

**HISTORY AND PHILOSOPHY
OF SCIENCE COURSEWARE**

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TABLE OF CONTENTS

Module	Title	Page
1.	The Structure of Science, Scientific Methods and Revolution Abimbola, I.O.	1
2.	Philosophical of problems and Scientific Explanations Akanji, M.A. and Yakubu, M.T.	19
3.	Concept of Matter Akoshile, C.O. and Abdus-Salam, N.	30
4.	Conservation of Conventional and Renewable Energy Sources and their Conversion Techniques Omosewo, E.O., Olaoye, J.O., Ajibola, T.B., Ajimotokan, H.A.	44
5.	Applications of Blood Group Systems and DNA Finger Printings ARISE, R.O., KURANGA, S. A., and OGUNJEMILUA, S.B	67
6.	Medicinal plants: myths, facts, Conservation and tissue culture techniques Yakubu, M. T., Akanji, M. A. and Adeyemi, S. B.	74
7.	Atmospheric Environment, Air Pollution and Public Health Adekola, F.A., and Abdul Raheem, A.M.O.	89
8.	Food Production and Preservation for Food Security: The Place of Cooperatives in Nigeria Omotesho, A.O., Joseph, J.K., Muhammad-Lawal, A. and Kayode, R.M.O.	101
9.	Global Threat of Counterfeit Medicines Williams, F. E. and Olurinola, P. F.	115
10.	Fundamentals of Poultry Production Adeyina, A.O. and Atteh, J.O.	126
11.	Human Nutrition- A Life Course Approach Temidayo Oladiji and Deborah Opaleke	143
12.	Achieving Knowledge Management Functionalities in the Emerging Technology-Driven Society Using Information Technology Jimoh, R.G. and Oyelakin, A.M.	155

13.	Science and Technology in the Service of Man Ayeni, A.A.	165
14.	Concepts of Hypothesis Testing in Sciences, Social Sciences and Humanities Adeleke, B.L. and Yahya, W.B.	170
15.	Microbes and Diseases Andes, A.T.	183
16.	Geomorphology of Africa Ige, O.O., and Ogunsanwo, O.	189

MODULE FOUR

CONSERVATION OF CONVENTIONAL AND RENEWABLE ENERGY SOURCES AND THEIR CONVERSION TECHNIQUES

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Introduction

Energy is one of the most fundamental parts of our universe. Everything we do is connected to energy in one form or another. We use energy to do work. Therefore, energy drives our day to day activities, at home, schools, businesses or offices. Concern for generation and access to available energy remain issues of national interest while energy trapped in diverse and abundant natural resources within our immediate environment remains unharnessed for human utilization. Therefore, in this module, efforts are made to discuss about energy and its conversion from one form to another. Types, workability, advantages and disadvantages are discussed. Conversion of potential energy to kinetic energy, chemical to electrical to light energy, electric to heat energy, heat energy to electrical energy and heat energy to light energy are discussed. Also, conversion of mechanical energy to electrical to heat energy; and conversion of electrical energy to mechanical and to sound energy are discussed.

Learning Outcomes

- i. sources and types of natural and conventional energy;
- ii. differentiate between natural and conventional, and renewable and non renewable sources of energy;
- iii. concept of energy sources and conservation methods;
- iv. sources and types of biomass resources;
- v. diverse methods of application of biomass and conversion techniques to renewable energy;
- vi. advantages of biomass as energy source; and method of production of biofuel / bio diesel and food security

Main Body

Introduction

The module discussed extensively on conservation of conventional and renewable energy sources and their conversion techniques. The module is discussed under 2 units.

Unit 1: Conservation of Natural and Artificial Energy Resources

Unit 2: Biomass as Sustainable Sources of Renewable Energy

Unit 1: Conservation of Natural and Artificial Energy Resources

Contents

1.0 Introduction

2.0 Learning Outcomes

3.0 Main Contents

3.1 Review of Energy and its Conversion

3.1.1 Mechanical Energy

3.2 Natural Sources of Energy

3.2.1 Solar Energy

3.2.2 Wind Energy

3.2.3 Hydroelectricity

3.2.4 Tidal Energy

3.3 Conventional and Non Renewable Energy Sources

3.3.1 Fossil Fuels

3.3.2 Nuclear Energy

3.3.3 Geothermal Energy

3.4 Conservation of Energy

3.5 Importance of Conservation of Energy

3.6 Conversion Devices for Renewable and Non Renewable Energy

3.6.1 Solar Energy Conversion

3.6.2 Wind Energy

3.6.3 Hydro Power Energy

4.0 Summary

5.0 Self-Assessment Questions (SAQs)

6.0 Tutor Marked Assignments (TMAs)

7.0 Further Reading

1.0 Introduction

In this unit, efforts are made to discuss about natural and artificial energy resources and its conversion from one form to another.

2.0 Learning Outcomes

At the end of this unit, you are should be able to:

- i. Identify the difference between renewable and non-renewable sources of energy;
- ii. Describe at least 5 types of energy
- iii. Describe the methods for converting energy from one form to another;
- iv. State at least five advantages and disadvantages of solar, fossil fuel, wind, tidal, hydroelectricity, geothermal and nuclear energy.

3.0 Main Content

3.1 Review of Energy and its Conversion

Animals convert food to energy in order to run. Plants grow through the grace of solar energy. Arrows fly by converting the potential energy of a stretched bow to the

kinetic energy of the moving arrow. Water flowing downward from the top of a dam converts gravitational potential energy into energy of motion. Combustion engines in motor vehicles convert chemical energy in gasoline and oxygen into energy of motion. Solar energy is radiated to us continually and without it, and the food-producing plants it supports, we could not survive. For sundry other functions, we rely on the fossil fuels (coal, petroleum and natural gas) and uranium. They are burned in the earth's crust and whatever their abundance they are limited and will eventually be depleted hence we think of alternatives.

Energy is needed for a person to work, to jump, to run, to eat and for plants and animals to grow. It is present in various forms such as in the electricity, which lights lamps and makes television sets produce pictures. Energy is also present in the coal and oil, which is used as fuel in furnaces, engines of cars and airplanes. The chief forms of energy are: mechanical, chemical, heat, nuclear and energy of electromagnetic radiation. These constitute conventional energy. The non-conventional energy includes fossil fuel, biomass, hydroelectric power, nuclear, geothermal, wind, tidal and solar. Energy are classified into renewable and nonrenewable, because their supplies are limited, conventional and non-conventional, depending on regular use and the green and non green forms of energy, which depend on their effect on the environment. **Renewable energy sources** include biomass, geothermal energy, hydropower, solar energy, and wind energy. They are called renewable because they are replenished in a short time. Effort is made here to discuss some of these energies.

3.1.1 Mechanical Energy

Kinetic Energy: This is the energy associated with masses in motion. An example of this type of energy is when a boy runs or when water is pouring down a waterfall. It is half the product of mass and its velocity square.

Potential Energy: This is the energy possessed by a system or an object due to its position. There are varieties of potential energies; as examples: there is mechanical potential energy in the wound spring of a clock or a stretched bowstring. There is gravitational potential energy in anything lifted against the pull of gravity, such as a stone lifted by a person. There is chemical potential energy in almost every known substance, since there is hardly anything known which will not react with some chemical agent and release its energy. There is electrical potential energy stored in an electrical field. The water at the top of a dam has potential energy and the potential energy depends on the mass, height, gravity and density.

