Energy Conversion Technologies (Biomass and Coal)

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Lecture 6

Environmental aspects of energy

Good morning everyone.

Welcome to part 3 of lecture 3 under the module 1. So, in this module we will discuss about environmental aspect of energy, conventional energy resources and their importance and disadvantages. So, before that let us first discuss about the environment and ecology.

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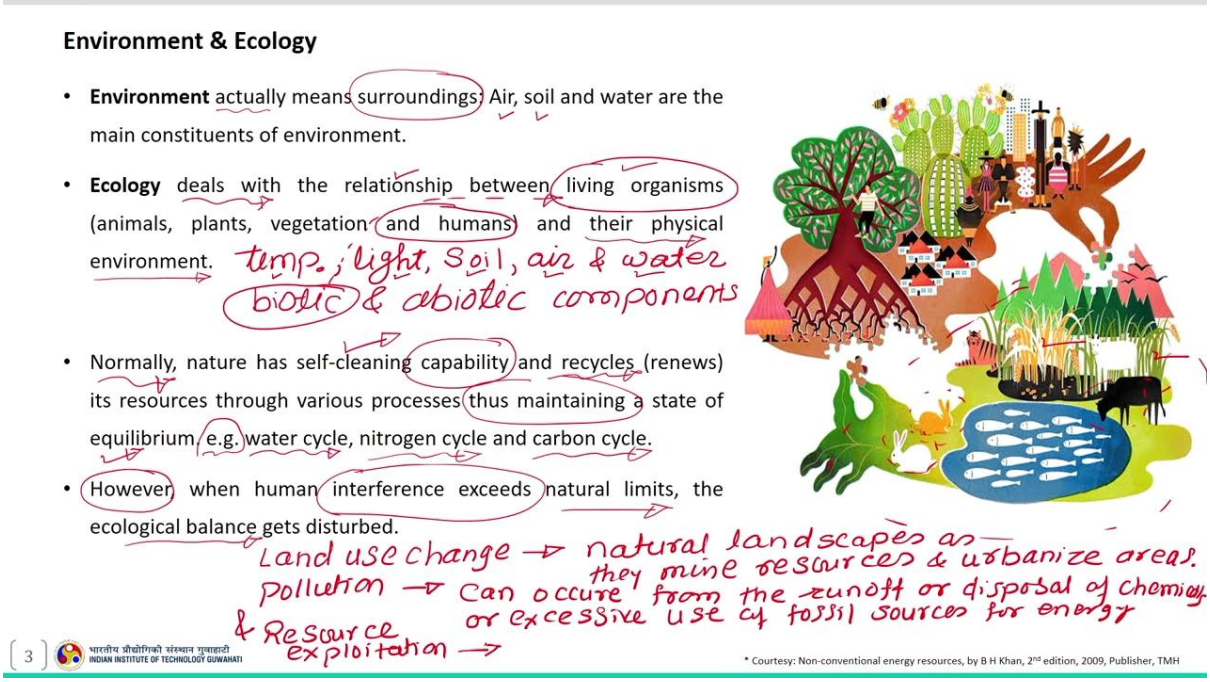

Environment literally means surrounding. That is air, soil and water are the main constituents of environment. And if you talk about the ecology, ecology deals with the relationship between living organism and their physical environment. The physical components include factors like temperature, light, soil, air water. The biological component consists of living organisms like animal, plants and microorganisms as well as humans. In the environment, both these biotic and abiotic components interact with each other.

The abiotic means temperature, light, soil, air and water; and the biotic means all living organisms. So, ecology it seeks to understand the vital connection between plants and animals and the world which is around them. Ecology also provides information about the benefit of ecosystem and how we can use earth resources in ways that leave the environment healthy for future generations. Normally nature has self-cleaning capability and recycles its resources through various processes by maintaining a state of equilibrium. And example of self-cleaning capability and recycles include water cycle, nitrogen cycle and carbon cycle.

If you recollect we discuss about the water cycle in one of the lecture in the same module, when human interference it exceeds the natural limits then the ecological balance it gets disturbed. So, the example like land use change. Because here what happens is like the humans may destroy the natural landscape as they mine resources and urbanized areas. But this is detrimental to the environment because it displaces residing species in the given location reduces available habitats and food sources. So, eventually it results into the degradation of the environment.

Similarly, pollution due to excessive use of fossil fuels for the energy generation. So, the pollution can occur from the runoff or we can say disposal of chemical or excessive use of fossil fuels for the energy generation. Because which eventually results in the emission of greenhouse gases and these are detrimental to the ecology at a specific location or you can say in the specific area and resource exploitation. Human consumes large amount of these resources for their own needs. Some examples include mining of natural sources like coal and the clearing of forest for urbanization and wood use. And due to this factor the ecological balance get disturbed.

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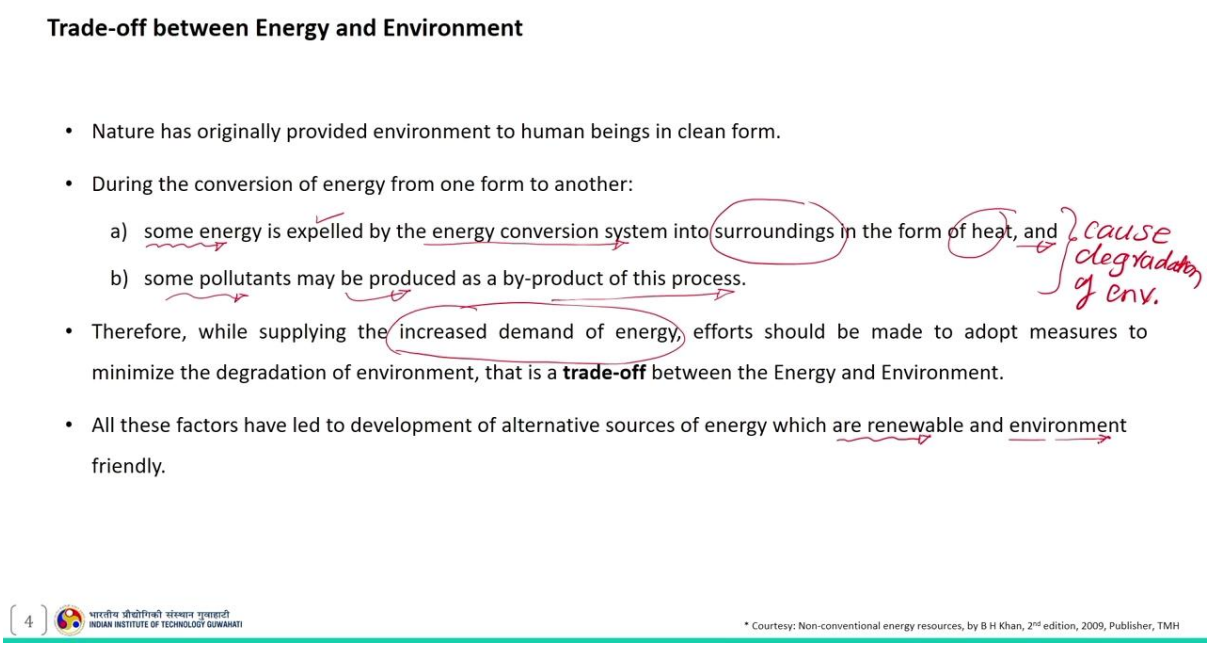

Now let us try to understand the tradeoff between energy and environment. Nature has provided environment to human beings in a clean form. However, with passage of time, the quality of the environment degraded due to various man-made reasons. And important factor among them are number of activities involving energy generation and its utilization.

