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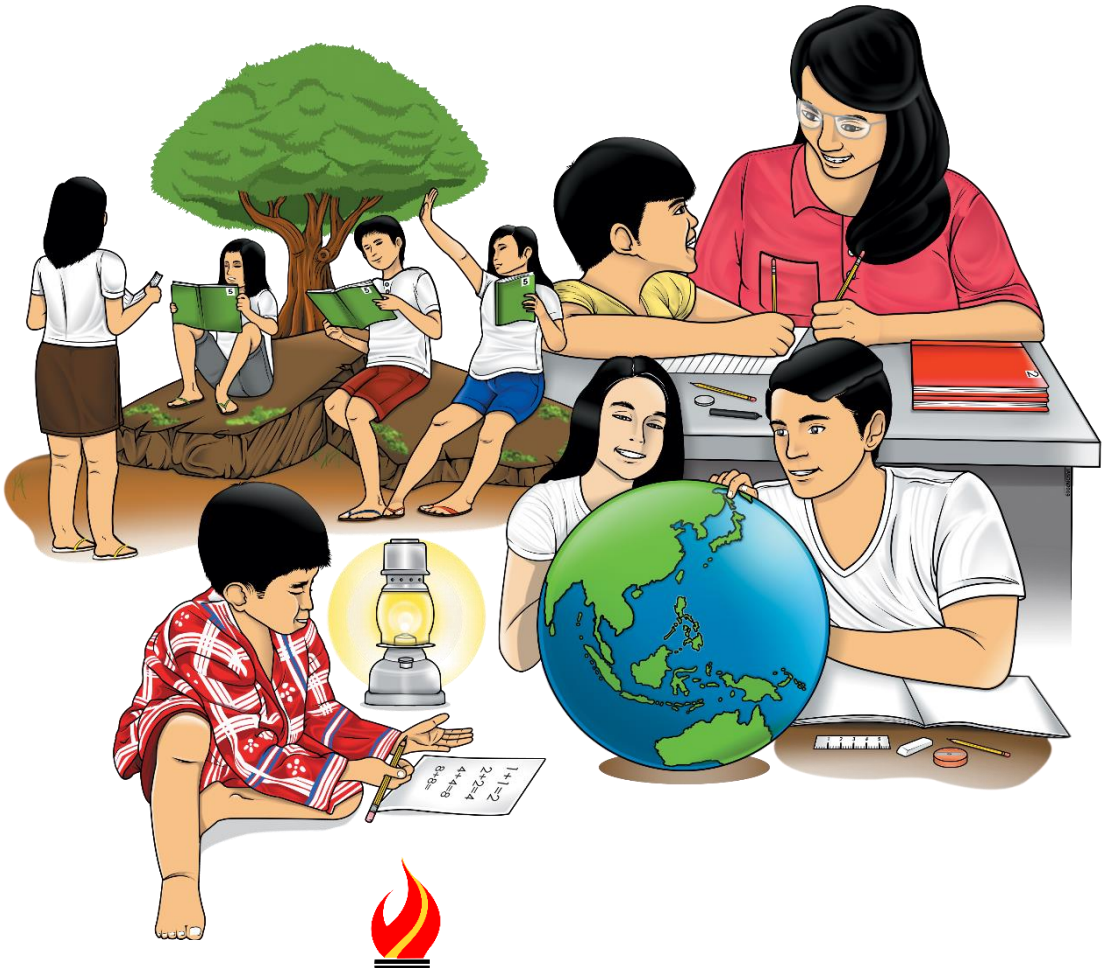
Science

Quarter 4 – Module 9:
Geothermal Energy



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Science

Quarter 4 – Module 9:
Geothermal Energy

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Introductory Message

This Self-Learning Module (SLM) is prepared so that you, our dear learners, can continue your studies and learn while at home. Activities, questions, directions, exercises, and discussions are carefully stated for you to understand each lesson.

Each SLM is composed of different parts. Each part shall guide you step-by-step as you discover and understand the lesson prepared for you.

Pre-tests are provided to measure your prior knowledge on lessons in each SLM. This will tell you if you need to proceed on completing this module or if you need to ask your facilitator or your teacher's assistance for better understanding of the lesson. At the end of each module, you need to answer the post-test to self-check your learning. Answer keys are provided for each activity and test. We trust that you will be honest in using these.

In addition to the material in the main text, Notes to the Teacher are also provided to our facilitators and parents for strategies and reminders on how they can best help you on your home-based learning.

Please use this module with care. Do not put unnecessary marks on any part of this SLM. Use a separate sheet of paper in answering the exercises and tests. And read the instructions carefully before performing each task.

If you have any questions in using this SLM or any difficulty in answering the tasks in this module, do not hesitate to consult your teacher or facilitator.

Thank you.

What I Need to Know

You've learned from previous lesson that Heat, as a form of energy has many practical applications in our daily lives; cooking, heating and cooling, and generating electricity all depend on energy transformations that end by transferring heat energy.

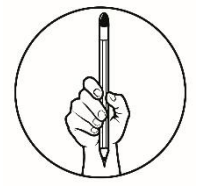
This module will help you learn how heat transfer and energy transformations make heat engines like Geothermal Plants work. The children will learn how electrical energy is being generated in a Geothermal Power Plants. Learners will do some activities and simple experiments. For us to do it, we will go through the following lesson;

Lesson 1: Geothermal Energy

At the end of this lesson, you will be able to explain how heat transfer and energy transformation make heat engines like geothermal plant works.

