Solar Photovoltaics :
Fundamental Technology and Applications
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Lecture - 01
Energy and its Sources

Welcome everyone to our solar photovoltaic fundamental technology and application course. I am sure you must be excited to go through our classes. Today, we have our first week and our first module. In today's lecture we will give you a basic introduction about why this course is important about or what is all about the energy and what are the different sources of energy and how we harness this energy and then we will make a case why we have to study about the solar photovoltaics.

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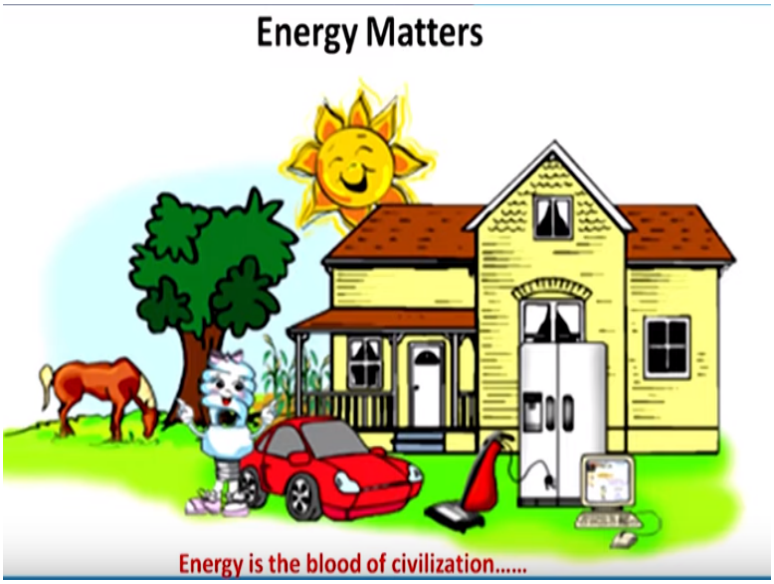

Now energy matters. So you know that if somebody becomes very weak, then we say that you know he do not have lot of energy. And then we give some external source of energy to make him or her work. So just like a human body similarly if you look at a broader perspective like our civilization, so from the morning to the night, to the time we go to the bed, we cannot imagine a single moment of our life without having the energy or some forms of energy.

Maybe it is an electricity or it is like a thermal energy or some other kind of energy but it will be some form of energy. Now whether you are using your electronic gadgets or whether you are watching this video in the computer or you are watching

some television show or you are using your mobile phone and each and everything, starting from the like you know even you take an example for the car, the car fuels and everything and industry, academia everywhere you see that we cannot consider a single moment without having the energy.

That is why the energy is called the blood of the civilization. Now, also recently there was this survey worldwide to recognize what are the top few problems of the upcoming world. And if we have to identify the 10 very upcoming problem for the next few decades, then it was considered that energy tops all the problem. Because all other problem like economic problem or residence or health and all these things, directly or indirectly is related to the energy.

So that is why it is a quest for human being for quite a long time how we can generate this energy. Now, so usually like there are different forms of energy generation. So one of the major form which we use the energy in our day to day life is in the form of electricity. Now, this electric is generated usually by burning fossil fuels like coal and petroleum, natural gas etc.

But as you know that as the population is increasing, so the effective space used by the people and the effective number of gadgets which is utilized by the people is also increasing day by day. But the resources of this conventional sources of energy they are limited. So very soon they will be depleted and very soon we will be out of any source of energy.

So, that is one of the reason like you know we have to be very concerned about to find out an alternative source of energy. And apart from that, whenever we use any form of energy, let us say we are burning coal to generate some kind of thermal energy. So, in this process we generate lot of waste or carbon residues. Now, this waste or carbon residues is actually add pollution to the environment.

They are not good for our marine lives, they are not good even for lot of plants and animal lives also. In addition to the fact like you know, all of us probably aware of this term called global warming. So if the increasing number of energy utilizations

always increase to the more and more global warming phenomena, which refers to the increase of the temperature of the earth's surface.

And the long term consequences is the change of the weather of the earth and as you can see that all the seasons like summer and winter, they have been altered and the temperature variation has been changed also significantly and scientists say that, this is all because of global warming. Now, these all things are related to how effectively we utilize and manage the energy.

And all this thing direct us to find out a safe use and a non alternative environmental friendly source of use of some form of energy. And that is so bad about this field and that is why there are so much of academic and industrial research interest in this field to find out an alternative source of energy, which will add less pollution to the environment.

But at the same time which will be able to fulfill the demand of our day to day life and also it will minimize the global warming. So if that kind of questions we need to answer, so then we have to do more and more research about finding what are the some alternative source of energy which will be less like you know pollution free or which will be like you know more environmental friendly to that sense.

So that is why we are looking towards something like solar energy, something like you know, hydropower energy, or like you know wind power energy. Now there are different forms of this renewable energy. Now, so as a tropical country like India in most of these places get a lot of sunshine. And it is assured that for us and future few generations for all of us, like sun will be there.

And if by some way like if we can harness energy from the sun so that will be kind of environmental friendly. Because all of us have seen that plants make their food by using sunlight. They utilize the water molecule and they take the carbon dioxide from the environment.

And by using the sunlight, the chlorophyll, the green pigments in the leaves, so by the process called photosynthesis, they make the glucose molecule oxygen and basically

they make the energy. So we have learned that lesson. So inspired by this idea the people were thinking, okay can I mimic the same kind of concept in the lab? Can we make an artificial photosynthetic system in the lab.

So that was the inspiration behind utilizations of the solar light or sunlight for making some useful form of energy. And that leads to this photovoltaics technology or solar energy technology. And since they said that, that a lot parts of the India like both the coastal area as well as the plain area, we got lot of sunshine like during most of the time of the year.

So if we can utilize the sunlight to make some useful form of energy that will be more economical and also that will be environmental friendly for all of us. And this is not only the picture for India, and we can say that is for the rest of the world this idea is also valid. Now there are some places where people use the hydel power or like you know the flow of the water to rotate the turbine and use that to generate some form of energy.

Now in some area like especially near the ocean or near the coastal area you can say that the wind is very nice. So we can utilize like you know this wind power to generate some form of electricity. So there you can see some windmill is there. So these are all like, you know different source of energy. But out of all of that solar energy is especially very popular for number of regions.

That we will discuss in our course and it is taking an exponential space, both academically and industrially nowadays for applications in our domestic life as well as like you know for different industries, airports, vehicles, cars and everywhere. So in our course, we will learn in details about the different form of this technology, how to generate the electricity from the sunlight.

What are the underlying basic technology behind it, the basic physics behind it, and then we will also go to some engineering aspect, like we will discuss about the different generations of the solar cell. For example, like you know, we will talk about the silicon solar cell, the solar cell which you have seen in your like you know calculator.

You must have seen that in your calculator there is a small transparent panel embedded in the right hand side; some calculator have some calculator does not have. So basically that is a solar panel right. So and in many of the like in house also we have seen that the solar panel has been installed. Now, these solar panels they are amorphous silicon cell.

So we will also learn like you know how to make this kind of solar cells and how what is the mechanism they generate the electricity. And coming to the modern time so as the technology becomes more and more matured, so the silicon technology has also evolved towards the time and people have came across with some new form of materials.

Now this new form of the materials, they involve some organic materials, as well as some engineer carbon nanomaterials. Now all of this thing has led to some new kind of solar cell, they are called third generation solar cell, which will also we will discuss in our course. Now and finally we will see that both in India and all of the countries, the solar energy or the solar cells has now utilized not only in the space mission, but for everywhere.

So what are the technology and what are the technological success behind the story that we will discuss in details in this course. But before going to all of this thing like first we have to have our like you know basic idea like you know where we are starting from or where basically where the problem starts from. The problem starts from our conventional source of energy.

So let us look at the first like you know what are the conventional source of energy or how we get that things, right?