Electrical Energy: Electricity is different from the other energy sources because it is a secondary source of energy. We must use another energy source to produce electricity. Electricity is sometimes called an **energy carrier** because it is an efficient and safe way to move energy from one place to another, and it can be used for so many tasks. As we use more technology, the demand for electricity grows.

The rate of charge flows of electricity with time is called electrical current, it is measured in ampere. The current that flows through a metallic conductor is proportional to the potential difference across its ends, provided temperature and all other physical quantities are constant. The constant of proportionality is Resistance, measured in Ohms.

Power is the rate of using or producing energy, it is measured in watt.

3.2 Natural Sources of Energy

3.2.1 Solar Energy

We have used the sun for drying clothes and food for thousands of years, but only recently have we been able to use it for generating power. The sun is 150 million kilometers away, and amazingly powerful. Just the tiny fraction of the sun's energy that hits the earth (around a hundredth of a millionth of a percent) is enough to meet all our power needs many times over. Infact, every minute, enough energy arrives at the earth to meet our demands for a whole year, if only we could harness it properly.

How it works

There are three main ways in which the energy from the sun can be utilized:

(a) Solar cells (really called “photovoltaic” or “photoelectric “cells) convert light directly into electricity. In a sunny climate, you can get enough power to run a 100w light bulb from just one square metre of solar panel. (Fig. 3.1).

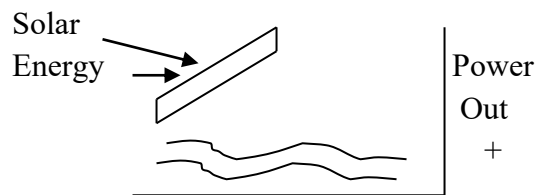


Fig. 3.1 Solar Cells Convert Light Directly to Electricity

Solar cells are used for mini electrical appliances such as calculators, cell phones etc. Solar cells provide energy to run satellites that orbit the earth, used for satellite TV, telephones, navigation whether forecasting, internet etc.

(b) Solar Water Heating

(i) Heat from the sun is used to heat water in glass panels on the roof. This means too much gas, or electricity, or kerosene or firewood is not used to heat the water used in the home. Fig. 1.2 presents the arrangement of solar water heating.

(ii) Water can be pumped through pipes in the panel. The pipes are painted black, so they get hot when the sun shines on them.\

This helps out your central heating system and cuts your fuel bill. However, in the U.K or U.S.A, you must remember to drain the water out to stop the panels freezing in the winter.

Solar heating is worthwhile in places like California, USA and Australia, where lots of sunshine is obtained. As technology improves, it becomes worthwhile in the U.K. However, during summer in the U.K, a lot of domestic water can be heated.

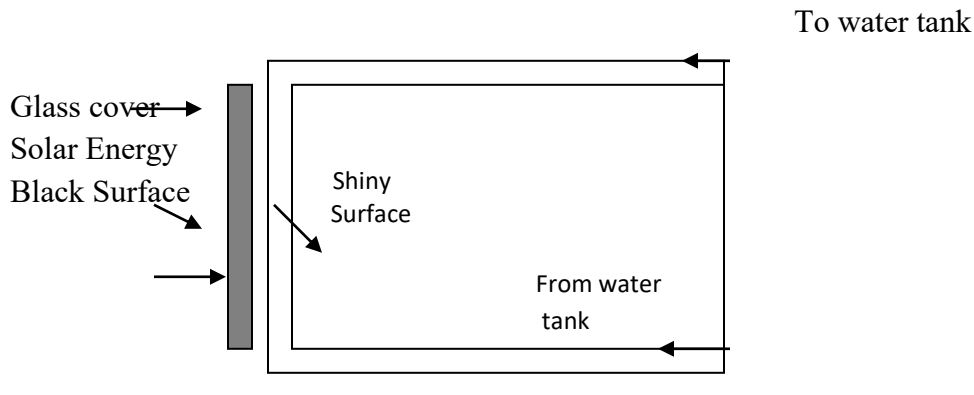


Fig. 1.2: Solar Water Heating

c) **Solar Furnaces**

Solar furnaces use a huge array of mirrors to concentrate the sun's energy into small space and produce very high temperatures. There is one at Odellio, France, used for scientific experiments up to 33,000 degrees Celsius.

Advantages of Solar Energy

- i. Solar energy is free. It needs no fuel and produces no waste or pollution.
- ii. In sunny countries, solar power can be used where there is no easy way to get electricity to a remote place
- iii. Handy for low-power uses such as solar powered garden lights and battery chargers.

Disadvantages of Solar Energy

- i. The does not shine at night
- ii. Very expensive to build solar power stations because of the cost of solar cells.
- iii. Can be unpredictable except you are in a very sunny climate.

3.2.2 Wind Energy

The sun heats the atmosphere unevenly, so some patches become warmer than others. Fig. 1.3 shows arrangement of wind energy assembly. The warm patches of air rise, other air blows in to replace them, hence wind blows. A wind turbine converts the Kinetic energy of the wind into rotational mechanic energy. The energy imparted to the rotating turbine increases as the wind speed increases. Also, the larger the diameter of the rotating blades, the more the energy that is

obtained from the turbine power that can be extracted from the air stream is given by $P = 0.5d^2v^3$ watts. d = diameter of the propeller in metres, v = speed of the wind in m/s

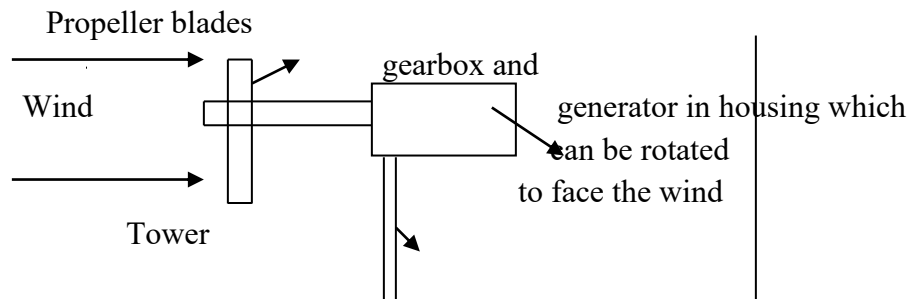


Fig. 1.3: Arrangement of Wind Energy Assembly

Advantages of Wind Energy

- i. Wind is free, wind farms need no fuel.
- ii. Produces no waste or greenhouse gases
- iii. The land beneath can be used for farming.
- iv. Wind farms can be tourist attractions
- v. A good method of supplying energy to remote areas especially in desert land

Disadvantages of Wind Energy

- i. The wind is not always predictable.
- ii. Suitable areas for wind farms are often near the coast, where land is expensive.
- iii. Some people feel that covering the landscape with these towers is unsightly.
- iv. Can kill birds when wind farms are built on migratory routes, since migrating flocks tend to like strong winds which blow birds to them.
- v. Can affect television reception of anybody that lives nearby.
- vi. Can be noisy. Wind turbines have a reputation for making a constant, low, 'swooshing' noise day and night.

3.2.3 Hydroelectricity

Gravitational potential is stored in the water above the dam. Because of the great height of the water, it will arrive at the turbines at high pressure, which means that a great deal of energy can be extracted from it. The water then flows away down the river normally.

In mountainous countries such as Switzerland and New Zealand, hydro – electric power provides more than half of the country's energy needs.

