Sudan University of Science and Technology

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College of Graduate Studies

Advantages of Using Biomass as Alternative Energy

مميزات استخدام الكتلة الحيوية كطاقة بديله

This submitted in partial for requirement of the degree of master in physics

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الآيــة

قال تعالى :

وَسَخَّرَ لَكُم مَّا فِي السَّمَاوَاتِ وَمَا فِي الْأَرْضِ جَمِيعًا مِّنْهُ

إِنَّ فِي ذَلِكَ لَآيَاتٍ لِّقَوْمٍ يَتَفَكَّرُونَ (١٣)

صدق الله العظيم
سورة الجاثية

Dedication

I dedicate this work;to my precious family, to my parents,to my friends. And to all who supported me to develop my academicskills.

Acknowledgment

I am grateful to Sudan University of Science and Technology. My thanks to Dr. Sawsan Ahmed Elhouri for supervision.

Last but not least my colleagues, professors whom I found help, support, and knowledge, my deep appreciation you all made my pleased.

Abstract

The focus of the researchis to investigate the advantages of biomass as an alternative energysource to prevent or reduce the additional emissions of greenhouse gases; that is released from the conventional fuels combustion. A studyalso put a spot of light on the potentialof different sources which can produce good amount of biomass as fuelfeed stock.It is clear that biomass can be used as an alternative source of energy if the mentioned recommendations are done.

المستخلص

هدف البحث هو فحص مميزات الكتلة الحيوية كمصدر بديل للطاقة لمنع او تخفيض الانبعاثات الاضافية من الغازات التي تتحرر من حرق الوقود التقليدي . اجريت الدراسة لتقييم توفر و امكانية تطوير المصادر المختلفة التي تُمكّن من انتاج كمية جيدة من الكتلة الحيوية كوقود خام . بعد الدراسة وُجِدَ أنّ الكتلة الحيوية يمكن ان تُستخدَم كمصدر بديل للطاقةإذا نُفِّـذَت التوصيات المذكورة.

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Chapter One

Introduction

1.1 Prelude

With the increase in world population, the demand for energy in the world is steadily is increasing. Global environmental issues and exhaustion of fossil resources also pose serious problems for energy consumption. Environment-friendly energy and a shift to non fossil energy resources that called renewable energy sources such as wind, water and biomass are expected. Renewable energy can help countries meet their policy goals for secure, reliable and affordable energy to expand electricity access and promote development.

1.2 Research Problem

Using of conventional sources (oil, coal, natural gas and nuclear fuel) to generate power for long time led to air pollution by releasing greenhouse gases, global warming, climate change and thereby environmental equilibrium change. All these changes cause health problems for human, animals and plants. The other problem is that the conventional sources are exist in limited amounts and cannot be renewed. Therefore, the world needs environment-friendly and renewable sources at least to reduce these problems.

1.3 Literature Review

- ***Antonio C. Caputo , Mario Palumbo , Pacifico M. Pelagagge , Federica Scacchia2005Evaluation***

The substitution of conventional fossil fuels with biomass for energy production results both in a net reduction of greenhouse gases emissions and in the replacement of non-renewable energy sources. However, at present, generating energy from biomass is rather expensive due to both technological limits related to lower conversion efficiencies, and logistic constraints. In particular, the logistics of biomass fuel supply is likely to be complex owing to the intrinsic feedstock characteristics, such as the limited period of availability and the scattered geographical distribution over the territory. In this paper, the economical feasibility of biomass utilization for direct production of electric energy by means of combustion and gasification-conversion processes, has been investigated and evaluated over a capacity range from 5 to 50 MW, taking into account total capital investments, revenues from energy sale and total operating costs, also including a detailed evaluation of logistic costs. Moreover, in order to evaluate the impact of logistics on the bio-energy plants profitability, the effects of main logistic variables such as specific vehicle transport costs, vehicles capacity, specific purchased biomass costs and distribution density, have been examined. Finally, a mapping of logistic constraints on plant profitability in the specified capacity range has been carried out [1].

- ***Gang Luo, Wen Wang, and Irini Angelidaki 2013, Study***

Syngas is produced by thermal gasification of both nonrenewable and renewable sources including biomass and coal, and it consists mainly of CO, CO_2, and H_2. In this paper we aim to bioconvert CO in the syngas to CH_4. A novel technology for simultaneous sewage sludge treatment and

CO biomethanation in an anaerobic reactor was presented. Batch experiments showed that CO was inhibitory to methanogens, but not to bacteria, at CO partial pressure between 0.25 and 1 atm under thermophilic conditions. During anaerobic digestion of sewage sludge supplemented with CO added through a hollow fiber membrane (HFM) module in continuous thermophilic reactors, CO did not inhibit the process even at a pressure as high as 1.58 atm inside the HFM, due to the low dissolved CO concentration in the liquid. Complete consumption of CO was achieved with CO gas retention time of 0.2 d. Results from high-throughput sequencing analysis showed clear differences of the microbial community structures between the samples from liquid and biofilm on the HFM in the reactor with CO addition. Species close to *Methanosarcina barkeri* and *Methanothermobacter thermautotrophicus* were the two main archaeal species involved in CO biomethanation. However, the two species were distributed differently in the liquid phase and in the biofilm. Although the carboxidotrophic activities test showed that CO was converted by both archaea and bacteria, the bacterial species responsible for CO conversion are unknown [2].

- ***Tony Bridgwater , 2006, Evaluation***

Bio-energy is now accepted as having the potential to provide the major part of the projected renewable energy provisions of the future as biofuels in the form of gas, liquid or solid fuels or electricity and heat. There are three main routes to providing these biofuels—thermal conversion, biological conversion and physical conversion—all of which employ a range of chemical reactor configurations and designs. This review focuses on thermochemical conversion processes for their higher efficiencies, lower costs and greater versatility in providing a wide range of energy, fuel and chemical options. The technologies of gasification and fast pyrolysis are described, particularly the reactors that have been developed to provide the necessary conditions to optimise performance. The primary products that can be derived as gas, liquid and solid fuels are characterised, as well as the secondary products of electricity and/or heat, liquid fuels and a considerable number of chemicals [3].

- ***W. W. Wilhelm,Jane M. F. Johnson,Douglas L. Karlenand David T. Lightle, 2007, Study***

Sustainable aboveground crop biomass harvest estimates for cellulosic ethanol production, to date, have been limited by the need for residue to control erosion. Recently, estimates of the amount of corn (*Zea mays* L.) stover needed to maintain soil carbon, which is responsible for favorable soil properties, were reported (5.25–12.50 Mg ha^{-1}). These estimates indicate stover needed to maintain soil organic carbon, and thus productivity, are a greater constraint to environmentally sustainable cellulosic feedstock harvest than that needed to control water and wind erosion. An extensive effort is needed to develop advanced cropping systems that greatly expand biomass production to sustainably supply cellulosic feedstock without undermining crop and soil productivity [4].

1.4 Objectives of the Study

The aim of this study is to find a solution for the above mentioned pollution problems; so biomass as alternative energy was a suggestion.
Biomass decreases the consumption of conventional sources and reduces air pollution.

1.5 Presentation Of The Thesis

In this research, chapter one views an introduction of energy in details. Chapter two defined the energy concepts and its units in addition to the classification according to different criteria. Chapter three clarifies disadvantages of conventional energy combustion on the environment and human health. Also the harms of conventional sources mining, milling or refining are mentioned. In chapter four illustrate the biomass types, conversion methods and advantages, and feedstock. Conclusion and recommendations are explained in chapter five.

Chapter Two

Sources of Energy

2.1 Introduction

Any physical activity in this world, whether carried out by human beings or by nature, is cause due to flow of energy in one form or the other. The word ‘energy’ itself is derived from the Greek word ‘en-ergon’, which means ‘in-work’ or ‘work content’. The work output depends on the energy input. Energy is the capacity to do work. Energy comes in various forms, such as motion, heat, light, electrical, chemical, nuclear energy, and gravitational. Total energy is the sum of all forms of the energy a system possesses. In the absence of magnetic ,electrical and surface tension effects, the total energy of a system consists of the kinetic, potential, and internal energies. The internal energy of a system is made up of sensible, latent, chemical, and nuclear energies. The sensible internal energy is due to translational, rotational and vibrational effects of atoms and molecules .Thermal energy is the sensible and latent forms of internal energy. The classification of energy into different ‘‘types’’ often follows the boundaries of the fields of study in the natural sciences. For example, chemical energy is the kind of potential energy stored in chemical bonds, and nuclear energy is the energy stored in interactions between the particles in the atomic nucleus. Microscopic forms of energy are related to the molecular structure of a system and they are independent of outside reference frames. Hydrogen represents a store of potential energy that can be released by fusion of hydrogen in the Sun. Some of the fusion energy is then transformed into sunlight, which may again be stored as gravitational potential energy after it strikes the earth. For example, water evaporates from the oceans, may be deposited on elevated parts of the earth, and after being released at a hydroelectric dam, it can drive turbines to produce energy in the form of electricity. Atmospheric phenomena like wind, rain, snow, and hurricanes, are all a result of energy transformations brought about by solar energy on the atmosphere of the earth. Sunlight is also captured by plants as chemical potential energy in photosynthesis, when carbon dioxide and water are converted into carbohydrates, lipids, and proteins. This chemical potential energy is responsible for growth and development of a biological cell. Energy is one of the major inputs for the economic development of any country. In the case of the developing countries, the energy sector assumes a critical importance in view of the ever - increasing energy required [5].

2.2 Energy Units

There are several units of energy used to determine the amount of energy , such as , British thermal unit (Btu) , is the energy unit in the English system needed to raise the temperature of 1 lb of water at 68 F by 1 F. Calorie (cal) is the amount of energy in the metric system needed to raise the temperatureof 1 g of water at 15 C^o by 1 C^o. and Joule (J) is an unit of energy in the international system (SI) ,Table (2.1) shows energy units [6].

Table (2.1): shows name of units, their symbols and definitions.

Name of unit	**Symbol**	**Definitions**
British thermal unit	Btu	1055 J
Btu/lbm	Btu/lbm	2.326 kJ/kg
Joule	J	$J = m*N = 1\ kg*m^2/s^2$
Calorie	Cal	4.1868 J
kJ	kJ	$kPa\ m^3 = 1000\ J$
kJ/kg	kJ/kg	0.43 Btu/lbm
Erg	erg	$g.cm^2/s^2 = 10^{-7}\ J$

Foot pound force	ft lb	g * lb * ft = 1.355 J
Horsepower hour	hph	hp * h = 2.684 * 10^6 J
Kilowatt hour	kWh	kW * h = 3.6 * 10^6 J
Electron volt	eV	1.602 17 * 10^{-19} ± 4.9 * 10^{-26} J

2.3 Energy Resources Classification

Energy resources classification can be based on the following criteria.

- Usability of energy.
- Traditional use.
- Commercial application.
- The origin.
- Large-term availability.

2.3.1 Based on usability of energy

According to this criteria energy resources divided in to three types.

2.3.1.1 Primary Sources

Primary energy sources can be defined as sources which provide a net supply of energy , such as, Sunlight , Wind ,Running water , Coal, Crude Oil and Uranium. These sources are available in raw forms; therefore, they cannot be used as such. But they must be extracted, processed and converted into a form as required by the consumer. Thus, some energy is spent to convert this raw form into usable form.

2.3.1.2 Intermediate sources

These types of sources are obtained from primary energy sources by transformation, and they used as vehicles of energy.

2.3.1.2 Secondary Sources

These are the final forms of energy sources which supplied to the consumer for utilization. This energy also called usable energy, e.g. electrical energy ,thermal energy and chemical energy .Some forms of energy sources may be categorized both in Intermediate as well as secondary sources, such as electricity and hydrogen.

2.3.2 Based on traditional use

Here energy divided into two

2.3.2.1 Conventional energy sources

Are sources which used traditionally for many decades around the oil crisis and include following sources

- Fissile fuels energy.
- Nuclear energy.
- Hydraulic energy.

2.3.2.2 Nonconventional energy sources

Such sources consider as modern sources and produced continuously in nature and are in exhaustible, and called renewable sources of energysome of these sources are:

- Solar energy
- Wind energy.
- Biomass energy.
- Tidal energy.

2.3.3 Based on commercial application

2.3.3.1 Commercial energy sources

This type includes usable energy forms which are essential for commercial activities, thus;

- Electricity.
- Petroleum.
- Diesel.

- Gas.

2.3.3.2 Noncommercial energy sources

These sources are derived from the nature and used directly without passing through a commercial outlet, such as;

- Wood.
- Animal dung cake.
- Crop residue.

2.3.4 Based on the origin

This classifying depends on the places of energy sources and they are;

- Fossil fuel energy (oil, natural gas and coal).
- Nuclear energy.
- Hydro energy.
- Solar energy.
- Wind energy.
- Biomass energy.
- Geothermal energy.
- Tidal energy.
- Ocean thermal energy.
- Ocean wave energy.

2.3.5 Based on long-term availability

This is depends on sustainability and renewability of an energy source, and have two types;

2.3.5.1 Nonrenewable energy sources

Theseenergy sources obtained from static stores with limited a mounts of energy that remain underground unless released by human interaction, the energy is initially an isolated energy potential, and external action is required to initiate the supply of energy for practical purposes, such energy supplies are called finite suppliesor brown energy, and cannot get renewed after its consumption. Examples are nuclear fuels and fossil fuels [10].

- ***Nuclear fuels***

Are heavier and unstable chemical elements used as fuel for nuclear reactors such as uranium and thorium. They do not pollute the air with harmful gases. Fuel provides the source for the heat which, ultimately, will allow generation of electricity, or indeed the production of energy for other applications. Fuel is the consumable component in reactors, it is held a few years in the reactor. In the event of an accident situation, fuels are the main potential source of radioactive pollution in the environment.

2.3.5.1.1 Nuclear energy

Nuclear energy produced through the fission reaction of nuclear fuels within the nuclear reactor, nuclear fuels undergo fission when struck by free neutrons and generate new neutrons leading to a self-sustaining chain reaction that releases energy in heat form at a controlled rate in a nuclear reactor.This heat is used to produce steam to be used in a turbine to produce electricity. Figure (2.1) illustrate how nuclear reactor works.In other situations, two small nuclei may join together to make a bigger one. This is the process of nuclear fusion. Nuclear fusion takes place inside the sun, releasing the energy we know as solar radiation [8].