Because during the conversion of energy from one form to another, some energy is expelled by the energy conversion system into surroundings and that is in the form of heat. And some pollutants may get produced as a byproduct of these processes and both these cause degradation of environment. Therefore, while supplying the increased demand of energy efforts should be made to adopt measures to minimize the degradation of environment and that is tradeoff between energy and environment. Similarly, every step must be taken to conserve the environment. Now, all these factors have led to the development of alternative sources of energy which are renewable and environment friendly.

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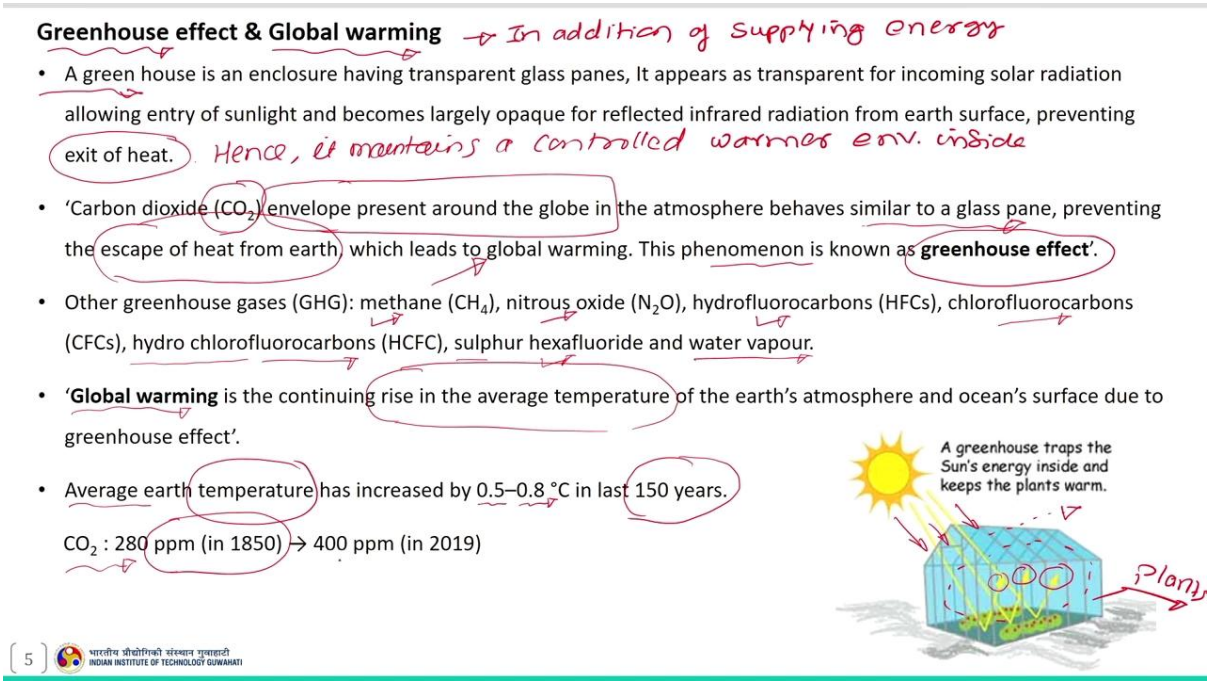

Now, after learning about this tradeoff between energy and environment, let us discuss about the greenhouse effect and global warming. So, in addition of supplying energy, fossil fuels are also used as a feedstock material for manufacturing of organic chemicals, which eventually results in the greenhouse gas emissions. Global warming is mainly caused due to the emission of excessive CO_2, due to excessive use of fossil fuels in industry, burning of wood and also due to the agriculture practices. A greenhouse is an enclosure having a transparent glass pan. So, if you see the image of the greenhouse is shown here in the schematic, it appears as transparent for incoming solar radiation allowing entry of sunlight and becomes largely opaque for outgoing infrared radiation from earth surface, thus preventing exit of heat.

Hence, it maintains a controlled warmer environment inside this greenhouse for growth of plants in places where climate is very cold. Similar to that carbon dioxide envelope present around the globe in the atmosphere behaves similar to a glass pane preventing escape of heat from the earth. And which eventually leads to the global warming. And this phenomenon is known as greenhouse effect. Apart from CO2, other harmful gases include methane, nitrous oxide, hydrofluorocarbons, hydrochlorofluorocarbons, sulfur hexafluoride and water vapor.

The global warming is the continuing rise in the average temperature of the earth atmosphere and ocean surface due to greenhouse effect. And if you see the average earth temperature has increased by 0.5 to 0.8 degree C in last 150 years. Similarly, the CO_2 concentration increase from 280 ppm in 1850 to 400 ppm in 2019. And this describe about the greenhouse effect and global warming.

