COURSE GUIDE

SED 224
ENERGY AND MATTER I

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CONTENTS

INTRODUCTION

SED 224 – This course 'energy and matter' will provide you with basic knowledge of the various forms of energy that can be generated from matter, and how these various forms of energy can be put to use.

WHAT YOU WILL LEARN FROM THIS COURSE

You will learn the definition of energy, how energy is measured, the energy cycle, the various sources of energy, their uses to man and how to mitigate energy crisis in the world.

COURSE AIMS

The aim of this course is to provide you with the basic knowledge of the concept of energy and its importance to man.

COURSE OBJECTIVES

After doing a thorough study of the content of this course, you will be able to:

- define energy;
- explain how energy is measured;
- list the various sources and forms of energy;
- explain how the various forms of energy are transformed from one form to another;
- describe the energy cycle;
- list the uses of the various forms of energy;
- write the energy equation; and
- discuss energy consumption, crisis and its mitigation.

WORKING THROUGH THE COURSE

In working through this course, you are expected to read the study units, and other relevant books and materials provided by the National Open University of Nigeria at the end of each unit of work.

Self-assessment exercises are provided in the course; and at certain points in the course, you are required to submit assignments for assessment purpose. This course is expected to last for a period of one semester after which there will be a final examination. The various components of the course are listed below. You are also provided with a guide on how you should allocate your time to each unit in order to complete the course successfully and timely.

ASSIGNMENTS

There are thirteen (13) assignments in this course, covering all the units studied.

You are expected to submit completed assignments to your facilitators in the course of the study whether in synchronous or asynchronous sessions. The marks you obtain for these assignments will count towards the final mark you obtain for this course. Further information on assignments will be found in the Assignment File and also in this Course Guide in the section on assessment. You are equally required to use in-text references to enrich your studies.

THE COURSE MATERIALS

National Open University of Nigeria will provide you with the following:

The Course Guide; The Course has three modules. Modules 1 and 3 have four units of work as listed hereunder, while module 2 has five units.

At the end of each unit, you are also provided with list of books and other reference materials for further reading in addition to some online resources. Note that while you may not have access to all of them, it is important to strive to get some of them as essential supplements to the main course materials.

STUDY UNITS

The study units are listed below.

Module 1 Energy: Meaning, Measurement, Forms and Transformation

Unit 1 Meaning of energy and matter
Unit 2 Measurement of energy
Unit 3 Forms, Transformation and Uses of Energy
Unit 4 Energy of the Universe and Energy Cycle

Module 2 Sources of Energy

Unit 1 Physical Sources of Energy
Unit 2 Chemical sources of energy
Unit 3 Biological sources of energy
Unit 4 Gaseous sources of energy

Module 1 presents the subject matter content in four units. This module focuses on the meaning, measurement, forms and transformation of energy.

Module 2 presents the subject matter content in five units focusing on the Sources of energy.

Module 3 presents the subject matter content in four units focusing on energy dissipation, consumption, equation and energy crisis.

ASSESSMENTS

Assessment is in three formats: Self-Assessment Exercises (SAEs), tutorial assignments and the final examination.

SELF ASSESSMENT EXERCISES

You are advised to be truthful to yourself in attending to the exercises. Ensure that you provide in-depth information about the knowledge and skills you have acquired in each unit. You are advised to adhere strictly to the deadlines indicated on your schedule of presentation/ academic calendar in submitting your assignment to your tutor for formal assessment.

FINAL EXAMINATION AND GRADING

The final examination carries 70% of the total mark. It will assess all areas covered in the course. The questions will normally follow the pattern of the self-testing, practice exercise and tutor marked assignments you have previously encountered.

You are advised to review your Self-Assessment Exercises, tutor-marked assignments and comments on them before the examination.

COURSE MARKING SCHEME

All submitted works will count for 30% of your total course mark while the final examination will count for 70% of your total marks. The grand total for the course would remain 100%.

HOW TO GET THE MOST FROM THIS COURSE

In distance learning, the study materials are specially developed and designed to replace the lecturer. Hence, you can work through these materials at your pace, and at a time and place that suits you best. The course materials are interactive enough and allow you to fill the gap created by the absence of the teacher in a face-to-face encounter. However, the online synchronous facilitation and instructional video supplements are also meant to bridge this gap. Visualize it as reading the lecture instead of listening to a lecturer.

Each of the study unit follows a common format. The first item is an introduction to the subject matter of the unit and how a particular unit is integrated with other units and the course as a whole. Next is a set of learning objectives/outcomes. These objectives let you know what you should be able to do by the time you have completed the unit. Use these objectives to guide your study.

When you have completed a unit, cross-check and be sure you have achieved the objectives of that unit. If made a habit, this will further enhance your chances of completing the course successfully.

The following is a practical strategy for working through the course:

- Read this course guide thoroughly.
- Organize a study schedule, which you must adhere to religiously. The major reason students fail is that they get behind in their course work. If you encounter difficulties with your schedule, please let your tutor/ facilitator know promptly.
- Turn to each Unit and read the introduction and the objectives for the unit.
- Work through the unit. The content of the unit itself has been arranged to provide a sequence for you to follow.
- Review the objectives for each study unit to confirm that you have achieved them. If you feel unsure about any of the objectives, review the study material or consult with your tutor.
- When you are confident that you have achieved a unit's objectives, you can then start on the next unit. Proceed unit by unit through the course and try to pace your study so that you keep yourself on schedule.
- After submitting an assignment to your facilitator/ tutor for grading, do not wait for its return before starting on the next unit. Keep to your schedule. When the assignment is returned, pay particular attention to your facilitator's comments.

- After completing the last unit, review the course and prepare yourself for the final examination. Check that you have achieved the units' objectives (listed at the beginning of each unit) and the course objectives (listed in this Course Guide).

FACILITATORS/ TUTOR AND TUTORIALS

There will be specific time made available for tutorial sessions, in support of this course. You will be notified of the dates, time and location of these tutorials, together with the name and phone number of your tutor, as soon as you are allocated a tutorial group.

Your tutor will mark and comment on your assignments, keep a close watch on your progress and on any difficulties, you might encounter and provide assistance to you during the course. You must mail your tutor marked assignments to your tutor well before the due date. They will be marked by your tutor and returned to you as soon as possible.

Do not hesitate to contact your tutor by telephone, e-mail or your discussion group (board) if you need help.

The following might be circumstances in which you would find help necessary. Contact your tutor if:

- You do not understand any part of the study unit or the assigned readings.
- You have difficulty with the self – tests or exercises.
- You have a question or problem with an assignment, with your tutor's comments on an assignment or with the grading of an assignment.

You should try your best to attend the tutorials. This is the only chance to have face-to-face contact with your tutor and to ask questions which are answered instantly. You can raise any problem encountered in the course of your study. To gain the maximum benefit from course tutorials, prepare a question list before attending them. You will learn a lot from participating in discussions actively.

SUMMARY

This course is designed to give to you some understanding of the concept of energy and matter that is required of you to be able to adequately teach the topic to students particularly within the framework of Basic Science and Technology. You should acquire the basic knowledge of the various forms of energy and their importance to man. A deeper understanding of the usefulness of energy to man and an appreciation of the beauty of nature would be achieved.

We, therefore, sincerely wish you the best and that you enjoy the course.

MAIN COURSE

CONTENTS

MODULE 1 ENERGY: MEANING, MEASUREMENT, TRANSFORMATION AND FORMS OF ENERGY

UNIT 1 MEANING OF ENERGY AND MATTER

Unit Structure

1.1 Introduction

Welcome to Unit 1 of this course SED224 entitled: Energy and Matter 1. You might have heard or learnt about Energy and Matter during your Basic Education and Secondary School Stages. **Are you not amazed that the course of world-wide development in every sphere of human activity is determined by supply and demand of energy?** Energy needs and concerns are ever- increasing globally. **Do living things need energy to survive?** The obvious answer is YES. For instance, human beings (people) derive and apply energy from food to live, function and perform different acts. The meaning of energy, global need for energy, its categorisation into potential or kinetic form, relationship with **matter** among others formed the focus of this unit. You are encouraged to pay rapt attention to the unit's content as this constitutes the foundation for discussions in subsequent units.

1.2 Intended Learning Outcomes

By the end of this unit, you will be able to:

- define energy and give five examples of processes involving energy within the community.
- categorise forms of energy into Kinetic, Potential or Combination of both.
- describe matter and the classification of matter
- examine the relationship between energy and matter

1.3 Meaning of Energy

In this unit, the general meaning of energy and examples of processes involving energy are focused on, also meaning of energy as it pertains to Chemistry, Biology and Physics is also highlighted. **Learn more about energy by clicking on the link**: energy

1.3.1 Meaning of Energy and Examples of Energy Processes

The natural continuous cycle co-existing between animals, plants and physical environment began to shift when primitive human beings discovered how to make fire. **What make cooking of meat and food possible?** The answer is **fire**. Light from fire was also used for illumination. Fire was used for heating up the living spaces to make the space warm. Predators were warded off with fire; and metals can be fashioned into tools for different uses and weapons of warfare using fire. Wind was used by people, then, to move boats from one place to another. As civilisation progressed, human beings have discovered and developed ways to conveniently utilise and convert energy to ease life.

Energy can be defined as the property of matter that can be converted to work, heat or light radiation and capable of being transformed to other forms. It is the working ability of matter/ things and the attributes of its state. TRUE or FALSE. TRUE. Energy can be harnessed to move things, do work, produce heat and be converted to other forms. The primary source of energy for most living organisms on earth is the sun. Energy is commonly defined as the capacity to do work and its derived unit is joule. A body that has energy is capable of doing work. For example, a battery stores the energy needed to power a radio/ Mp3 sound set and torch lights. The wind exerts sufficient energy capable of shaking trees. Vehicle engines use energy to transport goods and people. Weight –driven pendulum clock utilises energy to function. People have their bath with shower water warmed by energy from a hot water heater.

Is work a function of energy? Surely, work is a function of energy and done when a force acts on an object producing motion of the object. Other applications of energy to do work include pushing of wheel-barrow, loading and off-loading sacks of cassava roots in a lorry etc., utilises energy to do work. Energy is applied in lifting a bucket of water off the ground and ascending a staircase. Energy is dissipated in digging and excavating the earth/ ground for building foundation or farm work. Energy is useful in playing football and in conveying goods to different locations. Energy is utilized and transformed when kerosene stove is used to boil water or cook food, when iron is used in ironing clothes, in rubbing of the palms of the hands against each other, in stretching a rubber band or compressing a spring, in grinding maize or beans to form a paste etc.

Meaning of Energy as it Pertains Physics, Chemistry and Biology

In physics, energy is the quantitative property that must be transferred to a body or physical system to perform work on the body or heat it. In chemistry, energy is the attribute of a substance due to its atomic, molecular or aggregate structure. Chemical transformations and reactions are often accompanied by transfer of energy between the surroundings and the reactants. In biology, energy is an attribute of biological systems beginning from the biosphere to the smallest living organisms. Energy is responsible for growth and development within a biological cell or an organelle of a biological organism, for example energy is used in respiration and other metabolic process. Sunlight's radiant energy is captured by plants and chemical potential energy in photosynthesis.

In what ways is Energy important to mankind? It is a conserved scalar physical/ measurable quantity and a property that is useful conceptually and mathematically. It has helped to increase productivity in various sectors of the economy. It is useful in easing pressures associated with daily living. The internal systems of the human body require energy to function effectively. Machines and industrial equipment/ facilities used in various production and manufacturing factories and distribution systems are operational due to energy. Heating and cooling of rooms to maintain optimum temperature is realizable using energy.

Self- Assessment Exercises (SAEs) 1

Attempt these exercises to measure what you have learnt so far. This should not take you more than 5 minutes.

(1) Explain the meaning of energy in relation to Physics, Chemistry and Biology.

(2) Outline 5 importance of energy to mankind

1.3.2 Global Energy Demand and Supply

In fact, a substantial amount of man's daily income is spent on procuring energy. Advances in energy have positively affected civilisation and made life far more comfortable than that of the predecessors of human race. **Do people use more energy today than ever before?** Indeed, today, people use more energy than ever before and from a variety of sources for a multitude of tasks. However, another kind of problem is being created in the consumer society. Energy is treated as commodity that should be available on demand and other environmental hazards are coming up to be contained. Human race is presently faced with the challenge of inadequate energy supply. T**he prospect of dwindling reserves have prompted efforts to educate the citizenry on energy availability in matter and how to harness the various forms it exists for good of mankind.** Energy issues need to be addressed with an independent mind considering the open-ended nature.

1.3.3 Categorising Forms of Energy into Potential, Kinetic or Combination of Both

In what basic forms does energy exist? The total energy of a system is majorly categorised into potential, kinetic or a combination of the two in different forms.

Fig.1.1: Little Child Swinging

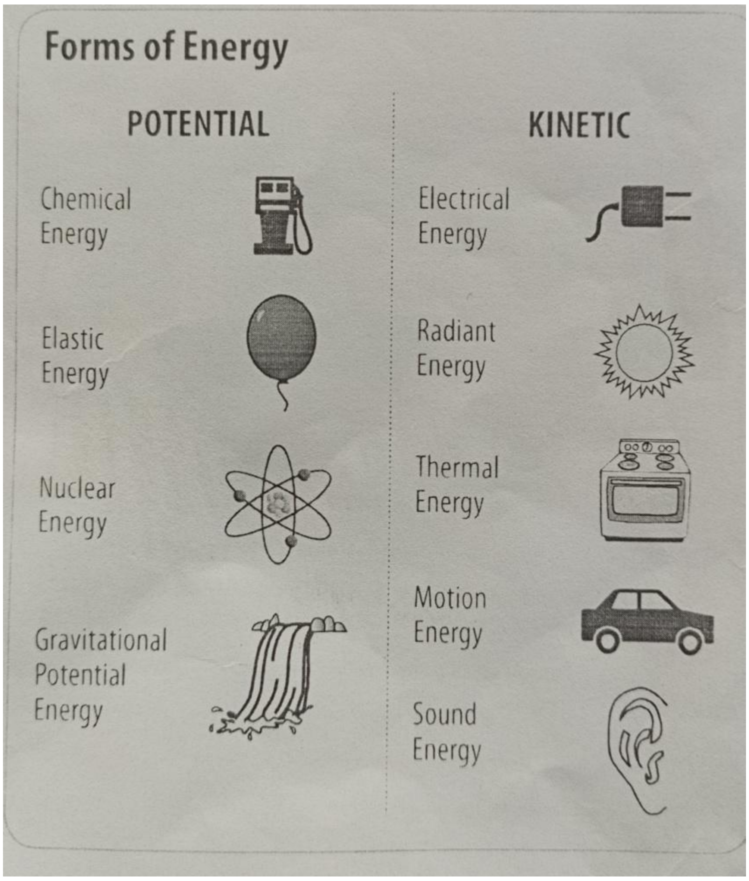

Fig.1.2: Forms of Energy (2018, The NEED Project)

Potential energy is energy stored in an object or the energy of position within a force field of an object. Chemical, mechanical (stationary), nuclear, magnetic, gravitational, and elastic energy (e.g. compressed springs and stretched rubber bands) can occur in a stored state. Elastic energy is energy stored in stretching solid objects. Kinetic energy is energy in a working state or in composite motion. Electrical (e.g. electricity and lightening), radiant/ Electromagnetic (e.g. visible light, solar, gamma rays, x-rays and radio waves), heat/ thermal (e.g. geothermal), sound, mechanical (motion e.g. wind and other moving objects) and sound are examples of kinetic energy. In nature, energy always keeps spreading from an object to another. In the transforming process, an object loses potential energy and increases kinetic energy. Chemical energy in stored state reduces as heat energy in working state increases during transformation process.

For example, stretching a rubber band gives it the potential to fly. The tension created from the stretching is potential mechanical energy. When the rubber band is released, it flies through the air using motion (kinetic energy). **The process of changing energy from one form to another is called ------.** What? **Energy transformation**. For instance, the rubber band is transformed from potential energy to kinetic energy.

Self-Assessment Exercises 2

Attempt this exercise to measure what you have learnt so far. This should not take you more than 5 minutes.

Categorise the following forms of energy into kinetic, potential or combination of both kinetic and potential energy: elastic, chemical, visible light, nuclear, magnetic, solar, x-rays, gravitational, radio waves, sound, geothermal, gamma

1.4 Meaning of Matter and the Classification

Anything that can be touched, seen or sensed is made up of matter. A piece of stone, a log of wood, a pencil, a biro, water, even the air we breathe, are all examples of matter. **Anything that has mass and occupies space is referred to as -------**. The answer is **matter**. There are **two parts** to matter. It must **occupy space** and it must **have mass**. Substances in nature exist in the form of solid, liquid or gas and they are commonly called **states of matter**. In the solid state, particles of matter are very closely packed together. Solids have definite shapes and volumes. In the liquid state, particles of matter are less closely packed to one another. Liquid has no shape, but takes the shape of the container where it is poured. A liquid has a definite volume. Particles in a gas are far away from one another. Gas has no shape and volume. Particles in a gas easily spread to fill any enclosed container. Gas can easily be compressed to fill a smaller container or volume. **Give examples of substances in the gaseous state.** They include oxygen, carbon iv oxide, water vapour, carbon monoxide and several other elements and compounds existing in gaseous state.

The amount of space an object occupies is normally measured by volume. You can think of the volume unit in terms of how big something is. For instance, compare the size of an elephant with that of a dog. Mass is a measure of the amount of matter in an object. This is not the same as the size of the matter expressed as the volume. The unit for mass is grams. Mass differs from weight, even though we, incorrectly, use them interchangeably. When we talk of weight we talk of the gravitational pull exerted on an object.

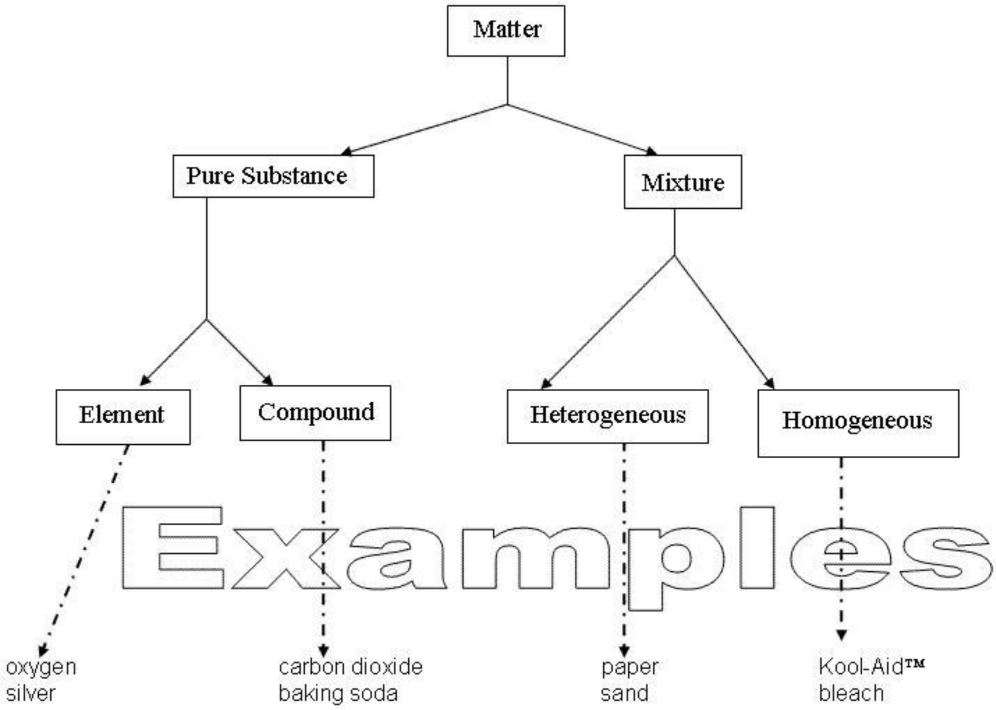

Fig.1.3: Classification of Matter

1. 5 Relationship between Energy and Matter

Physical and biological systems are characterised by energy and matter. Energy and matter can **interact**, **change forms** and **be cycled within a system**. Even though energy is not the same as matter, the two are closely related. **What relationship has energy and matter?** The fundamental relationship between energy and matter is the fact that all forms of energy are generated by changes in matter. Energy resides in matter. For instance, the human body is matter and it has energy residing in it. This is the energy we use to work and engage in our daily activities.

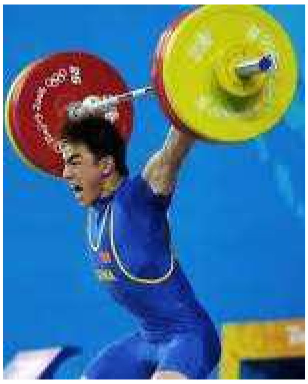

Fig.1.4: A Weight Lifter

Similarly, when wood is burnt, the energy in the wood is liberated and we can use this energy for cooking.

Matter is also converted into energy in nuclear reactors and nuclear bombs. Matter contains energy and energy makes its presence felt through matter. However, some forms of energy (e.g. light and radiant energy) can exist without contact with matter.

Fig.1.5: Burning Firewood

Self- Assessment Exercise 3

Attempt these exercises to measure what you have learnt so far. This should not take you more than 5 minutes.

(1) Discuss the states of matter and give five examples of matter.
(2) How can potential energy be transformed into kinetic energy?

1.6 Summary

In this unit, meaning, applications, demand and supply of energy as well as its relationship with matter are discussed. We have learnt that energy and matter are not the same but they are closely related. All forms of energy are generated by changes in matter. Energy is defined as the ability to do work. Matter is viewed as anything that has mass and occupies a space.

Also discussed is energy in the stored form called ***potential energy*** and energy in motion called ***kinetic energy.***

1.7 References/Further Reading

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1.6 Possible Answers to SAEs

These are the answers to the SAEs within the content.

Answers to SAEs 1

1) Meaning of energy in relation to Physics, Chemistry and Biology. In Physics, energy is regarded as that measurable quantitative property being transferred to a physical system or a body to perform work or heat up the system or the body. In Chemistry, energy is described as the attribute of a substance due to its atomic, molecular or aggregate structure resulting from a chemical reaction. In Biology, energy is the property responsible for growth and development within a biological cell or an organelle of a biological system and it spans from the biosphere to the smallest living organism.
2) Five importance of energy to mankind:
   - (i) It has helped to increase productivity in various sectors of society’s economy.
   - (ii) The functioning of the internal systems of human body can be effective due to energy.
   - (iii) Pressures arising from daily living can be eased up using energy.
   - (iv) Machines, industrial equipment, facilities and tools being used in various factories and distribution systems are operational due to energy.
   - (v) Maintaining optimum temperature of a space through heating and cooling is achievable using energy.

Answers to SAEs 2

Kinetic energy	**Potential energy**	**Combination of both K.E & P.E**
Visible light, solar, x- ray, radio waves, sound, gamma rays, geothermal	**Chemical, nuclear, magnetic, gravitational**	**Elastic: Potential energy when springs are compressed or rubber bands stretched and kinetic energy when the rubber band is released to fly in the air**

Answers to SAEs 3

1) The states of matter are the conditions it exists in space either of solid state, liquid state or gaseous state. In solid state, matters are very closely packed together to form a shape. In liquid state, particles of matter are less closely packed to one another, have no shape, but take the shape of the container in which it is poured as a volume. In gaseous state, particles are far away from one another, can easily spread to fill any enclosure or container and can easily be compressed to fill a smaller container, no shape. Matter is anything that has mass and occupies space.

2) Potential energy can be transformed into kinetic energy by applying heat or exerting some form of force to the energy stored /stationary in an object. For example, a rubber band stretched in its stationary state is transformed into kinetic energy when the rubber band is released into the air to fly. Also, potential energy in a pendulum at its extreme end of momentary rest transforms into kinetic energy at its lowest point where motion is highest due to force. The earth's gravity acts on a piece of wood nudged off the table it's resting on, accelerating it to give it kinetic energy as the wood falls.

UNIT 2 MEASUREMENT OF ENERGY

Unit Structure

2.1 Introduction

In the previous unit, you have learnt that energy could be stored and be subjected to motion. Energy can be produced and saved for later use. Energy is also a commodity and is available for sale. It has relationship with matter. Just like any other commodity, energy can be quantified and priced. **Can energy be measured?** In this unit, you will learn the various ways in which energy is measured.

2.2 Intended Learning Outcomes

By the end of this unit, you will be able to:

- state the S. I. unit of energy using a simple mathematical equation
- estimate the energy exerted in moving an object over a distance
- list the three other units of measuring energy apart from the SI unit
- convert energy values from one unit to another.

2.3 The S. I. System of Energy Units and How to Derive the Unit

In the previous section, we developed the concept of energy. We now must be able to measure and quantify it, using a standard set of units.

