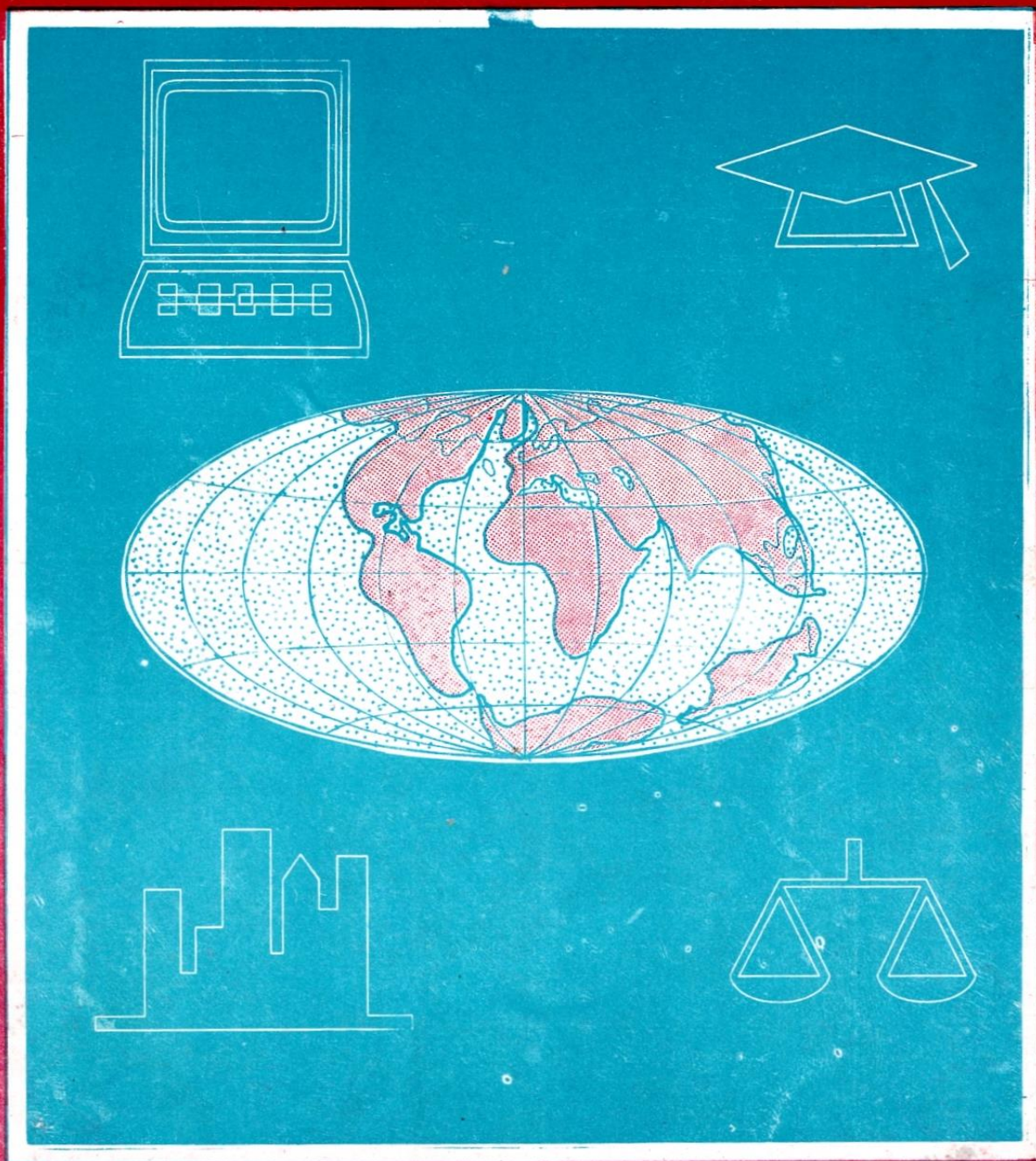


TECHNOLOGY, SCIENCE AND ENVIRONMENT; A CURRENT OVERVIEW.