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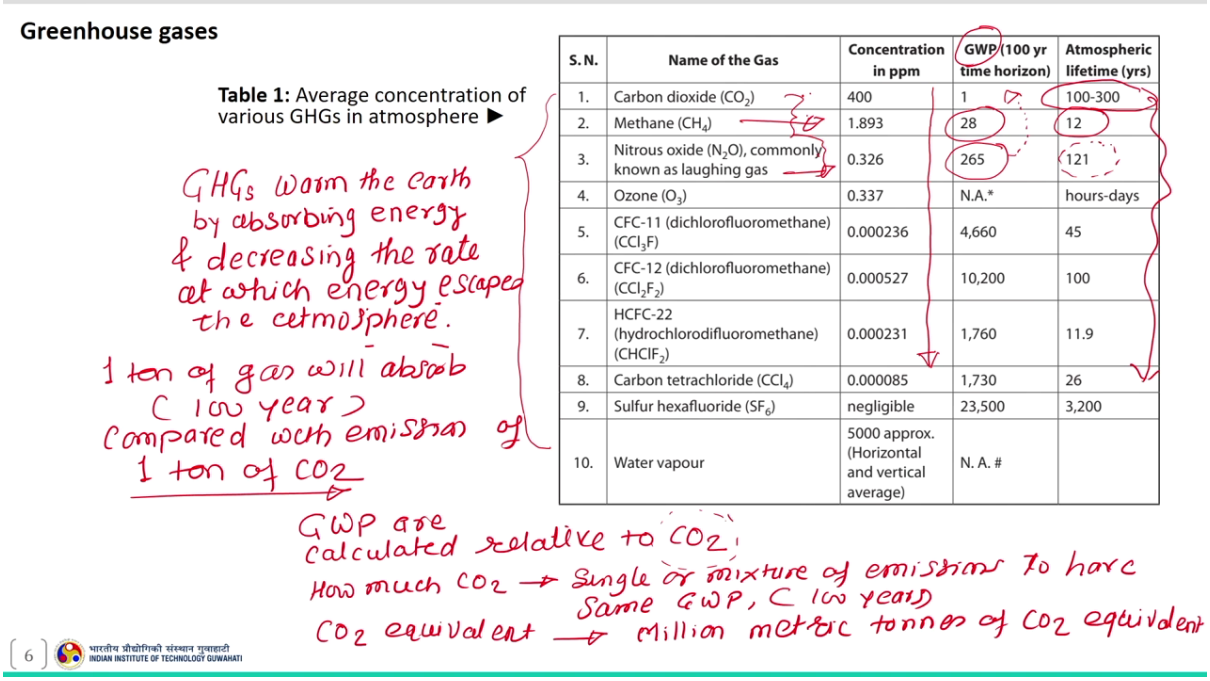

S. N.	Name of the Gas	Concentration in ppm	GWP (100 yr time horizon)	Atmospheric lifetime (yrs)
1.	Carbon dioxide (CO_2)	400	1	100-300
2.	Methane (CH_4)	1.893	28	12
3.	Nitrous oxide (N_2O), commonly known as laughing gas	0.326	265	121
4.	Ozone (O_3)	0.337	N.A.*	hours-days
5.	CFC-11 (dichlorofluoromethane) (CCl_3F)	0.000236	4,660	45
6.	CFC-12 (dichlorofluoromethane) (CCl_2F_2)	0.000527	10,200	100
7.	HCFC-22 (hydrochlorodifluoromethane) ($CHClF_2$)	0.000231	1,760	11.9
8.	Carbon tetrachloride (CCl_4)	0.000085	1,730	26
9.	Sulfur hexafluoride (SF_6)	negligible	23,500	3,200
10.	Water vapour	5000 approx. (Horizontal and vertical average)	N. A. #	

Apart from the carbon dioxide the average concentration of various greenhouse gases in the atmosphere is tabulated here in the tabular form. So it indicates the greenhouse gases and their average concentration in the atmosphere. Greenhouse gases warm the earth by absorbing energy and decreasing the rate at which energy escapes the atmosphere. These gases differ in their ability to absorb energy that is they have various radiative efficiencies.

In fact, they also differ in their atmospheric residence time that is called as atmospheric lifetime. Each specific gas has a specific global warming potential which allows the comparison of amount of energy the emission of 1 ton of gas will absorb over a given time period and usually the time period is 100 year, compared with emissions of 1 ton of CO_2. That is because this CO_2 has a very long residence time in the atmosphere. Similarly, if you try to see the methane's average atmospheric residence time, it is about a decade. However,

its capacity to absorb substantially more energy than CO_2 gives it a global warming of around 28.

Similarly, the global warming potential of nitrous oxide it is 265 times that of CO_2 with an average residence time of say 100 years. That means for a given amount of mass, they hold substantially more energy than does CO_2. And hence, the global warming potential are calculated relative to carbon dioxide because in general we try to measure the impact of various pollutant gases in the form of carbon dioxide equivalent. Carbon dioxide equivalency is one way to estimate how much CO_2 would be needed for a single or mixture of emissions to have the same global warming potential if measured over a period hundred years. So, the CO_2 equivalents are often expressed as million metric tons of carbon dioxide equivalent.

So, this table as well as the data given in this table would be very useful when we practice some example on this concept as well as this would be useful while solving example in assignments.

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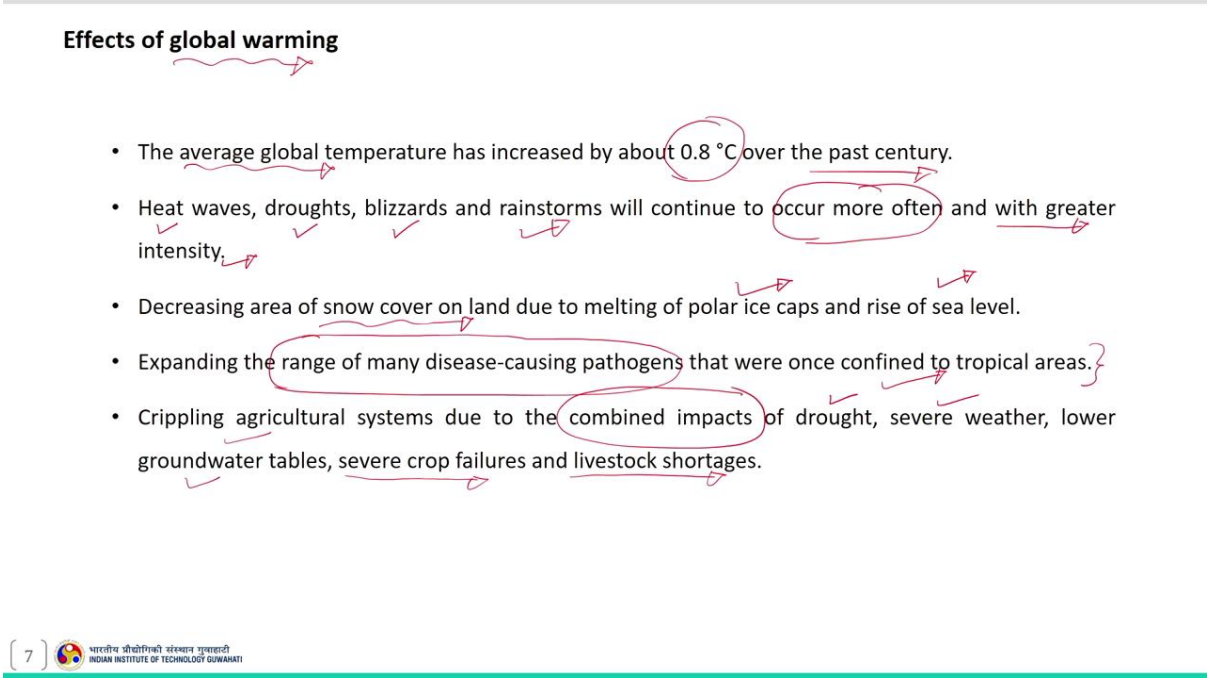

Now after learning about the greenhouse effects and global warming, let us discuss about the global warming in more detail. As mentioned just now the average global temperature has increased by about 0.8 degree C over the past century. And also experts have predicted that

heat waves, droughts, blizzards and rainstorm will continue to occur more often and even with the greater intensities.