2.3.1 S I Unit and Formulae of Energy

Energy is measured in various units by different industries or countries in much the same way as the value of goods is expressed in various currencies of nations of the world. Worldwide, two systems of units of measurement are commonly used today: the Metric System (System International) and the British System. The different units of measuring energy have some historical context depending on the process of energy transformation involved. **The S. I. system of units** is an internationally accepted system of units consisting of fundamental units which was introduced and modified using metre, kilogram and second (M. K. S.) system with some other supplementary units by General Conference of Weights and Measures held in October, 1960.

The units of energy described in these systems are derived from a technical definition of energy used by physicists. This definition suggests that energy can be represented by the following simple equation:

Work = Force x Distance

What can you say about the meaning of work? Work is defined as a force applied to some form of matter (object) multiplied by the distance that the object travels. **Physicists commonly describe force with a unit of measurement known as -------?** The answer is ***Newton,*** (named after a famous physicist, Sir Isaac Newton). **A Newton** is equal to the force needed to move a mass weighting one kilogram one meter in one second within a vacuum with no friction. The work or energy required to move an object weighting one kilogram with the force of one Newton over a distance of one meter is called a ***Joule***.

Example: How much energy will a body gain if a net force of 10 Newton was applied to the body and it moved 0.3m?

Answer:

Energy = net force x distance

Energy = 10 N x 0.3 m = 3.0 J

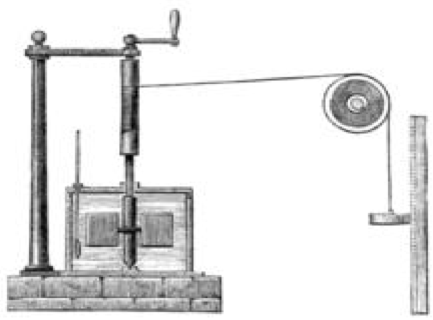

Fig.2.1: Joule's Apparatus for Measuring the Mechanical Equivalent of Heat. A Descending Weight Attached to a String Causes a Paddle Immersed in Water to Rotate (Unit Of Measure).
Use the link below to learn more about units of energy:

Units of energy
James Prescott Joule in 1943 carried out a series of experiments which led to the discovery of the mechanical equivalent. The experiment showed that the gravitational potential energy lost by the weight in descending was equal to the internal energy gained by the water through friction with the paddle. The 'Joule apparatus' is the most famous of these experiments.
The SI base units, J $=Kgm^2s^{-2}$
Dimension: $ML^2\ T^{-2}$

2.3.2 Defining Larger Units of Energy from the Least Unit

What size of energy is a joule? Relatively, the joule is a small unit of energy. Larger units can be defined using prefixes such as kilo (k), mega (M), giga (G), tera (T) etc. in that order.

1 kilo-joule (kj) = 1000 J
1 mega-joule (MJ) = 1 000 000 J
1 giga-joule (GJ) = 1 000 000 000 J
1 tera-joule (TJ) = 1 000 000 000 000 J

These prefixes can be applied to any unit. Thus, 6 kN is same as 6000 N. 4 MJ is same as 4 000 000 J.

Therefore, the SI unit of energy is the joule, a derived unit. However, energy can be expressed in several other units that are not part of SI, such as **calories**, **ergs**, **British Thermal Units** (applied in specific areas of science and commerce), **kilowatt-hours (Kw ⁻h)**, **electron-volt (eV)**, **foot-pound**, **kilocalories**, **food calorie** or **thermodynamic kcal** (based on the temperature change of water in a heating process) etc., which require a conversion factor when expressed in SI units. Definitions for some of the energy measurement units are as follows: The CGS energy unit is the **erg**. The imperial and US customary unit is the **foot pound**. The **Calorie**- equals the amount of heat required to raise 1 gram of pure water by from 14.5 to 15.5° **Celsius at standard atmospheric pressure** which makes a difference of 1°C . 1 calorie is equal to 4.1855joules ≈ 4.2J. Energy required to heat 1g of water by 1°C = 4.2J. The abbreviation for calorie is cal. A kilocalorie, abbreviated kcal, is equal to 1000 calories. 1 kilocalorie is equal to 4185 joules.

Btu - also called **British thermal unit** is the amount of energy required to raise the temperature of one pound of water by one degree

Fahrenheit. 1 ° F = 1.055kj ≈0.293KWh . Btu enables man to compare and measure energy contained in gasoline, wood, natural gas and or other energy sources. The term quad (Q) is used to measure very large quantities of energy. A quad is one quadrillion (1,000,000,000,000,000 or 10^{15}**)** Btu**.** A single Btu is very small. For example, if a kitchen match stick is allowed to burn completely, about one Btu of energy would be given off. One ounce of gasoline is said to contain almost 1,000 Btu of energy.

Watt (**W/m**^{2} or **Wm**$^{-2}$) - a metric unit of measurement of the intensity of **radiation** in watts over a square meter surface. One watt is equal to one **joule** of work per second. A kilowatt (**kW**) is the same as 1000 watts. Table 1 presents table different units for measuring energy, their definitions and conversions.

Self- Assessment Exercise 1

Attempt these exercises to measure what you have learnt so far. This should not take you more than 5 minutes.
If a net force of 5 kN moves a body a distance of 7 km, what is the energy gained by the body in:
(i) joules?
(ii) kilo-joules?
(iii) mega-joules?

2.4 Table for Units of Measuring Energy and their Equivalence in Joule

2.4.1 Units of Energy and it Equivalence in a Tabular Format

Use the link below to learn more about measurement of energy:

- **Measurement of Energy**

Table 1: Units of Energy

Unit	**Definition**	**Used In**	**Equivalent to**
British Thermal Unit	A unit of energy equal to amount of energy needed to raise energy needed to raise the temperature of one pound of water by one degree Fahrenheit. It	Heating and cooling industry 1 Btu = 1055	1 Btu = 1055 Joules (J) =1.055kj ≈ 0.293KWh

	could be likened to the energy found at the tip of a match stick.		
Calorie or small calorie (calorie)	The amount of energy to raise the temperature of one gram of water by one degree centigrade (Celsius).	Science and Engineering	1 colarie = 0.003969 BTUs
Food Calorie, Kilocalorie or large calorie (Cal, kcal, Calorie)	The amount of energy Needed To raise the Temperature Of one kilogram of water one Degree Celsius. The food calorie Is often used when measuring the energy content of food.	Nutrition	1 Cal = 1000 Cal, 4,187 J Or 3.969 BTUs
Joule (J)	It is a smaller quantity of energy than calorie and much smaller than a BTU	Science and Engineering	1 Joule = 0.2388 calories And 0.0009481 BTUs
Kilowatt Hour (kWh)	An amount of energy From the Steady Production Or Consumption of One kilowatt of power for a period of one hour.	Electrical fields	1 kWh = 3,413 BTUs Or 10^3 x60x60 joules = 3,600,000 J = 3411BTU ≈ 859.6 kilocalories

Therm	A unit describing the Energy Contained In natural gas.	Home Heating Appliances	1 Therm = 100,000 BTUs
Quad (Q)	The term quad (Q) is one quadrillion and used in measuring and comparing large quantities of energy	Measuring very large quantities of energy	1 quad = 10^{15} BTUs or 1,000,000,000,000,000 BTUs

Note also that one official horsepower contains 746 watts of energy.

2.4.2 Measuring Very Large Quantities Using BTUs

BTUs are often written in base 10 raised to a particular exponent. For example:

10,000 BTUs = 10^4 BTUs or 1 x 10^4 BTUs
100,000 BTUs = 10^5 BTUs = 1 x 10^5 BTUs
1,000,000 BTUs = 10^6 BTUs = 1 x 10^6 BTUs
The following is done when expressing measurements greater than those with a base of 10.
50,000 BTUs = 5 x 10^4 BTUs
700,000 BTUs = 7 x10^5 BTUs
9,000,000 BTUs = 9 x 10^6 BTUs

Self-Assessment Exercise 2

Attempt these exercises to measure what you have learnt so far. This should not take you more than 5 minutes.
1. Convert each of the following energy values to Joules
   i. 450 BTUs
   ii. 750 Calories
   iii. 450 therms
   iv. 670 kWh
   v. 5 quads

2.5 Summary

In this unit, we have learnt that energy can be measured using different units with relative values to the fundamental unit. The units can be converted from one type to another and each type of unit is preferred by different fields of science or nations of the world.

2.6 References/ Further Readings

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2.7 Possible Answers to Self-Assessment Exercises

Answers to SAE 1

Energy = net force X distance
Where net force = 5KN = 5,000N
Distance moved = 7Km = 7,000m

(i) Energy gained by the body in joules = 5,000 X 7,000 = 35,000,000J
(ii) Energy gained by the body in Kilo-joules = 35,000,000 ÷ 1000 = 35,000Kj
(ii) Energy gained by the body in Mega-joules = 35,000,000 ÷ 1.000.000 = 35Mj

Answers to SAE 2

(i) 1 Btu = 1055J
450 Btu = 450 X 1055 = 474,750J

(ii) Convert 750 Calories to Joules.
1 Calorie = 0.003969Btu
750 Calories = 750 X 0.003969 = 2.97675Btus
750Calories = 2.97675 X 1055 = 3,140.47J

(iii) Convert 450 Therms to Joules.
1 Therm = 100,000Btus
450 Therms = 450 X 100,000 = 45,000,000Btus
450 therms = 45,000,000 X 1055 = 47,475,000,000J

(iv) Convert 670Kwh to Joules
1Kwh = 3,413Btus =10^3 X 60 X 60 Joules
670Kwh = 670 X 10^3 X 60 X 60 = 2,412,000 X 10^3 = 2.412 X 10^6 X 10^3 J

(v) Convert 5 quads to Joules
1 quads = 10^{15} Btus
5 quads = 5 X 10^{15} Btus
5 quads = 5 X 10^{15} X 1055 = 5.275 X 10^3 X 10^{15} J

UNIT 3 FORMS, USES AND TRANSFORMATION OF ENERGY

Unit Structure

3.1 Introduction

You are welcome to Unit 3 of Module 1. It is gratifying that you can now explain the meaning of energy with practical illustration. Recall also that measurement and units of energy were discussed in the last unit. In this unit, we examine specifically the various forms of energy that exist, their uses, and the conversion of energy from one form to another. The relationship between energy, work and power is scrutinized in mathematical form. We have based our discussion on the law that energy cannot be created nor destroyed but can be transformed from one form to another.

3.2 Intended Learning Outcomes

By the end of this unit, you will be able to:

- list the fundamental forms of energy
- discuss four forms of energy and their uses
- distinguish between energy and power
- illustrate with two practical examples the conversion of energy from one form to another within your environment.

You can learn more about the forms of energy by clicking on the link below:

Forms of Energy - Vikaspedia

3.3 Basic Forms of Energy and their Uses

Energy exists in a number of different forms, all of which measure the ability of an object or system to do work on another object or system. There are six basic forms in which we use energy in our day-to-day life. These are: **mechanical (kinetic and potential) energy, thermal, chemical, nuclear, electrical and Radiant (light) energy.**

3.3.1 Mechanical Energy

Energy that a body possesses by virtue of its motion or its position. **The sum total of potential and kinetic energy is referred to as what? -----**. The answer is **mechanical energy**. Mechanical energy can either be kinetic energy or potential energy. Mechanical energy is involved in moving people and goods around (kinetic). It is the energy that a body possesses by virtue of its position relative to a reference point (potential). Examples of kinetic (mechanical) energy include: the piston of a petrol engine doing work in moving a vehicle, a footballer kicking a ball to score a goal, a baseball player pitching a ball, a plough being pulled by a tractor, and a hammer that is being used to pound/ drive nails into woods. A few examples of potential (mechanical) energy include: a parked car resting in a stationary position, a pendulum at its extreme end of momentary rest, a bow (archery), a spring, and a hammer that is raised in preparation to pound nails.

What type of energy is possessed by a book sitting on a piece of wood on a table? It is said to have **potential energy** because if it is nudged off the table, gravity will accelerate it, giving it **kinetic energy**. Because the Earth's gravity is necessary to create this kinetic energy, and because this gravity depends on the Earth being present, we say that the **Earth-wood system** is what really possesses this potential energy, and that this energy is converted into kinetic energy as the wood falls. **What are the mathematical formulae for kinetic and potential energy respectively?**

i. Mathematical formulae for Kinetic energy is
   $K.E = \frac{1}{2} mv^2$
   Where K.E = Kinetic energy
   M = mass of body
   V = velocity or speed

ii. Mathematically, formulae for potential energy (P.E) is
P.E = mgh
Where, m = mass of a body
g = acceleration due to gravity which is often a constant
h = height of the object or body

3.3.2 Chemical Energy

This is the energy locked in the bonds of molecules in the form of microscopic **potential energy**, which exists because of the electric and magnetic forces of attraction exerted between the different parts of each molecule. It is stored in the bonds of molecules and atoms that make up a substance. It is the same attractive force involved in thermal vibrations. The molecular parts get rearranged in the chemical reactions, releasing or adding to this Potential Energy. **When is chemical energy said to be either exothermic or endothermic?** Chemical energy may be exothermic when the energy is released or endothermic when energy is required for the reaction to take place.

Can you mention some substances that contain chemical energy? Examples include a battery, burning wood, and glucose in the body, fossil fuels (such as coal, oil, and natural gas) store energy in the form of chemical energy. When they are burnt, these fuels release energy in the form of heat and light. Chemical energy in fossil fuels is used to make electricity. After the burning of wood, it changes into a new substance as ashes.

An example of a biological substance that stores chemical energy is glucose (blood sugar). Glucose releases energy when it reacts chemically with oxygen during aerobic respiration in animals. When this happens, muscles use this energy to generate mechanical force (work) and also heat. When human bodies burn sugar during exercise, the sugar components are re-organized and energy released that was in the chemical bonds of the original substance. This energy enables human beings to perform daily tasks. Food contains calories and when you digest food, energy is released. As the molecules in food are broken down into smaller pieces, the bonds between the atoms break or loosen and oxidation occurs. Chemical reaction involved in digestion supplies human beings with warmth, helps to maintain and repair the body, giving the energy needed to move around.

How do plants harness chemical energy? Plants also use chemical energy. During photosynthesis, solar energy is converted to chemical energy. The chemical energy is stored as glucose or sugar. Chemical reactions can exist in six ways namely synthesis, combustion, single displacement, decomposition and acid base.

3.3.3 Thermal (Heat) Energy

This is the energy that combines microscopic, kinetic and potential energy of the molecules. **Give examples of this type of energy.** Examples include a hot cup of beverage and boiling water. Temperature is really a measure of how much thermal energy something has: The higher the temperature, the faster the molecules are moving around and/or vibrating, i.e., the more kinetic and potential energy the molecules have. Fuels are oftentimes burnt and converted to thermal or heat energy, which is then converted to motion in an automobile or electricity. Objects kept adjacent each other and having different temperatures will spontaneously transfer heat to achieve the same temperature.

A hot cup of water is said to possess "thermal energy," or "heat energy," because it has a combination of kinetic energy due to its vibrating molecules, and potential energy because the molecules have a mutual attraction for one another. The hot cup of water in a cool room loses some of its thermal energy as heat flows from the water to the room. The molecules in the water slow their vibration as the water loses heat and over time the water cools to the same temperature as the room.

3.3.4 Electrical Energy

Energy created through the movement of electrons among the atoms of matter. Recall that atoms are made up of smaller particles – protons, neutrons and electrons. Protons have positive charge, neutrons have neutral charge and electrons are negatively charged. Protons and neutrons are located at the centre or nucleus of an atom. Electrons orbit / revolve around the nucleus. Electrons that are loosely attached to their atoms in some materials (like metals) can easily move from one atom to another if an electric or magnetic field is applied to them. **How then is electricity created?** When those electrons move among atoms of matter, a current of electricity is created. Although electricity is seldom used directly, it is one of the most useful and versatile forms of energy. Following are some examples. When put into a toaster, it can be converted to heat;

When put into a stereo, it is converted into sound; When put into an electric bulb, it converts into light; When put into a motor it converts into motion or movement (mechanical energy).

3.3.5 Nuclear Energy

Energy produced when reactions occur in the nucleus of an atom, resulting in some type of spontaneous structural change in the nuclei is called **nuclear energy**. Few elements {such as uranium, radium and deuterium (heavy hydrogen)} are natural source of nuclear energy. Note that a large amount of energy is stored in the nucleus of every atom. **How many ways is nuclear energy produced?** Nuclear energy can be produced in two ways: either by **fusion** or by **fission**.

When do we have fusion? It occurs when two small nuclei join together to create one large nucleus or particle, and during this process, energy is released in the form of light and heat. The process in which the nuclei of light atoms are combined to form a nucleus of a heavier atom accompanied by the release of energy is known as nuclear fusion. Nuclear fusion requires a very high temperature. This mechanism is applied, for example in Stars or Sun, hydrogen nuclei fuse (combine) together to make helium nuclei which releases energy. This energy is transported to the sun's surface or that of the star, then released into space majorly in the form of radiant (light) energy. This type of reaction has been applied in making hydrogen bombs.

Fission occurs when the nucleus of one big atom splits into two new lighter nuclei, and during this process, a tremendous amount of energy and radiation are released in the form of light and heat. The disintegration of the nucleus of an atom into fragments of roughly equal mass and accompanied by the release of energy is termed **nuclear fission**. An example is in a nuclear reactor or the interior of the earth, uranium nuclei splits apart causing energy to be released. The reaction continues rapidly and called chain reaction. As the process continues spontaneously, a small amount of mass in each process of fission vanishes as huge amount of energy is released as represented by the energy equation of Einstein stated below. This energy finds use in boiling water to form steam used to drive a turbine for the generation of electrical energy. Uranium is the radioactive isotope used as key raw materials and processed into tiny pellets before being put into the power plant's reactor. **Name other radioactive isotopes?** Other such material includes plutonium and thorium.

In both fusion and fission, some of the matter making up the nuclei is converted into energy, represented by the famous equation by Albert Einstein:

$$\mathbf{E = mc^2}$$

Energy = Mass x (Speed or velocity of Light)^2

This formula indicates that energy intrinsically stored in matter at rest equals its mass times the speed of light squared. When matter is

destroyed, the energy stored is released. **What does this equation connote?** Guess.
This equation suggests that an incredibly huge amount of energy is released when a small amount of matter is converted to energy. **In what area is nuclear energy applied?** Nuclear energy apart from its usage in generation of electricity can be applied to power vessels sailing (such as sub-marine and ships) over a far distance and for long period without having a need to refuel. Also, some by-products in nuclear reactions are useful in medicine, agriculture and research. Example of such by-product is **radioisotopes**.

What are the hazards of nuclear energy? Some hazards of nuclear energy include: accidental leakage of harmful nuclear radiation which can penetrate human bodies to cause irreparable damage to cells; and problems associated with the disposal of dangerous and harmful radiant wastes produced in fission process and capable of emitting radiations to threaten the environment. As at the present time, most of the nuclear wastes released from nuclear power plants are being stored under-ground in strong lead containers, though a more satisfactory and safer method of disposing nuclear wastes is yet to be discovered. Generation of nuclear energy is under strict control because of the danger it poses to living things.

3.3.6 Radiant energy (Radiation)

Radiant energy is the form of energy radiated or transmitted in the form of light rays, electromagnetic waves or particles. Some examples include: Visible light that can be seen by naked eye such as the light from incandescent bulbs.

3.3.6.1 Infrared radiation;

Radiant energy includes: Ultraviolet radiation (UV) that cannot be seen with the naked eye; for example, Long wave radiation, such as TV waves and radio waves; Very short waves, such as x-rays and gamma rays.

3.3.6.2 Electromagnetic Radiation

In what form does energy of the sun reach the earth? Energy from the sun comes to the earth in the form of electromagnetic radiation, which is a type of energy that oscillates (side to side) and is coupled with electric and magnetic fields that travel freely through space. Electromagnetic radiation is composed of **photons** or particles of light, which are sometimes referred to as packets of energy. Photons, like all particles, have properties of waves. Photons make the world a brighter place. Energy of light from the sun makes life on earth possible. Radiation is heat transfer by the emission of electromagnetic waves which carry energy from the emitting object.

Self-Assessment Exercise 1

> Attempt this exercise to measure what you have learnt so far. This should not take you more than 5 minutes.
>
> *List and describe any four forms of energy.*

3.4 Work, Energy and Power

When is work said to be done in terms of science? In terms of science, work is said to be done when a force acts on an object and produces motion of the object. Pushing a manually operated sliding door, lifting a block or carrying a sack of cassava up an inclined plane are some instances of when work is done. Two factors affect work done:

1. the applied force
2. the distance moved in the direction of the applied force

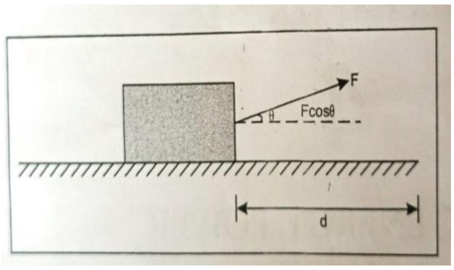
The formula for work done is $W = Fd \cos \Theta$
Where W = work done, F = applied force, d = distance moved, Θ = angle between the direction of the applied force and the displacement. Supposing that $\Theta = 90^\circ$, then
$W = Fd \cos 90^\circ = 0$ (no work is done). If the force and the displacement are in the same direction, then $\cos \Theta = 1$, hence $W = Fd$

What is the SI unit of work? The SI unit of work is the Joule (J). 1 Joule of work is done by a force of 1 Newton that acts through a distance of 1 meter. 1 Joule = 1 Newton/metre

Energy has been elaborately discussed in Unit 1 and 2; and has the same SI unit as work. In simple terms, energy is defined as the ability to do work. The various forms of energy have been discussed. Formula for Kinetic energy in linear motion differs from that in rotational motion. In linear motion $v = \sqrt{2gh}$, P.E = K.E, $\frac{1}{2} mv^2 = mgh$ The energy possessed by a stretched spring is referred to as the elastic potential energy. $E_p = \frac{1}{2}F.\varkappa = \frac{1}{2}k\varkappa^2$
Where E_p = elastic potential energy, F = force, $\varkappa$ = distance and k = constant in w/m

Power is defined as the rate of doing work. Power = work done/ time taken or
$P = W/t$ The SI unit for power is watt (W), 1 Watt = 1 Joule/ second

You can measure your own personal power by running up a flight of stairs and taking note of the time you have taken to reach the topmost floor as illustrated in Figure 3.2 below:



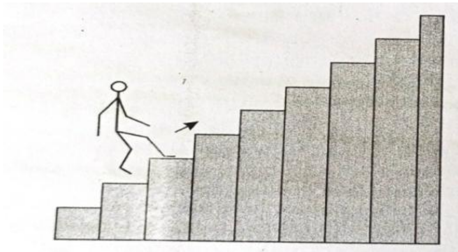


Fig.3.1: Work Done by Resolved Forces ***Fig.3.2: Measuring your Own Personal Power by Climbing a Flight of Stairs***

You take note of the following measurements:
1. Your weight (w),
2. The number of stairs
3. the height of each stair,
4. time taken to run up the stairs.

$$\text{Power} = \frac{\text{No. of stairs x the height of each stair x your weight}}{\text{Time taken}}$$

For example, supposing that No. of stairs = 100, height of each stair 13cm, your weight = 400 N, time taken to run up the flight of stairs = 2 minutes. Then

$$\text{Power} = \frac{400\text{N x } 100 \text{ x } 0.13}{2 \text{ x } 60}$$ (Recall that 100cm = 1m)

Power = 43.3 W

Self-Assessment Exercise 2

Attempt these exercises to measure what you have learnt so far. This should not take you more than 5 minutes.
What power is exerted when a boy weighing 500N runs up the flight of stairs in 3 minutes with the number of stairs equal to 50 and height of each stair 10cm?

3.5 Energy Conversion

Energy can be converted from one form to another. For example, gasoline chemical in automobiles provides mechanical (kinetic) energy when the engine works. When electrical energy in our car is passed into our TV, it is converted to light and sound. This also lightens a bulb when passed into it.

Figure 3.3 shows some examples of energy conversions.

