Energy Conversion Technologies (Biomass and Coal)

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Lecture 2

Sources of energy

Good morning everyone.

Welcome to part 2 of the lecture 1 under the module 1. So, if you recall our discussion in the previous lecture we discussed about the classification of energy sources followed by the energy chain. So, this is basically the continuation of the previous lecture. So, in this lecture we will discuss about the major sources of energy.

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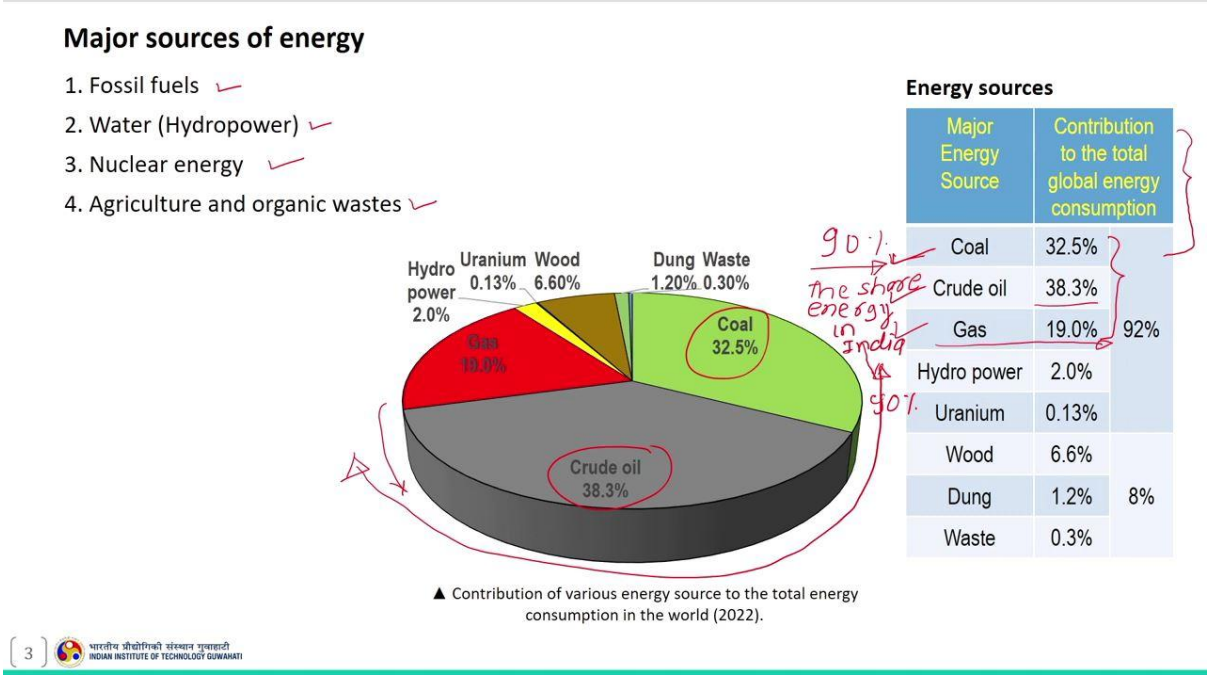

So, major sources of energy include fossil fuels, water that is hydro power, nuclear energy, agriculture and the organic waste. The average percentage consumption trend of various primary energy sources is indicated in this particular figure here. So, if you look at this particular figure on the slide, so this indicates the average percentage consumption trend of

various primary energy sources. So alongside the values are also tabulated in the tabular form. Here if you can see, the coal as a major source of energy so the contribution of the coal as a source to the total energy consumption around the world is around like 32.5%, crude oil is around 38.3% and the gas is around 19%. So, these are all basically the average values and the trend it may differ from country to country. Looking at this particular slide here we can see that the heavy dependence on the fossil fuel is still clearly stands out from this particular number say for example coal crude oil and gas. So, if you look at this particular number, so it indicates the heavy dependence on the primary fossil fuels for the energy purpose, about 90%.

So if you sum up these three figures, so it indicates around 90 percent of primary energy consumption in the world it comes from these fossil resources. And the share of energy consumption, the share of fossil fuels consumption in India is more than 90%. So, which indicates that still the world is relying on these particular primary energy resources for the consumption purpose.