Advantages of Hydroelectricity

- i. Once the dam is built, the energy is virtually free.
- ii. No waste or pollution is produced.
- iii. Much more reliable than wind, solar or wave power.
- iv. Water can be stored above the dam ready to cope with peaks in demand.
- v. Hydro-electric power stations can increase to full power very quickly, unlike other power stations.
- vi. Electricity can be generated constantly.

Disadvantages of Hydroelectricity

- i. Dams are very expensive to build.
- ii. Building a large dam will flood a very large area upstream, causing problems for animals that live there.
- iii. Finding a suitable site can be difficult – the impact on residents and the environment may be unacceptable.
- iv. Water quality and quantity downstream can be affected, which can have an impact on plant life.

3.2.4 Tidal Energy

The oceans contain an enormous amount of thermal energy but it cannot be extracted by a heat engine whose operating temperature matches the surface temperature of the ocean. However, a condition exists for extracting heat from the upper part of the ocean, converting some of the energy to useful work, and rejecting the remainder to the cooler deep region. This is by the use of the Ocean Thermal Energy Converter.

The features of ocean thermal Energy Converters (OTEC) are that they:

- 1. are essentially pollution free and
- 2. make use of the sun, which replenishes the internal energy of the ocean surface with its radiation.

Constructing such a system in the ocean presents some engineering problems. At present, there are about two tidal power schemes operating in the world, one in France and the other one in Russia.

Advantages of Tidal Energy

- i. The energy is free – no fuel needed, no waste produced
- ii. Not expensive to operate and maintain.
- iii. Can produce a great deal of energy.
- iv. It produces no greenhouse gases or other wastes.

Disadvantages of Tidal Energy

- i. Depends on the waves-sometimes loads of energy are obtained, sometimes nothing.
- ii. Needs a suitable site, where waves are consistently strong.
- iii. Some designs are noisy.
- iv. Must be able to withstand very rough weather.
- v. Only provides power for around ten hours each day, when the tide is actually moving in or out.

3.3 Conventional and Non Renewable Energy Sources

3.3.1 Fossil Fuels

Coal, oil and gas are called 'fossil fuels' which provide about 66% of the world's electrical power and 95% of the world's total energy demands (including heating, transport, electricity generation and other uses). They are the end product of a natural process of decomposition of vegetable matter buried in swamps and out of contact with oxygen for thousands of years.

How it works

The word 'coal' denotes a wide variety of solid fuels. The varieties in approximate order of their formation are peat, lignite, bituminous coal and anthracite.

Coal is crushed to a fine dust and burnt. Oil and gas can be burnt direct.

Burn Fuel → Heat water to make steam → Steam turn turbines → Turbines turn generators → electrical power sent around country

Coal provides around 28% of our energy, and oil provides 40 %. Burning coal produces sulphur dioxide, an acidic gas that contributes to the formation of acid rain.

Natural gas is a mixture of various compounds of carbon and hydrogen and small quantities of non-hydrocarbons existing in the gaseous phase, or in solution with oil, in natural underground reservoirs. It is classified into two categories;

Associated gas and Non-associated gas.

Associated gas is natural gas originating from fields producing both liquid and gaseous hydrocarbons simultaneously. On the other hand, non-associated gas is natural gas which is obtained independently. It is generally found in the space above an oil reservoir or an aquifer. Typically the major constituents of associated natural gas are methane (about 50 per cent by volume), ethane (about 20 per cent) and propane (about 10 per cent). The major constituent of non-associated natural gas is methane (more than 90 per cent by volume).

Natural gas provides around 20% of the world's consumption of energy, and as well as being burnt in power stations, is used by many to heat their homes.

Advantages of Fossil Fuels

- i. Very large amounts of electricity can be generated in one place using coal, fairly cheaply.
- ii. Transporting oil and gas to power station is easy.
- iii. Gas-fired power stations are very efficient
- iv. A fossil fuelled power station can be built anywhere, so long as you can get large quantities of fuel to it. Didcot power station in Oxfordshire has a dedicated rail link to supply the coal

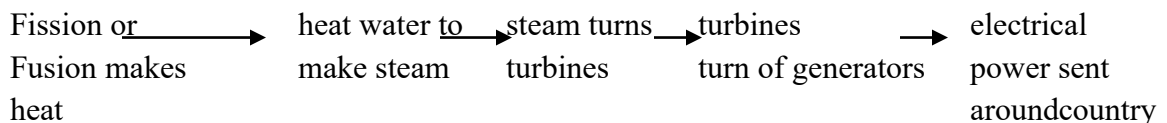
Disadvantages of fossil fuels

- i. Basically, the main drawback of fossil fuels is pollution. Burning any fossil fuel produces carbon dioxide, which contributes to the 'greenhouse effect' warming the earth.
- ii. Mining coal can be difficult and dangerous. Strip mining destroys large areas of the landscape
- iii. Burning coal produces more carbon dioxide than burning oil or gas. It also produces sulphur dioxide, a gas that contributes to acid rain. We can reduce this before releasing the waste gases into the atmosphere.
- iv. Coal-fired power stations need huge amounts of fuel which means train-loads of coal almost constantly. In order to cope with changing demands for power, the station needs reserves.

This means covering a large area of country-side next to the power station with piles of coal.

3.3.2 Nuclear Energy

Nuclear power is generated using Radio nuclei, such as uranium, for fission or very light nuclei for fusion.



Nuclear reactors must have strategic arrangement for

1. removing thermal energy from the reactor and
2. a scheme for controlling the energy output.

Russia, France and England have successfully operated nuclear breeder reactor electric power plants.

Special Problem with handling Plutonium

Extracting plutonium is not simple because the element is extremely dangerous. It has chemical effects on the body. Also, it is radioactive and it decays by emitting alpha particles, which are among the most damaging nuclear particles to the internal organs of

the human body. If plutonium is taken into the body in soluble form, it concentrates in the bones and the liver and tends to remain there. If taken into the lungs as small particles, it can produce intense local damage and possibly induce cancer. For these reasons, plutonium processing is done by remote control method. Another problem is that plutonium can be stolen to produce atomic bomb such as the one used in World War II.

Nuclear fusion Reactors

Fusion occurs when two light nuclei are fused together to form a heavier nucleus and energy is released.

Problem of Fusion

Very high temperature of the order of 10^8 K is required to overcome the coulomb repulsive forces between two light nuclei. This poses severe technological problem due to the fact that materials that withstand such a high temperature are difficult to come by.

Advantages of Fusion over Fission

1. Easily achieved with highest elements.
2. Raw materials are cheaply available. Hydrogen can be obtained by electrolysis of seawater which is cheap and plentiful for use.
3. Produces less dangerous by-products.
4. By-products are non-radioactive

In Britain, nuclear power stations are built on the coast and sea water is used for cooling the steam which is ready to be pumped. Also, carbon dioxide gas is blown through the reactor to carry the heat away. Carbon dioxide is chosen because it is very good coolant, able to carry a great deal of heat energy. It also helps to reduce any fire risk in the reactor (it is around 600°C). Any country that produces energy through nuclear reactor should have computers that will shut the reactor down automatically if things get out of hand. At Chernobyl, in Ukraine, they did not have such a sophisticated system. The reactor overheated, melted and excessive pressure blew out the containment system before they could stop it. Then, with the coolant gone, there was a serious fire. Many people lost their lives.

Advantages of Nuclear Power

1. Nuclear power costs about the same as coal. So it is not expensive to make.
2. Does not produce smoke or carbon dioxide, so, it does not contribute to the greenhouse effect.
3. Produces huge amounts of energy from small amounts of fuel.
4. Produces small amounts of waste
5. Nuclear power is reliable.