Similarly, the decreasing area of snow cover on land due to melting of polar ice caps, and rise of sea level are major signs of worldwide climate change. Apart from that expanding the range of many diseases causing pathogens that were once confined to our tropical areas is also a sign of worldwide climatic change. Crippling of agriculture systems due to combined impact of drought, severe weather, lower ground water tables, severe crop failures and livestock shortages are the signs of worldwide climate change. After learning about greenhouse effects and global warming, now let us discuss about the pollution that are responsible for greenhouse effect and global warming.

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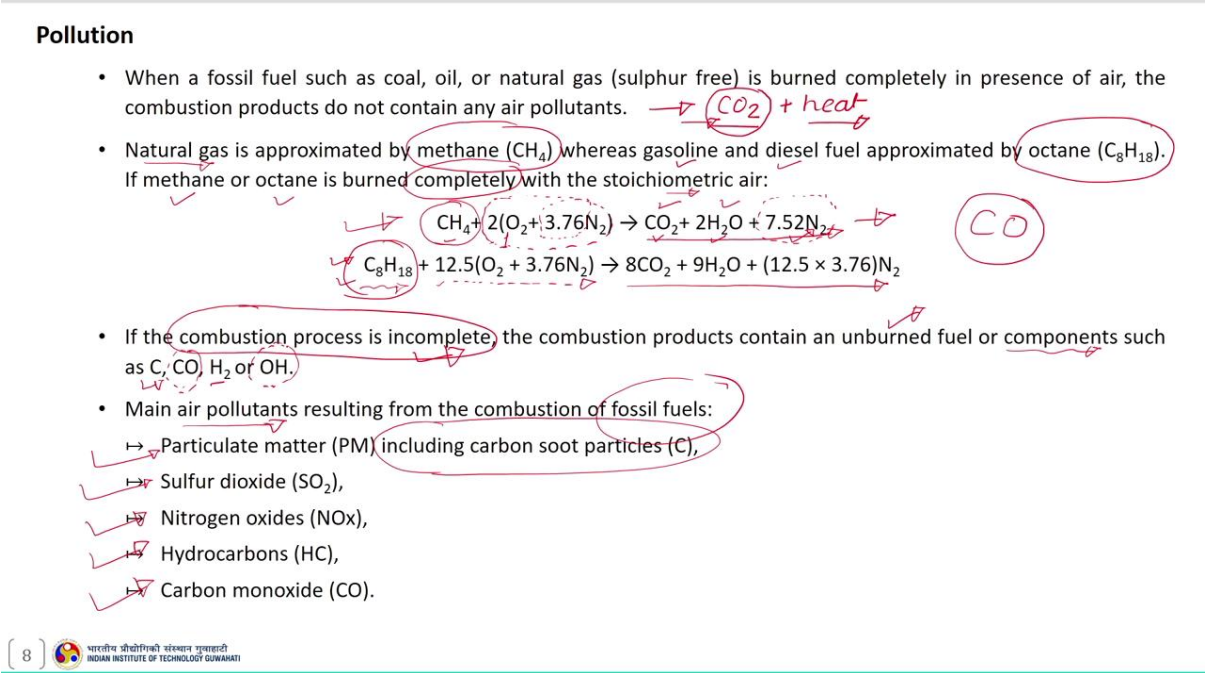

Fossil fuels such as coal, oil and natural gas when burn completely in presence of air, the combustion product does not contain any pollutant except CO_2. Because CO_2 and heat are the major products of the combustion process. Natural gas is approximated by methane, whereas the gasoline and the diesel approximated by octane. And if methane and octane is burned completely with a stoichiometric air, then the stoichiometric scheme of combustion of methane is shown here. It mainly produces carbon dioxide, water and these many moles of nitrogen. Because if you recollect our discussion, in air 1 mole of oxygen is accompanied by

3.76 moles of nitrogen. So, for complete combustion of methane it required this much stoichimetric quantity of air to produce these products. Similarly, for the combustion of diesel or gasoline it required this much amount of stoichiometric air to produce these products. Where if you see it mostly produces stable product in the form of CO_2, water and nitrogen and there is no presence of any unstable product. The meaning of unstable product is like there is no production of carbon monoxide in this process. But if this process of combustion is incomplete then the combustion product contain unburnt fuel or component such as it may have carbon, and as I just mentioned CO, hydrogen or OH.

And this is mainly because of the incomplete combustion of fuel in the combustion chamber and this mainly results in the emission of pollutant in the atmosphere. So, the main air pollutant, which are resulting from the combustion of fossil fuels include particulate matter including carbon shoot particles, sulphur dioxide, nitrogen oxides, hydrocarbon and carbon monoxide.

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▼ **Table 2:** Pollutants from various fuel-based power plants

Pollutant	Hard coal	Brown coal	Fuel oil	Other oil	Gas
CO_2 (g/GJ)	94,600	101,000	77,400	74,100	56,100
SO_2 (g/GJ)	765	1,361	1,350	228	0.68
NO_x (g/GJ)	292	183	195	129	93.3
CO (g/GJ)	89.1	89.1	15.7	15.7	14.5
Non methane organic compounds (g/GJ)	4.92	7.78	3.70	3.24	1.58
Particulate matter (g/GJ)	1,203	3,254	16	1.91	0.1
Flue gas volume, total (m^3/GJ)	360	444	279	276	272

So, now let us discuss about these pollutants in more detail. Pollutant from various fuel based power plant is depicted here in the tabular form along with their emission range. If you see the emission of carbon dioxide in gram per gigajoule by using hard coal as a fuel it is around this much. Similarly, for brown coal the value is around 101,000 and similarly for the other

fields also the values are tabulated. Apart from that the values are also tabulated for the other pollutants. So, this table would be also very useful while practicing the example in this module and on the similar concept the example would be given in the assignment.