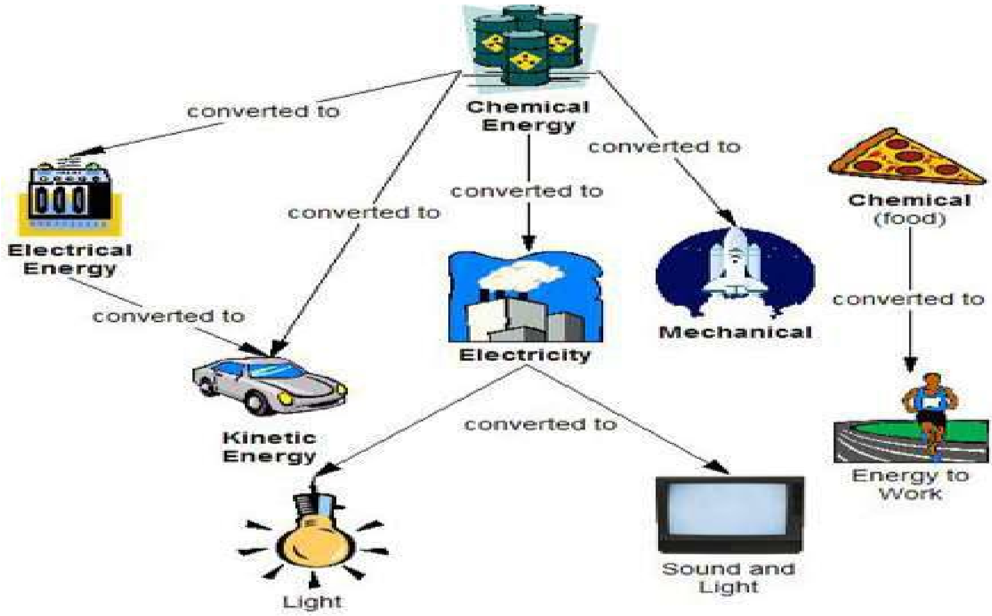


Fig. 3.3: Energy Conversions

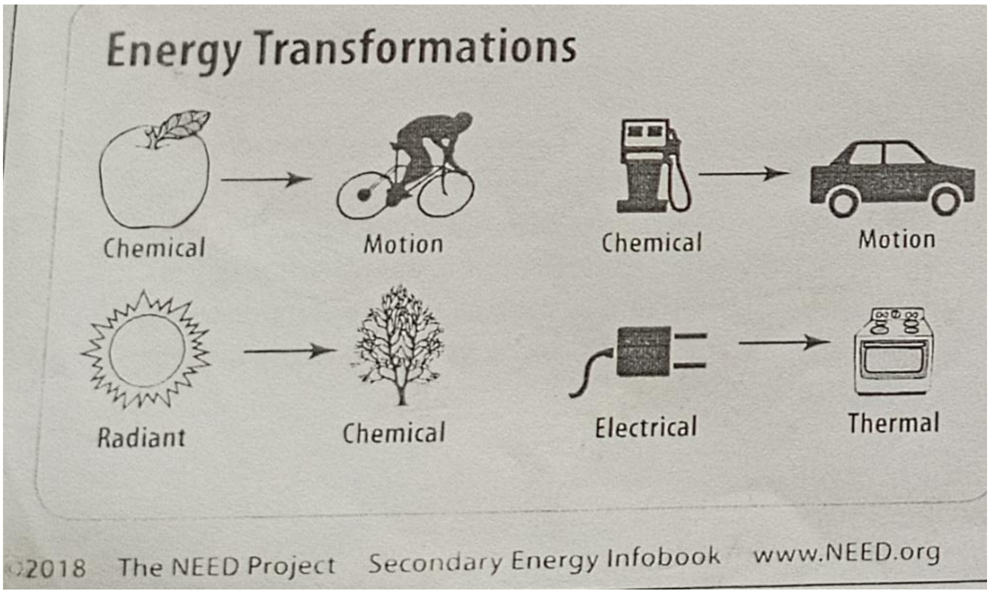


Fig. 3.4: Energy Transformation (2018 NEED Project)

Self-Assessment Exercise 2

Attempt this exercise to measure what you have learnt so far. This should not take you more than 5 minutes.
Discuss energy conversion with an illustration

3.6 Summary

This unit focused on the various forms of energy and their conversion from one form to another. Detailed discussions ex-rayed mechanical (kinetic and potential) energy, thermal, chemical, nuclear, electrical and Radiant (light) energy and how they can be converted to other forms.

3.7 References/ Further Reading

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3.8 Possible Answers to Self-Assessment Exercises

Answers to SAEs 1

1) Forms of energy listed:
   a) Mechanical (Potential and Kinetic) energy
   b) Chemical energy
   c) Thermal (Heat) energy
   d) Electrical energy
   e) Nuclear energy
   f) Radiant energy (Any 4 suffice)

Short explanations on the forms of energy

(a) Mechanical Energy: This is the sum total of potential and kinetic energy. Mechanical energy can either be kinetic or potential energy. It is the energy possessed by a body due to its motion or its stationary position. If the energy is involved in motion/ movement, it is kinetic (mechanical) energy e.g. kicking a football, pulling of a plough by a tractor during farm work etc. If it is possessed by a body due to its position relative to a reference point, it is potential (mechanical) energy e.g. a spring, a book resting on a table etc.

(b) Chemical energy: This energy is stored in the bonds of molecules and atoms that make up a substance. The molecular parts are re-arranged in chemical reactions to either release or add to the stored energy. It is exothermic when energy is released or endothermic when energy is added to enable the reaction. Example of chemical energy is that stored in a battery, burning wood, fossil fuels and glucose in the human body.

(c) Thermal Energy: A hot cup of tea possesses thermal or heat energy due to kinetic energy caused by the vibrating molecules in the hot tea and potential energy due to the mutual attraction of the molecules for one another. In a cool room, the hot tea cup losses thermal energy as heat flows from the tea cup to the room. The molecules in the tea slow their vibration as heat is lost, and over time, the tea cools to have a uniform temperature with the room. Other acceptable examples to illustrate thermal energy include hot/ boiling water, other hot beverages etc.

(d) Electrical Energy: This energy is generated through the movement of electrons among atoms of matter. Recall that atom is made up of protons which are positively charged, neutrons which have neutral charge and electrons which are negatively charged. While protons and neutrons are located at the centre or nucleus of an atom, electrons revolve around the nucleus. Electrons that are loosely attached to their atoms in some materials like metals can easily shift from one atom to another if electric or magnetic field is applied to them, When these electrons move among atoms of matter, current of electricity is created. Electrical energy is one the most useful forms of energy e.g. it converts electric bulb into light and can propel a motor into motion/ movement to generate mechanical energy etc

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(e) Nuclear Energy: This type of energy can be produced either through fusion or by fission when reactions occur in the nucleus of an atom, resulting in some type of spontaneous structural

change in the nuclei. Some elements that constitute natural sources of nuclear energy include uranium, radium and deuterium (heavy hydrogen). Fusion occurs when two small nuclei join together to create one large nucleus or particle of a heavier atom, and in the process, energy is released in the form of light and heat. Nuclear fusion requires a very high temperature e.g. applicable in making hydrogen bomb. Fission occurs when the nucleus of one big atom disintegrate into two new lighter nuclei, fragments of roughly equal mass and accompanied by the release of tremendous amount of energy and radiation in form of light and heat; e.g. applicable in nuclear reactor or the interior of the earth where uranium nuclei splits into smaller fragments releasing energy. For fission and fussion, energy is released from a small amount of matter that make up the nuclei, represented by the famous equation of Albert Einstein. $E = mc^2$
Energy = Mass X (Speed or Velocity of Light)^2

(f) Radiant Energy: This type of energy is radiated or transmitted in form of light rays, electromagnetic waves or particles. Radiant energy in form of infrared radiation includes ultraviolet (UV) e.g. long wave radiation such as TV waves, radio waves, Very short waves such as x- rays and gamma rays. Radiant energy in form of electromagnetic radiation can come from the sun to the earth and coupled with electric and magnetic fields that travel freely through space. Electromagnetic radiation is composed of photons or particles of light which have properties of waves. Radiation is heat transfer by the emission of electromagnetic waves which carry energy from the emitting object e.g. energy from the sun that makes life on earth possible.

Answer to SAE 2

$$\text{Power} = \frac{\text{No. of stairs x the height of each stair x your weight}}{\text{Time taken}}$$

Where the Boy's weight (w) = 500N, The number of stairs = 50
The height of each stair = 10cm, Time taken to run up the stairs =3 minutes.

$$\text{Power} = \frac{500\text{N x } 50 \text{ x } 0.10}{3 \text{ x } 60}$$ (Recall that 100cm = 1m)

Power = 13.8 W

Answer to SAE 3

Either of the sketch of Figure 3.3 or Figure 3.4 on energy conversion is an acceptable answer for illustration.

UNIT 4 ENERGY OF THE UNIVERSE AND ENERGY CYCLE

Unit Structure

4.1 Introduction

Recall that unit 1 focused on the relationship between matter and energy; and we have seen that everything in the universe is actually made from energy. **Do you know that physical and biological systems are characterised by energy and matter?** The type of energy and matter contained in the system and how matter and energy move through and between the systems is discussed in this unit. That the total amount of energy in the universe does not change is highlighted. The amount today is the same as the amount a million years ago. This means that it cannot be destroyed but can be transformed from one form to another. This unit gives an insight into the total amount of energy scientists believe is available in the universe, and the explanation for it.

4.2 Intended Learning Outcomes

By the end of this unit, you will be able to:

- discuss energy of the universe with 80% accuracy
- sketch the energy cycle
- explain chemical transformation in chemistry with emphasis on energy changes
- examine the role of energy in biological systems with an example
- illustrate how the total energy of the universe is zero.

4.3 Energy of the Universe and Energy Cycle

Learn more about energy cycle by clicking on the link provided below:
Earth System: Matter and Energy Cycles | MyNASAData

4.3.1 Cycle and Conservation

The energy in the universe never increases or decreases but it changes from one form to another through some natural processes like photosynthesis or through human activities like cooking. The total quantity of energy in the universe remains the same, though it can change form. The process of energy transformation is continuous and steady moving round in a cyclic order, though the efficiency of conversion may be limited depending on the forms of energy involved. The law of conservation of energy translates that when energy is used, it is not really being "used up", and instead, it is changing into other forms. In a closed system, where energy is transferred from potential energy to kinetic energy and then back to potential energy in a constant manner, conservation of energy is exemplified. Even though the advocacy to conserve energy is intense, it is talking about saving energy and not wasting it. **State the law of conservation of energy**. The law of conservation of energy states that the total amount of energy in a system is constant, though energy within the system can be changed from one form to another or be transferred from one object to another. Both energy and matter are conserved within a natural system. Everything in the universe is made from energy. It is pertinent to add that scientists seek to study the flow and interactions of matter and energy; while engineers often seek to minimise inputs and maximise outputs of matter and energy relative to a given system.

It has been stated that in a **closed system**, energy is neither created nor destroyed but is converted from one form to another. Therefore, the initial energy and the final energy are equal to each other. It has also been stated that energy in the universe neither increases nor decreases. Beyond the constraints of a closed system, open systems can gain or lose energy in association with matter transfer. **What does the energy cycle depict?** Energy cycle shows how energy moves from its natural source into the body of living things and is returned into the environment.

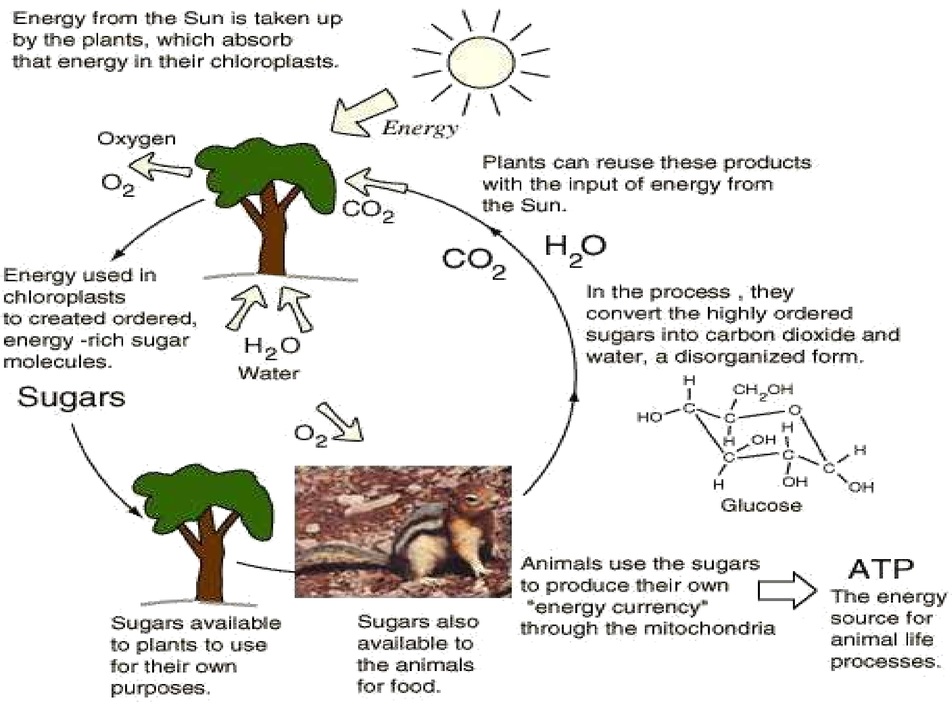

Fig. 4.1: The energy cycle

4.3.2 Transfer of Energy

Energy can be transferred between systems in what ways and manner? Examples of energy transfer include: the transmission of electromagnetic energy through photons, transfer of kinetic energy through physical collisions and the conductive transfer of thermal energy.

The kind of energy being transformed to other kinds and the direction of the energy transformation is commonly determined by a factor referred to as **entropy** (which is the equitable distribution of energy or matter among all available degrees of freedom in a random manner).

Table 4.1: Forms of Energy Transfer from One Object or System to Another

Type of transfer process	**Description**
Heat	The amount of thermal energy in spontaneous transit towards a lower temperature object
Work	The amount of energy in transit due to a displacement in the direction of an applied force
Material (Matter)	The amount of energy carried by matter that is moving from one system to another

4.3.2.1 Energy Transfer in Mechanical Systems and other Assorted Systems

Other instance of energy transfer is the lifting of an object against gravity using electrical energy in driving a motor crane. In lifting an object against gravity, mechanical work is performed on the object and gravitational potential energy is stored in the object. If the object falls to the ground, mechanical work is performed on the object by gravity and the potential energy in the gravitational field is transformed to kinetic energy discharged as heat on striking the ground by the object. When Footballers kick a ball, their body (leg) muscles transform the chemical energy derived from food into kinetic energy being used. As the ball moves through the air and across the ground, friction slows it down and its kinetic energy is changed to thermal energy.

Different forms of energy are transformed to other forms at various efficiencies. Items or devices that enable the transfer of energy from one form to another are often referred to as transducers. For example, battery can transform chemical energy to electric energy. **What kind of energy transfer is found in a dam?** A dam transforms gravitational potential energy to kinetic energy of flowing water and that of rotating blades of a turbine and further transformed into electric energy through an electric power generator and other forms of energy. When people talk on phone, their voices which generate sound energy is transformed into electrical energy transmitted through wire or the air. The phone on the other end changes the electrical energy into sound energy through the speaker. Equivalently, a television set changes electrical energy into light and sound energy. A turbo generator enables the transfer of heat energy of pressurised steam into electrical energy useful in doing various works.

4.3.2.2 Transfer of Energy in Other Process and Chemical Transformation

Over time, energy transformations in the universe are characterised by the transfer of different kinds of potential energy into various forms of active energy such as kinetic energy or radiant energy when a triggering mechanism is available, For example, at the highest point of an oscillating pendulum, the kinetic energy is zero and the gravitational potential energy is at the maximum. At its lowest point, the kinetic energy is at maximum with the potential energy witnessing an equivalent decrease. Without friction and other losses, the pendulum will continue to swing nonstop to eternity, considering the perfection in the energy conversion processes.

What happens in chemical reactions? During chemical transformation in chemistry, changes can take place in the atomic, molecular or aggregate structure of a substance which is accompanied by either an increase or a decrease in energy of the substance involved. Energy transfer occurs between the surrounding and the reactants of the reaction in form of heat or light. Therefore, it means that the products of a reaction may have more or less energy than the reactants. It is exothermic reaction if the final state is lower on the energy scale than the initial state. If the situation is the reverse, it is called endothermic reactions. For chemical reaction to take place, the reactants involved must surmount an energy barrier referred to as **activation energy.** The activation energy required for a chemical reaction can be available in form of thermal energy.

Self-Assessment Exercise1

Attempt these exercises to measure what you have learnt so far. This should not take you more than 10 minutes.

(1) Illustrate the energy cycle.

(2) Mention 5 devices and processes involving transfer of energy.

4.3.2.3 Energy Transfer in Biological Systems

In biological systems, energy is responsible for growth and development of cells or organelle of an organism. **What external source of energy does living organisms depend on?** Living organisms rely on external source of energy – **radiant energy from the sun** in the case of green plants, **chemical energy in the case of animals**. For example, energy used in respiration is stored in molecular oxygen and can be triggered by reactions with molecules of substances such as carbohydrates (of which sugar is inclusive), lipids and proteins stored by cells. In human beings, the human energy conversion involves the utilisation of a relative quantity of energy for metabolism (basal metabolic process measured in wattage per second) and the expenditure of a given amount of energy in running the activities/ tasks of the day measured in kilo-joule per day.

4.3.2.4 Why Energy of the Universe is claimed to be zero

Considering the amount of energy that we use on daily basis and in various forms, it may be rational to think the amount of energy available in the universe is huge. However, scientists have claimed that the total amount of energy in the universe is 0. The explanation given for this is that positive energy (light, matter and antimatter) are abundant in the universe but that that there is an equal amount of negative energy stored in the gravitational attraction that exists between all the positive energy particles. Physicists posit that the positive exactly balances the negative and hence, ultimately, there is no energy in the universe at all.

Self-Assessment Exercise 2

Attempt these exercises to measure what you have learnt so far. This should not take you more than 5 minutes.

(1) *Explain chemical transformation in Chemistry showing how energy changes.*
(2) *Examine the role of energy in biological systems*

4.4 Energy Efficiency

Usually, when energy is transformed from one form to another, loss of usable energy is experienced in form of heat. In theory, a 100 percent energy efficient device or machine would change all the energy put into useful work. **What is energy efficiency?** Energy efficiency is the amount of useful energy gotten out of a system. Most energy transformation processes are not very efficient. The human body system is not very efficient at converting food into useful work. Most of the energy in human body is discharged as heat energy. Food intake constitutes the fuel for the body and gives energy (e.g. kinetic) being used to breathe, think, move and carry out other human functions. Most electric power generating plants that rely on steam to spin the engine are not very efficient also.

Most part of the energy transformed is lost as waste heat which is dissipated into the environment where it cannot be put into practical use. The electric incandescent light bulbs used in homes for illumination purpose are very inefficient in that it converts only ten per cent of the electrical energy into light, while the rest ninety per cent is converted into thermal energy and lost. This explains for the intense hotness of the bulb when it is touched during the working state. This also explains the reason why many consumers are presently resorting to the use of LEDs and CFLs for lighting purposes. Most of these converted and unused energies from various processes and machines which end up as waste heat because they are so spread out to the extent that detecting or using them are difficult.

It is pertinent to note that the processes of Earth's climate and ecosystem are driven by the radiant energy received by the Earth from the Sun, and the geothermal energy contained within the earth. At any given moment, trillions of atoms and molecules are circulating between the living and the non-living world. Life processes like metabolism, growth, irritability and movement require a lot of energy which is gotten from nutrients introduced into the body through food intake. The sun begins the process by transmitting sunlight's radiant energy and captured by plants and other photosynthetic producers as chemical potential energy in photosynthesis. There is a repeated process of higher

organisms feeding on lower organisms. When living organism die, they decompose and their remains are returned into the cycle as inorganic molecules.
The sun is the primary source of the earth's energy. It derives its energy mainly from nuclear fusion in its core, converting nuclear binding energy to other forms such as radiant energy as protons and helium. Sunlight is absorbed and used by the producers to create matter from smaller matter. Energy from the sun is used to drive the process of photosynthesis, constantly renewing the energy lost to the environment as heat from life's processes. Release of the energy stored during photosynthesis as heat or light may be ignited suddenly by a spark, in a forest fire, otherwise, it may be available at a slow pace for animal or human metabolism, when organic molecules are ingested. Catabolism is triggered by enzyme action. The autotrophs, also known as the producers, include plants, many bacteria, plant-like protists and even some fungi photosynthesis and create the basic organic matter from inorganic matter using enzymes and chlorophyll. The producers (green plants and other autotrophs) break down some of the matter that they manufacture to produce energy.

Consumers (heterotrophy), feed on matter and digest it to form smaller pieces of matter which generate energy for their life processes. Scavengers and decomposers break down dead matter to return it to the soil for use by producers so that the cycle can begin again.

Self-Assessment Exercise3

Attempt these exercises to measure what you have learnt so far. This should not take you more than 10 minutes.

(1) *Explain the role of human beings in the energy cycle.*

(2) *The energy of the universe is zero. Discuss.*

4.5 Summary

The logical conclusion is that all the energy we see in the universe today must have always been here since the time it was created and energy just moves around in the ecosystem without increasing or decreasing in amount. This Unit focused on energy being cycled between the environment and the body of living organisms and different forms of energy that can be transferred from one object or system to another. It was also discussed that energy can neither be created nor destroyed; and the total energy of the universe is 0.

4.6 References/ Further Reading

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4.7 Possible Answers to Self- Assessment Exercises (SAEs)

Answers to SAEs 1

1) **Energy cycle** is the process of energy transformation which is continuous and steadily in moving round in a cycling order. The efficiency of conversion may be limited depending on the forms of energy involved. The energy of the universe never increases or decreases, but can change from one form to another through some natural processes, such as photosynthesis and human activities. The law of conservation of energy stipulates that when energy is use up it is not really being "used up", instead, it is changing into other forms.
A sketch of the energy cycle for illustration is also acceptable as in figure 11.

2) 5 devices and processes involving transfer of energy are the following:
   (a) Battery involving transfer of chemical energy to electric energy.
   (b) Dam involving transfer of gravitational potential energy to kinetic energy of flowing water and that of rotating blades of a turbine and further transferred into electrical energy through an electric generator.

(c) Motor crane involving lifting a heavy object/ load against gravity using electrical energy in driving the motor crane. In lifting the load against gravity, mechanical work is performed on the load and gravitational potential energy is stored in the object.

(d) Phone is used to transfer human voices from sound energy to electrical energy transmitted through wire or the air over a distance. Also, at the other end, capable of changing electrical energy into sound energy through the speaker.

(e) A television set changes electrical energy into light and sound energy.

Answers to SAEs 2

1) Chemical reaction in chemistry with particular emphasis on change of energy: During chemical reaction in Chemistry, changes take place in the atomic, molecular or aggregate structure of a substance which is accompanied by either an increase or a decrease in energy of the substance involved. Energy transfer occurs between the surrounding and the reactants of the reaction in form of heat or light. This means that the products of a reaction may have more or less energy than the reactants. It’s exothermic reaction if the final state is lower on energy scale than the initial state. If the reverse is the case, it is called endothermic reactions. For a chemical reaction to take place the reactants involved must surmount an energy barrier referred to as activation energy. The activation energy required for a chemical reaction can be available in form of thermal energy.

2) Role of energy in biological systems: In biological systems, energy is essentially responsible for manifestation of all the characteristics of living things, such as growth and development of cells or organelle of organisms. Living organisms rely on external source of energy – radiant energy from the sun in the case of green plants, chemical energy in the case of animals. For example, energy used in respiration is stored in molecular oxygen and can be triggered by reactions with molecules of substance such as carbohydrates (of which sugar is inclusive), lipids and proteins stored by cells.

Answers to SAE 3

1) Role of human beings in the energy cycle: The human energy conversion involves the utilization of a relative quantity of energy for metabolism (basal metabolic process measured in wattage per

second) and the expenditure of a given amount of energy in running the activities/ tasks of the day measured in kilo-joule per day. The human body systems convert chemical energy in food into useful energy for doing work. Most energy in human body is discharged as heat energy. Food intake constitutes the fuel for the body and gives energy (e.g. kinetic) being used to breathe, think, move and carry out other human functions. Also the carbon dioxide released by man during respiration is used by plants and other photosynthetic producers as chemical energy in photosynthesis actualised in the presence of sunlight's radiant energy. When living organisms (of which man is a part) die, they decompose and their remains are returned into the cycle as inorganic molecules.

2) The total amount of energy of the universe is zero, according to Scientists. The explanation given for this is that positive energy (e.g. light, matter and anti-matter) are abundant in the universe, but there is an equal amount of negative energy stored in the gravitational attraction that exists between all the positive energy particles. Physicists posit that the positive exactly balances the negative and hence, ultimately, there is no energy in the universe at all. In a closed system, energy is neither created nor destroyed, but is converted from one form to another. Therefore, the initial energy and the final energy are equal to each other. It has been stated that energy in the universe neither increases nor decreases, but moves around in the ecosystem. Beyond the constraints of a closed system, open systems can gain or lose energy in association with matter transfer.