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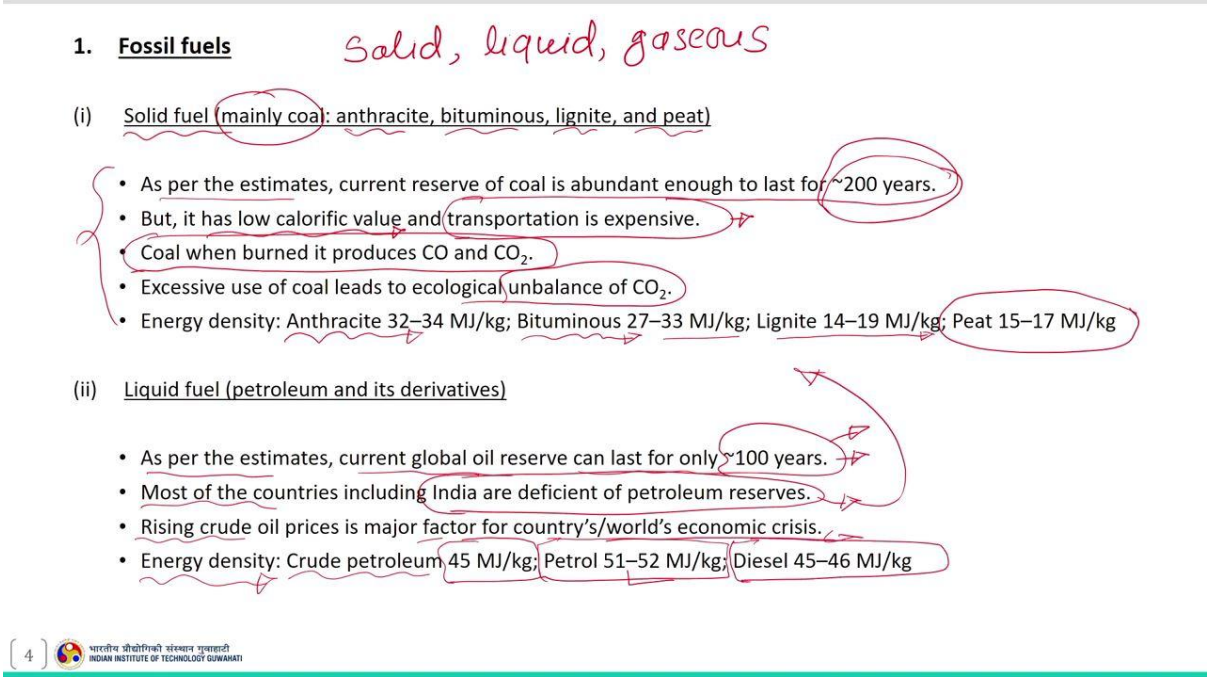

So, let us discuss about this primary sources of energy one by one. So, let us begin with the fossil fuels. So, fossils these are in fact the fossils of old biological life that once existed on the surface of the earth. It is formed in several parts of the earth at varying depth during

several million years of slow decomposition and chemical action of buried organic environment under favorable condition of say pressure, heat and marine bacterial environment. These fossil fuels include solid fuel liquid and gaseous fuel. So, let us discuss about this solid liquid and gaseous fossil fuels one by one. So, in case of solid fuel which mainly a coal it includes anthracite, bituminous, lignite and peat.

The fossil fuels are the major source of energy since about 1850s that is we can say the start of the industrial era. Currently we are passing through the peak period of fossil age and as per the estimate, if the world continues to consume the fossil fuels in the similar rate then the reserves of the coal will last only for 200 years. And these are basically an indication and not a realistic figure because the identification and discovery of the new coal site as well as the oil reserves will add the number to this particular figure. And eventually the figure may get changed and that is the reason this gives only an indication and not the realistic figure. Now if you see the consumption of the coal so as we discussed, so as per the estimate the current reserve of the coal is abundant and enough to last for 200 years.

That is what the indication is, but as we know the coal has a low calorific value and because of the discrete location of this particular coal site the transportation becomes expensive. And when coal burn it produces mainly a polluted in the form of CO_2 and CO. So, the excessive use of coal leads to ecological unbalance of CO_2 in the atmosphere. And that is the reason, the effective and the efficient utilization of the coal is the need of the so that it can be used efficiently for the energy purpose. Now if you look at the energy density value of these different coals, you can see that the anthracite has the energy density in the range of 32 to 34 MJ/kg, bituminous has the energy density of 27 to 33 MJ/kg, lignite has the energy density in the range of 14 to 19 MJ/kg and peat has the least energy density it is in the range of 15 to 17 MJ/kg.

So, now let us discuss about the next fossil source that is liquid which includes petroleum and its derivatives. So, similarly as per the estimate here as well the current global oil reserves can last only for 100 years. That is what the estimate is or you can say the indication right now. And this particular figure as I mentioned earlier as well it may change in future. So, most of the countries including India are deficient of petroleum reserve and because of that there is a shift over from petroleum to coal for the energy or you can say for the production of the valuable chemical.

