UNIT 10: POWER AND ENERGY PRODUCTION IN THE WORLD

Key unit competence:

By the end of this unit, I should be able to evaluate the success of sustainable development projects in power and energy production in different parts of the world.

Introductory activity

1. Observe pictures provided below and answer the following questions:

i. Identify the types of power and energy shown above.
ii. Which ones are renewable among them?
iii. Explain how each type of power and energy works.
iv. Indicate the types of power and energy used in Rwanda within those shown on the pictures above.

2. Describe the problems that some countries face in power and energy production.
3. Name the leading producing country of each type of power and energy sources worldwide.
4. How can power and energy contribute to the sustainable development of our planet?

10.1. Sources and forms of energy used in the world

Learning activity 10.1

1. Make a short tour in the school and the surrounding environment and answer the following questions:
   i. Identify the activities that require power and energy at your school.
   ii. Describe the forms of power and energy needed for each activity identified above.
2. Discuss the sources of power and energy exploited and not exploited in Rwanda.

10.1.1 Classification of energy resources

There are two main categories of energy resources:

- **Non-renewable resources:** These are resources of energy without the capacity of replenishing themselves after being used. When used they get exhausted and cannot be re-used. They include minerals, natural gas, oil and coal.
- **Renewable resources:** They are inexhaustible. These are resources of energy with the capacity of replenishing themselves after being used. They include water, wind, solar, plants (biomass) and animals (biogas).

10.1.2. Non-renewable energy sources

Non-renewable energy resources are available in limited supplies. This is usually due to the long time it takes for them to be replenished. They include nuclear energy and fossil fuels energy resources like coal, oil and natural gas.

a. Nuclear energy (Uranium)

Nuclear energy is energy obtained from uranium through a chain reaction. When it was realized that when the nucleus of an atom is bombarded by electron it disintegrates and releases enormous quantity of energy, two thoughts came in the mind of rational man:

- to build an atomic weapon, and;
- to generate electricity.

Thus, mankind has developed the art of both. The release of energy by this process is known as fission. Based on this process scientists build reactors in which controlled fission went on to produce energy (heat) and this heat generated electricity.

Generation of electricity involves a lot of technical know-how and so far, only highly developed countries have been able to master it. Thus, the USA, Canada, the UK, France, Japan, Germany are the largest producers of electricity by nuclear fission. Nuclear energy contributes about 9% of all energy produced in USA, though it produces 50% of all electricity generated by nuclear energy worldwide. France derives about 75% of its electricity from nuclear energy, 18.5% in Britain, 15% in Japan and 7% in German. Among the developing countries India is the leader producing 3% of her total requirements from nuclear power plants.

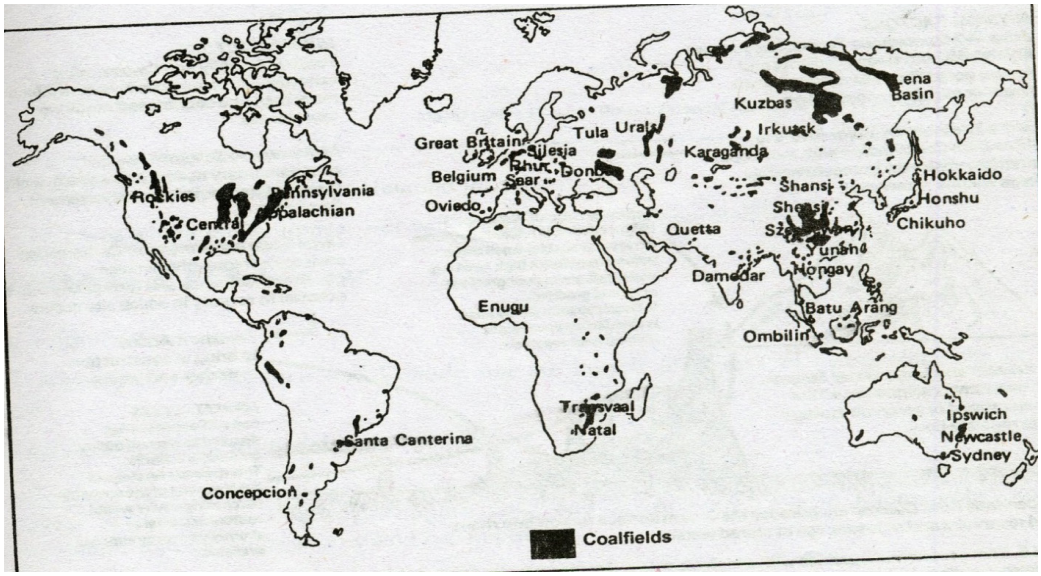
b. Coal

Coal is a sedimentary deposit formed by the slow action of heat and pressure on plant remain buried in the long past. It is a mechanical mixture of carbon, hydrogen, nitrogen, sulphur, etc. It is the content of carbon which determines the quality of coal.

i. Types of coal

The amount of fixed carbon and hydrocarbons forms the basis of classification of coal into various types. The following kinds of coal are generally recognized:

- **Anthracite:** It is a hard and dense coal which is relatively free from iron compounds and moisture. It is made by 95 % of carbon.
- **Bituminous:** It is unusually black and highly lustrous. The moisture content is relatively low. The fixed carbon content ranges from about 50 to over 80% and that volatile matter from 40 to 15%.
- **Lignite:** It is also known as brown coal. The higher grades vary from dark brown to almost black. It is characterized by high moisture content, generally about 40%. The fixed carbon content is also 40%. The structure is fibrous, and sometimes woody.
- **Peat:** It occurs in bogs, especially in areas of cool temperate climates. This is young coal which consists of partly decomposed vegetation.