MODULE 2 SOURCES OF ENERGY

Unit 1 Physical Sources of Energy
Unit 2 Chemical Sources of Energy
Unit 3 Biological Sources of Energy
Unit 4 Gaseous Sources of Energy
Unit 5 Non-Renewable and Renewable, Primary and End-use Energy

UNIT 1 PHYSICAL SOURCES OF ENERGY

Unit Structure

1.1 Introduction
1.2 Intended Learning Outcomes
1.3 Physical Sources of Energy
    1.3.1 Coal
    1.3.2 Hydroelectric Power
    1.3.3 Wind Energy
1.4 Considerations in Choosing Energy Source
1.5 Summary
1.6 References/ Further Readings
1.7 Possible Answers to Self- Assessment Exercise(s)

1.1 Introduction

Welcome to the first unit of module 2. In the previous module, you treated meaning, measurement, forms and transformation of energy. An insight into the various sources of energy is undertaken in this module. Energy is available in physical, chemical, gaseous and biological forms whether renewable or non-renewable. The physical sources of energy are described in this unit. Three sources of physical energy include: coal, hydroelectric and wind as discussed in this unit. The three physical energy sources **use physical quantities** to generate energy.

1.2 Intended Learning Outcomes

By the end of this unit, you will be able to:

- Identify three main sources of physical energy being used in your country.

- Describe Coal as a source of physical energy with 80 per cent proficiency in the description.
- Explain hydroelectric power as a source of physical energy with 75 per cent accuracy.
- Describe wind as a source of physical energy with 80 per cent accuracy.

1.3 Physical Sources of Energy

Use the link below to learn more:
Sources of Energy - Vikaspedia
Many sources of physical energy are used to provide humans with modern day conveniences such as light, heat, cooling and recreation. The demand for energy increases as the population of the earth increases. As many of the non-renewable resources of the earth deplete, there is an increasing demand for new and more efficient renewable resources for the production of more energy. As at present, most of the world's energy supply is from non-renewable energy sources. Coal, hydroelectric power and wind mills energy are examples of physical energy sources. Fossil fuels constitute the greatest source of world energy use as at 2017.

1.3.1 Coal

Coal is one of the largest sources of physical energy in the world. **What are the constituents of coal as a physical source of energy?** Coal consists of carbon- rich solid that had existed for millions of years ago and made from decomposed plant matter and deposits of substances in vast swamps subjected to conditions of high temperature and intense pressure. The process of forming coal is termed **"coalification**". **Mention the different forms that coal exist?** Coal exists in different forms and graded according to its carbon content such as peat, lignite, sub-bituminous, bituminous and anthracite. Coal also contains other combustible elements (e.g. hydrogen, sulphur) and various incombustible elements (e.g. nitrogen, water).

Use of Coal to Generate Electricity
More than one billion tons of coal is converted into energy per year within the United States, and more than two billion tons per year in China. Coal, a fossil-fuel, is turned into electric energy when it is burned at very high temperatures to boil water for steam. Coal has to be pulverized into a fine powder (making it a potential explosion risk) before it can be burned in power stations. Coal power plants are used to burn the coal in large furnaces to create huge amount of heat. The heat is used to boil water in boilers so as to convert into steam. The steam

expands, causing pressure to increase in the boiler. The moving steam generates energy that is converted into mechanical energy. The steam spins a turbine placed at the exit of the boiler which in turn operates a spinning generator. The rotating turbine is used to spin a magnet inside a power generator. The generator distributes electricity to the national power grid from where it is sent to various areas. It is important to know that coal is an efficient but not a particularly environmentally friendly source of energy. **State other areas where coal is utilised?** Coal has other uses, such as in cooking, in construction of rail system of transportation.

Self-Assessment Exercise1

Attempt these exercises to measure what you have learnt so far. This should not take you more than 5 minutes.

1. List 3 main sources of physical energy and mention three uses of each.
2. Briefly describe the process of using coal to generate electricity in

1.3.2 Hydroelectric Power

Hydroelectricity is electricity generated when hydropower plants convert the energy in flowing or falling water into electricity. It is the production of power through use of the gravitational force of falling or flowing water. It is among the most effective and widely used form of renewable energy resource, accounting for one-fifth of the world's electricity. **What is the prospect and potential of hydro-power in Sub-Saharan Africa?** Hydropower, if properly exploited can help deliver electricity to many of the 1.3 billion people of the world who presently live without electricity particularly those in Sub-Saharan Africa - where less than a third of the population has access to electricity. Hydroelectric power, also known as hydropower, is the use of water for the creation of electric energy. The energy from water is either in form of potential energy (reservoirs) or kinetic energy (e.g. rivers). In the two cases, electricity is generated by passing the water through large water turbines. The most common form of hydropower uses a dam on a river or sea to retain a large reservoir of water. Another form of hydropower system diverts water from the river and directs it through a pipeline to a turbine (often called **run-of-river**).

Waterwheels as displayed in figure 1.4 below were common in Western Europe by the end of the first millennium. **In which other area is power of water utilised?** The power of water was utilised during the ancient world for irrigation, grinding corn, metal forging and mining.

What other consideration gives hydro-power an advantage? This source is considered a cleaner form of physical energy than fossil fuels because the power plants that produce hydroelectric power do not contribute to greenhouse gases. No air emission is experienced. Hydroelectric power is also inexpensive to produce as opposed to energy sources that come from non-renewable elements like coal. Typically, the water used to generate hydroelectric power is stored in reservoirs at a high elevation, with flow controlled by a man-made dam. The water flows quickly through a turbine which spins a generator that produces the electric energy. Some nations of the world (for example India and Nigeria) are endowed with large hydropower potential capable of attracting heavy investments on large projects. Lately, hydroelectric power is used to electrify remote villages through mini and small hydro power.

Some of the merits of hydroelectric energy include: low operating costs, long plant life (typically 40 years and above before major refurbishment), efficiency (with minimal transmission losses), cleanliness (being eco-friendly with minimal impact on the atmosphere) and its susceptibility or quick response to sudden change in electricity demand. The **major demerit of hydropower** is that it alters the natural systems of rivers and adversely affects water quality, animals and plant habitats. Also, the capital cost of building dams is high and the payback period is very long. Other social and environmental issues of hydropower include: flooding, sedimentation, displacement of population and concerns of landslides around the dam. Recently, hydropower plants are being designed and operated to reduce to the barest minimum the impacts on the wildlife river habitat. Also, other approaches, such as improved turbines and fish ladders are being used to assist fish with migration and reduce the number of fish killed in the process.

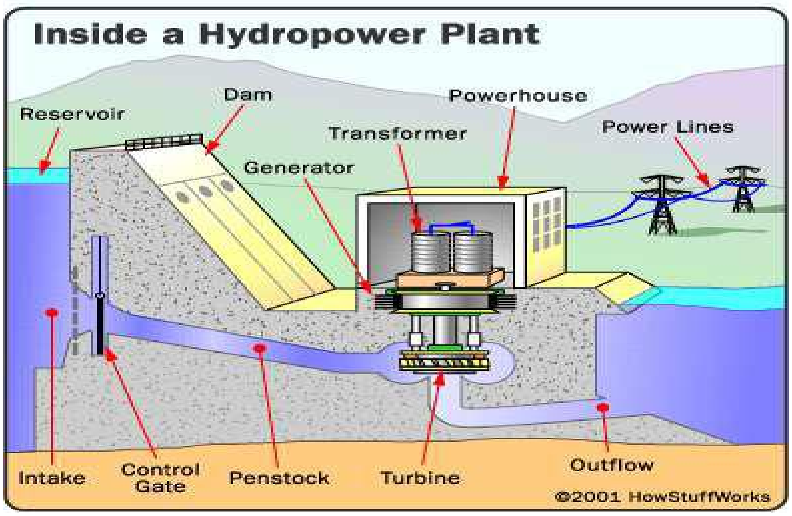

Fig. 1.1 : A Typical Hydropower Plant

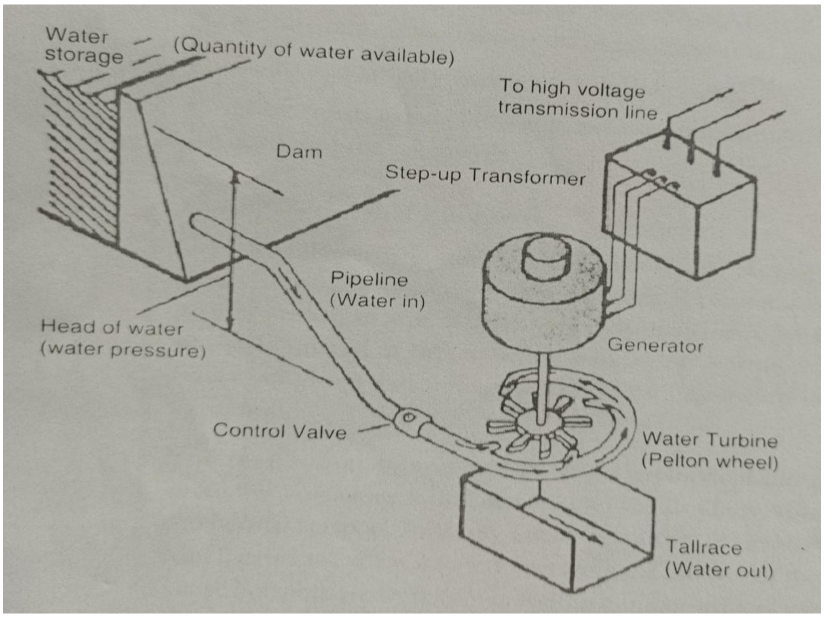

Fig. 1.2: Generation of Hydroelectricity

Fig. 1.3: A Hydro-Turbine

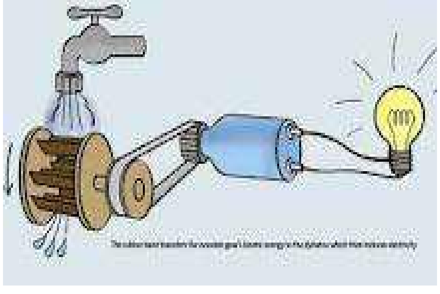

Fig. 1.4: A Waterwheel

Self-Assessment Exercise 2

Attempt these exercises to measure what you have learnt so far. This should not take you more than 10 minutes.

(1) Explain why hydropower is a good source of physical energy in Nigeria.

(2) Sketch any known procedure for the generation of hydroelectricity.

1.3.3 Wind Energy

What device/ facility is used in transforming wind energy? The energy generated by wind is normally converted into electrical energy using a **wind mill/ turbine. What then is wind?** Wind is the natural movement of air across the land or the sea. A **windmill** is a mechanical arrangement with blades rotating in a vertical plane and kept perpendicular to the wind; and converts wind energy into another form of energy (e.g. electrical energy and energy used in crushing grain or pumping water). **What considerations make wind energy advantageous?** Wind energy converted into electrical energy is a clean alternative to other energy sources such as nuclear power and fossil fuels.

Wind energy does not produce harmful by-products and environmental pollution to nature. This source is environmentally friendly, as wind does not deplete supplies of any natural resources of the earth. Also, it is freely and abundantly available in nature. A wind turbine is erected high to catch as much wind as possible. The flowing wind turns the mounted blades which cause the rotation of the shaft of a turbine connected to magnetic generators to produce electricity. The electricity is then sent to the power grid. **Is there any demerit associated with wind energy source?** Wind power is clean, yet it is not the most efficient source of energy because the amount of wind cannot be controlled nor predicted. Harnessing the wind is dependent on weather and location. Wind speed is not uniform at all the time thereby affecting power generation. It has high investment requirement.

NASENI is championing a wind energy project aimed at developing aerodynamic design, fabrication and installation of wind turbine blade that can give optimum performance at the wind speed region of Nigeria. Due to the low wind speed (i.e. between 3 to 5 m/s) experienced in Nigeria, imported blades cannot perform optimally since they are designed and built to operate at the speed of at least $8ms^{-1}$ and above. This fact has been the main setback to wind powered electricity generation in Nigeria. NASENI is charged with the responsibility of acquiring new sets of wind turbine whose engineering are conformable to other components (like tower, control system and power conversion unit). NASENI is also developing locally fabricated wind turbine blades for optimal wind energy conversion in Nigeria. **HEDI** in **Kano** is the proposed location for the local fabrication of the blades.

Fig. 1.5 : A Wind Mill/Turbine

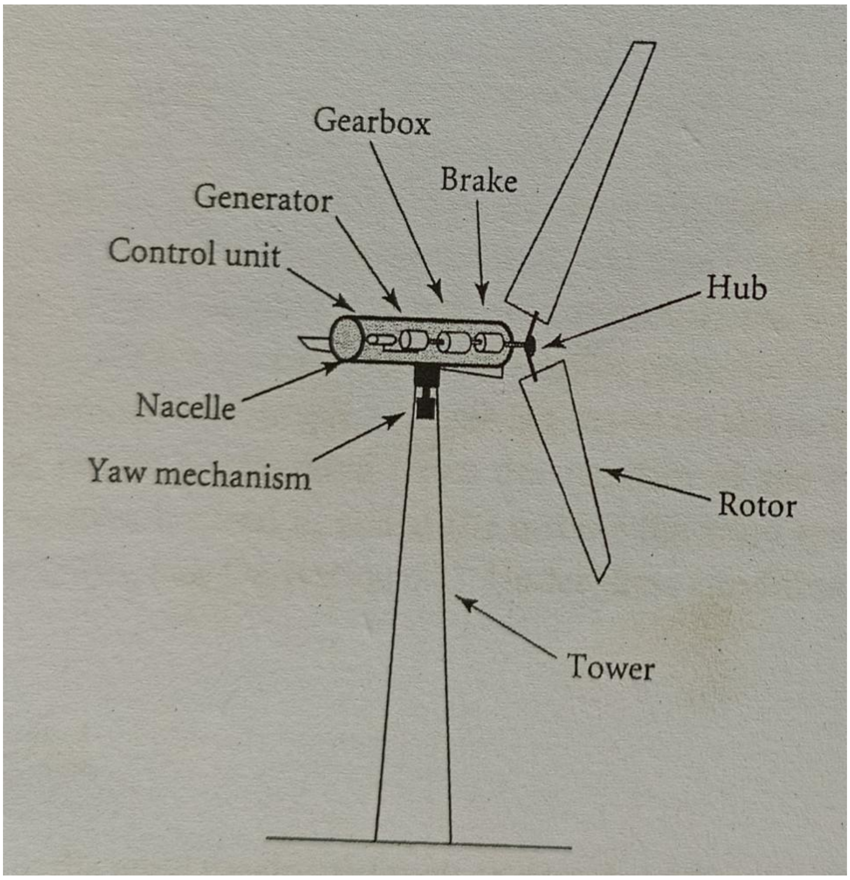

Fig.1.6 : Modern 5 MW Horizontal – Axis Wind Turbine

Self-Assessment Exercise 3

Attempt this exercise to measure what you have learnt so far. This should not take you more than 5 minutes. *With the help of a simple sketch, describe the operation of a wind turbine.*

1.4 Considerations in Choosing Energy Source

Technologies are continually being developed and enhanced to improve energy sources. Not all energies are ready for mass consumption. To choose an appropriate energy source to use for a particular purpose, the following questions are advised:

- Is it a renewable or nonrenewable source?
- What are the capital and setup costs?
- What are the ongoing operating costs?
- What size of energy storage is required?
- How efficient is it to produce one unit of energy?
- Can it be produced on a large scale?
- What is the cost to the consumer?
- What impact will it have on the environment?

1.5 Summary

In this unit, we have learnt that Coal, hydroelectric power and wind are physical sources of energy. Coal is viewed as the largest source of physical energy in the world. Though described as an efficient source of energy, it's not a particularly environmentally friendly source of energy. Hydroelectric power, also known as hydropower, is discussed as the use of water for the creation of electric energy. Then the energy generated by wind is shown to normally convert into electrical energy using a wind mill/ turbine. This unit also pointed out some considerations in choosing a source or a combination of sources of energy. This is often dependent on the environment of a given area and the natural resources available.

1.6 References/Further Reading

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1.6 Possible Answers to Self- Assessment Exercises within the content

Answer to self-Assessment Exercise 1

1) Three main sources of physical energy: Coal, hydro-power and wind.

   Coal is useful in generating electricity, useful in generating heat for cooking, and useful in the construction of railway system of transport.

   Hydro-power is useful mainly in generating electricity, useful in irrigation for farmland, useful in grinding corn and other grains, metal forging and mining.

   Wind can be used to generate electricity, useful in crushing solid minerals and grains and useful in pumping water.

2) Process of using coal to generate electricity in Nigeria briefly described.

Coal has to be pulverized into a fine powder before it can be burned up in power station. Coal power plants are used to burn the coal in large furnace to create huge amount of heat. The heat is used to boil water in boilers so as to convert it into steam. The steam expands, causing pressure to increase in the boiler. The moving steam spins a turbine placed at the exit of the boiler converting into mechanical energy which in turn operates a spinning generator. The rotating turbine is used to spin a magnet inside a power generator which generates electricity that is sent to the national power grid.

Answers to SAEs 2

1) Hydro-power as a good source of physical energy in Nigeria: Hydro-power is considered a cleaner form of physical energy than fossil fuels because the power plants that produce hydro-electric power do not contribute to greenhouse gases. No air emission is involved. It is eco- friendly with minimal impact on the atmosphere. In addition, hydroelectric power is inexpensive to maintain apart from the initial cost of installation as opposed to energy source from coal. It has long plant life with minimal transmission losses. The water used to generate hydro-electric power is stored in reservoirs at a high elevation, with flow controlled by a man- made dam. The water flows quickly through a turbine which spins a generator that produces the electric energy. Nigeria is endowed with large hydro-power potential capable of attracting heavy investments on large projects. Recently, hydro- power is being harnessed on a smaller scale to electrify remote villages through mini and small hydro power.

2) Sketch of any known procedure for the generation of hydro-electricity. Any of Figure 12, Figure 13 or Figure 15, well-labeled is an acceptable sketch.

Answer to SAEs 3

A simple sketch to describe the operation of a wind turbine: Either of the sketch in Figure 16 or Figure 17 and labeled suffice as an acceptable answer

UNIT 2 CHEMICAL SOURCE OF ENERGY

Unit Structure

2.1 Introduction
2.2 Intended Learning Outcomes
2.3 Chemical Sources of Energy and the Conversion Process
2.4 Summary
2.5 References / Further Readings
2.6 Possible Answers to Self- Assessment Exercises

2.1 Introduction

You have examined the physical sources of energy in the previous unit and can sketch the process of generating electricity using the physical sources. In this unit, chemical source of energy is described. **What happens when the human body burn sugar during exercise or strenuous activity? What changes are affected when wood is set on fire at the fireplace in the kitchen?** A lot of energy used by man at home exists in form of chemical energy. These transformation processes take off from either substances containing chemical energy or yield end product of substances containing chemical energy. In this unit, therefore, chemical energy and the transformation process involved therein are described and with diagram for illustration.

2.2 Intended Learning Outcomes

By the end of this unit, you will be able to:

- describe chemical source of energy with 80 per cent proficiency in the description.
- give 5 examples of process in which chemical energy is converted to other forms of energy
- explain the conversion of solar energy to chemical energy in plants and animals through photosynthesis.
- sketch the working of a thermal power station or a gas filling station.

2.3 Chemical Energy and the Conversion Process

Can you attempt the description of chemical energy? Chemical energy can be described as energy stored in the bonds or the rearrangement between atoms in molecules of a substance. Chemical energy is embedded in certain chemicals that have the capability of undergoing combustion to generate heat. For example, when the human body burn sugar during exercise or strenuous activity, the sugar components are re-organised/ re-arranged and energy is released in the chemical bonds of the original substance. Food contains calories which after digestion, releases energy. **What happens when wood is set on fire?** The chemical energy in a wood changes into heat energy and radiant energy when it is set on fire at fireplace.

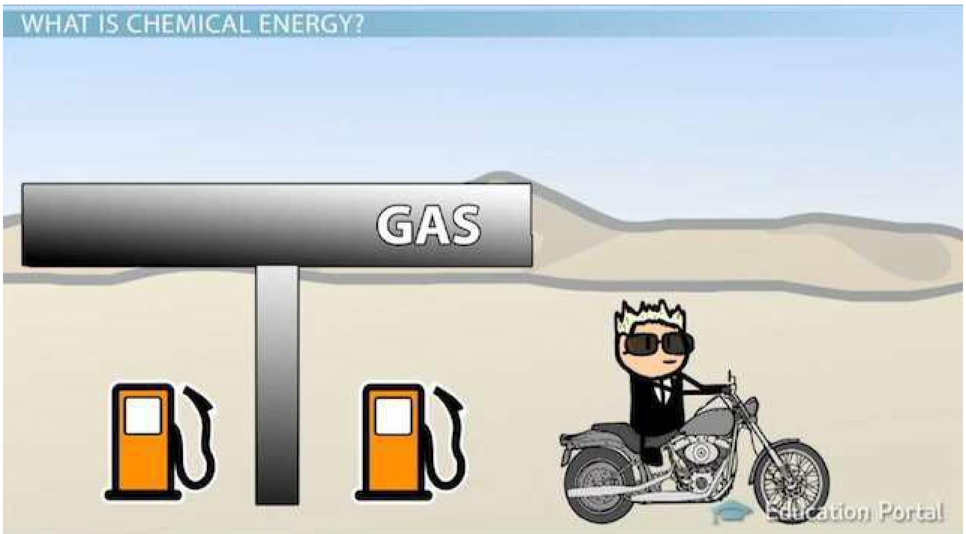

Fig.2.1: A Gas Filing Station

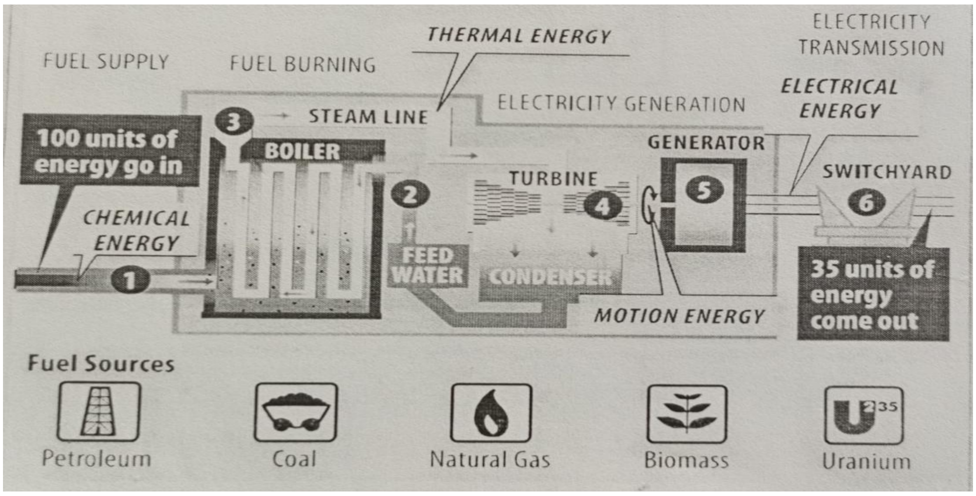

Fig.2.2 : Working of a Thermal Power Plant

Self-Assessment Exercise 1

Attempt these exercises to measure what you have learnt so far. This should not take you more than 5 minutes.

1. *Explain chemical source of energy.*

Give 5 examples of process in which chemical energy is converted to mechanical energy

A lot of energy used by man at home exists in form of **chemical energy**. **Why is it so referred?** It is so referred because the energy is embedded within chemicals; and stored in the bonds of molecules and atoms that make up the substance. Chemical energy is released in a chemical reaction, often in the form of heat. Chemical energy in fuels is used up by burning them. Common **sources of chemical energy** include: wood, natural gas, gasoline, kerosene, diesel, coal, even sugar etc. Chemical energy is naturally present in crude oil from which several fuels could be isolated through fractional **distillation**. When these fuels are burnt, heat energy is liberated in a process called **combustion**.

When chemical energy is released, the substance transforms into an entirely new substance. For instance, after the burning of wood, it changes to ash, as a new substance. When some chemical substance burns, huge amount of energy is released at once (either as a form of heat or heat and light). This can lead to explosion. This can be observed when gasoline is burnt in a fairly enclosed container. The same thing happens when dynamite explodes. A combustible chemical possesses potential energy when it is not burning. However, when it burns, this potential energy is converted to kinetic energy. For example, the chemical energy of fuel is converted into mechanical energy needed to move a car. Burning of fossil fuels entails the conversion of chemical energy into electrical energy needed on daily basis for various purposes by mankind.

What of the glucose in human body? The glucose (blood sugar) in the human body is said to have chemical energy because the glucose releases energy when chemically reacted (combusted) with oxygen during aerobic respiration in the muscles. The muscles use this energy to generate heat and mechanical force which manifests as shivering when we are cold and heat to keep the body warm and energy to move around. **What is the other by- products of combustion in human body?** Other by-products of the combustion process in human body apart from **heat** include **carbon dioxide** and **water**.

