Energy Conversion Technologies (Biomass and Coal)

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Lecture 3

Energy scenario

Good morning everyone.

Welcome to lecture 2 under the module 1. So, in this lecture we will discuss about energy scenario, prospect need of alternate energy sources, common forms of energy, conventional and non-conventional energy sources.

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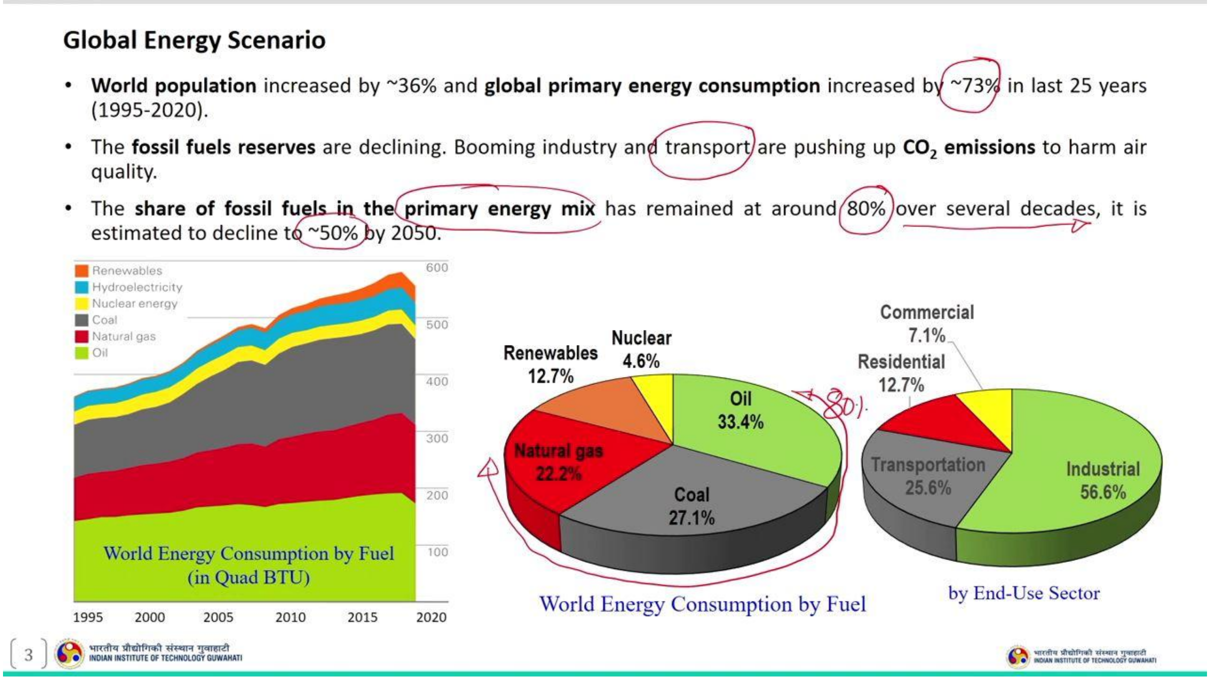

So, to begin with let us first discuss about the global energy scenario. So, in last 25 years world population increased by around 36 percent. And due to this rapid surge in population and industrialization global energy demand increased by leaps and bounds and that is close to around 73 percent.

Moreover, the demand of energy also increased in the transportation sector as well. This resulted surge in consumption of fossil fuels. But the excessive use of fossil fuel also causes pollution thereby their use also push up CO_2 emission which eventually harms the air quality. Now, if you look at the share of fossil fuel in primary energy mix, it has remained constant around 80% over several decades.

So, this particular figure here, it shows the share of fossil fuel consumption trend in India's primary energy mix. And this is close to around you can say 80% and this particular consumption pattern is almost constant over several decades, but it is estimated to decline to around 50% by 2050. So, this gives the information about the global energy scenario.