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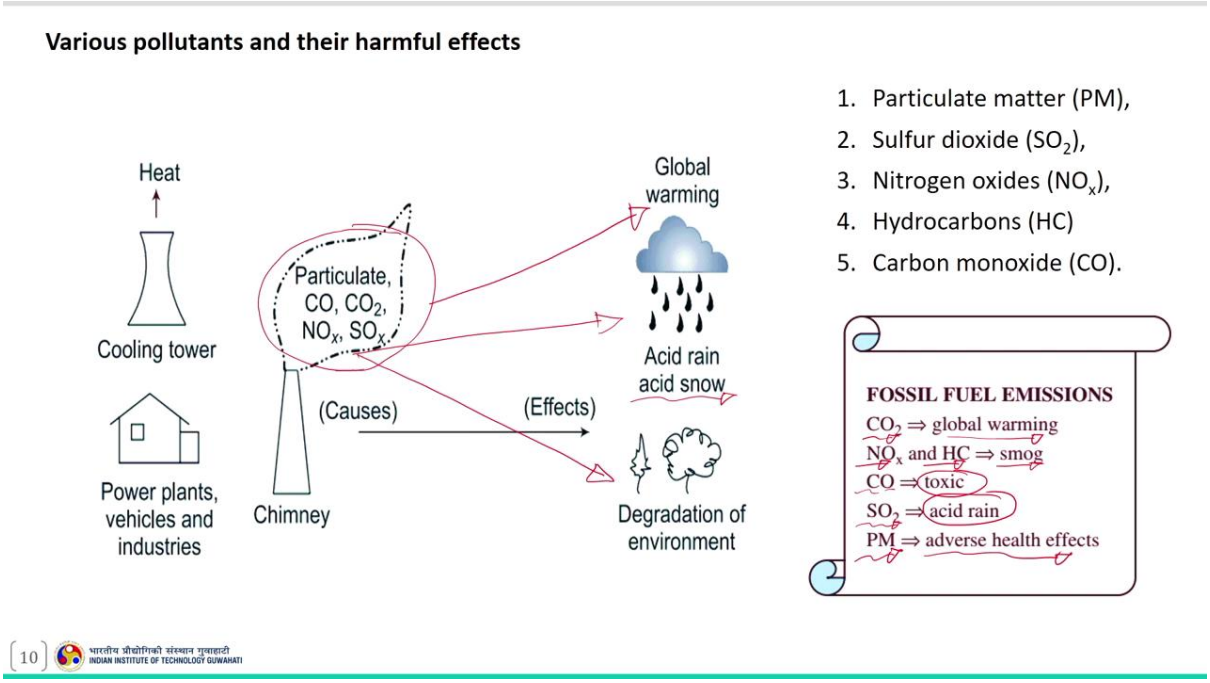

So, now after learning about the pollutants, let us discuss about these pollutants and their harmful effects. So, as we discussed earlier, the emission of pollutant from the burning of the fossil fuels results into the degradation of the environment, cause acid rain, even acid snow and global warming. The fossil fuels emission mainly CO_2. It causes global warming. NOx and hydrocarbon cause smog. Carbon monoxide is toxic. Sulphur dioxide causes acid rain. And the particulate matter causes adverse health effect. So, now let us discuss about these various pollutants one by one with their harmful effects.

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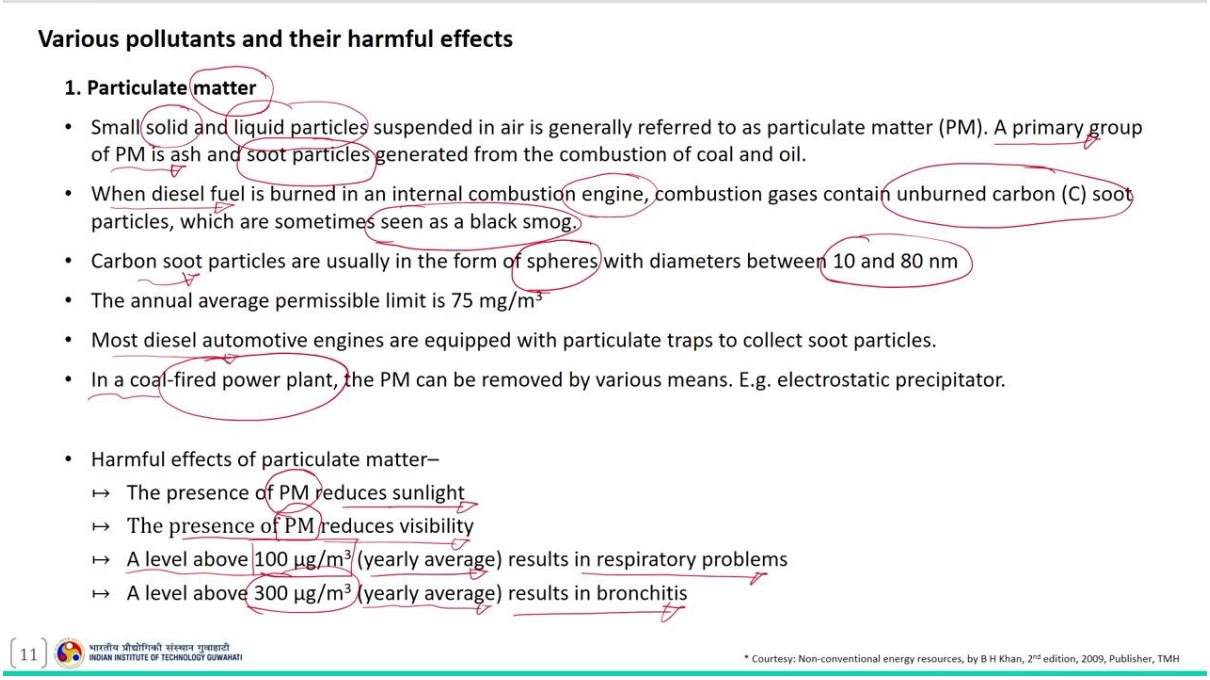

So, first let us begin with the particulate matter. Small solids and liquid particles suspended in air is generally referred as particulate matter. A primary group of particulate matter is ash and soot particles generated from the combustion of coal and oil. When diesel fuel is burned in an internal combustion engine, then the combustion gases from the exhaust mainly contain unburned carbon soot particles, which are sometimes seen as a black smoke from the exhaust of the internal combustion engine. These carbon soot particles are usually in the form of spheres with diameter between 10 to 80 nanometer. And the annual average permissible limit of particulate matter is 75 mg/m^3. Most diesel automotive engines are now equipped with particulate trap to collect soot particles.

Similarly, in coal fired power plant, the particulate matter can be removed by various means and one of the most popular examples is electrostatic precipitator. And the harmful effects of particulate matters are mentioned here. The presence of particulate matter in the atmosphere reduces sunlight. Because the excessive percentage of particulate matter in the environment diffuses the incoming solar radiation. And it get redistributed into the environment some going back into the space and some reaching to the earth surface. As a result the exact quantity of the radiation reaching to the earth surface reduces.

The presence of particulate matter in the atmosphere also reduces the visibility. Because the excessive percentage of particulate matter in the atmosphere mainly results in reducing the visibility in the atmosphere. A level above 100 microgram per meter cube that is yearly average again results in respiratory problems. And level above 300 microgram per meter cube that is also yearly average results in bronchitis. So, this is about the particulate matter and its harmful effects.