Specifically, after going through this module, you will be able to:

1. Identify the location of some Geothermal Power plants in the Philippine map.
2. Trace the energy transformations from thermal energy up to the generation of electrical energy in a Geothermal power plant.



What I Know

I. Multiple Choice: Read the statements carefully. Choose the BEST answer. Write the letter of your answers on the space provided before each number.

1. Which of the following geothermal power plants in the Philippines is/are still in operation up to the present?
   A. Tiwi Geothermal Power Plant
   B. Mt. Apo – EDC Geothermal Power Plant
   C. Unified Leyte Geothermal Power Plant
   D. All of the Above

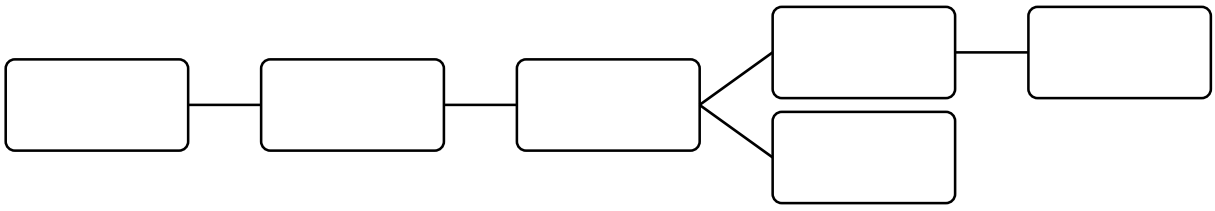
2. Where does geothermal energy come from?
   A. Wind
   B. Rivers
   C. Heat from the earth
   D. Sunlight

3. What does it mean when we say that geothermal energy is 'sustainable'?
   A. That it generates greenhouse gases.
   B. That it will not be used up.
   C. That there is a limited supply
   D. That it can be used anywhere on earth.

4. What potential environmental issue can occur when building a geothermal energy plant?
   A. The burning of fossil fuels
   B. Water pollution from the chemicals
   C. Toxic gases can be released when drilling
   D. All of the above

5. Geothermal power plants can generate _____ by using hot water and steam from deep in the earth.
   A. Air Conditioning
   B. Greenhouse Gases
   C. Electricity
   D. Hydropower

II. Arrange the following energy transformations that takes place in a geothermal power plant by placing the terms below inside the appropriate box.
   • Electrical Energy
   • Kinetic Energy of steam rotating turbine
   • Thermal Energy of Water trapped in underground reservoirs
   • Thermal Energy from earth's interior
   • Thermal Energy for Distribution
   • Kinetic Energy of Turbine and Generator



Lesson 1 Geothermal Energy

What's In

In the past lesson, you have learned the three methods of heat transfer. First is Conduction in which the transfer of heat is due to direct contact. An example is putting a Pot in firewood. The second is through Convection in which heat is transferred from one location to another by the movement of fluids. An example is using an Air-conditioner in your room. The third is Radiation, the transfer of heat by an electromagnetic wave. An example is using your microwave oven in baking some foods in your house. You have also learned that the spontaneous or the natural process is where energy flows from an object of high temperature to an object of lower temperature.

Further, you have learned how heat transfer can be turned into work and how doing work releases heat. In this module, we will make use of this mechanism of how heat transfer and energy transformations make heat engines like geothermal plant works.

What's New

There is a natural source of power found beneath surface of the earth that has been around for a considerable length of time. Underground, far underneath us, there are pools of water warmed by magma (or liquid rocks). These pools of water make up our geothermal repositories. Turning earth's temperature to electricity thus warming or cooling our homes and industries is the essence of Geothermal Energy.

"Geo" refers to "earth," and "thermal" refers to "heat," so geothermal energy means "heat from the earth". Geothermal energy is created during the radioactive decay of isotopes below the earth's surface. This procedure is constant such that geothermal energy is considered a sustainable power source.

There are currently geothermal power plants in over 80 countries in line with the Geothermal Energy Associations and although the United States of America is currently the worldwide leader of geothermal power, other countries like Indonesia,

Turkey and even our own country the Philippines are in the process of expanding their power capacities.

In the table below are list of the existing Geothermal Power plants in the Philippines as of December 2020 according to Philippines' Department of Energy.

Name	Design Capacity (MWe)	Location in the Philippines	Year Established
Maibarara 1 & 2 GPP	32	Sto. Tomas Batangas	1 – Feb. 2014 2 – May 2018
BACMAN GPP	140	Bacon & Manito Albay	Sept. 1993
-Makiling-Banahaw (Mak-Ban) Geothermal Power Plant -Mak-Ban Binary	442.8 15.7	Calauan, Laguna Bay, Laguna	Apr. 1979
Tiwi GPP	234	Tiwi, Albay	Jan. 1979
Tongonan I GPP	123	Kananga Leyte	June 1983
Nasulo GPP	49.4	Valencia, Negros Oriental	Sept. 2014
Palinpinon GPP	172.5	Valencia, Negros Oriental	August 1983
Unified Leyte GPP	610.2	Ormoc and Kananga Leyte	July 1996/1997
Mt. Apo – EDC GPP	108.5	Kidapawan, North Cotabato	December 1996

Can you recognize some of them? To do so, let us do the Activity in the next page.

Activity 1: Its more "HEAT" in the Philippines!