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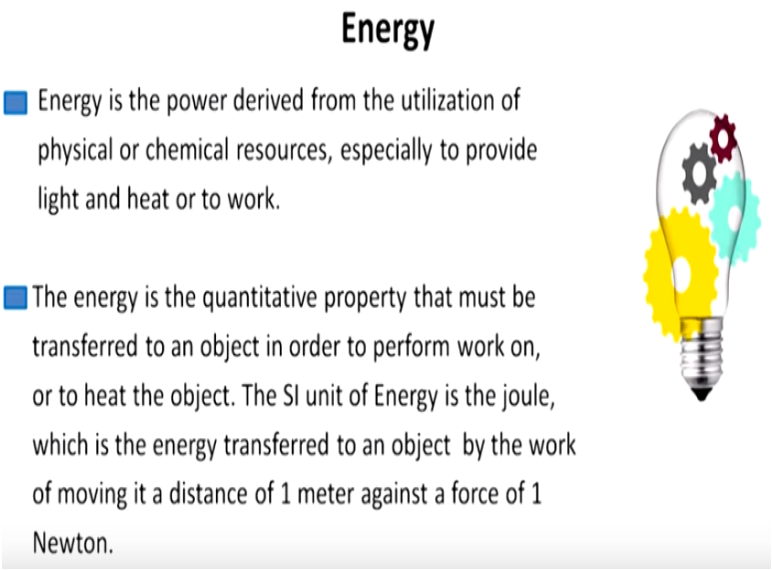

So as we said that energy is the power derived from the utilization of physical or chemical resources, especially to provide light and heat or to work. So whatever we do, either finally we have to generate light or we have to generate heat or we have to do some kind of work. So that is our ultimate goal when you generate the energy. Now, the energy is the quantitative property that must be transferred to an object in order to perform from work on, or to heat the object.

The SI unit of energy is joule, which is the energy transferred to an object by the work of moving it a distance of one meter against a force of 1 Newton. So if you apply a force of 1 Newton and if you want to move an object a one meter, so the amount of work done that is called the 1 joule. And that is a conventional SI unit of the energy.

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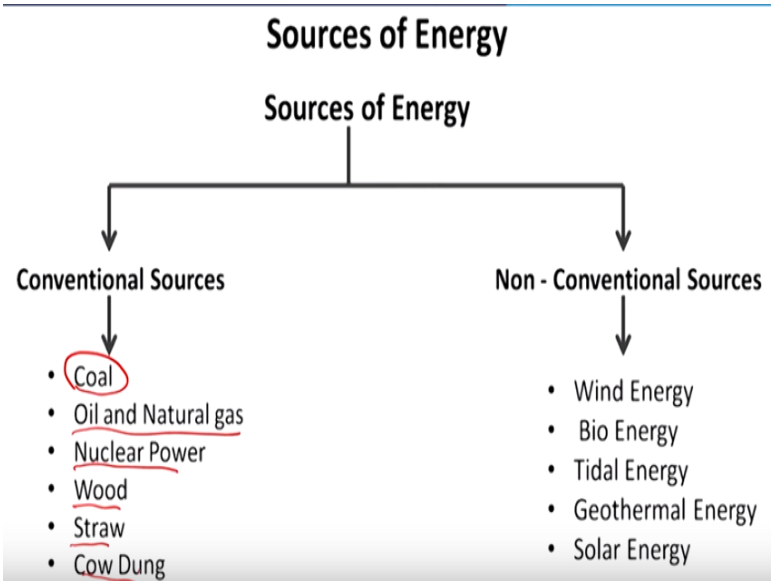

Now as we just mentioned, the sources of the energy, they can be broadly classified into two different categories namely the conventional source and non-conventional source. So the what are the conventional source? So as we have mentioned here by conventional source, the one of the main example is that coal, right? And then this oil and natural gas.

So these two things, coal, oil and natural gas, I mean you can say that they are the heart of producing energy nowadays, okay. So we burn coal we burn oil or natural gas to drive our car or like you know generate electricity in our house. In addition to that there are civilian application of the nuclear power. There are a lot of nuclear power plant in the country, which is used to generate the electricity.

And then there are other source of conventional source like you know, let us say from a forest you can get a lot of woods and in the village side if you go that we have seen that we burn the wood and we can generate thermal energy. That is also a source of energy. And then the straw an agricultural byproduct and then the cow dung or the biomass, right. So these are like you know some conventional source of energy.

And by non-conventional source of energy, we mean like you know some of the popular example are will be like you know wind energy, bio energy, and then tidal energy, geothermal energy and finally solar energy. Now wind energy that use like you know the wind power to rotate in a turbine to generate the electricity. Bio energy like you know they use some bioactive bacteria to convert some kind of waste material to generate the electricity.

Tidal energy so there we have used that like you know the tidal or the water flow, the power that has been converted to the electricity. Geothermal energy like you know it is considered that in the earth's surface there are some amount of heat gradient and if we can extract that the heat gradient that will also be useful for us. And then our solar energy, which we will discuss in our course.

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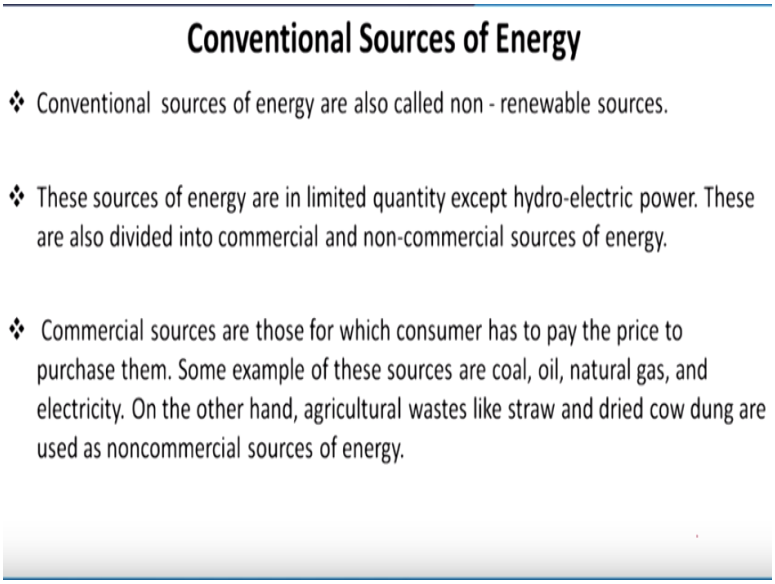

Now the conventional source of energy, now conventional source of energy are also called non renewable sources. Why non renewable? Because, like renewable means something which we can generate again and again. So non-renewable means which we cannot generate again and again. So this coal, natural gas or petroleum, they are actually extracted from the earth surface, right.

So I mean, their resources are limited. They have been found long back in the Carboniferous age. So once they are formed we are using that sources. So we cannot renew them. Today if you want like you know we cannot make a source of coal. So we have to use what we have. That is why they are called non-renewable sources. Now these sources of energy are in limited quantity except hydroelectric power.

These are also divided into commercial and non-commercial source of energy. Now what are the commercial source of energy? Commercial source are those for which consumer has to pay the price to purchase them, like for like you know in our home we know that we have to pay the electricity bill and why we are paying the electricity bill?

Because like you know the electricity which we are getting in our home that has been generated by burning coal or by like some kind of oil or natural gas, usually by coal. Now all this process involves some kind of money. So this is a form of revenue generation. So that and we have to purchase this electricity from the government or some like you know private organization.

So that is why they are commercial source of energy. Like some example of this source are coal, oil, natural gas, and electricity. On the other hand, agricultural waste like straw and dried cow dunk, they are used as a non-commercial source of energy. Well and in some of the parts of the world like you know, even people have to pay to get an energy which have been derived from the cow dung.

But as far as our country is concerned, if you talk about the raw material like straw, which is an agricultural byproduct, right or the cow dung, dried cow dung that is available freely and we do not need to pay any like you know money for buying straw or cow dung or to get to generate the electricity out of that.