So, rising of crude oil prices is another major factor for countries or worlds economic. So, in terms of energy density, if you look at this petroleum product, so the crude petroleum has the energy density of around 45 MJ/kg. While the petrol which is the pure form of energy it has energy density of around like 51 to 52 MJ/kg and the diesel has the energy density of around 45 to 46 MJ/kg. So this indicates the energy density value of petroleum products.

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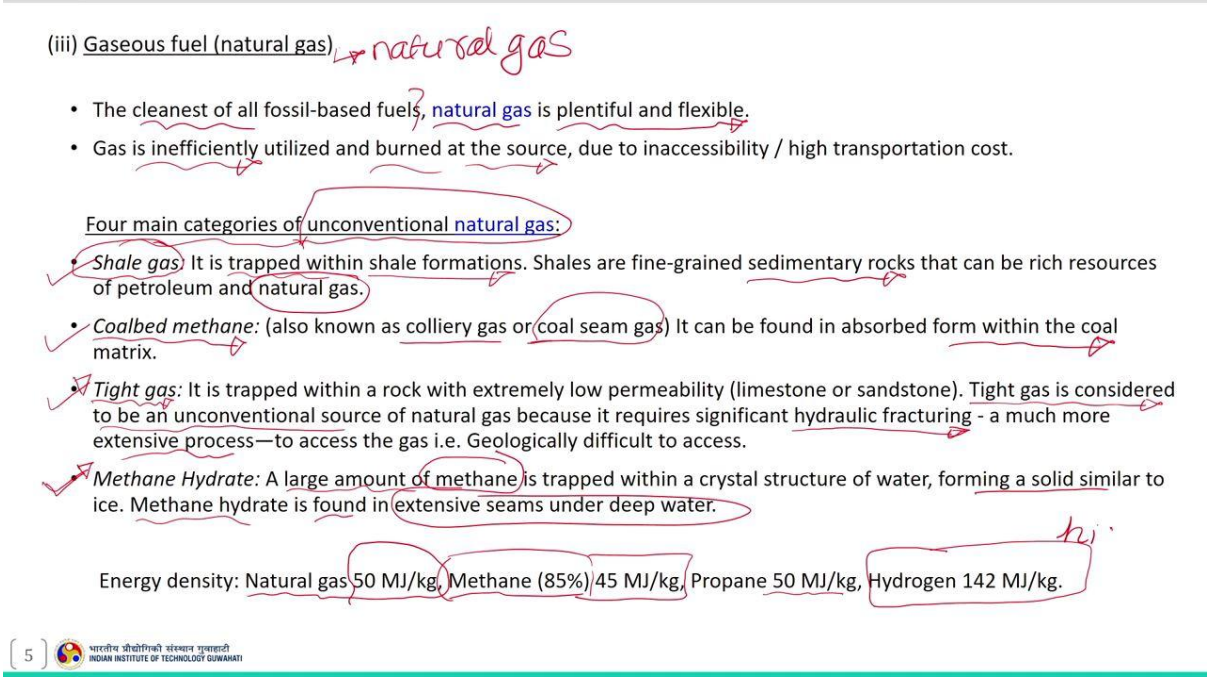

So the next in the fossil fuel category is the gaseous fuel which includes natural gas. So, the cleanest of all fossil based fuel is a natural gas which is plentiful and flexible. The gas is inefficiently getting utilized and burned at the source due to inaccessibility and high transportation cost. So, now if you look at this particular slide here, so here there are four main categories of unconventional natural gases are highlighted which are nothing but the shale gas, the coal bed methane, tide gas and methane hydrate. So let us discuss about these unconventional natural gases one by one.

So to begin with let us discuss about the shale gas. it is trapped within the shell formation. So, basically in this case what happens is like the gas is getting trapped during the formation of these shells and the shells are nothing but a fine grained sedimentary rocks and that particular rocks act as a rich source of petroleum and natural gas here. That is what is the meaning of

the shell gas in these particular unconventional natural gas resources. Secondly, here we can see that there is coal bed methane.

It is also known as a colliery gas or coal seam gas. So, basically it can be found in absorb form within coal matrix. So, this particular gas can be found in the absorbed form in the coal matrix under the earth surface. So, another category in these unconventional natural gases is tight gas. So, basically it is a gas which is trapped within the rock which has a low permeability.

So, the examples of low permeability rock are nothing but limestone and the sandstone. So, this kind of gases are getting trapped in this kind of rocks which has a very low permeability and because of that this tight gas is considered to be an unconventional source of natural gas. Because it requires significant hydraulic fracturing, a much more extensive process to access this particular gas. That means geologically it is very difficult to access this particular tight gas. So another class in the case of unconventional natural gases is methane hydrate.