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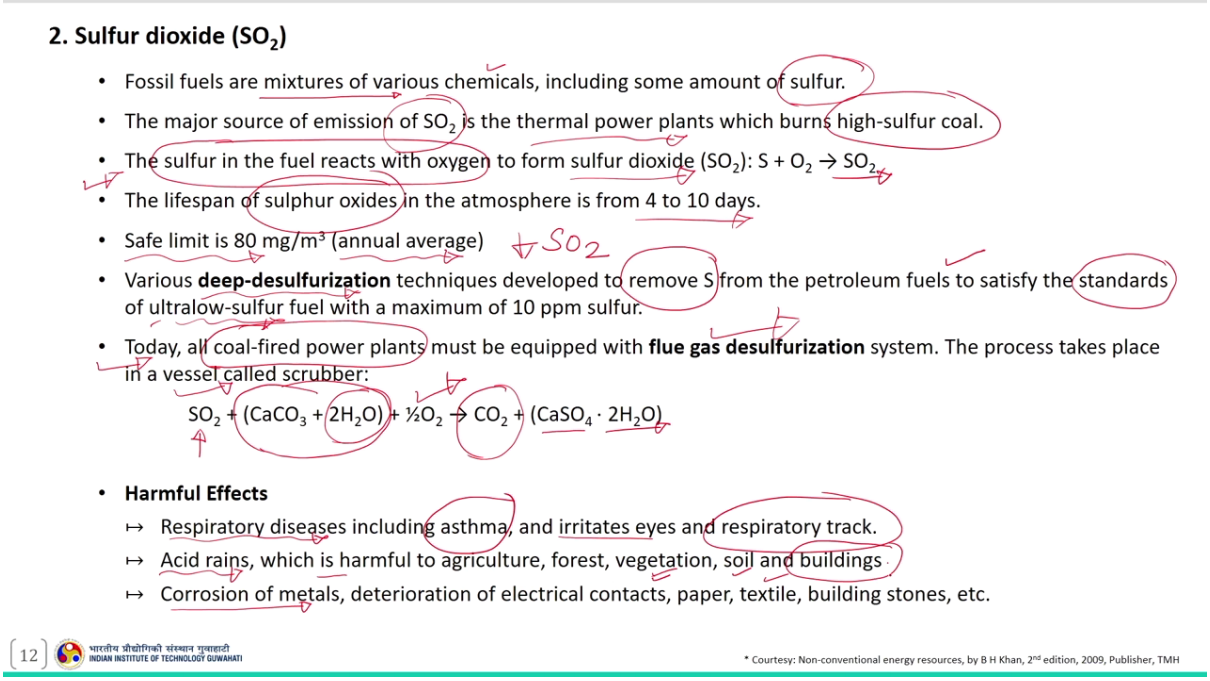

So now the next pollutant is sulphur dioxide. The presence of sulphur dioxide in the air is mainly due to manmade reasons involving combustion of fuel containing sulphur. Because fossil fuels are mixtures of various chemicals including some amount of sulphur. And the major source of emission of sulphur dioxide is the thermal power plant which burns high sulphur coal. And as we discussed this point even before, during the combustion process if the sulphur is present in the fuel, the sulphur in the fuel react first with oxygen to form sulphur oxide.

And the lifespan of sulphur oxides in the atmosphere is from 4 to 10 days as well as the safe limit of sulphur dioxide is 80 milligram per meter cube that is also on the annual average basis. And therefore, to reduce the emission of sulphur dioxide in the atmosphere various desulphurization techniques have been developed to remove sulphur from the petroleum

fuels, that is even to satisfy the standards of ultra low sulphur fuel with a maximum of 10 ppm sulphur in its composition. Apart from that all coal fired power plants are now equipped with flue gas desulphurization system, in which the process takes place in a vessel called scrubber. And the reaction takes place in the scrubber where sulphur dioxide reacts with the calcium carbonate with moisture and oxygen where it produces carbon dioxide along with calcium sulphate dihydrate which is also known as gypsum. And if you see the harmful effect it causes respiratory diseases including asthma and irritates eyes and respiratory tract.

It also causes acid rains which is harmful to agriculture, forest, vegetation, soil and buildings as well. It also causes corrosion of metals, deterioration of electrical contacts, textiles, paper and building stones. So, this is about the sulphur dioxide and its harmful effect.

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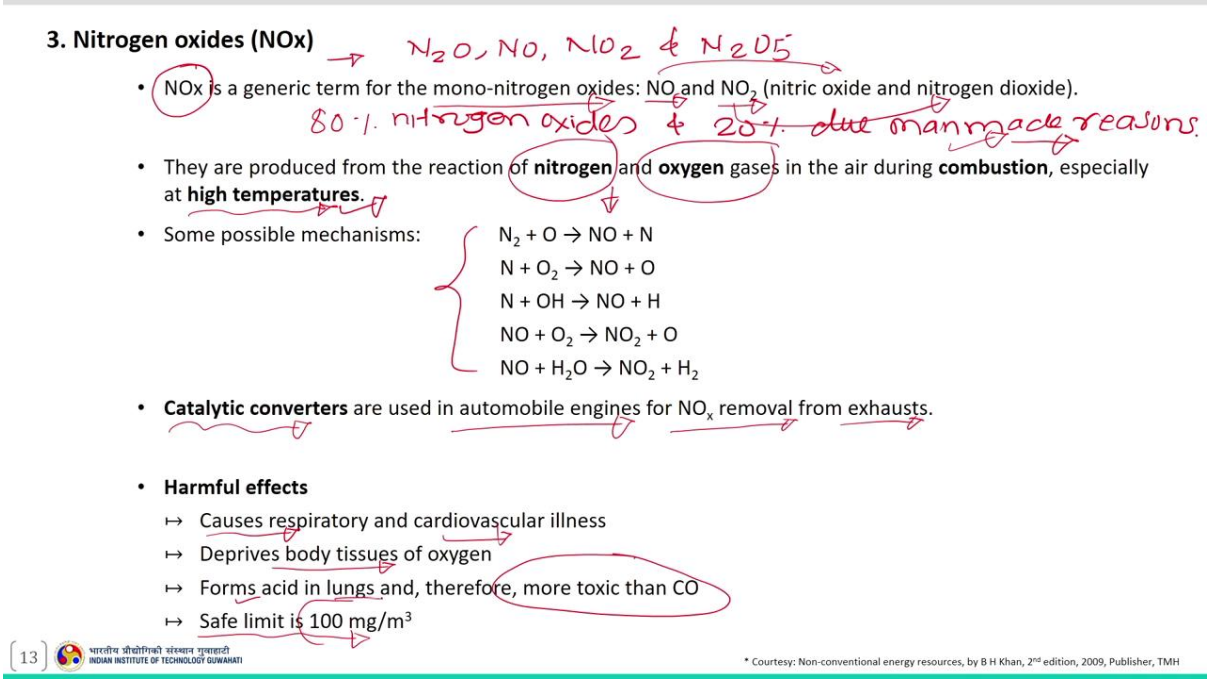

Now, let us discuss about nitrogen oxide and its harmful effect. Oxides of nitrogen such as N_2O, NO, NO_2 and are commonly referred as NOx. Basically, NOx is a generic term for the mononitrogen oxides like NO and NO_2. NO means nitric oxide and NO_2 means nitrogen dioxide. And they are mainly produced from the reaction of nitrogen and oxygen gases in air during combustion and especially at higher temperatures. And if you see the 80% of nitrogen oxides in the atmosphere are produced due to natural causes and about 20 percent due to

manmade reasons. And this is mostly due to combustion process in air at relatively higher temperature.