Disadvantages of Nuclear Power

1. Although not much waste is produced, it is very, very dangerous. It must be sealed up and buried for many years to allow the radioactivity to die away.
2. Nuclear power is reliable, but a lot of money has to be spent on safety. If it goes wrong a nuclear accident can be a major disaster.

3.3.3 Geothermal Energy

Geothermal energy is energy from heat inside the earth. Thermal energy within the earth is termed geothermal energy. Human beings live on a crust of earth with varying thickness. Beneath the crust is a semi-molten rock layer called the mantle. Beneath the mantle is a molten core of iron and nickel. The earth's crust is warmed from within by the hot interior and by radioactive decay products, in particular, emissions from uranium – 238, thorium – 232 and potassium – 40. The temperature of the crust increases about 2°C for each 100-m penetration. Geothermal energy is difficult to exploit. However, there are areas in which hot molten rock (magma) is forced up through structural defects and these sometimes produce concentrated sources of hot water or steam that can be tapped for a variety of energy uses. Thermal energy can be extracted by drilling to the rock. Injecting water into the entrance and recovering the steam formed when the water contacts the hot dry rock.

Although present in many parts of the world, these systems are probably incapable of making a substantial contribution to the energy demand of the industrialized nations, but could, on the other hand, constitute the decisive factor for the industrial take-off of many developing countries. New technologies are being studied or experimenting for creating artificial hydrothermal systems so that geothermal energy could make a significant contribution to the world's energy demand.

Types of Geothermal Fields

1. **Hot water fields:** These contain water in the 50°C – 100°C temperature range, which can be utilized for domestic heating, agricultural heating (that green house) or in industrial processes requiring heat.
2. **Wet Steam fields:** These contain pressurized water at temperatures that are usually well above 100°C, and small quantities of steam in the shallower, lower pressure parts of the reservoir. An impermeable cap rock prevents the fluid from escaping to the surface, thus, keeping it under pressure.
3. **Superheated Steam fields:** These are similar geologically to the wet steam fields. The water and steam coexist, with steam as the continuous predominant phase. This type of field produces dry steam (with no water in the liquid phase) generally superheated, with small quantities of other gases, particularly CO₂ and S₂. The superheated steam is used in generating electricity.

N.B: The electric energy produced by geothermal means is nowadays competitive with all other renewable and conventional energy sources and can draw on a technology based on some tens of years of work experience.

Advantages of geothermal Energy

1. Geothermal energy does not produce any pollution, and does not contribute to the greenhouse effect.
2. The power stations do not take up much room, so there is not much impact on the environment.
3. No fuel is needed
4. Once the geothermal power station is built, the energy is almost free.

Disadvantages of Geothermal Energy

1. The big problem is that there are not many places where a geothermal power station can be built. This is because hot rocks of suitable type are needed.
2. Sometimes a geothermal site may 'run out of steam' perhaps for decades.
3. Hazardous gases and minerals may come up from underground and can be difficult to safely dispose of.

3.4 Conservation of Energy

One kind of energy may be converted easily into another such as potential to Kinetic type or chemical to electrical form, while the total energy always remains the same. That is, energy is neither created nor destroyed in any given physical system. This idea is called the law of conservation of energy.

Examples of the law of conservation of energy are: when a bullet leaves a gun with a certain kinetic energy. As it flies through the air, some of its energy is lost, some of its energy is energy due to its friction with the air. As the bullet strikes its target, more energy is converted to sound and light. Heat will also be developed in the target. Another example is the kinetic energy of wheel as it spins can lift water and store it in a tank. The work done in lifting the water is stored as potential energy. If the water is allowed to fall back to earth, this potential energy is again converted to kinetic energy.

Further example is when Zinc and copper bars are partially immersed in a sulfuric acid solution, a chemical reaction takes place. If the parts of these bars that are above the surface of the acid solution are connected to each other by a wire, it will be found that an electric current will flow through this wire. This arrangement is called voltaic cell. If a globe is connected to this arrangement, it will glow. Can we add more examples from our day to day experiences?

The following is also an example of transformation of different forms of energy into heat and power.

Oil burns to make heat → Heat boils water → Water turns to steam
Steam pressure turns a turbine → Turbine turns an electric generator →
Generator produces electricity → Electricity powers light bulbs → Light bulbs give
off light and heat

It is difficult to imagine spending an entire day without using energy. In a home where electricity supplies all of the energy requirements, the average energy consumption is shown below:

Air conditioner and heater	=	50%
Water heater	=	20%
Lighting and small appliances	=	10%
Refrigerator	=	8%
Other	=	5%
Ovens and stoves	=	4%
Clothes dryer	=	3%

3.5 Importance of Conservation of Energy

Because of the limited amount of nonrenewable energy sources on Earth, it is important to conserve our current supply or to use renewable sources so that our natural resources will be available for future generations.

Energy conservation is also important because consumption of nonrenewable sources impacts the environment. Specially, our use of fossil fuels contributes to air and water pollution. For example, carbon dioxide is produced when oil, coal, and gas combust in power stations, heating systems, and car engines. Carbon dioxide in the atmosphere acts as a transparent blanket that contributes to the global warming of the earth, or “greenhouse effect”. It is possible that this warming trend could significantly alter our weather. Possible impacts include a threat to human health, environmental impacts, such as rising sea levels that can damage coastal areas and major changes in vegetation growth patterns that could cause some plant and animal species to become extinct. Furthermore, Sulfur dioxide is also emitted into the air when coal is burned. The sulfur dioxide reacts with water and oxygen in the clouds to form precipitation known as “acid rain”. Acid rain can kill fish and trees and damage limestone buildings and statues.

3.6 Conversion Devices for Renewable and Non Renewable Energy

Any known source of renewable energy is not useful in its natural state except it is converted through appropriate conversion devices.

3.6.1 Solar Energy Conversion

The basic components of solar power systems are shown in Fig. 3.4.



Fig. 3.4: Basic components of Solar Power systems
Source: <http://www.freesunpower.com/solarpanels.php>

Solar Energy is converted into useful form through application of the following conversion devices:

Solar Panels: Solar Panels supply the electricity and charge the batteries.

A Charger Controller: A Charge Controller is needed to prevent overcharging of the batteries. Proper charging will prevent damage and increase the life and performance of the batteries.

The Power Inverter: The [Power Inverter](#) is the heart of the system. It makes 120 volts AC from the 12 volts DC stored in the batteries. It can also charge the batteries if connected to a generator or the AC line.

Batteries Storage: Batteries store the electrical power in the form of a chemical reaction. Without storage you would only have power when the sun was shining or the generator was running.

Necessary and proper wires and cables will be needed to connect everything and a meter to keep an eye on things would be nice.

3.6.2 Wind Energy

A typical wind energy conversion system is shown in Fig. 3.5



Fig. 3.5: A typical wind Energy Conversion System

Source: http://www.daviddarling.info/encyclopedia/G/AE_generator.html

The major components of a typical wind energy system include: wind turbine, a generator, interconnection apparatus and control systems. Generators for wind turbines include synchronous generators, permanent magnet synchronous generators, and induction generators which could either be the squirrel-cage type or wound rotor type. For small to medium power wind turbines, permanent magnet generators and squirrel-cage induction generators are often used because of their reliability and cost advantages. Also, induction generators, permanent magnet synchronous generators, and wound field synchronous generators are currently used in various high power wind turbines.