So, in this case, a large amount of methane is trapped within a crystal structure of water forming a solid similar to that of ice. And the methane hydrate is found in extensive seams under the deep water. So, if you look at the energy density of these gases, so the energy density of the natural is around 50 mega joule per kg, whereas methane which is around 85%. Pure methane has the energy density of around 45 MJ/kg. Propane has 50 MJ/kg and the hydrogen has the highest energy density of around 142 MJ/kg. So among all these gases hydrogen has the highest energy density.

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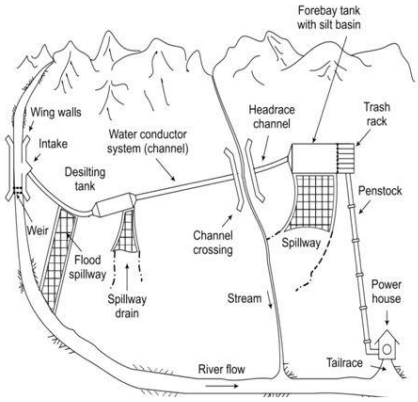
2. Water (Hydropower)

- Hydropower (also known as water power) is developed by utilizing gravitational potential energy of water.
- It is well developed and established source of electric power.
- Hydropower became cheaper after the development of electric power transmission in 1910s.
- Capital cost of hydropower plants is higher than other power plants, but the operating cost is quiet low.
- Current challenges: long-duration for setup, high capital investments, and environmental & social problems are major difficulties in its development.



Courtesy: Non-conventional energy sources, by G D Rai, Khanna Publishers, 2017
Non-conventional energy resources, by B H Khan, McGraw Hill Edu., 2017

So, now let us discuss about the next major source of energy that is hydropower. So, the hydropower is also known as water power is developed by utilizing the gravitational potential energy of water. It is a well developed and established source of electric power. Hydropower became cheaper after development of electric power transmission in 1910 and the cost of hydropower plant is higher than the other power plants but the operating cost is quite low.

But this particular energy source has certain challenges which includes long duration power setup, high capital investment and environmental and social problems are the major difficulties in its development. So, these are basically the challenges in this power source.

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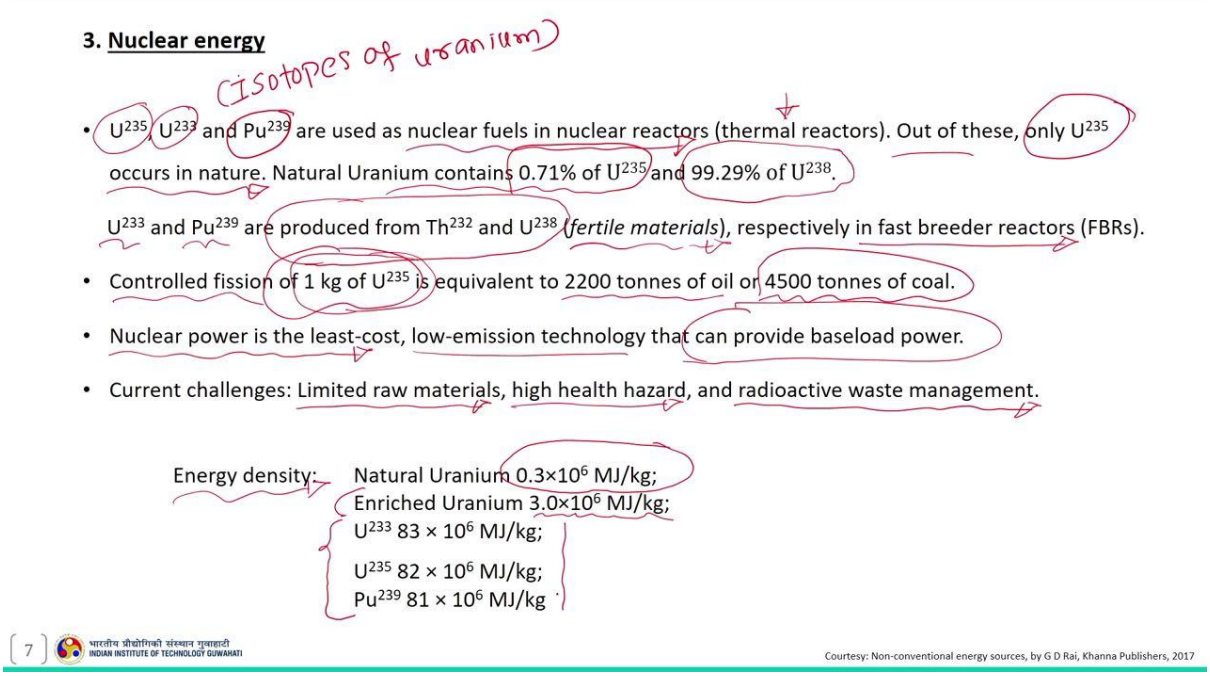