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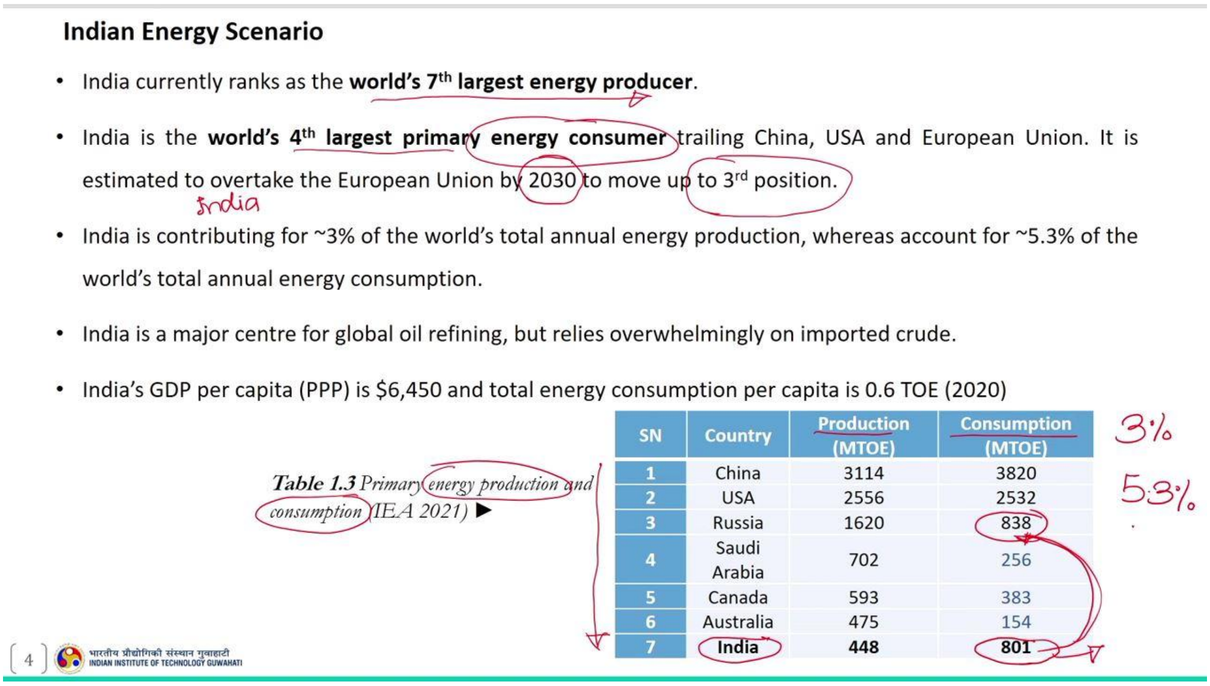

So, now if you just take a look at India's energy scenario, the table presented here in this slide show the primary energy production and consumption pattern of leading countries in the world. So, as per this table India rank as the seventh largest energy producer and rank as the fourth largest primary energy producer. So, as per this table if you see here, so this number indicates the primary consumption pattern of various countries, 801 indicate the energy consumption in India. So, it is ranked as fourth largest energy consumer. It is also estimated that India may take over European Union by 2030 to move up to the third position. So, India is also contributing for 3% of the world's total annual energy production, whereas accounting for 3 percent of the world's total annual energy consumption.

India is a major center for global oil refining, but relies overwhelmingly on imported crude. Now, if you look at the India's GDP per capita, it is around this much and the total energy per capita is 0.6 ton oil equivalent. So, this gives us information about the primary energy consumption and the production pattern in India.

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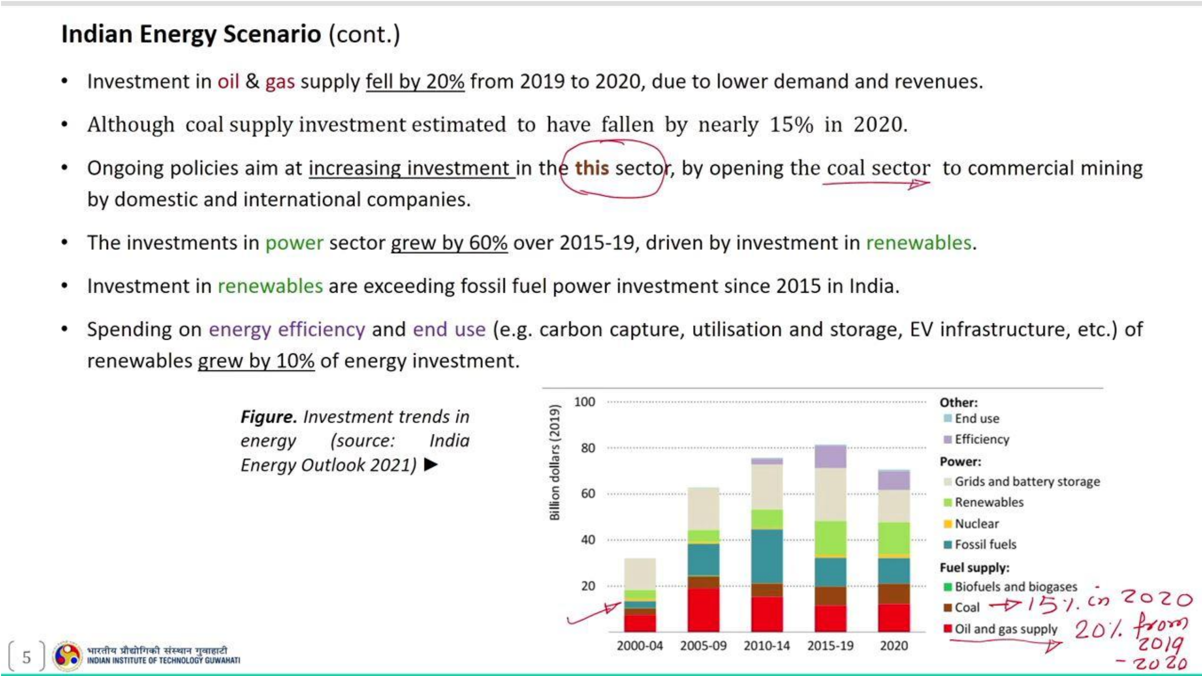