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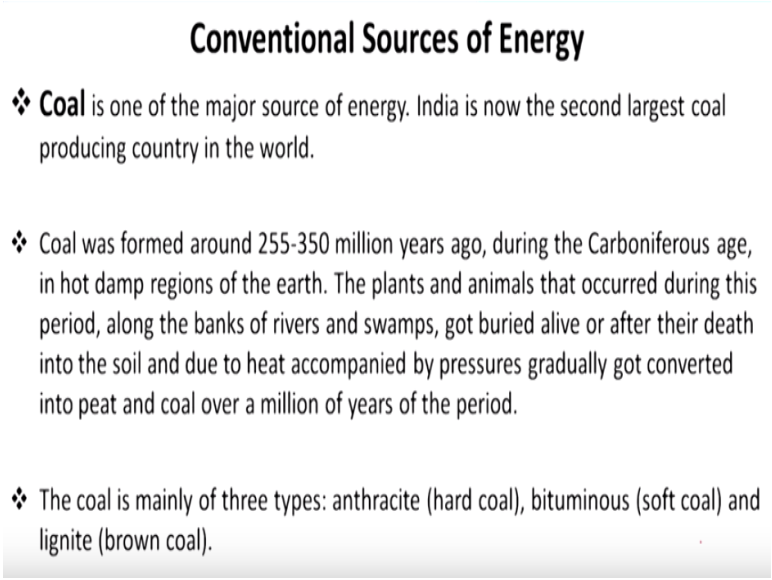

Now, coming to the conventional source of energy coal, so coal is one of the major source of energy. India is now the second largest coal producing country in the world. Coal was formed around 255 to 350 million years ago during the Carboniferous age in hot damp regions of the earth. So we are talking about a time which is 255 to 350 million years ago; long back during the Carboniferous age in the hot damp regions of the earth.

In the next slide we will show you a schematic diagram to get an idea about this phenomena. Now what happens the plants and animals that occurred during this period along the banks of rivers and swamps got buried alive or after their death into

the soil, and due to the heat accompanied by the pressure gradually got converted into peat and coal over a millions of years of the period.

So basically what happens like whatever the animals and the plants which were there across the riverside, they got buried either on a living condition or after the death and then over the time, by the use of the temperature and the pressure and also in the presence of some anaerobic bacteria, they have slowly converted to the peat and coal and this has taken a long period of the time.

The coal is mainly of three types; anthracite or hard coal, bituminous or soft coal and lignite or brown coal.

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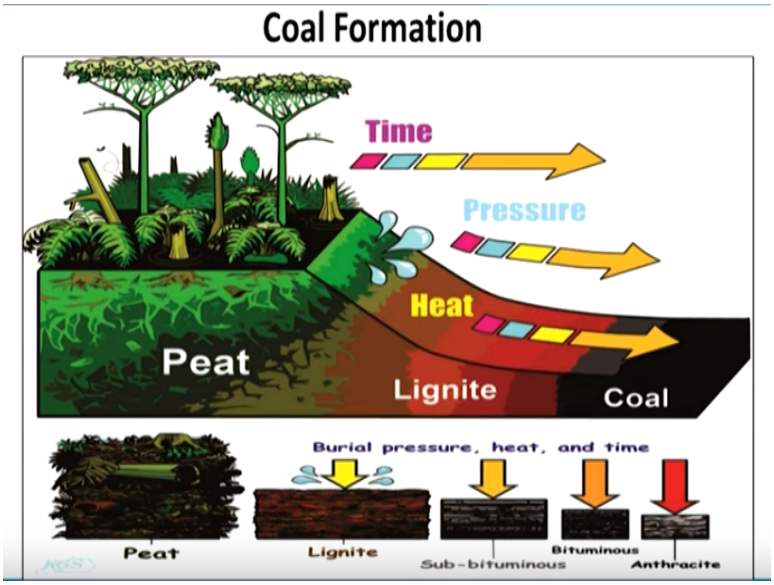

So in this picture like you know, we are showing how this coal promotion is happened. As you can see that here there are these plans are there and these are some of the animals which have been like you know buried in the earth surface and this is the time axis. So over the time by the use of the heat and the pressure so these are all of this like you know plants and animals, they have been slowly converted to the different forms of the coal.

First they have converted to the peat and then the lignite and then the coal. So from the peat like you know, when the pressure is there, you will get the lignite. And then if you use heat also along with the pressure you get a sub-bituminous and over the time

it become more solidified to become bituminous and anthracite. These are the different like you know I mean the form of the coal.

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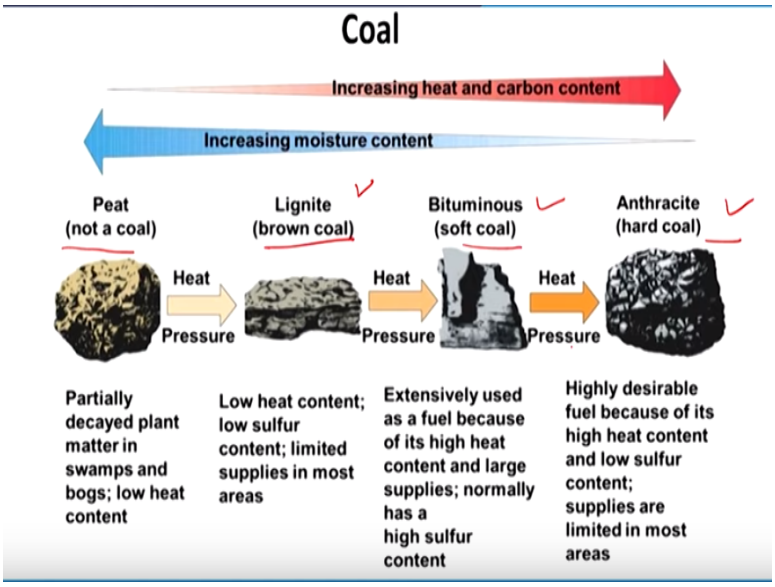

Now, so basically if we increase the heat and the carbon content based on that this different classifications of the coals are there. For example, peat. Peat is actually not a coal. It is partially decayed plant matter in swamps and bogs; low heat content. So I mean, whenever the plants and the animals they got buried, so they have been partially decayed by anaerobic bacteria, right.

So these are like you know, these are called peat, they are not coal. And if you burn them, they are like you know the amount of heat they will generate is not that high, okay. Now, if we allow the heat and pressure to act on the peat, then they converted to the brown coal. Brown coal is called lignite. Okay, so low heat content and they have a low sulfur content and limited supplies in most of the area.

Now, if I apply more heat and more pressure on the lignite or the brown coal, so it will convert it to the soft coal. The soft coal is called bituminous. This is extensively used as a fuel because of its high heat content and large supply. Normally it has a high sulfur content. So we can see that the sulfur content is related to the amount of heat generation.

For lignite we have low sulfur content and the amount of heat generation is also low. For bituminous the sulfur content is higher and the heat generation is also higher.

Now, starting from the soft coal if I put more heat and more pressure, then we get a hard coal or anthracite, okay. So anthracite is highly desirable fuel because of its high heat content and low sulfur content; supplies are limited in most of the area.

So there are three different types of coal we have discussed. One is the brown coal or lignite. Another is the soft coal or bituminous. Another is the hard coal or anthracite. Now how we get from one of them? By applying gradual heat and pressure. What is the major difference between the like lignite, bituminous and anthracite? The amount of the heat generation from them.