Some possible mechanism of nitrogen oxides are also shown here. So, to avoid this emission of nitrogen oxides into the atmosphere, now catalytic converters are used in the automobile engines for NOx removal from the exhaust gases. Now, the harmful effect of nitrogen oxides includes it causes respiratory and cardiovascular illness, deprives body tissue of oxygen, forms acid in lungs and therefore more toxic than carbon monoxide. And the safe limit of nitrogen oxide is 100 milligram per meter cube.

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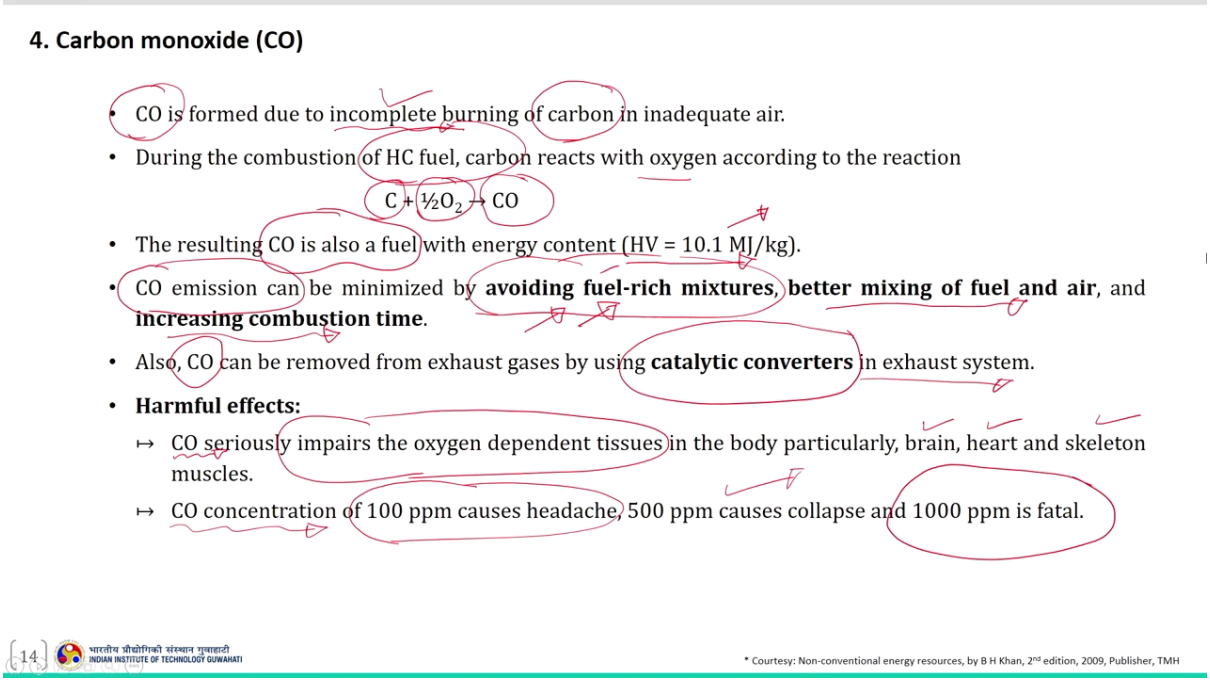

So, the next in the list is carbon monoxide. So, carbon monoxide it is mainly formed due to the incomplete burning of carbon in a inadequate air. So, this particular concept of incomplete combustion we have already just discussed few slides before. And during this combustion of hydrocarbon fuel carbon reacts with oxygen according to the following reaction where you can see the carbon is reacting with oxygen, but the oxygen is not adequate for the complete combustion of this carbon. As a result it is forming carbon monoxide as a product and the resulting carbon monoxide is also act as a fuel. Because it has the energy content of around like 10 MJ/kg.

So, this carbon monoxide further get oxidized to form CO_2 and along with this particular reaction it releases good amount of energy. Carbon monoxide emission it can be minimized by avoiding the fuel rich mixture that means the process should have adequate oxygen for the complete combustion of the fuel. Better mixing of fuel and air and increasing the combustion time, that means the gases should have proper residence time in the combustion chamber, so that the entire fuel should get combusted to a stable product in the form of CO_2. Also, carbon monoxide can be removed from the exhaust gases by catalytic converters in exhaust systems. The harmful effect of carbon monoxides are - carbon monoxide seriously impairs the oxygen dependent tissues in the body, particularly the brain, heart and skeleton muscles. Carbon monoxide concentration of 100 ppm causes headache, 500 ppm causes collapse and 1000 ppm is fatal. So, this is about the carbon monoxide and its harmful effects.

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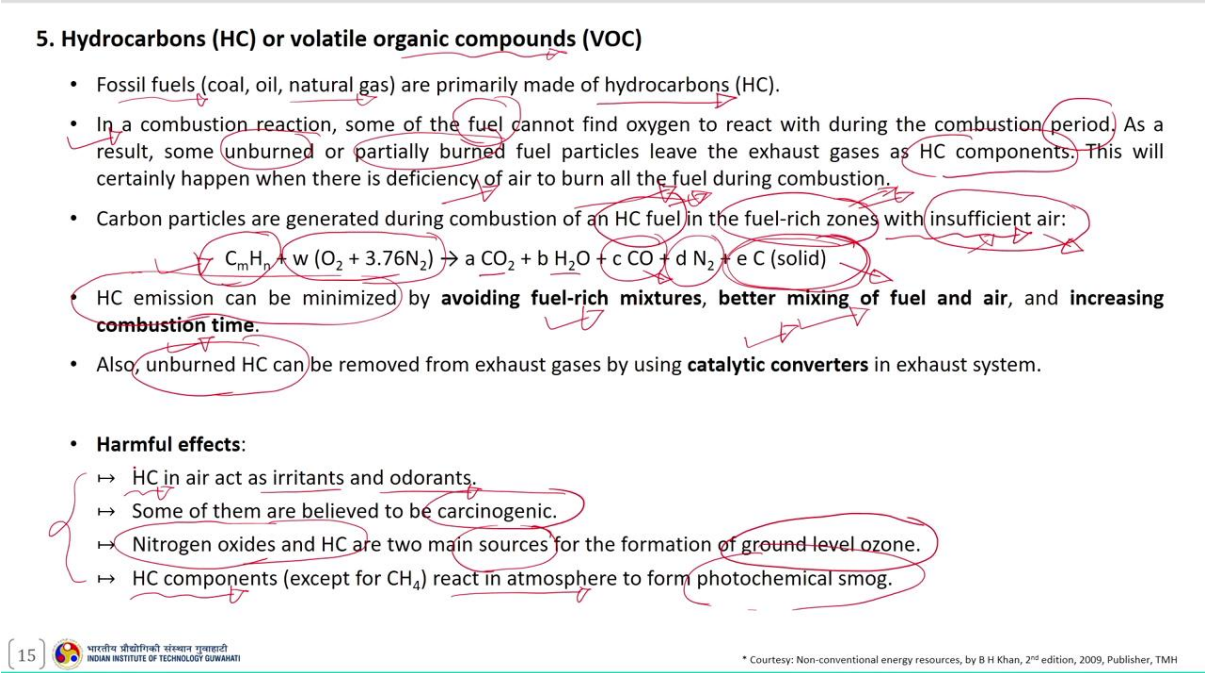