Source: *Jens Nordmann,et al. Harrison at http://www.pgdp.net*

Figure 10.182*: Major Coal fields in the World*

ii. Uses of coal

The coal can be used:

- in thermal generators to produce thermal electricity.
- as a domestic fuel for heating and indirectly in the form of a gas and electricity.
- in iron smelting e.g. through use of metallurgical coke in blast furnaces.
- to provide a number of raw materials for the chemical industries like coal gas, coal tar, benzele and sulphate of ammonia.

c. Petroleum (oil)

Petroleum is an inflammable mixture of oil hydrocarbons with very complex properties. Petroleum literally means 'rock oil.' It exists underground in solid, liquid and gaseous form. Accumulations of petroleum are found in underground fields, pools or reservoirs of sedimentary rock formations.

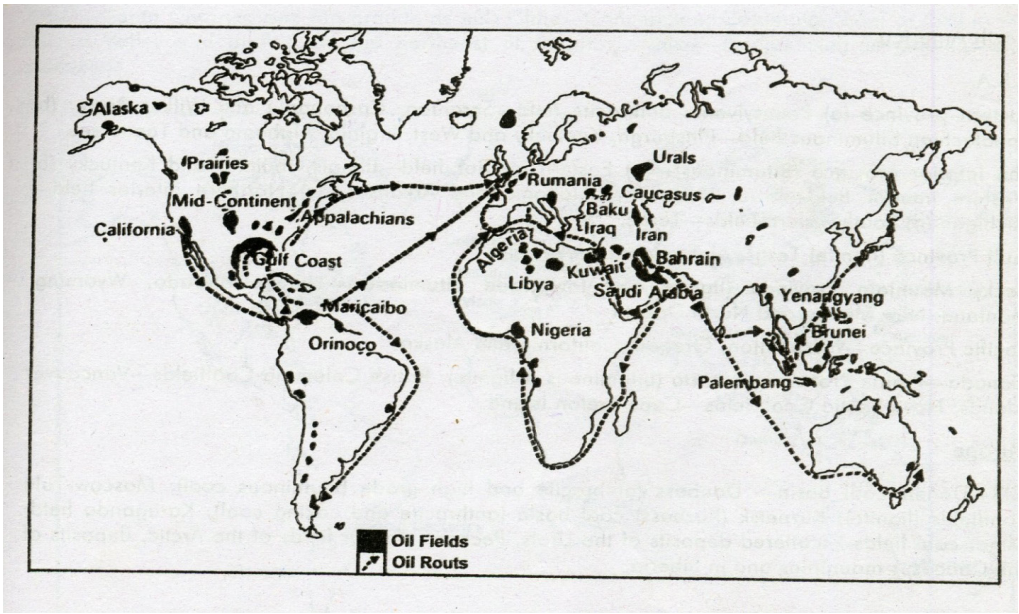
i. Three grades of crude oil according to gasoline yields

- Paraffin - base oil has high percentage of methane (highest yields)
- Mixed-base oil has high percentage of naphthene (intermediate yields)
- Asphalt - base oil has heavier hydrocarbons (lowest yield)

ii. Uses of petroleum

Petroleum can be used:

- for heating homes and hearths;
- as industrial power to drive/move engines and for heating furnaces and producing thermal electricity;
- as transport power for driving railways, motorcars, ships and aeroplanes;
- as lubricants of machines especially high-speed machines;
- as a raw material in various petro-chemicals industries, such as synthetic rubber, synthetic fibres, fertilizers, medicines.



Source: © 1996 The Washington Post Co

Figure 10.183: Major oil regions of the world

d. Natural gas

Natural gas is a naturally occurring hydrocarbon gas mixture consisting primarily of methane, but commonly including varying amounts of other higher alkanes, and sometimes a small percentage of carbon dioxide, nitrogen, hydrogen sulfide, or helium.

The world's proven reserves of natural gas are estimated at about 700 trillion cubic feet. The USA (40%), the Middle East (23%), and the former USSR (11%). Most of the rest is in northern Canada, Europe and Venezuela. Much smaller amounts are widely scattered in several countries including Mexico, South American countries, Pakistan, china, Indonesia and Australia. Nigeria is the first petroleum producing country in Africa.

Natural gas may occur with or without petroleum. Where gas occurs in association with oil, it is generally found in increasing amounts at the greater depths that needs to be drilled.