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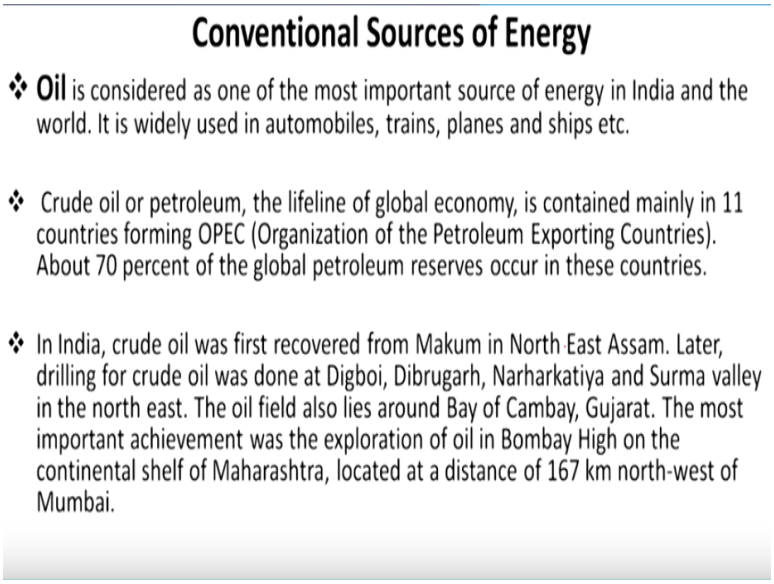

Now, the second conventional source of energy is the oil. Oil is considered as one of the most important source of energy in India and also in the world. It is widely used in automobiles, trains, planes and ships etc. Crude oil or petroleum the lifeline of global economy is contained mainly in 11 countries forming the OPEC or Organization of the Petroleum Exporting Countries.

About 70% of the global petroleum reserves occur in these countries. So these OPEC countries or the Organization of the Petroleum Exporting Countries, 70% of the global petroleum reserves occur in these countries. In India crude oil was first recovered from Makum in North East Assam. Later drilling for crude oil was done at Digboi at Dibrugarh and then Narharkatiya and Surma valley also situated in the north east.

The oil field also lies around Bay of Cambay, Gujarat. The most important achievement was the exploration of the oil in Bombay High on the conventional or the continental shelf of Maharashtra located at a distance of 160 km north-west of Mumbai. These are some of the place where India have the oil refinery. Although these are some of the example India has also some other place from where the oil has been extracted and a continuous search is going on to find out the new place for the old reserve.

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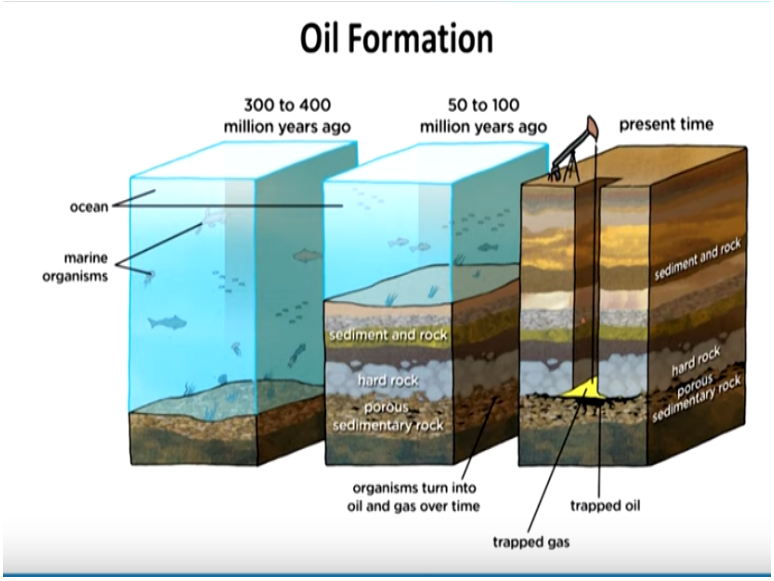

Now again the oil formation follows the same story like a coal. You see, this is the ocean and there are the marine organisms are there. We are talking about a story which is 300 to 400 million years ago; long back. So what happens this marine organisms they got buried and then from 50 to 100 million years ago the sediment and rock and we have a layer of the hard rock and the porous sedimentary rock and the organisms.

When the organisms which are like you know, which is situated in this hard rock and the porous sedimentary rock in this area the animal and the plants has been buried away, so the organisms turns into oil and gas over time. And finally, at the present time, they have been converted to the trapped oil and also some trapped gas and this is the oil and the gas that we extract using a tube.

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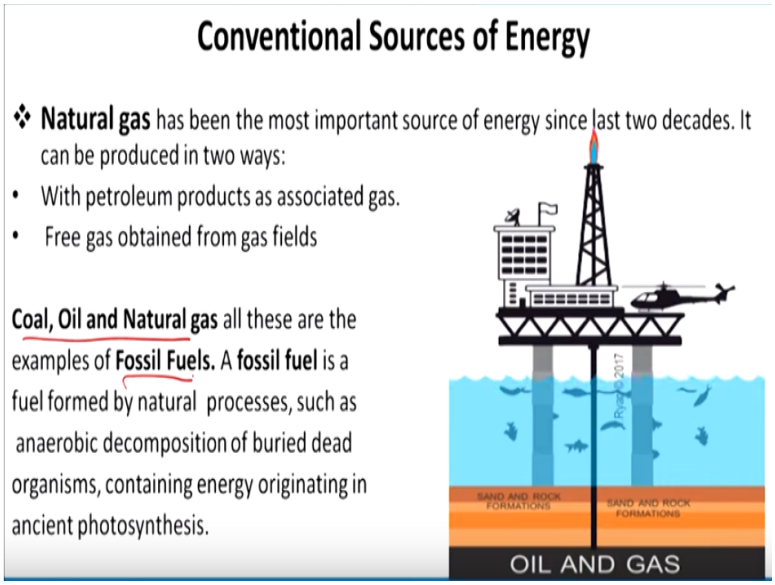

So the natural gas also produced in the same way right. The conventional source of energy the third source is natural gas has been the most important source of energy since the last two decades. And it is worthwhile to mention that in western countries, there are more and more interest to use natural gas over the oil. In India it has also been started and you can see that that the cost of the natural gas is little bit lower than the oil like petrol and diesel.

It can be produced in two different ways with petroleum products as associated gas or free gas often from the gas fields. So whenever we extract the petroleum as a byproduct also we can get a natural gas or there are some places in the earth where the natural gas is buried like as a gas field and we can extract also from there. Now this coal, oil, and natural gas these three things mainly, they are all the examples of the fossil fuels.

So what is a fossil fuel? A fossil fuel is a fuel formed by the natural process such as anaerobic decompositions of the buried dead organisms containing energy originating in ancient photosynthesis.

So all of this like you know animals and plants, when they got buried in this swamps and the river banks over millions of years of the time by using the pressure and heat and by anaerobic degradation so they have been slowly converted to coal, oil and natural gas, the different source of the conventional energy. So these are called fossil fuels.

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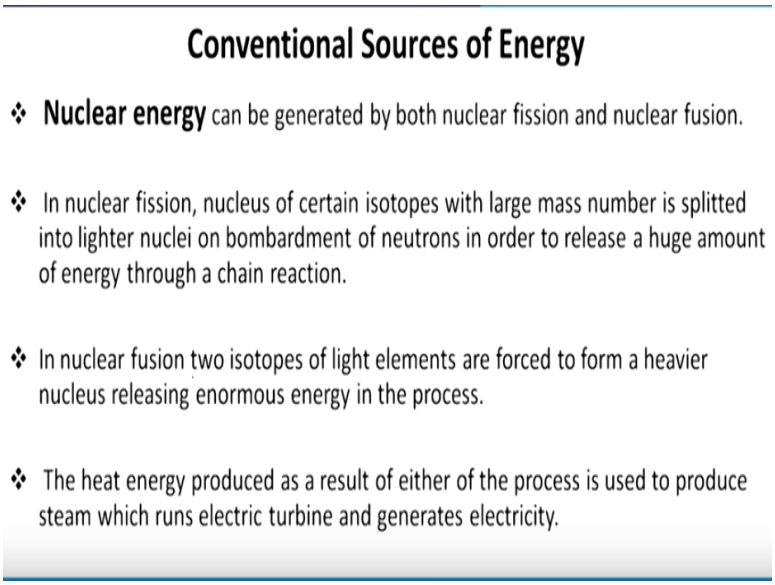

Now another conventional source of energy is the nuclear energy. Nuclear energy can be generated by both nuclear fission and nuclear fusion, right? In one of the case what happens like you know, one atom disintegrates into its constituent atoms and when it disintegrates, so then what will happen whatever the energy difference is generated, that is utilized.

