Technologies for Clean and Renewable Energy Production

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Lecture - 33
Geothermal Energy

Hi friends, now we will discuss on the topic geothermal energy.

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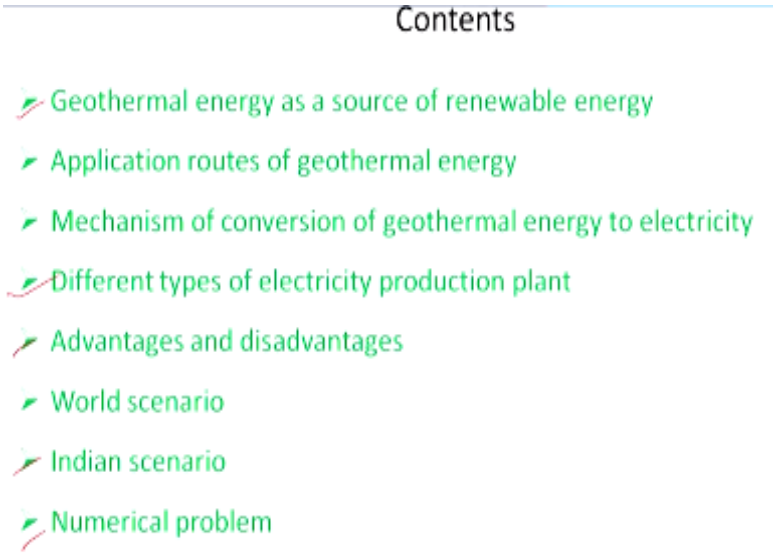

Contents of this class is geothermal energy as a source of renewable energy, application routes of geothermal energy, mechanism of conversion of geothermal energy to electricity, different types of electricity production plant or scheme, then advantages and disadvantages, world scenario, Indian scenario and one numerical problem. Now we will see geothermal energy as a renewable energy source. So, the term itself says the geo and thermal, so this is related to the thermal energy of earth.

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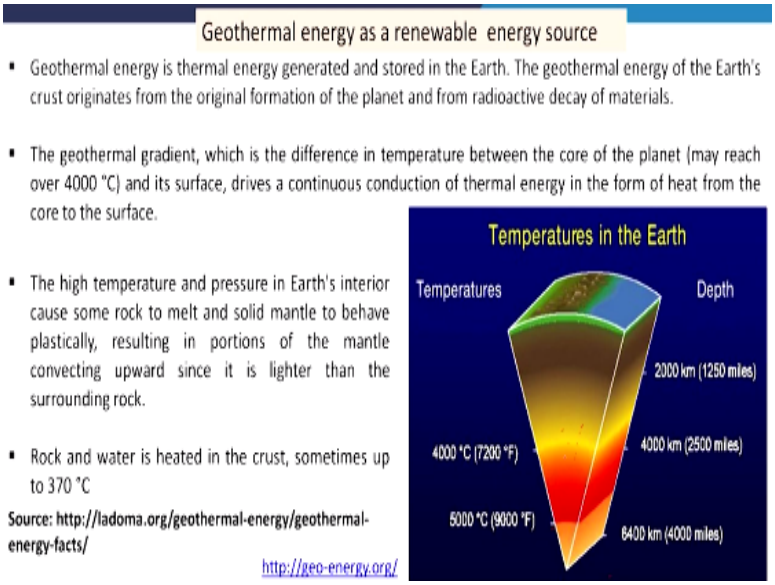

So see this figure we see at the core of the earth, the temperature is very high, it may be say up to 5000 degree centigrade even, so 4000 to 5000 °C temperature at the core of the earth and gradually the temperature decreases and at the surface we are at ambient temperature and we have green belt in some places and some are sea and some mountains etc. This indicates that there is a temperature gradient, so maximum temperature at the core and then gradually it decreases and the minimum at the surface where the living animals and living beings exist.

So the huge amount of heat energy which is available at the core which is basically generated due to different types of radioactive reactions that is transferred to some extent gradually to the surface, and it is believed that these at the core the material is in liquid form that is called magma and then some rock is also in molten form that can convecting the heat that can be a through convection, it can go off the molten salt and then that also heat the adjacent rock layers at the upper side.

Then that hot or heated rock layer if there is some liquid say water so that that water takes it from the heated rock and if temperature is very high, so this water can be converted to steam or depending upon the temperature of the adjacent rock, the water may be in water hot water or in steam. So if we can extract this water, hot water or steam whatever available at the crust of the earth or under the earth's crust so if we can extract it, then we can recover that heat available in the water?

