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ANALYSIS OF BIOMASS WASTE POTENTIAL FOR ELECTRICAL ENERGY GENERATION IN GHANA

Business Economy and Tourism

2010

VAASA UNIVERSITY OF APPLIED SCIENCES

Bachelor Of Business Administration In International Business

ABSTRACT

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Topic	Analysis of Biomass Waste Potentials for Electrical Generation in Ghana
Year	2010
Language	English
Pages	77
Name of supervisor	Adebayo Agbejule

In order to attain economic growth and development, all the world's economies had placed greater emphasis on renewable energy development and production. This had led to the advancement of technologies to invent conversion machineries that could transform biomass residues into electrical energy. Ghana is a typical West African country that produces large quantity of biomass residues that could be effectively utilized for the production of electrical energy.

The goal of this thesis/research is to contribute to a sound energy market that would provide sufficient, viable and efficient energy services for the economic development of Ghana and other African countries through the formulation of a comprehensive program that would identify the optimal path for the development, exploitation and proficient management of biomass-energy resources available to the country and the needed technological means to convert them into electrical energy.

Among the various sources of Biomass residues, this research is specifically focused on five main agricultural wastes due to the nature of biomass diversities and also because it's the most produced in the country. These sources include sawdust, palm-kennel, cocoa pods, coconut shell, and sugarcane waste. Data was collected by conducting many comprehensive interviews with officials from the ministry of food and agriculture, the Energy commission of Ghana, Bonsu Agricultural Institute of Ghana and also with farmers, wood workers and other whose fields are within the study criteria. Information used are from well known organizational sources and their internet sites, such as the UNEP, US.EIA and other similar well known site as aids for calculating and converting the material sources into electrical energy (KWH).

Keywords: Analysis of Biomass, Waste potential, Energy Generation, Electricity

VAASAN AMMATTIKORKEA OULU
Koulutusohjelma Kansainvälisyys

TIIVISTELMÄ

Lähettäjä	Okaine William Nii Tackie
Aihe	Biomassaenergian tuotannon ja teknologian (Ghanassa)
Vuosi	2010
Kieli	Englanti
Sivut	77
Nimi ohjaajan	Adebayo Agbejule

Taloudellisen kasvun ja kehityksen Saavuttamiseksi, jokainen talousalue ympäri maailman asettaa enemmän huomiota energian tuotantoon ja kehittämiseen. Yksi tällainen energian kehityksen keino on biomassan käyttö sähköenergian tuottamiseksi. Ghana on maa, joka tarvitsee sähköenergiaa ja omaa paljon biomassaresursseja.

Opinnäytetyöni tarkoituksena on analysoida erilaisia mahdollisuuksia käyttää biomassaa teknologisesti muuntamalla sähkön tuotannon kehittämiseen. Minun tavoitteenani on myös etsiä ja laskea sähkön kokonaismäärä, joka voisi muodostua näistä varoista.

Olen käyttänyt hyväksi viisi keskeistä maatalouden jätettä ja niiden mahdollisia resursseja: kämmen-kennel? kaakaos-kuori, kookos kuori, sahanpuru ja sokeriruo'on jätet. Keräsin tietoa suorittamalla paljon haastatteluja, elintarvike-ja maatalousministeriön-, energia komission ja maatalouden instituutin henkilöstön kanssa Ghanassa. Käytin myös Internet-pohjaista UNEP, US.EIA-järjestelmää laskemaan minun avainsanojani

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Avainsanat: analyysi biomassajätteestä, mahdollisuudet, Sähköenergian

AKNOWLEDGEMENT

I'm heartily thankful to my supervisor, Professor Adebayo Agbejule, (Doctor of Science Economics and Administration) whose encouragement, guidance and support from the initial to the final level enabled me to develop an understanding of the subject. I appreciate his guidance and supervision very much.

Not forgetting also is Mr. Emmanuel Ndzibah, (principal lecturer in international marketing and management VAMK) whose advice and support has aided in successfully completing this thesis. I'm also grateful to all my teachers, friends, family member and all those who might have helped me in diverse ways to bring this long journey to a successful end. I ask for God's blessings for all.

Lastly I give the greatest thanks to the Almighty and insurmountable one, Jehovah God, for his guidance, protection, life sustenance, good health and help that facilitated in bring this long lasting objective into its successful accomplishment.

Thanks to you all!

Vaasa University of Applied Sciences

June, 2010.

Okaine William Nii Tackie

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1. INTRODUCTION

1.1. Background

Ever since the earliest inhabitants on earth, biomass in the form of burned wood in campfires for heat has been the main source of energy for meeting human needs. Today, Biomass is one of the well-known renewable energy sources for many people and industries. Using biomass for energy can have many benefits, some of which includes cutting back on waste accumulation and support for agricultural products grown round the world. Unlike other sources of energy, biomass fuels have lots of benefits both to humans needs and also to the environment, even as will be explained later.

By general definition, biomass is the organic matter in trees, agricultural crops, living organisms, humans, animals, plant materials and organic compounds used to produce heat or to generate electricity. In a simpler term biomass is plant materials and animal waste used as fuel or to generate energy.

Energy is a major requirement of every human need. For many millenniums man depended on the suns energy for warmth and light. Later when man discovered fire, it became the only controllable form of energy for many thousands of years. Today, thanks to scientific discoveries and improvements energy comes in many different forms and sources. Modern day scientific discoveries and technologies varies from simple forms of energy like coal to complex systems like electricity, ethanol, geothermal, hydropower, municipal solid waste, natural gas, nuclear, petroleum oil, photovoltaic, solar thermal, wind, to mention just a few.

Energy aids in all aspect of life and has been a major source of economic growth and development. According to the economists and energy developers, there is a direct link between energy use, economic growth and standard of living. One major problem about energy unfortunately has been that, it appears as if very little ever comes at a cheap price today. Electrical power, connected to our homes, through the local electrical plant, is becoming more and more costly. The more comfortable you would like your home to be, the more money you need to

compensate for it. Thus the cry of many has been to shift from their present costly source of energy to a less expensive source. Discussions on how to achieve this achieve this has been a hot topic for consideration both by energy users and energy developing scientist. Thanks to modern scientific improvement and technological advancement, the solution is right here with us in what is term as the renewable source of energy.

Renewable Energy Development is continually increasing in many forms and different ranges, erupting from a simple know-how source to a complex and incomprehensible systems, sources and development. Despite the diverse sources of energy development, most are obscure to especially those in the less developed and developing countries. The benefits of these ever increasing technologies in energy development have helped many to cut down cost on energy consumption and have thus contributed to savings and better living conditions.

There are various sources of biomass that could be used for the production of electrical energy. These may include sources like forest wood, crops wastes, cocoa and coconut chaffs, municipal manures, some garbage, etc. These are usually burnt to produce steam for electricity generation, or to provide heat to industrial housing and homes. In the United State and other part of the world for example, many manufacturing plants in the wood and paper products industry use wood waste to produce their own steam and electricity. This has resulted in money savings since these companies needed not to pay for waste disposal and don't have to buy much electricity as they use their own waste produces.

1.2. Aim of the thesis

The goal of this thesis/research is to contribute to a sound energy market for all investors and to provide sufficient, viable and efficient energy services for the economic development of Ghana. This is to be achieved through the formulation of a comprehensive program that would identify the optimal path for the development, exploitation and proficient management of biomass-energy resources available to the country and the needed technological means to convert them into electrical energy.

My main targets for the supply of the biomass renewable energy will depend on the quantity of resource and the region of supply. The following are my potential customers companies, industries, woodworks, mining sites, manufacturers, communities, individual, regions and or the country as a whole should there be enough material supply. Calculations and conversions of the material sources into electrical energy supply in kilowatts per hour will help determine the quantity in supply and the potential beneficiaries.

The Main goal of the dissertation is centred on the subject: Analysis of Biomass waste potential for electrical energy generation in Ghana. It's noteworthy to know that Bio-waste is the second most flourishing source of energy to the solar in Ghana. Yet, due to lack of proper management, ineffective control systems and the lack of technological knowhow this important sources of energy goes waste. Instead of its benefits in generating energy and income, these important wastes materials rather causes havocs to the inhabitants of the country. Proper management and effective use of these wastes can benefit the whole country while else improper management or use can have a hazardous effect on the inhabitant. The answer as to how these wastes could be turn into beneficial end product is almost obscure to all. That is why I have taken the trouble to research into this field and find the most potential sources, quantity, location and the technological means available in converting them into electrical energy.

1.3. Research Questions of the Thesis

At the end of this research work, answers to the below questions should be obtained. These questions are to serve as guidance during the research work and data accumulation.

Q.1. What are the potential sources of Biomass in Ghana?

Q.4. How to convert biomass materials into electrical energy?

Q.3. What are the potential Biomass Technologies available for Ghana?

Q.2. How much residues/electricity could be obtained from each /total of all?

The above questions give a pretty fair idea concerning the objective of the research work. Aside these main focal point questions, I have developed a total of 20 secondary questions sub divided into two, named (1) main questionnaires, intended for particular governmental official and (2) minor questionnaires, intended for the field workers or people with little less knowledge about the subject area.

1.4. Target and Limitation of the Thesis

Though there are numerous biomass sources mainly categorised into four main groups; agricultural wastes, forest wastes, urban wastes and animal wastes, due to the broadness on the subject and the diverse nature of it, I will like to focus mainly on the agricultural residues. And under the various sources of agricultural wastes/residues, this research work will be limited to the following five sources; coconut-husk, cocoa pods, palm kennel, sawdust and sugarcane wastes, due to the following reasons:

- That the above mentioned are the main sources of biomass in Ghana
- The availability of Technology to support those sources in Ghana
- Challenges and difficulties that might be imposed in researching on all the other sources at present
- Lack of knowledge on those other sources and therefore room for further research

The reason the research was limited only to Ghana was also due to the below reasons:

- Unfamiliarity with other countries.
- The broadness of the subject
- Country of origin (researcher’s nationality)
- The present energy crises of Ghana

Further studies will be to consider the other three categories of biomass sources, quantity, location and total waste and energy it could generate. Other countries in Africa could also be good potential biomass material country sources where biomass materials may be located. And since technology is diverse and always advances, others technologies advancement and available for energy conversion could be a point of target for further works.

2. THEORETICAL FRAM WORK

2.1 Types of Biomass Residues

There are many types of biomass all categorised into four main groups even as briefly touched on above. These groups are: Agricultural wastes, forest wastes, animal and urban wastes. These main groups could be regrouped into six different areas on a brother basis even as illustrated in figure 1 below.

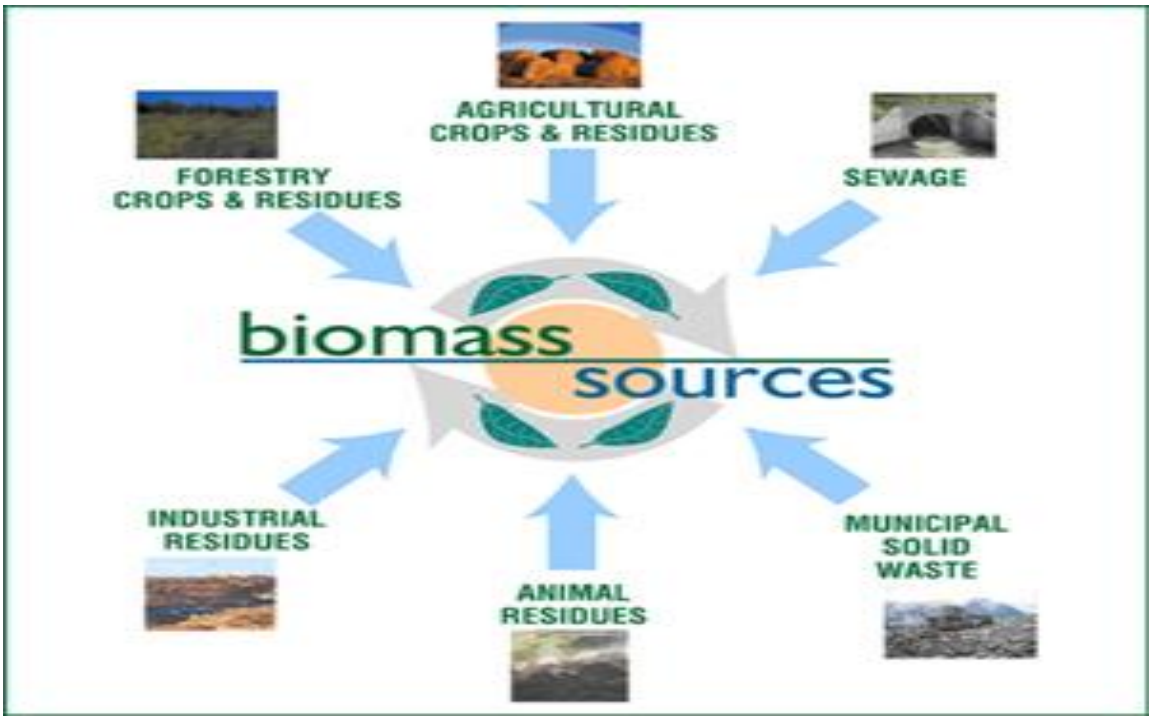


Figure 1.Sources of Biomass

2.1.1 Agricultural Wastes

Agricultural wastes are in wide ranges and varieties and the most appropriate energy conversion technologies and handling protocols also varies from one type to another. The most significant division in agricultural wastes is between those residues that are predominantly dry and those that are wet.