And in fusion like let us say, I have like 4 hydrogen atom or like you know, I mean I want to combine this 4 hydrogen atom. So that if I have like you know some constituent atoms and if we combine them, so whatever the final atoms will get, there will be a mass difference of the final atom from the constituent atoms and that mass difference is converted to the energy. That is a huge amount of energy we get.

That is called nuclear fusion. Now either this fission or the fusion, it is very difficult to control these processes, okay. In nuclear fission, nucleus of certain isotopes with large mass number is splitted into lighter nuclei or bombardment of neutrons in order to release a huge amount of energy through a chain reaction.

And in nuclear fusion two isotopes of light elements are formed to form a heavier nucleus releasing enormous energy in the process. The heat energy produced as a result of either of these processes is used to produce steam which runs electric turbine and generate electricity.

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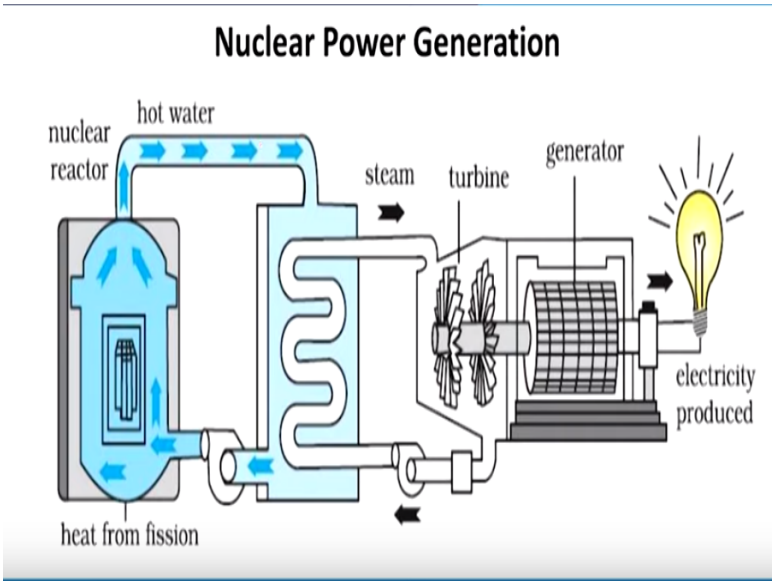

Here there is a conventional nuclear power plant is showing. As you can see that this is a nuclear reactor and which have been kept with a very good insulator. The insulator is actually protected from all kind of environmental leakage, okay? So the heat which have been generated from the nuclear fission that helps to heat the water and that water like you know that generate the steam and that steam rotate the turbine and using a generator we use the electricity. That is the safe use of the nuclear power.

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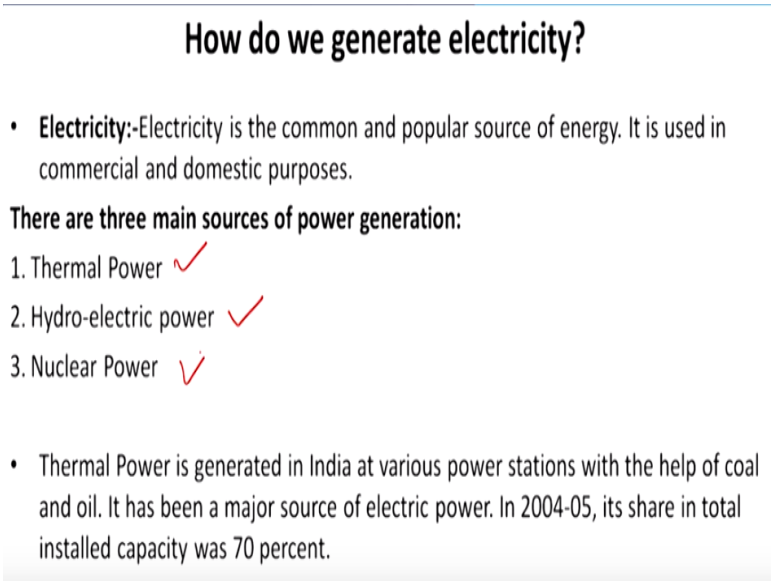

Now the finally like the electricity. So how do we generate electricity? Electricity is the common and popular source of energy. It is used in commercial and domestic purpose. Now there are three main source of power generation. One is thermal power, another is the hydro-electric power and other is the nuclear power. Thermal power is generated in India at various power stations with the help of coal and oil.

It has been a major source of electric power. In 2004-05 its share in total installed capacity was 70%. So still like you know, we depend on the thermal power the most. In the hilly area of some parts of the country we have the hydro power plant or hydroelectric power plant and some part of the country we have a very small source of nuclear power plant.

But the dominating source of energy or the major source of energy in the country is still the thermal power plant.

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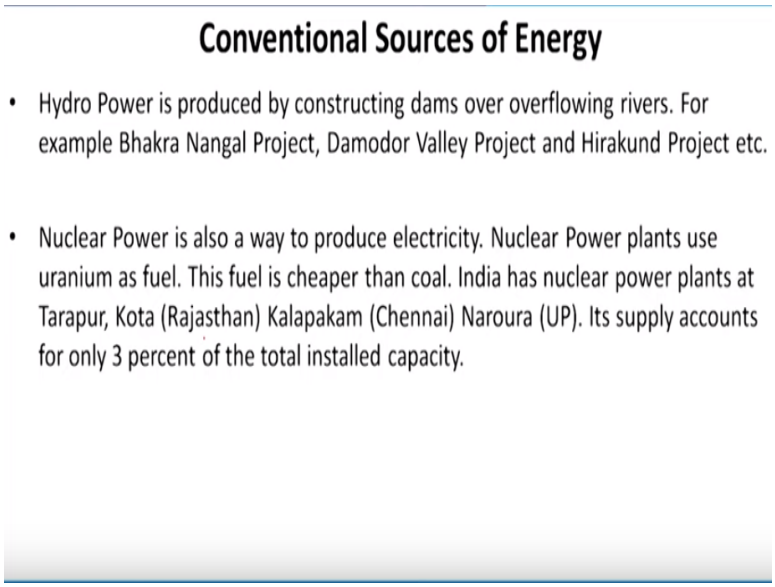

Hydropower is produced by constructing dams over overflowing rivers. For example, Bhakra Nangal Project, Damodor Valley Project and Hirakund Project. These are some of the very famous example of the country where the hydropower like you know this dam has been made. Nuclear power is also a way to produce electricity. Nuclear power plants use uranium as fuel. This fuel is cheaper than coal.

This is very interesting, right? India has nuclear power plants at Tarapur; Kota, Rajasthan; Kalpakkam Chennai; Naroura at UP. Its supply accounts for only 3% of the total installed capacity. So although like you know uranium as I said that as a source of the fuel it might be cheaper than the coal, but the processing when you talk about the total technology, it becomes very expensive.

So that is why the major contribution to the total electricity generation from the nuclear power is still very less. We have learnt about like you know conventional and non-conventional source of energy. Now just a few minutes back, we discussed about the renewable sources. So we can also classify the energy about renewable and non-renewable sources of energy, alright?

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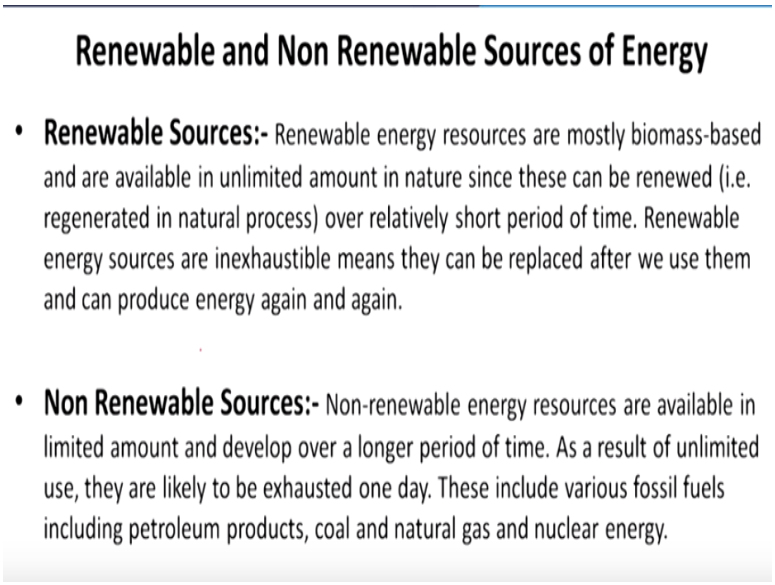

So what is renewable sources of energy? Renewable sources, renewable energy resources are mostly biomass-based and are available in unlimited amount in nature. Since this can be renewed that is regenerated in natural process over relatively short period of time. So as the name suggests renewable energy can be renewed over a short period of time.