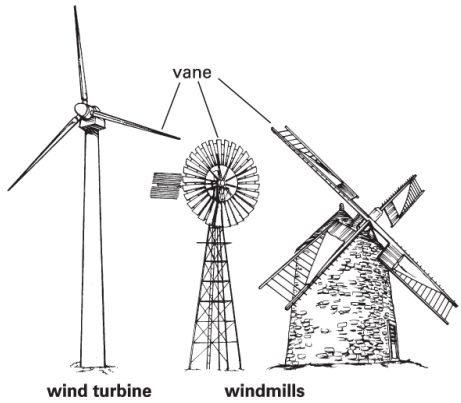
Natural gas (Methane) as a fuel may be used for cooking, heating and even to generate electricity. It has the advantage that it can be pumped through pipes from wells to consumption sites. It is also a "clean fuel". This means that it causes less air pollution. Natural gas can be shipped in liquid form, called liquefied natural gas.

10.1.3. Renewable energy sources

Renewable energy is the energy that is generated from the resources that are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves and geothermal heat. Renewable energy often provides energy in four important areas: electricity generation, air and water heating or cooling, transportation and rural energy services.

a. Wind energy

Wind power is an indirect form of solar energy that can be used to produce electricity. Wind is an almost unlimited, free, renewable, clean and safe source of energy. It has a moderate net useful energy yield and is based on fairly well developed technology. As we can see it from the figure below, the process of the production of energy from the wind is the following: usually a propeller blade is mounted on a tower. The blade is connected onto an electric generator. As wind blows, the blade spins and turns the generator which produces electricity by converting the kinetic energy of the wind into electric energy. A suitable site for a wind turbine depends on the local wind conditions.

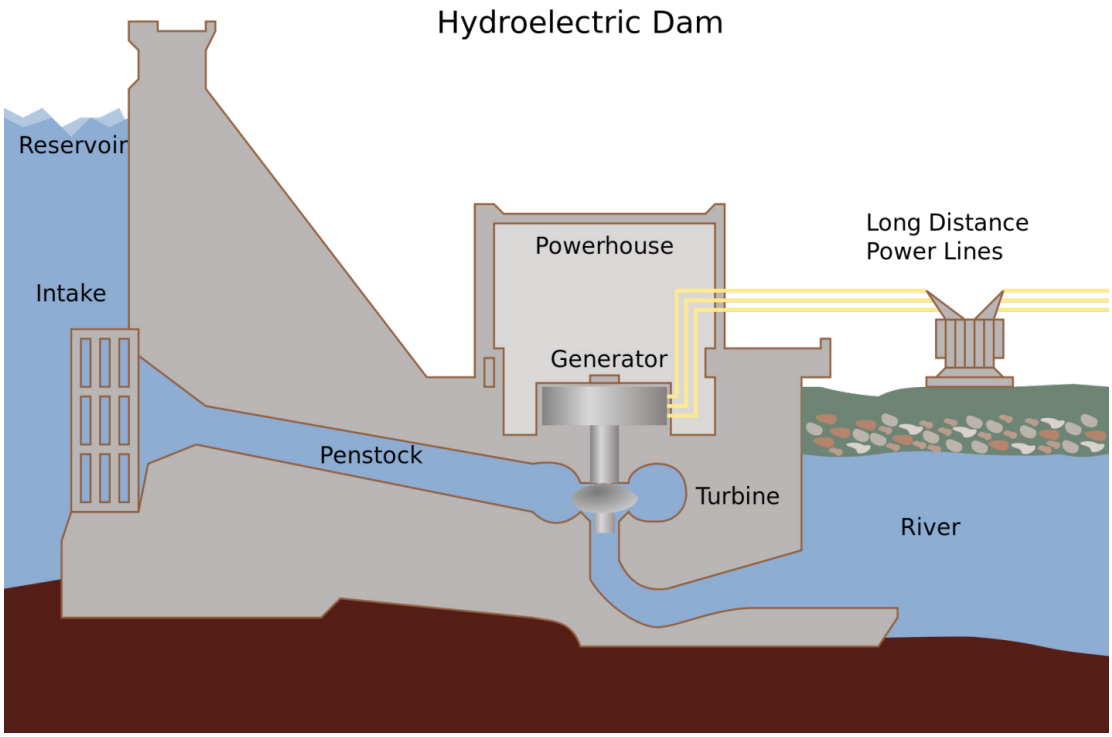


Source: Windmill (© 2018 State of Colorado)

Figure 10.184: Windmill

Water energy

This is the energy produced from running water. Usually, a dam is constructed along a river to store water. The water is then made to fall over a steep gradient. It then passes through a turbine hence spinning the blades of the turbine. Rotation of the blades causes the turbine to turn an electric generator that produces electricity.