I. Dry residues

These are usually those types of crops cultivated not to be used for the primary purpose of producing food, feed or fibre, etc like straw, corn stover, poultry litter etc. Such residues are mostly intended for direct use as for production of energy or other similar uses.

II. Wet residues

These include those residues or wastes that have high water content as collected. This makes them energetically inefficient to use for combustion or gasification (energy conversion technologies), and are generally financially and energetically costly to transport. It is therefore preferable to process them close to production, and to use processes that can make use of biomass in an aqueous environment. Typical wet residues may include: Grass silage, animal slurry and farmyard manure. A great deal of draining is needed in getting the water out before combustion.

Many agricultural crops and processes yield residues could be used for energy applications in a number of ways. Sources include:

- Arable crop residues such as straw or husks
- Animal manures and slurries
- Animal bedding such as poultry litters
- Most organic material from excess production or insufficient market, such as grass silage etc.

2.1.2. Forest Wastes

Forest wastes or residues are the portions of the trees that remain on the forest floor or on the landing as a result of slashing or after logging operations have taken place. Forest wastes consists mostly of tree branches, tops of trunks, stumps, branches, leaves, foliage and damaged trees that are not merchandise, wood and bark residues accumulated during wood manufacturing in industries etc. The various types are as listed below:

I. Logging Tops

This is the unmarketable upper portion of the stem. The top is typically a stick about 16-18 feet in length with a diameter of 7 inches at the base.

II. Culls

Culls are that portion of each year's growth of saw timber harvest that is classified as defective and cut and left in the woods. The cull tree does not contain at least 25 percent sound wood in a merchantable saw-log now or prospectively because of defect, rot, or species.

III. Pre-commercial Thinnings

This residue material comes from timber stand improvement and is generally round, densely stocked stands.

2.1.3. Animal Waste

The potential biomass from animal waste includes primarily waste from intensive livestock operations, from poultry farms, pig farms, cattle farms and slaughterhouses. Animal wastes are another form of biomass that is being well known for energy generation. The amount of animal waste residues depends on the type and size of the animal and the number of animal population and animal density for one location. Animal residues are generally used as fertilizers. This does not hold up any system of converting animal residues into energy.

2.1.4. Urban waste

Urban wastes are basically grouped into two types, municipal refuse that offer opportunities for energy recovery: (i) municipal solid waste (MSW) like urban refuse and garbage. (ii) bio-solids like sewage and sludge (usually as a result of industrial waste). Urban wastes may include waste wastewater from industries and manufacturing firms etc processed for energy production, and solid waste recovery from recycling biofuels for energy production.

Even as analysed above, biomass sources are large in variety and in many categories, however for the purpose of this thesis, the research done is limited mainly to that of agricultural wastes and wood as in the form of sawdust.

http://www.calrecycle.ca.gov/Organics/Conversion/AgForestRpt/Forest/

2.2. Some Facts to Consider about biomass

- Biomass supplied almost six times the energy of geothermal, solar and wind energy sources combined round the world.
- Globally, biomass meets about 14 percent of the world´s energy needs.
- In the United State, Biomass sources provide about 3 percent of all energy consumed
- Biomass supplies about 9 percent of all industrial energy consumed in the state alone.
- About 2.5 billion people – almost half the earth's population - are virtually dependent on biomass for their cooking, heating, and lighting.
- In the United States, biomass contributes about 4% of the primary energy nearly as much as nuclear power.

2.3. Overview of case country (Ghana)

The Republic of Ghana is a West African country with Accra as its capital town. It has an Area size of 238,533 sq km (92,098 sq miles), a population of 23.8 million (2009) and a GDP of $ 40 billion.

Ghana was the first place in sub-Saharan Africa where Europeans arrived to trade - first in gold and others later. It was also the first black African nation in the region to achieve independence from a colonial power, in this instance from Britain.

Figure 2.Location of Ghana on an African map

The country is rich in mineral resources like gold, diamond, bauxite, etc. no wonder it used to be called ‘the Gold-Cost’. It is also endowed with both natural and forestry resources like fertile land, rivers, sunlight, timber, cocoa share butter etc. Figure 2 above shows the location Ghana on an African map.

The focus of this thesis is to help such a worthy developing countries like Ghana to take advantage of the various technological advancement in turning its vast biomass waste produce into electrical energy for the benefit of its inhabitants, investors and other all other interested parties.

Almost every countries round the globe produces some amount of biomass waste that could be used to generate some amount of energy. In most African countries such as Ghana, the quantity of such waste production and accumulations are incredibly marvellous. In most developed countries these wastes are easily converted into useful end products such as recycling or for the production of energy. On the other side, most of these useful wastes go unused in underdeveloped or developing countries due to lack of technological know-how on turning these wastes into valuable use such as electricity etc. Thus the question as to who and how these huge biomass wastes could be effectively used and managed is where my research topic comes in, as in analysing the biomass waste potential for electrical energy generation. Of course it’s particularly for Ghana but the result could be beneficial for other countries.

Though the general idea behind this research work is to put into good use and effective management the mass waste production mainly by turning them into electricity production, the main focus and interest will be concentrated on the biomass sources, the various potential technologies available for conversion and the calculation of the material sources into electricity. Benefits may include solving the present energy crises in the country, bring investment and income, introduce conversion technologies and to solve the huge piles of unused bio wastes that might have havoc effect on the inhabitants

2.4. Background Studies

A background studies shows that much work had not been done on the analysis of biomass waste for electrical energy production in Ghana. One such attempt on finding the various sources of biomass waste in Ghana was made by Atakora from the Kumasi Institute of Technology and Environment (KITE). And though he touched on mainly some agricultural residues, his research was mainly limited to the Ashanti region; mainly Kumasi. Though he stated in his research that biomass is the most usable or perhaps the most important and cheapest source of energy for Ghana, his work came to a halt and no further action was taken up after he bequeathed the school. His work therefore served no useful purpose since it had been kept in the archive of no use. Many similar attempts by others had failed. The field of biomass residues for energy production had therefore been a potential region almost unattended needing exploration. This topic is therefore fitting in exposing the country's biomass potentials

Atakora S. B., Brew-Hammond A.1999, Availability of Wood Residues for Cogeneration in Ghana

KITE, 1999, Energy Use in some peri-urban areas in Kumasi

In recent years, the Energy commission of Ghana had made some effort to find useful information pertaining to the consumption of different forms of energy in the country and in this, the field of wood fuel as a source of biomass energy was taken into consideration even as we shall see later. The above mentioned are the main works done as far as biomass in Ghana is concern, otherwise all other efforts had proved futile. In most recent years the area of biomass had become a hot topic with little or almost no immediate actions on the part of the interested participants.

2.5. The present energy system of Ghana

The energy sector of Ghana is broadly divided between demand for energy and supply of energy to the economy. The strategic national energy plan and policy recommendation (SNEP) draft, therefore divided the Ghanaian energy sector into two volumes to facilitate ease of discussion:

Volume one covered the Demand Sector of the Economy, namely Residential (household); Commercial and Services; Agricultural and Fisheries; industry and transport.

Volume two covered the supply side of the energy sector, namely electricity, petroleum, woodfuels, and renewable.

Ghana's known renewable energy sources are wind, biomass, solar and hydro, discounting traditional woodfuel (biomass). Ghana's renewable energy resources are largely untapped except for the large hydropower plants of Akosombo and Kpong.

The development of the country's renewable energy sources has been seen as a credible option that has the potential of relieving the energy needs of the poor and securing the country's energy supply. Over the years, solar energy has been used for electricity production, crop drying and water heating.

An example is a survey of villages fitted with stand-alone solar home systems for lighting, radio and television, round the year 2001 and 2002. The outcome of that survey compared with the period before the solar projects was initiated shows that;

- More than 50 percent of the adults could now watch television and listen to radio or play cassette
- Television acquisition of solar home systems (SHS) has increased threefold. Commercial activities in the evening have increased by 30-50 percent.
- And emergency health cases like child delivery could be well attended to at night in lighting and preservation of vaccines improved with solar electric refrigeration.

Biomass based energy is mostly untapped, apart from the direct use wood as firewood and charcoal; otherwise its exploitation is very limited to Ghanaians. Biomass used for the generation of electricity, biogas or liquid fuels remains largely untapped in Ghana. Some biomass-fired co-generation projects have been

implemented in the oil-palm industry, but there underutilized. Two key factors have hindered their exploitation especially in the wood processing industry, though there are potential benefits of it. The first of such potential benefit unutilised is the prospective co-generators that have access to lower cost grid power. Secondly, there are virtually no financial or fiscal incentives neither are there a regulatory framework that would encourage them to generate and sell electricity to grid.

Though biomass technology has partially been demonstrated for cooking in households, direct lighting, small power generation and bio-sanitation, it general use on such basis has not been so successful. In addition, most of the household biogas plants built in the country have been abandoned due to lack of skilled biotechnology technicians to repair them. A very interesting development in the use of biogas technology however, has been in the area of bio-sanitation projects for schools, slaughterhouse, hospitals etc. These has led to the development of bio-latrines and biogas from sanitation wastes is also being piped to kitchens for used as cooking fuel in only three mission hospitals in the whole country.

Biomass in the form of Wood-fuel, account for more than 60% of the total energy used in Ghana even as illustrated in figure 3. Wood fuel is the main source of traditional energy in Ghana for most rural and even urban households. The bulk of the country's primary energy supply comes from wood, i.e. biomass. 14-16millon tones of wood were consumed as fuel annually between 2000 and 2004. According to the SNEP, wood-fuel is renewable and sustainable and thus supply could be increase to meet demand.

Wood-fuel provide the bulk of the energy needed for most informal enterprises such as bread-baking, processing of oil-palm, brewing of local drinks, tobacco curing, traditional textiles (tie and dye, batik), traditional soap making, fish smoking etc.

The wood subsector is the only energy subsector where cooking appliances and almost all the production equipment with the exception of the chainsaws are produced locally. It is estimated to contribute about 2 percent of the Gross

Domestic Product and indirectly supports the livelihood of over three million Ghanaians who mostly engaged in the informal, commercial and service sectors. The Pie chart below shows the percentage of different energy consumption in Ghana.

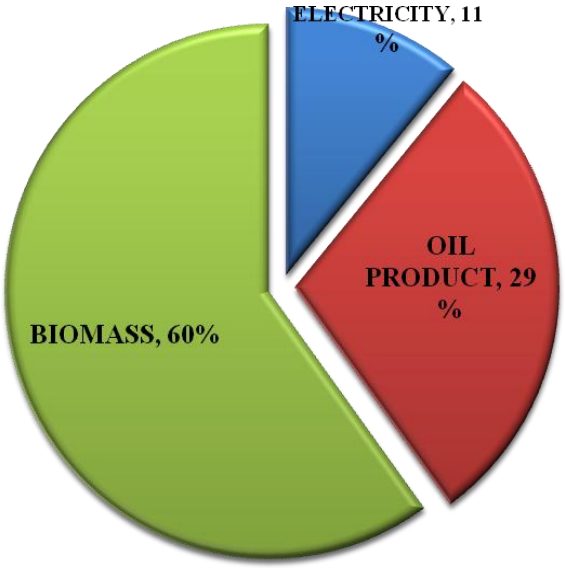


Figure 3. Energy consumption proportions in Ghana

According to SNEP, the demand for energy consumption in Ghana is on the increasing. A report from the Energy Commission of Ghana 2006, on the Strategic National Energy Plane 2006-2020 shows an incredulous rising demand for energy. It has been estimated that should the Ghana Poverty Reduction strategy (GPRS) targets to usher the country into the middle income rage of US $1000 per capita income by 2015 be realized, the total energy demand will increase from 6,900Gigawatts-hours to 18,000225 by 2015 and reaching about 24,000Gigawatts-hours by the year 2020. This aggravated demand for energy calls for an increase in energy sources and development. Already the present, production and supply of energy in the country is very low, causing the country to run into energy crises causing frequent power outs. The need for modern energy provision technologies has therefore become important issue for the provision of

categories of energy sources that will capacitate the present energy crises. According to professor Bartholonew Arma (Economic Analysis of Energy sector, in Ghana) the demand for wood fuels alone will grow from 38-46millon tones by 2012 to 54-66millon tones by 2020 and would put the nation's dwindling forest under undue stress which could culminate into serious deforestation, with serious consequences on climate changes, agriculture and water havoc if no significant action is taken.

(Strategic National Energy Plan, Energy Commission of Ghana; 2006. pages 1, 3&4)

The impending disaster mentioned above implies that there should be an alternative option energy availability to supplement the consumption of the wood-fuel energy source. It's most agreeable that though there are various energy sources, the cost for developing, maintaining and using many such sources could be extremely high. This therefore calls for the need to develop a more affordable source of energy for such developing country like Ghana.

Analysing from the above means that the wisest option to bring the most suitable solution for the resolution of all the above mentioned impending disaster means to develop and implement biomass energy technology into the country to substitute the hydroelectric power and wood-fuel energy sources. Biomass is already flourishing all over the country to the extent of causing hazardous impact to some inhabitants in certain communities. The introduction of biotechnology will therefore decrease the impact of the demand for wood-fuels on the forest and thus no need to be overly distressed about the above mentioned impending devastation on the wood forest. In addition investing into the bioenergy field will aid in dissolving the present energy crises and obviously also fetch the country and investors some money.