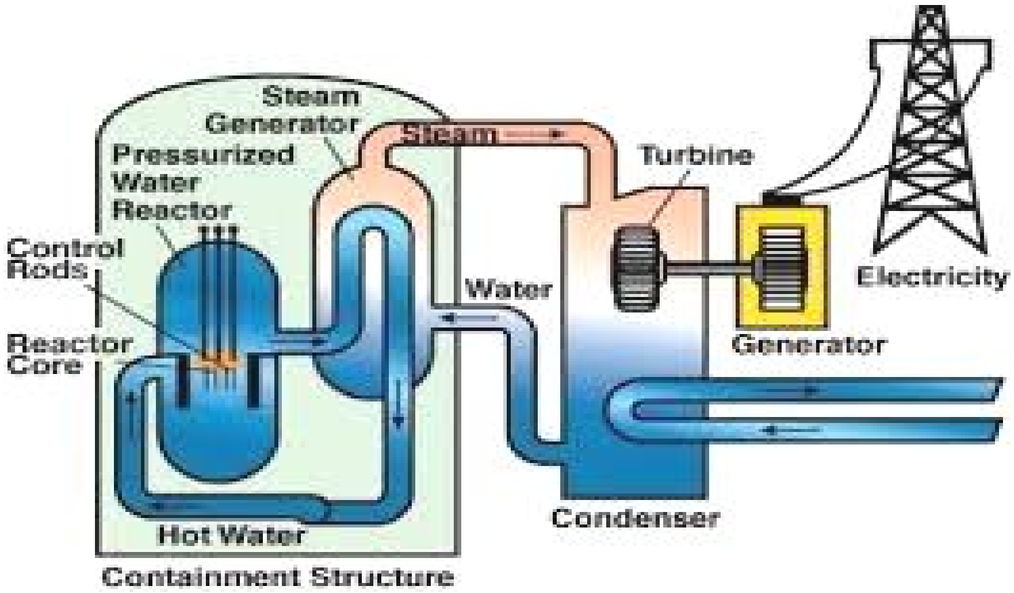


Fig (2.1): shows how nuclear reactor works to generate electricity.

2.3.5.1.2 Fossil fuels

Fossil fuel as these are formed by the decomposition of the remains of dead plants and animals buried under the earth for a long time.These are non-renewable sources of energy, which, if exhausted, cannot be replenished in a short time. Their reserves are limited and are considered very precious. These should be used with care and caution to let them last long. These are also contributing to the global environmental Pollution. Fossil fuels contain high percentages of carbon and include Coal, oil and natural gas.

2.3.5.1.2.1 Coal

Coals are sedimentary rocks containing combustible and incombustible matters as well as water. Coal comes in various composition and energy content depending on the source and type.Coal has impurities like sulfur and nitrogen and when it burns the release impurities can combine with water vapor in the air to form droplets that fall to earth as weak forms of sulfuric and nitric acid as acid rain. Coal also contains minerals, which do not burn and make up the ash left behind in a coal combustor.Because of high carbon content, coals generate more CO_2 per unit of released energy than any other fossil fuel.

- ***Types of Cool***

1. Lignite coal has less than 50% carbon and an energy density lower than wood. It is soft coal.

2. Anthracites coal, have more than 90% carbon, it is very hard and shiny and the ultimate maturation. Anthracite coal creates a steady and clean flame and is preferred for domestic heating. Furthermore it burns longer with more heat than the other types, and called hard coal.

3. Bituminous coals have mostly between 70 and 75% carbon.

Bituminous coal ignites easily and burns with a relatively long flame. If improperly fired, bituminous coal is characterized with excess smoke and soot and called house hold coal.

4. Peat coal has carbon percentage less than of lignite coal. Peat is the most inferior quality of coal. On strong heating, coal breaks up to produce coal gas, ammonia and coke [7].

2.3.5.1.2.2 Oil

It is a dark colored, viscous and foul smelling crude oil. ThePetroleum means rock oil. It is normally found under the crust of earth trapped in rocks. The crude oil is a complex mixture of several solid liquid, gaseous hydrocarbons mixed with water, salt and earth particles. It is a natural product obtained from oil wells. The crude petroleum is refined by the process of fractional distillation to obtain more useful petroleum products. The hydrocarbons present in petroleumis converted into energy-rich fuels, including gasoline, diesel, jet fuel, heating, and other fuel oil and liquefied petroleum gases. The remaining oil is converted to pharmaceuticals, solvents, fertilizers, pesticides, and plastics. Liquefied petroleum gas (LPG), is a flammable mixture of propane (C_3H_8) and butane (C_4H_{10}) used as a fuel in heating appliances and vehicles. Fuel oil, is made of long hydrocarbon chains, particularly alkanes, cycloalkanes, and aromatics and heavier than gasoline.

2.3.5.1.2.3 Natural Gas

Natural gas was created for the most part from large amounts of dead plankton which was layered on the floor of the ocean. It consists about 95% Methane and rest ethane and propane. It occurs deep under the crust of the earth either alone or a long with oil above the petroleum deposits. Natural gas is a major source of electricity production through the use of gas turbines and steam turbines. It burns more cleanly and produces less carbon dioxide than burning petroleum and burning coal foran equivalent amount of heat produced. The density of liquefied natural gas is in the range 410–500 kg/m^3. The flame temperature of natural gas is 1960 C^o, ignition point is 593 C^o. It is used as a domestic andindustrial fuel. The natural gas is now also available as Compressed Natural Gas (CNG) a substitution of petrol in automobiles [8].

- ***Advantages of nonrenewable energy***

1- Cost at present, these are cheaper than renewable sources.

2- Security, as storage is easy and convenient, by storing a certain quantity, the energy availability can be ensured for certain period.

3- Convenience, these sources are very convenient to use as technology for their conversion, and their use is universally available.

2.3.5.2 Renewable energy sources

Renewable Energy is any form of energy from solar, geophysical or biological sources that is replenished by natural processes at a rate that equals or exceeds its rate of use. Renewable Energy is obtained from the continuing or repetitive flows of energy occurring in the natural environment. Various types of Renewable Energy can supply electricity, thermal energy and mechanical energy, as well as produce fuels that are able to satisfy multiple energy service needs. Renewable Energy can be integrated into all types of electricity systems from large, interconnected continental-scale grids down to small autonomous buildings.Such energy may also be called Green Energyor SustainableEnergy. Major renewable energy sources are:

1. Hydro energy
2. Solar energy
3. Biomass
4. Wind
5. Geothermal heat
6. Ocean

Renewable energy generally gets cheaper in the long term, while fossil fuels generally get more expensive. The most important feature of renewable energy is that it can be harnessed without the release of harmful pollutants [7].

2.3.5.2.1 Hydro energy

Hydropower is the largest renewable resource used for electricity. Hydro energy is derived from the force or energy of moving water. Most hydroelectric energy comes from the potential energy of dammed water driving a water turbine and then generator which generates electricity. The power extracted from the water depends on the volume and on the difference in height between the source and the water's outflow. Figure (2.2) shows how dammed water used for power generation. This height difference is called the head. The amount of potential energy in water is proportional to the head. To deliver water to a turbine while maintaining pressure arising from the head, a large pipe called a penstock may be used. Potential energy of water is converted into Mechanical energy by using hydraulic turbines [5].

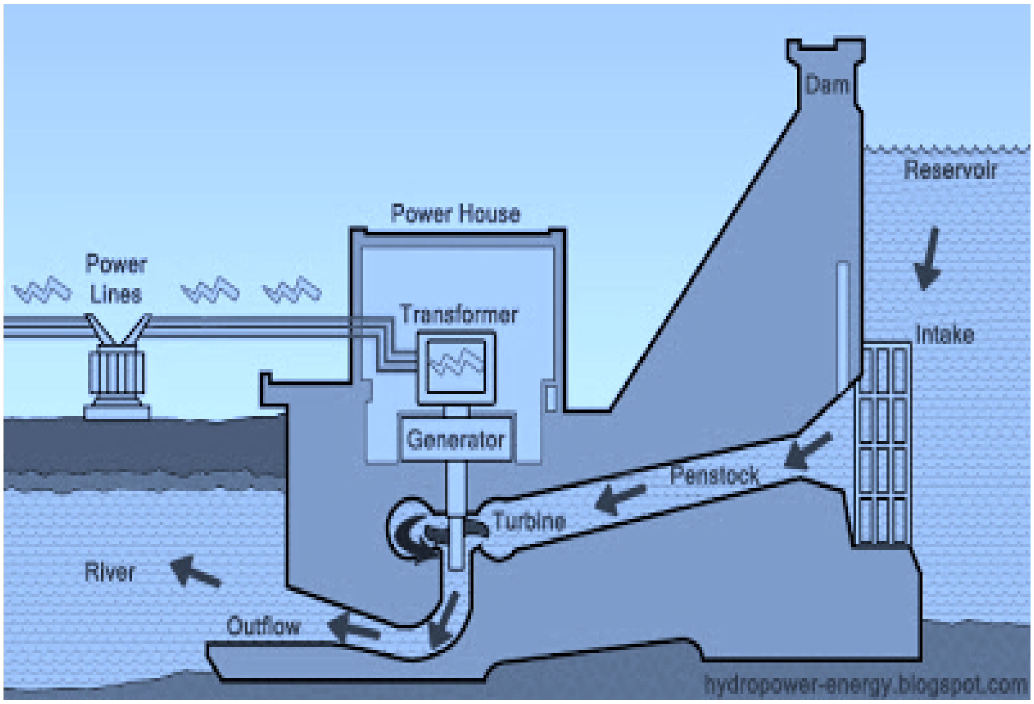


Fig (2.2): shows how electricity generated from dammed water.

2.3.5.2.1.1 Hydraulic Resources

Water-power potential depends on the hydro-geographic conditions of the area. Whereas the flow available depends on the rainfall rate and the catchment area, the head depends on the topography with the slopes available. Mountainous regions with regular rainfalls are therefore well suited for hydropower development. The annual rainfall and seasonal behavior is evaluated in the flow-duration curve, which shows the hydropower potential of a river catchment area. Depending on the characteristics of the area, the flow that can be utilized can be determined. In general, for a firm power required, the water flow should be ensured in the dry season. Storage dams and reservoirs collect surplus flow to distribute it for power generation in a time of less flow or peak power demand. In a river system with its catchment area, its water run-off, and drop in the water level. Most of the potential can be developed in big hydropower stations and will serve the national grids. Hydro systems without dam derive kinetic energy from rivers and oceans and denoted by Tidal energy sources.

2.3.5.2.1.2 Environmental and Social Impacts

Although hydroelectricity is generally considered a clean energy source, it is not totally devoid of greenhouse gas (GHG) emissions and it can often have significant adverse socio-economic impacts. Large-scale dams actually do not reduce overall GHG emissions when compared to fossil fuel power plant. To build a dam significant area of land need to be flooded often in densely inhabited rural area, involving large displacements of usually poor, indigenous peoples. Mitigating such social impacts represents a significant cost to the project, which if it is even taken into consideration, it can make the project economically and socially unviable. Environmental concerns are also quite significant, as past experience has shown. This includes reduction in biodiversity and fish populations, sedimentation that can greatly reduce dam efficiency and destroy the river habitat, poor water quality, and the spread of water-related diseases [9].

2.3.5.3 Solar Energy

Solar energy is derived from the sun through the form of solar radiation. Solar powered electrical generation relies on photovoltaic and heat engines. Other solar applications includes space heating and cooling through solar architecture, day lighting, solar hot water, solar cooking, and high temperature process heat for industrial purposes. Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy: active solar energy and passive solar energy.

- ***Active solar techniques***

Include the use of solar thermal collectors to harness the energy. Some active solar techniques include solar process heat by commercial and industrial buildings, space heating or cooling, and water heating. A typical water heating system includes solar collectors that work along with a pump, heat exchanger, and one or larger heat storage tanks. The most common collectoris called a flat-plate collector. Mounted on a roof, it consists of a thin, flat, rectangular box with a transparent cover that faces the sun. Smalltubes run through the box and carry the heat transfer fluid mainly water or air tobe heated. The tubes are attached to an absorber plate, which is painted black toabsorb the heat. As heat builds up in the collector, it heats the fluid passing through the tubes. The storage tank then holds the hot liquid. It can be just a modified water heater, but it is usually larger and very well-insulated. Systems that use fluids other than water usually heat the water by passing it through a coil of tubing in the storage tank, which is full of hot fluid. As shown by Fig (2.3 a).

- ***Applications of flat plate collector:***

1. Solar water heating systems for residence, hotels, industry.
2. Desalination plant for obtaining drinking water from sea water.
3. Solar cookers for domestic cooking.
4. Drying applications.
5. Residence heating.

Fig (2.3 a): Shows flat plate collector

- ***Parabolic trough collector***

Parabolic trough with line focusing reflecting surface provides concentration ratios from 30 to 50. Hence, temperature of high as 300 C^o can be obtained. Light is focused on a central line of the parabolic trough. The pipe located along the centre line absorbs the heat and the working fluid is circulated through the pipe, as shown bellow [6]. Fig (2.4) explains parabolic trough collector work.