Source: https://commons.wikimedia.org/wiki/File:Hydroelectric_dam.png

Figure 10.185: Hydro-electric power station set up

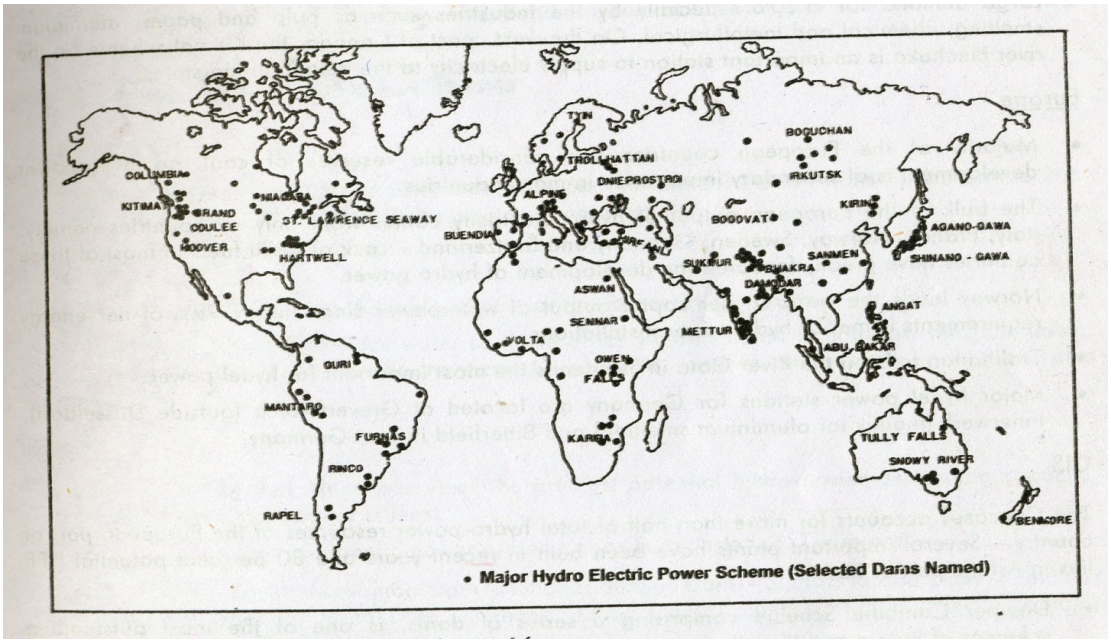
Hydro-electrical power energy requires the following physical and economic conditions:

i. Physical conditions

- A seismological less sensitive area.
- High quantity of water supplied by fairly heavy rainfall distributed throughout the year.
- Great altitude with steep slope to enhance water velocity.
- Existence of rapids and falls favour the development of power by increasing the velocity of stream.
- Narrow steep-sided valley to facilitate dam construction.
- A hard rock for firm foundation.
- Existence of lakes or space for water reservoir.
- The absence of coal, petroleum, etc., expedites the development of waterpower.

ii. Economic Conditions

- Market: Large demand for hydroelectric power;
- Huge capital outlay;
- Technological knowledge and skill and
- Transport facility.



Source: Zarfl et al (2014) (https://freshwaterblog.net/2014/12/01/how-will-the-hydropower-boom-affect-global-river-ecosystems)

Figure 10.186: Major hydroelectric power schemes

Solar energy

Breeder reactors, fusion reactors and solar energy are the only energy alternatives that could support high energy generation indefinitely. However, breeders have potentially serious environmental and economic problems and nuclear fusion is so complex, it can never be economically feasible. In contrast solar energy is abundant, clean, safe and virtually inexhaustible free fuel.

If the direct sunlight falling on the earth in only 3 days is concentrated and converted to useable form of energy, it would equal all of the energy in the earth's known reserves of coal, oil and natural gas.

The figure below shows the process of solar energy production. A greenhouse uses panels of transparent glass to trap solar energy. Another way of tapping solar energy is by use of solar cells. This transforms sunlight directly into electricity.