Renewable energy sources are inexhaustible means they can be replaced after we use them and can produce energy again and again. So we can do like you know regeneration or recyclability. So we can generate the energy from the same system again and again. So like for example, like if I have a coal once you burn the coal so it become, it generate the energy and then it becomes ash.

So we cannot use that ash for generating again the energy. But if I have a solar panel, today I can use them for making energy. Okay, for generating energy and tomorrow again I can use that solar energy in solar panel to generate the energy. I do not have to like you know throw that solar panel after one time use to generate the again next cycle of the energy. Well of course, everything has a life lifetime.

After like you know certain period of time like it will lose its capacity. That comes from the material degradation. That is a separate story. But in terms of the like you know energy generation capacity or regenerability, this renewable energy sources will be those which we can regenerate again and again over a short period of time. So non-renewable sources, non renewable energy resources are available in limited amount and develop over a longer period of time. Just we mentioned, right?

Coal, natural gas oil, millions of years. As a result of unlimited use they are likely to be exhausted in one day. These include various fossil fuels, including petroleum products, coal, and natural gas and nuclear energy.

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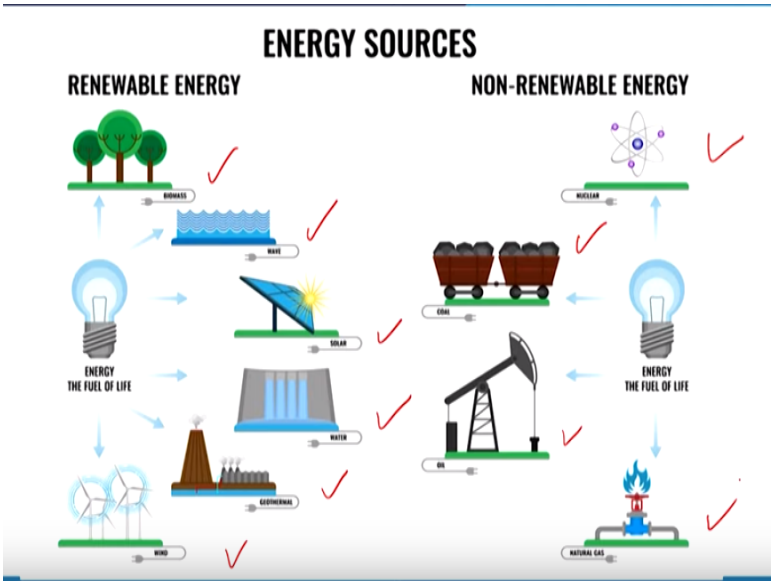

So you see this in this pictorial diagram, we are classifying just to show you what are the renewable energy, like biomass, like wave and then solar power, water, geothermal, wind. And what are the non-renewable sources of energy like nuclear, then coal, oil and the natural gas. Both of them can generate the electricity. Both of them the renewable energy and non-renewable energy can be used to generate the electricity.

But some of them can be used again and again over a short period of time. Some of them can be not be regenerated again and again over a short period of time. And the making of their source takes billions of years of time. Now there are certain environmental impacts of this fossil fuels. The main things are the following.

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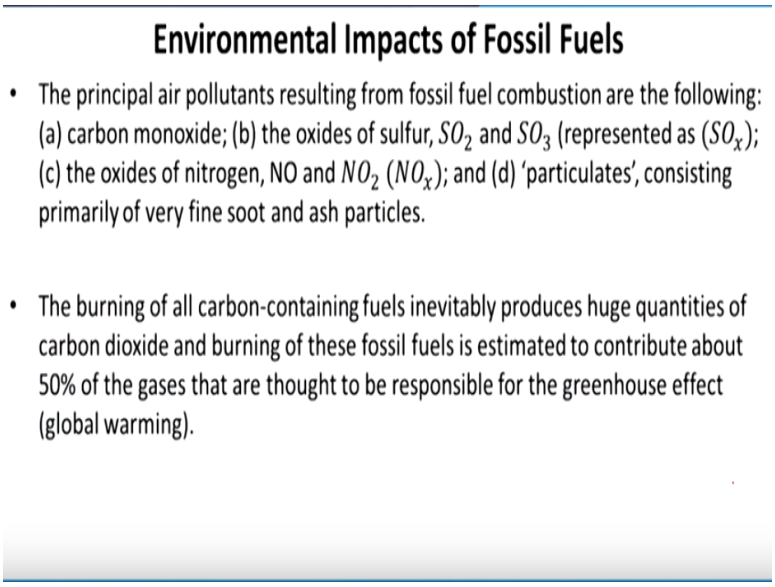

The principal air pollutants resulting from fossil fuel combustion are the following; carbon monoxide, the oxide of the sulfur like sulfur dioxide and sulfur trioxide, sometimes represented as a SO x. The oxide of nitrogen, nitrogen monoxide and nitrogen dioxide. You can also write as NO x where x stands for like you know 1 or 2 and particulate matters consisting primarily of very fine soot and ash particles.

So whenever like you know this fossil fuels they burn, so they generate all kind of this pollutant gas, like carbon monoxide, sulfur dioxide, nitrogen dioxide, nitrogen monoxide and some particulate matters. The burning of all carbon containing fuels inevitably produce huge quantities of carbon dioxide and burning of these fossil fuels is estimated to contribute about 50% of the gas that are thought to be responsible for the greenhouse effect global warming.

So only the burning of the fossil fuel contribute to the 50% of the gas that contribute to the greenhouse effect. Now, what we are doing to mitigate that effect? Who are the entity to absorb that carbon dioxide from the nature, plants. But due to the growth of the civilization we are cutting that plants.

So in one way we are burning the fossil fuels to fulfill the need of our day to day life which is adding like 50% of the this dangerous gases or the greenhouse gases, which is contributing to the global warming and on the other hand, the sources which can

absorb those gases that we are cutting. So because of that, like you know this two way work so the total environment is getting polluted day by day.

And that is why it is a serious concern about the weather change and the global warming. So the greenhouse effect a term like you know, which you all heard about again and again in newspaper, TV, radio and everything, people talk about greenhouse effect. So the greenhouse effect is like you know a very simple idea.

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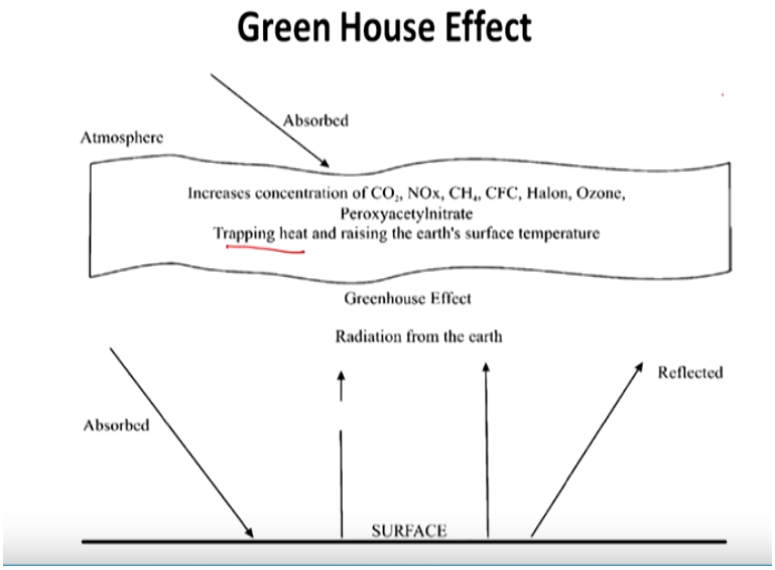

So here like you know you can think about like there is this is the earth's surface, right. And this is our atmosphere. So as you know that this atmosphere has different layers; stratosphere, troposphere, ionosphere, ozonosphere etc, etc. Now whatever the radiation which is coming, they get absorbed in the atmosphere. Now in the atmosphere, there are also the air molecules are there. There gas molecules is there.

