. Circulated fluidized bed gasifier

5 BARRIERS OF BIOMASS IMPLEMENTATION

The reduction of greenhouse gas emission worldwide has been an issue of very high importance over the past decades. It has been the main topic for hundreds of international conferences all over the world and major decisions are taken during those conferences. For instance the Kyoto protocol gave rigorous requirements on greenhouse gas emission levels and their reduction for developed countries. (Gubina, Xiangyang, Zhengmin, 2006)

This reduction is only possible if the use of fossil fuel is drastically minimized and gradually substituted with the use of renewable energy sources (RES) like wind, hydro, biomass, solar among others. Therefore, the development of RES coupled with efficiency improvement is the key to sustainable development

Among all RES, biomass is one of the most used and can be found locally or imported depending on where energy is needed. Figure 19 below shows the global energy demand and share of the main categories of total renewable in 2006.

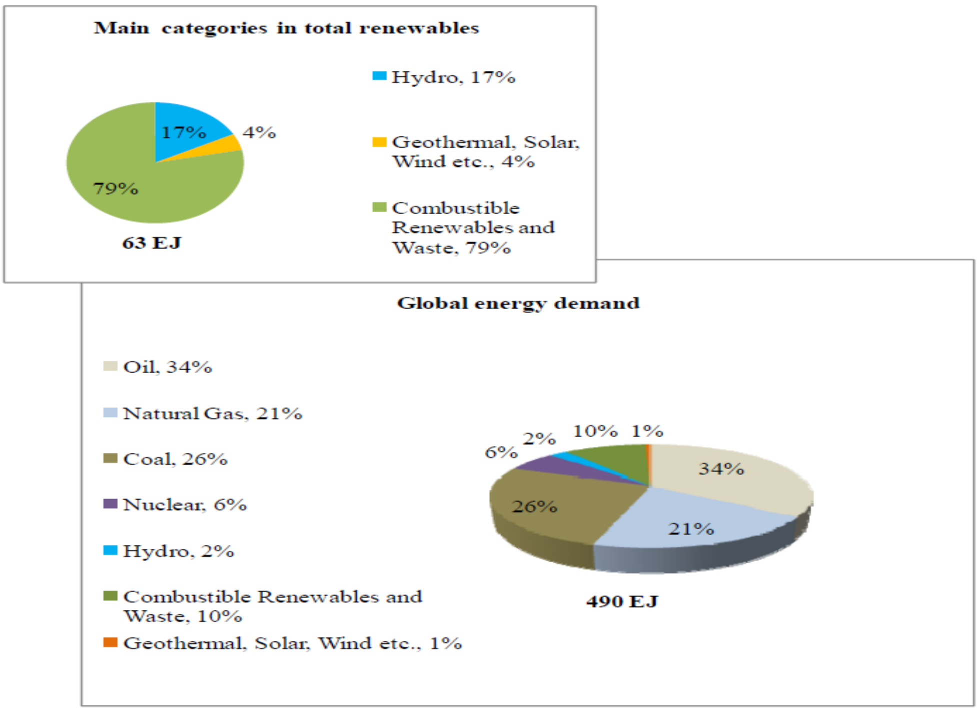

Figure 17. Global energy demand and share of the main categories in total (Ladanai & Vinterbäck, 2009)

Despite being widely available, biomass development in developed and developing countries faces wide range of barriers. These can either be expressed culturally, economically, technically and sometimes institutionally. The EU experience has revealed that there are five main barriers to the development of bio-energy.

- **Opposition from major energy producers:** This hesitation is comprehensible, because major fossil fuel companies have a very huge influential role on government policy. Bio-energy generation is also more decentralized compared to the use of fossil fuels for energy production, threatening the large centralized energy distributors.
- **Technology and process cost:** Apart from the combustion of residues from the forest products industry, bio-energy remains uncompetitive with fossil fuels all over the world.
- **Inappropriate and poorly-devised policy frameworks:** With all the barriers that bio-energy faces, specific national policies are necessary in order to facilitate bio-energy development. The absence of policies or when policies are not well defined, they can act as barriers to bio-energy. The EU Biomass plan even mentioned this as the main barrier to bio-energy.
- **Fuel chain complexity:** The overall complexity is no less than that of fossil fuels which has benefited of an experience of more than a century of common use. Bio-energy is the only RES that cannot be exploited for free, hence leading to high costs.