Objectives:

1. After performing this Activity, you should be able to;
   - Identify the location of some Geothermal Power Plants in the Philippine map;
   - Determine the region in which the Power plant belongs.

Materials Needed:

- Pictures of Geothermal Power Plant in the Philippines
- Philippine Map
- Pins

Procedure:

1. Prior to answering this activity, you can have a virtual eco tour at Tongonan Leyte (now Unified Leyte) Geothermal Power Plant in Ormoc City. Please type the link in your internet browser. (https://www.youtube.com/watch?v=2NzzKLtuqSU)

2. Using the Philippine Map, identify the location of the geothermal power plants based on the table below
3. Using the table below, fill in the blank column and write the region of the Power plants location.
4. Using the Google search engine, look for pictures of the different Geothermal power plants on the internet. Then, print a small size, cut, and pin the pictures of the power plant on the Philippine map.

Name	**Design Capacity (MWe)**	**Location**	**Region**
Maibarara 1 & 2 GPP	32	Sto. Tomas Batangas	
BACMAN GPP	140	Bacon & Manito Albay	
-Makiling-Banahaw (Mak-Ban) Geothermal Power Plant -Mak-Ban Binary	442.8 15.7	Calauan, Laguna Bay, Laguna	
Tiwi GPP	234	Tiwi, Albay	
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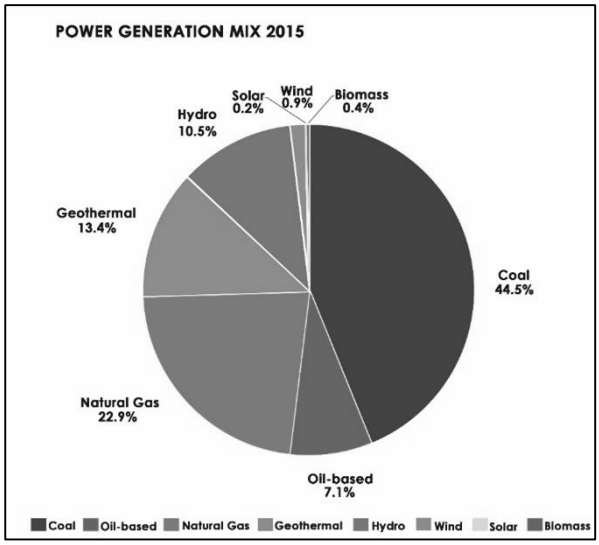
Palinpinon GPP	172.5	Valencia, Negros Oriental	
Unified Leyte	610.2	Ormoc and Kananga Leyte	
Mt. Apo – EDC GPP	108.5	Kidapawan, North Cotabato	

The Philippines is one of the world's top producers of geothermal power, as it is located along the Ring of Fire. It is the third biggest maker of geothermal power after the United States of America (USA) and Indonesia. Based from ThinkGeoEnergy Research 2020, as of 2019, the USA had a capacity of 3676 megawatts of geothermal power, followed by Indonesia with 2133 megawatts while that of the Philippines was 1918 megawatts. The Philippines was followed by Turkey with 1526 MW.

The Philippines currently has nine operational geothermal fields which supply about 13.4 % of the nation's energy.



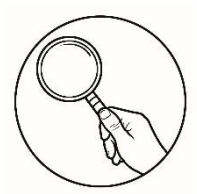
Illustrated by: Corazon E. Booc

According to the Philippines' Department of Energy (DoE) during the Public Consultation for the Philippine Energy Plan (PEP) 2008-2030 held at Tacloban City on July 21, 2008, from 2008-2020 the government has a long-term plan to double capacity of Renewable Energy which is 4.8 % growth rate. Further they have set plans that by 2030 there will be already an optimization of Renewable Energy Resources.

With that, chances would be the Philippines will hold the no 1. spot of the world's top producers of geothermal power replacing the mighty country USA that has an installed capacity of around 3,676 MW. Moreover, as part of the governments' Energy Efficiency and Conservation policies, optimization of renewable energy resources are vital to the country's contribution to the global movement of cutting down carbon emissions, the attainment of sustainable development and the improvement of quality of life of the Filipino consuming public.

Guide Questions:

1. Where is your place of residence?
2. Are there any Geothermal Power plants present near your area? If yes, please identify them.
3. What do you think of the Philippines target to increase its geothermal power capacities? Could it help solve the energy crisis (power shortages) the country is facing today? And could it be the answer to the Philippines' goal of mitigating effects of climate change through cutting down carbon emissions? Explain your answers.