So, now if you try to understand the investment trend in energy, so the schematic here gives the information about the investment trend in energy in India. Oil and gas supply fell by around 20 percent from 2019 to 2020. That is mainly due to lower demand prices and revenues. Although the coal supply investment estimated to have fallen by 15% in 2020. However, ongoing reform aims increasing investment in this sector by opening coal sector to commercial mining by domestic and international companies. Now, if you take a look at the investment in power sector, so it mainly grew by around 60% over 2015 to 19 and which is mainly driven by investment in the renewables.

So, now if you take a look at these two bar in this particular graph which clearly indicates the investment in the power sector, which is grew by around like 60 percent and which is mainly driven by renewables over 2015 to 19. Now if you compare this green block in 2015-19 with green block over 2010-14, which clearly indicates a significant increase in the investment in the power sector and which is mainly driven by the renewables. Similarly, the investments in the renewables are exceeding the fossil fuel power investment since 2015 in India. So, for example, if you try to compare the investment in the renewables with that of the fossil fuel investment.

So, from this two bar graph, it is clearly evident that there is a significant increase in the investment in the renewables than that of the fossil fuels. Because this particular block indicates the investment in the fossil fuels and the green block indicates the investment in the renewables. So, the comparative analysis between 2010-14 with 2015-19 shows a clear indication of investment in the renewables are exceeding over the fossil fuels power investment since 2015 in India. Spending on efficiency and end use of renewable grew by around 10% of energy investment. If you just try to compare these three block here over the period of time here which shows that the investment or the spending on energy efficiency and end use of renewables also grew by around 10 percent of energy investment. So, this gives us the information about the investment trend in energy in India.

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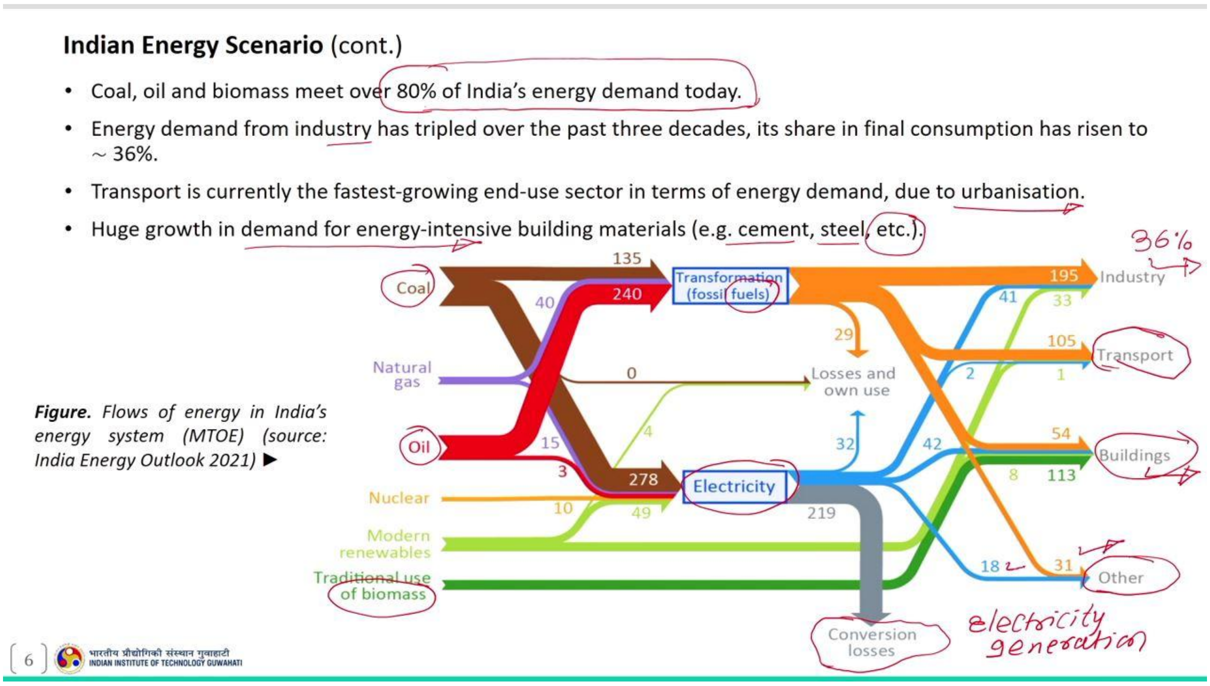

Similarly, this schematic here shows the flows of energy in India's energy system. This includes the various transformation processes for fuel and for electricity and also shows the substantial conversion losses that may occur in the process of electricity generation. So, as per this particular schematic, coal, oil and biomass meet over 80% of India's energy demand and that is the reason the share of fossil fuel in the primary energy mix has remained at around 80% over several decades.