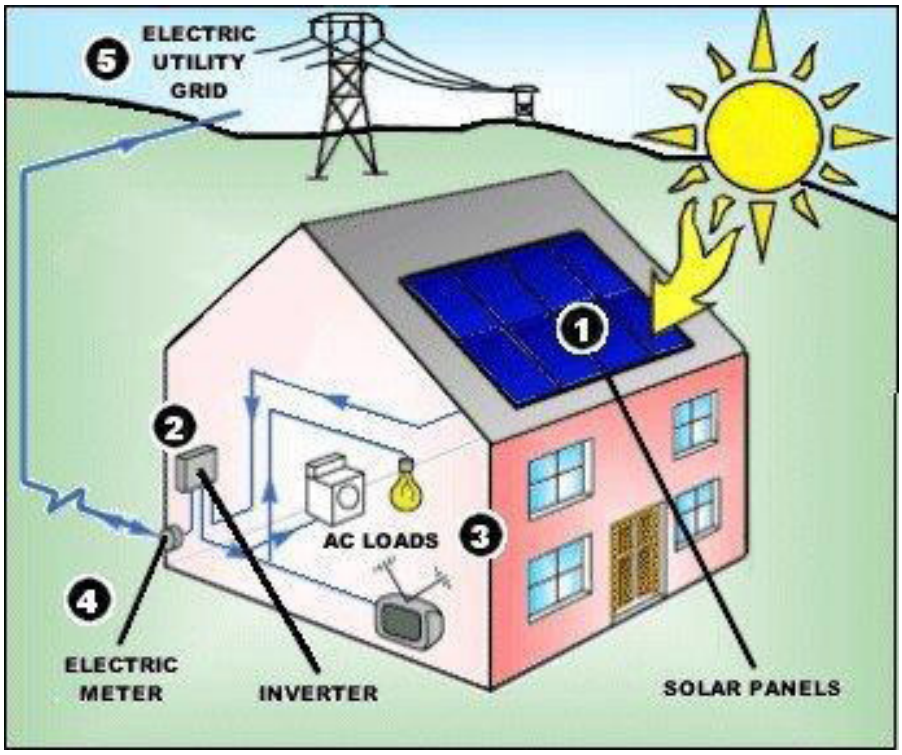
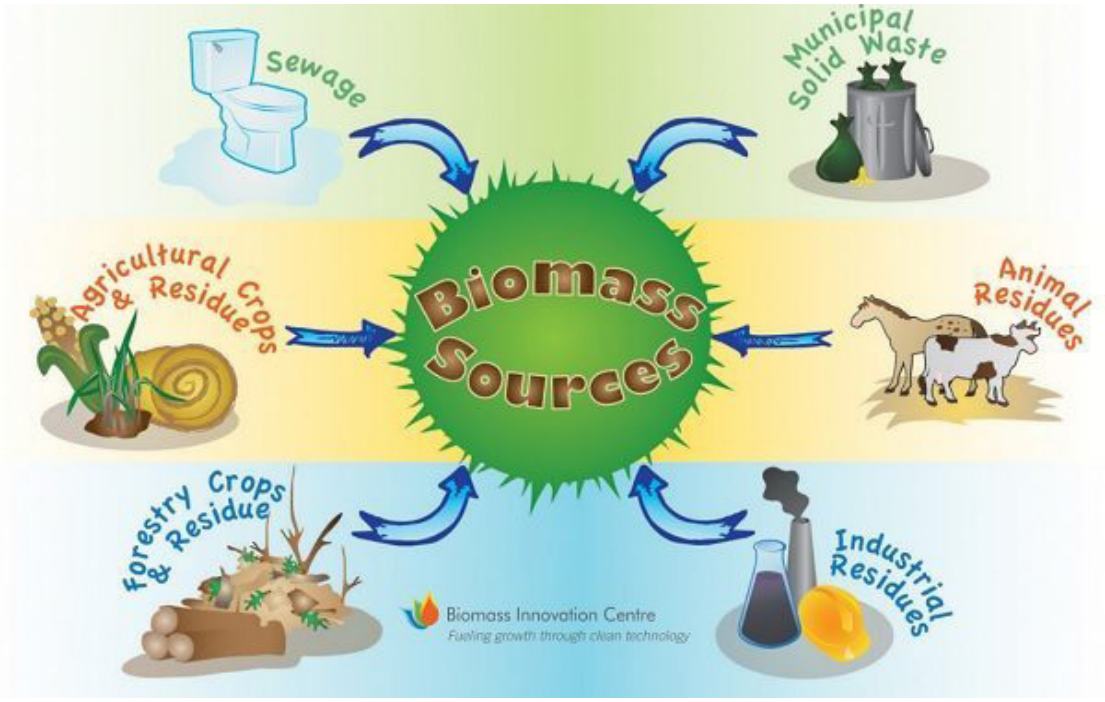


Figure 10.187: Solar panel

b. Biomass

Many people consider the wind and the sun as the main forms of renewable energy. However, biomass (plant material and animal waste) is the oldest source of renewable energy, used since our ancestors learned the secret of fire.

Biomass is a renewable energy source for the two reasons: first the energy in it comes from the sun, second, biomass can re-grow over a relatively short period of time compared with the hundreds of millions of years that it took for fossil fuels to form. The generation of energy starts through the process of photosynthesis. Through this process, chlorophyll in plants captures the sun's energy by converting carbon dioxide from the air and water from the ground into carbohydrates—complex compounds composed of carbon, hydrogen, and oxygen. When these carbohydrates are burned, they turn back into carbon dioxide and water and release the energy they captured from the sun.
Bio-mass energy includes: wood fuel, Bio-gas and Gasohol.



Source: () found in March 27, 2018

Figure 10.188: Biomass sources.

i. Wood fuel: This is a very important source of energy in third world countries. The wood obtained from forests is either used directly or converted to charcoal.