So, let us discuss about the next source of energy that is the nuclear energy. So, in this case the Uranium 235 and Uranium 233 these are isotopes of Uranium and Plutonium 239 are used as nuclear fuels in nuclear reactors. These are nothing but the mainly thermal reactors. And out of these only U^{235} occurs in nature. India has modest reserves of uranium and the natural uranium mainly contains 0.71 percent of U^{235} and 99.29 percent of U^{238}. So, as I mentioned earlier as well India has the modest reserves of uranium. So, similarly Uranium 233 and Plutonium 239 are produced from thorium 232 and uranium 238, which are known as a fertile material respectively in a fast breeder reactor. So, the thorium is abundantly available in India in the form of Monazite ore.

So, if you look at this particular point here which indicates the control fission of 1 kg of Uranium 235 is equivalent to 2200 tons of oil or 4500 tons of coal, which indicates that use of 1 kg of uranium will lead to energy production which is equivalent to 2200 tons of oil or 4500 tons of coal. So, that means the energy which is produced from 2200 tons of oil or 4500 tons of coal is equivalent to one controlled fission reaction of 1 kg of U-235U in a reactor. That is what the meaning of this particular sentence here is.

So, the last the nuclear power is the least cost, low emission technology that can provide base load power. But similar to other major sources, this particular source also has certain

challenges. These are nothing but limited raw materials, high health hazard and radioactive waste management. And if you look at the energy density of the natural uranium, it has energy density of 0.3 into 10 to the power 6 MJ/kg and the enriched uranium has the energy density of 3 into 10 to the power 6 MJ/kg. Similarly, for the Uranium-233, Uranium-235 and Plutonium-239, these are energy densities respectively.

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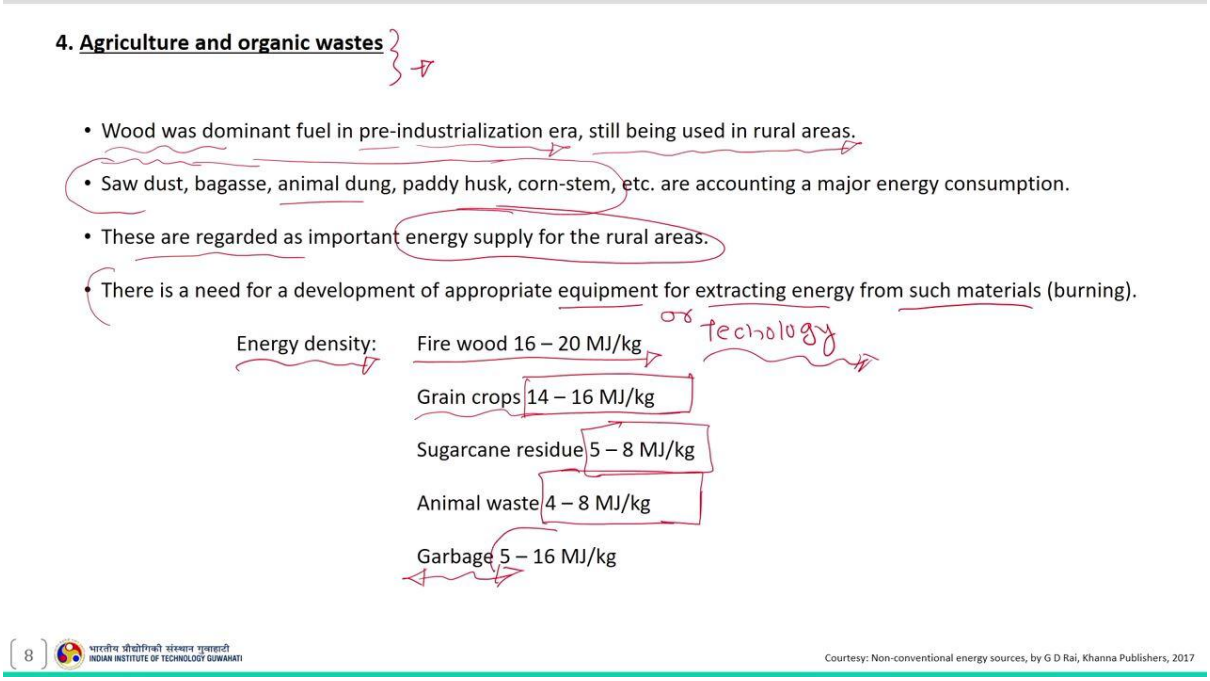

So, the next major source of energy is agriculture and organic waste. So, in this case wood was a dominant fuel in pre-industrialization era and still being used in rural areas for the energy purpose. So, in terms of agriculture or you can say the organic waste, the sawdust, bagasse, animal dung, paddy husk and corn stave are accounting a major energy consumption. And these particular sources are regarded as important energy supply for rural areas.