Energy demand from industry has tripled over last three decades and its share in the final consumption has risen to around 36 percent. Transport is currently the fastest growing end-use sector in terms of energy demand and that is mainly due to urbanization. However, there is a huge growth in demand for energy intensive building materials. Example cement, steel, etcetra. Because in the past there were clear differences in the way in which urban and rural houses were built.

That has been changed rapidly and in the 2018 80 percent of rural houses and 97 percent of the urban houses were built using modern building materials. And that has impacted heavily; as a result there is a surge in the energy demand in this particular sector. Similarly, if you try to see the contribution, the other sectors are also consuming significant amount of the energy. So, this gives us the clear information about the flow of energy in India's energy system. So to understand this concept in more detail, let us try to solve one small example here.

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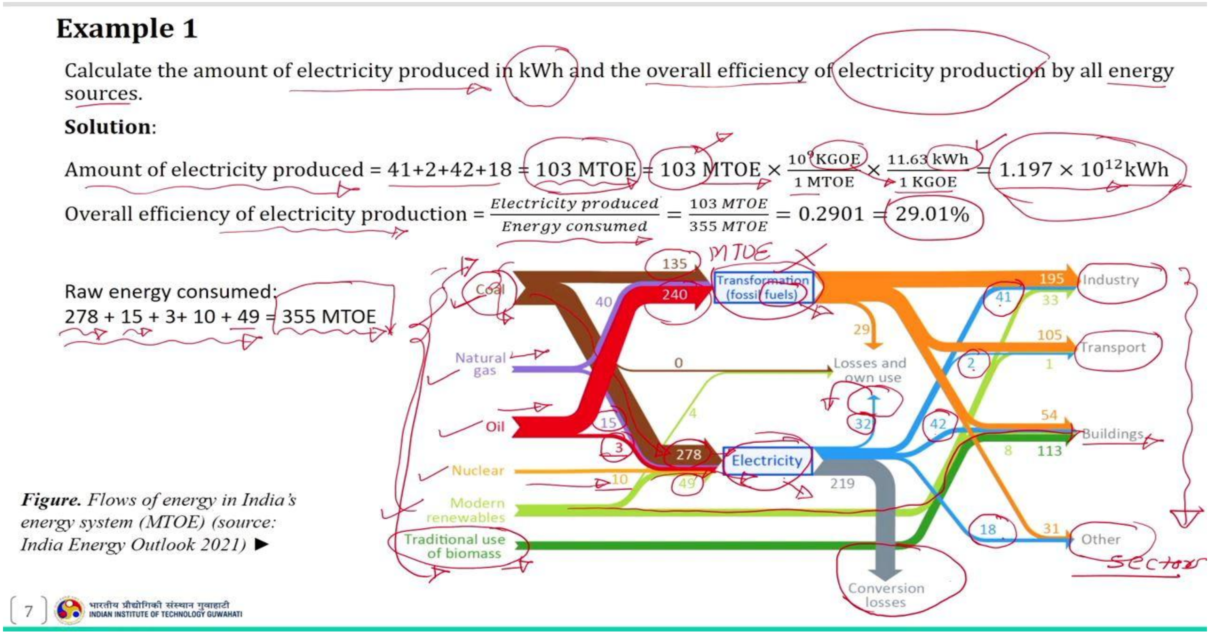

So, this particular schematic on the slide gives a visual representation of flow of energy in India's energy system. So, majorly the resources mentioned here are coal, natural gas, oil, nuclear, modern renewables, and traditional use of biomass. So, these resources undergo various transformation processes either for fuels or for electricity generation. And as I mentioned earlier as well during this process, substantial conversion losses are happening and that are mainly in the process of electricity generation. So, if you see here this small arrow indicates the losses and the own use that means the amount of energy which is lost as well as used for their internal consumption is indicated here.

So, to understand these concepts take the example of coal. So, out of the total resources available, here 135 million ton oil equivalent of this resource is transformed using the transformation process to produce fuels and 278 million ton oil equivalent undergoes the transformation process to produce electricity. Similarly, we can see for the natural gases how the distribution is taking place similarly for the oil. So, in case of oil the major fraction goes for fuels and very minimal fraction goes for the electricity production. Similarly, for the nuclear there is only one option that is electricity.

Modern renewable, it can be used for electricity production. Similarly, it can directly be used as a material for this sector and traditional use of biomass. So, in this particular example, we have to calculate the amount of electricity produced in kilowatt hour as well as we have to calculate the overall efficiency of electricity production by all energy sources. So, we have to take the count of all energy sources which are contributing for the electricity production. So, here we are not discussing about the fuels.