2.6. Future Demand for Energy

Figure 4 below is SNEP's forecast on energy demand for Ghana from 2010 until 2020. Even as the figure vividly illustrates, the absence of any action to resolve the energy problem could result in economic breakdown and thus a devastating result on the whole country. This may halt activities of industrial and

manufacturing firms who use electricity as their means of energy for the production of goods. This will lead to no other option than could lead to will lead to a halt in the manufacturing firms, industries and other will have to close down or movie to a location where energy dependency will be more reliable. Which means people will lose their jobs, thus creating unemployment, which will lead to less or no savings, low per capita income and thus low or no development.

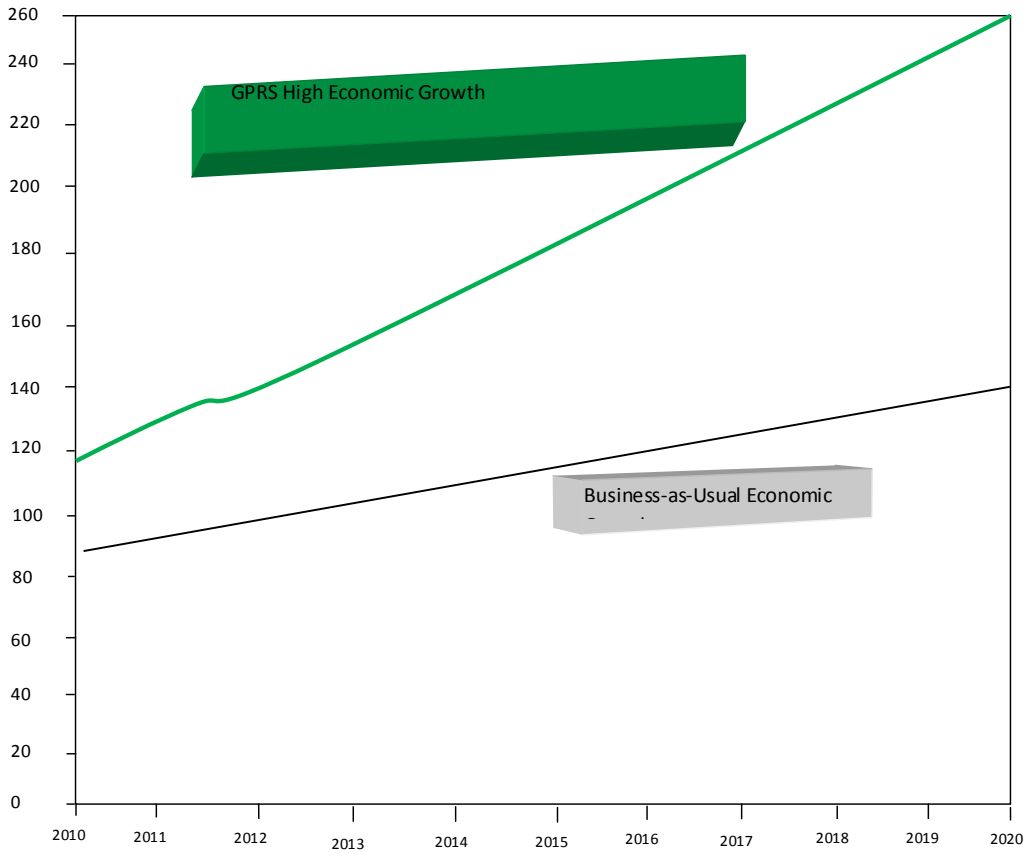


Figure 4. Ghana future energy consumption forecast from 2010-2020

We could ascertain from figure 4 above that the demand for energy by the year 2020 will be incredibly high and thus the need for additional energy sources or development wouldn't be an option, but a must. If this is not done, as mentioned earlier, the country is certain to be in a serious devastation

As was noted from figure 3 above, about 60% of the country's population (about 14,000,000) uses wood fire as their heating system, though mostly for cooking.

All the same such an archaic system of using biofuel is causing havoc to the environment causing the wood forest to dwindle at a very high rate. Most of these users have admitted that they would prefer a more comfortable and modernize form of energy, only at a cost cheaper than what the country's hydro electric power supply system is charging. In addition, it has been estimated that an additional 15-20% more are likely to change their present energy system to the biomass electrical energy system due to the ever increasing electricity rate and its inconsistency. Now we are certain to conclude that an estimated 2/3 or more of the country's present population will likely be using biomass electrical energy system by 2020. And this percentage would have increased at a rate of 1/3 by that same year. Thus the demand for energy and especially the alternative biomass electrical energy will be incredibly high. The reason may be due to its consistency, affordability and reliability.

3. CONVERSION TECHNOLOGIES AVAILABLE

Advancement in modern day technology had made it possible to do the unthinkable in today's world. As we will soon come to know, scientists have invented various forms of energy conversion technologies that could be used to convert biomass residues into different forms of energy. It varies from simple systems to a more incomprehensible complex system. For example, the energy content of waste products can be harnessed directly by using them as a direct combustion fuel, or indirectly by processing them into another type of fuel. This can be done by recycling through thermal treatment, ranging from using waste as a fuel source for cooking or heating, to fuel for boilers to generate steam and electricity in a turbine. E.g. Pyrolysis (decomposition of complex molecules by heating) and gasification (to convert a solid or liquid into gas) are two related forms of thermal treatment where waste materials are heated to high temperatures with limited oxygen availability. The process typically occurs in a sealed vessel under high pressure. Pyrolysis of solid waste converts the material into solid, liquid and gas products. The liquid and gas can be burnt to produce energy or refined into other products. The solid residue (char) can be further refined into products such as activated carbon. Gasification and advanced Plasma (a hot ionized gas) are used to convert organic materials directly into a synthetic gas (syngas) composed of carbon monoxide and hydrogen. The gas is then burnt to produce electricity and steam. Figure 5, below illustrates how the whole process goes.

Various technologies exist in today's world for the conversion of biomass residues to generate power, heat, and fuels. Many of such known technologies exist in commercial quantities whiles a minute fraction are piloted or used in the field of research and development. As new technologies and processes develop, there becomes the need to monitor its progress in order to determine its potential applications for biomass expansions.

Bioenergy comes in different forms. It may be in solid, liquid, or as in gaseous fuels.

Liquid fuels can be used directly in the existing road, railroad, and aviation transportation network stock, as well as in engine and turbine electrical power generators. Solid and gaseous fuels can be used for the production of electrical power from purpose-designed direct or indirect turbine-equipped power plants. Chemical products can also be obtained from all organic matter produced. Additionally power and chemicals can come from the use of plant-derived industrial, commercial, or urban wastes, or agricultural or forestry residues. Biomass resources are categorised into primary, secondary and tertiary depending on its source.

Primary biomass resources are produced directly by photosynthesis and are taken directly from the land. They include perennial short-rotation woody crops and herbaceous crops, the seeds of oil crops, and residues resulting from the harvesting of agricultural crops and forest trees (e.g., wheat straw, corn stover, and the tops, limbs, and bark from trees).

Secondary biomass resources result from the processing of primary biomass resources either physically (e.g., the production of sawdust in mills), chemically (e.g., black liquor from pulping processes), or biologically (e.g., manure production by animals).

Tertiary biomass resources are post-consumer residue streams including animal fats and greases, used vegetable oils, packaging wastes, and construction and demolition debris. The various conversion technologies known for the conversion of biomass residues into energy are as discussed below. The figure 12 below shows a diagram, giving an overview of the various Biomass conversion process.

Bioenergy Conversion Processes overview

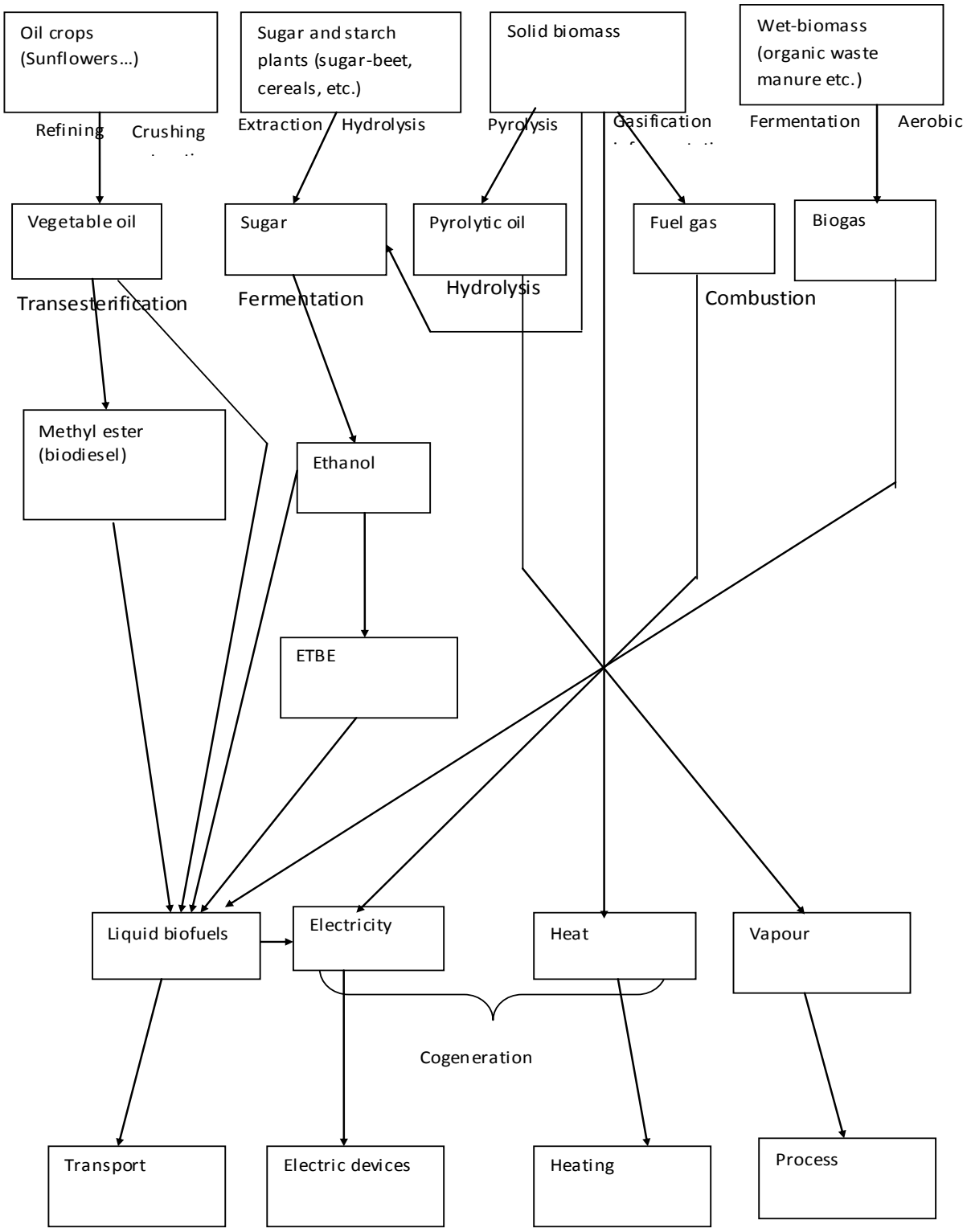


Figure 5. Accumulated sugarcane for alcohol production and waste burning

The following are some modern day technologies available that can be adapted and used in Ghana for the development and conversion of biomass residues into electrical energy.

3.1. Biomass for Power and Heat

3.1.1. Combustion

Combustion is a technology that converts renewable biomass fuels to heat and electricity using processes comparable to those employed with fossil fuels. At present, the primary approach for generating electricity from biomass is combustion direct-firing. Combustion systems for electricity and heat production are similar to most fossil-fuel fired power plants. The biomass fuel is burned in a boiler to produce high-pressure steam. This steam is introduced into a steam turbine, where it lows over a series of turbine blades, causing the turbine to rotate. The turbine is connected to an electric generator. The steam lows over and turns the turbine. The electric generator rotates, producing electricity. This is a widely available, commercial technology. Combustion boilers are available in different designs, depending on application and biomass characteristics. The main options are to burn the biomass on a grate (fixed or moving), or to fluidize the biomass with air or some other medium to provide even and complete burning. Steam turbine designs also vary in terms of their application. To maximize power production, condensing turbines are used to cool steam.

3.1.2. Combined Heat and Power

In general biomass-fired steam turbine plants are located at industrial sites that have a steady supply of biomass available. These may include factories that make sugar and/or ethanol from sugarcane at pulp and paper mills. At these sites, waste heat from the steam turbine can be recovered and used for meeting industrial heat needs and further enhancing the economic attractiveness of such plants. Referred to as combined heat and power (CHP) facilities (also called cogeneration facilities), these facilities are highly resource efficient and they provide increased levels of energy services per unit of biomass consumed compared to facilities that generate power only.

Conventional thermoelectric stations convert only about one-third of the fuel energy into electricity. The rest is lost as heat. The adverse effect on the environment through wasteful use of power, particularly detrimental in light of rising fuel costs means that the efficiency of thermoelectric stations must be increased. CHP provides more efficient production of electricity, where more than four-fifths of the fuel's energy is converted into usable energy, resulting in both economic and environmental benefits. Cogeneration is the consecutive (simultaneous) production and exploitation of two energy sources, electrical (or mechanical) and thermal, from a system utilizing the same fuel. CHP could be applied to industry in West Africa where there is simultaneous demand for electricity and heat.

In most West African countries, there is also significant need for cooling (including refrigeration and air conditioning). Heat from a CHP plant can be used to produce cooling via absorption cycles. At present, most biomass-fired power plants rely on low-cost (or no-cost) biomass residues. In African countries and particularly Ghana, given the breadth of sugarcane processing industries, significant opportunities exist, particularly for steam-based CHP generation.