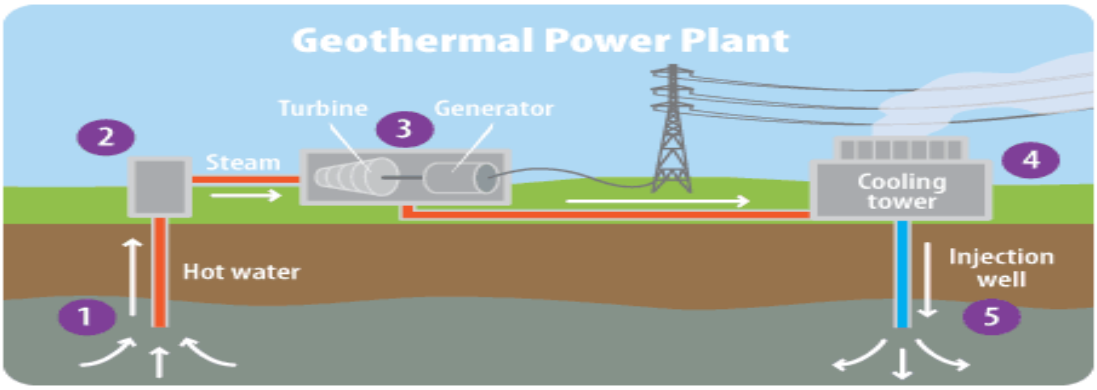
ii. Waste products (Bio-gas)**:** This is a flammable gas produced by micro-organisms, when organic matter is fermented under specific temperatures, moisture content and acidity. It is mainly composed of methane which burns with a blue flame.

iii. Gasohol: Plant material may be converted to alcohol which is a fuel. Wood, wood wastes and garbage can be heated to produce methanol. Most plants containing starch and sugar like sugarcane and cassava can be converted to ethanol. Corn, corn stalks, manure and sewerage can be fermented and distilled to give ethanol. Both methanol and ethanol are directly burned as a fuel.

c. Geothermal

Geothermal energy is produced when rocks lying deep below the earth's surface are heated to high temperatures by energy from the decay of the radioactive elements in the earth and from magma. Geothermal energy can be considered as renewable source of energy if deep underground heat flows can be tapped.

Geothermal energy can either be used for heating water, directly and space heating needs in agriculture and for domestic purposes or it can be converted into electricity.



Source: (https://www3.epa.gov/climatechange//kids/images/4-1-5-geopower.gif)
Figure 10.189: Generation of geothermal energy

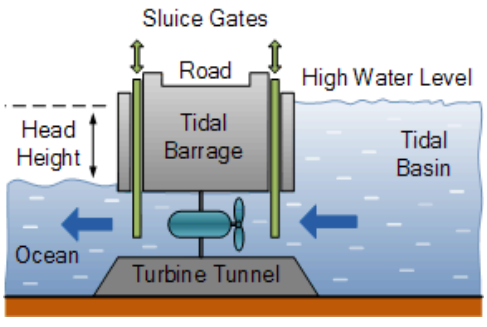
d. Tidal energy

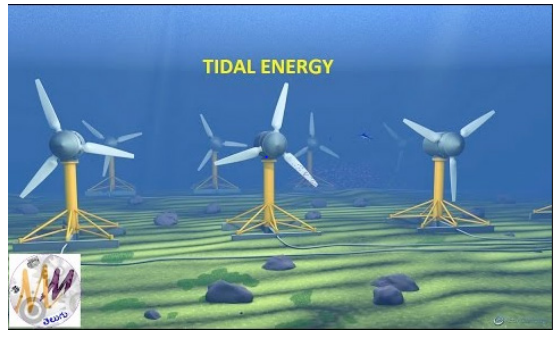
Tidal energy or tidal power is a form of hydropower that converts the energy obtained from tides into useful forms of power, mainly electricity. Although not yet widely used, tidal energy has potential for future electricity generation.

As the tide rises and falls water flows into and out of bays and estuaries. If the bays and the estuaries can be closed by a dam the energy in the tidal flow can be extracted four times a day and used to spin a turbine to produce electricity.

Although all coastal areas are subject to some tidal changes, only those few areas with a large enough tidal range of some four to five meters are potential sites for tidal power plants. These sites are located for most part on both sides of North Atlantic, the English Channel and the Arctic coast of the C.I.S. a few developing countries such as Argentina and India also have some tidal power potential.

There are presently two tidal power projects: one in Commonwealth of Independent States (C.I.S) and the other in France.





Source: Alternative Energy Tutorials © 2010 – 2018
Figure 10.190: Tidal Energy Syms

Application activity10.1

i. Describe the sources of power and energy exploited in Rwanda.
ii. Indicate the main hydro-electric power stations in Rwanda.
iii. Suggest other alternative sources of power and energy that can be used in the world.
iv. What types of energy sources promote environmental sustainability?

10.2. Factors and importance of power and energy production in the world

Learning activity 10. 2

1. Describe the areas of power and energy production in Rwanda and showing the reasons of their geographical location.
2. What are the challenges that Rwandans would be facing if those areas identified above were not there?

10.2.1 Factors favouring power and energy production in the world

The following are the major factors influencing power and energy production in the world:

- Availability of market is a pre-requisite for the power and energy production. For example, densely populated areas, industrially and commercially advanced, have a great demand for electricity.
- Availability of capital to invest in power and energy production. Production of energy/power, setting up power houses, and transmitting electricity through wires to the areas of consumption require a lot of capital in terms of money.
- A high degree of technical knowledge and skills.
- The amount of energy to be produced depends on the potentiality of power and energy generator. For example, the amount of hydro-electrical power to be produced depends on the quantity of water and velocity of stream. The latter, in turn, depends upon the gradient of the stream.
- The natural environment of the area where the power and energy will be produced and transported such as the topography (e.g. nature of terrain and slope), climate (e.g. amount of rainfall, sunshine), hydrology (e.g. quantity and quality of water), vegetation (e.g. amount of biomass) affect the production of power and energy.