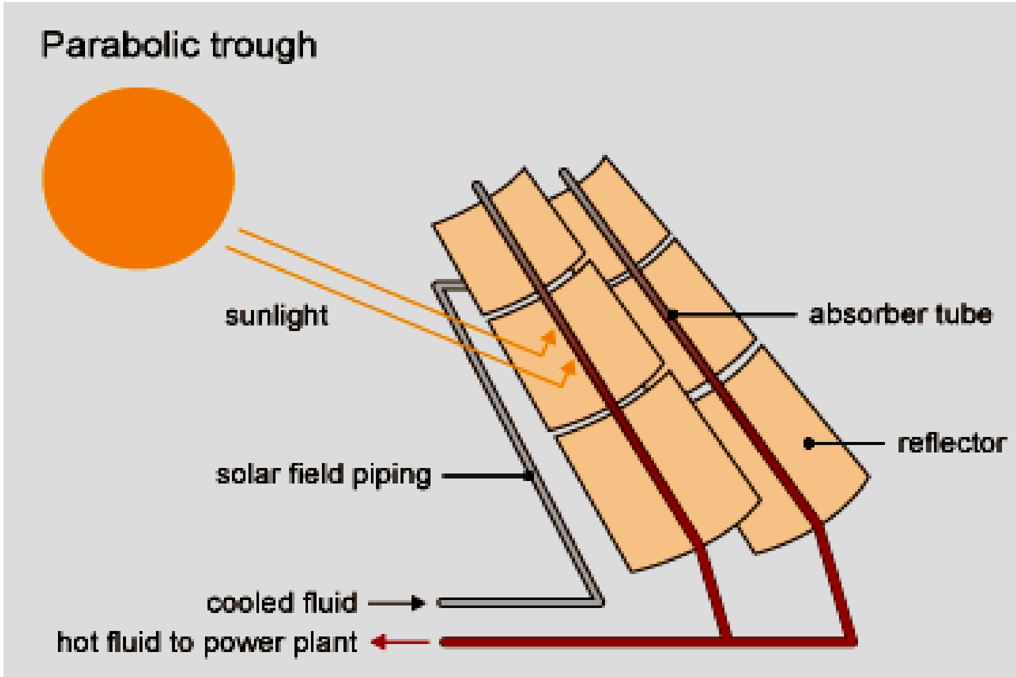


Fig (2.4): shows how parabolic trough collector works.

- ***Passive solar technique***

Rely on gravity and the tendency for water to naturally circulate as it is heated. Passive solar techniques orient buildings to the Sun, select materials with favorable thermal mass or light dispersing properties, and design spaces that naturally circulate air. Fig (2.5 b) shows a house with passive solar design.

2.3.5.3.1 Solar Electric Generating Systems

Solar electric generating system use parabolic trough collectors to collect the sun's energy to generate steam to drive a conventional steam turbine. The parabolic mirrors automatically track the sun throughout the day. The sun light is directed to central tube carrying synthetic oil, which heats around 400 C^{o}. The heat is used to convert water to steam to drive a steam turbine and produce electricity.

Fig (2.5 b): shows house with passive solar system.

2.3.5.3.2 Photovoltaic

Solar photovoltaic (PV) convert light into electricity using semiconductor materials. Photovoltaic cell is a solar cell, which is a solid state electrical device that converts the energy of light directly into electricity. Assemblies of cells are knownas solar modules or solar panels. Solar modules are typically deployed as an array of individual modules. A module consists of many jointly connected solarcells. Photovoltaic systems produce direct current, which must be converted to alternating current via an inverter if the output from the system is to be used in the grid.There are two types of inverters:

A stand-alone inverter is used in off-grid applications with battery storage.Grid-interactive inverters must follow the voltage and frequency characteristics of the utility-generated power presented on the distribution line. For both types of inverters, the conversion efficiency is a very important consideration. See fig (2.6)bellow [5].

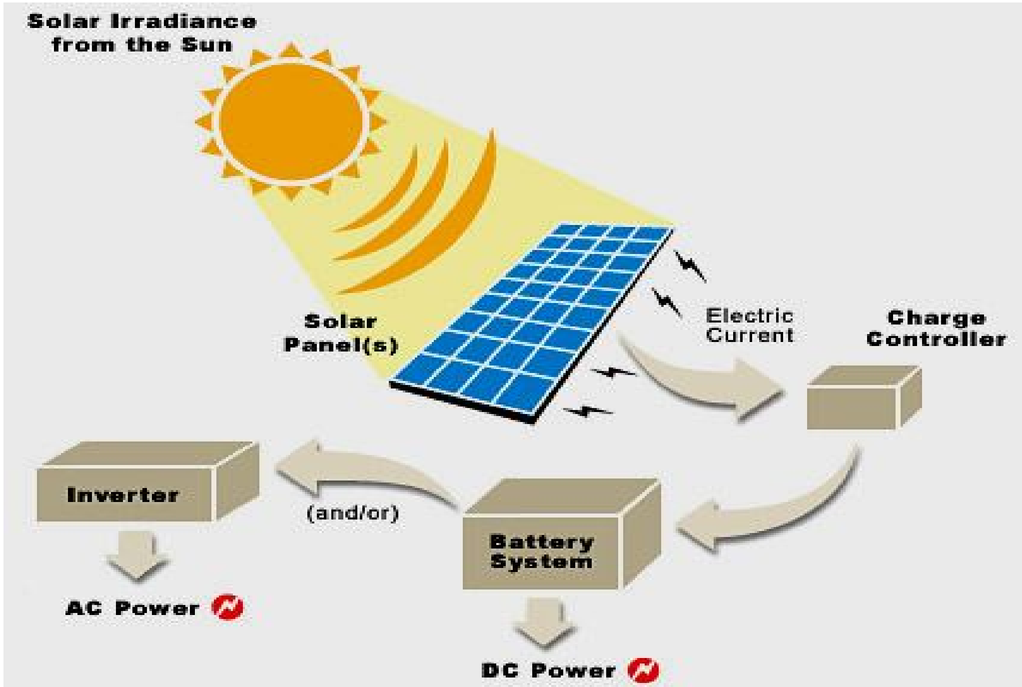


Fig (2.6): illustrate how photovoltaic converts sunlight into electricity.

2.3.5.4 Wind energy sources

The Earth is unevenly heated by the sun and the differential heating drives a global atmospheric convection system reaching from the earth's surface to the stratosphere. Most of the energy stored in these wind movements can be found at high altitudes where continuous wind speeds occur. Winds are caused because of two factors.

1. The absorption of solar energy on the earth's surface and in the atmosphere.

2. The rotation of the earth about its axis and its motion around the Sun.

Wind power is a totally renewable energy source with no greenhouse gas emissions. Wind Turbine is a machine with rotating blades that converts the kinetic energy of wind into useful power. Fig (2.7) shows wind turbine.

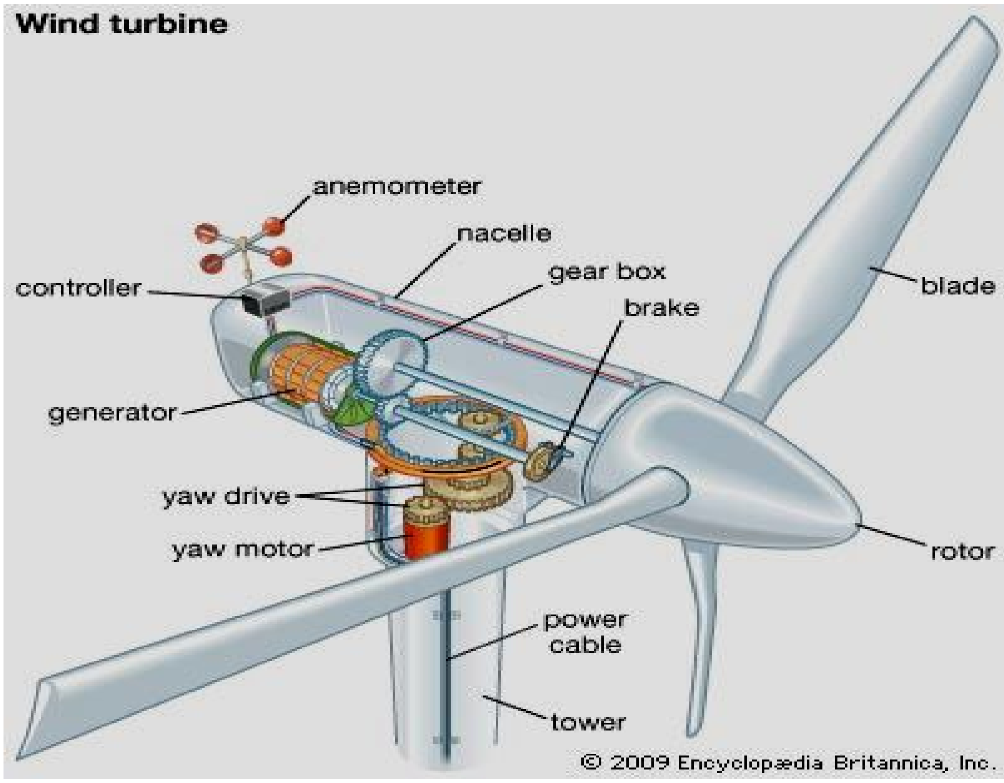


Fig (2.7): shows parts of wind turbine.

The wind turbine captures the wind's kinetic energy in a rotor consisting of two or more blades mechanically coupled to an electrical generator. The turbine is mounted on a tall tower to enhance the energy capture. Numerous wind turbines are installed at one site to build a wind farm of the desired power generation capacity. Obviously, sites with steady high wind produce more energy over the year. Two basic categories of Wind Turbines exist: horizontal-axis wind turbines (HAWT) as shown in fig (2.8) and vertical-axis wind turbines (VAWT) as shown in fig (2.9), depending on the orientation of the rotor axis.

Fig (2.8):horizontal-axis wind turbine(VAWT).

Fig (2.9):vertical-axis wind turbines(HAWT).

- ***Wind speed profiles***

The roughness of the earth surface diminishes the velocity of the wind. With growing height above ground level, the roughness has less effect and the velocity of the wind increases [10].

2.3.5.5 Geothermal Energy Sources

The inner core of the earth reaches a maximum temperature of about 4000C^o. Heat passes out through the solid submarine and land surface mostly by conduction – geothermal heat – and occasionally by active convective currents of molten magma or heated water. The average geothermal heat flow at the Earth's surface is only 0.06Wm^{-2}, with a temperature gradient of <30C^{o}km^{-1}. This continuous heat current is trivial compared with other renewable supplies in the above surface environment that in total average about 500Wm^{-2}; see Figure(2.10). However, at certain specific locations, increased temperature gradients occur, indicating significant geothermal resources. These may be harnessed over areas of the order of square kilometers and depths of ~5km at fluxes of 10–20Wm^{-2}to produce ~100MW. Geothermal heat is generally of low quality, and is best used directly for building or process heat at about 50–70 C^o, or for preheating of conventional high temperature energy supplies.

Fig (2.10): Geothermal source

Hot water or steam reservoirs deep in the earth are accessed by drilling. Geothermal reservoirs located near the earth’s surface maintain a relatively constant temperature. The hot water and steam from reservoirs can be used to drive generators and produce electricity as shown in figure (2.11). In other applications, the heat produced from geothermal is used directly in heating buildings and industrial plants [7].

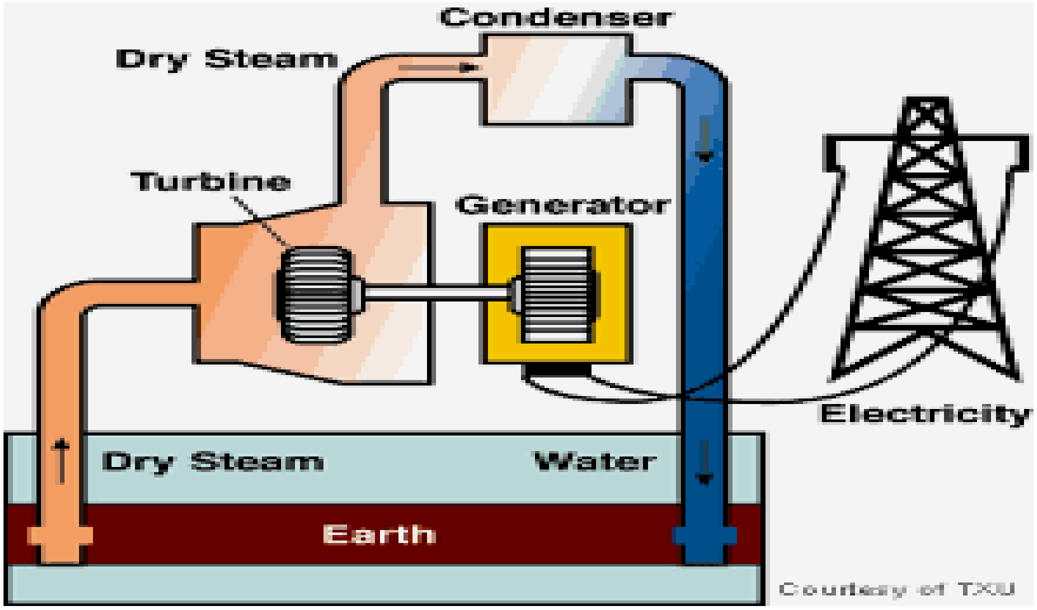


Fig (2.11): generating electricity by geothermal energy.

Heat passes from the crust by:

(1) Natural cooling and friction from the core.

(2) Radioactive decay of elements such as uranium and thorium.

(3) Chemical reactions.

There are three classes of geothermal region:

1) Hyper thermal. Temperature gradient is $\geq 80\ C^o km^{-1}$. These regions are usually on tectonic plate boundaries

2) Semi thermal. Temperature gradient is ~40–80 C^okm. Such regions are associated generally with anomalies away from plate boundaries. Heat extraction is from harnessing natural aquifers or fracturing dry rock.

3) Normal. Temperature gradient is $< 40\ C^o$ km. These remaining regions are associated with average geothermal conductive heat flow at ~ $0.06 Wm^{-2}$. It is unlikely that these areas can ever supply geothermal heat at prices competitive to present or future energy supplies.

- ***Heat obtained methods***

1) Natural hydrothermal circulation. In this, water percolates to deep aquifers to be heated to dry steam, Vapour, liquid mixtures or hot water. Emissions of each type can be observed in nature.

2) Hot igneous systems. These are associated with heat from semi-molten magma that solidifies to lava.

3) Dry rock fracturing. Artificial fracturing from boreholes enables water to be pumped through the hot rock to extract the heat.

2.3.5.5.1 Environmental Impacts

Geothermal fluids contain variable concentrations of gases, largely nitrogen and carbon dioxide with some hydrogen supplied and smaller proportions of ammonia, mercury, radon and boron. Most of these chemicals are concentrated in the disposal water which is usually reinjected back into the drill holes so that there is minimal release into the environment. The concentrations of the gases are usually low enough not to be harmful or else the abatement of toxic gases can be managed with current technology [6].