Now, there is a need for development of appropriate equipment or you can say a technology which we can say efficient or effective technology for extracting energy from such materials. Because although there are some existing technologies are available for the conversion of such raw material, majorly we can see here for the burning purpose. But still some refinement is required in this equipment as well as in these technologies, so that it can be used more effectively for the energy purpose. Majorly we are highlighting in the form of burning

purposes. So, if you see the energy density of these particular resources, so in that the firewood has the energy density of 16 to 20 MJ/kg. The grain crops, it has the energy density of 14 to 16 MJ/kg, Sugarcane 5 to 8 MJ/kg, animal waste it has the energy content of 4 to 8 MJ/kg and the garbage which is a mixed waste it has the energy density of 5 to 16 MJ/kg.

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Comparison of various energy sources

Energy source	Type of energy source	Advantages	Disadvantages
Coal	Conventional; Non-renewable	• Extensively available; • Efficient conversion to electricity	• Polluting source; • Bulky to transport.
Oil	Conventional; Non-renewable	• Easier to transport; • Basis of petrochemical industry.	• Pollutants released causes acid rain; • Exploration of new fuel is not easy.
Natural gas	Conventional; Non-renewable	• Easier to transport (Pipelines); • Cleaner than oil and coal; • Cheaper than oil.	• Pollutants released causes acid rain; • Exploration of new fuel is not easy.
Fire wood	Non-Conventional; Renewable	• Easy access; • Provides energy to large population	• Collection is time consuming; • Polluting & Promoting green house effect;
Nuclear energy	Conventional; Non-renewable	• Emits large amount of energy	• Generates radioactive waste; • Expensive.

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Courtesy: Bhatia, S. C., & Gupta, R. K. (2019). *Textbook of renewable energy*. Woodhead Publishing India PVT. Limited.

So, now let us compare these different sources of energy in this particular table. So, if you look at this particular table it shows the sources of energy, the types of this particular energy source, its advantages and disadvantages. So, now let us discuss about coal, oil, natural gas, firewood and nuclear energy.

Among all these energy sources, this firewood is no more regarded as a conventional energy source and that is why it is accounted under the non-conventional energy sources, although it is a renewable source of energy. So, now if you start with the coal, so coal is a conventional source of energy, but it is a non-renewable source. And its advantages are it is extensively available and efficient conversion technologies are available for effectively converting this raw material to electricity. But disadvantages associated with the utilization of this source include polluting, as this is a polluting source which mainly produce CO and CO_2 as a pollutant along with the NOx and shocks and bulky to transport.

Now if you look at another source that is oil, this is again a conventional source of energy but non-renewable in nature. And its advantages are easy to transport and it is a basis of petrochemical industry for the production of various chemicals. However, the disadvantages associated with this particular source are pollutant release causes acid rain and exploration of new fuel is not easy for this kind of source. Similarly, if you discuss about the natural gas, it is again a conventional source of energy, but non-renewable in nature.

And its advantages easier to transport because the pipelines are already in place for the transportation of such energy source, cleaner than oil and coal and cheaper than oil. But it has certain disadvantages; pollutant release also causes acid rain by the utilization of this kind of resources. Exploration of new fuel is not easy for this kind of resources as well. So, now let us discuss about the next source that is firewood.

So, as I mentioned Firewood is no more regarded as a conventional source of energy and that is the reason it is accounted under the non-conventional energy source, but it is a renewable source of energy. And the advantages associated with the utilization of this particular source for the energy purpose includes easy accessibility and provides energy to large population. Whereas, this particular source also has certain disadvantages that are collection is time consuming. Because the collection of this kind of resources is not easy as this kind of resources are not available at a single site. These particular sources cause pollution and because of that it is promoting a greenhouse effect.

And the next source of energy in this table is nuclear energy. It also comes under the category of conventional source of energy and non-renewable in nature. The advantages of this particular source of energy it emits large amount of energy this is what is the advantage. If you recall our discussion in the previous slide itself I have discussed about the amount of energy which can be released by utilizing this kind of resources.