10.2.2. Importance of power and energy in the development of the world

Power plays a role in the development of a country in different ways such as:

- **Earns foreign exchange**: Energy can be exported in neighboring country and in that way, it is contributing to the earning of foreign exchange. The economies of many countries are depending on the production of petroleum which is the most used worldwide source of energy. For example, the DRC earns $40 million annually through exports of electricity from Inga dam plant.
- **Development of industrial sector:** The engine that moves the industrial sector is energy and without it the whole sector would ground to a standstill. Most industries use petroleum and its by-products to run the machines. Electricity is also used to run machines while wood fuel is used in various processing industries such as tea processing.
- **Development of transport sector:** Petroleum is used in road transport, water transport and air transport meaning that it is the basic element in transport.
- **Creation of employment opportunities:** The generation of electricity is offering employment to a good number of people.
- **Development of Agricultural sector:** Solar energy is used to dry grains and other produce such as tobacco, cocoa and coffee. Petroleum and its products are used to run water pumps and other agricultural machinery. Wind power is used in dry regions to pump water for irrigation.
- **Improvement of welfare of people in general:** Various forms of energy is used for various purposes such as cooking, lighting and heating. In the rural areas, the main sources of energy are firewood, charcoal and liquid petroleum. In Urban sector, charcoal, kerosene, liquid petroleum, gas and electricity are used.

Application activity 10.2

1. Describe requirements for Rwanda to fully exploit its available power and energy resources.
2. Visit your local industrial areas and identify the role of power and energy in an industry.

10.3. Problems and possible solutions for power and energy

Learning activity10.3

Visit a power station in your environment and do the following:

i. Identify the problems of power production
ii. Suggest the possible solutions to the identified problems.

10.3.1 Problems hindering the development of power and energy in the world

The energy crisis is still experienced in different parts of the world. This is due to the following reasons:

- Coal has some inherent problems. Petroleum is not going to last long. Hydroelectricity has its own limits and nuclear energy has some political problems for it to be socially accepted worldwide because of the risks of its catastrophes.
- Overdependence on oil and its products. Many countries rely on petroleum and petroleum products in industrial, transport and agricultural sectors. It therefore becomes quite difficult to switch to other sources when there is a problem with the supply of oil.
- Economic and political embargoes fixed by the rich countries. For example, in 1973 the oil producing countries in the Middle East imposed oil embargo on USA because of its interference in the Israel and Palestine war.
- Increase in oil prices imposed by the Oil Producing and Exporting Countries (OPEC).
- Depletion of wood fuel due to overexploitation of forests.
- Exhaustion and deepening of coal mines. Coal is a non-renewable source of energy. Its continuous use leads to the deepening of the mines hence its exhaustion. Consequently, the cost of extraction increases leading to high prices of coal in the world market.
- Environmental pollution: Some sources of energy like coal and petroleum are sources of Carbon dioxide which is emitted in atmosphere. The increase of carbon dioxide in atmosphere leads to ozone layer depletion and climate change with their consequences.

10.3.2 Possible solutions for power and energy in the world

As the energy is used at a very high rate and people will continue to do so in the future, there is no doubt that it will be exhausted one day. Since our energy resources are limited, certainly there is a need to do something about it like:

- **Move towards renewable resources:** The best possible solution is to reduce the world's dependence on non-renewable resources and to improve overall conservation efforts. Much of the industrial age was created using fossil fuels, but there is also known technology that uses other types of renewable energies – such as steam, solar and wind. The major concern is not so much that we will run out of gas or oil, but that the use of coal is going to continue to pollute the atmosphere and destroy other natural resources.
- **Buy Energy Efficient products:** Replace traditional bulbs with fluorescent tube lights CFL's and light emitting diode (LED's). They use less watts of electricity and last longer. If millions of people across the globe use LED's and CFL's for residential and commercial purposes, the demand for energy can go down and an energy crisis can be averted.
- **Energy Simulation:** Energy simulation software can be used by big corporates and corporations to redesign building unit and reduce running business energy cost. Engineers, architects and designers could use this design to come with most energy efficient building and reduce carbon footprint.
- Government may come in and improve on public transport efficiency so as to reduce the need to use personal vehicles to reduce the use of petroleum.
- On the domestic front, energy conservation can be achieved by making electrical appliances like refrigerators, television, electric cookers more energy efficient. This can be supplemented by switching of electricity gadgets when not in use.
- Educating the public about the importance, the conservation and the sustainable use of energy resources.

Application activity 10.3

This is an extract of an interview with Wilson Karegeya, a firm's director for commercial services, Rwanda Energy Group held with iPAD Rwanda Power & Infrastructure Investment Forum in Kigali.