2.3.5.6 Ocean Energy Sources

Ocean energy source include four types:

1. ***Wave energy***, it is a concentrated form of wind energy. Wind is generated by the differential heating of the atmosphere and, as it passes over the ocean, friction transfers some of the wind energy to the water, forming waves, which store this energy as potential energy and kinetic energy. This energy can be captured and converted into useful power [11].
2. ***Ocean thermal energy***, conversion uses, the temperature difference that exists between deep and shallow waters to run a heat engine. Ocean thermal energy conversion (OTEC) plants have three conversion

schemes: open, closed and hybrid. In the open conversion cycle, seawater is the circulating fluid - warm surface water is in a partial vacuum chamber. The steam produced passes through a turbine to generate power, after which it is condensed, using cooler, deep seawater. Closed conversion cycles offer more efficient thermal performance. A secondary working fluid, such as ammonia, propane or Freon-type is vaporized and re-condensed continuously in a closed loop to drive a turbine. A hybrid conversion cycle combines both open and closed cycles. Steam is generated by flash evaporation and then acts as the heat source for a closed Rankin cycle, using ammonia or other working fluid [12].

3. ***Salinity Gradient***, It has been known for centuries that the mixing of freshwater and seawater releases energy, therefore, a river flowing into a saline ocean releases large amounts of energy, this energy may transfer to the power [11].

4. ***Tidal energy***, Tide is periodic rise and fall of the water level of the sea. Tides occur due to the attraction of seawater by the moon. These tides can be used to produce electrical power which is known as tidal power. A dam is constructed in such a way that a basin gets separated from the sea and a difference in the water level is obtained between the basin and sea. The constructed basin is filled during high tide and emptied during low tide passing through sluices and turbine respectively. The Potential energy of the water stored in the basin is used to drive the turbine which in turn generates electricity as it is directly coupled to an alternator [12]. Fig (2.12) clarify tidal power generation.

Biomass is the last type of renewable energy sources and will be identified in detail in chapter four.

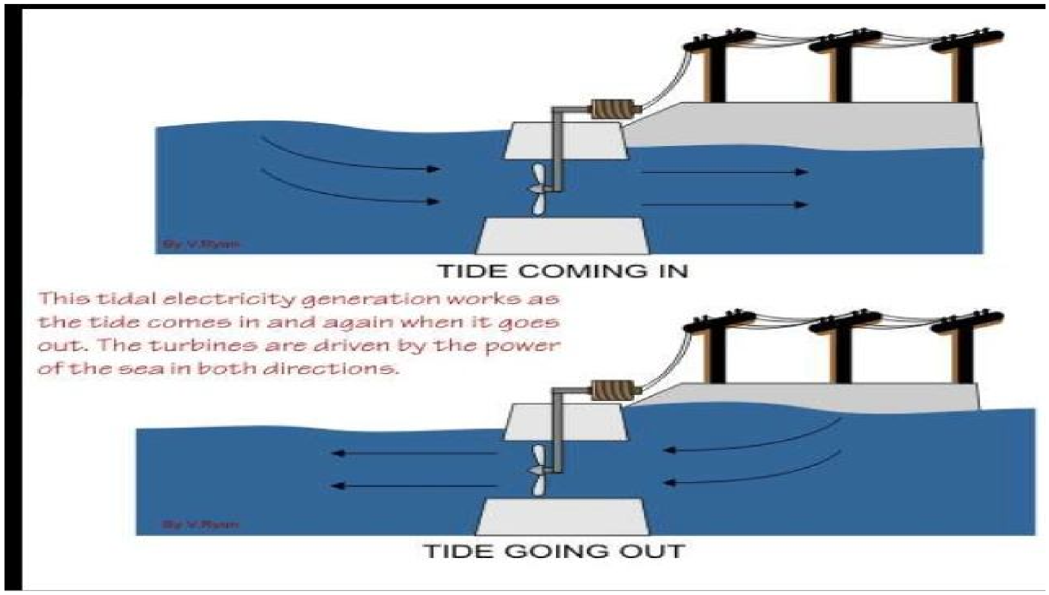


Fig (2.12): Tidal power generation.

Chapter Three

Disadvantages of Conventional Energy Source

3.1 Introduction

Saving environmental equilibrium is very important for both human and other living organism life to be healthy. So, any change to environment leads to a negative biological impact, a greater part of this change acts by human activities which include; fossil fuel burning and nuclear fuel reactions (conventional sources). These activities cause air pollution and so environment [13].

3.1 Types of Air Pollution

Air pollution affects a human health and increase hospital admissions in addition to the environmental problems [10], and has two types:

1- Indoor pollution, this is mainly caused due to use of conventional energy sources such as, firewood in rural areas which lead to air pollution.

2- Outdoor pollution, this type is mainly caused due to use of fossil fuel.

3.2 Greenhouse Effect

The “Greenhouse Effect” is a term that refers to a physical property of the Earth's atmosphere. If the Earth had no atmosphere, its average surface temperature would be very low of about – 18 C^o rather than the comfortable 15 C^o found today. The difference in temperature is due to a suite of gases called greenhouse gases which affect the overall energy balance of the Earth's system by absorbing infrared radiation. In its existing state, the Earth atmosphere system balances absorption of solar radiation by emission of infrared radiation to space. Due to greenhouse gases, the atmosphere absorbs more infrared energy than it reradiates to space, resulting in a net warming of the Earth atmosphere system and of surface temperature. This is the “Natural Greenhouse Effect”. With more greenhouse gases released to the atmosphere due to human activity, more infrared radiation will be trapped in theEarth's surface which contributes to the Enhanced Greenhouse Effect [14]. Fig (3.1) clarifies how greenhouse effect occurs.

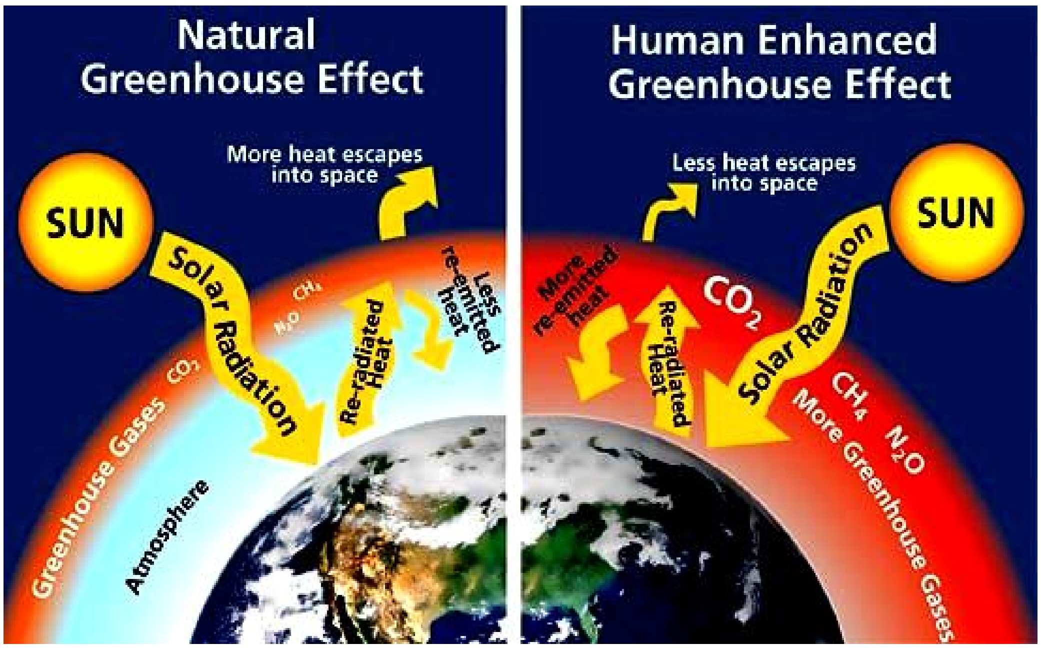


Fig (3.1): Natural and Human enhanced green house effect.

3.3 Greenhouse Gases

Greenhouse gases comprise less than 1% of the atmosphere. Their levels are determined by a balance between “sources” and “sinks”. Sources and sinks are processes that generate and destroy greenhouse gases respectively. Human affect greenhouse gas levels by introducing new sources or by interfering with natural sinks. The major greenhouse gases in the atmosphere are [15]:

1- Carbon dioxide and carbon monoxide.
2- Methane.
3- Nitrous oxide.
4- Atmospheric water vapor.
5- Ozone.
6- Chlorofluorocarbons.

3.4 Global Warming

Global warming refers to the overall increase in the average temperature of the Earth’s surface; Greenhouse gases produced by various activities are released into the atmosphere, where they trap heat, causing a reduction in outgoing infrared radiation, and then warm global [16].

3.5 Climate Changes

Climate change refers to the different changes in climate that may result from global warming. In other words, the planet as a whole is warming, but that does not mean that all regions of the world will become warmer.The Earth's climate must change somehow to restore the balance between incoming and outgoing radiation. This climatic change will include a global warming of the Earth's surface and the lower atmosphere as warming up is the simplest way for the climate to get rid of the extra energy. However, a small rise in temperature will induce many other changes, for example, cloud cover and wind patterns. Some of these changes may act to enhance the warming (positive feedbacks) and others to counteract it (negative feedbacks) [15].

3.6 Fossil Fuel Combustion

Fossil fuel include coal, natural gas and oil, are the main sources of heat. All these fuel contain the major constituents (carbon, hydrogen and oxygen) and other materials including metal, sulphur and nitrogen compounds. Thus fossil fuel combustion is however associated with environmental pollution which in turn impact adversely on the physiological and mental health of the associated human lives. During the combustion process different pollutants fly ash, Carbon dioxide (CO_2), nitrogen oxides (NO_X), sulphur dioxide (SO_2), carbon monoxide (CO), and particulate matter are released. Carbon dioxide is a greenhouse gas whose presence in the atmosphere has a warming effect on the earth's climate. Nitrogen oxides (NO_X) deplete the ozone; sulphur dioxide (SO_2) is associated with impaired visibility, damage to vegetation and materials, harm to human health and production of acid rain [16].

3.6.1 Pollutants and Their Harmful Effects

1) Particulate matter, the presence of particulate matter are:

- Reduces sunlight.
- Reduces visibility.
- A level above 100 µg $/m^3$ results in respiratory problems.
- A level above 300 µg $/m^3$ results in bronchitis (inflammation of mucus membrane inside the bronchial tube, branches of the wind pipe).

2) Carbon dioxide (CO_2), It is ordinarily not considered a toxic gas. But increased concentration of carbon dioxide adversely affects the global climate. Excess emission of carbon dioxide in the atmosphere causes global warming due to greenhouse effect. The increasing of carbon dioxide level is mainly due to:

- Large-scale combustion of fossil fuel in coal fired thermal power plants.
- Felling of trees on a large scale (deforestation) for urbanization, agriculture and industrialization, resulting in reduced photosynthesis process.

3) Carbon monoxide (CO), It is formed due to incomplete burning of carbon in inadequate air. It seriously impairs the oxygen-dependent tissues in the body, particularly the brain, heart and skeletal muscles. Carbon monoxide causes headache and collapse by different concentrations. The

toxic effect mechanism of carbon monoxide (CO) is well known. Carbon monoxide binds more tightly to hemoglobin than oxygen, so when it is inhaled, it rather than oxygen is absorbed by red blood cells. Consequently the body's tissues are starved of oxygen. Organs with the greatest oxygen demand, the heart and brain, are most affected. The amount of carbon monoxide that has been absorbed can be measured by

the amount of bound hemoglobin (carboxyhemoglobin). Small amounts of carboxyhemoglobin are associated with headache, drowsiness and cardiac arrhythmias. Higher levels cause coma and death. Levels high enough to cause these effects usually occur indoors due to malfunctions in appliances such as, a gas furnaces and non-electric space heaters.

4) Sulphur dioxide (SO_2), the presence of sulphur dioxide in the air is mainly due to combustion of fuels containing sulphur. It can oxidize to form sulphur trioxide (SO_3), which in turn forms sulphuric acid when absorbed in water. It is harmful effects are:

- Causes respiratory deceases including asthma, the irritate eyes and respiratory track.
- Causes acid rains, which are harmful to agriculture, forest, vegetation, and soil and stone.
- Causes corrosion of metal and deterioration of electrical contacts.

5) Nitrogen oxides (NO_X), these are produced due to natural causes and combustion of fossil fuel in air at high temperature. And their harmful effects are:

- Causes respiratory and cardiovascular illness.
- It deprives the body tissues of oxygen.
- It also forms acid in lungs and, therefore, is more toxic than carbon monoxide.

6) Ozone (O_3), ground-level ozone, a principal constituent of smog, has been recognized as a pollutant with detrimental health effects in both developed and developing countries throughout the world. Numerous

health effects have been linked to ground level O_3, including damage to lung tissue, particularly among the elderly and children, reduced breathing function, and sensitization of airways to irritants and other allergens. The complex interrelationship between O_3 formation, atmospheric temperature, and meteorological conditions has led to a serious concern that increasing global temperatures will lead to increased production of O3 and increased human health problems [10].The common manmade methods of air pollution are due to fossil fuel burning by motors, industry, power plants and solid waste.

3.7 Nuclear Fuel Reaction

Nuclear power has minimal air pollution impacts as it is a combustion-free source of energy, but it has moderate impacts on climate change and severe impacts for water and land use. Uranium milling, mining, and leaching all produce substantial amounts of greenhouse gases (GHGs). In terms of land use, nuclear power's most significant impacts arise from uranium mining and the storage of nuclear waste. In terms of water, the nuclear industry has serious consequences both for human consumption and for the environment. Nuclear fuel are unstable, and prone to ejecting subatomic particles or high energy photons from the nucleus as alpha particles, beta particles and gamma radiation, in the process decaying into a new isotope or element. Such an unstable isotope is said to be radioactive, and the subatomic particles and photons it emits are collectively described as atomic radiation. If the new isotope or element is also unstable, the decay process continues until a stable form is reached, such as uranium [8].