In addition to the five main barriers discussed in the EU Biomass plan. It appears that the barriers would differ from each continent specifically. With respect to the developing countries and rural settlements, the following barriers are prevalent:

- **Land competition:** Food security is an issue of high importance when talking about bio-energy production in rural areas. The crops for the energy production are the same crops consumed by individuals and also for food that. This in a way makes bio-energy production to be seen now as a threat.

- **Financial barriers:** Presently in developing countries, a lot of grants are being issued for the implementation of green energy projects. However, the bio-energy technologies are quite new, characterized by a high rate of improbability, hence becoming barrier for its development. A colossal amount of money is still injected into research, development and deployment. Most often, the setup cost for efficient equipment is higher if we compare it to the standard alternative and the payback period may also be unacceptable. Banks and others financial institutions are hesitant in financing renewable or green projects due to the high risk involved and also the lack of technical knowledge on the part of the financiers. (Indati)
- **Management capacity:** Bio-energy projects in the world most of the time suffer from management capacity, leaving just a hand few projects to be standing and operational. This is in actual fact is a major barrier. Occasionally, failures of these projects are primarily related to weak management and are demonstrated in the following: poor construction, incorrect operation, inadequate maintenance, poorly designed dissemination programs, inadequate monitoring and low ownership responsibility.
- **Institutional or regulatory barriers:** Developing countries are focusing on huge development or expansion plans are given RE a lower priority in the governments' agenda. However, to give a significance to RE, governments should rethink about their energy fuel mix equation to foremost and gradually eliminate and or transfer subsidies of conventional energy to RE (Indati)
- **Technical barriers:** This is one of the barriers making the implementation of biomass technologies very difficult. This can be more understood in the following dimensions.
    - I. The bio-energy technologies are still in a way considered "unapproved" and would not be able to survive the competition of more established option.
    - II. The local communities lack of expertise on operation and maintenance of the equipment.

III. The cheap price of electricity from fossil fuels also weakens renewable energy efforts. Generation of energy from renewables has a high cost both in term of investment costs and final energy costs unlike conventional energy. Table 3 below shows example of the price of electricity from conventional and RES in Malaysia.

Table 5. Prices of electricity from conventional and renewable energy (Malaysia)

Sources	Investment Cost (US$/KW)	Electricity Cost (US$cents/KWh)
Hydro	900 – 10,000	1-12
(Small Hydro)	(1,000)	(5-10)
Biomass	1,700 – 2,000	7 - 15
Solar Thermal Power	3,000	20-25
Geothermal	1,500	7 – 10
Wind	1,000	1 – 2
Conventional electricity (Gas and Coal)	700 – 1,200	4 - 6

5.1 Barriers of biomass gasification

The quest for the reduction and emission of greenhouse gases in line with the significance of Kyoto agreement has established biomass (renewable energy source) and the process of biomass gasification to substantially substitute the use of fossil fuels. Although, the development of biomass gasification is still ongoing, it has indeed captured the interest and attention technologically with respect to combustion.

This technology in many and recent years choke some successes globally both in its demonstration and on a large scale. However, biomass gasification process like any other technology has it peculiar barriers which need to be analytically observed before its implementation. Further developments have been undertaken to speedily facilitate the acceptance and penetration of such technology into the energy market. Even when it has to be integrated with any current technology to demonstrate its economic viability.

A biomass gasification barrier may differ from country to country but most of these barriers are similar. It can be classified under technical and non-technical barriers depending also on the gasifier type, the fuel use and the oxidant.

5.2 Technical barriers

Below are some of the technical barriers associated with biomass gasification. These barriers are deserves to be critically examine for any development and acceptance of this technology in the world market.