So, main emphasis is on the electricity production. So, for example, after production of the electricity 41 million ton oil equivalent is getting consumed in industries, 2 million ton oil equivalent in transport, 42 million ton oil equivalent buildings and remaining 18 million ton oil equivalent contributing to the other industrial sectors. So, now once you take the summation of these 41 to 42 and 18 which gives information about the amount of electricity produced and distributed to this end use sector here. So, summation of these numbers comes out to be around 103 million ton oil equivalent and if you convert this million ton oil equivalent into kilogram oil equivalent first and then kilowatt hour. So, we will get the final amount in this form.

So, here 1 million ton oil equivalent is equal to 10 to the power 9 kilogram oil equivalent. Similarly, now we have to convert this kilogram oil equivalent into kilowatt hour. So, 1 kilogram oil equivalent equals to 11.63 kilowatt hour. So, once you multiply this number here, so final amount comes out to be this much which is in kilowatt.

Similarly, we have to calculate the amount of resources which are being used in this particular process of transformation to produce electricity of 103 million ton oil equivalent. So, the amount of resources which are used for this purpose coal, if you see here is 278 million ton oil equivalent of coal is transformed in this process here to produce the electricity. Similarly, 15 million ton oil equivalent is transformed here to produce electricity, oil 3, nuclear 10 and modern renewables 49. Now, if you take the summation of this number, it comes out to be around 355 million ton oil equivalent. So, this represents the amount of raw source of energy which is being used in this transformation process to produce the electricity.

So, now if you have to calculate the overall efficiency of electricity production, so it is the ratio of electricity produced that means 103 million ton oil equivalent is the amount of electricity produced here. And then the energy consumed that is nothing but the raw form of energy which is consumed to produce this much electricity. So, the energy consumed here is 355 million ton oil equivalent. So, ratio of these two is equal to 29.0. So, this is basically the overall efficiency of electricity production by using all these resources in this particular flow system. So, I guess this clear your doubt about this flow of energy in India's energy system. Similarly, we can also calculate the amount of fuel produced from all these energy sources, so which are contributing in the transformation process to produce the fuel. So, likewise even we can calculate for the individual sources.

Similarly, we can calculate this for all energy sources that is the amount of raw form of energy which is required to undergo this transformation to produce fails. So, after understanding the concept of flow of energy in India's energy flow system, let us try to solve another example on unit conversion system. Because the unit of energy in SI system is in joule and the commercial unit of energy is in kilowatt hour. But sometimes when you are trying to solve some practice example as well as the example in assignment the unit may not be given in the common form. So, that time we need to take help of this energy unit conversion system. So, to understand this concept in more detail, let us try to solve one example here.

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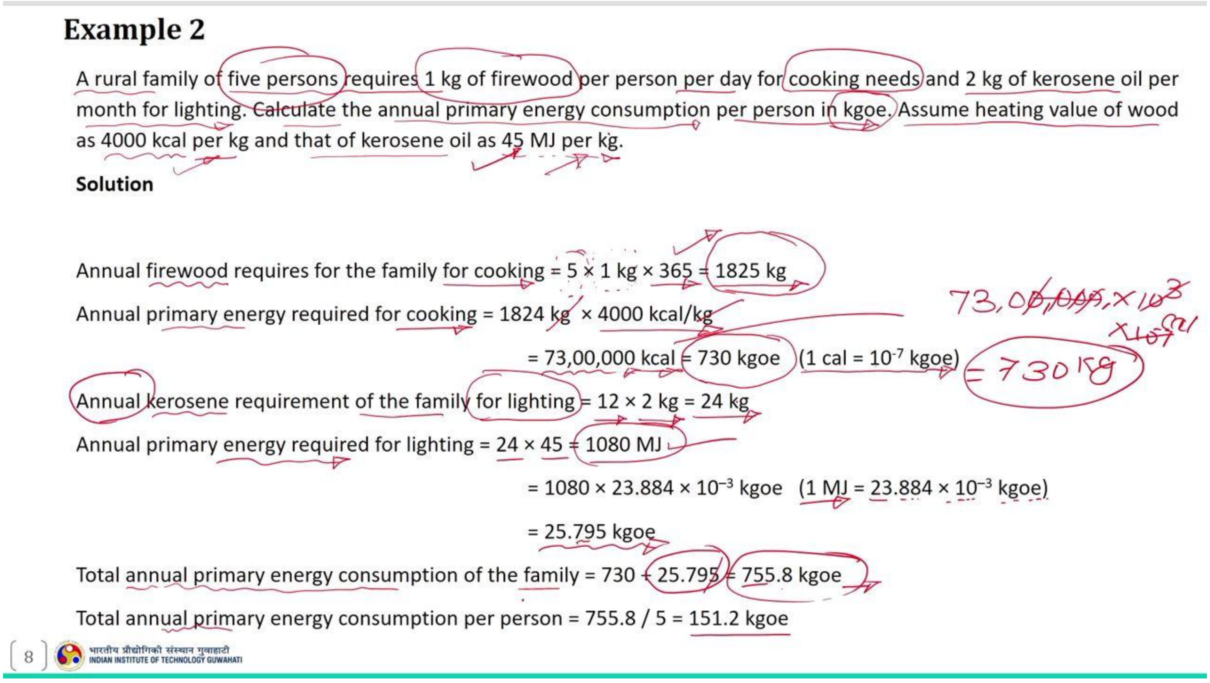