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Chapter Eleven

Man and Energy Resources: The Lithospheric and Synthetic Sources

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The power by which material body or radiation uses to do any form of work is called energy. This implies that everything that works need energy. All around us are many things including plants and animals that do one form of work or the other. They all need energy which exists or manifests in different forms. For example, from fire can be derived heat and small amount of light energy. Enormous quantity of light and heat energy comes in the form of solar illumination. Plants use the light energy to manufacture their food which is stored up as chemical energy; when burnt, the chemical energy turns into heat energy. When herbivorous animals eat the plants they also inherit the energy from the plants. So also do carnivores derive energy by eating other animals. That means energy can be transferred. It can also be converted from one form to another but cannot be destroyed. Dead plants and animals have their energy returned to the earth. But every time energy changes form some heat of low level form is lost into the atmosphere or the central pool. Energy can be converted from one form to another but the total quantity remains the same in accordance with the conservation law.

Energy derived from position is potential energy (P. E.). The stretched spring, for example has elastic potential energy. Water in the overhead tank has potential gravitational energy. Fossilized plants which come in the form of petroleum, lignite, anthracite and graphite among others and oxygen necessary for combustion have chemical potential energy due to relative positions of the atoms in them. Waves that strike the coastal rocks, running water that erode the soil and wind that bend the trees have mechanical energy. Different forms of energy therefore exist around us.

The original, major and most enduring source of energy is the sun. But the earth also has an enormous store-house of energy: fossil fuel (coal, petroleum, natural gas), mineral energy (uranium), and heat or geothermal energy, among others, which are either directly or remotely related to the sun: the ultimate source of all energy forms.

Classification of Sources of Energy:

Energy sources can be either renewable (income) or non-renewable (capital), according to their characteristics. Table 11.1. summarizes energy sources into cosmic, atmospheric, biospheric (biome), lithospheric, hydrospheric and synthetic. These are sub-grouped with relevant examples.

Non-Renewal (Capital) Energy:

The energy sources that are exhaustible and unreplenishable are usually referred to as the capital sources of energy. Apart from the fact that they can be easily used up, such energy sources also require large capital supply in the form of money, equipment, human and material resources. They are also very easily depleted while their production, transportation, distribution and utilization processes can be very hostile and destructive to the environment if carelessly handled.

All lithospheric (except the geothermal sources) and synthetic sources of energy (except alcohol fuel sources) are largely non-renewable.

Table 11.1 Energy Sources and Examples

Source	Types and Examples	Renewability
Cosmic and Atmospheric	Solar energy (sun) - photosynthesis - solar panels - solar electricity - solar cells	Renewable
	Lunar energy (moon) - Tidal energy	
	wind - aerogenerators	
Biospheric (Biomic)	- Plant - Fuelwood - Charcoal - Alcohol - Oil (palm, groundnut, castor, cashew, etc) - Methane (gas) - Food/drink	Renewable
	Animal - Oil (whale, cod, etc.) - Physical energy (horse, camel, elephant) - Food/drink - Fuel (dung)	
Lithospheric	Geothermal - hot springs - geysers - fumaroles	Renewable
	Fossil: Solid - peat, lignite, anthracite, graphite, shale. Liquid - petroleum, Slime. Gas - natural gas	Non-Renewable
	Metallic: Uranium - nuclear	
Hydrospheric	wave - duck hydro-electricity - dam tidal energy (lunar induced) - dam	Renewable
Synthetic	Mineral - Shale oil - Coal gas/liquid	Non-Renewable
	Plants/animals - Alcohol fuel	Renewable

Lithospheric Sources of Energy:

These sources, generally derived from the earth, include fossil, metallic and geothermal energy sources.

They are briefly discussed below:

Fossil Fuels:

These are organic substances that occur naturally in three major forms: solid, liquid and gas. They originate from decayed remains of biome (plants and animals) that have undergone series of metamorphic processes over millions

of years. Fossil fuels are hydrocarbon compounds. These mineralized remains occur as sediments and in sedimentary rocks. Sometimes they are exposed through seepage or erosion to the surface of the earth. Their discovery, wide application and use, organized distribution and associated technological innovations have serious global environmental consequences as well as socio-political, health and economic implications of universal dimensions.