3.2. Biogas

3.2.1. Gasification

Like coal, biomass materials can be a cumbersome fuel source because it is a solid. By converting biomass into a gas, it can then be made available for a broader range of energy devices. For example, biomass-sourced gas can be burned directly for heating or cooking, converted to electricity or mechanical work (via a secondary conversion device such as an internal combustion engine), or used as a synthetic gas for producing higher quality fuels or chemical products such as hydrogen or methanol.

Gasifiers operate by heating biomass in an environment where the solid biomass breaks down to form a flammable gas. The biogas can be cleaned and filtered to remove problem chemical compounds. The gas can be used in more efficient power generation systems called combined-cycles, which combine gas turbines and steam turbines to produce electricity.

3.2.2. Anaerobic Digestion

Anaerobic digestion is a commercially proven technology and is widely used for recycling and treating wet organic waste and waste waters. It is a type of fermentation that converts organic material into biogas, which mainly consists of methane (approximately 60%) and carbon dioxide (approximately 40%) and is comparable to landfill gas.

Similar to gas produced via gasification above, gas from anaerobic digestion can, after appropriate treatment, be burned directly for cooking or heating. It can also be used in secondary conversion devices such as an internal combustion engine for producing electricity or shaft work. Virtually any biomass except lignin (a major component of wood) can be converted to biogas, including animal and human wastes, sewage sludge, crop residues, industrial processing by products, and landfill material.

The conversion of animal wastes and manure to methane/biogas can yield significant health and environmental benefits. Methane is a greenhouse gas (GHG) that is 22 to 24 times more powerful than carbon dioxide (CO2) in trapping heat in the atmosphere. By trapping and utilizing the methane, GHG impacts are avoided. Further, the pathogens existing in manure are eliminated by the heat generated in the bio-digestion process and the resulting material provides a valuable, nutrient-rich fertilizer. Small-scale biogas digesters have been used throughout many developing countries, most notably China and India, but also Nepal, South Korea, Brazil, and Thailand.

3.3. Bio Fuels

Liquid biofuels include pure plant oil, biodiesel, and bioethanol. Biodiesel is based on etherification of plant oils. Ethanol is primarily derived from sugar, maize, and other starchy crops. Global production of biofuels consists primarily of ethanol, followed by biodiesel production. The various biofuel conversion technologies are as follows:

3.3.1. Straight Vegetable Oil (SVO)/Pure Plant Oil (PPO):

SVP/PPO can be used in most modern diesel vehicle engines only after some technical modifications. Principally, the viscosity of the SVO/PPO must be reduced by preheating it. However, some diesel engines can run on SVO/PPO without modifications. PPO is obtained from edible oil-producing plants such as the African palm, groundnuts, cotton seeds, sunflower, canola, or non-edible oils such as jatropha, neem, or even balanites. These raw oils, unused or used, can be employed in certain diesel engines, for cooking, or in diesel generators for the production of electricity.

3.3.2. Biodiesel

Biodiesel can be used in pure form or may be blended with petroleum diesel at any concentration for use in most modern diesel engines. Biodiesel is raw vegetable oil transformed, treated, and standardized through chemical processes. The standardization of this product, and its industrial production, renders its use much more diverse than PPO. Biodiesel is used in diesel engines and diesel vehicles. Biodiesel can be produced from different feedstocks, such as oil feedstock (e.g., rapeseed, soybean oils, jatropha, palm oil, hemp, algae, canola, lax, and mustard), animal fats, and/or waste vegetable oil.

3.3.3. Alcohols

Ethanol, butanol, and methanol are produced principally from such energy crops as sugarcane, maize, beets, yam, or sweet sorghum. Ethanol is the most widely used alcohol, primarily as a fuel for transportation or as a fuel additive.

Bioethanol can be produced from a variety of feedstocks, including sugarcane, corn, sugar beet, cassava, sweet sorghum, sunflower, potatoes, hemp, or cotton seeds, or derived from cellulose waste.

Several processes exist to convert feedstocks and raw materials into biofuels. First-generation biofuels refer to the fuels that are produced through well-known processes such as cold pressing/extraction, transesterification, hydrolysis and fermentation, and chemical synthesis. The resulting fuels have been derived from sources such as starch, sugar, animal fats, and vegetable oil. First-generation biofuels are already established in the fuel markets and usually produced from fuel crops. The most popular types of first-generation biofuels are biodiesel, vegetable oil, bioethanol, and biogas.

Second-generation biofuels are not yet commercial on a large scale as their conversion technologies are still in the research and/or development stage. Second-generation biofuels are produced through more advanced processes, including hydro treatment, advanced hydrolysis and fermentation, and gasification and synthesis. A wide range of feed stocks can be used in the production of these biofuels, including lignocellulosic sources such as short-rotation woody crops. These produce biodiesel, bioethanol, synthetic fuels, and bio-hydrogen

3.4. Biorefineries

An emerging concept for the African countries to be aware of is bio refineries. A bio refinery involves the co-production of a spectrum of bio-based products (food, feed, materials and chemicals) and energy (fuels, power, heat) from biomass bio refinery is a facility that integrates biomass conversion processes and equipment to produce fuels, power, and value-added chemicals from biomass. The bio refinery concept is analogous to today’s petroleum refinery, which produces multiple fuels and products from petroleum.

By producing several products, a bio refinery takes advantage of the various components in biomass and their intermediates, therefore maximizing the value derived from the biomass feedstock. A biorefinery could, for example, produce

one or several low-volume, but high-value, chemical products and a low-value, but high-volume liquid transportation fuel such as biodiesel or bioethanol. At the same time, it can generate electricity and process heat, through CHP technology, for its own use and perhaps enough for sale of electricity to the local utility. The high-value products increase profitability, the high-volume fuel helps meet energy needs, and the power production helps to lower energy costs and reduce GHG emissions from traditional power plant facilities. Although some facilities exist that can be called bio refinery, the bio refinery concept has yet to be fully realized. Future bio refinery may play a major role in producing chemicals and materials that traditionally were produced from petroleum.

3.5. Cooking and Related Applications

3.5.1. Biomass Densification or Briquetting

This is the process of compacting loose biomass feedstocks into a uniform dense form, producing a higher quality fuel. Better and more consistent thermal and physical qualities allow for more complete combustion of briquettes, providing greater efficiency, reduced emissions, and greater control for residential and industrial applications. Briquettes offer easier transport, storage, and mechanical handling in both household and industrial settings. Briquettes can be efficiently produced using relatively simple technologies. Stalks, husks, bark, straw, shells, pits, seeds, sawdust - virtually any solid organic by product of agricultural or silvicultural harvesting that can be used as a feedstock. Biomass wastes with relatively low moisture content (less than 15%) are most suitable for efficient production of briquettes.

3.5.3. Ethanol Gel

Ethanol gel is a clean burning fuel that consists of gelatinized ethanol bound in a cellulose thickening agent and water. Cook-stove specially designed for use with ethanol gel have been developed in the last few years, as have ethanol gel burners that can be retrofitted into several traditional cooking stove. Used in such appliances, ethanol gel is a highly controllable, easily lit cooking fuel with a

heating efficiency of roughly 40%. Initial market penetration has taken place in several countries in Africa, such as Zimbabwe, Malawi, and South Africa. Experience has shown that ethanol gel can substitute for wood fuels and kerosene, stabilize household energy markets, and reduce CO2 emissions and indoor air pollution.

3.5.3. Improved Cooking Stoves,

The key use for fuelwood, charcoal, and other forms of biomass in African countries is for cooking. Utilizing smokeless, efficient, and low-cost stoves that exist in the marketplace today can help reduce woodfuel demand, improve indoor air pollution, and lessen deforestation for the above options; markets may be constrained by cost factors. However, policies and incentives to reduce deforestation; eliminate subsidies for fossil fuels, such as butane; and promote alternatives to fuelwood can help address the cost constraint. Also, it is important to note that these activities should be linked to improved forest management programs and practices. As mentioned earlier the Ghana wood forest is heading towards that and therefore the need to adapting to this technology will be useful.

3.5.4. Biochar

Biochar is a line-grained charcoal high in organic carbon and largely resistant to decomposition. Biochar is produced by heating biomass in the absence (or under reduction) of air, or Pyrolysis. It is found in soils around the world as a result of vegetation fires and historic soil management practices. Intensive studies of biochar-rich dark earths in the Amazon (Terra Preta), have led to a wider appreciation of biochar’s unique properties as a soil conditioner.

In developing countries, Biochar systems can reverse soil degradation and create sustainable food and fuel production in areas with severely depleted soils, scarce organic resources, and inadequate water and chemical fertilizer supplies. Low-cost, small-scale biochar production units can produce biochar to build garden, agricultural, and forest productivity, and bioenergy for eating, cooking, drying and

grinding grain and producing electricity and thermal energy (International Biochar Initiative, 2008).

Given the serious land degradation facing many west African countries, biochar could be an option to consider.

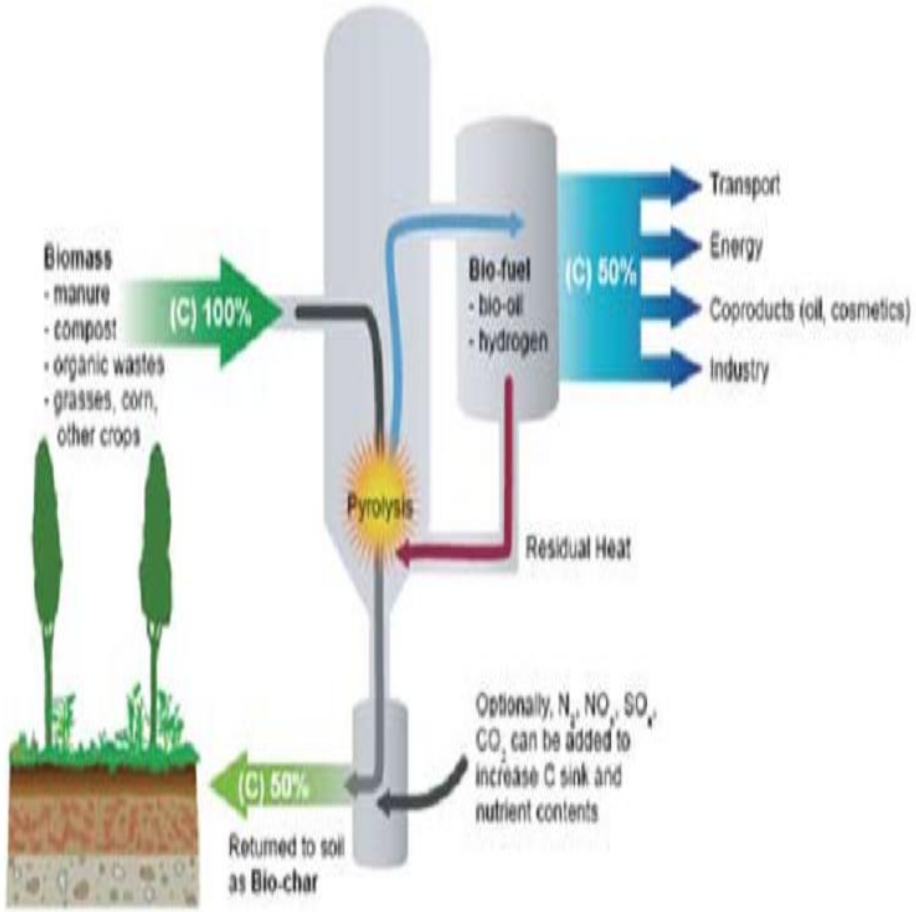


Figure 6. .Production of Biochar

4. ADVANTAGES AND DISADVANTAGES OF BIOMASS ENERGY DEVELOPMENT

Asking about the importance of biomass energy is as important as asking about the importance of energy itself. This is because bio energy is no difference from any form of energy since it could be used to produce energy of any kind; being electrical, dry cell, liquefied fuel etc. The importance of energy could be seen from the very time we wake up from our beds to the time we go to sleep at night. Energy affects our lives in almost all circumstances whether we notice it or not. Without it people would have a harder time doing anything or getting anywhere. Examples of energies that we use in our everyday life may includes mechanical energy in a wind up alarm or electric energy in a battery or plug-in alarm that wakes us up from bed; also heaters that we use to make our houses warm. We also use energy to heat could water before showering or washing our faces in the morning or at night. Just imagine washing your face or taking a shower with ice cold water in the winter, wouldn't it be terrible? Energy even effects when you put on fresh clothes in the morning, probably we iron our cloths before taking it to school or work. Those cloths were probably made in a factory, which was powered by electrical energy.

What of our mobile phones, computers, watches, cars, home lights etc; all these are empowered by energy. Without energy we could hardly be comfortable living an enjoyable and easier life. Life might be simple without energy but difficult to do without it. Let's now see some importance in developing such energy.

4.1. Advantages/Importance of Bioenergy Development in Ghana

4.1.1. Ecological Importance

In recent years, environmental pollution has become a global discussion. Internationalization of industrial and social activities has given rise to problems such as global warming, desertification, and acid deposition. These problems are rooted in the materially-rich lifestyles which are supported by abundant and wasteful use of fossil fuels in industrialized countries. Rapidly increasing industrial activities in China, India, and in other developing countries implicates

that these countries will inevitably contribute to deterioration of the global environment and the destruction of the global ecosystem. Lifestyle changes and changes in our key industrial systems are required in order to minimize the impact of environmental pollution. The recycling of materials and minimizing the generation and use of waste, is a basic concept which must be implemented in order to meet the new demands of sustainable development in both industrialized and developing countries such as Ghana.