- Moisture content

Many times the operating performance of the reactor depends on the moisture content. This also goes a long way to influence the temperature of the reactor. The genesis of some major technical barriers is as a result of this factor. Furthermore, most of the reactors have been rendered inefficient today due to these challenges. It is also vital to note that aside the already specified gas composition and gasification heating values are affected respectively.

- Tar minimization and cleaning

This is one of the utmost reasons why biomass gasification is facing a lower patronage even until now. Many investors and entrepreneurs are not poise to further invest in biomass gasification project. Similarly all the used methods for basically scrubbing are consistently providing less or lower result. Looking at the production of large quantities of condensate from tar, it clearly signals the problems it creates in the environment.

- Gas cleaning

Rotating particles separators, tar crackers, ESP, cyclones, solid beds and scrubbers are some examples of cleaning device. The sign gas from CFB gasifiers usually contains between 6 and $20 g/m_n^3$ of dust. In addition, the sulfur removal is also important before the application of the gas product. These cleaners are sufficiently capable at the moment but there is the need not to lose truck of their economic characteristics. This is critical because it can provide some kind of room for compromising safety.

- Ash handling

Handling the ash is also very important and many times appears to be one of the technical barriers for biomass gasification. This if not handled and melted properly will result in slagging effect both in the pipe lines and the gasifiers. This is when especially municipal solid biomass waste is used as a feedstock.

- Limited technical expertise

Although biomass gasification is an old technology, commercialization on a large scale has not been satisfactory due to the limited technical expertise required to promote this technology and adequate engineering skills for service and maintenance. Not only does it has a limited technical expertise but also lack of development and manufacturers respectively. This stumbling block needs to be precisely addressed to enhance the acceptance of this technology.

5.3 Non-technical barriers

Most of the barriers of biomass gasification are not technically related and therefore should be noted to provide the speed this technology deserves before its diffusion on a large scale. Some of these may include the following

- Sustainability and supply chain process

There are much specific evidences of clearly abandoning biomass gasification plants for reasons being that sustainability and issues of adequate supply chain processes were not properly stated initially. Even though biomass gasification has enormous advantages especially for the rural communities, we should not underestimate the technological competition from other biomass technologies as well. Constant fuel supply to the reactor can be a barrier due to the fact that other technologies might as well be competing if not for the same feedstock. This development may in the long run place a high demand on the fuel and even increasing the prices as well. Tolerable feasibility study is therefore a prerequisite in overcoming this kind of barrier.

- Inadequate government policies and incentives

The acceptance of biomass gasification will largely depend on government's policies and some initiates. Without this the concept of biomass and rural electrification would not be worth any consideration. This policy should noticeably define issues related to distribution, power generation and pricing. Undeniably, most rural communities need some kind of financial incentives, which can actually be in any form and entirely connects to the individual and social activities in the community.

- Limited quality control and guarantee

The feedstock for the energy production suffers from sufficient infrastructure to ascertain the quality of a particular fuel. Quality control, is a key berried for this technology. Furthermore, most of the manufactures today are not able to provide the necessary performance guarantee needed to stake holders because of limitations with large scale commercialization repertoire and experience.

- Market pull

The competition in the energy market is still keen. This for all time is determined by the amount of crude oil in the world market. The price of fossil fuels for energy production is lower than bio-fuels for energy production. But, this scenario will differ when crude oil price appreciates. This development would arguably promote bio-fuels (biomass). (Dalili, 2009)

5.4 Some characteristics of rural settings

To some extent, the characteristics of most rural areas throughout the world are similar. The main occupation in these areas is farming or agriculture and their incomes are constraint due to the fact that rural economy cannot provide them with lucrative jobs or self-employment opportunities. Furthermore, they lack the certain basic necessities, such as portable drinking water, electricity, health facilities, education, telecommunication services, transportation and good road networks.

The access to modern energy can be described as a household's capacity to again an energy services, should it decide to do so. But most rural communities experience low access to this modern energy services due to the challenges of availability and affordability. They rely solely on some traditional fuels, such as crop residues and wood for major part of their energy needs. This has a negative impact on the productivity and the living standards of the people in the community.