Fossil fuels in solid forms (Coal):

This non-renewable hydrocarbon appears in its solid form generally as coal. As rocks of fossil origin, coal results from mineralized transformation of ancient decayed plant matter that having been buried in swampy environment passes through centuries of progressive compression and heating process. For example, when sand or mud buries partially decayed plants in swamp so that the original water and volatile contents are driven off and with high pressure the original materials are progressively transformed into coal.

Coal can be classified on the basis of its calorific value or percentage of carbon and volatile content. Whereas carbon produces steady hot smokeless flame, volatiles burn with long smoky flame. Following this criteria, coal can be classified into peat, lignite, bituminous coal and anthracite.

Peat:

Peat is a soft crumbly fibrous and spongy substance, brown to black coloured. It contains little carbon but much water and volatiles. Peat is the first stage of coal formation. It usually occurs in open bog environment in most parts of the world where the presence of water does not allow for immediate decay and oxidation of plant remains. Owing to this partial mineralization process, peat usually retains some of the structure of the original vegetative matter as its volatile content. Most peat bogs are made up of mosses, sedges and rushes. They occur most under humid atmosphere especially where mean annual temperatures are below $45^{\circ}F(8^{\circ}C)$.

Peat varieties are useful for various purposes including mulching, potting compost and insulation. They can also be cut into turfs, stacked away to dry and used as low-grade fuel for home heating. Some small-scale industries in temperate regions rely completely on peat fuel partly because it is cheap and widely available and partly because of the technological structures of such industries. Peat burning is however one major source of environmental pollution because of its high carbon dioxide output.

Lignite:

This is also known as brown coal. This type of coal still retains much of its soft woody texture reflecting the physical and chemical traces of its vegetative fibrous origin. It represents a mid-way stage in the mineralized transformation process between peat and the bituminous coal. Lignite burns easily. It has low percentage of carbon content and much water. It produces black bituminous smoke. It can also be distilled to produce acetic acid and coke. In some countries, for example the scandinavia, it is used mostly to generate thermal power.

Bituminous Coal:

This is the most common form of coal. It has black shiny banded structure and burns with smoky flame. Its fixed carbon is relatively higher than that of

Formation of Petroleum:

Scientists generally accept that petroleum originates from decomposed microscopic marine or vegetative matter such as plankton. Their dead bodies which accumulate on the sea-beds are decomposed by bacteria which turn them into "sapropel" (organically formed slimy sediment in muddy water). These contain droplets of oil which get stocked up in the muddy sea bottom sediment. With time, the mud hardens into shale. Increasing heat and pressure from accumulated materials set in to gradually transform the chemical composition of the sapropel into series of hydrocarbons (82-87%), hydrogen (12-15%), sulphur (1-5%) and small quantities of nitrogen and oxygen.

Petroleum forms as mineral oil droplets in the shale. These droplets are gradually squeezed out owing to increasing heat and pressure from the materials that have accumulated for millions of years. The squeezed oil droplets, compelled by the increasing pressure, also gradually "migrate" sometimes for hundreds of kilometres to regions of lower pressure especially where such regions provide suitable conditions for its accumulation.

Among others, the following four major geological conditions are necessary for trapping of petroleum in the rock (see also figures 11.1 (a) to (c)).

- (a) **Sandstone formation:** Sandstone is mechanically formed permeable sedimentary rock type. It has spaces which the mineral oil can occupy. Sandstones are usually derived from sand grains and quartz fragments of granite origin.
- (b) **Oil traps:** Most often, dome-shaped sandstone anticline formations provide suitable traps for the mineral oil. The anticlines are the "up-fold waves" of the earth crust. Mineral oil usually occupy the crest of the anticlines. Oil can also be trapped in faults where pervious and impervious rock strata are juxtaposed. Mineral oil in volcanic areas are also possible. Here, impermeable dyke can intrude into alternating rock layers and trap mineral oil.
- (c) **Non-porous (impermeable) rock layers:** Mineral oil deposits are usually trapped between two layers of non-porous or impermeable layers called impervious cap rocks. They seal up the oil.
- (d) **Gas-oil-water arrangement:** Mineral oil is usually trapped between gas above and water below. This conforms with Archimedes' hydrostatic equilibrium which states that a body floats or sinks depending on whether the buoyancy is less or greater than the weight of the body. That means the body which is heavier than the liquid will sink to the bottom of the liquid. In order to tap the oil, the natural gas above it must first be controlled. This accounts for the gas flaring which is often associated with mineral oil drilling in Nigeria. This practice is not only wasteful in terms of the natural resources (gas) but is also very hostile to the environment.