So if because of the burning of the fossil fuel, if we add more and more this gaseous product this dangerous gaseous product to our atmosphere, for example, if we increase the concentration of carbon dioxide, nitrogen based oxide and then methane CFC that is chlorofluorocarbon a pollutant which is also released from the refrigerator and then Halon, ozone and then peroxyacetylnitrate.

So these are the all of these products like they have generated by burning the fossil fuels. So whenever we burn the fossil fuels, we generate them and these are adding to our atmosphere. Now what happens like you know, when the radiation falls on the

earth surface or on the atmosphere, this gas will absorb those radiations. So what will they do?

So if they absorb the radiation the job of the atmosphere was to transfer the radiation to the earth surface. But they are now absorbing that heat here. So they are the trapping heat. So once they are trapping heat, so what will happen like so basically the temperature in the top of the atmosphere is now increasing, okay. And on the other side, like you know, whatever the radiation which is absorbed on the earth surface, so they are supposed to reflect it from the earth surface.

Now, if I have a layer of this kind of highly dense, high refractive index gases on top of the earth surface, then those reflected gas cannot escape from the earth surface to go to the outer atmosphere. So in one way, you are blocking you are increasing the heat of the exact nearest environmental atmosphere temperature, and in other way we are blocking the escape of this radiation after reflection from the earth surface.

So what will be the result? Consequently, like you know whatever the radiation which is not able to escape from there, they will go and they will get absorbed in this gas molecule and increase the heat of this thing. So finally, the heat of the earth surface is increasing. So this effect is like you know, I mean this effect is called the greenhouse effect.

And as you can see this from this picture, it is directly related to the burning of the fossil fuel. As more and more like these high specific heat gases will add to the atmosphere so more and more heat trapping and more and more like you know obstacle or the hindrance to the escape of this radiation from the earth surface will occur and that will effectively increase the temperature on the earth surface and heat on the earth surface. So that is called the global warming or the greenhouse effect.

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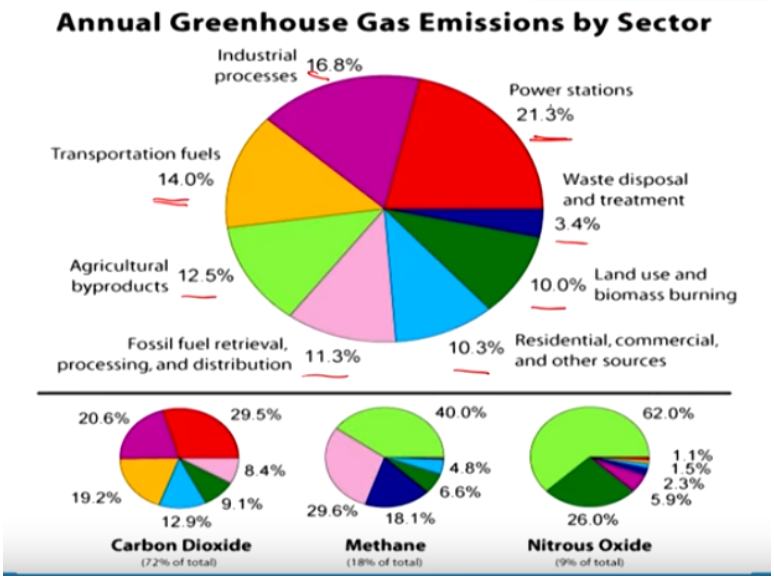

For an example, there is an estimate which have been done annual greenhouse gas emission by the different sectors. See the industrial process they add 16.8% to the greenhouse gas emission. Power station 21.3%. Waste disposal and treatment 3.4%. Land use and biomass burning 10%. Residual, commercial, and other source 10.3%. Fossil fuel retrieval, processing and distribution 11.3%. Agricultural 12%. Transportation 14%.

So what are the main sources? Power stations, 21%, industrial process 16.8% and transportation 14%. Now can we stop any of this process? Can we stop power station? Can we stop industrial process? Can we stop transportation? We cannot stop any of these process. So we have to, we have to run all these techniques. So that means we will be continuously adding all these greenhouse gases to the environment.

Now you can see that the carbon dioxide consists 72% of the total greenhouse gases in the atmosphere, followed by the methane 18% and nitrous oxide 9%. So these are very dangerous situations. So to run our civilization to run our day to day life, we have to run the powerhouse, we have to power station, we have to run the industry, we have to run the transportation. So that means we have to burn the fossil fuels.

One way their resources are limited. And other way when you are burning them we are adding dangerous greenhouse gases like carbon dioxide, methane and nitrogen dioxide to the atmosphere. So not only that, like you know I mean the immediate

consequence we can feel and realize in our day to day life. They have a severe environmental hazards, severe effects on the health.

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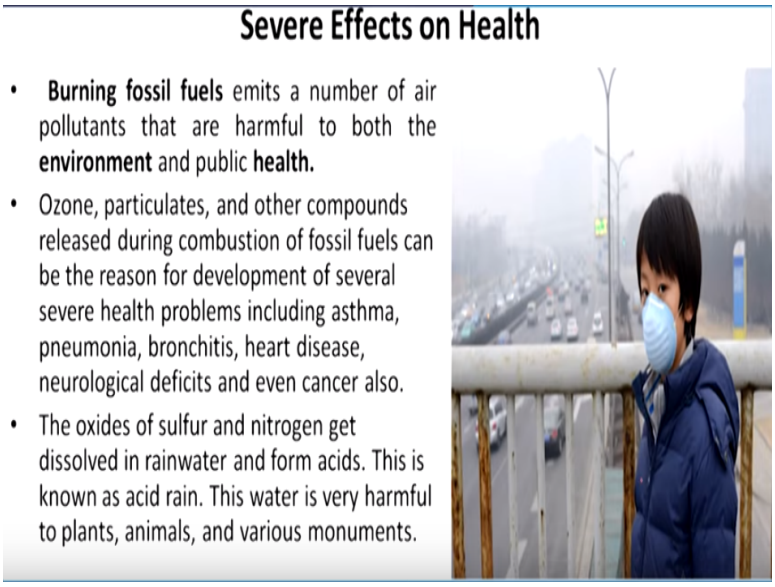

As you can see from this little boy, he is walking in his house with a mask. You look at any of the metro city, like you will see even in the morning time, there is a very dense fog or smoke which have been smeared all over the area. And this is all coming because of the formation of the large particulate matter. Burning fossil fuels emits a number of the air pollutants that are harmful to both the environment and public health.

Ozone, particulates and other compounds released during combustion of fossil fuels can be the reason for development of several severe health problems including asthma, pneumonia, bronchitis, heart disease, neurological deficits and even cancer also. So more and more like you know this detrimental disease they are increasing because of this severe environmental pollution. The oxide of sulfur and nitrogen get dissolved in rainwater and form acids.

This is known as acid rain. This water is very harmful to plants, animals and various monuments. So you might have heard this story that Taj Mahal and other like you know I mean this some historical monuments and the towers they are fading. They are fading up sometimes because of this acid rain. Because all of this like you know sulfur and nitrogen oxide, they can dissolve in the water and they can be made like you know some kind of acid.

And if the acid then mixed with the water we will get the acid rain. So they will corrode the surface slowly over the time and they will fade the color.