Consequently, the burning of these traditional fuels produces some harmful chemical substances which accompanied with health problems, such as acute respiratory infections when they are used indoors. Obviously, traditional fuels cannot provide modern energy services, such as electricity and mechanical power, thus limit their ability to progress in some aspects of life such as education and employment.

5.5 Rural electrification

Rural electrification is a phrase used to describe the providing electricity for rural communities or areas. The use of electricity in modern day has not only been for lighting and other household purposes but also for communication that is the transmission of signals, mechanization of many farming operation and in the manufacturing industries to drive almost every moving part in the factoring, just to mention a few.

On the other hand, it estimated that less than 10 % of sub-Saharan African rural households have access to electricity and the overall access rate is below 25 percent. Most developing countries in sub-Saharan Africa are still struggling to meet the energy demands. Worldwide, more than 3.6 billion people do not have access to electricity, out of which 83 percent live in rural areas.

The need for rural electrification is one of the key forces to enhance the economic and socio-cultural development of rural societies. However, the generation and distribution of power or electrification rate in these areas are difficult to obtain and so need to be address well. Nevertheless, some of the challenges affecting rural electrification include:

1. The right technology solution.
2. Financial models that will ensure smooth running of these projects after completion.
3. The effectiveness of mechanism that will enable these communities to benefit from the electrification.
4. The lack of funding for the projects.

5.6 Benefits of rural electrification

In spite of the challenges with rural electrification, there are enormous benefits associated with it. Some of such benefits include:

- Reduce Poverty. The access to this service will eventually enhance the economic and socio-cultural development of the society. Self-employment and locally owned businesses will be established which could create employment for most people.
- Provision and/or improvement in health facilities and systems. The emergence of these facilities due to the availability of energy will improve the functionalities. For example, lighting of operating theaters, refrigeration of medicines and vaccines, sterilization of equipments and transportation to and from health clinics. However, child and maternal mortality will be reduced, as well as diseases.
- Reduce hunger and improve access to safe drinking water. The provision of energy service will improve community’s access to pumped drinking water and well cooked foods.
- Improvement in education. To achieve the universal primary education, energy services will provide lighting that will permit home studies for students, improve security and enable educational media and communication in schools, not forgetting information and communication technology (ICTs).

- Environmental sustainability. Pollution that was associated with the burning of traditional fuels could be minimized thus reducing emission and the use of cleaner energy can aid to attain sustainable use of natural resources that seem to be suffering a decline.
- Farming activities will eventually improve since farmers will get more modern and advance equipment to enhance the work.

5.7 Why biomass gasification is appropriate for rural electrification

This paper had subsequently revealed in chapter three some of the advantages of gasification. But, it is important to again consider actually why such technology is and will be appropriate for rural community globally and Ghana in particular. The appropriateness of biomass and rural electrification can be many but below is just to mention a few.

- The biomass and agricultural residues are mostly found in large quantities in these rural areas. Basically, the availability of the raw materials is not a problem. Since they are in abundance, and gasifiers might suffer little or no fuel supply
- It is cheaper to most of the renewable energies and also better than solar power given that the cost per KW is less than 30 %.
- The provision of employment because power based on gasification technology in a sense gives entrepreneurship to the rural community as they learn to run the reactors and moreover collects the biomass run the plant. In other words they get sufficient amount of industrial training for running an industry.
- Biomass gasification technology is more reliable than solar and wind technology. Because, with gasification the community can get electricity at any time when required. The absolute need for wind blowing and sunshine will not be of importance.
- Finally, the cost for transmission which includes wiring to the community and the creation of sub-power stations would be eliminated making more for savings.

5.8 Policies that can promote biomass gasification in Ghana

The implementation of policies always plays an important role in the commercialization of any technology. It is a fact that, governments alone cannot provide to full every infrastructure needed for biomass gasification to reach a full scale commercialization.

With this respect, the policies and other financial mechanisms for the promotion of all bio-energy technologies are more or less no different from biomass gasification (UNDP-UNEP, 2009). Below are some of the policies to help promote biomass gasification in Ghana.