So, as per the statement of example a rural family of 5 person requires 1 kg of firewood per person per day for the cooking needs and 2 kg of kerosene oil per month for lighting purpose. So, with the help of this, we have to calculate the annual primary energy consumption per person in kilogram oil equivalent. And for solving this example, we can assume the heating value of wood as 4000 kilo calorie per kilogram, and that of kerosene oil as 45 mega joule per kilogram. So, here itself you can see the heating values are given in two different unit form and we need to convert all this value into kilogram oil equivalent. So, let us try to solve this example. So, in this case the annual firewood required for the family for cooking purpose can be calculated very easily here, because 5 persons in a family required 1 kg of food per day.

So, now there are 365 days in a year. So, on annual basis if you see here, you can just simply multiply 5 into 1 into 365. So, the figure comes out to be around like 1825 kg. So, this is nothing but the requirement of fire wood for the family for cooking purpose on annual basis. Similarly, the annual primary energy which is required for cooking purpose, so, simply here we have to multiply the heating value of the wood.

So, it is given in the example as 4000 kilo calorie per kilogram. So, here this kilogram will get cancelled and then we will get the number in the form this much kilo calorie. So, now we know 1 calorie is equal to 10 to the power minus 7 kilogram oil equivalent. So, once we convert this figure here, that is 73 into 10 to the power 3 so it will be in the calories. So, now as 1 calorie is equal to 10 to the power minus 7, so, once you multiply this 10 to the power minus 7 number here, so the final amount comes out to be 730 kilogram right. So, this is the final amount which is equivalent to the annual primary energy which is required for cooking purpose and it is in the form of kilogram oil equivalent. Similarly, now we have to calculate the annual kerosene requirement of the family for lighting purpose. So, as we know, 2 kg of kerosene oil per month is required for lighting purpose, simply you can just multiply here by the 12 month. So, we will get the answer as 24 kg on annual basis.

And once you have to calculate this energy required for lighting purpose. So, you can simply multiply here the heating value of kerosene. So, 45 into 24 which come out to be around like 1080 mega joule. Because the kilogram here and the kilogram here will get cancel out. So, we will get it in the mega joule. So, we know the conversion system for mega joule that 1 mega joule is equal to 23.884 10 to the power minus 3 kgoe. So, if you directly multiply this number here, so the final answer comes out in the form of 25.795 kilogram oil equivalent. It may not be required to go up to third point after decimal, simply we can use up to two point after decimal for the calculation purpose.

Now, if you take the summation of these two numbers that is 73 and 25.79, so the answer comes out to be around 755.8. So, this is nothing but the total primary energy consumption of the family is this much. Similarly, we can calculate on per person basis. So, simply we can divide this number by 5, because there are 5 members in a family. So, this is nothing but the total annual primary energy consumption per person, and that is 151.2 kilogram oil equivalent. So, these are the kind of simple example which we are trying to solve here. So, similar kind of examples will be given in the assignment as well.