3.6.3 Hydro Power Energy

The major components of a typical hydropower system include:

Penstock: Main pressure building conduit. Must use care if head is large, 130 psi or greater. High head pressure can be dangerous

Hydro Turbine or Wheel: Depending on type of system chosen (Impulse or Reaction)

Gear Box or Belt Drive: Gear belt and belt drive provide most efficient range of Turbine operation and maintain generator output at correct frequency.

Generator: Most common types used are either synchronous or induction depending on power application.

Power Switch & Breaker: These are safety device to disconnect power

Transformer: AC conversion of generator output voltage to transmission line or use voltage.

AC Output to Load or Grid: Transmission line to point of use, voltage and current define loss based on wire gauge and distance.

4.0 Summary

Energy are classified into renewable and nonrenewable, conventional and non-conventional, and the green and non-green forms of energy, depending on whether their supplies are limited, regular use and their effect on the environment. **Renewable energy sources** include biomass, geothermal energy, hydropower, solar energy, and wind energy. They are called renewable because they are replenished in a short time

5.0 Self-Study Questions

1. Differentiate between renewable and non-renewable sources of energy.
2. List 5 types of energy you know
3. Describe one method for converting one type of energy to another;
4. State five advantages and disadvantages of the following types of energy:
 - i. solar
 - ii. fossil fuel
 - iii. wind
 - iv. tidal
 - v. hydroelectricity
 - vi. geothermal
 - vii. nuclear energy.

6.0 Tutor Marked Assignment

1. Describe the energy conversions that take place in the following:
 - (a) A boy riding a bicycle
 - (b) An electric pressing iron
 - (c) Radios and televisions
 - (d) The Telephone
 - (e) Electric Motor
2. Describe briefly how energy is obtained by
 - a) Solar energy
 - b) Tidal energy
 - c) Hydroelectricity
 - d) Geothermal energy
 - e) Wind energy
 - f) Nuclear energy
3. Enumerate distinct features of the following:
 - a) Conventional Energy Source
 - b) Non Conventional Energy Source
 - c) Renewable Energy Source
 - d) Non Renewable Energy Source

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8.0 Further Reading

Unit 2: Biomass as Sustainable Sources of Renewable Energy

Contents

1.0 Introduction

2.0 Learning Outcomes

3.0 Main Contents

3.1 Biomass as Sources of Energy

3.2 Relationship of Biomass with Renewable and Nonrenewable Energy

3.3 Biomass Utilization Now and in the Future

3.4 Transformation of Biomass to Renewable Energy

3.4.1 Combustion

3.4.2 Pyrolysis

3.4.3 Destructive distillation

3.4.4 Gasification

3.4.5 Anaerobic Biogasification

3.4.6 Fermentation and Distillation

3.4.7 Transesterification of Vegetable Oil

3.5 Advantages of Biomass as Energy Source

3.6 Production of Biofuel and Food Security

4.0 Summary

5.0 Self-Assessment Questions (SAQs)

6.0 Tutor Marked Assignments (TMAs)

7.0 Further Reading

1.0 Introduction

This unit introduces various types of biomass as forms of alternative energy. The energy potential of these important commodities are examined. The environmental benefits of biomass are discussed. The processes involved in conversion of biomass to various sustainable energy products are also highlighted with their unique characteristics. The issues related to energy crop and food security were presented and obvious factors that may lead to food shortage and price increase beside production of biofuel from biomass are highlighted.

2.0 Learning Outcomes

At the end of this unit, you are should be able to:

- i. Define biomass
- ii. List four advantages of biomass as a source of energy
- iii. State five methods for transformation of biomass to renewable energy
- iv. Identify the challenges of biofuel production in developing countries

3.0 Main Content

3.1 Biomass as Sources of Energy

The term biomass refers to all organic matter generated through photosynthesis and other biological processes. Biomass is considered as the solar energy stored in chemical form in plant

and animal materials and it is among the most precious and versatile resources on earth. It provides not only food but also energy, building materials, paper, fabrics, medicines and chemicals. Biomass has been used for energy purposes ever since man discovered fire. Today, biomass fuels can be utilised for tasks ranging from heating the house to fuelling a car and running electrical and electronic appliances.

If we burn biomass efficiently (extract the energy stored in the chemical bonds) oxygen from the atmosphere combines with the carbon in plants to produce carbon dioxide and water. The process is cyclic because the carbon dioxide is then available to produce new biomass. This process leads credence to earnings of Carbon Credit. Hence, use of biomass can help reduce global warming compared to a fossil fuel-powered plant. Plants use and store carbon dioxide (CO₂) when they grow. CO₂ stored in the plant is released when the plant material is burned or decays. By replanting the crops, the new plants can use the CO₂ produced by the burned plants. So using biomass and replanting helps close the carbon dioxide cycle. However, if the crops are not replanted, then biomass can emit carbon dioxide that will contribute toward global warming. So, the use of biomass can be environmentally friendly because the biomass is reduced, recycled and then reused. Today, new ways of using biomass are still being discovered. One way is to produce ethanol, a liquid alcohol fuel. Ethanol can be used in special types of cars that are made for using alcohol fuel instead of gasoline. The alcohol can also be combined with gasoline. This reduces our dependence on oil or fossil fuel.

Wood may be the best-known example of biomass. But wood is just one example of biomass. Various biomass resources are derived from different sources. Bagasse from sugarcane, corn fiber, rice straw and hulls, and nutshells are examples of agricultural residues. Sawdust, timber slash, and mill scrap are derived from wood waste. Examples of municipal wastes include the paper trash and urban yard clippings. Energy crops are fast growing trees like poplars, willows and jatropha. Grasses like switchgrass or elephant grass are also examples of energy crops. The methane captured from landfills, municipal waste water treatment, and manure from cattle or poultry, are typical examples of biomass. (Olaoye, 2001; Corcoran et al., 2008).

3.2 Relationship of Biomass with Renewable and Nonrenewable Energy

Six most utilized renewable energy sources are hydropower, tidal wave, solar, wind, geothermal, and biomass. All energy forms derived from biomass sources are renewable. Renewable energy sources refer to forms of energy sources that can be regenerated in a short period of time after utilization while nonrenewable energy sources cannot be regenerated in a short period of time. Nonrenewable energy are mainly sourced from the ground as liquids, gases and solids. Examples of these include crude oil, natural gas and coal, respectively. These products are essentially biomass as they formed from the buried remains of plants and animals that lived millions of years ago. Fig. 2.1 shows various forms of renewable and nonrenewable energy.

Fossil fuels contain the same constituents - hydrogen and carbon - as those found in fresh biomass. Environmental impacts pose a significant distinction between biomass and fossil fuels. When a plant decays, it releases most of its energy back into the

atmosphere. In contrast, fossil fuels are locked away deep in the ground and do not affect the earth's atmosphere unless they are burned.

Rising world fuel prices, the growing demand for energy, and concerns about global warming are the key factors driving the increasing interest in renewable energy sources and in biomass in particular. Biomass is the best alternative energy source as it is available in large amounts and production of some form of energy from biomass is also less costly. The use of renewable energy is not new. Now biomass that could normally present a disposal problem is converted into electricity and other useful energy alternative.