3.8 Radiation and Health

There are three types of atomic radiation of principal concern to human health and safety in regard to uranium mining, refining and nuclear power generation. These are alpha, beta and gamma radiation. Alpha and beta radiation involve high-speed electrically charged particles with mass, and gamma radiation involves electromagnetic energy. All of these are capable of displacing electrons from atoms and molecules, and are referred to as ionizing radiation. Alpha particles are the most biologically destructive of the three. They have been found to be up to 20 times more damaging to intracellular structures than gamma rays. They were once considered to be safe by the nuclear industry because they do not normally penetrate skin. Ingested or inhaled, however, and positioned within living tissue, they can discharge their alpha particles directly into the structures of the cell, damaging the cell's contents, including its DNA. Radon, the second leading cause of lung cancer after smoking, is an alpha emitter, as are plutonium 239, uranium 238 and its daughters, uranium 234, thorium 230, radium and polonium [4].Some DNA damage is reparable by the cell, but alpha particles are more likely than other forms of radiation to cause double-strand DNA breaks which are not readily repaired. Attempts at repair can lead to deletions, inversions, a centric fragments and cross-linking, as repair enzymes try to work with missing and scrambled pieces. It is well known that damaged DNA can trigger many diseases in humans such as cancer, birth defects, chromosomal abnormalities and inheritable disease. Beta particles are high-speed electrons, with a small amount of mass and considerable energy. Their effects on biological tissue are somewhat intermediate between alpha and gamma radiation, although closer to those of gamma radiation.

Gamma rays are very high-energy photons with good penetrating power and no mass. They are similar to the radiation found in X-rays. They are more likely to cause single point damage in DNA, and single-strand DNA breaks which are more readily repaired. Even here repair is not always perfect. If it is imperfect, a mutation arises and persists. There is evidence now that gamma rays may also be absorbed by certain structures in the cell and give rise to local cascades of high energy electrons which can be more damaging than the gamma ray itself. Uranium atoms lodged in tissue can absorb gamma rays in this way, and produce such electrons, as well as being emitters of alpha radiation. This phenomenon is under investigation; to the extent that it occurs in living tissue, it may make uranium more genotoxic than previously suspected [8].

3.8.1 Genetic Effects

Damage to the DNA of body cells can lead to errors in cell proliferation and eventually cancer. This has become a well-recognized effect of ionizing radiation exposure on living tissue. Damage to the DNA of germ cells (eggs and sperm) by ionizing radiation can be passed on to future generations, and can be expected, over time, to give rise to increases in levels of malformations and genetic disease. The human body has two copies of every gene, except those on the X and Y chromosomes in the male. Damaged recessive genes, with undamaged partners that can take over function, will go undetected, until they accumulate in a population to the point where two of these recessive genes end up in the same person at the same time, one from each parent. Even then, many of these mutations will be lethal to the developing embryo and will manifest as reduced fertility or early miscarriage. It must be kept in mind that eggs develop in a female fetus' ovaries during gestation. Therefore a pregnant woman's exposures may affect not only herself and her children, but her grandchildren as well by damaging the eggs in her unborn daughter's [8].

3.8.2 Uranium Mining

Uranium mining is the messiest and most contaminating stage of nuclear power generation. Uranium mining, in particular open pit mining, which is involves digging thousands of tons of radioactive rock out of a giant hole. Large quantities of this rock are dumped onto the earth's surface. The ore is then transported to a milling facility, usually nearby, and crushed to a fine sand-like consistency, creating large amounts of radioactive dust and a huge volume of finely ground mill tailings.

Dust containing long-lived radioactive elements like Radon, can leave the site on wind. Radon is a major contributor to the excess of lung cancer by inhalation. Uranium in drinking water, at levels in excess of the safe drinking water standard of .02 mg/L, is principally toxic to the kidney, in particular the proximal tubules. It may cause malformations in fetuses and might be associated with reproductive cancers. Dry piles of uranium mill tailings are subject to erosion by wind and water. Tree roots and plants take up this radioactive material, often concentrating it, and are eaten by biological organisms (birds, insects, mice, deer, etc.) which disperse it in their feces or their bodies. Root systems help to bring radon up to the leaves where it can be transpired into the air [15].

3.8.3 Nuclear Reactor Operation

Some reactors use heavy water (deuterium oxide) as a moderator and coolant. Deuterium can easily become tritium by absorbing a neutron, so reactors produce more tritium. Tritium is a radioactive isotope of hydrogen. It can therefore become pervasive in the natural environment, and incorporate itself into human tissue. Tritium is a carcinogen, a mutagen and a teratogen. It has been involved in testicular and ovarian tumors, chromosome breaks and aberrations, fetal death and malformations, and in mental retardation after in utero exposure.

Tritium escapes continuously from all operating reactors built to current designs. Most of the escaping tritium is released as steam into the air from the chimneys of the reactors; some is released into the cooling water and from there into local bodies of water. In addition to tritium, all functioning reactors routinely release many other radioactive substances to the air and into the cooling water. The noble gases xenon 137 and krypton 90 decay relatively quickly into the deadly cesium 137 and strontium 90. Cesium 137 accumulates in muscle, including the muscle of food source animals such as cattle, and sheep; strontium 90 accumulates in bone. Other radioactive isotopes of xenon, krypton and argon are also released. Iodine 131 is mostly trapped by filters, but can escape in accidental releases. It is highly toxic to the thyroid, particularly in children [15].

3.8.4 Waste Disposal

At the end of its useful life in a fission reactor, the spent fuel contains hundreds of different fission products, many of them not found in nature. Collectively, the fuel rods are radioactive, so the spent fuel can be placed in large containers for dry storage, where circulating air continues to cool it. Interference with water circulation could result in overheating of the fuel rods. One of the most critical issues facing the nuclear energy industry is its inability to permanently and safely dispose of spent fuel, which remains radioactive and highly toxic for many thousands of years.

Both reprocessing and storage underground involves handling highly radioactive and toxic materials, creating elevated risks for both workers and surrounding communities. Because any escape of spent fuel causes the environmental pollution [8].

Chapter Four

Biomass Energy Sources

4.1 Introduction

Biomass is the term used for all organic material originating from plants including trees and crops and is essentially the collection and storage of the sun’s energy through photosynthesis. Biomass energy, or bioenergy, is the conversion of biomass into useful forms of energy such as heat, electricity and liquid fuels. It is organic, carbon-based, material that reacts with oxygen in combustion and natural metabolic processes to release heat. Such heat, especially if at temperatures >400 _C, may be used to generate work and electricity. The initial material may be transformed by chemical and biological processes to produce biofuels. The term bioenergy is sometimes used to cover biomass and biofuels together.Biomass is usually not considered a modern energy source, given the role that it has played, and continues to play, in most developing countries. Because it was the first energy source harnessed by humans and for nearly all of human history, wood has been our dominant energy source. Only during the last century, with the development of efficient techniques to extract and burn fossil fuels, replaced wood as the industrialized world’s primary fuel. It considered asa renewable resource so far as its production is continued in a sustainable way [10].

4.2 Types of Biomass

Biomass feedstock come in a variety of forms and has different properties that impact their use for power generation. There is a wide range of biomass feedstock and these can be split into whether they are urban or rural.

- ***Rural Biomass feedstock***, this type collected from rural areas, and include; Forest residues and wood waste, agricultural residues (corn stoves, wheat stalks, etc.), Energy crops (grasses or trees) and Biogas from livestock effluent.
- ***Urban Biomass feedstock***, include urban wood waste (packing crates, pallets, etc.), Waste water and sewage biogas, Landfill gas, municipal solid waste and Food processing residues.fig (4.1) shows types of biomass.

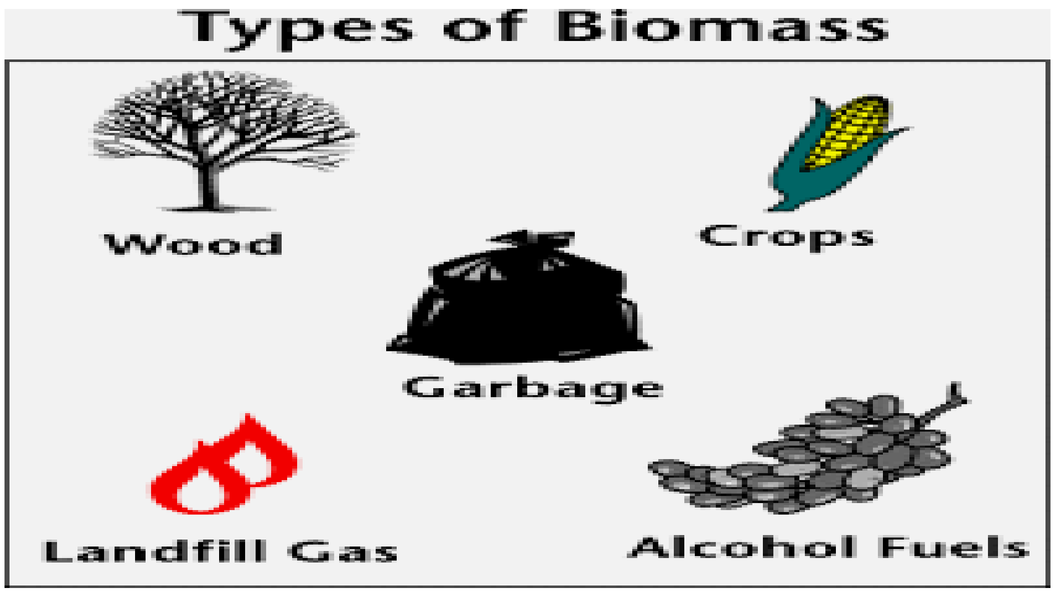


Fig (4.1): Types of biomass.

A critical issue for the biomass feedstock is its energy, ash and moisture content, and homogeneity. These will have an impact on the cost of biomass feedstock per unit of energy, transportation, pre-treatment and storage costs, as well as the appropriateness of different conversion technologies [17].

4.3 Biomass Conversion Methods

Bioenergy can be converted into power through two ways:

1. Thermo-chemical processes include combustion, gasification and pyrolysis.
2. Bio-chemical processes like anaerobic digestion.
3. Agro-chemical processes include fuel extraction and biodiesel.

Power generation from biomass can be achieved with a wide range of feedstock and power generation technologies that may or may not include an intermediate conversion process. In each case, the technologies available range from commercially proven solutions with a wide range of technology suppliers (e.g. solid fuel combustion) through to those that are only just being deployed at commercial scale [18].

4.3.1 Thermo-chemical Processes

4.3.1.1 Combustion

Direct combustion remains the most common technique for deriving energy from biomass for both heat and electricity production. Fig (4.2) shows direct combustion. In colder climates domestic biomass fired heating systems are widespread and recent developments have led to the application of improved heating systems which are automated, have catalytic gas cleaning and make use of standardized fuel (such as pellets). The efficiency benefit compared to open fireplaces is considerable with advanced domestic heaters obtaining efficiencies of over 70 percent with greatly reduced atmospheric emissions.The predominant technology in the world today for electricity generation from biomass, at scales above one megawatt, is the steam-Rankine cycle. This consists of direct combustion of biomass in a boiler to raise steam which is then expanded through a turbine. The steam-Rankine technology is a mature technology introduced into commercial use. Steam cycle plants are often located at industrial sites, where the waste heat from the steam turbine is recovered and used for meeting industrial process heat needs. Such combined heat and power (CHP), or cogeneration, systems provide greater levels of energy services per unit of biomass consumed than systems that only generate power. An alternativeto the above-described direct-fired biomass combustion technologies, and considered the nearest term low-cost option, is biomass co-combustion with fossil fuels in existing boilers. Successful demonstrations using biomass as a supplementary energy source in large high efficiency boilers have been carried out showing that effective biomass fuel substitution can be made in the range of 10–15 percent of the total energy input with minimal plant modifications and no impact on the plant efficiency and operation. This strategy is economical when the biomass fuels are lower cost than the fossil fuels used. This can mean a substantial amount of biomass and related carbon savings and emissions reductions, particularly for coal substitution. Dry homogeneous input is preferred. There are two types of boilers:

- ***Stoker boilers***, burn fuel on a grate, producing hot flue gases that are then used to produce steam, the ash from the combusted fuel is removed continuously by the fixed or moving grate.
- ***Fluidized bed boiler***, suspending fuels on upward blowing jets of air during the combustion process.

Boilers also categorized as either atmospheric or pressurized units. ***Atmospheric fluidized bed boilers*** are further divided into bubbling-bed andcirculating-bed units; the fundamental difference between bubbling-bed and circulating-bed boilers is the fluidization velocity (higher for circulating). Circulating fluidized bed boilers (CFB) separate and capture fuel solids entrained in the high velocity exhaust gas and return them to the bed for complete combustion.

Pressurize fluidized bed boilers, pressurized (CFB) are available, although atmospheric-bubbling fluidized bed boilers are more commonly used when the fuel is biomass [18].

A significant proportion of the world's population depends on fuel wood or other biomass for cooking, heating and other domestic uses. A large consumption arises from the widespread use of inefficient cooking methods, the most common of which is still an open fire. But a greater part of heat is lost by incomplete combustion of the wood, by wind and light breezes carrying heat away from the fire, and by radiation losses. Considerable energy is also wasted in evaporation from uncovered pots. Moreover, the smoke is a health hazard to the cook unless there is an efficient extraction chimney. However, Cooking efficiency and facilities can be improved by using dry fuel, Introducing alternative foods and cooking methods, e.g. steam cookers and decreasing heat losses using enclosed burners or stoves, and well-fitting pots with lids.

The combustion of firewood is a complex and varying process and much depends on the type of wood and its moisture content [17].