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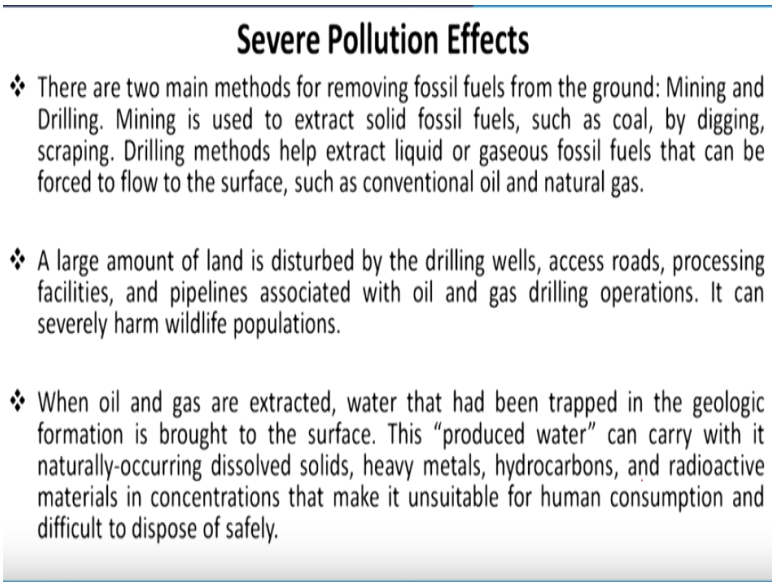

There are two main methods of removing fossil fuels from the ground, mining and drilling. Mining is used to extract solid fossil fuels, such as coal, by digging scrapping, and drilling methods help extract liquid or gaseous fossil fuels. That can be forced to flow to the surface such as conventional oil and natural gas. A large amount of land is distributed and disturbed by the drilling wells, access roads, processing facilities and pipelines associated with oil and gas drilling operations.

It can severely harm wild life population. When oil and natural gas are extracted water that had been trapped in the geologic formation is brought to the surface. This produced water can carry with it naturally occurring dissolved solids, heavy metals, hydrocarbons and radioactive materials in concentrations that make it unusable for human consumption and difficult to dispose of safely.

So basically, like the two major methods of extracting the fossil fuels, drilling and mining, they also associated with some secondary pollution. So now we are convinced that we need a alternative source of energy. There are so much environmental hazards. There are so much hazards on our health. So need for sustainable energy sources. The energy requirement of the world is ever increasing.

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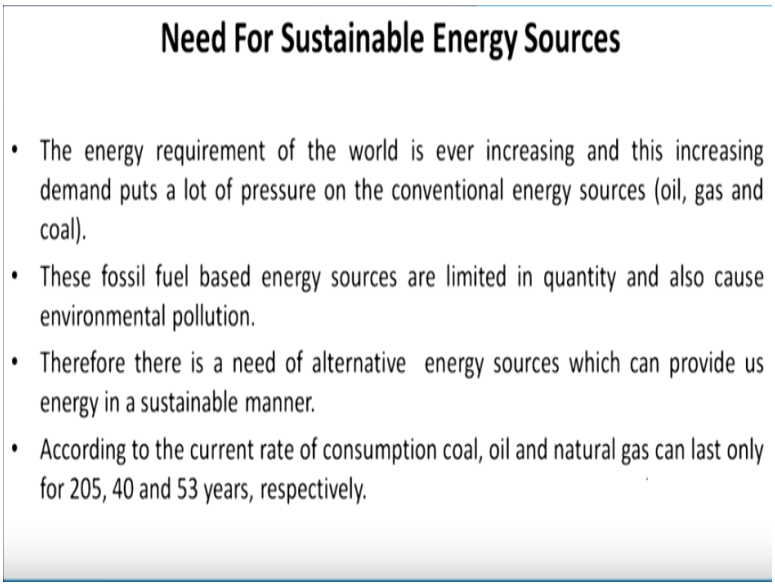

And this increasing demand puts a lot of pressure on the conventional energy sources oil, gas and coal. This fossil fuel based energy source are limited in quantity and also cause environmental pollution. Therefore, there is a need of alternative energy source, which can provide us energy in a sustainable manner. According to the current rate of consumption of coal, oil and natural gas, they can last only for 205, 40 and 53 years respectively.

So not very long time before which the sources of coal, oil, and natural gas will be finished. And this statistics has been given considering the present utilization rate which is ever changing in a increasing side. So we never know that probably in a less amount of time this resources will be decreased, right. So what are the need for the sustainable sources? To explain that we have given this table.

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Need For Sustainable Energy Sources

Resources	Unit	Current Reserves	Current Production Rate	Availability (No. of years)
Oil	Billion barrels	1047.7	26	40.2
Gas	Trillion scf	5501.5	102.2	53.8
Coal	Billion tons	984	4.8	205

Source: adapted from www.bp.com 2003

Like how much the current reserves of the different fossil fuels, what is the current production rate and what is the availability of the number of years. If we look at the oil, current reserves is thousand 1047.7 billion barrels, current production rate is 26 billion barrels. In this rate, it will run 40.2 years, not even 50 years from now. Natural gas 5501.5 trillion scf, scf is a unit for the natural gas volume measurement. Current production rate is 102.2.

With this estimate, it will run 53.8 years. What about coal? 984 billion tons of coals reserves is there. Current production rate 4.8 billion tons. Little bit safe, not much; 205 years the amount of the coals which last. But again, I should emphasize the fact all these statistics has been calculated considering the present growth rate and present economic growth rate.

Now if the utilizations rate and the growth of the economy increase, so this number will also be changed. So today, like you know I mean we are pretty much convinced that the time has come we have to look for an alternative source of energy. The conventional source of energy like coal, oil and natural gas, which were the blood of our civilization, which was the lifeline of our day to day life we are dependent on them very much. We cannot imagine a single moment of our life without them.

But we have learned that, first of all, like their resources are limited. We have given a statistics how long they can run. And the most important thing is that burning the fossil fuels, we are adding severe environmental hazards and a phenomena called the

global warming or greenhouse effect. Because of that, not only the animal and the plant ecology is changing also like you know the temperature of the earth is changing.

Our overall weather on the earth surface is altering and it is adding a several health hazards. So it is a high time now, we have to think about some alternate or some renewable sources of the energy. Now today whatever we discussed, there are lot of nice references also if you wanted to do some additional study.

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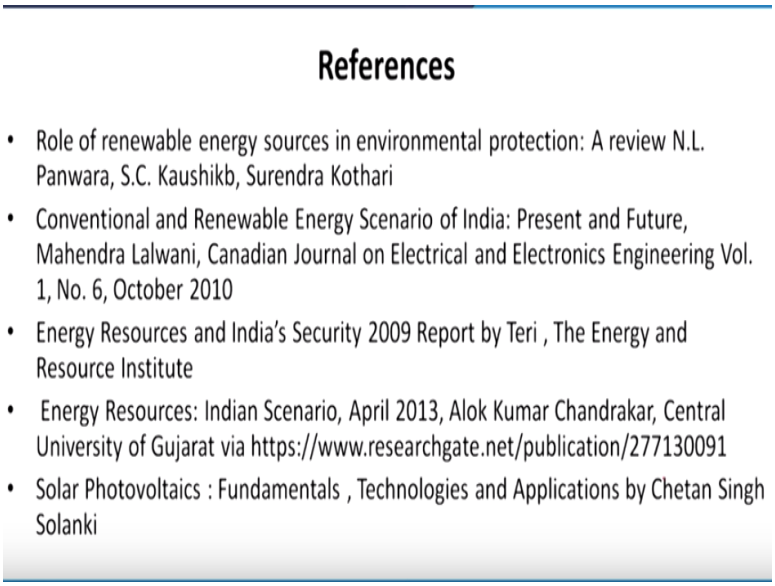

For example some of this we have listed here like Role of renewable energy sources in environmental protection, a review paper. Then Conventional Renewable Energy Scenario of India: Present and Future. Energy resources and India's security. Energy resources: Indian Scenario. And then there is a textbook Solar Photovoltaics: Fundamentals, Technology and Application by Chetan Singh Solanki.

So you can look all of these references for additional subject matter and you will get these things. Thank you very much for your attention.