Mineral oil has a wide variety of uses in Nigeria. Apart from contributing to over 90% of Nigeria's foreign earning and being a major employer of labour it is the source of petrol, kerosene, diesel oil and various forms of petrochemical and related industrial inputs.

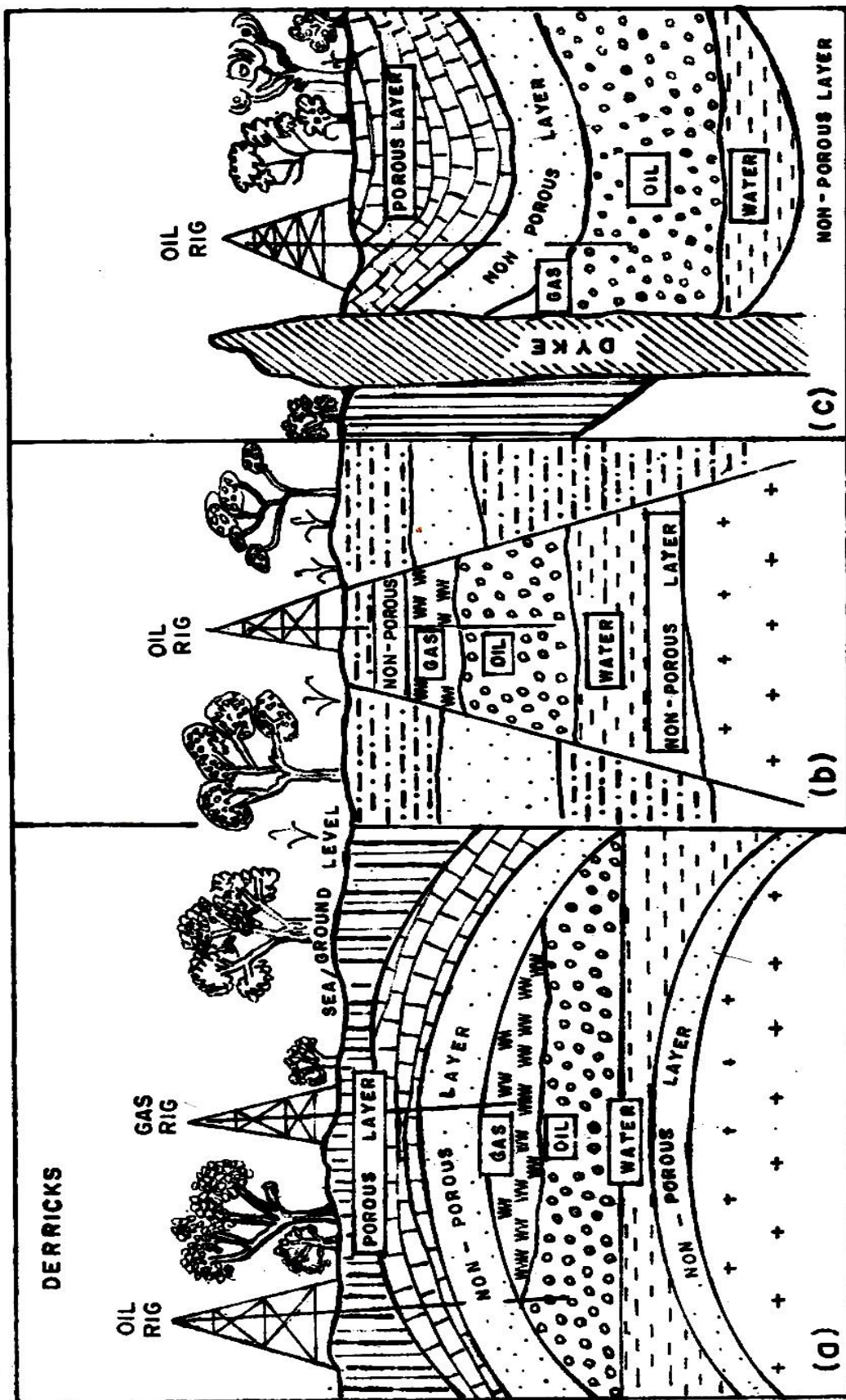


Figure 11.1 Anticline, Fault and Dyke traps of mineral oil.