So in this case either we can send water from the surface to this rock layer for the transfer of heat and then we can take the heat the water out from it and recover the energy from it. So

this is the mechanism by which the geothermal energy, the inner thermal energy of the earth inside the earth, we can use for our application. Now this phenomena is basically a natural phenomena and this will exist, this will never end, that is why this energy geothermal energy is a renewable energy, it is considered as renewable energy. Now how we will use this.

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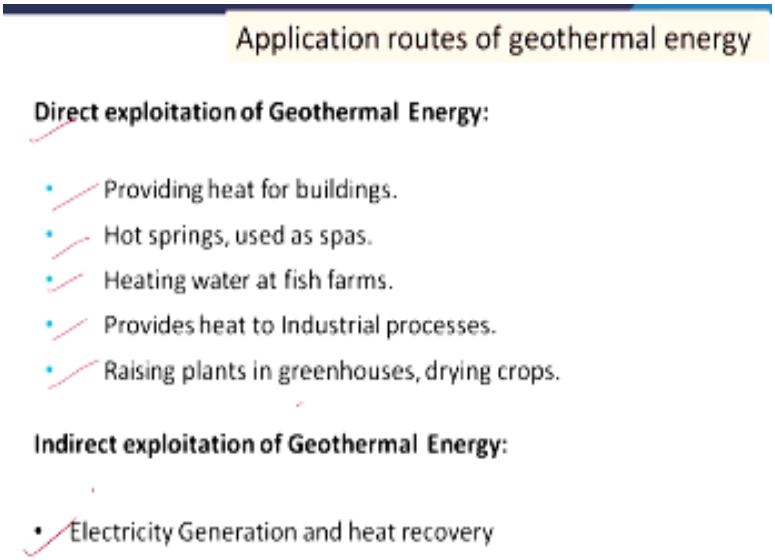

We can use the heat directly or indirectly. So direct exploitation of geothermal energy may be by providing heat for building, then hot springs used as spas and heating water at fish firms, or it provides heat to industrial processes or raising plants in greenhouses and drying crops, means particularly in the country where the temperature is below zero degree or at very low temperature, ambient temperature is very low in this case this energy can be used to raise the temperature of the greenhouses and drying crops.

These are the very direct use of this geothermal energy, but we can convert this energy the which is available in terms of steam or hot water that energy can be converted to electricity and that is indirect mode of application and most usable form of the energy that is electricity that can also be produced from the geothermal energy.

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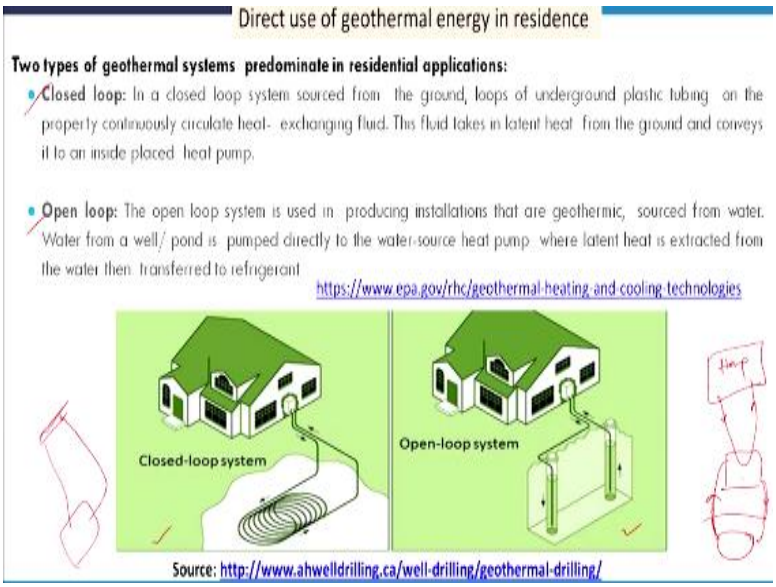

Now we will see now if we want to use directly, then there may be 2 modes, one is your closed loop and another is your open loop. So this is the diagram, this figure shows us the closed loop application of geothermal energy. So here we have some piping arrangement under the earth where the heat source is available. So there may be some liquid, say rock layer. So we are sending this pipeline, so through this pipeline we are sending liquids or water and then it is going and taking the heat inside the earth in this layer and again it is coming back from this to our house.