How do green plants make food? Solar (radiant) energy is converted to chemical energy during **photosynthesis** in green plants. Green plants take in radiant energy from sunlight to make food. This solar energy is stored in carbohydrates produced by the plant (as glucose or sugar). **Photosynthesis** in plants requires **sunlight, water and carbon dioxide** to take place. The stored energy in these carbohydrates is released when these compounds break down into simpler compounds when we eat and digest green plants. The energy produced from the metabolic processes in our body is used for our daily activities. Thus chemical energy in us is converted to heat energy and mechanical energy.

Fig. 2.3: Photosynthesis

Self-Assessment Exercise 2

Attempt these exercises to measure what you have learnt so far. This should not take you more than 5 minutes.

1. *Describe the process of converting solar energy to chemical energy in plants.*
2. *Illustrate the working of a typical thermal power plant. A sketch of a power station, labeled is acceptable.*

2.4 Summary

In this unit, we have described chemical energy as the energy stored in the bonds between atoms in molecules. It is embedded in certain chemicals that have the capability of undergoing combustion. When they burn, this potential energy is converted to kinetic energy. Chemicals in which chemical energy are embedded are given. Combustible chemicals possess potential energy when they are not burning. The conversion of chemical energy in plants and animals using solar energy was discussed also.

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Chemical energy: http://education-portal.com/academy/lesson/what-is-chemical- energy definition-examples.html

2.6 Possible Answers to Self- Assessment Exercises

Answers to SAEs 1

1) Chemical energy is regarded as the energy stored in the bonds or the re- arrangements between atoms in molecules of a substance. It is embedded in certain chemicals that have the capability of undergoing combustion to generate heat and sometimes light e.g. food contains calories which after digestion, releases energy used by animals to do work.

2) Five examples of processes in which chemical energy is converted to other forms of energy:
   (i) Chemical energy in wood changes into heat energy and radiant energy when it is set on fire.
   (ii) Human bodies burn chemical energy in sugar/ glucose during exercise or strenuous activity to release heat and mechanical force.
   (iii) When chemical energy in gasoline is burnt, it releases heat and light.
   (iv) Chemical energy in petrol (fuel) is converted into mechanical (kinetic) energy essential for the moving of a car.
   (v) When fossil fuel are burnt, chemical energy is transformed to produce electric energy.

Answers to SAEs 2

1) Process of converting solar energy to chemical energy in green plants:

   The process of converting solar energy to chemical energy in green plants occurs during photosynthesis. Green plants absorb radiant energy from sunlight to make food which is stored in carbohydrates as glucose or sugar. Photosynthesis in plants requires sunlight, water and carbon dioxide to manifest. The sketch in Figure 20 illustrating photosynthesis can be added for further illustration.

2) In a thermal power plant, the fuel supply can be either of natural gas, petroleum, coal or any other available fuel source which constitutes the chemical energy measured in units of energy. The fuel goes through a combustion process, releasing heat used in heating up water in a boiler to generate steam. The thermal energy so released from the steam line is used to rotate a turbine

which rotation translates into mechanical energy passed through a generator that produces electric energy. A sketch of figure 19 illustrating the working of thermal power plant with 70% proficiency in the illustration and labeling can be accepted.

UNIT 3 BIOLOGICAL SOURCES OF ENERGY

Unit Structure

3.1 Introduction

Recall that you have been acquainted with the conversion processes of physical and chemical sources of energy as described in Unit 1 and Unit 2 respectively of this module. In this unit, biological sources of energy are examined. **When living organisms use their metabolic capacities to transform other forms of energies into energy yielding molecules, what type of energy source is involved?** The reactions that lead to the production of these energy yielding chemicals are collectively referred to as *metabolism*, and are discussed in this unit as **biological source of energy**.

3.2 Intended Learning Outcomes

By the end of this unit, you will be able to:

- explain the path taken by solar energy to its conversion to biological energy with 70% proficiency in the explanation
- enumerate various processes through which biological energy could be generated with a short note on each of them
- itemise three area of advantages and uses of biological energy sources to the society.
- state three limitations/ challenges of using biological source of energy as the main energy source for a community.

3.3 Biological Sources of Energy

Biological energy is sustainable low- carbon energy source technology derived from organic matter such as plants, animals and industrial residues. It is the form of energy that is produced in living organisms when they use their metabolic capacities to transform other forms of energies into energy yielding molecules like hydrogen, methane, alcohols, ammonia and bio-plastics. Mention **the major advantage of biological source of energy over other sources?** Biological energy technology provides environmentally friendly alternatives to some industrial processes, thus reducing the emissions of greenhouse which are toxic to the environment. Industrial processes generate CO, CO_2 and other dangerous gases which contribute to global warming. **The need to explore biological energy has been hinged on many reasons**:

- Economic –It is anticipated that the world will eventually run out of crude oil which is a major source of energy presently.
- Political –Not all nations of the world are naturally endowed with crude oil, hence they rely on importation. If advancement is made with biological energy technology source, such nations will depend less on foreign imports of energy.
- National security - Famine induced instability in countries relying on nuclear energy because such countries face economic sanctions from super powers.
- Moral - people will starve/ die as a result of the effects of global warming which results from the impacts of combustion.

One of the most serious environmental problems today is that of global warming, caused primarily by the heavy use of fossil fuels. The CO_2 generated by this process could potentially be recovered with relative ease through the use of established technologies involving chemical absorption. **What are the means of generating biological energy?** Biological energy can be generated through:

a. Photosynthesis
b. Conversion of Biomass wastes into energy
c. Fuel production through micro-algal CO_2 fixation

3.3.1 Biological Energy through Photosynthesis

Biological energy comes from solar energy essentially. The sun has been proven to be the primary and ultimate source of energy for all living things and the ecosystems of which they are part. Plants, algae and cyano-bacteria use the radiant energy directly from the sun to grow and make organic matter through the process of photosynthesis. **The beginning of energy flow through almost all food webs takes off from where?** The answer is the **sun**. **The process through which green plants synthesise (manufacture) their food (carbohydrates) and oxygen from carbon (IV) oxide and water in the presence of sunlight and chlorophyll is c**alled **------**? It is called **Photosynthesis**. It is simply represented by the equation:

$6CO_2 + 6H_2O$ + light (photons) and chlorophyll $\rightarrow C_6H_{12}O_6 + 6O_2$
Or $CO_2 + H_2O$ + sunlight and chlorophyll $\rightarrow O_2 + [CH_2O]$

For every mole of CO_2 fixed during photosynthesis, approximately 114 kilocalories of free energy are stored in plant biomass. The simplest carbohydrates are sugars or monosaccharide, which have the composition $(CH_2O)_n$. **Glucose, $C_6H_{12}O_2$** is the commonest plant sugar and is called a 6-sugar as it contains six carbon atoms. The glucose molecule can exist in several forms, in which the atoms have different bonding and orientations, called **'structural isomers'**. Photosynthesis occurs both in the terrestrial and aquatic habitats, hence, both terrestrial and aquatic plants could be used for biomass energy production.

3.3.2 Conversion of Biomass Wastes into Energy

What's your idea of biomass? Biomass connotes plant – and – animal – derived material such as straw, logs, dung and crop residues that are used either directly or indirectly to generate heat, electricity and fuels. The type of fuel produced by biomass is commonly referred to as **biofuel**. Municipal wastes like manure, lumber, pulp mill wastes, and energy crops / forest and agricultural / factory residues constitute a large source of biomass. Biomass supply in the future depends on planting large areas with dedicated energy crops. Sufficient amount of biomass must be produced to make it a viable source of energy.

Fig.3.1: The Making of Biofuel

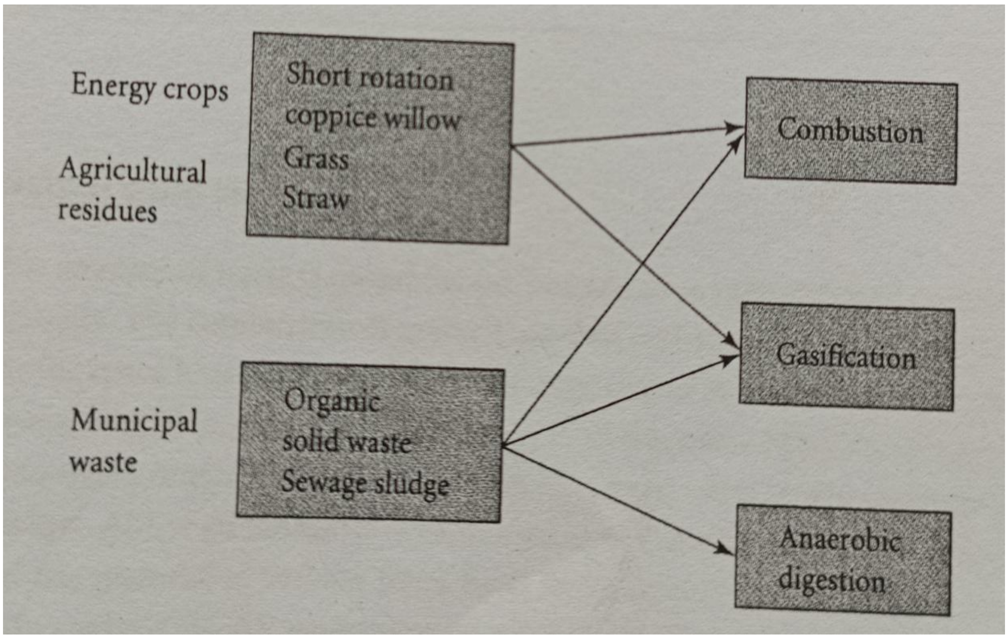

Fig.3.2 : Biomass Sources in The UK (Source: UK2020)

Self-Assessment Exercise 1

Attempt these exercises to measure what you have learnt so far. This should not take you more than 5 minutes.
(1) Explain the meaning of energy in relation to Physics, Chemistry and Biology.
(2) Outline 5 importance of energy to mankind

3.3.3 Fuel Production through Micro-Algal Fixation

Photosynthetic microalgae could be potentially tilized for absorbing excessive amounts of CO_2, since when cultivated these organisms are capable of fixing CO_2 to produce energy and chemical compounds when exposed to sunlight. **What is it about algae also?** Algae, a three-carbon (C_3) based compounds produced in photosynthesis can have a high conversion efficiency, potentially producing more biofuel per hectare than other sources. However, **the challenge** is to find robust strains of algae that can be harvested cost-effectively. **Enumerate the possible uses and advantages of biomass?** Biomass could be converted to modem gaseous and liquid fuels such as hydrogen, methane, ethanol, and oils which could serve as sources of energy. Biomass, particularly the type from agricultural waste, wood, charcoal and dried dung has widespread uses for household cooking and heating. Biomass can also be heated in the absence of oxygen to chemically convert it into a type of fuel oil referred to as pyrolysis oil used for power generation and as feed-stock for fuels and chemical production. Bio-fuels are easy to transport; and they possess high energy density, therefore, they are favoured in fuelling vehicles and power generating plant.

3.4 Benefits and other application of Biological Energy Sources

It is a source of clean fuel when compared to fossil fuels. It is a low-cost option to reduce undesirable emissions such as nitrous oxide emissions. By **trapping carbon dioxide**, it helps to clean the environment. It can be locally sourced. It is simple to use, biodegradable, non-toxic and essentially low in sulphur and other sensitive odour than coal. Biological processes for the conversion of biomass high in carbohydrates to fuels include ethanol fermentation by yeast or bacteria, and methane production by microbes under anaerobic conditions.

The largest source of ethanol is corn. Ethanol is used in some cities as gasoline additive to help meet air quality standards for ozone. Flex-fuel vehicles are presently on the market which can use a mixture of ethanol (85%) and gasoline (15%). Biodiesel is another form of biofuel that can be made from vegetable and animal fats and usable to fuel a vehicle or used as fuel additive to reduce emissions, and useful as biogas digesters for improved cook stoves. Biomass (such as corn, wheat, soybeans, wood and other residues) can be applied in the production of chemicals and materials that are sourced from petroleum. Cornstarch can be used to make commodity plastics such as shrinkwrap, plastic eating utensils and car bumpers. Effort is being made presently to commercially mass produce thermoset plastics such as electrical switch plate covers derivable from wood residues.

Self-Assessment Exercise 2

Attempt these exercises to measure what you have learnt so far. This should not take you more than 5 minutes.

(1) *Mention three advantages and applications of biological energy sources in the society.*
(2) *What is the major challenge facing the adoption of biological source for energy supply?*

3.5 Summary

In this unit, biological energy was defined as a form of energy that is produced in **living organisms** when they use their metabolic capacities to transform other forms of energies into energy yielding molecules like hydrogen, methane. This form of energy source has been described as a sustainable technology that provides environmentally friendly alternatives to some industrial processes, thus reducing the emissions of greenhouse which are toxic to the environment. Reasons for exploring biological energy were explored and the various processes of generating this form of energy discussed.

3.6 References/Further Reading

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3.7 Possible Answers to Self- Assessment Exercises

Answers to SAEs 1

1) Path taken by Solar energy to its conversion to biological energy:

The sun is the primary source of energy for all living things and the ecosystem of which the living things are part of. The beginning of energy flow through almost all food webs takes off from the sun. Green plants synthesise their food in form of carbohydrates and oxygen through the process of photosynthesis using carbon iv oxide and water in the presence of sunlight and chlorophyll. It is simply represented by the equation:

$6CO_2 + 6H_2O$ + light (photons) and chlorophyll $\rightarrow C_6H_{12}O_6 + 6O_2$

Or $CO_2 + H_2O$ + sunlight and chlorophyll $\rightarrow O_2 + [CH_2O]$

For every mole of CO_2 fixed during photosynthesis, approximately 114 kilocalories of free energy are stored in plant biomass. Photosynthesis occurs in both terrestrial and aquatic habitats (Plants). These carbohydrates in form of sugars and glucose alongside oxygen can be utilized by man and other animals for energy used in daily functioning. Plants' produce are raw materials for biomass energy production.

2) Processes of generating biological energy source

(a) Photosynthesis
(b) Conversion of biomass wastes
(c) Fuel production through micro-algal CO_2 fixation

Short note on each of them

(a) **Photosynthesis**: This is the process by which green plants synthesize carbohydrates, also releasing oxygen from the reaction of Carbon (IV) oxide and water in the presence of sunlight and chlorophyll. Plants, algae and cyanobacteria use radiant energy directly from the sun to grow and make organic matter through the process. Photosynthesis occurs both in the terrestrial and aquatic habitats and could all be used for biomass energy production. Photosynthesis is represented by the equation:

$6CO_2 + 6H_2O$ + light (photons) and chlorophyll $\rightarrow C_6H_{12}O_6 + 6O_2$

Or $CO_2 + H_2O$ + sunlight and chlorophyll $\rightarrow O_2 + [CH_2O]$

These carbohydrates in form of sugars and glucose alongside oxygen can be utilized by man and other animals for energy used in daily life's activities.

(b) Conversion of biomas wastes: Biomass are plants and animals derived materials such as straw, logs and crop residues that are used either directly or indirectly to generate heat, electricity and fuels for other purpose. The type of fuel produced by biomass is commonly referred to as biofuel. Biomass could be converted to modern gaseous and liquid fuels such as hydrogen, methane, ethanol and oils that could serve as sources of energy. Municipal wastes like manure, lumber, pulp mill wastes, and energy crops/ forest and agricultural/ factory residues constitute a large source of biomass. Biomass supply in the future depends on planting large areas with dedicated energy crops. Sufficient amount of biomass must be produced to make it a viable source of energy.

(c) Fuel Production through Micro-algal CO_2 fixation: Photosynthetic microalgae could be potentially harnessed for absorbing excessive quantity of CO_2, since it is capable of fixing CO_2 when cultivated and can produce energy and chemical compounds when exposed to sunlight. Algae is a three- carbon (C_3) based compounds produced during photosynthesis and with high conversion efficiency potentially producing more biofuel per hectare than other sources. The major constraint is finding robust strains of algae that can be harvested cost- effectively.

Answers to SAEs 2

1) Three Advantages and Applications of Biological Energy source in the Society:

The advantages of biological energy source include: Low- cost option in reducing undesirable emissions such as nitrous oxide emissions. By trapping carbon dioxide, it helps to clean the environment. It can be locally sourced. It is simple to use biodegradable, non- toxic and essentially low in sulphur and other sensitive odour than coal.

Three applications of biological energy source: Biomass (such as corn, wheat, soybeans, wood and other residues) can be applied in the production of chemicals and materials that are sourced from petroleum. Ethanol, gotten from corn is used in some cities as gasoline additive to help meet air quality standards for ozone. Flex- fuel vehicles are presently on the market which use a mixture of ethanol (85%) and gasoline (15%). Biodiesel is another form of biofuel that can be made from vegetable and animal fats and usable to fuel a vehicle or used as fuel additive to reduce emissions, and useful for biogas digesters for improved cook stoves.

2) The major challenge facing the adoption of biological source for main energy source in a community is the challenge of finding robust strains of algae that can be harvested cost- effectively.

UNIT 4 GASEOUS SOURCES OF ENERGY

Unit Structure

4.1 Introduction
4.2 Intended Learning Outcomes
4.3 Gaseous Sources of Energy (Natural Gas)
  4.3.1 Composition of Natural Gas and its Characteristics
  4.3.2 Advantages of Natural Gas
  4.3.3 Disadvantages of Natural Gas
4.4 Summary
4.5 References/Further Reading
4.6 Possible Answers to Self- Assessment Exercises

4.1 Introduction

Welcome to Unit 4 of Module 2 on the sources of energy**.** Recall that in the last units, we discussed physical sources, chemical sources and biological sources in that order. This unit focuses on the gaseous sources of energy with particular interest on natural gas. The occurrence of **Natural Gas** as a fossil fuel energy source in a gaseous state is explored. What made natural gas to be popular for commercial and industrial use, and electric power generation are discussed. Some demerits of natural gas were also highlighted in the unit.

4.2 Intended Learning Outcomes

By the end of this unit, you will be able to:

- Describe natural gas as a source of energy
- Examine the existence of natural gas and its drilling procedure.
- List the characteristics of natural gas.
- Compare and contrast the uses of natural gas with gasoline.

4.3 Gaseous Sources of Energy

4.3.1 Composition of Natural Gas and its Characteristics

What is the main content of natural gas? Natural gas as a fossil fuel energy source exists in a gaseous state and is composed mainly of methane (CH_4) and a small percentage of natural gas liquids and other hydrocarbons (e.g. ethane, propane, butanes, pentanes) and water vapour. Natural gas may also contain non-hydrocarbons such as sulphur, helium, nitrogen, hydrogen sulfide and carbon dioxide, mostly removed from natural gas before being sold to consumers.

Where is natural gas located? Natural gas is found deep inside the earth and drilled in same way as crude oil. Natural gas deposits can be found on land, some are offshore and others deep under the ocean floor. It is cheaper and cleaner than gasoline and produces less greenhouse emissions than its counterparts. It burns completely and can be safely stored. Natural gas can be used in the form of compressed natural gas (CNG) or liquified petroleum gas (LPG). It is useful as a fuel and to make materials and chemicals. Natural gas is widely used domestically especially in developing countries with poor supply of electricity. Hence, various schools, hospitals, hotels, motels, restaurants, office buildings also use natural gas for cooking. Natural gas can be classified into conventional natural gas and unconventional natural gas (shale gas or tight gas) based on type of formations. Natural gas can occur with deposits of crude oil and sometimes found in coal deposits. Sometimes natural gas occurs in tiny spaces with some shale and sandstone formations and other types of sedimentary rock. Natural gas can also exist with deposits of crude oil and commonly referred to as associated natural gas. The type of natural gas found in coal deposits is referred to as coalbed methane. The right places to drill natural gas can be found by geologist using seismic surveys and exploration on land and in the sea. The results of the test survey reveal information on the quality and quantity of natural gas available in the resource.

Why is a harmless chemical that smells like rotten egg added to natural gas? Due to the colourless, odourless and tasteless nature of natural gas, companies drilling natural gas often add to natural gas a harmless chemical that smells like rotten eggs called mercaptan with the aim of giving it a distinct and unpleasant odour to enable easy detection of leaks in natural gas pipelines.

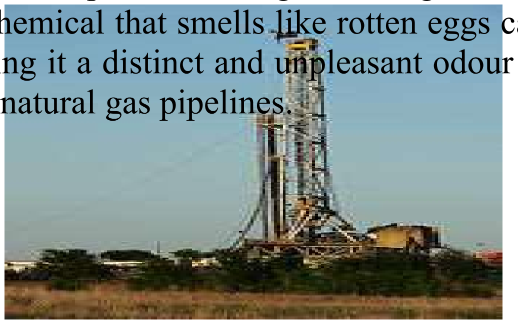

Fig. 4.1: Natural Gas Drilling

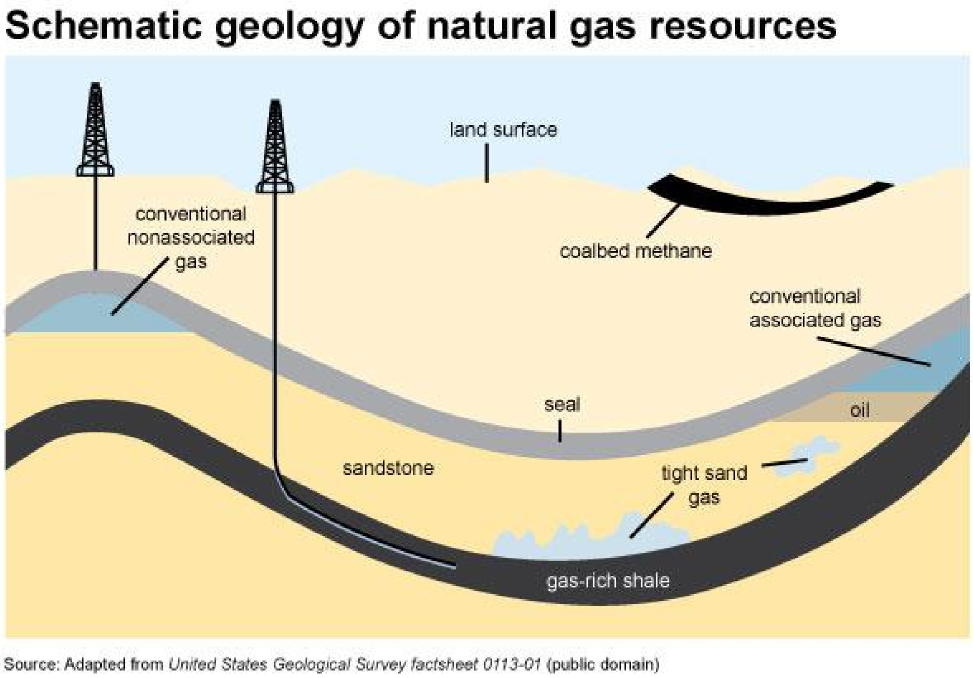

Fig. 4.2 : Schematic Geology of Natural Gas Resources

Self-Assessment Exercise 1

Attempt this exercise to measure what you have learnt so far. This should not take you more than 5 minutes.

1) *Describe natural gas as a source of energy pointing out some of its characteristics.*
2) *Examine the natural existence of natural and its drilling procedure.*

4.3.2 Advantages of Natural Gas

- It is less harmful than coal or oil: As compared to petroleum or coal, natural gas causes less damage to the environment. It is made up of methane and results in less carbon emissions.
- It can be easily stored and transported: Natural gas is easier to preserve than other fuels. It can be stored and transported through pipelines, small storage units, cylinders or tankers on land and sea.
- Residential Use: Natural gas can be piped into houses for heating and cooking purposes and running a variety of appliances. Where there are no pipes, it can be supplied in small tanks.