- (a) Anticline formation: Mineral oil in the crest of an anticline.
- (b) Mineral oil trapped in a fault.
- (c) Mineral oil trapped by a dyke

Natural gas: Fossil fuel in gaseous form:

Natural gas is often found in close association with mineral oil. It is a mixture of flammable gases: methane (being the main one), ethane, propane and butane which are all hydro-carbons. However natural gas also include small amount of other gases. It can sometimes occur on its own without close association with mineral oil. It can also be completely dissolved within the mineral oil.

Natural gas is burnt as fuel both for domestic and industrial uses. The propane component of natural gas along with other heavier fractions know as *natural gas liquids* are removed for additional processing because of their increasingly high market value as petrochemical and chemical inputs. Two forms of gas: associated and non-associated gas exist. The associated gas is the natural gas components that come together with crude oil. Its higher, more volatile components are obtained after the heavier, less volatile components have been extracted. The non-associated gas, on the contrary is extracted directly from the gas well. It has higher gas-to-oil ratio than the associated gas form.

Natural gas can be used as an energy source. It is usually cheaper, cleaner and more environmentally friendly. It is also a requirement for chemical and petrochemical industries including ammonia, methanol and fertilizer. Gas is also very useful for domestic purposes such as cooking, house heating, refrigeration and air conditioning. Glass, ceramic, paint, printing and textile industries use gas for a variety of purposes. The manufacture of carbon black for tyre production also requires the use of gas. From the above it is obvious that natural gas has some advantages over other fossil fuels. For example, natural gas burns smokelessly, consequently it is more economical. Maintenance cost for clearing up of burner tips, clearing of soot, ash handling and deposition, clearing up of oil sills, repainting of soot-covered structures and equipment is almost nil. For direct firing it is quite efficient. It is more environmentally friendly because it produces neither smoke nor ash. Gas burning can also be more easily controlled than other fossil fuels. It is more versatile and continuous supply can be better assured.

Three forms of processed natural gas can be found in Nigeria. These are:

(a) Compressed Natural Gas (CNG):

Natural gas in compressed form is an alternative to petrol. Attempts to convert petrol-driven vehicles to compressed natural gas is still at the experimental stage although success has been reported at a small scale.

(b) Liquefied Natural Gas (LNG):

Natural gas in liquid form. It is most economically transported to remote areas where piping is not feasible. One cubic metre of natural gas occupies $\frac{1}{600}$ of its gaseous volume when liquified. Consequently large volumes of natural gas can be transported most cheaply to the receiving region where it is regasified and piped for local consumption. The liquefaction process involves cooling the predominantly methane gas to about -161°C by removing water, acidic gases, lighter molecular weight hydrocarbons and other impurities. The purified gas is then passed through heat exchanger and refrigerant before transferring to LNG storage facilities. The LNG is an export-oriented project located in Bonny, Rivers State.

(c) Liquefied Petroleum Gas (LPG):

It is a mixture of propane and butane, liquified at room temperature under slight pressure as opposed to the LNG which is under -161°C . It is the cooking gas.

Fossil Fuels in Nigeria:

Nigeria is very rich in fossil fuels (coal, gas and petroleum). The exploitation of the mineral oil and natural gas concentrate in the south, along the coastal areas (on-shore) and on the continental shelf (Off-shore). However, five oil-rich zones have been identified in Nigeria. They include the Niger delta which is extensively explored and exploited already; the Chad Basin, the Sokoto Basin, the Dahomey basin and the Benue trough are yet to be.