Mechanisms for implementing this concept and for establishing environmentally compatible technologies which support the future "recycling" world are required. Systems which utilize energies produced from biomass are typical examples of energy recycling systems. Biotechnology is one of the future-oriented technologies, and one that will play a major role in the exploitation of biomass energy. All biomass (plant, animal and microbial), originates through CO_2 fixation by photosynthesis. Biomass utilization is consequently included in the global carbon cycle of the biosphere. Using biomass as an energy source creates a ‘closed carbon cycle’. As a biomass energy source grows CO_2 is absorbed from the atmosphere, when it is burnt the CO_2 stored by the biomass as is released, making biomass fuel ‘carbon neutral’. Most biomass fuels are clean, containing no noxious metals, chemicals or other pollutants and so will not evoke environmental issues such as acid rain and human respiratory problems. Good for the planet and good for you.

Biomass energy in developing countries mostly originates from fuel-wood, animal wastes, and agricultural residues, and is primarily utilized for activities which are essential to survival, such as cooking and obtaining water. Improvements in the living standards in these countries will result in the non-essential use of energy. The use of bio wastes in such ways therefore reduces the hazardous impact that it would have otherwise had on the environment and its inhabitants.

4.1.2. Waste Reduction and Health Improve

The widespread use of fossil fuels has brought numerous benefits to industrialized societies. Large amounts of agricultural, domestic and industrial wastes generated in these countries as a result of development mostly have detrimental effects both on the environment and on human health. The Itai-itai and Minamata diseases in Japan are just two examples of the effects of air and water pollution on human health. Therefore, the importance of taking effective measures to control and put our mass production of waste into good and effective use cannot be over emphasised. This is typically the reason why scientists have put tremendous effort into researching into technologies that will make good use of such wasted to avoid any disastrous outcome. Such great efforts put into developing such mechanisms has aided in the generation of electrical energy, agricultural fertilizers, fuel gas, chemicals for preservation and to mention just a few. These efforts have reduced the adverse impact that the high accumulation of waste would have otherwise have on human health.

4.1.3. For the Production of Energy

Wood and agricultural residues are burned as a fuel for cogeneration of steam and electricity in the industrial sector. Biomass is used for power generation in urban and city sectors for the generation of electrical energy both for space heating in residential and commercial buildings.

Today, waste materials that are organic in nature, such as plant material, food scraps, and paper products, are recycled using biological composting and digestion processes to decompose the organic matter. The resulting organic material is then recycled as mulch or compost for agricultural or landscaping purposes. In addition, waste gas from the process such as methane can be captured and used for generating electricity. The generated electricity is thus used to empower our fridges, computers, TVs, heaters, lights, and most electronic gadgets that we might own.

According to the Energy Information Administration (EIA), in its Annual Energy Outlook 2002 (AEO2002) reference case 1, it projected that biomass will generate

over 15.3 billion kilowatt-hours of electricity, or 0.3 percent of the projected 5,476 billion kilowatt-hours of total generation, in 2020. In other scenarios, electricity generation from biomass is projected to increase substantially. The production of electrical energy is a means of developing our society thus conformable living conditions for all.

4.1.4. Income Generation

Gone were those days where waste was termed ‘useless’. In today’s world waste is termed ‘money’. How? To help us understand let’s take an example from the Energy Information Administration in US. According to the EIA estimation of biomass resources shown, there are over 590 million wet tons of biomass available in the United States alone on an annual basis; 20 million wet tons (enough to supply about 3 gig watts of capacity) are available today at prices of $1.25 per million Btu or less. That means it’s possible to generate an approximate amount of $735.5million from biomass in US alone even as a minute fraction of the total supply of energy availability.

Biomass can also be converted into other forms like liquids, which could be used as transportation fuel in vehicles and other similar motor engines. Biodiesel and similar liquefied fuels are some examples. There are other researches being conducted on the production of biomass residues that could be used as fuels or chemicals for the preservation of goods. Biomass materials can also be used directly or indirectly in the manufacture of other varieties of products. All of which could be sold for income (money).

(http://www.eia.doe.gov/oiaf/analysispaper/biomass/)

4.1.5. Developments

A sustainable energy supply, both in the short- and the long-term, is needed for promoting good economic growth and infrastructural development which will in turn promote high and quality living conditions of people, as well as a lucrative, protective and illuminative environment.

Energy is a precious resource that facilitate the development of infrastructural amenities like hospitals, educational institutions, transportations system, industrial and co-operative firms, manufacturing, technological improvement etc.

The need for a greater diversification of energy resources is very important; if we are largely dependent on one energy source we risk price rises and supply disruptions. Therefore the development of different kind of energy means that there will be less demand for a particular supply of energy, and this will call for alternatives and choices thus like the economics described it " the lower the demand the lower the price. Biomass energy development in Ghana will be an alternative source to the hydro and solar sources and will therefore force its competitors to lower the price, thus means of savings for development.

4.1.6. Low cost, savings and improved living standard

Undoubtedly biomass is known to be relatively less expensive compared to any other form of electrical energy. This therefore shows that, introduction of bioenergy in Ghana will be highly patronized by the most. This will include both those who could not afford electrical energy previously and also those might already be using other alternative sources due to its relatively low cost (biomass-electricity.) Low cost on energy usage will mean less money doled out, thus this will promote more savings. And more savings will lead to lead to improved living standard since the unused money will be used in catering for other needs like hospital expenses(good health), school feels (quality education and skilled labour), balanced and nutritious food (strong and healthy), better homes, good and advanced electronic gadgets(computers etc.) and the list goes on and on. Thus the living conditions and standards of people will be better off.

4.2. Disadvantages of Biomass Energy Development

Despite the vast uses and importance of biomass energy there are however some disadvantages and limitations. Some of these may include the follows.

a. More serious air pollution was found when burning plants matters, e.g., CO2, CO, solid particulate matter. These are pollutants my include the emission of carcinogens into the air and also some toxic gases and ash

b. It may also take too much energy to collect, dry and transport the residues to power plants. Some of the waste may contain a lot of moisture and will therefore make it difficult for transportation from one place to another. The system of collecting these wastes might not also be easy since they are usually scattered about all over the country and not accumulated in one place. Reduce soil nutrient replenishment.

c. It may raise the price of food, wood and wood products indirectly. Since the source material may be used for other alternative use, the demand for it might cause the price of it to rise, even as the economist have suggested, that the higher the demand the higher the price.

d. It uses large area to grow biomass. Large size of land is needed to grow biomass material since the material will be needed every time to feed the power plant. Also since it takes a longer period for some of these plants to mature, it may require a large area of land so there will always be enough material for use; because lack of material will mean lack of power supply.

e. It may cause saltilization and decrease the total size of the arable land. Available land that could be used in cultivating food might be used to cultivate biomass materials. This means that the land size for growing food will shrink.

The source of biomass can use fertilize soil, e.g., crop residues and animal manure.

f. It can cause deforestation and soil erosion. Overly using these materials and not replacing them can cause deforestation or might even erode the soil. This

will make the soil lose its nutrient since the top soil will be washed away and might gradually cause great disaster leaving the land bare and unusable.

g. Either high technological level or catalytic combustion is needed. Biomass conversion system might require a advanced technological equipment for the conversion of the material sources into energy. These equipments might also need highly skilled personnel to install and use them. It will also require that, it is regularly maintained and thus a skilled labour will also be needed.

The diagram below shows the cycle and benefits that the development and use of biomass could bring us.

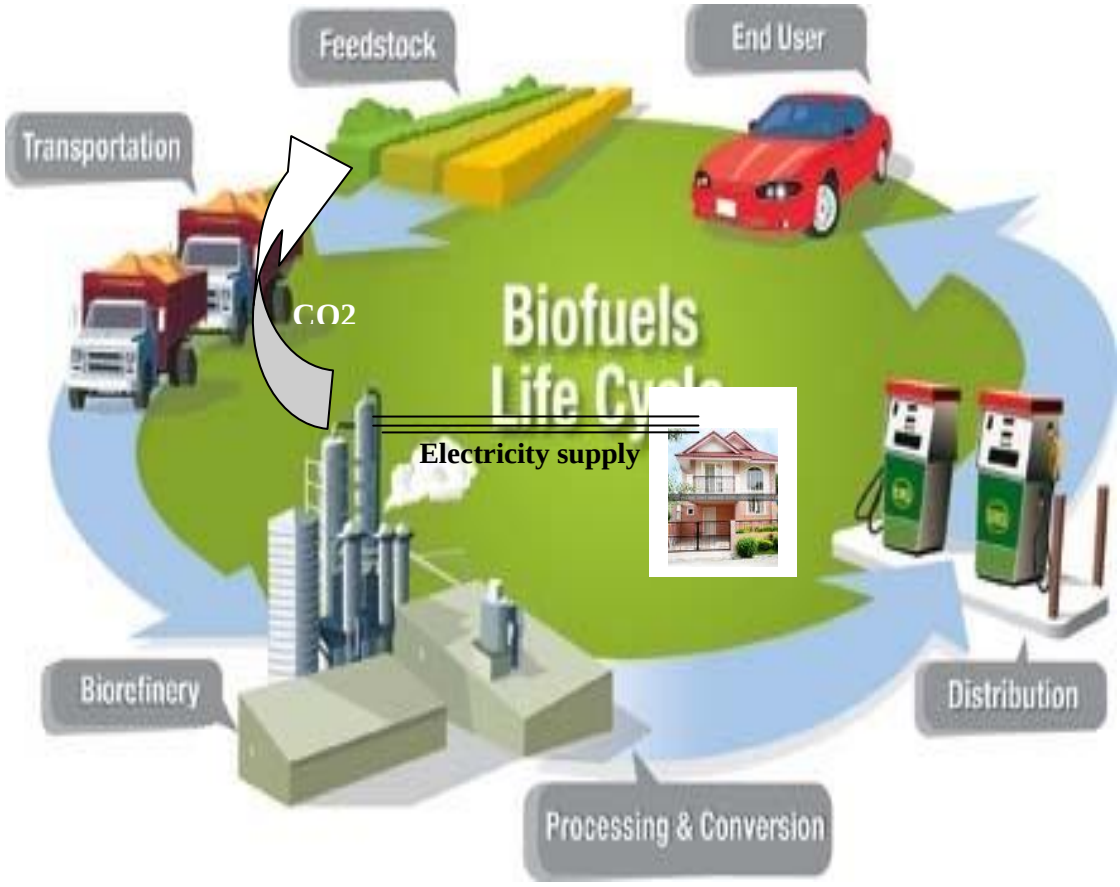


Figure 6. Biomass Energy life Cycle and benefits

From figure 6 above, we could see the various uses and benefits that biomass can bring to us.

5. RESEARCH METHODOLOGY

There are several kinds of research methods used in classifying research information, all of which are grouped into two distinct types: quantitative and qualitative.

5.1.1. Quantitative Research

Quantitative research methods is concerned with the measurement of the potential market size, segment etc. It defines an investigative approach resulting in numerical data, in contrast to those methods resulting in qualitative textual information. Quantitative research is especially useful when

- Obtaining measurement
- Comparing information and opinions
- Estimating error and
- Testing hypotheses

Quantitative research is almost always based on extrapolating from a sample of the general population and research design and particularly the sampling methods must be sufficiently rigorous to allow this.

5.1.2. Qualitative Research

Qualitative research methods are those investigative approaches that result in descriptive textual information, in contrast with quantitative methods where results are usually summarised numerically. The qualitative research approach is especially useful when examining

- Opinions, feelings and values
- Participant interpretations and responses
- Behavioural patterns
- Processes and patterns

5.2. Case studies

In obtaining and interpreting quality information, there is recognition that such information is interpreted according to a set of values belonging to the researcher. Qualitative research is generally exploratory in nature; it may be preceded or followed by quantitative investigations. It is especially important in the social sciences, where its aim is often to understand the complex reason for human behaviour. Key qualities of qualitative research features includes

- Case studies
- Interviews
- Focus groups

Qualitative and quantitative research methods are not mutually exclusive and may be used in the same investigation. There are however other research methods that could be categorise under the above two main methods. Some of these include

5.3.1. Exploratory research; usually used when the primary objective is to identify a problem more precisely or to investigate the possibility of new alternative courses of action. Exploratory usually deals with question like what, when, where, why, who, how or any combination of the above.

5.3.2. Descriptive research aims at providing a descriptive of the existing market phenomena. Such research is used to determine the frequency of occurrence of market events. The descriptive method usually tackle's the 'what' aspect in content and survey analysis.

5.3.4. Casual research aims at identifying the precise cause and effect relationship present in the market. The level of precision is higher than that for other types of research because reasonable unambiguous conclusions regarding causality must be presented.

5.3.5. Observatory research targets a wide range of approaches where the investigator will examine an artefact person or location and description in words.

This may include a biological habit, a patient's symptoms, drawing, painting, illustration etc.

5.3.6. Focus group made up of small discussion groups (usually 4-6 members are considered as an ideal) where participants are ask to comment on an issue. Focus group allows you to take account on several viewpoints at the same time and to observe the outcome of open and dynamic discussion among focus group members. It is for business purpose and a product of marketing tool.