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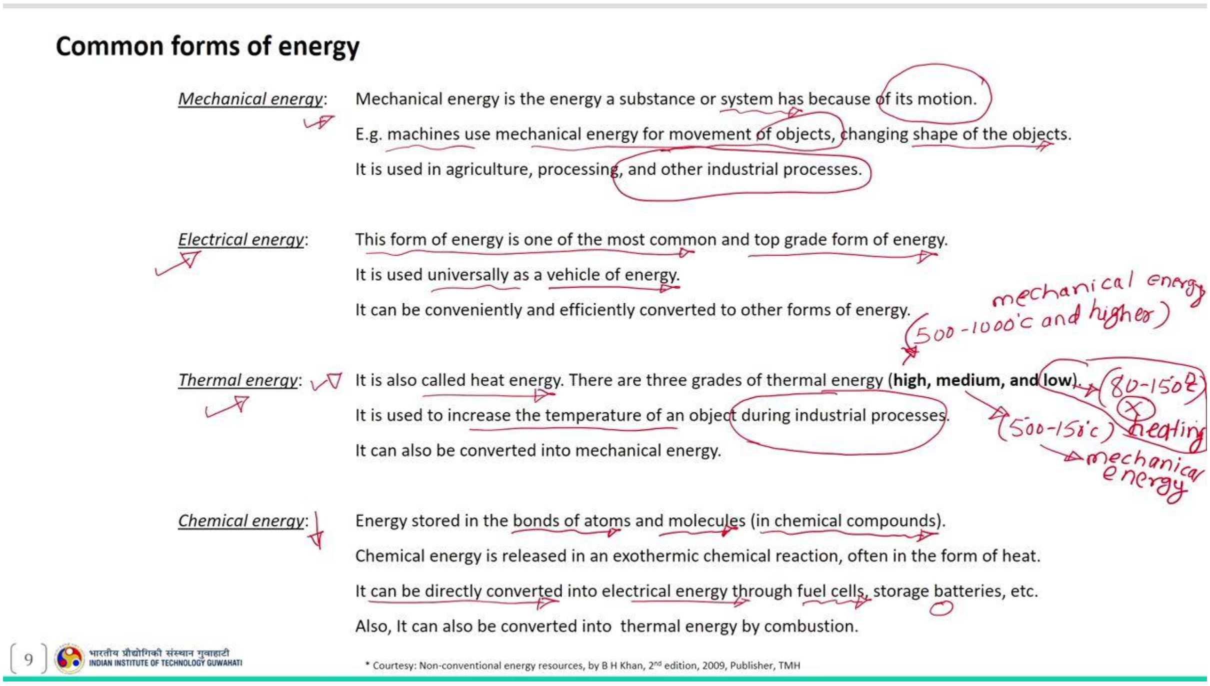

So, now let us discuss about the common forms of energy. So, these are basically the following common forms of energy which includes mechanical energy, thermal energy, electrical energy and chemical energy. So, let us discuss about these common forms of energy one by one. So, let us begin with the mechanical energy. Mechanical energy is the energy a substance or system has because of its motion and the example includes that machine use mechanical energy for movement of object as well as changing the shape of the object.

It is also used in agriculture, processing and other industrial processes. Similarly, the next in the list is electrical energy. So, electrical energy is one of the most common and top grade forms of energy. It is used universally as a vehicle of energy. Because it can be conveniently and efficiently be converted into other forms of energy.

For example, electrical energy can be converted into a mechanical energy very easily and efficiently. That is what the meaning of this sentence here is. So, the next in the list is the thermal energy. It is also called heat energy and there are three grades of thermal energy that is high grade energy, medium grade energy and low grade energy. So, let us discuss about these three grades of thermal energy one by one.

So, in case of high grade energy the temperature varies between 500 to 1000 °C and even higher and it can be efficiently converted into mechanical energy. Similarly, if you talk about the medium grade of energy, so in this case the temperature varies between 500 to say 150 °C and it can also be converted into mechanical energy but with certain difficulties. And the low grade of energy here, the temperature range varies between 80 to 150 °C here and it cannot be converted into mechanical energy.

However, mostly it is being used for heating purpose. So this is this low grade of energy mostly used for heating purposes. So this gives information about the thermal energy. So, this particular form of energy also used to increase the temperature of an object during industrial processes. As I mentioned earlier this form of energy can be converted into a mechanical energy and the last in the list is the chemical energy.

Chemical energy is stored in the bonds of atoms and molecules. That means in chemical compounds and the chemical energy is released in an exothermic reaction in the form of heat. That is what the real meaning of the chemical energy is. Because in this particular form of energy the energy is stored in the form of bonds of atoms and molecules. And when this compound undergoes chemical reaction that is mainly exothermic reaction, so significant amount of heat get released during this particular reaction and which can be act as a kind of a heat source or you can say the energy source. It can be directly converted into electrical energy through fuel cells and storage batteries.

Similarly, this form of energy can also be converted into a thermal energy by the process of combustion, where we can directly use the fuel for the combustion purpose. And significant amount of the heat energy released during this combustion process can be used as a source of energy in the processing industries.