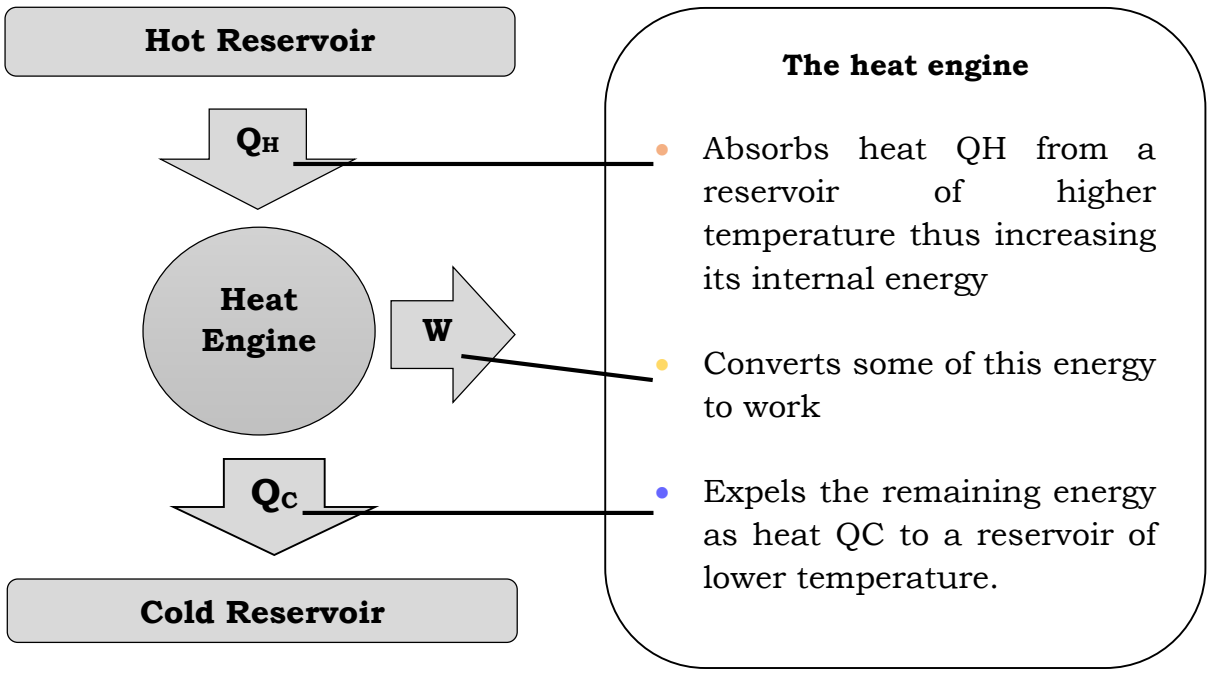
What is It

How a Geothermal Power Plant Works?

There are a three main types of geothermal plants: 1) Dry steam, 2) Flash steam and 3) Binary cycle.

What these types of geothermal power plants all share for all intents and purpose is that they use steam turbines to produce Electrical energy. In general, a steam turbine is a rotary heat engine that converts thermal energy contained in the steam to mechanical energy or then to electrical energy. This process is fundamentally the same as other thermal power plants utilizing different sources of energy than geothermal.

To enhance our understanding about how a Geothermal Power plant works, let's take a look back at the schematic diagram of a Heat Engine.



Gasoline and diesel engines, jet engines, and steam turbines are all heat engines that do work by using part of the heat transfer from some source. Heat transfer occurs spontaneously from a hot object to a cold one, consistent with the first expression of the second law of thermodynamics which states that "***Heat transfer occurs spontaneously from higher- to lower-temperature bodies but never spontaneously in the reverse direction.***"

Further, as heat engines use a large amount of energy from a reservoir of higher temperature $\mathbf{Q_H}$, scientists make sure that the work is done as efficient as possible. So that the work done W will be equal to $\mathbf{Q_H}$, and no heat transfer ($\mathbf{Q_C=0}$) to the environment. However, this is impossible and will violate the second expression of the second law of thermodynamics which states "***It is impossible in any system for heat transfer from a reservoir to completely convert to work in a cyclical process in which the system returns to its initial state.***"

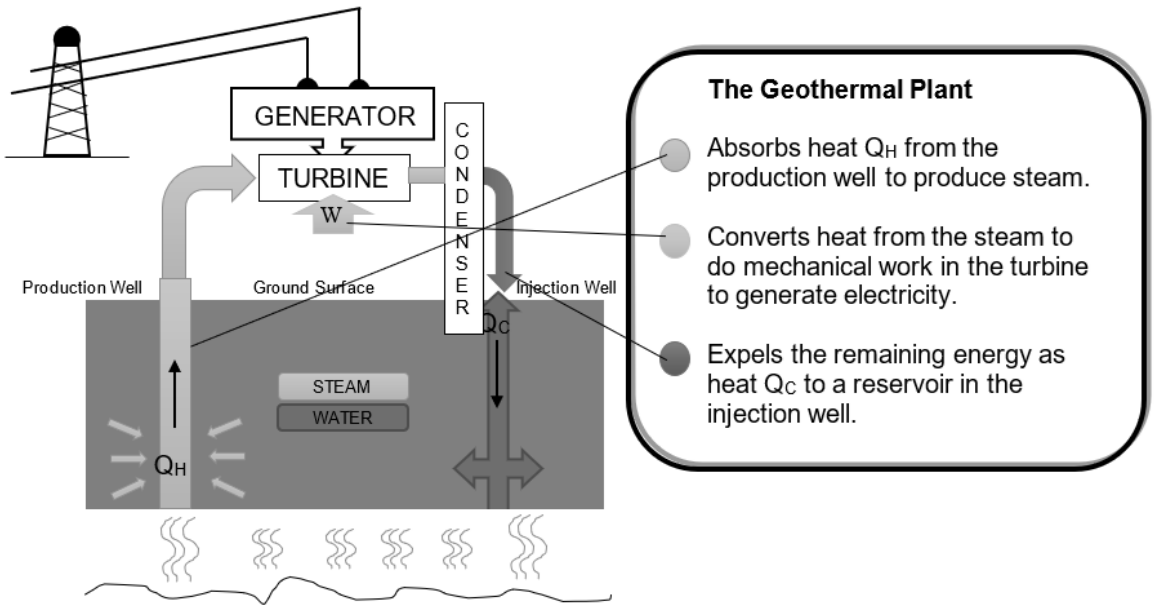
Based from the diagram, a heat engine operates between reservoirs of different temperatures. It is a device that uses a cyclical process. Therefore, the heat $\mathbf{Q_H}$ taken from the hot reservoir cannot be used completely to do work **W**, hence, there will always be a transfer of heat $\mathbf{Q_C}$ that is expelled to the environment.