This interview was conducted two months before splitting EWSA into WASAC and REG. Read it carefully and answer the questions related to it.

Let's start with an update on the reform of the energy and water organisations in Rwanda.

Rwanda Energy Group today was still EWSA two months ago. EWSA was the Energy, Water and Sanitation Authority, a government parastatal, which they thought splitting the organisation would ensure more efficiency, better and quick service delivery. So it was split two months ago,

forming two corporations: one for water, the Water and Sanitation Corporation, headed by a Managing Director. It was a department in EWSA and is now a standalone company and still 100% owned by government. There is also the Rwanda Energy Group (REG), which will specifically deal with energy projects. REG also has two subsidiaries, the Energy Development Corporation Ltd and the Utility Corporation. The Energy Development Corporation will mainly

What do you hope to achieve in the next 12 months?

We have now embarked on asset separation; EWSA had a lot of assets that need to be shared between the water company and the electricity company. There are issues of accounts and fixed assets like land and buildings that need to be split and shared. That is what the new companies are doing right now. We are being assisted by Price Waterhouse and some other specialised companies to make sure the reform is done well for better service delivery.

And we expect, of course, more specialisation for these companies. The water company will now specialise in making sure that they deliver clean water to the population. They will be less distracted because they will be mainly focused on providing clean water. And the electricity company will now not be overstretched, looking into water and electricity but looking specifically into electricity projects, so I expect more focus for these companies that will lead to better service delivery.

The energy projects that you will invest in, can you highlight specific challenges and how

you will overcome them? One challenge is that we were used to government investments where government invests in energy projects. We have now adopted an approach to involve the private sector more in the generation phase of it: where we identify projects that need to be developed, advertise them, attract private investors, (IPPs) and negotiate the power purchase agreements with them, once we agree and sign the contract, the project is up and running. Where I see challenges is in the contract management. It is an issue that we are not used to working with IPPs. Although you sign a PPA with an independent power producer, it is more about managing the contract from day one up to the last day of the contract. So that is a challenge there but we hope to overcome it by training our staff to make sure they know how to deal with IPPs, know what to expect and when and what the IPP has to

deliver. That is very important.

In terms of generation capacity in Rwanda, what is currently available and how much are you projecting?

Currently we are at 110 megawatts capacity and we expect to generate up to 563 megawatts by 2017. That is the target we have. There are on-going projects that will enable us achieve this targeted megawatts and some are nearing completion. We have also taken the direction of utilising the regional interconnectors to be able to share power with the neighbouring countries. We are currently negotiating a PPA with Kenya aiming at purchasing power from Kenya through Uganda.

Power generation goes hand in hand with other infrastructure development such as roads,rail etc. what are the plans there?

In the transmission sector we have also started using private developers. We recently advertised a tender to attract investors to come and do the transmission lines and improve the networks as we expand the capacity. Of course, there is a need to improve the network, so we are doing that concurrently. What is a day like in Rwanda in terms of electricity supply? Until recently there weren't many power outages in Rwanda. But now industry is growing and the demand for energy is growing and we are striving every day to increase the capacity to serve all our customers, be it investors, industrial or domestic. Of course, you get investors who come to us saying —I want 5 megawatts, I want 15 megawatts, I want up to 10 megawatts‖, so you have to work hard to make sure you use all the resources available to provide such electricity.

A recent example is a new cement factory that has asked for up 15 megawatts, and we have a total capacity of 110 megawatts for the whole country. So you can imagine how hard we have to work. The good news is that we have secured the power the factory requires.

Who looks at tariffs and the regulation around tariffs?
It is RURA (the Rwanda Utility Regulatory Agency). But if we are attracting investors for projects above 5MW, we negotiate a tariff. For projects below 5 megawatts, there is a feed in tariff set by RURA. For big projects, Rwanda Energy Group negotiates with the developer and agrees a tariff at which it will supply electricity.

What is the situation with residential access to power?

For now, the residential users are connected and satisfied. The challenge we are facing is the new industries that are emerging. Otherwise the domestic customers had no issues so far. Perhaps they might have to start competing for the insufficient power that we have – to share this among the commercial and domestic clients that

we have. But we are working very hard to bridge the demand gap that is growing day by day.

What do you see happening in the East African region in the next five years?

My personal view is that if the current trend of cooperation among the East African member States continues, I see success. When I look at the engagement between member countries, sharing power, that is success. When I see the opening of borders for trade, that is success, and opening of borders for human capital, that is success. If this trend is maintained I see a powerful East African Community.

Extracted from: ESRI AFRICA: AFRICA'S POWER JOURNAL, Published on September 10, 2014

End unit assessment

1. Assess your district infrastructures and suggest the potential power and energy sources to be exploited
2. If you were the chairperson of African Union propose appropriate strategies for sustainable power and energy development in Africa.
3. Account for the status of power and energy production in the world.
4. Basing on relevant examples or case studies, explain how energy resources contribute to the development of some countries. What about Rwanda in that regard?
5. Analyze the figure below and discuss the trend of the use of energy in the world and the challenges that it is likely to cause in the future.