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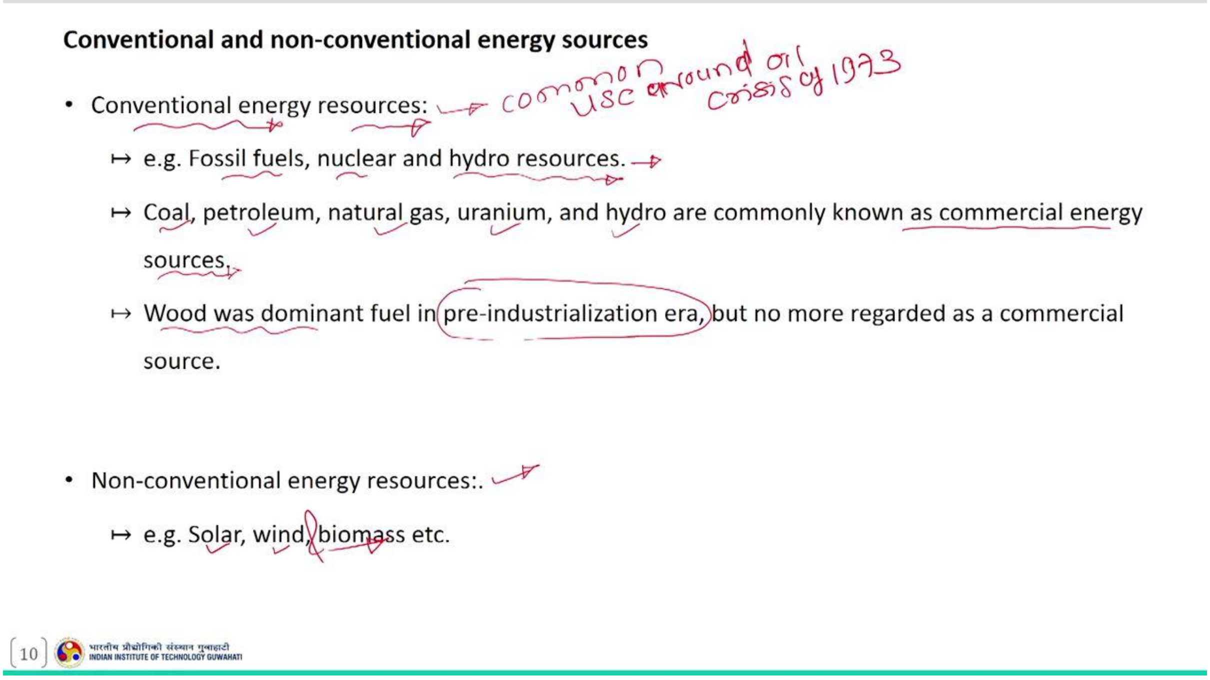

So, the next is conventional and non-conventional energy resources. So, let us discuss about the conventional energy resources. The energy resources which are traditionally being used and were in common use around oil crisis of 1973 is termed as conventional energy resources. And the examples of these conventional energy resources are fossil fuels, nuclear and hydro resources. Although the hydro resources are considered as the renewable source of energy, but it is accounted under the conventional energy. So, coal, petroleum, natural gas, uranium and hydro are commonly known as commercial energy sources. Similarly, wood was dominant fuel in pre-industrialization era but no more regarded as a commercial energy source.

Because it is accounted under the non-conventional source of energy, so if you try to see the non-conventional energy resources, so the resources which are considered for large scale use and were not in use during the oil crisis are termed as non-conventional energy resources. And the examples are solar, wind and biomass. So, this gives us the information about the conventional and non-conventional energy sources. Now let us discuss about the prospect and need of this alternate energy sources. Because the concern for the environment and due to ever increasing use of fossil fuels and rapid depletion of natural resources have led to the development of alternate sources of energy which are renewable and environment friendly.

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Prospects / need of alternate energy sources

1. The global demand of energy is increasing rapidly, because of population and economic growth, and hence the conventional sources of energy will not be sufficient to meet the growing energy demand.
2. Conventional /non-renewable sources are bound to finish one day.
3. Similarly, more usage of these resources cause pollution thereby their use degrades the environment.
4. Apart from supplying energy, fossil fuels are also used extensively as feedstock materials to manufacture organic chemicals.

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So, the following points also support the prospect and need of alternate energy sources. First of all if you see here, the global demand of energy it is increasing rapidly and that is mainly because of population and economic growth and hence conventional source of energy will not be sufficient enough to match this growing demand of energy. So, to substitute or supplement this conventional source of energy, it is highly essential to have the alternate sources of energy in place so that it can supplement these conventional sources of energy as well. Apart from that these conventional energy sources are non-renewable in nature. That means these particular resources do not get replenished on its own and as a result they are bound to finish one day.

So, this is also the another alternate sentence here which indicates that there is a prospect and need of alternate energy sources. Similarly, more uses of these resources cause pollution. Thereby their use degrades the environment as well because the excessive use of these fossil fuels will emit the pollutants in the form of CO, CO_2, NOx, SOx and hydrocarbon along with the particulate carbon as well. So, as a result it will harm the environment and also harm the air quality. And next point in the list is apart from supplying energy fossil fuels are also used extensively as a free stock material to manufacture organic chemicals or you can say compounds.

Due to these reasons it has become important to explore and develop non conventional energy sources. So, that to reduce too much dependence on the conventional energy resources. However, the recent trend of development of non-conventional energy sources indicates that these will serve as a supplement rather than the substitute for conventional energy sources for some more time to come. So, this gives overall information about the conventional and non-conventional energy resources as well as the prospect and need of alternate energy sources.

So, with this we will end our lecture here. So, regarding this lecture if you have any doubt, feel free to contact me at vvgoud@iitg.ac.in. So, in the next lecture we will discuss about the environmental aspects of energy. In that we will discuss about energy from biomass and energy from coal, environmental aspects of energy utilization that is conventional energy resources and their importance.