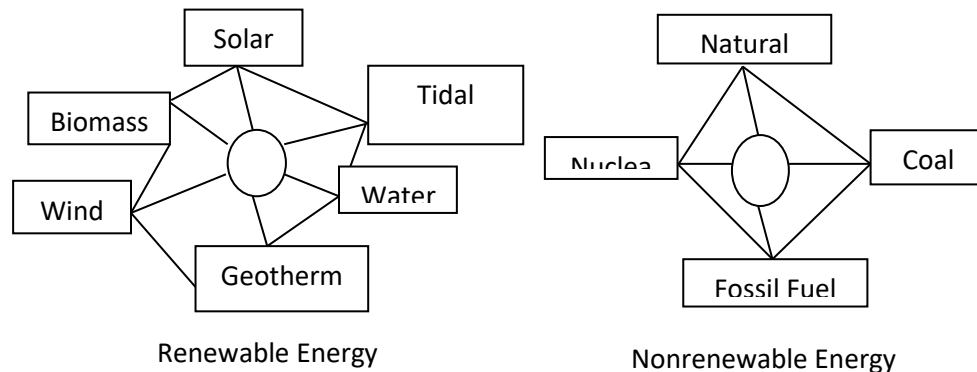


Fig. 3.1: Illustrations of renewable

and

nonrenewable energy

3.3 Biomass Utilization Now and in the Future

According to *Henniges and Zeddies (2006)*, biomass is considered to be one of the key renewable resources of the future at both small- and large-scale levels. It already supplies 14 per cent of the world's primary energy consumption, and for three quarters of the world's population living in developing countries biomass is the most important source of energy. With increases in population and per capita demand, and depletion of fossil-fuel resources, the demand for biomass is expected to increase rapidly in developing countries. On the average, biomass produces 38 percent of the primary energy in developing countries and about 90 per cent in Brazil. Biomass is likely to remain an important global source in developing countries well into the next century. Even in developed countries, biomass is being increasingly used. A number of developed countries use this source quite substantially, for example in Sweden and Austria, 15 per cent of their primary energy consumption is covered by biomass. Sweden has plans to increase further use of biomass as it phases down nuclear and fossil-fuel plants in the near future. In the USA, which derives 4 per cent of its total energy from biomass (nearly as much as it derives from nuclear power), now more than 9000 MW electrical power is installed in facilities firing biomass (Keeney and DeLuca, 1992, Rosentrater et al., 2009). In Nigeria, with massive available land and agricultural infrastructure the biomass reserve could, sustainably, revamp the epileptic supply of energy generated through the hydropower plants without any serious threat to food security. Furthermore, biomass can be used to produce ethanol (biofuel) which could reduce also oil imports up to 50 per cent.

Nigeria has abundance of required resources for biomass production. The climatic and ecological ambiances are most suitable conditions for growth of energy crops. All existing opportunities along the production chain from cultivation of energy crop to extraction of ethanol or biodiesel can be exploited as a means of generating employment. The teeming youthful population can provide the desired labour requirements.

Conversion of biomass to energy can become employment generating venture for the nation, leading to strong financial returns. Nigeria has an arable land of 33,000,000 Ha (NBS, 2007). Brazil with similar climatic conditions but smaller arable land area has successfully translated her biomass resources into useful form through production of biofuels from agricultural feedstock. Sambo (2009) estimated the quantities of available biomass resources in million tonnes in Nigeria as follows; fuelwood 39.1, Agro-waste 11.2 and Saw Dust 1.8 while the corresponding heat values in Mega Joules are estimated as 531.0, 147.7, and 31.433, respectively. The resources quantity for Municipal Solid Waste is estimated as 4.075 million tonnes.

Figure 3.2 clearly illustrates various characteristics of biomass and diverse forms of energy that can be produced. Table 2.1 presents different sources of biomass, their forms, and their conversion process to respective forms of energy.

3.4 Transformation of Biomass to Renewable Energy

The processes of conversion of biomass into a useful source of energy include combustion, pyrolysis, destructive distillation, gasification, anaerobic bio-gasification, fermentation and distillation of alcohol and transesterification of vegetable oil. (<http://www.world-agriculture.com/>, <http://www.world-agriculture.com/agricultural-bioenergy/alcoholic-fermentation-process.php>, Nan et al., 1994, FOE, 2009).

3.4.1 Combustion

Combustion involves burning of biomass fuels in the presence of air to generate heat energy. Main products of combustion are ash and fuel gases. Usually fuels are burnt on hot furnace. The heat generated is used to drive steam engines and also for irrigation and threshing purposes.

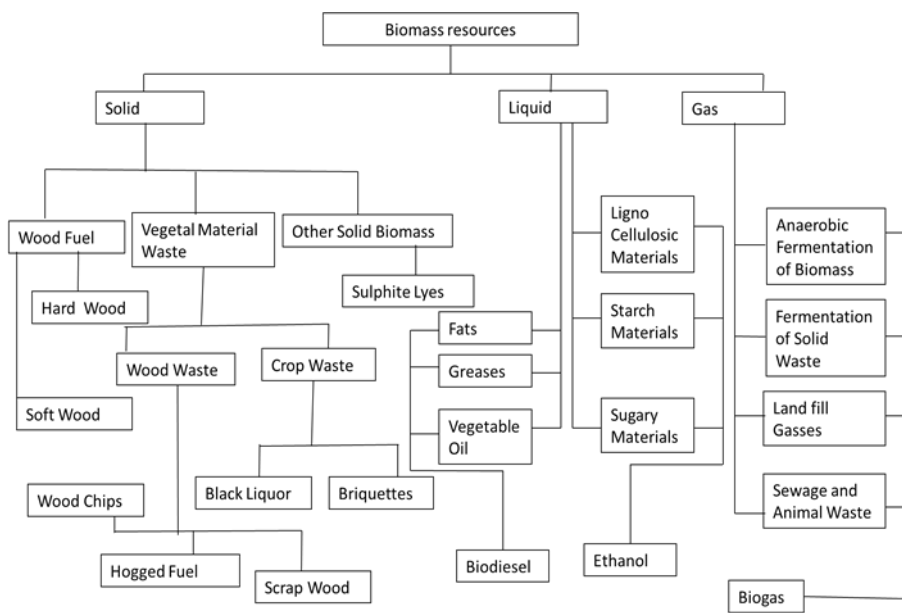


Fig. 3.2: Characteristics of biomass and diverse forms of energy that could be produced

Table 3.1: Biomass Resources, Conversion Process and Energy Derivatives

S/No	Sources of biomass	Forms of biomass	Conversion process	Forms of energy
A	Plantations			
1	Siviculture	Fire wood	Combustion	Heat
2	Energy plantation	-do-	Destructive distillation	Charcoal
3	Agriculture	Carbohydrates		Ethanol
4	Energy crops	Hydrocarbons	Fermentation	Fuel oil
5	Aquatic biomass	Aquaculture		Methanol
6	Weeds	Whole plant body		Methane
B	Residues/wastes/weeds			
1	Rural/urban wastes/ industrial wastes		Combustion Pyrolysis Fermentation	Fire/fuel Fuel oil Ethanol
2	Forestry wastes	-do-	Combustion Pyrolysis Gasification Fermentation	Fuel Oil gas Gas Ethanol
3	Agricultural wastes	Wastes	Fermentation	Methane
4	Weeds & aquatic biomass	Wastes	Fermentation	Methane
5	Cattle dung	Wastes	Fermentation (biomass)	Methane

Source: <http://www.world-agriculture.com>, Heiermann, *et al.*, 2009

3.4.2 Pyrolysis

Pyrolysis is the process of heating wood and agricultural residues at temperature varying between 540 - 1100 °C in the absence of air near several hours to breakdown plant materials into a complex mixture of liquids. Earthen kilns, pit kilns, brick kilns or portable steel kilns are used for this process. The resulting product has a high calorific value, easy to transport, store and distribute and more efficient in burning and has a characteristic feature of creating less pollution. A good example of pyrolysed product is charcoal. From eight tonnes of wood, around one tonne of charcoal can be made. The gases that are produced during the process of pyrolysis can be converted or synthesized into methanol and liquids which are used as fuels. (Shah *et al.*, 1989). Depending on the temperature, the degradation stages of pyrolysis revealed different products. The stages of pyrolysis by breaking down wood and agricultural residues into mixture of liquid in the absence of air are identified by four distinct temperature zones 0 – 170 °C yielding evaporation of moisture, 170 – 270 °C resulting into evolution of carbon monoxide and carbon dioxide, 270 – 400 °C yielding evolution of methanol and at 400 – 500 °C to produce charcoal with optimum carbon content. (<http://www.world-agriculture.com>).