Moving forward, let us now see how heat transfer and energy transformations in a Geothermal plant works by relating it to the processes of a heat engine. In a geothermal power plant, the temperature in a production well is higher than the temperature in the Injection well (Condenser). We can also call the wells as hot and cold reservoirs, respectively.

In a Geothermal Power plant;

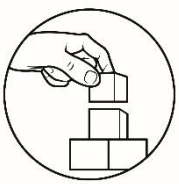
1. Heat transfers from the mantle to the hot reservoir (Production well) of the Power plant. Then, the plant absorbs heat QH from the production wells to produce steam.
2. Next, steam coming from the production well is used to spin electricity turbines which is connected to a generator to generate electricity. Here, you see that the heat coming from a source is used to do mechanical work in moving the turbine. This shows that heat QH can be partly used to do work W same as heat engines.
3. And lastly, it expels some of the heat QC in an Injection well (condenser), this will ensure that the water that is drawn up from the production wells returns to the geothermal reservoir where it regains the thermal energy that was used to generate electricity.

Let us see the diagram of a Geothermal Plant from this site https://www.eia.gov/energyexplained/geothermal/geothermal-power-plants.php to understand this better.



Thermal Energy from the Mantle

Based from the diagram, water is being heated deep below (mantle) from the earth surface. Then, the plant uses up the Heat QH from the production well to produce steam. This will be sent to the steam turbine where the thermal energy is converted to electricity with a generator through a process called electromagnetic induction. The following stage in the cycle is cooling the liquid and sending it back to the heat source.



What's More

Activity 2: A closer look at a Geothermal Power plant!

Most power plants—regardless of whether energized by coal, gas, atomic force, or geothermal energy—share one element for all intents and purpose: they convert heat to electricity.

Here is something you will do to understand this better. Read the following steps on how a Geothermal Plant works. After that, in the given illustration, label the locations where the different processes (energy transformations) in a Geothermal Power Plant take place. Good luck!

1. **Thermal Energy from the Mantle**

   A Geothermal Power Plant gets its energy deep below the surface of the earth.

2. **Production Wells are drilled**

   Shafts/wells are bored down a few kilometers to the earth surface. One shaft is used to pump water down to the hot rocks, and another one which will permit the steam to rise up.

3.1 Steam Turns the turbine

Steam is used to spin electricity turbines which is connected to a generator.

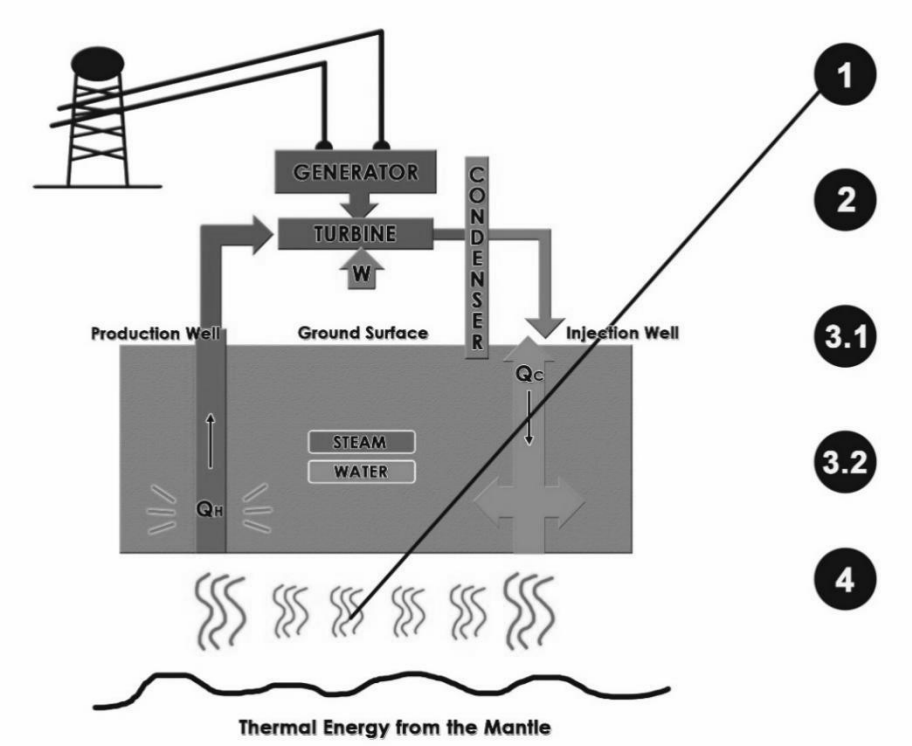
3.2 Injection Wells

At this part of the power plant, this will ensure that the water that is drawn up from the production wells returns to the geothermal reservoir where it regains the thermal energy (heat) that we have used to generate electricity.