So, in that nuclear energy is at the top. However, this particular source is also associated with the certain disadvantages, which includes it generates radioactive waste which is a major challenge for utilization of this kind of resources for energy purpose and also expensive. So, this covers the major sources of energy as well as their advantages and the disadvantages. So, in the next slide let us discuss about some other sources of energy as well.

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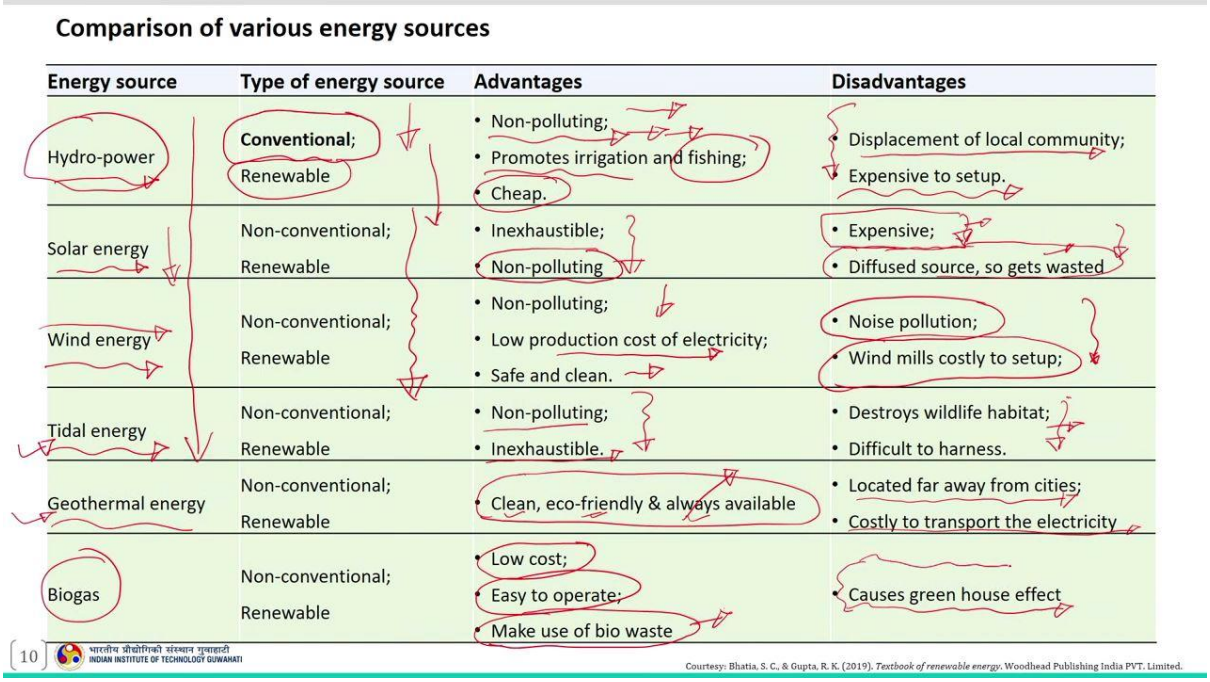

So, now if you take a look at this particular table here which shows major other sources of energy ranging from hydro power, solar energy, wind energy, the tidal energy, geothermal and biogas.

So, now if you take a look at this particular second column here, in this table among all these energy resources which are listed in this table the hydropower is the only conventional source of energy and a renewable source of energy as well, whereas all other sources are non-conventional in nature but renewable sources of energy. So, now let us discuss about the hydro power first and its advantages. So, the advantages of hydro power for the energy purpose includes non-polluting because it does not emit any pollutant while utilizing this kind of source for energy purpose, promotes irrigation and fishing as well.

It is a cheap source of energy. However, the disadvantages of this particular source are displacement of local community. That is a major disadvantage of this particular source and expensive to set up hydro power plant that is the another disadvantage of this kind of source. So, now next in the list is solar energy. The advantages of this source of energy includes it is inexhaustible in nature and non-polluting as well. Whereas the disadvantages includes expensive because the installation of solar power plant is a expensive process.

And majorly most of the radiation goes waste because of the diffuse source. That is another disadvantage associated with the utilization of this source for the energy purpose. Now, the next in the list is wind energy. So, the advantages associated with the wind energy, again it is a non-polluting source, low production cost of electricity, safe and clean source of energy. But the disadvantages are noise pollution which is a major disadvantage of this particular source, windmills costly to set up that means the installation of the windmill is costly.