So this in the house, we have one circuit, this is in our house say there is some pipeline say. So it is going to the underground and then it is coming to this one. So that way it is a closed loop, there is no opening, that is a closed loop system, but we can have another open loop system. So open loop system means we are using water something here, then this is from the home we are using the some solvent for taking the heat from this open system, that means from the underground we are taking the water in some open form and then from this is we are using in at the home.

So this is our home, in out, home out home in, and then this is our one reservoir where we are making it purposefully to extract the heat which is getting out from the inner of the earth. So this is the fluid which is going there and then it is open and this is coming in contact with this one and it is going that way, we can have open loop system. So the open loop system is used in producing installations that are geometric and sourced from water or water from a well or pond it is pumped directly to the water source heat pump where latent heat is extracted from the water, then transformed to refrigerant, so that which I have explained is mentioned here.

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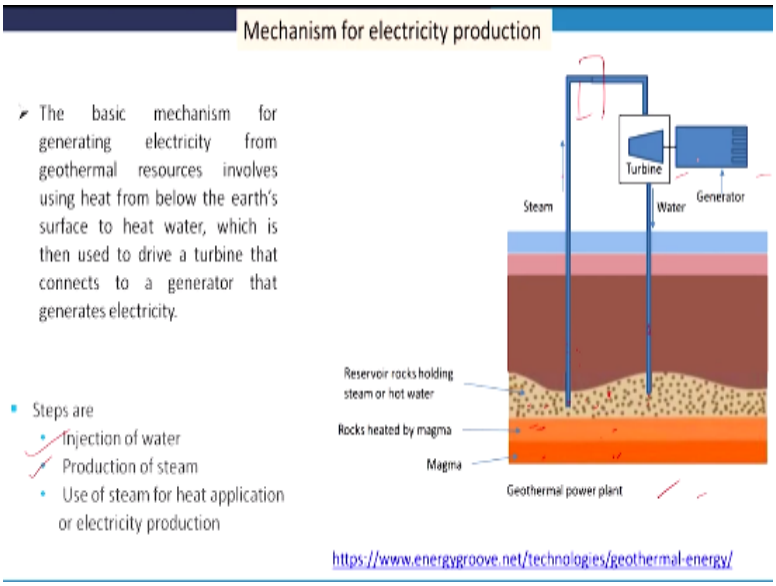

Now we will see the mechanism for the electricity production from the geothermal energy. So here this figure shows us the working of a geothermal power plant. So you see this is our magma and then the rocks heated by magma, so this rock is heated and here we are having reservoir rocks holding steam or hot water. So gradually lower temperature here with respect to this very high temperature, then temperature is less, here temperature is less.

So this rock is molten here, but here the rock is not molten but it is heated, that not that much temperature is not available here that it will be molten but it is heated, sufficient temperature is there. So then water is adjacent to this rock, so that will be produced, the water can be converted to steam by taking the heat from this rock and that steam will come out. Now this water which is available here that may be in steam form or may be in water form depending upon the temperature of the rock.

If very high temperature is available there, so we may get steam and directly the steam may come out here and you can use the steam at turbine and then the turbine will be connected to this generator, so we will get the electricity from here and the condensed water will be sent back to the underground part where the heat source is available. Again it will heated up and will come to the turbine after conversion of steam, water to steam. So this is one simple configuration when this temperature is very high and water is available in steam form, but it is not necessary that this water will be available steam in everywhere.

So in some places the temperature is higher, some places that temperature is lower, so far

around say 370 degree centigrade temperature has been reported and available, and here this water is under very high pressure also. So when this water will come here not in steam form but high temperature and high pressure, so water is in water form high temperature and pressure, but if we use some flash drum in this case, so then also we will get some steam here.

So different type of possibilities are there, but whatever may be the condition here, for the electricity production we need steam and that steam directly available or will convert the water to steam and that steam will be used in the turbine for the electricity generation. So that is the basic principles for the production of electricity from the geothermal plant. So what are the steps here?

So our first step is injection of water, we will inject water here water injection, then production of steam, so then production of steam we are using this here, and use of steam for heat application or electricity production, this is the step three. So this is the mechanism.