4. **The turbine drives the electric generator**

   The rotational energy from the turning turbine shaft is used directly to spin magnets inside a large coil and create electrical current. The turbine and generator are the primary pieces of equipment used to convert geothermal energy to electrical energy.

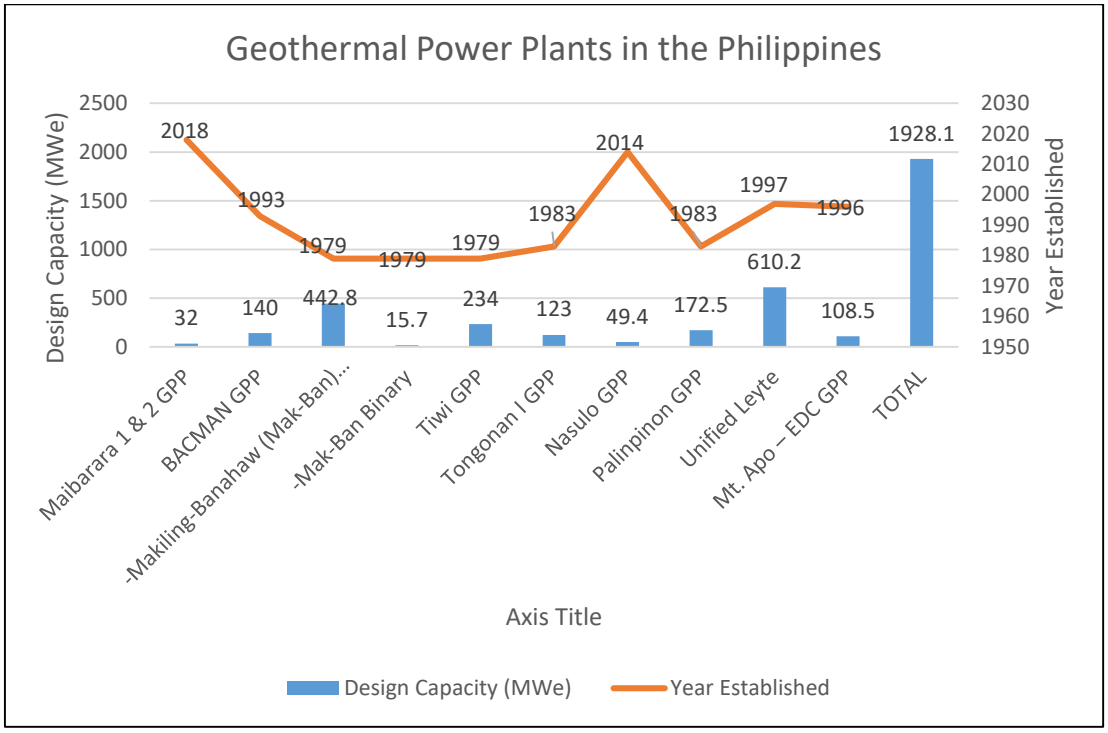
Now it's your turn! Can you locate the five processes that take place in a Geothermal Power plant in the following diagram? The first step is done for you!



Illustrated by: Corazon E. Booc

Activity 3:

Identification. Using the graph below, carefully answer each of the questions below.



1. In what year did the Philippines had its first Geothermal Power Plant established? Which plant/s is it?

   _____.

2. Among the Geothermal Power Plants in the Philippines, which has the greatest contribution to electricity generation? How much is it in terms of Megawatt electric (MWe)?

   _____.

3. Which plant has the lowest generated electricity?

   _____.

4. How much is the total generated electricity in terms of Megawatt Electric (MWe) of all the Geothermal Power Plants based on their design capacity?

   _____.

5. Would you support the local government in your area if a geothermal power plant will be built? Why?

   _____.

What I Have Learned

I. Write T if the statement is True and F if the statement is false.

_____ 1. A heat engine takes in heat from the low temperature reservoir, does work using this energy, and expels the rest in the heat sink at the high-temperature reservoir.

_____ 2. A Geothermal Power plant takes its energy from the heat deep below the earth's surface.

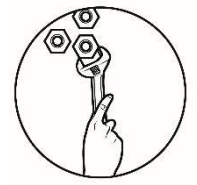
_____ 3. Heat naturally travels from cold to hot objects.

_____ 4. Steam engines takes it energy from the condenser to drive the turbines and generator in generating electricity.

_____ 5. The main energy transformations in geothermal power stations are;

Kinetic Energy ---->Thermal Energy ----> Electrical Energy.

II. Explain briefly how heat engines processes conforms with the mechanisms of how Geothermal Plants generates electricity.



What I Can Do

According to an article entitled Environmental effects of heat provision from geothermal energy in comparison to other sources of energy, from Proceedings World Geothermal Congress by Kaltschmitt, M. (2000, May), he compares heat provision from geothermal energy with the provision of heat from other renewable energy and fossil fuel energy sources. This was done based on Life Cycle Analysis (LCA) methodology for the potential impacts "finite energy resource consumption", "additional anthropogenic greenhouse effect", "acidification of lakes and rivers" and "human and ecotoxicity (based on SO2 and NOx)". During his investigation, he compared heat provision from the soil and from groundwater with heat pumps, from hydrothermal resources and from deep wells as well as from biomass, from solar collectors and from light oil and natural gas. His study showed that the heat provision from geothermal energy could contribute considerably to reduce the environmental impact caused by the use of fossil fuel energy to accomplish the same supply.