Although oil exploration started in Nigeria (1937) before the second world war, its export began in 1958 with crude oil production of 5,000 barrels per day (bpd). In 1979 crude oil production stood at 2.3 million bpd. Currently the Organization of Petroleum Exporting Countries (OPEC) guidelines restrict Nigeria to about 1.7 million bpd although her production capacity far exceeds that. These sell for about (\$18.00) eighteen US dollars (or over N360.00) per barrel (using 1992 average exchange rate). The price however fluctuates between seventeen and over twenty dollars per barrel. Nigeria has over 3.1 billion barrels of crude oil and over 75 trillion standard cubic feet of gas based on the fully explored zones only.

The Nigerian crude oil is light and almost sulphur free. It is generally classified as Bonny Light. It is better preferred to the heavy oil because it is less polluting to the environment when burnt. Experts however agree that fossil fuels are non-renewable and the petroleum will one day be exhausted in Nigeria in spite of the newly discovered oil reservoirs. This timely warning presupposes the urgent need to diversify the economy, fully utilize the natural gas instead of flaring it, judiciously invest the oil revenue and focus better on sustainable development of the economy.

Coal is less widely distributed in Nigeria. Its major location is around Enugu where mining started in 1915. Coal is also found at Okaba, Ankpa and Lafia. But Nigeria's coal is graded as sub-bituminous which means it still retains high percentage of its soft woody texture and consequently has low carbon content, burns slowly and smokes thickly with pungent odour. Lignite (brown coal) of tertiary age is more abundant and is wide-spread in Nigeria than its sub-bituminous counterpart. Its deposit extends from Benin City in Edo State across River Niger to Abia and other eastern states. The Nigerian lignite has low calorific value which is about the same with the sub-bituminous coal.

Geothermal Energy:

Energy generated within the earth or lithosphere by radioactive processes set in motion by such elements as uranium, thorium and potassium is referred to as geothermal energy. Literally, it means earth heat. Geothermal energy is an income or renewable source of energy. Like the solar energy it can be regarded as an external source of energy.

Materials thrown out by volcanic eruptions, borehole drillers and miners of petroleum, coal and other deepseated minerals have confirmed the findings made by geophysicists, geologists and other earth scientists that the temperature of the lithosphere generally increases with depth. The rate of increase

may be almost zero. To tap the geothermal energy in such region demands that the engineers should, among other activities:

- (a) bore two adjacent holes right into the hot dry-rock zone;
- (b) shatter the surrounding rocks (possibly using hydrofracture process - a process of using water under high pressure to break up the rock);
- (c) pump surface water into one of the holes; harness the jets of steam from the other hole to turn turbines which generate electricity (see Figure 11.2).

Metallic (Nuclear) Energy:

This is an energy source of uranium (metallic) origin. Like other metals, uranium occurs in the form of ore which is a valuable deposit of solid sediment or rock. Ores occur naturally as mineral aggregates that have potential economic and other values. When processed through smelting, ores can yield one or more metals. Uranium belongs to the group of actinides, that is any element with atomic number between 89 and 105. All actinides are radioactive. Some other actinides include radium, actinium, thorium. They emit alpha particles, beta particles and gamma rays.

Uranium was first recognized in 1789 by Martin Heinrich Klaproth. It was first isolated from the oxide in 1841 by Eugene Melchoir Peligot. Uranium ores occur naturally as uranium oxide (UO_2), that is as a compound of uranium, oxygen and other minerals. Two forms of uranium oxides are commonly found. These are uraninite (otherwise referred to as pitchblende) and carnotite. Uraninite is mostly uranium oxide in composition while carnotite has a more complex composition. Uranium oxides occur in different parts of the world, most especially in Niger, South Africa, Zaire, Canada, USA, Australia, New Zealand and Japan among other countries.

As a natural resource, uranium (U) occurs in three varieties or isotopes. An isotope is one of two or more atoms with fixed atomic number (number of protons) but different number of neutrons, hence the difference in atomic mass. For example, uranium commonly has 92 protons but since it occurs in three forms the difference in the atomic mass among the forms result in the variety in the number of neutrons. Uranium - 238 (U-238) has 146 neutrons, U-235 has 143 and U-234 has 142 neutrons in addition to the fixed number (92) of protons each.