- Vehicle Fuel: Natural gas can be used as a fuel for vehicles (cars, trucks, jet engines). It is a cleaner, cheaper fuel than diesel or gasoline.
- Burns Cleaner: Natural gas burns cleaner without leaving any smell, ash or smoke when compared with gasoline.
- Instant energy: Natural gas is an economic and instant fuel for heating water and large areas as well as cooking. It is ideal because it provides precise control and quick results. It helps in oven cooking as it does not require pre-heating.
- Precision in Kitchen: Natural gas is the best fuel to power kitchens because of its control, reliability and precision. A gas flame provides for precise temperature control and variety of heat settings allowing shift from hot to cold or vice versa, with the turning of the knob.
- Industrial use: Natural gas is used for producing hydrogen, ammonia for fertilizers and some paints and plastics.
- 9. It is abundant: It is relatively abundant compared to other fossil fuels, burns more cleanly and is easy to distribute.
- 10. It is Safer: It is lighter than air and tends to dissipate when there is a leakage unlike Propane, which being heavier than air, collects into explosive pockets.
- 11. It is very versatile: It can be used for heating, drying clothes, cooking, backing up generator power, and many other uses.
- 12. It is cheaper: Natural gas is cheaper than electricity. It is quicker when used for cooking and heating water and majority of gas appliances are cheaper than electric appliances.
- 13. It is neater: Gas appliances do not create electric fields which are unhealthy near your homes.
- 14. It is used to produce electricity

4.3.3 Disadvantages of Natural Gas

- It is toxic and flammable: Leaks of natural gas are tremendously dangerous. Such leaks may cause explosions or fire. When inhaled, the gas is highly toxic. The main danger is that it is odorless and leaks cannot be detected unless some odorant has been added to the gas. It is for this reason that LPG (residentially used gas) is suffused with odorants, that in the event of a leak, detection is easy and appropriate actions can be taken. In the case of an underground leak, we are helpless as odorant becomes weaker and the gas leak goes undetected.
- It could cause damage to environment: Burning of natural gas also releases carbon dioxide, carbon monoxide and other carbon compounds which are greenhouse gases that cause global warming and climate change. Even though it is cleaner than oil or

coal as far as its by products are concerned, leakage of natural gas can be have serious consequences as methane is more toxic than carbon dioxide.

- Its processing is complex: For use as fuel, except for methane, all other constituents of natural gas have to be extracted. Processing results in many byproducts: hydrocarbons (propane, ethane etc.), sulfur, water, helium, nitrogen, and carbon dioxide.
- It is non-Renewable: Like all fossil fuels, natural gas though found in abundance is non-renewable and a finite source; hence likely to be exhausted at some point in time. It is therefore not a long term solution to our energy problems.
- It is expensive to installation: The infrastructure for natural gas production and distribution is fairly expensive. This includes separate plumbing systems and specialized tanks.
- Inefficiency in Transportation: Natural gas when used as a fuel in vehicles provides less mileage than gasoline.

In spite of the disadvantages, the entire process of producing, transporting and making use of natural gas provides an energy efficiency which is best among all fossil fuels. It proves to be less harmful to environment when it comes to pollution. It may not last forever but as of today it is the most popular energy source.

Self-Assessment Exercise 2

Attempt this exercise to measure what you have learnt so far. This should not take you more than 5 minutes. *Compare and contrast the uses of natural gas and gasoline.*

4.4 Summary

In this unit, you have learnt that Natural gas is obtained from the earth like crude oil and coal. It is a commonly used source of energy. It exists in the gaseous state as fossil fuel. It is very cheap and is a clean source of energy. However, it is a non-renewable source of energy.

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4.6 Possible Answers to Self- Assessment Exercises

Answers to SAEs 1

Description of natural gas as a source of energy and some of its characteristics:

1) Natural gas is a fossil fuel energy source and can in burn completely. It is composed mainly of methane (CH_4) and a small percentage of natural gas liquid and other hydro carbons (such as ethane, propane, butane, and pentane) and water vapour. Natural gas may also contain non-hydro carbons such as sulphur, helium, nitrogen, hydrogen sulphide and carbon dioxide, mostly removed from the natural gas before being sold to consumers. It can be used in the form of compressed natural gas (CNG) or liquefied petroleum gas (LPG). It is very popular for commercial and industrial use and for electric power generation. Also, it is widely used domestically especially in developing countries with poor supply of electricity. Apart from being use as fuel, it’s used to make materials and chemicals. It is colourless, odourless and tasteless,

2) The natural existence of natural gas and its drilling procedure:
It is found deep inside the earth and drilled in same way as crude oil. Natural gas deposits can be found on land, some offshore and others deep under the ocean floor.

Natural gas can exist with deposits of crude oil and sometimes found in coal deposits. Sometimes natural gas occurs in tiny spaces with some shale and sandstone formations and other types of sedimentary rock.

The right place to drill can be found by geologist using seismic surveys and exploration on land and in the sea. The results of the test survey reveal information on the quality and quantity of the natural gas available in the resource. Due to the colourless, odourless and tasteless nature of natural gas, companies drilling natural gas often add to natural gas a harmless chemical that smells like rotten eggs called mercaptan with the aim of giving it a distinct and unpleasant odour to enable easy detection of leaks in natural gas pipelines. The sketch of the schematic geology of natural gas resources in figure 24 is acceptable for an answer.

Answer to Self-Assessment Exercise 2

Compare and contrast the uses of natural gas and gasoline

Natural gas is cheaper and cleaner than gasoline and produces less greenhouse emissions than gasoline. It burns cleaner without leaving any smell, ash or smoke when compared with gasoline. It is easier to preserve (during storage and transportation) than gasoline. It can be stored and transported through pipelines, small storage units, cylinders or tankers on land and sea. In residential use, it can be piped into houses for heating and cooking and running variety of appliances unlike the gasoline. Where there are no pipes, it can be supplied in small tanks. It is an economic and instant fuel for heating because it provides precise control and quick results. It does not require pre- heating and helpful in oven cooking. It is relatively more abundant than gasoline. It is lighter than air and tends to dissipate when there is a leakage unlike gasoline which being heavier than air, collects into explosive pockets. Like other fossil fuels, it can be used to produce electricity.

Under demerits of natural gas, it is more toxic when inhaled, easily flammable and terribly dangerous in case of leakage. Because of the odourless nature, leakages cannot easily be detected unless some odorant has been added to the gas. It is capable of causing damage to the environment. Its processing is complex. Processing it results in many by-products. It is non-renewable just as other fossil fuels are non-renewable, hence, likely to be exhausted at some point in time. It is expensive to install the infrastructure for the production and distribution of natural gas. It is inefficient in transportation when compared to gasoline. Natural gas when used as fuel in vehicles provides less mileage than gasoline.

UNIT 5 CATEGORISING FORMS OF ENERGY INTO RENEWABLE AND NON-RENEWABLE, PRIMARY AND END- USE ENERGY

Unit Structure

5.1 Introduction

Based on the previous units studied, you can explain the meaning of energy, measure energy and classify energy sources into physical, chemical, biological and gaseous energy resources. **Are you aware that the various forms of energy at the disposal of mankind today can further be grouped into categories of (a) non- renewable and renewable energy (b) primary and end- use energy?** The need to categorise energy into the ones available at the starting point of the energy chain and the ones being used by consumers at the end of the energy chain is necessary; and in accordance with the global market standard. You will discover that available energy cannot be used in its original form in all situations. Another categorisation of energy is highlighted. Some forms of energy sources are continually being replenished in nature in a short period of time, while others are continually being depleted and difficult to replenish in a short period of time. The various categorisations of energy, their importance and limitations are discussed in this unit.

5.2 Intended Learning Outcomes

By the end of this unit, you will be able to:

- differentiate non-renewable energy source from renewable energy source; and mention three examples of each source being used in Nigeria
- draw a pie chart showing the percentage contribution of renewable and non- renewable energy sources to global energy supply
- distinguish between primary and end- use energy within the classroom environment.
- sketch energy flow- chart depicting the flow of energy from primary to end-use.

5.3 Categorising Forms of Energy into Non- renewable and Renewable Sources

Forms of energy can be categorised into non- renewable and renewable energy sources as will be discussed in the following sub-sections. Do well to pay rapt attention to these categorisation methods. **Use this link to learn more about**: **Renewable and Non-Renewable Energy**

5.3.1 Non-Renewable Sources of Energy

Some of the energy sources can be replenished in a short period of time, whereas other sources are being used up and cannot be generated in a short time. The energy sources that cannot be regenerated in a short period of time or cannot be used again and again are called non-renewable sources of energy. They occur in limited and exhaustible quantities. **Can you give examples of such limited energy source that is being depleted on usage and not easily replenished?** The answer include: crude oil, coal, natural gas (all fossil fuels). Solid fuel (such as coal), gaseous fuel and liquid fuel are natural sources of heat energy. They are created over millions of years from the remains of plants and animals. It is found in deposits beneath the surface of the earth. When human beings ignite fossil fuels, they combust/ burn and create heat energy.

Number of years expected for our crude oil, natural gas and coal reserves to last have been reliably predicted to be no longer than another 100 years assuming no other major new field or well deposit is discovered. The need for judicious use of these non-renewable energy sources have been emphasised again and again. Wastages of this category of energy source must be prevented at all cost. Incidentally, as at today, fossil fuels (e.g. coal, oil and natural gas) supply most of the world's energy needs. **Figure 25** below shows that non-renewable energy sources make the greatest contribution to the world energy use today. The million dollar question is '**What will happen to the global energy needs when the reserves of these non- renewable energy sources are exhausted?**' There is also the problem arising from the damaging effects on the environment by these fossil fuels. It is pertinent to point out also that radioactive elements (such as natural uranium) are non- renewable. When the atoms of uranium are split into two or more parts, a very large amount of energy is released usable in the generation of electrical energy.

5.3.2 Renewable Energy Sources

On the other hand, energy sources that are continually replenished by nature are called renewable energy sources. **Why is it so**? Guess. The energy is derived from a source that has no possibility to run out of supply. Renewable energy technologies transform energy resource (of the sun, the wind, the water, the earth's heat and plants) into usable forms of energy (such as electricity, chemicals, heat or mechanical power etc.). Renewable energy sources are environment friendly naturally, available in abundance and a good alternative to fossil fuels. Geographical and geological features of a country determine the type of renewable energy technology to be cited. For example, hydro power energy source can only be cited in areas with rivers and streams and usually requires a mountainous terrain. Renewable energy has some limitations that must be addressed before being used successfully. The technology may be considered expensive and not necessarily market-ready. The resources are not always available. The energy may be intermittent and may be defected by quality and energy density issue.

What can you say about the sun's energy? The sun's energy travels to Earth as electromagnetic radiation; and the amount of radiation depends on the time of day and season. Sunlight is a clean renewable and sustainable resource. Electricity can be generated from solar radiation through Solar Photovoltaic (SPV) cells. Homes, street lighting and water pumping in village have been successfully powered using the SPV solar technology. The stored energy can be used when sunlight is not available. Natural heat energy can be sourced from biomass (plant and animal products and industrial wastes). **What about wind energy**? Wind energy gotten from the natural movement of air across the land or sea can be used to turn the blades of a wind mill which in turn turns the shaft to which they are attached in order to produce electricity. Wind energy is environmentally friendly and freely available. But it requires

initial high investment cost. Wind speed not being uniform at all the time wind can affect power generation. Special mention need to be made about geothermal energy and ocean energy.
Geothermal energy is derived from thermal energy available underground and stored in earth's crust. The heat is produced within the Earth's core (which is made of solid iron surrounded by molten lava). The radioactive decay of particles of rocks creates the magma that enables the generation of geothermal energy. Geothermal heat finds utilisation in the direct heating of homes and buildings using hot springs or underground water. It can also be used to generate electricity. It is environmentally friendly power source and not affected by the severity of climate change during winter months (unlike hydro and sun-dependent solar PV). Geothermal energy, though treated as renewable energy, is traceable to a resource that may eventually run out with time. Geothermal energy resource is likely available only in countries with potential volcanic geology.

For the ocean energy (e.g. tidal and wave), the renewable energy technologies required for its utilisation are yet to be perfected as testing and development is still on- going. Kinetic energy exists in the moving waves of the ocean. The wave energy can be used to power a turbine. Also, the tidal energy of ocean can be harnessed by trapping water at a high tide and then capturing its energy as it rushes out and drops to low tide. The power of the tides has been harnessed in Canada and France to generate electricity. Ocean water temperature variations can also be used to generate energy. Temperature difference between deep and surface waters in the ocean is useful in extracting energy from the flow of heat between the two. The process of using temperature difference is called "ocean thermal energy conversion" (OTEC). Power plants can be built and used to generate energy utilising the difference in temperature. Demonstration projects to generate energy are being implemented in Hawaii and Japan using temperature difference between deep and surface waters in the ocean.

Apart from the renewability of these energy sources (i.e. water, wind, sunlight, geothermal, sea waves, hydrogen and biomass), can you conjecture other reasons why advocacy is intense on switching over to such energy sources? These other reasons include the following: By-products of non-renewable energy sources (such as pollutants, greenhouse gases and toxins) are reduced to the barest minimum. Renewable energy sources can be of help in the preservation of delicate eco- system equilibrium of the earth and also in the conservation of the limited non-renewable energy sources. Fossil fuels and available nuclear capacity are rapidly being used up than they are being created. The Renewable energy sources are unlimited and inexhaustible. The various means of harnessing renewable energy sources have less damaging effects on the environment; and the waste disposal problem of the non-renewable sources is mitigated using the renewable energy sources.

Problems of greenhouse gases and pollutants contributing to global warming and health risks will be ameliorated Renewable energy sources will help fill in the gap expected to be created when these non-renewable sources are retired. It can be sourced based on indigenous and local availability. The quest for energy independence and security being sought by comity of nations can easily be achieved with the result of saving cost and strengthening of the energy system. Renewable energy technologies have great potential to meet up with the energy needs of rural dwellers in a sustainable way and in consonance with conventional systems. The decentralised nature of some renewable energy technologies allows them to be easily matched with specific needs of different rural societies.

Some downsides of renewable energy include: the energy resources may not always be available in ample amounts when needed and everywhere. For example, some years of monitoring are needed to determine the suitability of a site before wind power installation is carried out and the energy source may be intermittent. **A wind turbine can generate power only when there is wind, same goes for solar**. ***True or False*?** Answer: True. The technology may not always be market ready. The amount of energy per unit mass or volume (i.e. energy content) is significantly lower than that of fossil fuel.

Self- Assessment Exercise (SAE) 1

Attempt these exercises to measure what you have learnt so far. This should not take you more than 5 minutes.

1. Differentiate between non- renewable and renewable energy sources.
2. Mention three examples of non- renewable and renewable energy sources respectively as used in Nigeria.

5.3.3 Pie-Chart on Contribution of Non- Renewable and Renewable Sources to Global Energy Resource

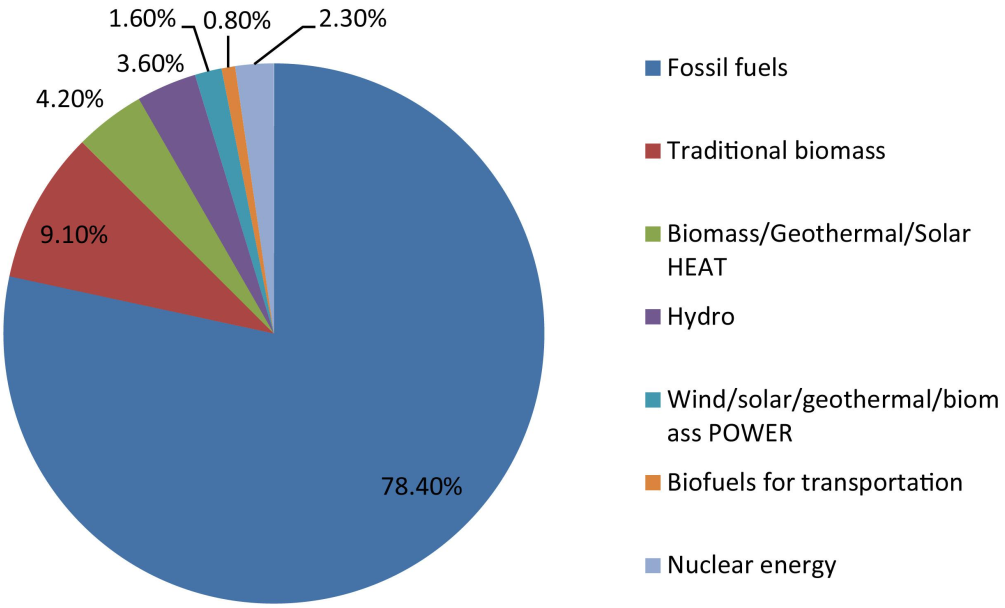

Fig. 5.1: Contribution of Renewable and Non- Renewable Energy Sources to Global Energy Use as at 2015 (Data Source: REN21, GSR2017)

Self- Assessment Exercise (SAE) 2

Draw a pie- chart to show the contributions of non- renewable and renewable energy resources to global energy Supply.

5.4 Categorising Forms of Energy into Primary and End-Use Energy

It is also important to categorise energy into those available at the starting point of the energy chain and those being used up by the energy consumers at the end of the chain. This method of categorisation is important at the global market.

5.4.1 Primary and End- Use Energy, Compared

Some energy forms can be used directly by the end user – consumer, whereas others are produced from other forms of energy which in turn are the products of other energy sources. Primary energy constitutes the original form of energy that come into circulation either from non-renewable or renewable energy sourced from either within or imported from outside the country. End- use energy is the energy that has been transformed for final consumption through various processes. It is ultimately used by the consumers. For instance, cooking gas, petrol can be used directly by the end use consumer. Electricity can be produced from diesel which is a product of crude oil. Electricity, for an example, is an end-use energy and provided to the consumers under the controlled by licensed Utility companies of the country (for example PHCN is there for Nigeria). The electricity utilities of the given society generate electricity from a collection of different sources such as fossil fuel, nuclear fuel and or renewable energy sources depending on the energy resources available to a nation. The energy processes start from the primary energy source, undergo transformations and gets to the final tilized on stage in the form of end- use energy. All the energy forms may not be tilized by the economy of a society. Utilisation and use depends on the following: energy requirements of an economic sector, energy forms required and the means/ methods of producing the forms of energy needed.

5.4.2 Energy Flow- Chart

The energy flow chart below provides an elaborate description of the concepts.

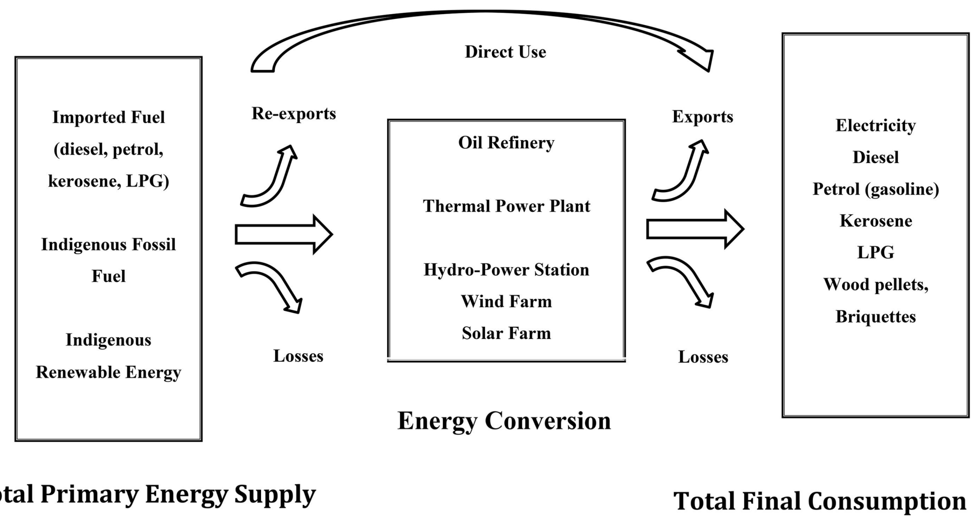

Fig. 5.2: An Energy Flowchart Depicting the Flow from Primary to End-Use Energy

Self- Assessment Exercise 3

(1) Distinguish between primary and end- use energy

(2) Sketch Energy Flow-chart from Primary to End- Use Energy

5.5 Summary

This unit discussed the categorisation of energy sources into non-renewable and renewable on one hand; and into primary and end- use forms of energy on the other hand. Non – renewable energy sources are being used up and cannot be replenished within a short time. Renewable energy sources are continuously replenished by nature and cannot easily run out of supply. Primary energy is the original form the energy is existing before being transformed to other forms. End- use energy is that which has undergone transformations in the energy chain processes to reach the final form of consumption by consumers.

5.6 References/ Further Readings

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5.7 Possible Answers to Self- Assessment Exercises

Answer to SAEs 1

NON- RENEWABLE ENERGY SOURCE		RENEWABLE ENERGY SOURCE
1.	Cannot be easily replenished in a short time and cannot be used again and again	Can be replenished by nature in a short period of time and can be used again and again
2.	Occurs in limited and exhaustible quantities	Derived from a source that has no possibility to run out of supply (Available in abundance)
3.	The need for judicious use of non- renewable energy sources are often emphasised	Energy resources may not always be available in ample amount when needed and everywhere
4.	Make the greatest contribution to the world energy use today	Not necessarily market ready due to the expensive technology involved. Contribution to world energy use is limited
5.	It has a more damaging effect on the environment	It's sources are environment friendly naturally (alternative to fossil fuels)

2. Three (3) examples of non- renewable energy resources in Nigeria are crude oil, coal and natural gas. Three examples of renewable energy resources in Nigeria are water (hydro power), solar and wind

Answer to SAE 2

Drawing of the pie chart as displayed in figure 5.1 above

Answer to SAE 3

Primary energy resources are available at the starting point of the energy chain. End- use energy sources are being used by the energy consumers at the other end of the energy chain. Primary energy constitutes the original form of energy and can come from either non-renewable or renewable energy sources. End use energy is the energy that is transformed for final consumption through various processes e.g cooking gas, petrol, diesel, electricity. The energy processes start from the primary energy source, undergoes transformation and gets to the final utilisation stage in form of end- use.

SAE 4

Sketch the energy flow chart showing flow from primary to end-use energy in figure 5. 2 above.

MODULE 3 ENERGY DISSIPATION, CONSUMPTION AND ENERGY CRISIS

Unit 1 Energy Dissipation
Unit 2 Forms Consumption
Unit 3 Energy Equation
Unit 4 Energy Crisis and Its Mitigation

UNIT 1 ENERGY DISSIPATION

Unit Structure

1.1 Introduction
1.2 Intended Learning Outcomes
1.3 Energy Dissipation
1.4 Energy Dissipation Devices and Types
1.5 Factors for Selecting Energy Dissipater
1.6 Summary
1.7 References/ Further Readings
1.8 Possible Answers to Self- Assessment Exercises (SAEs)

1.1 Introduction

Welcome to Unit 1 of Module 3 of this course. You should now be familiar with what energy means, its measurement, forms of its existence and various sources of energy. We have further decided to discuss **energy dissipation** in this unit. Do well to pay rapt attention to this aspect of energy as a concept. **What can you say has happened when a snooker ball is slid on the snooker board, it moves quickly, then slowly and gradually comes to a stop?** It is the kinetic energy of the ball that decreased and has made the ball to gradually come to a stop. This means that the kinetic energy of the ball has been **dissipated** through friction. This unit focuses on the meaning and circumstances of energy dissipation, energy dissipation devices and factors for selecting energy dissipater. It's a pleasure to have you in this class.

1.2 Intended Learning Outcomes

By the end of this unit, you will be able to:

- define energy dissipation
- give at least three examples of energy dissipation in your environment
- name and explain any two energy dissipation devices and types
- enumerate the factor for selecting energy dissipater.

1.3 Energy Dissipation

Energy dissipation is a physical process through which energy becomes unavailable and irrecoverable in any form. **Energy Dissipation** is defined as the process in which energy is used or lost without accomplishing useful work as friction causing loss of mechanical energy. An example is the cooling of a body in an open air. When a hot object is exposed to an open air, it gradually losses heat to the environment. The lost heat is no longer available to the object. During energy dissipation, energy is transformed from some initial form to some final form making the capacity of the final form less than that of the initial.

In what other circumstances must energy be dissipated? It is necessary to artificially dissipate energy under certain circumstances. For instance, excess kinetic energy of flow must be dissipated downstream of the hydraulic structures specially built for the purpose of energy dissipation commonly known as energy dissipater in hydroelectric dams. This is because the excess kinetic energy of the stream causes flow distortion resulting in highly non-uniform velocity distribution. This flow distortion that results in the highly non-uniform velocity distribution makes it difficult to generate electricity from the dam. Hence, energy dissipaters are deployed to contain any excess energy flow.