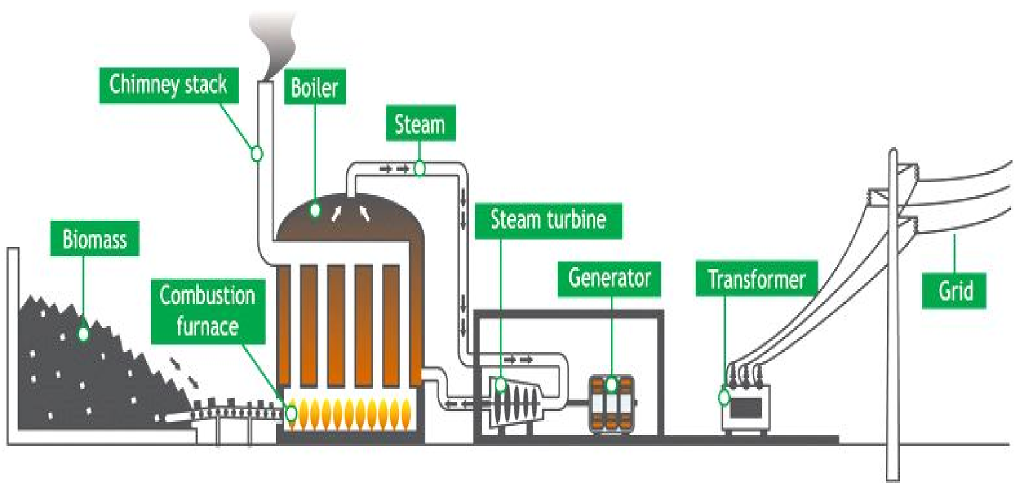


Fig (4.2): Direct Combustion ofBiomass for power generation.

4.3.1.2 Gasification

Gasification is achieved by the partial combustion of the biomass in a low oxygen environment, leading to the release of a gaseous product (producer gas or syngas). Indirect gasification is also possible. The gasifier can either be of a “fixed bed”, “fluidized bed” or “entrained flow” configuration. The resulting gas is a mixture of carbon monoxide, vapour, CO_2, char, tar, nitrogen and hydrogen, and it can be used in combustion engines, micro-turbines, fuel cells or gas turbines. When used in turbines and fuel cells, higher electrical efficiencies can be achieved than those achieved in a steam turbine. It is possible to co-fire a power plant either directly such as; biomass and coal are gasified together or indirectly like gasifying coal and biomass separately for use in gas turbines.There are a wide range of possible configurations, and gasifiers can be classified according to four separate characteristics:

1) Oxidation agent: This can be air, oxygen, steam or a mixture of these gases.
2) Heat for the process: This can be either direct (i.e. within the reactor vessel by the combustion process) or indirect (i.e. provided from an external source to the reactor).
3) The pressure level: Gasification can occur at atmospheric pressure or at higher pressures.
4) Reactor types: these can be fixed bed, fluidized bed or entrained flow.

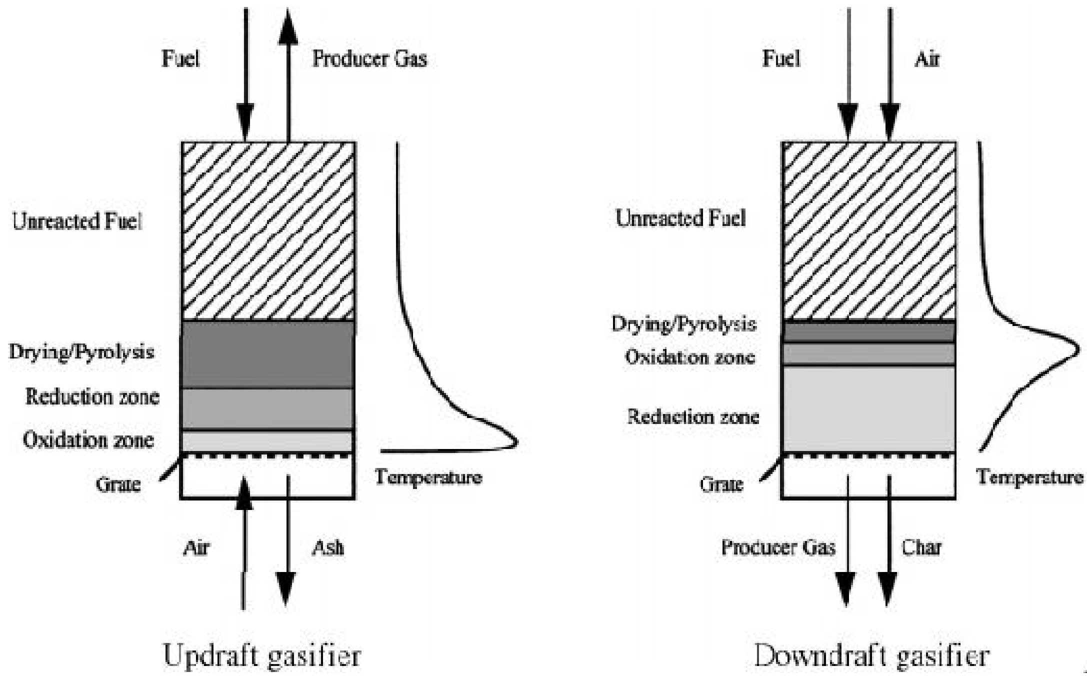
Gasification comprises a two-step process. The first step, paralysis, is the decomposition of the biomass feedstock by heat. This yields 75% to 90% volatile materials in the form of liquids and gases, with the remaining non-volatile products being referred to as char. The second step is the gasification process, where the volatile hydrocarbons and the char are gasified at higher temperatures in the presence of the reactive agent (air, oxygen, steam or a mixture of these gases) to produce CO and H_2, with some CO_2, methane, other higher hydrocarbons and compounds including tar and ash. These two steps are typically achieved in different zones of the reactor vessel and do not require separate equipment. A third step is sometimes included: gas clean-up to remove contaminants, such as tars or particulates. The gasification process is a predominantly endothermic process that requires significant amounts of heat. The producer gas, once produced, will contain a number of contaminants, some of which are undesirable, depending on the power generation technology used. Tars, for example, can clog engine valves and accumulate on turbine blades, leading to increased maintenance costs and decreased performance. Some producer gas cleanup will therefore usually be required. After cleaning, the producer gas can be used as a replacement for natural gas and injected in gas turbines or it can produce liquid biofuels, such as synthetic diesel, ethanol, gasoline or other liquid hydrocarbons [18].

4.3.1.2.1 Fixed Bed Gasifiers

Fixed bed gasifiers typically have a grate to support the gasifying biomass and maintain a stationary reaction bed. They are relatively easy to design and operate and generally experience minimum erosion of the reactor body. There are three types of fixed bed designs:

- ***Updraft fixed bed gasifier***, biomass enters at the top of the reactor and the reactive agent (i.e. air, steam and/or oxygen) below the grate. The producer gas, together with tars and volatiles, exits from the top while chars and ashes fall through the grate (at the bottom). These gasifiers are often used for direct heating, but gas clean-up can remove the relatively high levels of tar and other impurities to allow electricity generation. Slagging problems can also arise if high-ash biomass is used.
- ***Downdraft fixed bed gasifier***, the biomass and the reactive agent are introduced at the top of the reactor and the tars pass through the oxidation and charcoal reduction zones, meaning levels of tar in the gas are much lower than in updraft gasifiers. They tend to require a homogenous

feedstock to achieve the best results [17]. Fig (4.3) explains fixed bed gasifier types.



Fig(4.3): Types of fixed bed gasifier.

- ***Cross-draft fixed bed gasifiers***are similar to downdraft gasifiers and are often used to gasify charcoal, but the reactive agent enters at the side, low down in the reactor vessel and parallel to the biomass movement. They respond rapidly to load changes, are relatively simple to construct and the gas produced is suitable for a number of applications. However, they are more complicated to operate and if a fuel high in volatiles and tars is used, very high amounts of tar and hydrocarbons will be present in the producer gas. Fixed bed gasifiers are the preferred solution for small- to medium-scale applications. Biomass gasification is successfully applied in India, and rice-husk gasification is a widely deployed technology. To produce electricity, piles of rice husks are fed into small biomass gasifiers, and the gas produced is used to fuel internal combustion engines. They can be an important part of off-grid electricity access in rural areas. The critical factors for these gasification systems are the reliability of the gasifier and the cost of the biomass supply [18].

4.3.1.2.2 Fluidized Bed Gasifiers

There are two main types of fluidized bed gasifiers: bubbling fluidized bed (BFB) and circulating fluidized bed (CFB), which can be either atmospheric or pressurized. In fluidized bed gasification, the gasification process occurs in a bed of hot inert materials (usually sand or alumina) suspended by an upward motion of oxygen-deprived gas. As the flow increases, the bed of these materials will rise and become fluidized.

- ***Bubbling Fluidizing Bed gasifiers***, the reactive gases pass through the reactor bed at the minimum velocity required to achieve a bubbling effect where the "bubbles" flow upwards through the bed material. At the top of the inert material, the bubbles burst and the bed material falls back into the bed.
- ***Circulating Fluidized Bed gasifiers***, the gas velocities are higher than the minimum fluidization point, resulting in the circulation of the inert bed materials in the gas stream. The bed particles thus exit the top of the reactor with the producer gas and must then be separated in a cyclone to be re-circulated to the reactor.The use of inert materials in the bed increases the rate of reaction of the biomass with the fluidized bed compared to fixed bed reactors, thereby improving performance. Also they can accept a wider range of feedstock, achieve larger scales and potentially yield a production gas with higher energy content. However, fluidized bed systems cost more and are significantly more complex [19]. Figure (4.4) shows types fluidized bed gasifier.

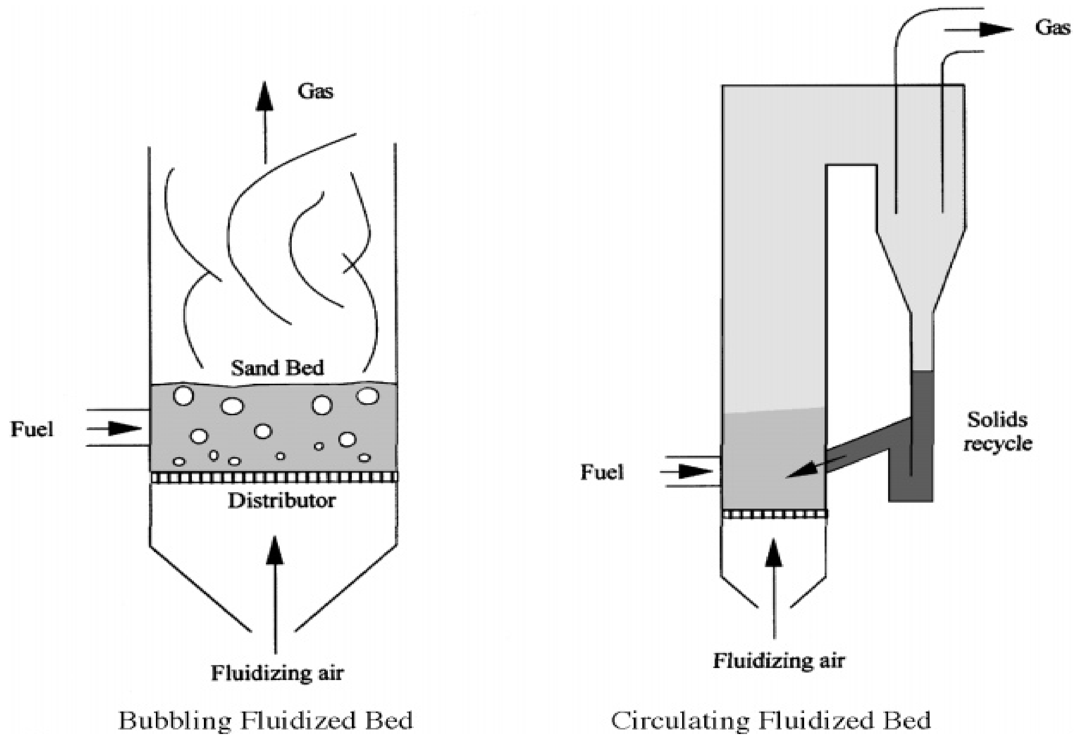


Fig (4.4): Types of fluidized bed gasifier.

4.3.1.2.3 Advantages of Fluidized Bed Gasifiers

Fluidized bed gasifier creates a homogenous and good quality producer gas, it can accept a range of feedstock and particle sizes, and has an excellent heat transfer performance through contact with bed materials, also it has a large heat storage capacity and good temperature control.

4.3.1.2.4 Disadvantages of Fluidized Bed Gasifier

Fluidized bed gasifiers have a complicated control needs, slow response to load changes and high cost. For circulating fluidizing bed gasifier it has less efficient heat exchange than bubbling fluidized bed gasifier, Temperature gradients in the reactor vessel, and fuel particle size can be an issue, also high velocities can accelerate erosion [17].

4.3.1.2.5 Gas Clean-up

The gasification process yields a producer gas that contains a range of contaminants, depending on the feedstock and the gasification process. These contaminants are not usually a major problem when the gas is combusted in a boiler or an internal combustion engine. However, when used in turbines to achieve higher electric efficiencies, some form of gas clean-up will be required to reduce gas contaminant concentrations to harmless levels. Different technologies have different tolerances to contaminants, so the correct design and selection of feedstock, gasifier and the generating technology can help minimize gas clean-up requirements [17]. Fig (4.5) shows biomass gasification and power generation.

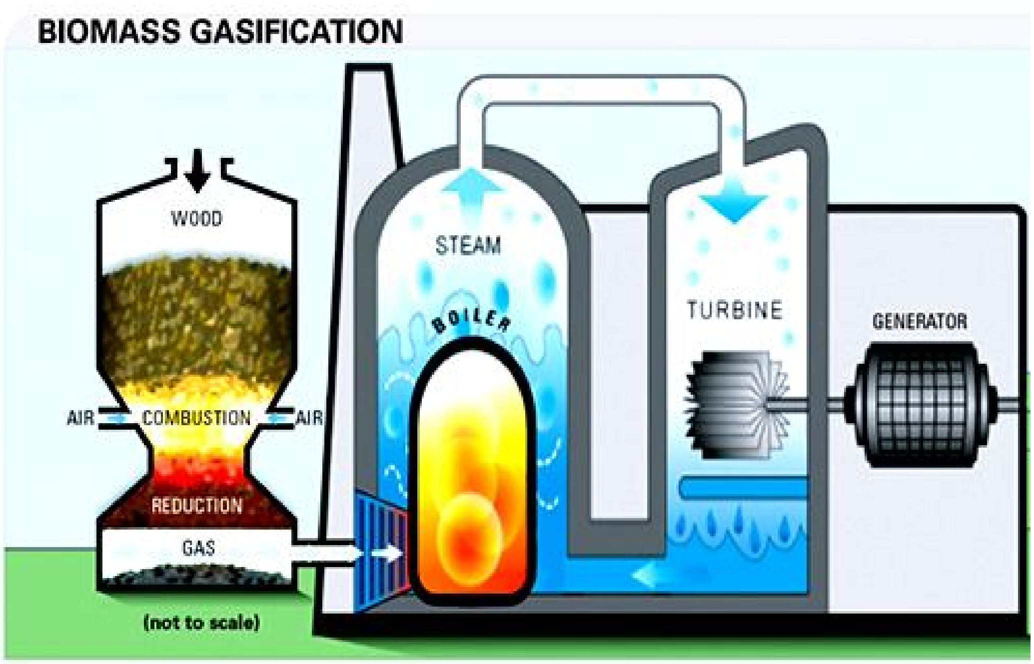


Fig (4.5): Biomass Gasification uses for power generation

4.3.1.2.6 Producer Gas Contaminants

- *Particles*, includes ash, charcoal and fluid bed material. It causes erosion in gasifier and prime mover.
- *Alkali metals*, Includes Sodium and Potassium compounds. It causes hot corrosion.
- *Nitrogen compounds*, they are cause local pollutant emissions.
- *Tars*, are the name given to the mostly poly-nuclear hydrocarbons, such as pyrene and anthracene, that form as part of the gasification process, such as refractive aromatics, they cause clogging of filters and other fouling.