To find out more of this study, let us do the following activity.

How do the emissions from a geothermal power plant compare to those from a fossil fuel power plant?

Objective/s:

1. After performing this activity, you should be able to;
   - Perform laboratory experiments using household materials.
   - Know and differentiate the combustion products from fossil fuel power plants and a geothermal power plant.
   - Understand and explain how does the combustion products of power plants from different fuel source contributes to air pollution.

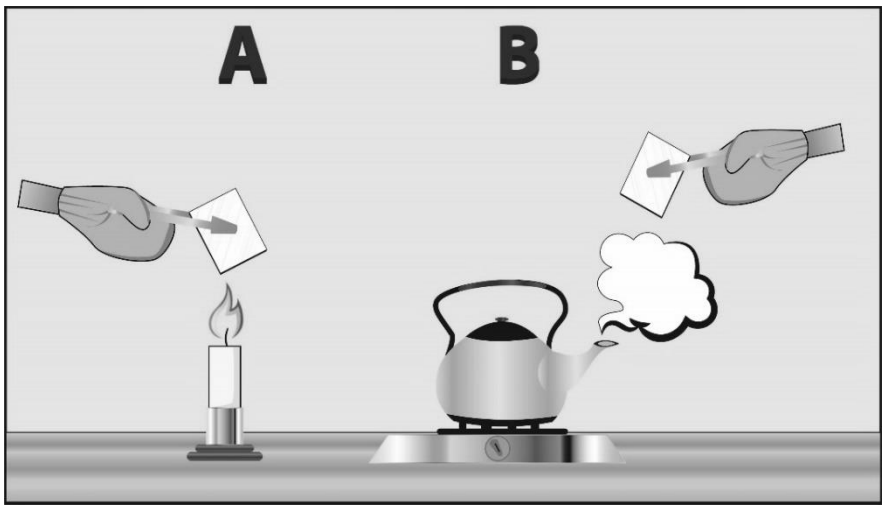
Materials & Equipment Needed:

- Bunsen Burners (Candle Lamp or gas stove)
- Charcoal and wood chips
- Matches
- Kettle
- Water
- Small mirror
- Tongs (Kitchen tool)
- Hand gloves

Safety and Environmental Requirements: Caution should be used when handling hot materials, especially the mirror. Fuels are combustible and should be kept contained while burning. When using the Bunsen burner, be sure to keep the mirror high above the flame. Parents can do the activity following the procedure while letting their children observe what happens during the experiment.

Suggestions: You can use multiple fuel sources to determine the amount of particulates produced by each source.

Procedure:



Illustrated by: Rene Y. Sumagang

A. Candle Pollution (see figure A) – Fossil Fuel Power Plants

1. Light a candle and let it burn for a few seconds.
2. Hold the small mirror above the flame using a tong so that the glass touches the top of the flame.
3. After soot has covered most of the surface, set it upside down to cool. Repeat as many times as you want. (Tip: Older students can do this in small groups. Please bear in minds that the glass will get HOT.)
4. Observe the mirror and see (or you can touch it if you want but let it cool first) the black substance covering the mirror.
5. What is it? How is it formed?

The black substance that is created in the mirror is what we call soot. The soot is the build-up of carbon particles from burning a candle. This is a small-scale version of the air pollution resulting from the burning of fossil fuels.

B. Heating Up Water (See Figure B) – Geothermal Plants

1. Using a kettle, bring to a boil a small amount of water using a Bunsen burner or a stove.
2. Hold the small mirror above the steam using a tong so that the glass touches the top of the water vapor.
3. Observe the mirror and see if it contains any particulates (soot) covering the mirror?
4. Did you see any soot? If yes, how it is formed?

Record your observations in the table below:

Question	**Experiments**	
	Set-up A	**Set-up B**
1. Did you see any soot in the mirror?		
2. How it is formed?		
3. Describe the combustion products in terms of its physical appearance.		
4. Can this combustion product contributes to air pollution? Why?		

Guide questions:

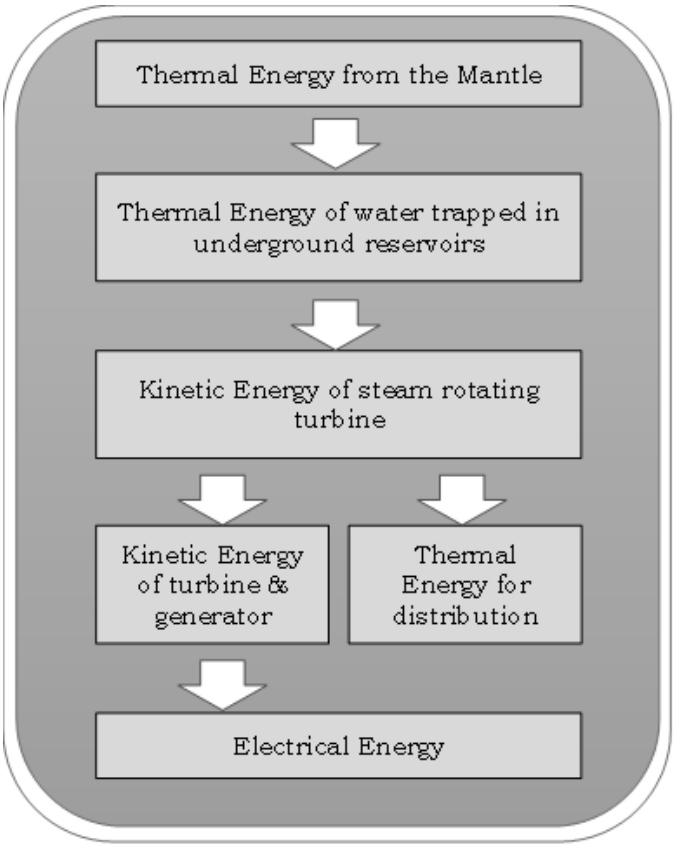
1. If you answer yes in the question 1 in the table above, how it is formed in A? in B?
2. How are you going to compare the combustion products of fossil plants and geothermal plants?
3. Which of the two combustion products contributes to air pollution? Explain why?