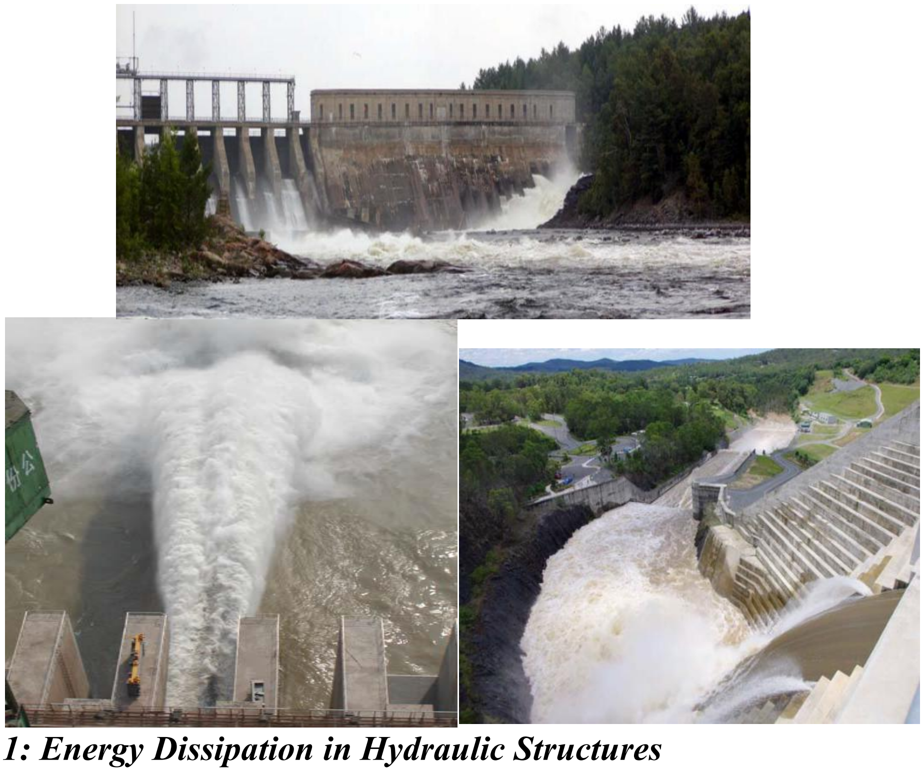

Fig. 1.1: Energy Dissipation in Hydraulic Structures

Self- Assessment Exercise (SAE) 1

Attempt these exercises to measure what you have learnt so far. This should not take you more than 5 minutes.

(1) Define energy dissipation.

(2) Give three examples of energy dissipation process in your environment.

1.4 Energy Dissipation Devices and Types

Technological advancement has enabled the development of innovative design and construction of large dams, reservoirs and channels with the provision of adequate flood release facilities. In hydroelectric dams, hydraulic structures enable the spillage of large water discharges (using spillways, dam outlets, drops, regulators flow meter/ flood control, and reservoir) without a damaging effect on the structure itself and to its environment. The hydraulic structure makes provision for the flood waters to rush in an open channel flow or free- falling jet. It is extremely necessary that excess kinetic energy of flow must be dissipated downstream of the hydraulic structures specially built for the purpose of energy dissipation (commonly known as energy dissipater) and with the aim of preventing damage to the hydraulic structure and its surroundings.

A wide range of design techniques are used to achieve energy dissipation. Recent development is making energy dissipation feasible along the chute, in a downstream energy dissipater or a combination of both. Engineers must take cognizance of the complexity of energy dissipater designs with special consideration to the physical processes taking place and the structural reinforcement required. Failure has been witnessed with several energy dissipaters, spillways and storm waterways because of poor engineering design. Poor knowledge and lack of understanding of the turbulent dissipation and basic interaction processes between free-surface aeration and flow turbulence is a major issue for Engineers.

There are several types of energy dissipaters used in dams. Selection of a particular type of energy dissipaters depends upon the amount of energy to be dissipated and erosion control required downstream of a structure.

- Hydraulic jump and stilling basin: is defined as a dissipater in which whole or part of a hydraulic jump is confined. In this type of dissipater, the energy is dissipated by formation of hydraulic jump within the basin after free over-fall.

- Water cushion (plunge pool type dissipater): in this type, the nappe impinges into the stilling water cushion below. There is no clear standing wave formation and the energy is dissipated by the turbulent diffusion as the high velocity jet enters the deep pool on the downstream.
- Sold roller bucket type dissipater: an upturn sold bucket is used when tail water depth is much in excess of sequent depth and in which dissipation of considerable portion of energy occurs as a result of formation of two complementary elliptical rollers, one in the bucket proper is called bucket roller, which is anti-clockwise (if the flow is to the right) and the other downstream of the bucket called ground roller which is clockwise.
- Slotted roller bucket type dissipater: an upturn bucket with teeth in it used when the tail water is much in excess of sequent depth and in which the dissipation of energy occurs by lateral spreading of jets passing through bucket slots in addition to the formation of two rollers as in solid roller bucket.
- Ski-jump (flop or trajectory bucket) type dissipater: an upturn solid bucket is used when the tail water depth is insufficient for the formation of hydraulic jump and the bed of the channel downstream comprises of sound rock which is capable of withstanding (without excessive scour), the impart of high velocity jet.
- Other design techniques available are block ramps, stepped spillways & cascades and impact dissipaters

Self-Assessment Exercise 2

Attempt these exercises to measure what you have learnt so far. This should not take you more than 5 minutes.

1) *Describe energy dissipation device in two sentences?*
2) *Mention and explain 3 types of dissipater.*

1.5 Factors for Selecting Energy Dissipater

The following factors are considered in selecting the type of energy dissipater

- Type of dam and its spillway
- Frequency and intensity of flood flows
- The degree of protection to be provided for high floods
- Proximity of power house, tail race and other structure
- Velocity and nature of flow
- Elevation of tail water at various discharges
- Nature of foundations
- Type and amount of bed material rolling on the spillway

- Safety of existing structure downstream
- Hydraulic approach conditions including specific discharge, energy head of approach flow, head loss and type of outlet.

Self-Assessment Exercise 3

Attempt this exercise to measure what you have learnt so far. This should not take you more than 5 minutes. *Enumerate 5 factors responsible for selecting energy dissipater*

1.6 Summary

This unit focused on energy dissipation, what causes it, energy dissipation devices, dissipaters and factors considered in their selection. Energy dissipation explain how mechanical energy (kinetic energy) is either used or lost without accomplishing useful work which is caused by friction. You can explore the abundant knowledge on the world web for further information on energy dissipation and other aspects of it.

1.7 References/ Further Reading

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1.8 Possible Answers to Self- Assessment Exercises (SAEs)

Answers to SAE 1

1) Energy dissipation is a physical process through which energy becomes unavailable and irrecoverable in any form. EITHER Energy dissipation is a physical process in which energy is transformed from some initial form some final form making the capacity of the final form less than that of the initial. OR
Energy dissipation is a system in which mechanical energy (kinetic energy) is either used or lost without accomplishing useful work which is caused by friction.
Any of the above definition is acceptable

2) Three examples of energy dissipation in our environment:

(a) In hydroelectric dam, excess kinetic energy of flow is being dissipated downstream of the hydraulic structures built for the purpose of energy dissipation. The energy dissipaters are deployed to contain any excess energy of flow.

(b) In reservoirs and channels, innovative designs are provided for adequate flood release facility and enable the spillage of large water flow/ discharges.

(c) In hydraulic structures, provision is made for flood waters to rush in an open channel flow or free- falling jet with the aim of preventing damage to the hydraulic structure and its surroundings.

(d) In the game of snooker ball, when a snooker ball is slid on the snooker board, it moves quickly and then slowly, as the kinetic energy of the ball decreases and gradually comes to a stop. The kinetic energy of the ball has been dissipated through friction.

(e) The cooling of a body or hot object in an open air involves energy dissipation. The cooling process involves the gradual loss of heat to the environment.

Answer to SAE 2

1) Description of energy dissipation device in two sentences:

Energy dissipation device is a technology innovative design, facility or construction that enables the discharge of excess kinetic energy in a system. A wide range of design techniques and structures are used as energy dissipation devices and often called energy dissipaters.

2) Choose any three of your choice out of the six dissipaters discussed in the unit lesson. Any Three types of dissipaters:
   (i) Hydraulic jump and stilling basin
   (ii) Water cushion (plunge pool type dissipater)
   (iii) Ski- jump (flop or trajectory bucket) type dissipater

   The explanation for the above mentioned dissipaters can be gotten from the main body of the unit lesson.

Answer to SAE 3
Five factors responsible for selecting energy dissipater:

(i) Frequency and intensity of flood floor
(ii) Hydraulic approach conditions including specific discharge, energy head of approach flow, head loss and type of outlet
(iii) Safety of existing structure downstream
(iv) Nature of foundations
(v) Degree of protection to be provided for high floors

UNIT 2 ENERGY CONSUMPTION

Unit Structure

2.1 Introduction

From energy dissipation discussed in the first unit of this Module, we progress to energy consumption. In this unit, search-light is beamed on Energy consumption, with particular mention of the various energy users and categories of Usage. We discuss the use of energy at every moment, how it sustains life and its use to run lives. In this unit we examine the concept of energy consumption to make us realize how important energy is to our daily survival.

2.2 Intended Learning Outcomes

By the end of this unit, you will be able to:

- discuss briefly the four or five main categories of energy users
- explain the purposes for which energy is used in residential and commercial buildings
- list five major categories of energy-intensive industries
- state the reasons for the differences in energy consumption among countries
- outline 3 ways of reducing energy consumption.

2.3 Energy Consumption: Energy Users

Use the link below to learn more about energy consumption:
Energy Consumption - an overview | ScienceDirect Topics
What are the common instances of man's daily activities involving energy consumption? For instance, you wake up in the morning, stretch your muscle and jump into your bathroom, energy is being used. You turn on the tap and warm water comes out from your water heater and after your bath, you switch on your radio to listen to the news. Then, you land on your dining table to eat so that you can have energy for the day's work. You then enter your car and off you go to work. Your car is driven on chemical energy. Getting to your place of work, you enter an elevator, the elevator is powered by electricity and as soon as you enter your office, the first thing you do is to switch on the light, and then boot your computer, and on and on it goes in that order on daily bases. This illustration tells us how much of energy we consume in a day.

Energy users can be categorised into five:
1. Residential
2. Commercial
3. Industrial/ Factory
4. Transportation and
5. Electric Power

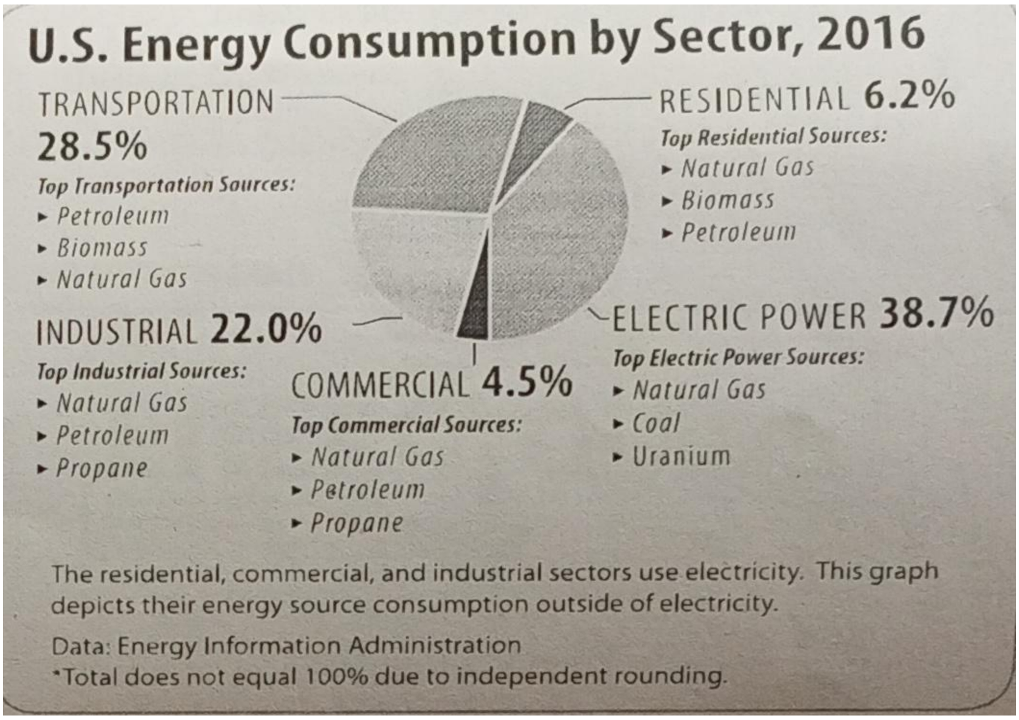

Fig. 2.1: U.S. Energy Consumption by Sector, 2016. (Source: The NEED Project, 2018)

2.3.1 Residential and Commercial Use of Energy

The residential and the commercial uses of energy are taken together for discussion because the uses to which energy is put in both instances are similar. Any place where people live is considered a residential building. Commercial buildings include offices, stores, hospitals, restaurants, and schools. Energy is used in residential and commercial buildings for **heating and cooling, lighting, heating water, and operating appliances.** In developed countries, electrical energy dominates the type of energy used for residential and commercial purposes. In Nigeria, however, power supply has remained a serious problem for decades. Hence, people have resorted to the use of generators at homes and offices. Artisans (e.g. tailors, hairdressers, welders etc.) depend on electrical power for their work. Without this, they cannot work efficiently because the machines they use are driven by electrical power.

2.3.1.1 Heating and Cooling

In cold countries, rooms and offices have to be heated and in hot countries, air conditioners have to be used at home and offices to make life comfortable. It takes a lot of energy to heat rooms in winter and cool them in summer. In the United States for instance, it has been reported that fifty-six percent of the energy used in the average home is for heating and cooling rooms. The three fuels used most often for heating in the United States are natural gas, electricity, and heating oil. Today, more than half their homes use natural gas for heating followed by electricity. Electricity also provides almost all of the energy used for air conditioning. It is hoped that in the near future, renewable energy sources will be the main resource for heating and cooling homes and workplaces.

2.3.1.2 Lighting

Homes and commercial buildings also use energy for lighting. In the developed world, electricity is the main source of power for lighting. However in developing countries e.g. Nigeria, most homes rely on chemical energy (kerosene) to produce light when it is dark. The invention of the fluorescent bulb has helped improve energy conservation. The incandescent bulbs that are still commonly used in developing countries (because they are cheaper to buy) are not efficient because about 90% of the energy that produces the light is lost as heat. Fluorescent lighting costs more to install, but it uses a lot less energy to produce the same amount of light. As a consequence of Act enacted at the global regulatory body lately on Energy Independence and Security, most traditional, inefficient incandescent light bulbs have been phased out and no longer fashionable for consumers use. End- users have to choose any of the available energy – saving fluorescents or halogen light bulbs in the market. The new lighting systems use less percentage of energy and last three times as long. More efficient Compact fluorescent light bulbs (CFLs) and Light emitting diodes (LEDs) can be used as light fixtures in homes, businesses and workplaces. Apart from being affordable option for lighting, they use less energy and lasts longer than the traditional incandescent bulbs.

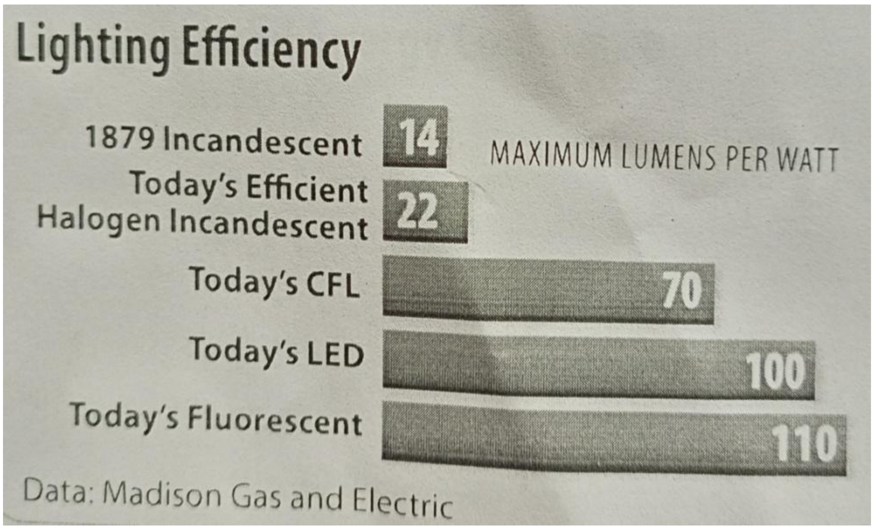

Fig. 2.2 Lighting Efficiency of Different Bulbs Produced

Fig.2.3: A Fluorescent Bulb

2.3.1.3 Operating Appliances

Advancements in science and technology have led to the production of many energy efficient appliances. Today, we use many more appliances than before and they have changed the way we spend our time at home. Chores that used to take hours can now be done in minutes by using electricity instead of human energy. Water heaters, refrigerators, clothes washers, and dryers all use much less energy today than they did 30 years ago. Users of appliances are advised to learn the **Energy Efficiency Ratio (EER)** of the appliance which reveals how much it costs to operate the appliance. This information is contained on the yellow Energy Guide Label on every appliance. Also consider the payback period of the appliance being purchased. The **payback period** is the amount of time the appliance must be operated before reaping the benefit of the energy- saving -capacity. Most high- efficiency appliances cost more than less efficient ones. This explains the need to be acquainted with the yearly cost of operating the appliance and the number of years it can still be used.

2.3.2 Industrial/ Factory

The industrial sector has to do with companies engaged in different kinds of enterprises ranging from manufacturing, construction, mining, farming, fishing, forestry and to factories among many others that consume energy. Countries that are highly industrialised use a lot of energy. Every industry uses energy, but six energy-intensive industries could be identified. They are:

- Petroleum refining industry
- Steel manufacturing industry

- Aluminum Manufacturing industry
- Chemical Manufacturing industry
- Paper & Pulp Manufacturing industry
- Cement Manufacturing industry

Short notes on the six energy- intensive industries mentioned above:

2.3.2.1 Petroleum Refining Industry

Petroleum refining industries, for example, oil refineries use enormous amount of energy to convert crude oil into gasoline, diesel fuel, and aviation fuel, heating oil, chemicals and other related products.

2.3.2.2 Steel Manufacturing Industry

Steel manufacturing industries use great amount of energy to turn iron ore and metal scraps into steel which are useful in the production of hundreds of steel products put into utilisation on a daily basis. Steel is very hard and durable metal that must be heated at a very high temperature which takes lot of energy to manufacture.

2.3.2.3 Aluminum Manufacturing Industry

Aluminum manufacturing industries consume huge amount of electrical energy to make aluminum from aluminum ore or bauxite. Aluminum is a light- weight, versatile metal and finds use in the production of soft drinks cans, building materials, car parts, foils and several other products. Recycled aluminum is less energy consuming than converting bauxite into metal.

2.3.2.4 Paper and Pulp Manufacturing Industry

The paper and pulp manufacturing industry uses energy to chop, grind and cook wood into pulp. More energy is used to roll and dry the pulp into paper for everyday use. Recycled paper lowers the energy in paper and pulp manufacturing industries, but it costs money to collect, sort and process the waste paper for recycling. Paper and pulp are utilized in making newspapers, books, bags, boxes and other products.

2.3.2.5 Chemical Manufacturing Industry

Chemical manufacturing industries use great amount of energy partly to power the machinery used in making the chemicals; and partly to produce hydrocarbons from which the chemicals are made. To power the machines, coal, oil and natural gas can be used. The hydrocarbons used in making chemicals are sourced from petroleum, propane and natural gas. Chemicals are used in the production of medicines, cleaning products, fertilizers, plastics and many other products.

2.3.2.6 Cement Manufacturing Industry

Cement manufacturing industries consume a lot of energy in making cement. Concrete is made from cement, water and crushed stone and with or without sharp sand usable every day in the construction of roads, bridges, buildings and other different kinds of constructions. Energy consumption in cement plants can be reduced by the use of innovative waste -to -energy programmes. Such wastes include printing inks, dry cleaning fluids, used tires and could have wasted in a landfill.

2.3.3 Transportation

Automobile vehicles are major means of transportation. Modern automobile vehicles have been designed to consume less fuel. We are also learning to choose rightly when we want to buy automobiles. A major factor that people now consider in purchasing automobiles is fuel efficiency. Trucks, trains, and aircrafts also use fuel. Technologies are continually being advanced to produce automobiles that consume lesser amount of fuel. Automakers have recently made advances in automobile technology leading to the production of smaller and lighter cars and with smaller and more efficient engines. Fuel use in transportation is consumed by passenger cars, light trucks, commercial vehicles (e.g. trains, light rail, sub-way, trucks, buses, ships and airplanes). Commercial vehicles carry people and products all across the vast country and oversea. Commercial vehicles are made today with great improvement in the energy efficiency. Mass transit is public transportation for moving people around the cities or from suburbs to cities and from suburb to suburb. Workers commuting to work places can use public transit systems. If public transit is made convenient and cost made reasonable/ affordable, people may leave their cars at home. So doing, traffic congestion will reduce and the worry about air pollution will be mitigated.

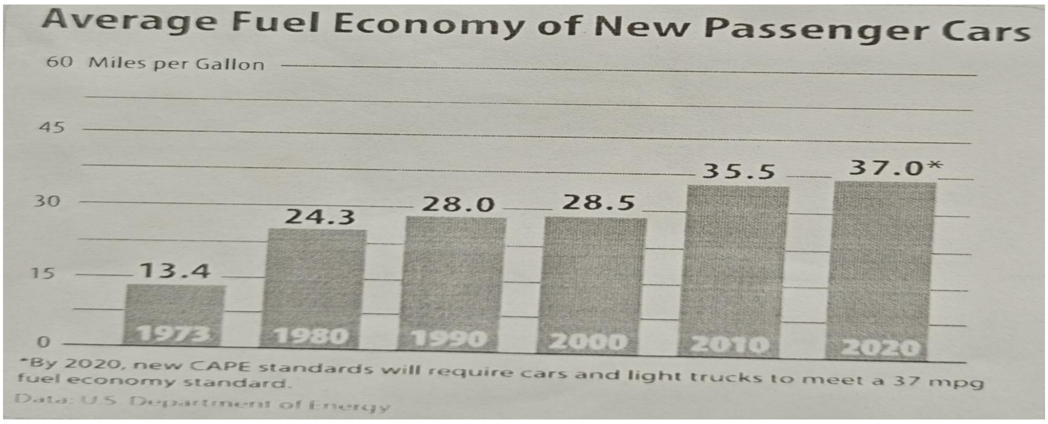

Fig.2.4 : Average Fuel Economy of New Passenger Cars. (Data: US Department of Energy)

2.3.4 Electric Power

Electric power sector includes electricity generation facilities and power plant. All other sectors utilise electricity generated by electric power for different purposes. The electric power sector consumes a lot of energy (more than any other sector) from both non-renewable and renewable resources.

Self-Assessment Exercise 1

Attempt these exercises to measure what you have learnt so far. This should not take you more than 5 minutes.

(1) List five categories of major energy users.

(2) Write short note on 3 uses of energy in residential and commercial buildings.

2.4 The World's energy supply sources

The World's energy consumption for the year 2008 is shown in the figure 2.5

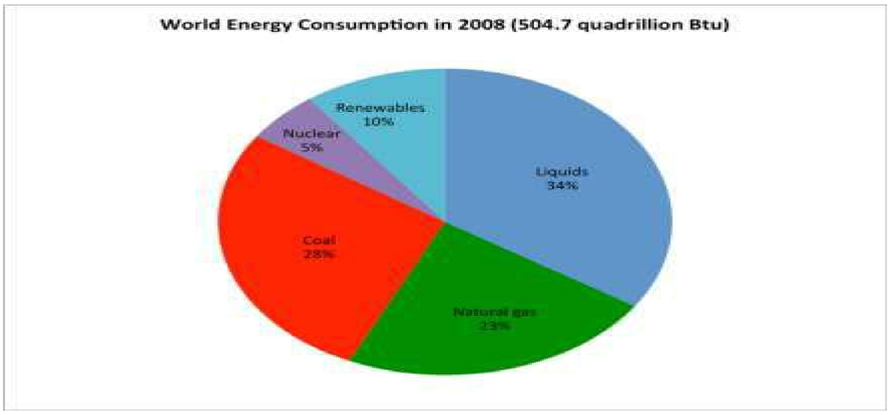

Fig. 2.5: World energy consumption in 2008

2.4.1 Three World's Largest Energy Sources Compared

Table 2.1 : Three of the World's Largest Energy Sources

Three of the world's largest energy sources

	Future Outlook	Advantages / Disadvantages
Oil	It is the world's foremost source of Primary energy consumption, and it is expected to remain in that position throughout the 2008 to 2035 period.	Robust Growth in Transportation energy use—Overwhelmingly Fueled by Petroleum products—is Expected to continue until 2035. As a result, oil is Projected To Retain its predominance In the Global energy mix and meet 29% of the total Primary energy consumption in 2035.
Natural Gas	Expected to remain an important supply source for New Electric power Generation in The future (23% of the total primary energy in 2035).	it is seen as the desired option For Electric power, given its Relative efficiency and environmental Advantages In comparison with other Fossil energy sources. Natural Gas burns more cleanly than either coal or oil, making it a more Attractive choice for countries Seeking to reduce greenhouse gas emissions.
Coal	World coal use has been in a period of generally slow growth since the 1980s, and that trend is expected to continue Through the projection period. Coal use will continue to dramatically increase in developing countries, but in Developed or industrialized	Coal use is projected to increase in all regions except for Western Europe, Eastern Europe And The former Soviet Union (excluding Russia), Where coal is expected to be displaced by natural gas and, in the case of France, Nuclear power, for Electric power

	countries, it will not increase but may slightly decrease.	generation. Large increments in coal use are projected for developing Asia, Especially in China and India. World coal consumption increased sharply from 2003 to 2004, largely because of a 17-percent Increase in China and India. Coal remains a vital fuel for world's electricity markets and is expected to continue to dominate energy markets in developing Asia.