- 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 meet 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.

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 reason why the government has issue such and including policies, to attract investors to help promote biomass gasification for rural electrification. (Derrick, 1998)

5.9 Community participation

The participation of the community is paramount to the success of any rural electrification project. The reasons are many among which includes:

I. Raw materials

As discussed earlier, the availability of raw materials and its sustainability is crucial to this technology. Owing to this, the participation of the community should not be undermined. In reality their inclusion to decision making will go a long way to speeding the commercialization and acceptance because, they are primarily farmers and most of these raw materials and bio-materials can be supplied by them for the production of electricity in the community.

II. Benefits

The benefits of such projects should be clearly defined to the people for them to apprehend. The success more or less is dependent on this factor in a way. Some of the benefits are as follows: the improvement and provision of health facilities, reduction of poverty, the reduction of hunger and moreover improvement of the access of safe drinking water, some kind of security when light are provided in the night, improves education just to mention a few.

III. Taking ownership

It is when the community takes ownership completely of this project and integrates their socio-cultural activity to the success of the project. This is when they feel and experience some sense of inclusion in the national discuss. The community will then makes provision within the limit of their abilities to safe guard and ensure the success of such project when undertaken.

6 CONCLUSION

This paper reveals the enormous potential of biomass in SSA and in Ghana in particular, with respect to its traditional and conventional uses. It further reveals the various kinds of biomass available, and the potentials of biomass gasification for rural electrification. There are vast deposits of biomass and resources available in the country and in the rural community. Nonetheless, the road to massive rural electrification should indeed be linked to farming activity, and the social-cultural behaviors should also be taken into consideration.

The call for decentralization of the energy has been highly discussed by the government, and many other initiatives have met positive considerations. In this light, biomass gasification can be seen as a formidable technology to additionally bring impetus to rural electrification. Besides, its simplicity with respect to operation and efficiency should not be underestimated. The diffusion of this technology would in a way reduce the waste management challenges battling most of these communities.

The benefit of biomass generally among others and in Ghana in particular, includes the following: it is environmental-friendly, ecological, economical, and it's a renewable source. The issue of employment can also be addressed, since bioenergy industries in any community would definitely create some lucrative opportunity for employment. The prospects for biomass gasification are very bright, and moreover its challenges in commercialization and implementation are indeed pretty high. That is why enough feasibility studies and conceptualization of any project should be exceedingly embraced.

A stagnant energy leads to a definite stagnant economy and globally most of the industries are looking for economies with a stronger energy network to invest in, and also, looking specifically for a cheap and cleaner energy source for production. This thesis showed that there is more than enough biomass material and fuel for this technology as discussed in chapter 3 for energy production.

And moreover, for any biomass gasification project to be very successful rurally, then the connection between agricultural and electricity should be harmonized, for the establishment of unique sustainability.

6.1 Recommendation

At the moment biomass gasification remains a viable alternative for rural electrification with respect to an integrated energy programs. This presupposes that, for this technology to be successful for a large scale commercialization, the underneath recommendations in retrospect would have to be considered.

- The policies discussed extensively in chapter 5 would have to be undoubtedly formulated with respect to biomass gasification and commercialization. Furthermore, having these policies alone in a way cannot ensure the success of biomass gasification. But, implementation mechanisms would have be introduced to guarantee a desirable accomplishment.
- The existing energy policies also need to be visited, and the prices revised to actually reflect the exact of amount of energy production. The dissemination of this technology may face following obstacles: energy pricing, distribution and finally the generation.
- On the other hand, the technology should not be very complicated because of the position of the gasifier. Since the rural community will fully participate in the success of the technology, some kind of minimum technical responsibility would be demanded from them to feel integrated. The complicatedness of the technology would shrink their participatory abilities.
- Again, the technology in should have this characteristics of easy operation. This is moreover important for biomass gasification for rural electrification. The people in the neighborhood might as well be responsible for the plant and its operation. This is the reason why technology easy to operate will be accepted.
- The installation of the plant and the technology entirely should be easy. This is because of the rural settings and access roads to some of these communities is extremely challenging. Owing to this the installations

should not take much time and traveling distance for electrification to commence.