- *Sulphur and Chlorine*, cause corrosion and emissions.

Tars are a major problem, as they can build up on turbine blades and /or foul turbine systems. One solution to this problem is to “crack” the tars. Cracking can be either thermal or catalytic.

4.3.1.2.7 Biomass Integrated Combined Cycle Gasification

Biomass integrated combined cycle gasification (BIGCC), or biomass integrated gas turbine technology (BIG-GT), as it is sometimes referred to, has the potential to achieve much higher efficiencies than conventional biomass-powered generation using steam cycles by creating a high quality gas in a pressurized gasifier that can be used in a combined cycle gas turbine.

4.3.1.3 Pyrolysis

Pyrolysis is a subset of the gasification system. Essentially, pyrolysis uses the same process as gasification, but the process is limited to between 300°C and 600°C. Fig (4.6) explains pyrolysis process. Conventional pyrolysis involves heating the original material in a reactor vessel in the absence of air, typically at between 300°C and 500°C, until the volatile matter has been released from the biomass. At this point, a liquid bio-oil is produced, as well as gaseous products and a solid residue. The residue is char – more commonly known as charcoal – a fuel which has about twice the energy density of the original biomass feedstock and which burns at a much higher temperature. With more sophisticated pyrolysis techniques, the volatiles can be collected, and careful choice of the temperature at which the process takes place allows control of their composition. The liquid bio-oil produced has similar properties to crude oil but is contaminated with acids and must be treated before being used as fuel. Both the charcoal and the oil produced by this technology could be used to produce electricity (although this is not yet commercially viable) and heat.

The output depends on temperature, type of input material and treatment process. In some processes the presence of water is necessary and therefore the material need not be dry.

- ***Other thermo-chemical processes***

A wide range of pre-treatment and process operations are possible. These normally involve sophisticated chemical control and industrial scale of manufacture; methanol production is such a process, e.g. for liquid fuel. Of particular importance are processes that break down cellulose and starches into sugars, for subsequent fermentation [18].

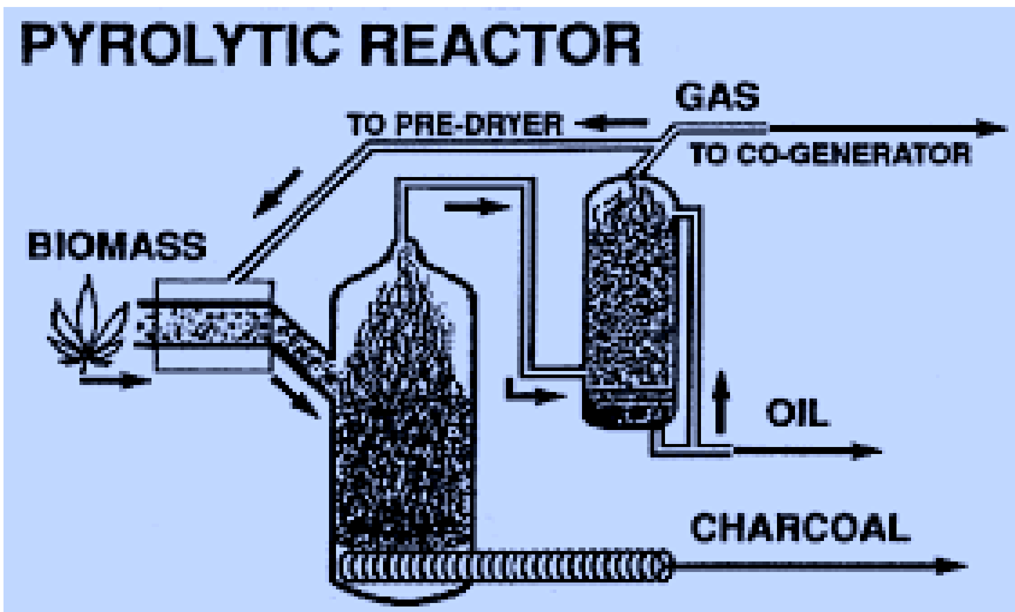


Fig (4.6): Pyrolysis Process

4.3.1.4 Feed Stock

Biomass feedstock for thermo-chemical processes is the organic material of recently living plants from trees, grasses and agricultural crops. Biomass feedstock is very heterogeneous and the chemical composition is highly dependent on the plant species. This highly heterogeneous nature of biomass can be a problem since, although some combustion technologies can accept a wide range of biomass feedstock, others require much more homogenous feedstock in order to operate. Biomass' chemical composition is comprised of generally high (but variable) moisture content, a fibrous structure, which is comprised of lignin, carbohydrates or sugars and ash. Lingo-cellulose is the botanical term used to describe biomass from woody or fibrous plant materials. It is a combination of lignin, cellulose and hemicelluloses polymers interlinked in a heterogeneous matrix. This chemical composition of the biomass feedstock influences its energy density. The main characteristics that affect the quality of biomass feedstock are moisture content, ash content and particle size, and density.

4.3.1.4.1 Moisture Content

The moisture of biomass can vary from 10% to 60%, or even more in the case of some organic wastes. Stoker and CFB boilers can accept higher moisture content fuel than gasifiers. In anaerobic digestion, several options are available, including high solids-dry, high solids-wet or low solids-wet. In the case of a low solids-wet configuration, such as with manure slurry, the solids content can be 15% or less. The key problem with high moisture content, even when it is destined for anaerobic digestion, is that it reduces the energy value of the feedstock. This increases transportation costs and the fuel cost on an energy basis, as more wet material is required to be transported and provide the equivalent net energy content for combustion. Improving the energy density of the feedstock can improve combustion efficiency. The principal means of achieving this is through drying by natural or accelerated means.

4.3.1.4.2 Ash Content and Slogging

An important consideration for feedstock is the ash content, as ash can form deposits inside the combustion chamber and gasifier, called "slogging" and "fouling", which can impair performance and increase maintenance costs. Grasses, bark and field crop residues typically have higher amounts of ash than wood. Slogging occurs in the boiler sections that are directly exposed to flame irradiation. Slogging deposits consist of an inner powdery layer followed by deposits of silicate and alkali compounds. Fouling deposits form in the convective parts of the boiler, mainly due to condensation of volatile compounds that have been vaporized in previous boiler sections and are loosely bonded. Slogging and fouling can be minimized by keeping the combustion temperature low enough to prevent the ash from fusing.

4.3.1.4.3 Feedstock size

The size and density of the biomass is also important because they affect the rate of heating and drying during the process. Large particles heat up more slowly than smaller ones, resulting in larger particles producing more char and less tar. In fixed bed gasifiers, fine-grained or fluffy feedstock may cause flow problems in the bunker section, resulting in an unacceptable pressure drop in the reduction zone and a high proportion of dust particles in the gas. In downdraft gasifiers, the large pressure drop can also reduce the gas load, resulting in low temperatures and higher tar production. The type of handling equipment is also determined by the size, shape, density, moisture content and composition of the fuel. The wrong design will have an impact on the efficiency of the combustion or gasification process and may cause damage to the handling system [17].

4.3.2 Bio-Chemical Processes

4.3.2.1 Aerobic Digestion

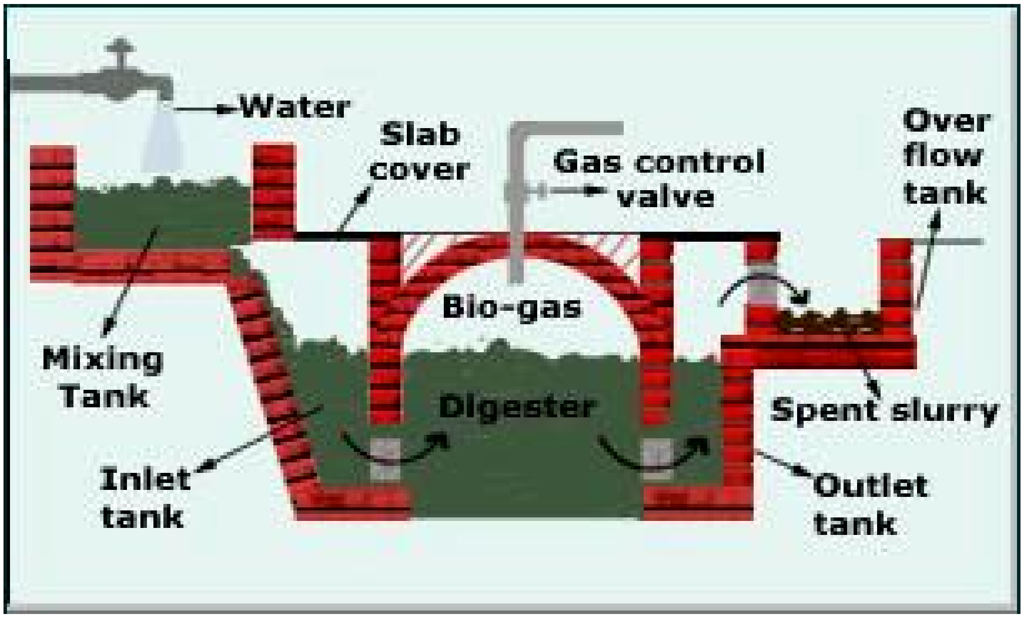
In the presence of air, microbial aerobic metabolism of biomass generates heat with the emission of CO2, but not methane. This process is of great significance for the biological carbon cycle, e.g. decay of forest litter, but is not used significantly for commercial bio-energy [18].

4.3.2.2 Anaerobic Digestion

In the absence of free oxygen, certain microorganisms can obtain their own energy supply by reacting with carbon compounds of medium reduction level to produce both, carbon dioxide and methane (CH_4). The process may also be called ‘fermentation’, but is usually called ‘digestion’ because of the similar process that occurs in the digestive tracts of ruminant animals. The evolved mix of carbon dioxide (CO_2), methane (CH_4) and trace gases is called biogas as a general term, but may be named sewage gas or landfill-gas as appropriate, and it can be used for heat and stationary power without an emission problem [17].

4.3.2.2.1 Bio-Gas

Biomass that is high in moisture content such as animal manure partially decomposed green plants and food processing waste is suitable for producing biogas using anaerobic digester technology. The biogas process requires an input material (mostly agricultural waste) provided as partially composted liquid slurry with around 80 – 90 percent solid content. It is important to use materials which break down readily as highly fibrous materials like wood and straw are not easily digested by micro organism, but softer feed stocks like dung and leaves reacts well to the process. Also some feed stocks are more productive than others. For optimum performance the internal temperature of the digester needs to be maintained within the range of 25 – 37 degree centigrade and within a pH range of 6.7 to 9.4. For optimum gas generation, the pH must be maintained at a reasonable alkaline condition. Four basic types of microorganism are involved in the production of biogas from agricultural feed stock (Biomass); Hydrolytic bacteria break down complex organic waste into sugar and amino acids. Fermentative bacteria then convert those products into organic acids; Acidogenic microorganism converts the acids into hydrogen, carbon dioxide and acetate. Finally, the methanogenic bacteria produce biogas from acetic acid, hydrogen and carbon dioxide. This whole process takes place in air tight chamber called a biogas digester. Bio gas contains 55-70% methane and 30-45% carbon dioxide as well as small quantities of some gases. It is lighter than the air and has an ignition temperature of approximately 700C°. Fig (4.7) shows biogas generation. The bio gas system is most suitable technology to solve the energy problems in rural areas, as it Produces Manure, clean fuel and improves rural sanitation. Its thermal energy per unit volume is sufficient to meet domestic energy needs.



Fig(4.7): Biogas Generation Process (Fixed)

4.3.2.2.2 Advantages of Biogas

- It provides a better and cheaper fuel cooking, lighting and for power generation.
- It produces good quality, enriched manure to improve soil fertility.
- It proves an effective and convenient way for sanitary disposal of human excreta, improving the hygienic conditions.
- It generates social benefits such as reducing burden on forest for meeting cooking fuel by cutting of tree for fuel wood, reduction in the drudgery of women and children etc.
- As a smokeless domestic fuel, it reduces the incidence of eye and lung diseases.
- It also helps in generation of productive employment [9].

Biogas feedstock is organic matter produced by plants, both terrestrial (those grown on land) and aquatic (those grown in water) and their derivatives. It includes forest crops and residues, crops grown especially for their energy content on “energy farms” and animal manure.