5.4. Research Method Used

5.4.1. Qualitative

The popular saying that 'seeing is believing', is a means of ascertaining an indisputable conclusive evidence on a subject. Thus the researcher presence and personally witnessing an even is an utmost importance for determining a conclusive and an irrefutable judgement on his findings. Seeing something is a means of properly understanding it and properly interpreting it than just judging on others viewpoints with just yes or no questionnaires. It is so because the respondent might not actually have concrete evidence of information on the area under discussion but may only answer all the same from his or her personal perspective in order to please the researcher. Therefore the need to journey to the site of material sources and witnessing for oneself the true existence, quantity and location of the material sources is a very important way to determining a good and accurate conclusion. The qualitative methodology approach is therefore the most appropriate and suitable research method in such instance for obtaining information both from the respondents and on site. Among others, the qualitative research method is also a means of ascertaining surety, regular supply of material, continuity of production, proper calculations of accumulated material and even for determining the distance between material source and manufacturing site or from the end user. The above reasons are just some few reasons why the qualitative research methodology will be most suitable this thesis or research work.

Another reason for adopting the qualitative method is also because my presence was most needed in ascertaining the respondent view on the topic. To properly comprehend a subject more fully, one's questionnaires must be structured in such a way that a respondent will comprehend the meaning of the question. Thus the question should be easily understandable for people of perspective.

In this research work, the questionnaires were thus structured suitably for people of all sorts ranging from highly educated personalities as well as low level educated persons who might have limited academic knowledge. Thus I used the qualitative research methodology to aid in obtaining a multiplicity of opinions from workers of various sectors of the economy such as highly trained governmental officials who have specialised on their field of work, private institutions, sole enterprises and individuals of the general public whose knowledge might not be book based but rather personal experiences. Despite the limited number of respondents interviewed, the feedback was positive and most convincing. As we shall see below, there were two different groups of people that the questionnaires where designed for. The first and foremost group were the highly trained officials who have data on the country's economic structure. The second group were the low level people. Group 1, was to give valid information pertaining to the subject and group 2, was used to verify or buttress the already collected data from group one for the sake of authenticity.

My main research tools used under the qualitative research methodology are **Exploratory** and **Focus Groups.**

5.4.2. Exploratory

As earlier said, the exploratory research methodology deals with the why, when, what, where etc. This helps in identifying a problem more precisely or to investigate the possibility of new alternative courses of action. The view on this kind of research work is more precise and interrogative. By this approach, conducting an intensive interview with highly qualified persons who has good knowledge on the subject is of utmost importance. In this thesis the targeted group therefore included persons from the National Energy commission among others

Mr. Joseph K Essandoh-Yeddu, the chief of strategic Planning and Policy and Mr. Otu Danquah the manager and chief of renewable energy; the ministries of food and agriculture Mr. John Okang Nortey Agric Economist & statistician (statistics, research and information directorate) and Mr. J. Baidoo Williams (Directorate of crop services); also was Mr Ayi Klotey the vice president of Bonsu Cocoa College (Bonso agricultural institute). I had face to face interactions with these ones. I also conducted intensive interview with governmental officials of high positions in order to gather reliable information from them, thus the source of my data could be deemed accurate and dependable.

Below are the main questionnaires intended for the above mentioned group of people. It could be ascertained after reconsidering these questions that it's much precise and demand good foreground knowledge about the subject area in order to be able to answer them.

5.4.2a. Structured Questionnaire

The questions below were derivatives of the original questions intended for this research work. The below are sub-based and used as guidance for reaching the main goal of the thesis. The targeted groups in this case were mainly those members from the energy commission of Ghana, the ministry of food and agriculture and the agricultural institutes of Ghana. The questionnaires are as follows:

1. What is the present energy structure of Ghana and what are the future demand and supply conjecture?

2. Is the country's energy supply dependable and will there be the need of an alternative source both now or in the future?

3. What will be the importance of the invention and implementation of biomass technologies for electrical energy production in Ghana?

4. What is the potential market segment/size for the utilization of biomass electrical energy consumption?

5. What are the potential Biomass sources, locations and quantity available in Ghana?

6. What are the potential Biomass Technologies available that will be beneficial for Ghana?

7. How much accumulation of biomass materials exists presently and how much energy (electricity in gig watts) could be derived from it/year?

8. What are the future plans in place to help supplement the present energy crisis?

The above questions as could be ascertained were for specific personalities who should have a valid and better understanding about the country's economic structure on areas of energy and agriculture.

This was the reason why I choose to use the qualitative research method so I could have them interviewed on personal basis.

5.4.3. Focus Groups

The focus group is usually made up of small discussion groups usually making up of about 4-6 people, where the participants are ask to comment on a particular issue. The focus groups help in taking several viewpoints/opinions of different people one conducts discussions with on a particular subject at the same time. This approached also helps in observing the outcome of an open and dynamic discussion among the group members.

The targeted group in this case were people from various other sectors of the economy like crop producers or farmers, the mining industry, woodworkers, manufacturing and industrial companies and people from similar background. I had group discussions with these. In most cases the group member varies between 3-5 persons. The response and opinions of these ones were highly respected since they are the ones in the fore front of the economy and also through their personal experiences and observations they have better understanding concerning reality. Granted they are the ones who could tell what is actually happening in the

country. They also added in understanding the present existing circumstances of the economy and expectations of the future. My questionnaires to these ones were structured such that it will have the same idea and format of the first group, but in basic term so they could properly understand, that is from the average man's perspective. These are usually the ones who have frequent power out problems in their communities or work places. They thus better understand the effects of electrical energy and the need for such energy development better than those high officials who might be rich and could afford for other alternative sources like solar or generators. Their response as has been analysed in chapter seven is very valid and dependable if the overall data was to be most accurate.

6. EMPERICAL PART

There are various sources of biomass all categorised into four main groups. These main groups consist of agriculture waste, forestry waste, animal and urban wastes. My research work however is limited to only one out of the four main parts, Agricultural waste. And the basic parts of these are in turn sub-divided into five main areas.

6.4. Agricultural waste

Agricultural waste is a well known source of biomass materials for the provision of energy. Agriculture accounted for more than 40 percent of Ghana's GDP in 2005 and employed three-fifths of the workforce. However, despite its importance, sectoral growth has lagged behind other sectors of the economy and has been unpredictable, as most farming is reliant upon rainwater. Agricultural growth however has increased to about 5.3 percent starting the year 2006.

About 57% of the land area of Ghana is used for agricultural purposes and almost the same percentage of the Ghanaians population is employed in the agriculture sector. Since agriculture is one of the most important sectors of the Ghanaian economy, the production of agricultural goods are also in large quantity. However most of these crops go bad due to lack of preservation systems. Therefore its most likely that waste generated both before and after using these agricultural goods are likely to be in large quantity also. And without doubt that has actually been the case. Since Ghana has no use for these wastes, the amount of accumulated wastes from theses agriculture crops are in amazement.

agricultural wastes in Ghana may includes palm kennel, millet, coconut husk/shell, palm-kennel, tobacco, sugar cane, corn husk, wheat, millet, ground-nut, share butter, kola nut, timber, cocoa pods, etc. Ghana is one of the world's leading producers of cocoa, mostly grown on small farms. Cocoa production reached 650,000 metric tons in 2008 and a projection of 700,000 metric tons during cocoa seasons. Another important cash crop in Ghana is sugar cane; a full capacity of 150,000 cubic meters is expected by 2010 for ethanol production per

year. Sugarcane is now under major cultivation to be used for the production of ethanol to be exported to Sweden. This is an expected open source of waste that could be used to generate electrical energy for the country. The two examples mentioned above gives a general idea of how much waste would be generated from these crops yearly and how much electricity could be derived out of that. A detailed analysis is seen in chapter 7. *http://www.thelocal.se/11536/20080504.* *http://www.mbendi.com/indy/agff/coco/af/gh/p0005.htm#5*

6.2. The main Sources of Biomass in Ghana

Ghana among many African countries is very rich as far as biomass waste is concern. As mentioned earlier, the availability of accumulated waste is incredibly marvellous. It is possible to see a mountain like heaped wastes in certain parts of the country.

Despite the various sources of biomass wastes, the research work will be limit on the major sources of bio-wastes in Ghana. The research is limited to the agricultural field and the sources of my research are as follows:

- COCOA POD
- PALM-KERNEL/HUSKS
- WOOD WASTES / SAWDUSTS
- COCONUT WASTES
- SUGARCANE WASTES

6.3. Cocoa Pod

Ghana is the second largest of cocoa producer in the world. Cocoa is grown in seven out of the ten regions of Ghana with the exceptions of the Northern regions. The quantity of cocoa produced various from region to region with the leading producers being the western region. Cocoa is a very luxuriant cash crop in Ghana, the cultivation of cocoa in Ghana is therefore on a high rate, no wonder being the leading commercial crop of the country.

After cocoa has been harvested, the beans are taken out of the pods and process into making cocoa butter, chocolate, etc. When the left over cover or pods becomes overly accumulated and dried, they are usually burnt into ashes or sometimes a minute fraction of it is used in making soap otherwise leftover to decay. These left over pods are highly dense in texture and can be used as a source of biomass residues for producing electrical energy. The below shows the cocoa processes before its depletion.

Fresh Cocoa in its raw state

cocoa pods with beans taken out

Semi dried pods

very dry, decaying and partly burnt pods

Figure 7. cocoa and its gradual stages to depletion

Figure 7 above depicts the various stages of cocoa before it finally depletes. These pictures represented the many similar thousands forms of cocoa stages found in almost every cocoa farm in Ghana.

Among places I collected information concerning the productions of cocoa includes the cocoa marketing board of Ghana, the ministry of food and agriculture

of Ghana and from the Bonsu agriculture collage of cocoa. I had similar data concerning the location and quantity on the total annual cocoa production of the country. This data was important if one wants to project with accuracy the annually residues that can be obtained from them. It will also aid in calculating the total electrical energy that could be generated from these residences. I was also able to strike the yearly average for future estimation. The details are shown in table 1 below. The figures shown here help us to see the annual cocoa production, the yearly wastes projection and the annual electrical energy estimation.

Table 1. Annual cocoa production, waste and electricity generation

	´Total production	Moisture value-X%	residual rate	Total biomass from crop residues	Total biomass energy (k.J)	Total biomass energy (kwh)	Calorific Value	Power Factor Efficiency Y%
2005								
2006								
2007								
TOTAL								
AVERAGE								

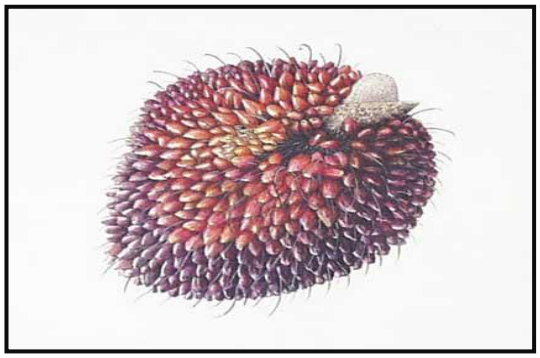
Table 1 above shows the annual production of cocoa from 2005-2007, the average yearly production, total residues and the electricity production per year. This is intended to help us project the average yearly cocoa production and the approximate yearly electrical energy production.

6.4. Palm-Kernel

Palm-nut from which Palm-kernel is obtained is the second most productive commercial crop cultivated in Ghana. The palm-nut tree is grown in almost all the regions and communities of Ghana, both for domestic use and on commercial basis too. It takes between 30-36 months for the plant to be fully matured for

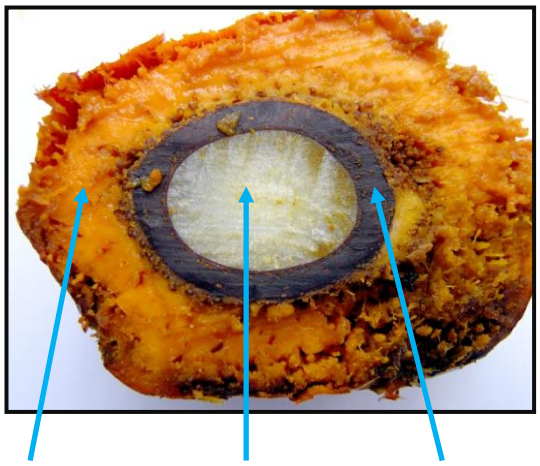
producing fruits. It produces palm fruits all year long with harvesting intervals between 4 to 6 months/year. Each tree could bear as much fruit as 8 to 15tons/year. When the palm is harvested, the fruit covering the nut is removed and used for making, soup, soap, cooking oil etc. The nut is cracked and oil is extracted from it or thrown away. The shell covering the nut which is of most important for my thesis are mostly discarded as wastes, otherwise and on rare occasions used by metal workers to heat metals so it becomes malleable for conversion into farm tools. This hard cover of the palm kennel also known as the palm shell is highly dense for the generation of electrical energy. Figure 8 below gives general description of how the palm looks like and various stages until palm kennel and later palm shell is derived. As could be seen from the picture, the final product, i.e. the palm shell goes accumulated and unused.

A bunch of fresh harvested palm nut



pieces of palm nuts from the bunch

Cross-section showing the parts of the nut



palm nut after food removed

Accumulated palm nut husk unused surroundings surrounded by palm husk

Figure 8. Palm nut and palm kennel accumulated

It's quite amazing the total amount of palm-nut harvested each year in Ghana. Table 2 below show in details the total amount of palm-nuts produced each year and the estimated palm-kernel wastes that could be derived from these nuts.