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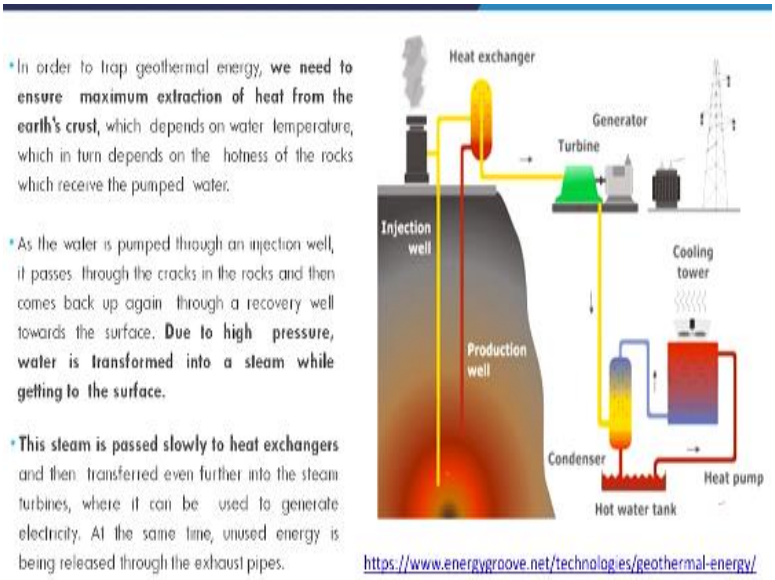

Now we see that we are talking about that temperature of the rock may not be very high, the water may also be available in water form at high temperature. So in this case this is our high temperature water, if it comes here then, there will be some heat exchanger, the heat exchanger after cooling this water will again come back and some after heat exchange, there may be one flash drum if the water comes, then this water at high pressure.

If pressures reduced then there will be flashing and steam will form. So that steam will be

used here for turbine and the remaining water will be recycled back to the soil and the steam will use in the turbine for electricity production with the help of the generator, and then the steam is coming and again it will be high temperature water, condensed water and that will be cooled here and after cooling then that will also be used. So that way this is called heat pump.

So that water, which is produced from the condensation of the steam can be further cooled. So this is the one way of the production of electricity when the water is present here at high temperature and high pressure and we are using some flash drum. Due to high pressure, water is transformed into a steam while getting to the surface, already we have discussed this. So this steam is passed slowly to heat exchangers and then transferred even further into the steam turbines when it can be used to generate electricity.

At the same time, unused energy is being released to the exhaust pipes, already we have discussed.

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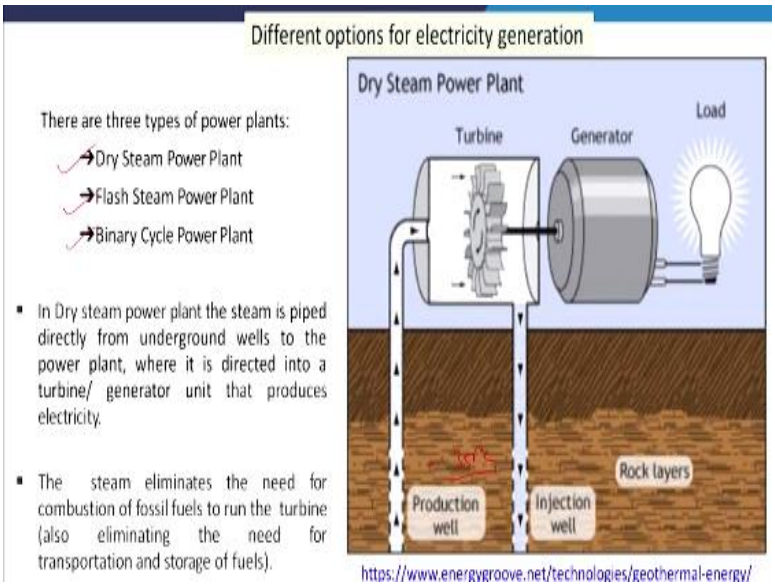

Now we will see different options for electricity generation. So depending upon the temperature and pressure of the water available in this site, we can choose basically 3 types of electricity generation schemes. One is dry steam power plant, so dry steam power plant, then flash steam power plant and another is binary cycle power plant. So what is the dry steam power plant?

In this case, the temperature is very high here, so very high temperature, so steam is produced directly here, water is converted to steam at the under the earth and then it is directly sent to

the turbine and then condensed steam in terms of water condensed water it is sent to the well again through injection well and then we can get electricity with the use of generator with the turbine. So this is dry team steam power plant, this temperature requirement is very high.