4.3.2.3 Alcoholic Fermentation

- ***Ethanol***is a volatile liquid fuel that may be used in place of refined petroleum. It is manufactured by the action of micro-organisms and is therefore a fermentation process. Conventional fermentation has sugars as feedstock. In industrialized countries ethanol is most commonly produced from food crops like corn, while in the developing world it is produced from sugarcane. Its most prevalent use is as a gasoline fuel additive to boost octane levels or to reduce dependence on imported fossil fuels. Ethanol has a smaller heat value but a higher octane rate than gasoline, which enables higher of engine efficiency with a larger compression ratio. At present it is most advantageous in terms of energy ratio and cost to get it from sugar crops. In the temperate regions, ethanol is usually obtained from the fermentation of starch crops like corn. Fig (4.8) shows fermentation process. Ethanol is used for spark-ignition engines either in the form of a 20%–23% mixture with gasoline or in its pure form. While ethanol production from maize and sugarcane, both agricultural crops, has become widespread and occasionally successful it can suffer from commodity price fluctuation relative to the fuels market. Consequently, the production of ethanol from lignocelluloses biomass (such as wood, straw and grasses) is being given serious attention. In particular, it is thought that enzymatic hydrolysis of lignocelluloses biomass will open the way to low cost and efficient production of ethanol.

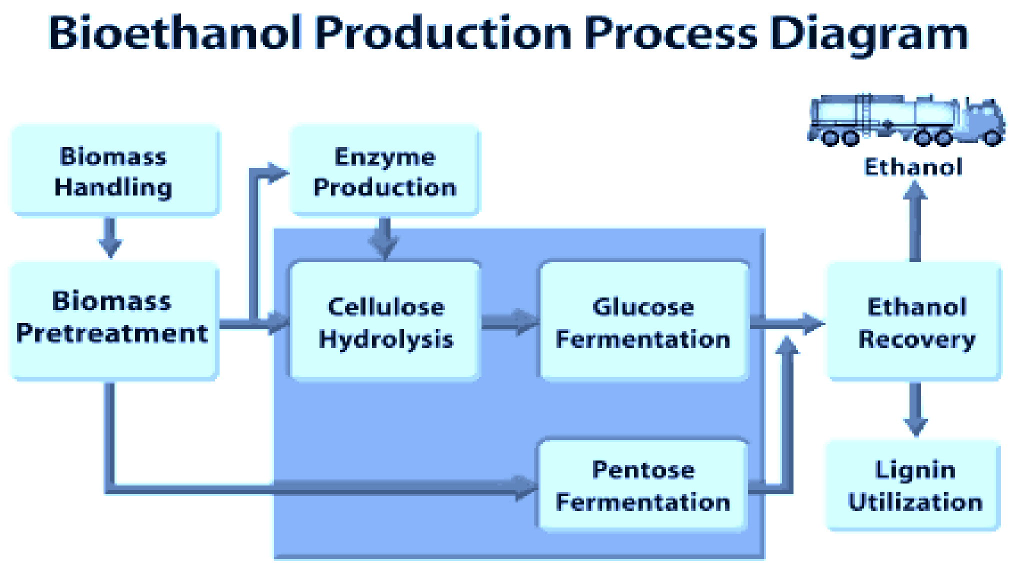


Fig (4.8): Ethanol production by fermentation process.

- ***Methanol*** can be synthesized from biomass pyrolysis gas and can be used as an alternative fuel to gasoline. It is, however, more easily processed from natural gas. There are two methods of using hydrogen and carbon monoxide gas to produce synthetic methanol from natural gas: the catalytic steam reforming method and the partial oxidation method. At present, the catalytic steam reforming method is mainly used. In this method, the main components of the natural gas methane react with using hydrogen and carbon monoxide gas to produce synthetic methanol at high temperatures (250–400C^{o}) and high pressures (5.07–30MPa) with the use of a catalyst of the Cu–Zn or Zn–Cr–Cu group. Then Crude methanol from a synthetic process is rectified in the prepurifying column. Ingredients with low boiling points, such as dimethyl ether and methyl formatted, are removed from the top of the column and an aqueous methanol solution is obtained from the bottom of the column. Next, the methanol–water solution is distilled in the rectifying column, and ingredients with higher boiling points, like higher alcohols, paraffin, ethanol, etc., and water come out from the bottom of the column. At this point, refined methanol is obtained from the top of the column [17].

4.3.2.4 Biophotolysis

Photolysis is the splitting of water into hydrogen and oxygen by the action of light. Recombination occurs when hydrogen is burnt or exploded as a fuel in air. Certain biological organisms produce, or can be made to produce, hydrogen in biophotolysis. Similar results can be obtained chemically, without living organisms, under laboratory conditions. Commercial exploitation of these effects has not yet occurred.

4.3.3 Agro-Chemical Processes

4.3.3.1 Fuel Extraction

Occasionally, liquid or solid fuels may be obtained directly from living or freshly cut plants. The materials are called exudates and are obtained by cutting into (tapping) the stems or trunks of the living plants or by crushing freshly harvested material. A well known similar process is the production of natural rubber latex. Related plants to the rubber plant Herea, such as species of Euphorbia, produce hydrocarbons of less molecular weight than rubber, which may be used as petroleum substitutes and turpentine [18].

4.3.3.2. Bio-Diesel and Etherification

Concentrated vegetable oils from plants may be used directly as fuel in diesel engines. Rudolph Diesel designed his original engine to run on a variety of fuels, including natural plant oils. However, difficulties arise with direct use of plant oil due to the high viscosity and combustion deposits as compared with standard diesel-fuel mineral oil, especially at low ambient temperature. Both difficulties are overcome by converting the vegetable oil to the corresponding ester, which is arguably a fuel better suited to diesel engines than petroleum-based diesel oil. Vegetable oils from rapeseed, soybean, sunflower, and others can be used for diesel engines. Raw vegetable oils are usually so viscous and their cetane numbers are so low for high-speed diesels that transesterification with methanol is performed. Emission from biodiesel is characterized with low sulphur oxides (SO_x)content. It is reported that in some cases nitrogen oxides (NO_x) increases, but with the adjustment of valve timing, nitrogen oxides (NO_x)could be kept on the same level as that of conventional diesel fuel.The etherification process is straightforward for those with basic chemical knowledge, and, with due regard for safety, can be undertaken as a small batch process. Biodiesel can also be made from waste (used) cooking oil and from animal fat [18].

4.4 Advantages of Biomass Energy

- Can supply on demand, base load power.
- Available year-round with storage.
- Carbon neutral.
- Can be processed into a syngas or liquid fuel.
- Can be used for power generation, space heating, and transportation applications.
- Biomass energy is an abundant, secure, environmental friendly and renewable source of energy. Biomass does not add carbon dioxide to the atmosphere as it absorbs the same amount of carbon in growing as it releases when consumed as a fuel.
- One of the major advantages of biomass is that it can be used to generate electricity with the same equipment or in the same power plants that are now burning fossil fuels.
- Biomass energy is not associated with environmental impacts such as acid rain, mine spoils, open pits, oil spills, radioactive waste disposal or the damming of rivers.
- Biomass fuels are sustainable. The green plants from which biomass fuels are derived fix carbon dioxide as they grow, so their use does not add to the levels of atmospheric carbon. In addition, using refuse as a fuel avoids polluting landfill disposal.

- Alcohols and other fuels produced by biomass are efficient, viable, and relatively clean burning.
- Biomass is easily available and can be grown with relative ease in all parts of the world.

4.5 Disadvantages of Biomass Energy

- Expensive to handle, low energy density.
- Must be utilized near its source.
- Labor intensive.
- Bulky - storage can be a challenge.
- Small scale technologies for power generation still emerging.
- Biomass is still an expensive source of energy, both in terms of producing biomass and converting it into alcohols, as a very large quantity of biomass is needed.
- On a small scale there is most likely a net loss of energy as a lot of energy must be used for growing the plant mass; biomass is difficult to store in the raw form.
- One of the disadvantages of biomass is that direct combustion of biomass can be harmful to the environment as burning biomass releases carbon dioxide, which contributes to the warming of the atmosphere and possible climatic change. Burning also creates soot and other air pollutants.
- Over-collecting wood can destroy forests. Soils bared of trees erode easily and do not hold rainfall. Increased run-off can cause flooding downstream.
- When plant and animal wastes are used as fuel, they cannot be added to the soil as fertilizer. Soil without fertilizer is depleted of nutrients and produces fewer crops.
- Biomass has less energy than a similar volume of fossil fuels [10].

4.6 Biomass Energy Sources in Sudan

Sudan is enjoyed with biomass resources as well as hydro and wind energy sources. Like many tropical countries, Sudan has ample biomass sources that can be efficiently exploited in a manner that is both profitable and sustainable. Biomass source includes forest residues and wastes, agricultural residues and wastes, and animal wastes [20].

4.6.1 Agriculture sector

Agriculture is the backbone of economic and social development in Sudan. About 80% of the population depends on agriculture, and all other sectors are largely dependent on it. Agriculture contributes to about 46% of the gross national product. This share is reflect in providing raw materials to local industries and an increased export earning besides raising percentage of employment among population.Sudan is endowed with large areas of cultivable land, which are situated between the Blue Nile and the White Nile, and in the region between the Blue Nile and the Atbara River. Other regions with cultivable land are the valleys of the plains, where irrigation is extensively used, and in the narrow Nile valley. This land has different uses [20].Three farming systems characterize Sudan: irrigated (21.1% of agricultural area), rain-fed semi-mechanized (e.g. hand-driven threshers) (8.3%), and rain-fed traditional agriculture (15.5%). Whereas, the total area of cultivate land is about 120 million Fadden with annual agricultural production estimated as 15 million tones mainly sugar, wheat, sorghum, cotton, millet, groundnut, sesame and fruits [21]. Fig (4.9) shows conventional and mechanical agriculture.

Conventional Agriculture

Mechanical Agriculture

Fig (4.9): conventional and mechanical agriculture.

4.6.2 Livestock

Sudan has the second largest livestock inventories in Africa, next to Ethiopia. It possesses about 132 millions head of animals (cattle, goats, sheep and others). Fig (4.10) shows sample of livestock. Good natural pastures cover almost 24 million hectares and the nomadic pastoral sector accounts for more than 90% of the huge animal population. Cattle and sheep and goats provide an important capital asset and a risk management tool for pastoralists and farmers in times of drought, and they are increasingly important in agricultural irrigated areas as well. Sudan possesses about two million hectares of water surfaces with fish stock determined with 40000 tons per year [22].

Fig (4.10): Sample of livestock in Sudan.

4.6.3 Forests

Sudan has, according to FAO's classification, become a low forest cover country with about 11% of its total surface area under forest cover. Sudan's forest domain is basically contained in reserved forests (government and community tenure) and natural non-reserved forests. The plantation area is 1.3 million hectares. A part of the plantation area is supported by irrigation, particularly in irrigated agricultural schemes and at some community out-growers level. The forests follow the ecological classification profile and rainfall trends as from north to south with forests taking the form of bush land and scattered trees and shrubs in the north and in denser woodlands and forests with larger trees in mixture of acacias and broad-leaved trees in the southern end of the savanna region. The largest rates of deforestation occur in the savanna where the major land use is for agriculture. In low rainfall savannah there is about 18000 square kilometer of area covered by forest and woodland. The total biomass which can be obtained from different sources per year is distributed as follow;Natural and cultivated forestry 3 million tones, Agricultural residues 5.2 million tones, Animal wastes 1.1 million tones and Water hyacinth and aquatic weeds 3.2 million tones [23]. Fig (4.11) views sample of forest.

Fig (4.11): Sample of Forest in Savannah (South Kordofan).

Chapter Five

Conclusion & Recommendations

5.1Conclusion

Now, the world is looking for new energy sources to replace the conventional sources because of its negative impact on climate and human health. But, no energy source is free of some type of environmental impact, though energy efficiency practices properly implemented are the most environmentally friendly. While renewable energy sources such as wind and solar have clear environmental benefits compared to conventional sources, they are not free of consequences and have a high costs.Renewable energies are generally having fewer disadvantages on the environment.

Fossil fuel (oil, coal and natural gas) combustion release greenhouse gases which lead to the air pollution. This pollution causes acid rain that damage forests and cultivated crops, different diseases for human and animals. Fossil fuel mining, refining and transforming are cost high, and also nonrenewable source. From the extraction of uranium from rock formations, through the milling, refining, and enriching of uranium, to the operation of reactors, and the unsolved dilemma of what to do with spent fuel, there are major health effects at every stage of the nuclear fuel chain. Although it is widely accepted that there is no safe threshold for radiation exposure, low-level radiation emissions from nuclear facilities have not been considered a threat to human health. The link between radiation exposure and cancer is becoming increasingly clear, and the cellular mechanisms involved in this process are becoming better understood. There are enormous public health risks posed by the millions of tons of radioactive tailings from uranium mining, and the many thousands of tons of radioactive waste produced in reactors that will remain toxic for long time, an accident or meltdown causes a catastrophic release of radioactive particles into the air, water and soil. Biomass (forest residues and wastes, agriculture residues and wastes, and animal's wastes) is a renewable, sustainable and cheaper source. Animals waste depends on the density of livestock in a certain area to produce good amount of biogas fuel. Forest products constitute a significant foundation for both local and national economies in Sudan, in addition to environmental and social services provided by the forests. Wood constitutes the major source of energy in Sudan providing about 70-80% of the energy needs of the country for almost all segments of the population and institutions.Natural forests cover nearly 40.0 million hectare, the forest reserves area at present is 13.5 million hectare. Plantation forests are considered as an approach for addressing the recurrent problems of over exploitation of the natural forest resources, but the area of planted forests in Sudan is rather small. Agriculture residues and wastes can be used as biomass source. Agriculture contributes to about 46% of the gross national product in Sudan. The total area of cultivate land is about 120 million Fadden with annual agricultural production estimated as 15 million tones.

5.2 Recommendations

According to the previous information about Biomass, some procedures are recommended to consider Biomass as very useful alternative energy:

- Forest classification and analysis of the distribution of forest types within different zones and in relation to rainfall distribution, should be developed and adopted in order to have a basis for a management and conservation, Monitoring and evaluation of deforestation and forest degradation and provision of rates and conversion figures for forest cover and biomass changes using successive inventories, and Increasing the area of forest reserves with respect to government forest reserves.
- Sustainable Development in forestry and forest products to be integrated with agriculture and animal husbandry in order to support successful community-based practices through private and public partnerships.
- It is very important to increase the area of different agricultural schemes in order to get large quantities of residues and wastes as Biomass. Also there must be special scheme used for biomass production.
- Regions with high density of animals (cattle, camel, goat and sheep) must be provided with health care stations, enough water sources and feed. Also increasing of animal number per area increase their waste which is good for biogas generation.

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