So, now next in the chart is the tidal energy. So, the advantages associated with this particular source of energy, again it is a non-polluting and inexhaustible source of energy whereas if you see the disadvantages it destroys the wildlife habitat and difficult to harness. So, these are the major disadvantage of this particular source of energy. And the next is the geothermal source of energy. So, the advantages associated with this source of energy, it is a clean, eco-friendly and always available. That means this kind of source is always available for the extraction of the energy.

However, the disadvantages of this particular source are located far away from cities, costly to transport the electricity to the consumer. So, that is another major disadvantage of this particular source of energy. So, now last in this particular chart is biogas. So, if you look at the advantage of utilization of this particular source for the energy purpose which includes the low cost technology, easy to operate and make use of the waste which is available in nature.

It can be effectively utilized to produce energy. However, the disadvantages it causes greenhouse effect as I mentioned earlier as well the pollutants which are emitted during this particular process, it cause majorly a greenhouse effect that is the major disadvantage of this particular process.

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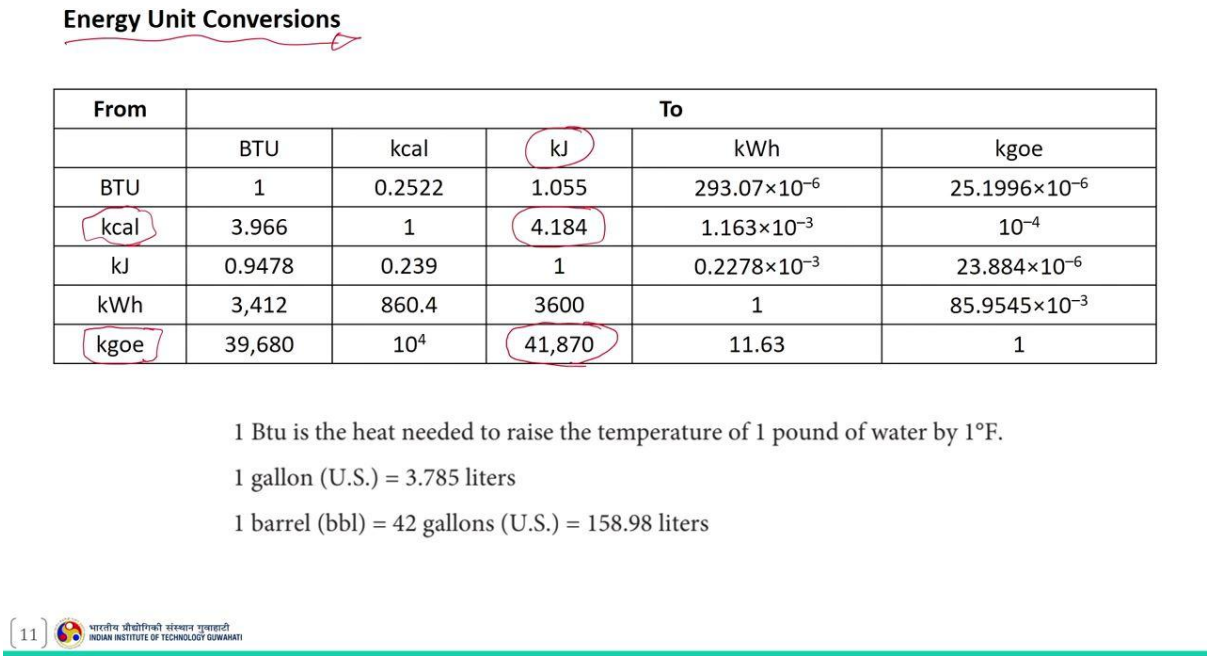

So, now let us discuss about the energy unit conversions. So, these conversion systems will be utilized for solving the practice example in this module as well as in the next module. So, for example purpose if you see here this particular table. So, if I have to convert 1 kilo calorie of energy equivalent to 1 kilo joule of energy.

So, you can see that 1 kilo calorie of energy is equivalent to 4.184 kilo joule of energy. Similarly, if you just take an example of this kilogram of oil equivalent. So, 1 kilogram of oil equivalent is equivalent to 41,870 kilo joule of energy. So, likewise this conversion system will be utilized while solving the practice example as well as the examples in the different modules.

So, I will not go in details of this unit conversion system here these are basically for the reference purpose as and when required you can refer to this particular unit conversion slide for solving this examples, okay. So, with this we will end this particular lecture. So, in the next lecture we will discuss about energy scenario prospects, need of alternative energy sources, common forms of energy, conventional and non-conventional energy sources. Regarding this lecture, if you have any query, feel free to contact me at vvgoud@iitg.ac.in.

Thank you.