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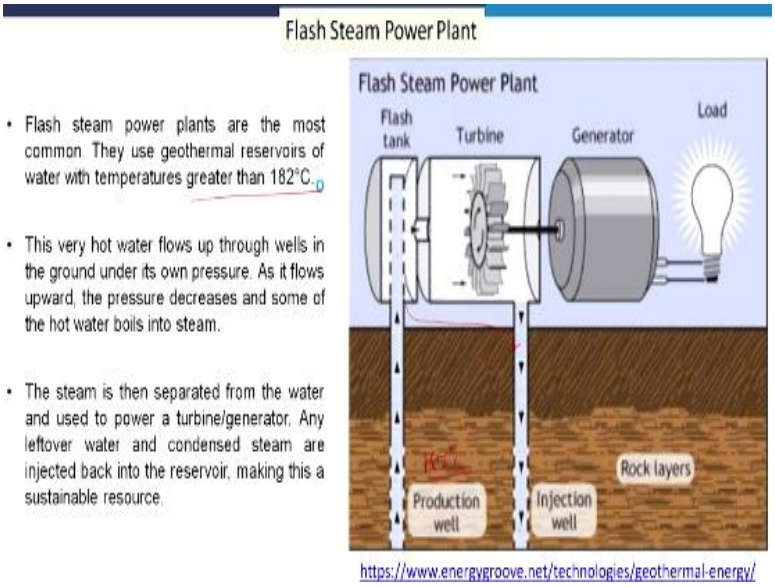

Then flash steam, here the temperature it is greater than 180 °C, 182 °C as reported, 182 °C is available here, so water at high pressure at 180 °C is available there. So when it comes at the surface, then you reduce the pressure, then it gives sufficient amount of steam that is used in the turbine and condensed is sent back. The water here also it comes back through it and then it comes into the injection well and goes under the earth and again here exit.

The high temperature and high pressure water is available and which comes again through this production well and thus this cycle continues and we get the electricity. So here, the typical condition is that the temperature is greater than 182 °C, but in this case dry steam power plant, this is much more, this is around say 350 like °C, high temperature is there.

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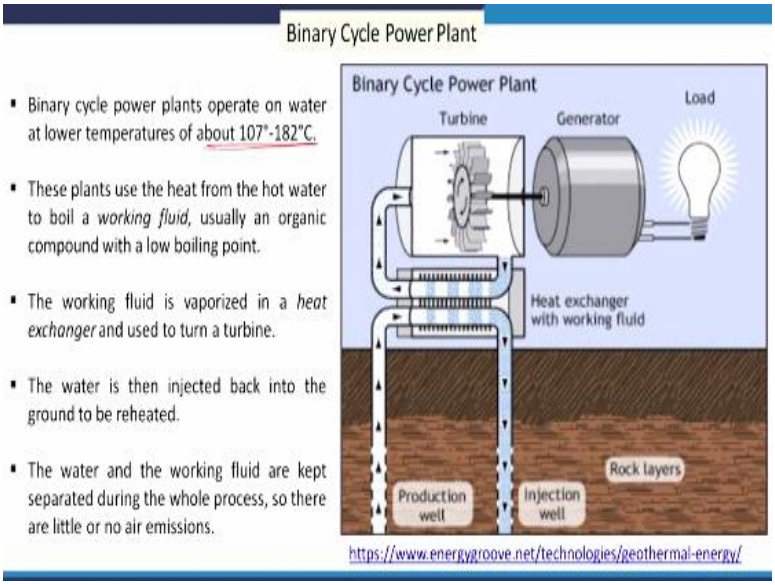

Then binary cycle power plant, but if this temperature is not that high, here say 107 to 182 °C and then water will be at high pressure. So this will come here and then we will be using some solvent here, we will be using some solvent for the recovery of that heat. So this water at 107 to 180 centigrade, it will come here, will recover the heat available in this water, and then other organic solvent is used.

So that will be vaporized at lower temperature and that vapor will be used for the running of the turbine blades, and then turbines have coupled with the generator will give as the electricity. So this is one mode of electricity production in a geothermal power plant and this is called binary cycle power plant. Here one working fluid is required apart from the water which is in the inner circle which is going under the earth and taking heat from the earth and getting out and helping transferring the heat to the working solvent.

So that is what binary cycle, so this water cycle one is and another is your organic solvent cycle. So these 2 cycles are required for the production of electricity.