2.4.2 Causes of Disparity in Energy Consumption Rate among Nations

The differences in energy consumption among countries are the result of:

- efficiency of industrial, transportation, commercial, residential energy and electric power sectors' energy demand,
- climatic peculiarity and geographical area of a country;
- lifestyles (use of more gas guzzling cars and SUVs and bigger size houses);
- The nature of the products produced by the nations' industries

Reducing Energy Consumption

Energy Consumption can be reduced through the following strategies: Energy conservation (i.e. the practice of decreasing the quality of energy being used), efficient energy use, practice energy mix, enact policy that supports efficient energy use, energy transformation.

Effects of energy consumption manifest in form of the environmental impact from industries and the problem of global warming.

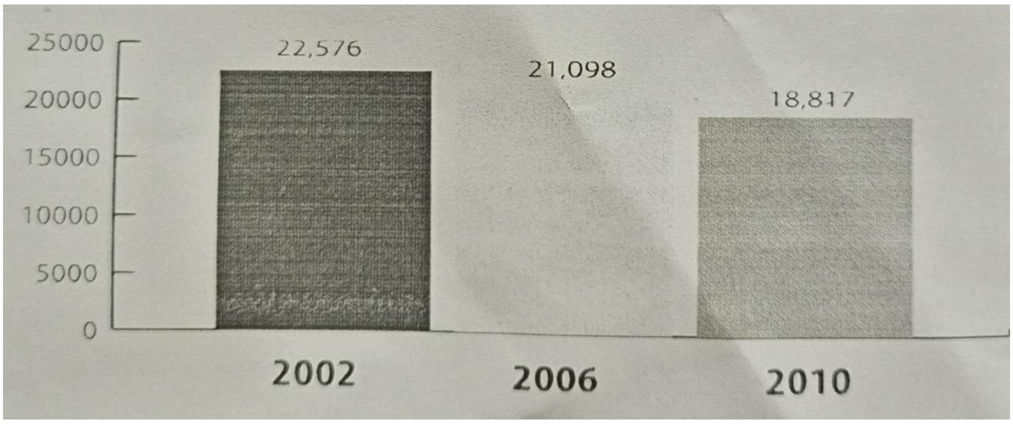

Fig. 2.6: Reduction in Manufacturing Energy Use, 2002 – 2010. (*Data; Energy Information Administration)*

With advancements in technology and increased efficiency and conservation measures, the total U S manufacturing energy consumption decreased by 17% from 2002 to 2010.

Self-Assessment Exercise 2

Attempt these exercises to measure what you have learnt so far. This should not take you more than 5 minutes.

(1) State 3 reasons for the difference in energy consumption among nations,

(2) *Mention three ways to reduce energy consumption rate.*

2.5 Summary

In this unit, we have highlighted that mankind depends on energy for everyday activities. Energy use is called **energy consumption**. It is also discussed that **energy uses can be classified into residential**, **commercial**, **industrial**, **transportation and Electric power sector**. The unit also focused on the differences in energy consumption among countries which primarily is the result of efficiency in energy demand, climatic condition, geographical areas of a country and the people's lifestyles.

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2.6 Possible Answers to Self- Assessment Exercises (SAEs)

Answers to SAE 1

1) Five categories of major energy users:

- Residential energy users
- Commercial energy users
- Industrial/ Factory energy users
- Transportation
- Electric Power

2) **Any three uses of energy in residential and commercial buildings**:

- ➢ Use of energy for Heating and Cooling
- ➢ Use of energy for lighting
- ➢ Use of energy for operating appliances

Answers to SAE 2
Any three reasons for the difference in energy consumption among nation:

(i) Efficiency in energy demand used for industries/ factories, electric power supply, transportation, commercial and residential facilities/ equipment
(ii) Climatic peculiarity and geographical area of a country

(iii) Lifestyle of people in the society
(iv) Nature and quality of products produced by nations industries

Answer to SAE 3
Any three ways to reduce energy consumption rate:
(i) Energy conservation (i.e practice of decreasing the quality of energy being used)
(ii) Enact policy that supports efficient energy use of energy
(iii) Practice energy mix

UNIT 3 ENERGY EQUATIONS

Unit Structure

3.1 Introduction
3.2 Intended Learning Outcomes
3.3 Energy Equations
 3.3.1 Energy Mass Relationship
 3.3.2 Energy Dissipation in Reversible and Irreversible Process
 3.3.3 Kinetic and Potential Energy Expressed Mathematically
3.4 Summary
3.5 References/Further Reading
3.6 Possible Answers to Self-Assessment Exercises

3.1 Introduction

You have learnt about energy dissipation and energy consumption in the last units of this module. **Did you remember in Module 1 about Energy being described as a quantitative phenomenon that can be measured?** In the study of the relationship between energy and matter, some mathematical relationships have been established between various parameters. Such parameters include mass, velocity, weight, height etc. This unit focuses on these relationships that have been mathematically established by scientists. Pay rapt attention as three mathematical energy equations are considered.

3.2 Intended Learning Outcomes

By the end of this unit, you will be able to:

- formulate the mathematical equations for rest energy as presented by Albert Einstein
- state the mathematical equations for kinetic energy
- explain down the mathematical equations for potential energy
- describe the relationship between the parameters involved in these equations.

3.3 Energy Equations

Use the link below to learn more about energy equation:
Energy Equation - an overview | ScienceDirect Topics

From energy mass relationship, the equations for resting energy, kinetic and potential energy are derived. Energy dissipation in reversible and irreversible process is briefly discussed. The law of conservation of mass is combined with the law of conservation of energy for ordinary chemical reactions.

3.3.1 Energy Mass Relationships

The law of conservation of energy states that energy can neither be created nor destroyed. **What about mass? Can mass be created or destroyed?**

The law of conservation of mass states that mass is neither created nor destroyed, and the total mass of substances involved in a physical or chemical change remains unchanged. For instance, if 4.032g of Hydrogen reacts with 31.9988g of Oxygen to produce 6.0308g of Water, the sum of the masses of the reactants is equal to the sum of the mass of the product, and hence mass is neither created nor destroyed.

Mass and energy are equivalent. Any object with mass when stationary also has an equivalent amount of energy existing in a form called rest energy. Any additional energy of any form acquired by the object that is above the rest energy will increase the object's total mass just as it increases its total energy. In 1905, Albert Einstein concluded from his observations that mass and energy are related; and quantified the relationship between rest- mass and rest- energy within the concept of special relativity. He posited that mass, by its very nature is energy called rest energy which is represented by the famous equation.

$$\mathbf{E = mc^2}$$

where, E = Energy equivalent of the mass, m = mass of the body, and c = velocity of light in vacuum (free space) = 3×10^8 m/s. According to this relationship, if one gram of mass was completely converted to energy then 2.15×10^{13} calories of heat energy would be liberated. This amount of heat would raise the temperature of 215,000,000 kgs of water from 0 to 100°C! Similarly, according to this equation, a hot potato weighs more than a cold one, however, the change in mass may be too small to detect. Part of the rest energy (which is equivalent to rest mass) of matter may be converted to other forms of energy, but neither energy nor mass can be destroyed

In ordinary chemical reactions, the energy changes involved are relatively small (in the order of $5 X 10^{-4}$ J or$5 X 10^{-5}$J) and the mass change is of the order of $2X10^{-9}$ to $2 X 10^{-8}$gms, which is too small to be detected on most balances. In the reaction of hydrogen and oxygen to form water the loss of mass would amount to about $5.35 X 10^{\wedge -9}$gms. However, in nuclear reactions, the amount of mass converted to energy is quite significant and is great enough to be detected but we can still conclude that the law of conservation of mass is valid for ordinary chemical reactions. Hence, to be completely accurate, we must combine the Law of Conservation of mass with the Law of Conservation of Energy and state that **the total of the mass and energy can neither be created nor destroyed and this total is constant.**

Self-Assessment Exercise 1

Attempt these exercises to measure what you have learnt so far. This should not take you more than 5 minutes.

1) Highlight the relationship between mass and energy.
2) *Express the mathematical equations for rest energy as formulated by Albert Einstein, explaining what the variables denote.*

3.3.2 Energy Dissipation in Reversible and Irreversible Process

Thermodynamics divides energy transformation into: reversible and irreversible processes. An irreversible process is one in which energy is dissipated (spread) into empty energy states available in a volume, from which it cannot be recovered into more concentrated forms without degradation of more energy. A reversible process, energy is dissipated into states from which it can be recovered. For example, in a pendulum system, conversion of energy from one type of potential field to another is reversible. As the universe evolves in time, more and more of its energy is trapped in irreversible states as heat or some other kinds of increase in disorderliness. In this condition, the energy of the universe may not change, but the fraction of energy available to do work by being transformed to other usable forms of energy grows less and less.

3.3.3 Kinetic and Potential Energy Expressed Mathematically

When an object moves, the change in position of the object indicates that the object is moving. This energy of the object which results from this movement is called Kinetic energy. Kinetic energy (KE) of an object is normally expressed in terms of the mass of the object and its velocity because both mass and velocity are properties of the object. It is mathematically expressed as

KE= $1/2mv^2$ Joule (J) = kg m^2 sec^2
Where m = mass in Kg and v= velocity in metre per second
Example: A stone of mass 20kg is dropped from a height of 175 m. Determine the kinetic energy of the stone at t = 2.0 sec.
Answer:

KE = $\frac{1}{2}mv^2$ where m = mass, v = velocity = $\frac{\text{distance}}{\text{time}}$

V = 175/2 = 87.5m/s

KE = ½ x 20 x 87.5 x 87.5 = 76563 J

If an object describes both linear and rotational motion like the wheel of a moving bicycle, then KE = $1/2mv^2$ x Lw^2 where w = velocity in rotational motion = $\sqrt{(2\alpha\Theta)}$
$\tau = I\alpha$ where τ = torque, I = moment of inertia and α = angular acceleration
for linear motion, v = $\sqrt{2gh}$ where velocity for linear motion, g = acceleration due to gravity, h = height.
The elastic potential energy possessed by a stretched spring is given by

$$E_p = ½ F.\varkappa = ½ \kappa\varkappa^2$$

Potential energy (PE) is energy possessed by an object at rest. However, potential energy is converted to Kinetic energy when the object moves. The potential energy of an object due to gravity is mathematically expressed as
PE = weight x height Joule (J) or kg m^2 sec^2.
For example, If the mass of a stone is 10 kg and the height above the ground is 10 m, what is the potential energy possessed by the stone?
Answer:

PE = mgh
= 10 x 10 x 10
= 1000 J

Self-Assessment Exercise 2

Attempt this exercise to measure what you have learnt so far. This should not take you more than 5 minutes.
A stone of mass 15 kg dropped from a height 50 m.

Determine the kinetic and potential energy of the stone at

3.5 sec.

3.4 Summary

In this unit, energy is expressed mathematically in form of equations. Resting energy is expressed as $E=mc^2$. The energy mass relationship, reversible and irreversible processes as it concerns energy transformation and the expression of kinetic and potential energy in mathematical forms were discussed. Kinetic energy is expressed as KE= $1/2mv^2$ Potential energy due to gravity is PE = weight x height

3.5 References/Further Reading

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3.6 Possible Answers to Self-Assessment Exercises

Answer to SAE 1

1) Mass energy relationship: Mass and energy are equivalent. Any object with mass when stationary also has an equivalent amount of energy existing in a form called rest energy. Any additional energy of any form acquired by the object that is above the rest energy will increase the object's total mass just as it increases its total energy. In 1905, Albert Einstein concluded from his observations that mass and energy are related; and quantified the relationship between rest- mass and rest- energy within the concept of special relativity. He posited that mass, by its very nature is energy called rest energy which is represented by the famous equation.

$E = mc^2$
where, E = Energy equivalent of the mass, m = mass of the body, and c = velocity of light in vacuum (free space) = 3×10^8 m/s. According to this equation, a hot potato weighs more than a cold one, however, the change in mass may be too small to detect.

2) *Albert Einstein* posited that mass, by its very nature is energy called rest energy which is represented by the famous equation.
$E = mc^2$
where, E = Energy equivalent of the mass, m = mass of the body, and c = velocity of light in vacuum (free space) = 3×10^8 m/s. According to this relationship, if one gram of mass was completely converted to energy then 2.15×10^{13} calories of heat

energy would be liberated. This amount of heat would raise the temperature of 215,000,000 kgs of water from 0 to 100°C!

Answer to SAE 2

Answer: Kinetic Energy of the stone:

$KE = \frac{1}{2} mv^2$ where m = mass, v = velocity = $\frac{\text{distance}}{\text{time}}$

V = 50/3.5 = 14.3m/s

KE = ½ x 15 x 14.3 x 14.3 = 1534 J

Potential energy of the stone:

PE = mgh

= 15 x 10 x 50

= 7500 J

UNIT 4 ENERGY CRISIS AND ITS MITIGATION

Unit Structure

4.1 Introduction

Welcome to the last unit of the last module for this course. It is certain by now that you are acquainted with energy dissipation, energy consumption and energy equation as discussed in the last units. From previous studies you can appreciate the fact that human beings need energy for survival and development. However, in this unit, energy is described as a limited resource and also creates environmental problem. This is a source of serious concern to living things particularly mankind. Instances and reasons for energy crisis are considered in this unit. Also some methods for mitigating the challenge are explored.

4.2 Intended Learning Outcomes

By the end of this unit, you will be able to:

- explain the term “energy crisis”
- itemise three reasons behind energy crisis
- describe various methods of mitigating the energy crisis
- **Use the link below to learn more about global energy crisis and strategies for its mitigation:**
- Causes, Effects and Solutions to Global Energy Crisis

4.3 Energy Crisis

Have you ever pondered on the reason for the slow pace of development in Sub-Saharan Africa and other developing nations of the world? This trend can be attributable to paucity of energy supply and availability. For example the instability in electricity supply in the nation and frequent power outages particularly in rural communities are consequence of energy insufficiency and poor management of the limited energy resource.

4.3.1 Incidence of Energy Crisis

Every activity of mankind involves the use of energy of different forms. As human needs continue to grow with increasing population, demand for energy continues to grow as well. Energy crisis is a condition in which a society suffers frequent disruptions in energy supplies due to large and expanding gaps between energy availability and energy demand. Energy crisis is often accompanied by very high prices of energy resource which threaten economic and social development. Global demand for energy in recent years is experiencing a surge particularly those being used as fuel for industrial development, population growth and supply of electricity to national grids. Energy crisis pertains to the growing demands on limited resources with the threat of the limited resources running out of supply. The world's energy supply, as at today is majorly sourced from oil, coal and natural gas. These natural resources are in limited supply and diminishing as demands for them are rising. The availability of these energy resources are very limited, and predicted not to last beyond a few decades from now. To replenish the stores, it will take hundreds of thousands of years.

Apart from depletion of the energy resources on-going, some environmental problems are being created by the continual use of these resources particularly the non- renewable energy resources. Burning of fossil fuels releases greenhouse gases (e.g. CO_2, CO and others). **What are the hazards posed by the release of these greenhouse gases to the environment?** These gases create a blanket on the earth's surface responsible for tearing the ozone layer and preventing the release of the sun's short rays at night and making the earth warmer by promoting global warming. It may be difficult to bridge the gap between energy demand and energy supply in Nigeria and other developing nations, even if more of these resources are mined every day. Households in Nigeria had to resort to different tasking self-help and stressful means to source fuel for cooking purposes due to the high cost of kerosene and cooking gas. The common man cannot afford the high cost of fuel for cooking purposes. The increasing prices of gas and petrol at the pump station as well as the worsening cases of long lines at filling stations make the problem of energy crisis a reality to the common man. Apart from being exorbitant, reliance on firewood and charcoal has led to deforestation and pollution. There is also the concern about the future of energy resources that the next generation will inherit and efforts to cushion the effect.

4.3.2 Reasons for Energy Crisis

Reasons behind most energy crisis in societies revolve around the following:

(a) Over reliance on limited and exhaustible energy sources such as oil deposits and coal. The strain on natural resources such as fossil fuels is being traced to over-consumption which in turn constitutes a strain on other resources resulting in dire consequences to humanity and living things generally.

(b) Widening gap between demand and supply of energy is causing pressure and strain on the limited available ones. Increase in world's population, growth of human civilization and its demands for energy is draining the energy resources at a faster rate.

(c) Price increase of energy at the global market and inability of international organizations (such as OPEC charged with the responsibility of regulating prices of energy resources such as crude oil, gasoline, natural gas etc.) to live up to expectation.

(d) Lack of political will to invest in alternative and renewable sources of energy (e.g. solar, wind, bio-energy etc.) which can be more environmentally friendly and readily available at a cheaper rate. Renewable energy resource still remains untapped in most nations of the world.

(e) Wastage and misuse of the available limited energy resources. People in some parts of the world do not appreciate the need to conserve energy. Ignorance and paying of lip service by the enlightened ones towards energy conservation needs is a source of concern. The abuse and wastage of energy can occur due to neglect of simple guidelines, such as switching off energy using gadgets (e.g. fans, light bulbs etc.) when not in use, walking/ trekking instead of driving over short distances, use of Compact fluorescent light bulbs (CFLs) and Light emitting diodes (LEDs) for illumination instead of the traditional bulbs, proper insulations to prevent leakage of energy etc.

(f) Natural disasters and accidents. Examples of natural disasters that can disrupt energy supplies include: volcanic eruptions, floods, earthquakes, hurricanes/ heavy destructive storms, landslides, wild-fire etc. Accidents can occur with the distribution system, for example, pipeline burst.

(g) Insecurities and War situation can cause interruption in the energy supply as witnessed in Middle East countries experiencing insecurities and war. The Gulf war of 1990 caused price increase of oil that led to global shortage which created problems to energy consumers dependent on the supply.

(h) Other factors that can cause energy crisis include the following: poor energy distribution system, network and bad policies; strike by trade unions in oil producing firms, coup d' tat and political upheavals; hike and spike in tax; sudden increase in demand for energy occasioned by extreme weather condition, for example, severe hot summer or very cold winter can be a cause of sudden high energy demand.

Self-Assessment Exercise 1

Attempt these exercises to measure what you have learnt so far. This should not take you more than 5 minutes.
(1) Describe Global energy crisis in 2 minutes?
(2) Outline any three effects of energy crisis.

4.4 Mitigating Energy Crisis

Any significant bottleneck in the supply of energy resources to an economy can result in energy crisis and certain conscious efforts and steps can be taken to mitigate the crisis.

4.4.1 Methods of Mitigating the Energy Crisis

(a) Everyone should make sincere efforts to save and conserve energy. Governments of nations and their agencies, concerned non-governmental organisations and individuals can work together to lessen the irresponsible use of natural supplies through increased conservation. An energy conservation approach in people's daily lifestyles can be initiated to aid the solution to the problem of energy crisis. Some useful tips on how to save energy can be inculcated into the citizenry through mass media campaign and social media enlightenment, symposia, conferences, seminars and other non-formal, social and mass literacy programmes and other public awareness creation media. Saving of energy can be undertaken by the public in the following ways: electrical appliances (e.g. fans, bulbs etc.) can be switched off when not in use, water taps should be turned off after use, more energy-efficient appliances should be used, car - owners should use public transport system provided by the government instead of driving alone to offices and business centres, soak food grains and substances in water before cooking and don't use excess volume of water when cooking. All hands must be on deck to minimise energy loss.

Consumers of energy are encouraged to use energy- efficient products. This type of products consumes fewer watts of electricity and can last longer. Compact fluorescent light bulbs (CFLs) and Light emitting diodes (LEDs) are recommended for lighting system for residential and commercial purposes. If this is done, the demand for energy is reduced and the energy crisis can be mitigated. Also cash is saved in the long run.

(b) Renewable energy resource should be promoted as better alternative against the use of non-renewable sources. Stakeholders should make the use of renewable resources a priority. The energy crisis is becoming intense due to the environmental hazards, degradation and threats of depletion associated with the non-renewable energy sources, not leaving out the high cost of maintenance. Nigeria is generally considered to have a rich renewable energy sources. Such renewable energy sources that can be invested upon include: solar power, hydroelectric power, wind power, biogas and biofuel etc. Solar technology is a key source of modern day electricity generation in various parts of the world. Nigeria lies within a high sunshine belt and within the country; solar radiation is fairly and well distributed. Private households/ home owners also want to have a sense of environmental responsibility and control over energy production.

Businesses have realised the need to mitigate the risk of relying entirely on external energy suppliers. Both residential and industrial energy consumers are realizing the need to invest in solar in order to have more control over their future energy bills.

(c) Ingenuity can be applied by utilising agricultural produce in the production of ethanol and biofuel. Such agricultural crops that can be used include sugarcane and vegetable oils.

(d) Other ways of mitigating the energy crisis include the following: use of energy simulation software by corporate organisations to redesign building unit and come up with better energy efficient building, also reduce carbon impact. One can identify the areas where homes and offices are losing energy through energy audit and take steps to improve the energy efficiency. A common approach towards energy matter can be taken by developing and developed countries in synergy with international organisations charged with responsibility of mitigating energy crisis. Efforts must be focused on cutting emissions to halve the current emission rate by 2050.

4.4.2 Energy Efficiency

Energy efficiency economies and soci higher GDP, huge increased productiv consumer surplus a pollutant emissions.

Attempt this exercise to measure what you have learnt so far. This should not take you more than 5 minutes.

1. *Explain any three methods of mitigating the problem of energy crisis in Nigeria.*
2. *Mention four things that energy efficiency can do?*

Self-Assessment Exercise 2

Attempt this exercise to measure what you have learnt so far. This should not take you more than 5 minutes.

3. *Explain any three methods of mitigating the problem of energy crisis in Nigeria.*
4. *Mention four things that energy efficiency can do?*

4.5 Summary

In this unit, we have discussed the meaning of energy crisis as pressure and disruption in the management and supply of energy occasioned by increasing gap between energy demand and supply. Effects of energy crisis to the environment and the depletion of resources are outlined and reasons and causes of global energy crisis were explored. The various ways of mitigating the energy crisis are examined finally.

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4.7 Possible Answers to Self-Assessment Exercises

Answers to Self-Assessment Exercise 1

1) **Description of global energy crisis:** Global energy crisis can be described as the instability created by the paucity of energy supply and availability in a society. It is a condition in which a society suffers frequent disruption in energy supplies due to large and expanding gaps between energy availability and energy demand. For example, the erratic and frequent power outages in Nigeria are consequence of energy insufficiency and poor management of the limited energy resource available.

2) **Three effects of energy crisis:** Households in Nigeria had to resort to different tasking self-help and stressful means to source fuel for cooking purposes due to the high cost of kerosene and cooking gas. The common man cannot afford the high cost of fuel for cooking purposes. The increasing prices of gas and petrol at the pump station as well as the worsening cases of long lines at filling stations make the problem of energy crisis a reality to the common man. Apart from being exorbitant, reliance on firewood and charcoal has led to deforestation and pollution. There is also the concern about the future of energy resources that the next generation will inherit.

Answer to Self Assessment Exercise 2

1) 3 Methods of mitigating energy crisis in Nigeria:

(a) Renewable energy resource should be promoted as better alternative against the use of non-renewable sources. Nigeria is generally considered to have a rich renewable energy resource. Such renewable energy sources that can be invested upon include: solar power, hydroelectric power, wind power, biogas and biofuel etc. Solar technology is a key source of modern day electricity generation in various parts of the world. Nigeria lies within a high sunshine belt and within the country; solar radiation is fairly and well distributed.

(b) An energy conservation approach in people's daily lifestyles can be initiated to aid the solution to the problem of energy crisis. Some useful tips on how to save energy can be inculcated into the citizenry through mass media campaign and social media enlightenment, symposia, conferences, seminars and other non-formal, social and mass literacy programmes and other public awareness creation media.

(c) Ingenuity can be applied by utilizing agricultural produce in the production of ethanol and biofuel. Such agricultural crops that can be used include sugarcane and vegetable oils.

2) **4 things Energy Efficiency can do: (a)** Energy efficiency can lead to job creation and self- reliance. (b) It can result in a significant reduction in greenhouse gas and pollutant emissions (c) It can manifest into an improved and better public budget balance by the state (d) Energy efficiency can lead to increased productivity in different sectors of the economy and higher GDP.