Table 2. Palm nut production, residues and electricity production

Year	´Total production	Moisture value- (X% shell only)	residual value	Total biomass from crop residues	total biomass energy (kJ)	total biomass energy (Kwh)	Calorific Value	Power Factor Efficiency Y%
2005								
2006								
2007								
2008								
Total								
Average								

6.5. Wood Waste/Saw-Dust

Wood is a substantial renewable resource that can be used as a fuel to generate electric power and useful thermal output. Wood for use as fuel comes from a

wide variety of sources. The Nation's forestland (or timberland) is the primary and known source of wood in Ghana. Wood for fuel use is also derived from private land clearing and urban tree and landscape residues. A third major wood source is waste wood, which includes manufacturing and wood processing, wastes, as well as construction and demolition debris. Saw-dust is a derived product from wood shaves. It has a variety of practical uses, including serving as mulch, as an alternative to clay cat litter, as heat generating fuel, for the manufacture of particleboards etc. Until the advent of refrigeration, it was used as icehouses to keep ice frozen during summer etc.

Ghana is the third largest producer of timber and the second largest exporter of wood and wood products in Africa. Ghana has about 5,517,000-ha forest area which forms about 24.2% out of the total land coverage. This shows a high possibility of wood-works which will in-turn generate wood wastes. With no doubt woodworks or carpentering, is a major occupational sector for many Ghanaians. Carpentry works could be seen in almost every community of Ghana usually as SSB or MSB. Some of these carpentry workshops could produce as much as 1-5tons of sawdust per day depending on the size.

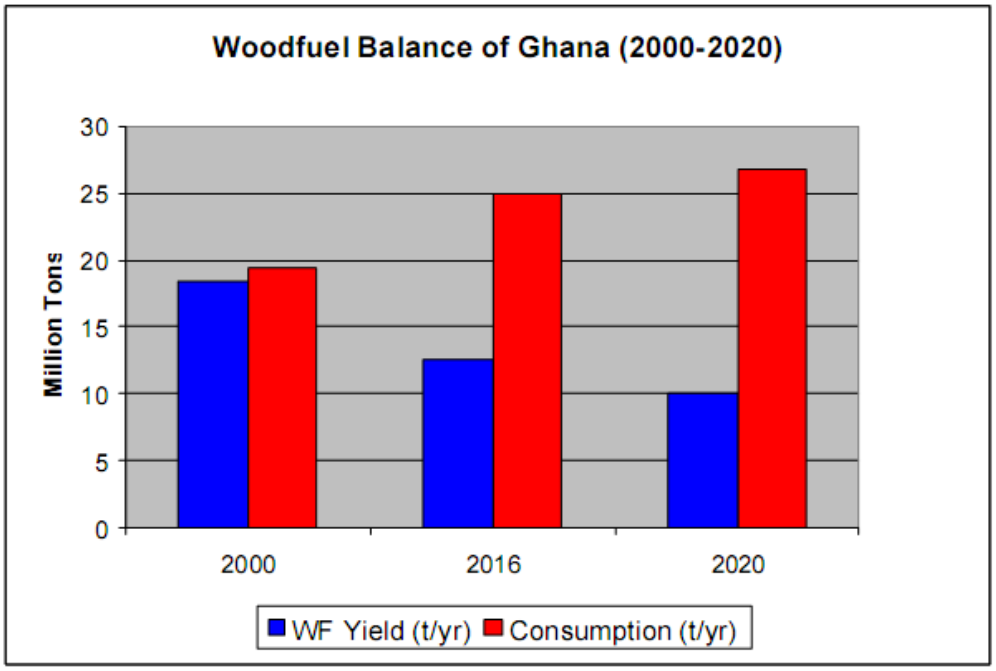


Figure 9. woodfuel consumption forecast for 2020

As illustrated in figure 9 above, by 2020 the woodfuel consumption will reach 25 million tonnes and above. According to reliable sources most of the then woodfuel supply will come from standing stocks i.e. 15 million tonnes from standing stock and the rest 10 million tonnes from newly yields. The government is therefore looking for available means of controlling the mass consumption of wood used as fire-wood which is mostly used as fuel for cooking, to a more modernised system of energy to save the wood forest from degrading into deforestation. Since wood used for biomass fuel forms about ¼ of what is burnt as firewood, it will be better and wiser to replace the fuelwood system by introducing biomass energy production technologies to help reduce the impending disaster of deforestation.

In Ghana, wood waste in the form of sawdust is mostly used by poultry farmers as carpet for their birds or to save the birds droppings from smell and contaminations and pollution from the environment. The fraction used for this purpose is very small. a minute fraction of some wood workshops sawdust are also sometimes used for making cardboards. In most cases even as shown in figure 10 below, the sawdust is accumulated over a period of time then burn into ashes as a means of disposing it off. http://www.ghanachamber.org/aboutghana.php

Figure 10. accumulated sawdust in a capentry shop- Ghana

The estimated figure of sawdust production per year = **267,105.33**

WET SAWDUST

Table 3. calculation of sawdust residues for electricity production

YEAR	´Total production	Moisture Value - (X%)	Residual Value	Total biomass from crop residues (tons)	Total biomass energy (kwh)	Calorific Value	Power Factor Efficiency Y%
quentity							
TOTAL							
AVERAGE							

DRY SAWDUST

YEAR	´Total production	Moisture Value - (X%)	Residual Value	Total biomass from crop residues (tons)	Total biomass energy (kwh)	Calorific Value	Power Factor Efficiency Y%
quentity							
TOTAL							
AVERAGE							

6.6. Coconut Husk

Coconut is a well known and one of the most; if not the most consumed fruit in Ghana. It's usually plugged and sold fresh on the road sides, at market places, bus-stops, school, hospitals etc. It's usually peeled with one end pointed for easily consumption of water. The fruit is then cut into halves so the fresh fruit inside the nut can be easily assed and eaten. The sellers of the coconut usually pile up the waste at his surroundings of sales, a nearby rubbish dump or any available grounds they could deposit with ease. After sometime, these wastes become overly populated and begin to spread round its surroundings. When the rain comes down, they easily run off into gutters, blocks pedestrians passage ways or even cause when it rains otherwise blocks pedestrian's passage ways and other similar disastrous effects. If not the above they are burnt into the air causing air pollution.

It starts as Fresh coconut for sales and ends up as nuisance causing havoc

Dry coconut husks accumulated

dry coconut shaves accumulated

Figure 11. fresh for sale and waste dumped in bush

Table 4 below depicts the annual coconut production, residues generation and electrical energy generating.

Table 4. Annual coconut production, waste and electricity generation

YEAR	´Total production	Moisture Value - (X%)	Residual Value	Total biomass from crop residues	total biomass energy (kJ)	total biomass energy (kwh)	Calorific Value	Power Factor Efficiency Y%
2005								
2006								
2007								
TOTAL								
AVERAGE								

6.7. Sugarcane Waste

Sugarcane as the names suggest, is mainly used for the manufacturing of sugar. It can also be used as a bio-fuel alternative to gasoline. A typical example where coconut is most popular is Brazil, the leading producer of sugarcane in the world. In Brazil, sugarcane is used to produce biofuels which is widely used in cars as an alternative for gasoline. This has become a promising alternative to gasoline, and the primary product of sugarcane processing, rather than sugar.

(*http://www.scidev.net/en/features/sugarcane-ethanol-brazils-biofuel-success.html*)

Compared to the other agricultural crops mentioned above, sugar cane is the least produced in Ghana (though efforts are now being made for mass production). Yes, it's the least in production but not the least in waste generation. On the average sugarcane generate more waste than the other three mentioned above with the exception of coconut. After the extraction of the sweet liquid in the cane, the solid goes waste. Those that become overly gown are unused. Accumulated harvested canes that also become dried up are also left unused. Though sugarcane has many

uses, (e.g. such as the production of ethanol) its mainly used in Ghana for the production of alcohol, otherwise are sold on the domestic market to be consumed fresh for its sweet tasty liquid. What is usually left afterwards (the fibre) are burnt or deposited off at wastes grounds.

(http://www.energy-daily.com/reports/Ghana_to_produce_ethanol_for_export_to_Sweden_999.html)

Fresh sugar cane ready to be used for alcohol extraction

unused sugar cane partly dried

Sugar cane waste after liquid has been extracted

waste being burnt because of over population

Figure 12. sugar cane for alcohol production and waste being burnt

On the average Ghana produces about 237,000 tons of sugar cane every year. But due to the new idea of bio-fuel, and the contractual agreement with Sweden, Ghana is maximizing its produce to a capacity that demands.

Table 5. Annual sugarcane production in ghana, waste and electricity generated

YEAR	´Total production	Moisture Value - (X%)	Residual Value	Total biomass from crop residues	total biomass energy (kJ)	total biomass energy (kwh)	Calorific Value	Power Factor Efficiency Y%
TOTAL								
AVERAGE								

7. ANALYSIS AND DEDUCTIONS OF RESEARCH RESULT

There were at least six different individuals used for the intensive face to face interview. As was touched on earlier, these are people specialised at their field of work and thus have good knowledge about the subject.

According to Mr. Joseph Essandoh-Yeddu (the chief SPP) and Mr. Otu Danquah (chief of RE) the demand for energy in the country is ever increasing and the need for alternative energy sources is essential if the country's economic planes are to be achieved. According to them, Ghana is presently suffering from energy crises and though efforts are being made to supplement the present energy system, much of these efforts had turned futile. All the same, they claimed that there are various expected projects taking place to redeem the country from its present status. They claimed that my biomass research work will be very helpful should it be achieved. As has been discussed in previous chapters and also shown in the chart on pages 24 and 58 the demand for energy by the year 2020 will be incredibly high. It was also ascertained that the segment for the future demand for electrical energy will also rise from the present 11% to about 55% - 85% of the total population.

Concerning any intention of future energy planes, they claim it was their goal to implement some renewable energy projects. However the only potential renewable energy plane by the government is the Tamale solar energy plane otherwise much has been left in the hands of private individuals to invest.

According to the claim by the energy commission of Ghana, there are enough biomass energy sources that could supply the country's energy crises. In addition Mr. John Okang Nortey an Agric Economist and statistician from the ministries of food and agriculture (MOFA) supported that the Ghanaian economy, produces enough biomass material so much that it could meet the country's demand and supply of energy if utilised. This was of cause fortified from the energy commission of Ghana in their 2006 SNEP year book on Woodfuel and Renewable, where biofuels was mentioned to be about 60% in used.

In addition mr. Ayi Klotey the vice president of Bonsu Cocoa College (Bonso agricultural institute) helped me in locating the regional sectors where cocoa large cocoa producers were found. Others, like Mr. J. Baidoo Williams (Directorate of crop services) from the Ministry of Food and Agriculture, gave me the various regions and sites where most of the sources in question are produced and figures of the annual production quantities.

In addition to these, group interviews with the focus groups were very amazing. This is because all the claimed during the various discussions tally's exactly with that of the result of the high officials. I interviewed a total of about 50 individuals in the focus groups, ranging from 4-7 mostly in each group discussion. The final result of these 50persons is shown in table 6 below.

Table 6. Response from respondents in focal groups

Quest.No	Question	Opinion 1. (positive)	Opinion 2. (Negative)
1.	What do you think about the present energy system? Good or Bad?	GOOD/OK - 8	BAD - 42
2.	Would you like to use or switch to a different source of energy? Why so / why not so?	Yes -reasons was mostly because the present source is unreliable and expensive 41	No / not sure. 9
3.	Should there be a less expensive and a more reliable source of energy, would u like it?	Yes / Definitely 50	No/Never 0
4.	Do you have any idea where any of the following could be located? (Cocoa, coconut-husk, sawdust, palm kennel or	Yes 45 But some in small quantity	NO/NOT SURE 5 Because they think is very

	sugar-cane waste).		small
5.	What is the average production of (any of the criteria mentioned above) /day x week x year? *(mainly to the producer's of any of the known sources in question)*	Details of this question is analysed below. No. Of respondents 26	Details of this question is analysed below.
6.	Do you know what biomass energy is or would you like to know what it is?	Yes or somehow 3	No or never 47
7.	How will you like to have a renewable form of energy "biomass energy" at your own convenience and for personal use	**Yes-**If reliable and uncomplicated and less expensive **41**	**No/don't know** most reasons being because they don't want any complications **9**
8.	How much do you pay / will you otherwise like to pay (monthly) on electricity?	**Mostly** ¾ of what they presently pay **34**	**Mainly** because they don't use/have the system **16**
9.	Will you prefer the use of bioenergy to other alternatives? Like solar, wind, hydro (Yes/No)	Yes- 38	No- 12
10.	Why the choice made in the question above?	If most or all the afore mentioned features are there	Because of complications and easiness of other alternatives

In question number 1 most concluded that the present energy system was bad because they frequently experience power outs. Others claimed that sometimes their source of power supply does not flow for weeks. Others do not have electricity at all or then the system is in place but not functioning. Those who

claim it was good or otherwise ok where mostly living round the urban areas and either have frequent flow of power supply or had lived previously round areas where they had no power supply or then the system was worse than what they have now.

In question 2 most people would like to change their system because they don't trust the present system. These include people who might have their refrigerators or other items ruined/spoiled because of frequent power out breaks. In opinion 2 in question 2, those who were not sure are those who are not concern about source but are more interested in having power of any kind.

In question 3, as could be seen from the chart; all the people I had discussions with will either want to switch to another source or for those who do not have any source of power will appreciate getting one less expensive and most reliable. 100% of all I talked to where in favour of the question.

Question 5 was conducted only on some particular groups of people or individual who are actually producing the waste material. Most of these are farmers, carpenters/wood works, coconut sellers and sugarcane alcohol factories. In the discussion, those who were not sure of themselves were not incorporated.