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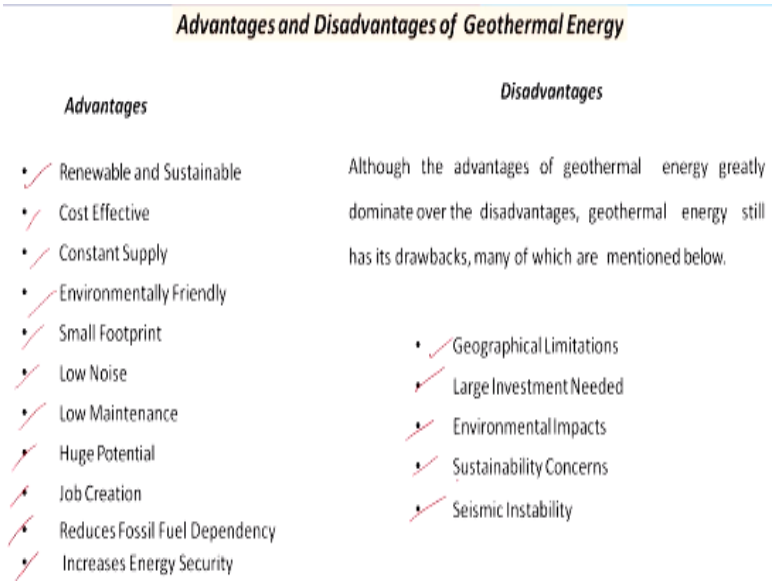

Now we will see the advantage and disadvantages of this geothermal energy. So if we see, there are a number of advantages like say renewable and sustainable, it is cost effective, it is constant supply, it is environmentally friendly, small footprint it requires, low noise, low maintenance, huge potential, it can create job, reduces fossil fuel dependency and increases energy securities. All these are its positive point, but still in spite of that, there are no wide applications of geothermal energy in the world because of some other reasons.

Obviously some disadvantages are also there and some of those are say geographical limitations, so as everywhere we do not have the availability of hot spring or hot water sources and large investment is needed, it requires very large investment, initial investment is very high. Then environmental impacts, it is not well understood. Then it has sustainability concerns there is some debate on how long it will continue etc, whether there will be changes in scenario or not, and systemic instability. So these are the disadvantage due to which this has not used widely in the world.

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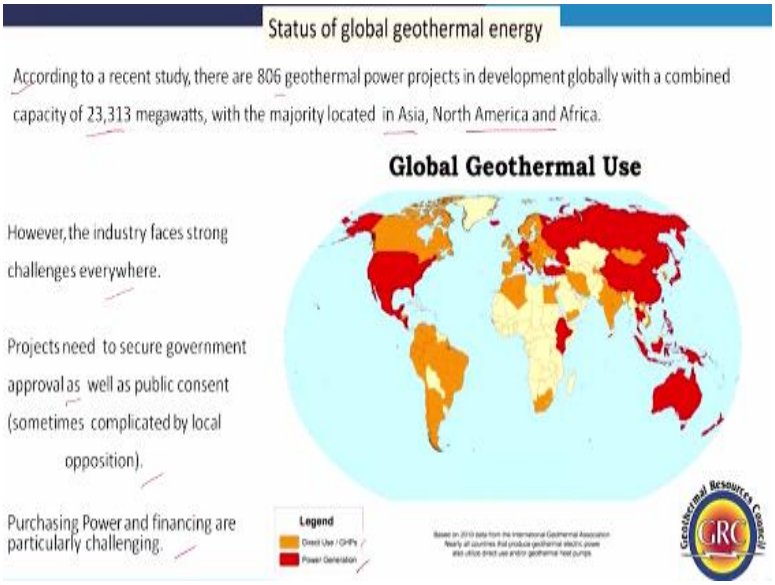

This is the status of global geothermal energy. We see this red the potential power generation, so they have the power generated and so this is your direct use and this is your power generation. So we have discussed that geothermal energy can be used directly, from the heat available in the water can be used directly for the extraction of heat from it for different applications or electricity production, but electricity production takes place here, it is the red color portions and these portions directly used.

In India, also we have some direct use, but electricity production is not here in the country. It is according to a recent study, there are 806 geothermal power projects in development globally with a combined capacity of 23,313 megawatts with the majority located in Asia and North America and Africa. The industry faces strong challenges everywhere. Projects need to secure government approvals as well as public consent and sometimes complicated by local opposition.