3.4.3 Destructive distillation

The destructive distillation is carried out in long steel retorts or earthen kilns. Only the wood wastes such as branches, trunks of trees are used as raw materials. The process involves decomposition of wood at high temperatures in the absence of air. At an initial temperature of 230 °C, the moisture is evaporated and then the temperature is raised to 370 °C and maintained for 6 hours. At the end of this period, wood is converted to charcoal which is cooled in the absence of air for 48 hours. After cooling, they are spread in open sheds, two days for drying and thereafter ready for supply to consumers. Figure 3.3 displays a typical setup during the process of destructive distillation of wood in Nigeria to produce charcoal.



Figure 3.3: The process of destructive distillation wood to produce charcoal.

3.4.4 Gasification

Gasification is a process of degradation of carbonaceous material (wood wastes) under controlled air or pure oxygen at a high temperature of 1000 °C. As a result of gasification, high amount of gases are produced. Biomass gasification is done in gasifiers designed in various ways. Gasifiers are generally classified based on the physical conditions of the feed stocks in the gasifiers. These include fixed bed gasifier, stirred bed gasifier, tumbling bed gasifier, fluidized bed gasifier. (FOE, 2009).

The vapours of the volatile matters that are formed during the distillation process subsequently condensed to tar, methanol, acetic acid, methyl acetate, oil and gas. Charcoal is used as a fuel, source of carbon in making carbon-di-sulphide. Methanol is used as a solvent and an antifreeze for automobiles. Acetic acid is used as a raw material for the manufacture of acetic anhydride, sodium acetate, cellulose acetate, ethyl acetate, and butyl acetate among other applications. Methyl acetate is a solvent used in paint industry. A product of tar known as "pitch" is used as rubber softener. Oils are used as solvent and insecticide. Gases are used as fuel for heating wood distillation and fuel for boilers (<http://www.world-agriculture.com>, Nan *et al.*, 1994).

In the course of gasification, a number of chemical reactions take place. As soon as the biomass is ignited four distinct zones are set-up in the gasifier-unit. Biomass when introduced into the gasifier, enters into drying zone where the temperature is 200 - 400 °C. The products of this zone are vapours of tar, organo-chemicals, and liquid oils. (Guo, 2004). After drying zone it enters the pyrolysis zone, of temperature 400 – 750 °C. Pyrolysis at this point results in char, organic liquids and some gases. At 750 - 1000 °C, mainly gases like carbon-di-oxide, carbon mon- oxide, hydrogen, methane etc. are produced and this stage is called as gasification zone. The oxidation zone which is at 1000 - 1400 °C also produces gases like nitrogen, carbon-di-oxide and hydrogen. (Shah *et al.*, 1989; Guo, 2004.). When the process of oxidation is over, with the steam treatment, ash, an inert material is formed. The gasification process, thus, ultimately results in a number of gases which are in mixture. This mixture of gases is referred to as producer gas. Producer gas somewhat burnt like a natural gas which can be used as a fuel for engines. The composition is given in Table 3.2.

Table 3.2: Composition of Producer Gas.

S/No	Components of producer gas	Percentage Composition
1	Carbon monoxide	20 – 22
2	Hydrogen	15 – 18
3	Methane	2 – 4
4	Carbon-di-oxide	9 – 11
5	Nitrogen	50 – 53

Source:

<http://www.world-agriculture.com/>

3.4.5 Anaerobic Biogasification

Degradation of organic matter in the absence of air to methane and carbon-di-oxide is called anaerobic biogasification. In villages, cattle manure is used as a fuel for cooking purposes.

Consequently, preparation of biogas has become popular among rural people. Biogas can be utilized for cooking, lighting, operating diesel engines, water pumps etc. Animal wastes such as cattle dung, chicken droppings, and night soils are the main raw material for the production of biogas. The main advantages of the biogasification are that the biogas production can be started by constructing permanent structures such as tanks at a convenient place at home (Plöchl et al., 2009, Heiermann *et al.*, 2009). It can be manufactured with least maintenance. Initial investment is also cheap. Gobar gas or biogas contains 60 per cent methane and 40 per cent carbon-di-oxide. The digested manure contains 1.5 - 2 per cent nitrogen and other soil nutrients, which can be used as an organic fertilizer. The biogas can be easily purified to methane which is an enriched fuel gas of high calorific value.

3.4.6 Fermentation and Distillation

The materials for alcoholic fermentation to produce ethanol are Sugary, Starchy and Lignocellulosic materials. The first two categories are first generation energy crops and the third category is referred to as the second generation energy crop. The sources of cellulose and lignocellulosic materials are the agricultural wastes and wood. All these categories are in abundant distribution in Nigeria. Nigeria being traditional agro-based country with the soil conditions that support production of diverse types of feedstocks for production of biofuels. Biofuel is a transportation fuel in the form of ethanol.

Ethanol is an alcohol fuel made from the sugars found in grains, such as corn, sorghum, and wheat, as well as potato skins, rice, sugar cane, sugar beets, and yard clippings. Researchers are experimenting with "woody crops", mostly small poplar trees and switchgrass, to see if they can grow them cheaply and abundantly to avoid total dependency on food crop. Any gasoline powered engine can use E10, that is a mixture of 10 per cent ethanol and 90 per cent gasoline. Only specially made vehicles can run on E85, a fuel that is 85 per cent ethanol and 15 per cent gasoline.

There are two major treatments that are necessary after the pretreatment operations. These are fermentation and distillation. Fermentation is to convert the larger, complex dextrose molecules into smaller, simple sugar molecules called maltose and glucose.

Once the mash's sugar is fermented by yeast, then the fermented liquid product is put into a still where it is heated for distillation. Distillation can happen because water boils at 100 °C and ethanol boils at 78 °C hence, ethanol can distill out and leave most of the water behind. (<http://www.ethanolrfa.org/industry/statistics/#E>). Ethanol production in Nigeria is still limited to application in beverages, allied and pharmaceutical industries.

3.4.7 Transesterification of Vegetable Oil

The basic treatment in the production of biodiesel is referred to as transesterification. This process is achieved in four principal stages as follows: pre-treatment of feedstock, transesterification, methyl ester purification and glycerol purification. Pretreatment of feedstock is to remove contaminants and components that will be detrimental to subsequent processing

steps. Transesterification is the reaction process followed by the separation of the methyl ester and glycerol. Methyl ester purification stage is to remove the excess methanol, catalyst and glycerol from the transesterification process. Also at this stage the methanol removed is recycled to the transesterification process. The glycerol obtained is further processed to remove impurities such as catalyst and methyl esters that are contained in order to produce a higher grade glycerol if economics dictate. Figure 2.4 presents the flow chart of the biodiesel process.