Summary:

In this module, we have learned that:

- "Geo" refers to "earth," and "warm" refers to "heat," so geothermal energy means "heat from the earth".
- According to ThinkGeoEnergy Research 2020, as of 2019, the Philippines is the third biggest maker of geothermal power after the United States of America and Indonesia.
- Geothermal reservoirs are pools of water heated by magma deep below the surface.
- Megawatt Electrical (MWe) is a unit of electrical power used in the electric power industry.
- Heat Engines takes in heat from the high temperature reservoir, does work using this energy, and expels the rest in the cold sink at the low-temperature reservoir.
- Geothermal Power Plant takes its energy from the heat deep below the earth's surface.
- Geothermal Power plants takes the same heat processes and energy transformations as heat engines.
- The main energy transformations that takes place in a Geothermal Power station are; Thermal Energy ---> Mechanical Energy ----> Electrical Energy

The diagram below shows how energy transfers in a Geothermal Power Stations.



Assessment

I. Select the letter of the option that answers each question or complete the statements.

1. Heat transfers in heat engines just like in a Geothermal Plants from
   A. From/to reservoirs of the same temperature
   B. From cold to hot reservoirs
   C. From hot to cold reservoirs
   D. Cannot be predicted

2. According to International Geothermal Association (IGA), worldwide, the Philippines ranks _____ to the United States of America in producing Geothermal Energy.
   A. First
   B. Third
   C. Second
   D. Fourth

3. A geothermal Power plant takes its energy from
   A. Wind
   B. Water
   C. Sunlight
   D. Heat from the earth

4. What country is the largest producer of Geothermal Energy?
   A. Russia
   B. United States of America
   C. Japan
   D. China

5. All of the following power plants uses steam to drive the turbines to produce electricity except
   A. Hydropower
   B. Coal-fired
   C. Geothermal
   D. Nuclear

II. Complete the following paragraph by filling in the blank space.

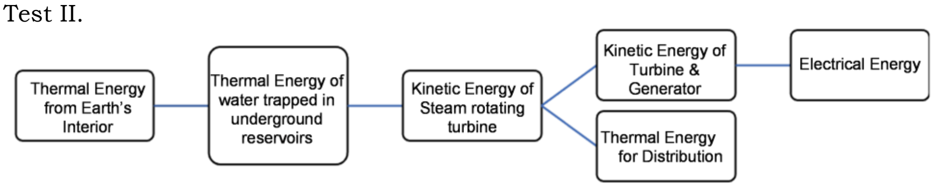
The main energy transformations in Geothermal power stations are: _____ ---> _____ ---> _____ .

A geothermal power plant gets energy from the _____ deep below the surface of the earth. _____ are drilled down, often as deep as several kilometers, one to pump water down to the hot rocks, and another nearby which will allow the _____ to rise up. This _____ is then used to spin turbines which is connected to a generator that generates _____.

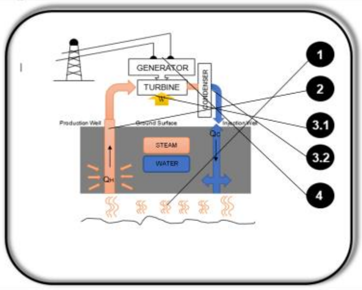
Answer Key

What I Know
Test I.
1. D
2. C
3. B
4. C
5. C

Test II.



What Is It



What I have Learned
I. 1. F 2. T 3. F 4. F 5. F
II. Heat engines absorbed heat from hot reservoir to increase its internal energy. The heat taken from the hot reservoir is partly used to do work, whereas the remaining heat is expelled to the cold reservoir (environment). Similarly, in a Geothermal Power Plant, they absorbed heat from the production well (hot reservoir) to produce heated water (steam) and this steam (heat energy) is used to do mechanical work (turn turbines) to produce electricity and releases some of the heated water (steam) going back to the injection wells (cold reservoir).

What's More
I. Identification:
1. 1979. Tiwi GPP, Mak-Ban Binary and Mak-Ban GPP.
2. Unified Leyte GPP. 610.2 MWe.
3. Mak-Ban Binary.
4. 1928.1 MWe.
5. Answers may vary.

Assessment
Test I.
1. C 2. C 3. D 4. B 5. A
Test II. The main energy transformations in Geothermal power stations are:
Thermal Energy --->Mechanical Energy --->Electrical Energy.
A geothermal power plant gets energy from the heat deep below the surface of the earth. Wells are drilled down, often as deep as several kilometers, one to pump water down to the hot rocks, and another nearby which will allow the heated water (steam) to rise up. This steam is then used to spin turbines which is connected to a generator that generates electricity.

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