Then purchasing power and financing are particularly challenging, so these are some challenges of this method.

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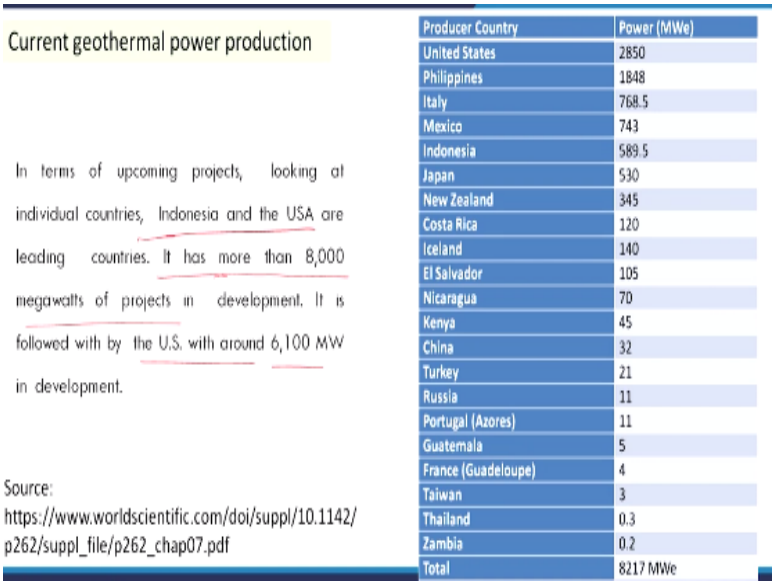

Now we will see some global energy production, electricity production from geothermal route. So total 8217 megawatt equivalent energy is produced. So out of these if we think about the projected means which are the projects under development, so then we see that Indonesia and US these 2 countries are in the top position. So Indonesia, it has more than 8000 megawatts of projects in development. So when it will be developed, it will be having the capacity of 8000 megawatts and it is followed by the US that is 6100 megawatt. These are the existing capacity.

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This is very interesting information that in Iceland which is a seismic area containing a lot of hot water and steam geysers, say they use this geothermal energy for raising the temperature of the greenhouse for the production of banana and largest banana production in Europe is Iceland. So this is the one example of the use of geothermal energy.

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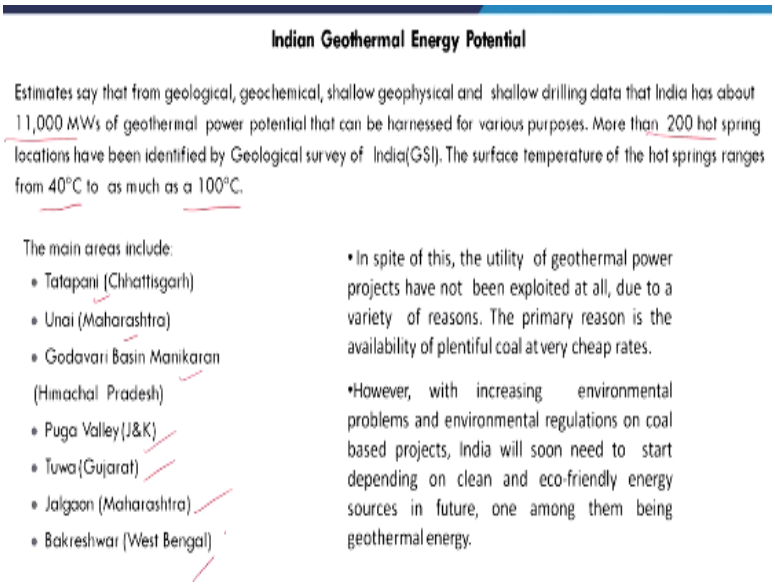

Indian geothermal energy potential if we see we have some reserves, basically up to say 100 °C we can have 45 °C to 100 degree °C of water is available and we have around 11,000 megawatts geothermal power potential and we have more than 200 hot springs and the some locations are say Tatapani, Chhattisgarh; Unai, Maharashtra; Godavari basin Manikaran; Puga Valley; Tuwa; Jalgaan; and Bakreshwar, West Bengal.

So these are the source we have, but still we are not able to use it, there are some reasons because of the investment is very high in this case and we also have plenty of coal which is of low cost. So that is why on economic aspect point of view, this was not explored, but gradually we are becoming more concerned about environmental pollution, so in future we may also have to think about the alternative sense for the use of geothermal energy.