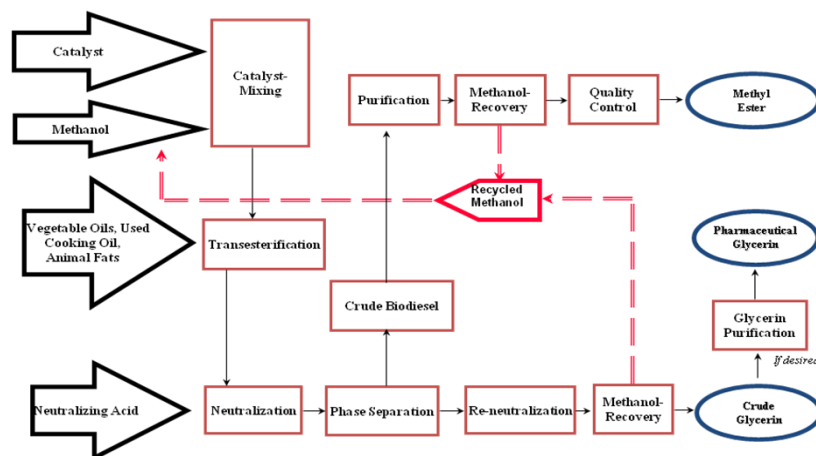


Fig 2.4: Schematics of Biodiesel processing

Biodiesel is a fuel made with vegetable oils, fats, or greases - such as recycled restaurant grease. Biodiesel fuels can be used in diesel engines without changing them. It is the fastest growing alternative fuel in the United States. Biodiesel, a renewable fuel, is safe, biodegradable, and reduces the emissions of most air pollutants. (Wood, 1993, <http://journeytoforever.org/biodiesel>)

3.5 Advantages of Biomass as Energy Source

Rural economic development in both developed and developing countries is one of the major benefits of biomass. The new incomes for farmers and rural population improve the material welfare of rural communities and this might result in a further activation of the local economy. (Braun and Pachauri, 2008, Von Braun *et al.*, 2008, Arndt *et al.*, 2008). This new market diversification will provide farmers with stable income, and strengthen the local economy by keeping income recycling through the community. In the end, this will mean a reduction in the emigration rates to urban environments, which is a very common situation in many areas of the world.

The number of jobs that can be created through the production chains of biomass would be enormous. For instance, investigation revealed that 17,000 jobs can be created per every million of gallons of ethanol produced. About 50 million acres of land would be required to produce 5 quadrillion Btu's (British Thermal Units) of electricity. These would increase overall farm income tremendously (Von

The use of biomass energy has many environmental benefits. It can help mitigate climate change, reduce acid rain, soil erosion, water pollution and pressure on landfills, provide wildlife habitat, and help maintain forest health through better management. Biomass-energy systems can increase economic development without contributing to the greenhouse effect since biomass is not a net emitter of CO₂ to the atmosphere when it is produced and used sustainably. It also has other benign environmental attributes such as lower sulphur and NO_x emissions and can help rehabilitate degraded lands (Arndt et al., 2008). There is a growing recognition that the use of biomass in larger commercial systems based on sustainable, already accumulated resources and residues, can help improve natural resource management.

Biomass is generally and wrongly regarded as a low-status fuel, and in many countries rarely finds its way into statistics. It offers considerable flexibility of fuel supply due to the range and diversity of fuels which can be produced. Biomass energy can be used to generate heat and electricity through direct combustion in modern devices, ranging from very-small-scale domestic boilers to multi-megawatt size power plants electricity (e.g. via gas turbines), or liquid fuels for motor vehicles such as ethanol, or other alcohol fuels.

Biomass can be adopted for generation of energy. If the energy is properly utilized it will meet a sizeable percentage of the country's demands for fuel as well as energy. Agricultural and forest residues can be collected to produce fuels, organic manures and chemical feed stock. Waste from urban and industrial locations can be converted to fuel in boilers and as a feedstock for producing methane and some liquid fuels. Some specific energy plants could be cultivated for use as energy feed stock and cultivation of commercial forestry, aquatic and marine plants for different products. Thus production of biomass helps in developing cheaper source of energy from unutilized agricultural residues, wastes, forest wastes, plantations etc. which is an alternative source of energy for fossil fuel energies.

3.6 Production of Biofuel and Food Security

A major criticism often levelled against biomass, particularly against large-scale fuel production, is that it could divert agricultural production away from food crops, especially in developing countries. The basic argument is that energy-crop programmes compete with food crops in a number of ways (agricultural, rural investment, infrastructure, water, fertilizers, skilled labour etc.) and thus cause food shortages and price increases. However, this so-called 'food versus fuel' controversy appears to have been exaggerated in many cases.

The subject is far more complex than has generally been presented since agricultural and export policy and the politics of food availability are factors of far greater importance. The argument should be analysed against the background of the world's (or an individual country's or region's) real food situation of food supply and demand (ever-increasing food surpluses in most industrialized and a number of developing countries), the use of food as animal feed, the under-utilized agricultural production potential, the increased potential for agricultural productivity, and the advantages and disadvantages of producing biofuels.

Generally, there are obvious factors that may lead to food shortage and price increase beside production of biofuel from biomass. These factors include combination of policies which were biased towards commodity export crops and large acreage increases of such crops, hyperinflation, currency devaluation, and price control of domestic foodstuffs. Developing countries are facing both food and fuel problems. Adoption of appropriate agricultural practices is necessary to be able to utilise available land and other resources to meet both food and fuel needs.

4.0 Summary

Various types of biomass were highlighted as forms of alternative energy. The energy potential of these important commodities were examined. The benefit of biomass is not limited to energy source but it could lead to increase in farm income and market diversification, reduction of agricultural commodity surpluses and derived support payments. Biomass development can enhance international competitiveness, revitalization of retarded rural economies, and reduction of negative environmental impacts. The reduction of negative environmental impacts is most important issues related to utilisation of biomass as energy source. The environmental benefits of biomass were discussed and some of the environmental benefits include ability to mitigate climate change, reduce acid rain, soil erosion, water pollution and pressure on landfills, provide wildlife habitat, and help maintain forest health through better management. Biomass-energy systems can increase economic development without contributing to the greenhouse effect. The processes involved in conversion of biomass to various sustainable energy products were highlighted with their unique characteristics. The issues related to energy crop and food security were presented and obvious factors that may lead to food shortage and price increase beside production of biofuel from biomass were highlighted and it was concluded that adoption of appropriate agricultural practices is necessary to be able to utilise available land and other related natural resources to meet both food and fuel needs for biomass utilization.

5.0 Self-Study Questions

- i. What is a biomass?
- ii. List four benefits of biomass as a source of energy
- iii. State five methods for transforming biomass to renewable energy
- iv. Identify two challenges of biofuel production in developing countries

6.0 Tutor Marked Assignment

1. Identify the various stages in transformation of Biomass to Renewable Energy and discuss in details the products and by products of the following processes:
 - a) Combustion
 - b) Pyrolysis
 - c) Destructive Distillation
 - e) Gasification
 - f) Anaerobic Biogasification
 - g) Fermentation and Distillation
 - h) Transesterification of Vegetable Oil

2. With the aid of Schematics diagram present the processing flow diagram of
 - a) Biodiesel processing
 - b) Biofuel processing
3. Use appropriate diagram to illustrate production of biogas in a biogas digester with the blend of a cow dung and green vegetable matter as the substrate.

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