- Finally the technology should be economical, just so that the communities can pay for services and maintenance of the plant with and without some help from the government money-wise. This would ensure the longevity and sustainability of this project.

6.2 Limitation

The inability to get a case company for information, facts and figures directly to an extent brought limitations to this study. However, with the help of the literature search the study was able to present a frame work for biomass gasification for rural electrification in Ghana.

Additionally, in future I would like to work together with a case company here in Finland or anywhere who are directly into biomass gasification to facilitate with some technical knowhow, information to further ascertain the chemical composition of some biomass feedstock' from Ghana. That would help to identify the reactor type to use for rural electrification.

7 REFERENCES

A, D. (1998). Financing mechanisms for renewable energy. *Renewable energy*, 211-214.

A, S.;& J, S. (2010). Financing energy efficiency in developing countries- lessons learned and remaining challenges. *Energy policy*, 5560-5571.

A.K, R. (ei pvm). Biomass gasification. 1-20.

AV, B.;AACM, B.;& K, S. (1999). *New solution in energy supply, an assessment of the possibilities for transfer of European biomass gasification technology to china.* Luxembourg: office for official publications of the European communities .

Brown, T.;& Sutter, T. (2012). *8th Edition Marketing Research.* Mason, South-Western Publishing.

Dalili, S. (ei pvm). Opportunities and barriers for efficiency and sustainability. *Biomass gasification and pyrolysis*, 233-264.

Fanchi, J. R. (ei pvm). *Biomass energy and Energy conversion in the 21 centry.* World Scientific Publishing Company, Incorporated.

Gubina, A. F.;Xiangyang, X.;& Zhengmin, S. (2006). nalysis and Support Policy Recommendation of Renewable Energy Sources in Western China. *International Conference on Power System Technology 2006.* IEEE.

J, D. (1995). Financing the energy sector in developing countries. *Energy policies*, 929-939.

J.P, C.;& J.J, M. (2002). Benchmarking biomass gasification technologies for fuels,chemicals and hrdrogen production. 1-24.

Ladanai, S.;& Vinterbäck, J. (2009). *Global Potential of Sustainable Biomass for Energy*. Uppsala 2009.

M.H, D.;Gu, S.;& E.B, H. (2011). Renewable and Sustainable Energy Reviews. *A comprehensive review of biomass resources and biofuels potential in Ghana*, 404-415.

Quaak, P.;Knoef, H.;& Stassen, H. (1999). *Energy from biomass, A review of combustion and gasification technologies.* Washington DC: World Bank Technical Paper no. 422.

S, D. (2011). Energy for Sustainable Development. *Potential of biomass energy for electricity generation in sub-SaharanAfrica*, 203-213.

Siti Indati, M.;Leong, Y. P.;& Amir Hisham, H. (ei pvm). *Issues and Challenges of Renewable Energy Development: A Malaysian Experience.* Selangor.

Wenngenmayr, R.;& Buhrke, T. (2008). *Renewable energy, sustainable energy concept for the future.* Frankfurt: WILEY-VCH Verlag GmbH & co. KGaA.

http://www-tnswep.ra.utk.edu/activities/pdfs/ha-ma-W.pdf

http://pontianakbiomass.wordpress.com/2011/10/17/what-is-biomass/

http://science.howstuffworks.com/environmental/green-science/landfill3.htm

http://www.ejnet.org/landfills/

http://alternativefuels5.tpub.com/3709/37090003.htm (alcohol

http://earthsciencebiomass.tripod.com/id6.html

http://www.esru.strath.ac.uk/EandE/Web_sites/03-04/biomass/background%20info4.html

http://www.earthpeace.com/Biomass/BiomassTypes.htm http://pontianakbiomass.wordpress.com/2011/10/17/what-is-biomass/

http://www.sussex.ac.uk/research/news/?id=7198