I was really astounded to know that most people in question 6 have no idea what biomass was, and even those who knew marvelled together with those who didn't know about the marvellous prospects of what it's capable of doing. Some were so happy to know that their own waste could be used for the generation of electricity for their use and that they could cut down cost on power supply.

After knowing what biomass could do, most people as in question 7 were ready to accept and switch to biomass electrical energy supply. Most people who choose opinion two were actually not sure if they would like it or then because of some complications that might incur during its usage. Otherwise they would like too; more especially if it will be less costly in relativity to their present energy supply.

In question 8, majority either pays electricity bill or knows how their managers, fathers, house owners etc complains about the high cost of electricity bill. Most of

those in opinion two don't even have electrical power supply at all. Some in opinion 1 are ready to switch, even if they are going to pay a little more but will have a more reliable source of electrical energy supply. Some of the reasons for their claim was because sometimes they get unannounced power out which endangers their electronic gadgets they use at their homes or for business purposes thus slack back on business. Others also claim they sometimes get electricity bills they have no ideas where it might be coming from because they have not actually used it and have no idea where it might be coming from. Such ones prefer to have a more reliable alternative source of energy.

I tried to make some comparison between the use of biomass electricity and other alternative electricity supply for the likelihood that some might prefer those ones in relation to biomass electrical energy, but the outcome was quite different and most assuring. The reason for choosing biomass in alternative 9 was explained in during the discussions in question 10. Most claimed that if biomass will be less expensive, more reliable and easy to maintained, then they don't see why they should go for any other alternative. Most who said will like other alternative source mainly wanted solar only on the grounds that it will be reliable, cheaper lower cost of maintenance and the availability of trained/skilled service personnel's, then they wouldn't mind using that, otherwise biomass electrical energy will be the next alternative. The availability of skilled service men was very important since there had been efforts by some to promote solar energy, but had turns out in most cases that there are no skilled service men to service it in times of faulty.

Table 6 below depicts the summation of the research result based on the five chosen agricultural residues. The data is intended to ascertain the totals of theses material so one could determine the quantity of biomass material supply for the production of electrical energy. It is to help us see if there are enough and reliable material sources for the generation of electricity in the country. Analysing from the below, we have no doubt that there are more than enough materials for the production of electrical energy. The implementation of the technology and investing into the field is therefore profitable.

Table 6. Total result of waste collection and electricity generation

TOTAL	´Total production	Moisture value - (X%)	residual value	Total biomass from crop residues	Total biomass energy (k.J)	Total biomass energy (kwh)	Calorific Value	Power Factor Efficiency Y%
cocoa pods								
Palm-kennel								
coconut husk								
sugar cane waste								
sawdust								
TOTAL								

8. CONCLUSION

This thesis presents the status of research of biomass potentials for the production of electrical energy in Ghana. Biomass potentials can be generated from different sources. These may include residues from agricultural produce; forest plants wastes, rural or animal wastes. The technical electrical energy calculations considered in this thesis was done using conversion techniques such as the Thermo-chemical conversion from the UNEP international environmental technology centre (IETC)

Among other things we also realise the economic importance of biomass. Biomass is one of the cheapest forms of renewable energy today. It also has many environmental and ecological benefits and offers numerous economic security and energy benefits. As an example, biomass already supports 66,000 jobs in the United States alone. Other objective planed by the AOE shows that the realization of its plane could support the biomass industry and create as much jobs as three times what exist presently in the US. Similar interests had been developed in Ghana to boost up the sugar cane cultivation for ethanol production and exportation to Sweden. The resultant waste could thus be used for the generation of electrical energy.

Since the development of every economy depends much on the availability of energy, the availability of biomass energy for such developing country like Ghana will boost up its economic development at a higher rate. The production will also help in supplementing the present energy crises thus boosting up production. The availability of dependable energy supply will give a reliable view of the country's energy system to investors, thus investors can develop confidence in the energy system so as to invest in the country. Investment will open lots of job opportunities for numerous people.

We have seen the numerous benefits that come with biomass. These advantages may also include lower cost on energy consumption for especially biomass waste producers like woodworker and farmers. It is also reliable and controllable.

The result of this research work also shows that most Ghanaians are ready to switch or adapt to biomass electrical energy source of supply. Aside the above benefits the end output of converted biomass material could also be used as fertilizer for agricultural use. Biomass is also good for green house plants. In addition the introduction of this system will substantially do away with the mass piles of waste thus good health for all. Even as previously mentioned, gone are the days were waste was useless, today waste is termed money and money is he means of development and better living standards and conditions.

The result of this research work also shows that there are enough biomass material resources in Ghana for the production and distribution of electrical energy to a large percentage of the inhabitants. With most gratitude to all who helped in diverse ways, the goal of this research was successfully achieved.

Thanks to advancements in science and technology, the various conversion technologies discussed in chapter 3 are means of achieving the dreams of the research objective fully. Already there are I'm putting plans in reaching investors who might be interested in taking such untapped opportunity.

In whole, the success of this research work will benefit the whole country as well as similar African countries or Africa as a whole. It will also foster good business relationship between Ghana and other African countries as well as the country or countries of the investing company or companies.

In addition to this work, there is still room for further research work on other sources of biomass residues such as the other 3main areas mentioned earlier. Ghana as well as other African countries has many biomass wastes sources for electrical energy production, thus those sources are potential grounds for further researches.

8.1. Suggestion for Future Studies

There are various types of biomass sources all group under four main categories, as discussed earlier. Since this work was just based on one out of the four main categories and was also limited to five potential sources only on the agricultural residues; there are 3main alternatives together with their sub alternatives that could be examine. So as a recommendation for the future, I will suggest that any or all the other three areas and their sub divisions could be studied. These include forest wastes, animal wastes and urban wastes. The methods employed in my research, could be adapted and used as a basis for further reach.

Even in the category of the agricultural wastes, there are other biomass residues untapped. Some of these among others are included in the below categories.

Straw	Sewage sludge
Leather waste	Animal litter
Coal	Tyres
Oil sludge/waste	Energy crops
Oil seed rape husks	Rice and Corn husks
Packaging Waste	Chicken Waste

9. REFERENCES

9.1. Biography

Biomass Assessment Handbook: Bioenergy for a Sustainable Environment

Author: Rosillo-Calle, Frank Hemstock, Sarah de Groot, Peter

Publisher: Earthscan Publications, Limited

Released: 2006

Subjects: Biomass -- Measurement. Biomass energy.

Bioenergy from Sustainable Forestry : Guiding Principles and Practice

Author: Richardson, J Bjorheden, R. Hakkila, P.

Publisher: Kluwer Academic Publishers

Released: 2002

Subjects: Biomass energy. Forest management. Fuelwood crops. Fuelwood industry and Sustainable forestry.

Planning and Installing Bioenergy Systems : A Guide for Installers, Architects and Engineers

Author: Deutsche Gesellschaft fur Sonnenenergie Staff ECOFYS (Firm) Staff

Publisher: Earthscan Canada

Released: 2004

Subjects: Biomass energy and Energy conversion.

Energy in the 21st Century

Author: Fanchi, John R.

Publisher: World Scientific Publishing Company, Incorporated

Released: 2005

Subjects: Power resources. Energy development.

Hagan E. B., 1985, Pyrolysis of Wood Shavings and Sawdust - A review of the demonstration project in Ghana

Hagan E. B., 1994, Production of Sawdust Briquettes in Kumasi Hagan E. B., 1997, Pre-feasibility study on proposed Letus Power Plant and

Coordinator, Dr. Adebayo Agbejule Principal Lecturer and project manager of EXIMIN

UNEP Environmental Technology centre

Mr. Joseph K Essandoh-Yeddu, the chief of strategic Planning and Policy at Ghana energy commission

Mr. Otu Danquah, the manager for the division of renewable energy at the Ghana energy commission

Mr. Ayi Klotey the vice president of Bonsu Cocoa college

Bonsu Agriculture institute for Ghana

Department of Tree Crop Development Unit; Ghana

Directorate of Crop Services; Ghana

Ministries for food and Agriculture (MOFA), Ghana

Coconut Sector Development Project

Energy Commission of Ghana

Websites

http://www.abesafrica.com/

http://www.oregon.gov/ENERGY/RENEW/Biomass/BiomassHome.shtml

http://www.educypedia.be/education/Biomass.htm

http://www1.eere.energy.gov/biomass/

http://www.google.com/Top/Science/Technology/Energy/Renewable/Biomass_and_Biofuels/

http://en.wikipedia.org/wiki/Biomass

http://www.nrbp.org/papers/046.pdf

http://rainforests.mongabay.com/20ghana.htm

http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/rentrends04.html#_ftn11

www.unep.org

http://www.eia.doe.gov/

http://www.ucsusa.org/clean_energy/technology_and_impacts/energy_technologies/how-biomass-energy-works.html#Types_of_Biomass

http://www.princeton.edu/~energy/publications/pdf/2001/Li_01_ESD_China_biomass_energy.pdf

http://faostat.fao.org/site/567/DesktopDefaulthttp://www.ecn.nl/phyllis/Multi.asp?Selected=6:-1:-1
http://faostat.fao.org/site/567/DesktopDefault

http://www.carbontrust.co.uk/resource/measuring_co2/Measuring_CO2_Methodologies.htm

http://www.tedmontgomery.com/convrsns/index.html

http://www.scidev.net/en/features/sugarcane-ethanol-brazils-biofuel-success.html

10. ABBREVIATIONS

AEO - Annual Energy Outlook

CHP - Combined Heat and Power

DOE - Department f Energy

ECG - Energy Commission of Ghana

EIA – Energy Information Administration

GHG - Green House Gas

GPRS - Ghana Poverty Reduction Strategy

IETC - International Environmental Centre

KITE - Kumasi Institute of Technology Environment

MSB – Medium Size Business

MOFA - Ministry of Food and Agriculture

MSW - Municipal Solid Waste

PPO - Pure Plant Oil

SSB – Small Size Business

SHS - Solar Home Systems

SHS - Solar Home Systems

SNEP - Strategic National Energy Plan

SVP - Straight Vegetable Oil

UNEP- United Nations Energy Programme

11. APENDIXIES

Appendixes 1 – Biomass Technologies

Appendixes 2 – Methodology of study

Appendixes 3 – Qualitative

Appendixes 4 – Exploratory

Appendixes 5 – Focus Group

Appendixes 6 – Research Result on Total Energy Generation

Appendixes 7 – References

Appendixes 8 - Pyrolysis - decomposition of complex molecules by heating

Appendixes 8 - gasification -to convert a solid or liquid into gas

Formula used in calculating residual rate and electricity

Total Biomass From Crop Residues = S X d

Total Biomass Energy (TOE) = *Total Biomass From Crop Residues X Heat Value of Crop

Conversion of Kilojoules to Kilowatt/hour = multiply by 0. 0002778

1 tonne Oil Equivalent = 11630 kWh

CO2 emissions in tonnes = Energy Consumption (kWh) X Fuel Emission Factor for Electricity Use (0.43kg CO2/kWh) X Global Warming Potential of CO2 / 1000) 0.001

CH4 emissions in tonnes = Energy Consumption (kWh) X Fuel Emission Factor for Electricity Use (0.43kg CO2/kWh) X Global Warming Potential of CH4 / 1000) 0.023

N20 emissions in tonnes = Energy Consumption (kWh) X Fuel Emission Factor for Electricity Use (0.43kg CO2/kWh) X Global Warming Potential of N20 / 1000) 0.31

SF6 emissions in tonnes = Energy Consumption (kWh) X Fuel Emission Factor for Electricity Use (0.43kg CO2/kWh) X Global Warming Potential of N20 / 1000) 0.0239

Figures, calculations, etc. are not present due to sensitivity and privacy.

FOR MORE DETAILS ON THE CALCULATIONS, FIGURES, X% VALUES, ETC.

You can contact me personally at: Tackwilly@yahoomail.com. *Thank you.*

QUESTIONAIRES

Targeted Groups

1. What is the present energy structure of the Ghanaian economy and the future demand and supply conjecture?

2. Is there the need for an alternative energy sources for Ghanaians both now and in the future?

3. Of what importance will the invention and implementation of biomass technologies be for the Ghanaian economy?

4. What is the potential market segment or size for biomass energy consumption?

5. What are the potential Biomass sources, locations and quantity available in Ghana?

6. What are the potential Biomass Technologies available that will be beneficial for Ghana?

7. How much accumulation of biomass materials exists presently and how much energy (electricity in gig watts) could be derived from it/year?

8. What are the future plans in place to help supplement the present energy crisis?

Focus Groups

1. What do you think about the present energy system? Good or Bad? Reasons.....

2. Would you like to use or switch to a different source of energy? Why so / why not so?

3. Should there be a less expensive and a more reliable source of energy, would u like it?

4. Do you have any idea where any of the following could be located? (Cocoa, coconut-husk, sawdust, palm kennel or sugar-cane waste).

5. What is the average production of (any of the criteria mentioned above) /day x week x year? *(mainly to the producer's of any of the known sources in question)*

6. Do you know what biomass is or would you like to know what it is?

7. How will you like to have a renewable form of energy "biomass energy" at your own convenience and for personal use at manufacturing or constriction sites, township/community, home, office etc?

8. How much do you pay / will you otherwise like to pay (monthly) on electricity?

9. Will you prefer the use of bioenergy to other alternatives? (Yes/No)

10. Why the choice made in the question above?

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