Although uranium is a very important source of energy because of its strategic and economic importance, it poses one of the most dangerous threats to the human race and the entire ecosystem. Its production, processing, transportation, distribution, use and by-products need perfect handling to avoid devastating consequences. A minor mishandling, a minute leakage or an iota of its exposure to the atmosphere without adequate control is capable of large scale permanent destruction of all life and property. Its destructive effects could last for over 100 years. One recent example is the Chernobyl nuclear leak of April, 1986 which caused environmentally destructive effects, scientists agree may not be completely cleared within the next 100 years. The destructive effects of that single minor nuclear leak was so devastating that people had to be permanently evacuated within 30 km (19 miles) radius of the power plant. Toufexis (1990) points out that the minor leakage will cost over 358 billion US dollars to clean up and pay for damaged agricultural produce. The land, plants, animals, water, air, equipment, buildings and furniture were completely

polluted by the destructive nuclear radiation. Genetic mutation is one obvious consequence of even a minor exposure to it. The radioactive isotopes of the Chernobyl leak were traced to Sweden, north of Chernobyl and thousands of kilometres away.

Synthetic fuel (Synfuel) Sources:

The synthetic sources of energy are also known as synfuels. Their major sources are coal, shale and alcohol. Only the last is a renewable energy source. Researchers in synfuels are gradually expanding in developed countries, particularly in the U.S., as an alternative to the existing energy forms. An understanding of the major objectives of researches into synfuels can be very instructive to the developing nations. These include, among others, the need to:

- (a) attempt to solve energy problems;
- (b) enhance conservation and sustainable development;
- (c) economize the use of all forms of energy; and
- (d) develop additional forms of energy from untapped natural resources.

It is believed that effective development of synfuels need international co-operation, especially among the "hi-tech" countries including the United States, Japan and Germany among others. This is partly because of the high level of technology involved and partly because such projects are highly capital-intensive. Although synfuels sources are the conventional ones, the process and products have new perspectives, new dimensions and demand new technologies.

Coal Sources:

Coal as a source of synthetic fuel yields coal gas and coal liquid which are cleaner and more efficient fuels than coal. Moreover, coal is very widely available in many parts of the world. Large expanse of coal reserves, especially with the advent of petroleum, have been left untapped in many parts of the world. In Nigeria, coal mining had sharply declined with increasing exploration, mining and use of its petroleum alternative. Petroleum is better preferred because it has various advantages over coal: it is cleaner, more portable, easier to light and less polluting. *Gasification* and *liquefaction* of coal have therefore been thought of as two ways that coal can be made to acquire some of the characteristics that petroleum has over it. Both the gasification and liquefaction processes begin with pulverisation.

Coal Gasification:

Coal gasification is the process of generating gas from coal. Coal gas was first used in the 18th century. But it was expensive, dirty and inefficient. However up to the early 1930's residential gas used in developed countries was mostly coal-derived.

Coal gasification begins with pulverisation or the crushing of coal into its powdery form. The powdered or pulverised coal is then distilled by heating under great pressure. It is then oxygenated and hydrogenated before passing through a set of catalytic reactors and purifiers. The coal gas is finally piped for domestic and industrial uses. But owing to the variety of coal quality, coal gasification process may vary greatly or slightly. Some coal types gasify easily

while others tend to coke, swell and stick together when heated. Coal gas may however not be easily stored. It has limited use in chemical industries.

Coal Liquefaction:

The process of producing oil from coal is known as coal liquefaction. The rationale for its use stems from the wide availability of coal in many parts of the world coupled with the ever increasing prices of petroleum. Coal liquid and petroleum are essentially the same when used.

Two main liquefaction processes (direct and indirect) are known to scientists. The direct liquefaction process involves the Hydrogen-Coal (H-Coal) method and the Solvent Refined Coal (SRC) technique. The H-Coal method adds hydrogen to coal paste, passes it through a catalytic reactor and squeezes oil out. The Kentucky experiment uses the H-Coal method to get an average of three tons of oil from one of coal.

The SRC technique mixes the pulverised coal with coal oil to form coal paste which is subjected to intense heat (over 450°C) and pressure (about 140 kg/cm^2). This treatment dissolves the coal paste which then combines with hydrogen to form coal oil. The by-product (ash and sulphur) have agricultural and chemical values while the environment stands to benefit.