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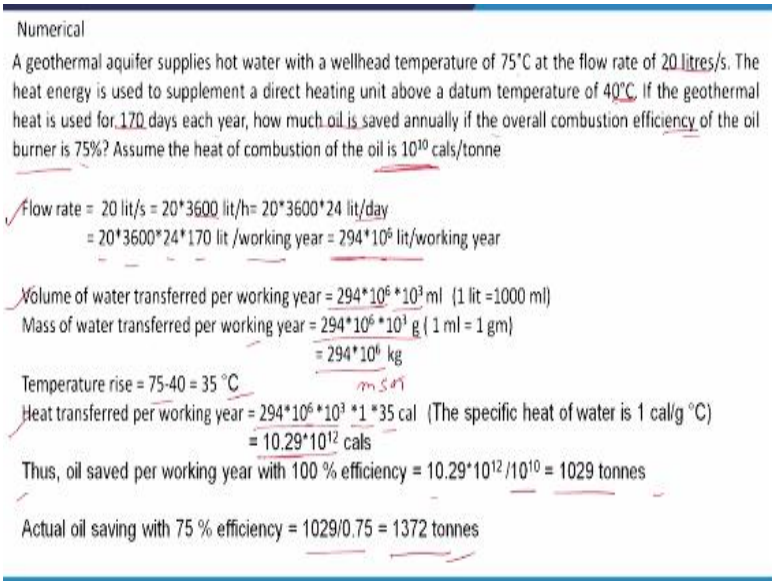

Now we will see one numerical problem. So a geothermal aquifer supplies hot water with a wellhead temperature of 75 °C at the flow rate of 20 liters per second. The heat energy is used to supplement a direct heating unit above a datum temperature of 40 °C. If the geothermal heat is used for 170 days each year, how much oil is saved annually if the overall combustion efficiency of the oil burner is 75%. Assume the heat of combustion of the oil is 10 to the power 10 calories per tonne.

So this is a problem statement. So what is happening in this case for direct applications, we are using the geothermal energy. So to raise the temperature above 40 °C to 75 °C, so if we do not use thermal energy, then we have to use some oil to get this amount of heat and heat of combustion for the oil is 10 to the power 10 calories per ton, so this statement is given. Now we have to calculate how much oil is saved annually. So this is a very simple problem which is based on energy balance.

So what is the energy required to raise the temperature from 40 to 75 °C of the total water which will be used during the year, so that amount of heat will calculate that is the energy required by this water to raise its temperature from 40 to 75 °C and then we will see how much oil is needed to get that amount of heat due to the combustion of it because the heat of combustion is given. So that two mass balance we have to do.

So now we have the flow rate that is 20 liters per second, so 20 liters per second of water, so then 20 x 3600 liter per hour, so that is per day if we want to calculate we have to multiply by 24, so 20 x 3600 x 24 litre per day. Now we have in a year 170 days, that is a working year,

so 20 x 3600 x 24 x 170 litre per working year, so that is 294 x 10 to the power 6 litre per working year, so this is the amount of water to be used for this application. So the volume of water transferred per working year is equal to this litre into 10 to the power 3 milliliter.

Then mass of water transferred per working year, so this we have to multiply it into density that is 1 gram per cc or ml, so this the same this gram and that is equal to 294 x 10 to the power 6 kg, so that we can get this much of water we need to use it. Then temperature rise is 75-40, so 35 degree centigrade. So heat transferred for working year due to the water that is equal to $ms\Delta T$, so specific heat, mass, and temperature difference.

So here we are getting 294 x 10 to the power 6 x 10 to the power 3 gram x 1 calorie per gram per °C specific heat x 35 °C. So this total calorie you are getting, so that is equal to 10.29 x 10 to the power of 12 calories, so this amount of heat is transferred. Now same amount of heat is coming due to the combustion of the oil and the heat of combustion is given is equal to 10 to the power of 10 calories per ton. So what will be the oil requirement?

Here another is given that the efficiency of the oil burner is 75%. So if we assume it is 100% efficient, then we can calculate the oil requirement is equal to 10.29 x 10 to the power 12/10 to the power 10, so we are getting 1029 tonnes, but the efficiency is 75%, so we will divide it by 0.75, so we are getting 1372 tonnes. So this one 1372 tonnes of oil would be required which can be saved due to the use of this geothermal energy. So up to this in this class. Thank you very much for your patience.