Shale Oil and Shale Gas:

Shale is a fine-grained black sedimentary rock with very thin layers. It is a kind of consolidated mud or clay rock that readily splits into thin laminae along its bedding-planes (rather than splitting into flakes as mudstone). Geologists refer to oil shales as maristone. Essentially oil shales are immature oil-yielding rocks. They contain high quality hydrocarbons called *kerogen* which when heated to about 482°C produces oil and gas of very high quality (most often of higher quality than petroleum).

Shale oil can be produced by either the *Above-ground* or *In-situ* methods. The former technique involves conventional mining, pulverisation and distillation of oil away from the mining site. This old and conventional method is plagued with problem of waste disposal because the processed oil shale is toxic; it also easily doubles its original size. Consequently the left-over becomes hazardous to the environment, most especially as its original mine pit can contain only about half of the processed oil shale volume. Its toxic content also forbids its deposition anywhere close to source of surface or underground water. Moreover, the oil shale waste has no known use and no technology exists yet for its recycling.

The *In-situ* method is therefore considered as an alternative. It is more current and more environmentally sustainable. One form of the in-situ technique involves, among others, four major activities. These are:

- (a) mining out about 20% of the oil shale to form an underground compartment;
- (b) shattering the oil shale cavity with explosives to create an underground chimney;
- (c) igniting the top of the shattered oil shale for shale oil to flow to the bottom of the underground compartment; and
- (d) pumping out the shale oil from the bottom of the oil shale well while the shale gas is piped from the top.

It is noteworthy that the synfuels so far discussed are non-renewable or capital rather than income energy sources. They are both exhaustible and non-sustainable energy sources. However the alcoholic energy sources are renewable and more sustainable.

Alcohol fuels:

Solar energy is trapped by plant tissues in the form glucose, maltose, starch (carbohydrates) from which alcohol is derived. Alcohol fuels are produced from a wide variety of plant sources collectively referred to as biomass. They have found ready use in the automobiles. In Brazil, for example, where alcohol fuels are widely used there is a well-developed gasohol program. Gasohol is a mixture of 90% petrol (gasoline) with 10% ethyl alcohol or ethanol. Ethanol can be derived from grains such as maize and wheat, from root crops such as potatoes, cassava and sugar beet, and from stems such as sugar cane and palms, among others, through the process of fermentation and distillation. The by-products have agricultural values in terms of animal feed.

Alcohol fuels seem to have one major obstacle: diversion of food crops towards ethanol production. This could raise food prices beyond what the ordinary man can cope with. The ultimate social, economic, political and environmental effects could be disastrous.

Closely associated with ethanol is methane gas which is derivable from decaying plants and plant-related garbage kept in oxygen-free containers called digesters. Bacteria which work without oxygen can then break down such garbage to produce methane (gas) which can be piped or bottled for domestic or small-scale industrial use. The by-products of such process have ready use as organic fertilizer.

Implications of Synfuels for the Future:

Synfuels production may be plagued with major social, economic, technological and environmental problems, among others. Rising demand for skilled labour, coal, oil shale and their miners, for example can generate increased labour cost which can also add up to the over-head cost of the synfuels. It can also stimulate employment opportunities by creating new jobs.

Coal and oil shale are the two major mined sources of Synfuels. Most often mining results in serious environmental damage. Consequently there is need to re-emphasize environmental rehabilitation so that the land where coal and oil shale had been mined can be restored. The problem of waste disposal, especially as regards shale oil production has already been identified. Acid rain and air pollution arising from increased production of synfuels may however not occur. The reason is that during processing of oil shale and coal into synfuels, the sulphur compounds combine with other materials and are removed in solid form, hence they cannot get into the atmosphere.

Increasing food prices arising from diversified use of food crops can stimulate more growth of food. But it can also result in increased pressure on the marginal land and rising demand for inorganic fertilizers which can add to pollution, forest depletion, environmental degradation and other hazards. All these have inter-related economic, social and technological consequences.

Synfuels should however be seen as only a small portion of the total human energy requirement. Its dynamics, logistics and the sustainability value should be appraised in terms of balance between the economy, future requirements

and sustainability of the environment, given appropriate technology as a base line.

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