And the last in the list is the hydrocarbon or volatile organic compounds. As we know the fossil fuel that is coal, oil and natural gas are mainly made of hydrocarbons. And in the combustion reaction some of the fuel cannot find the oxygen to react with during the combustion period. And as a result what happens is like some unburnt or partially burnt fuel loses the exhaust gases as hydrocarbon component. And this will certainly happen when the sufficient quantity of air or oxidant is not available for the combustion process to take place. So, the carbon particles generated during the combustion of hydrocarbon fuel in the fuel rich

zone that means when there is insufficient oxygen or air is available for the combustion process. That means it is also called as a insufficient air in the combustion process which eventually results in the emission of carbon particles along with the hydrocarbon. Because complete combustion of the hydrocarbon fuel may not takes place in the combustion fuel because of the insufficient air in the combustion process which eventually results in the emission of unburnt hydrocarbon along with the exhaust gas.

So, this scheme represents the combustion of hydrocarbon fuel with air. And it produces CO_2, water, CO, nitrogen and solid carbon as a product. Here, because the carbon monoxide is getting produced due to insufficient air in the combustion process along with the solid carbon particles are also getting produced. Because the entire carbon particles are not taking part into the reaction due to insufficient amount of air in the combustion process. Hydrocarbon emission can be minimized by avoiding fuel rich mixtures, better mixing of fuel and air and increasing combustion time that means, increasing the residence time in the combustion chamber.

Also, the unburnt hydrocarbon can be removed from the exhaust gases by using catalytic converter in the exhaust system. The harmful effects of the hydrocarbon are hydrocarbon in air act as a irritants and odorants. Even some of them are believed to be carcinogenic in nature. Nitrogen oxides and hydrocarbon are two main sources for the formation of ground level ozone. Similarly, the hydrocarbon components react in atmosphere to form photochemical smog.

These are basically the harmful effects of hydrocarbon. So, now after learning about these various pollutants and their harmful effects, let us discuss about the conventional energy sources, their importance and disadvantages.

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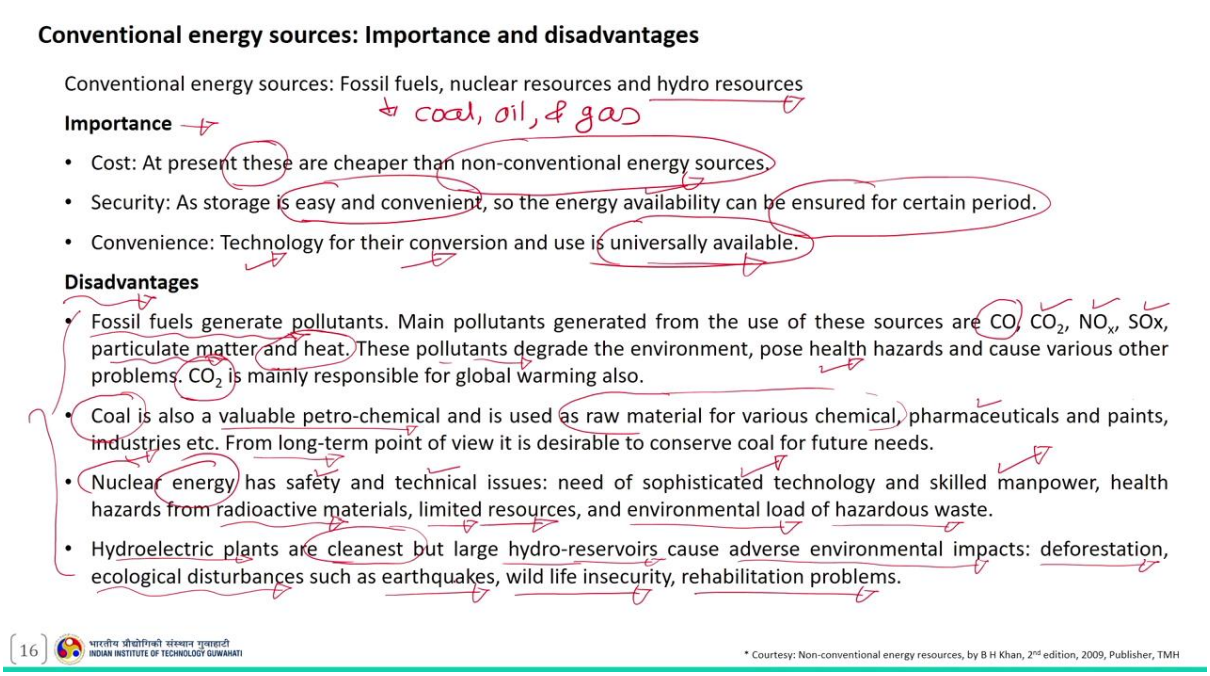

Conventional energy sources include fossil fuels, nuclear resources and hydro resources. The fossil fuels include coal, oil. And now, if we talk about the importance of the use of conventional sources of energy, so at present these sources are cheaper than the non-conventional energy sources. From the security point of view as the storage of these sources is easy and convenient, so the energy availability can be ensured for a certain period of time.

Apart from that, the technologies which are used for their conversion and use is universally available. That means the technology for the conversion of these conventional sources of energy is already in place and as a result these particular technologies are currently being used for the energy production. And due to the convenience of this particular technology the utilization of these resources for the energy purpose is also convenient. And this is basically importance or we would say the advantage of utilization of the conventional sources for energy purpose. However, disadvantages associated with the utilization of these conventional energy sources are because these fossil fuels mainly generate pollutants.

And the main pollutants generated with the use of these sources are carbon monoxide, carbon dioxide, NOx, SOx and particulate matter. Along with that this particular use of energy resources also releases significant amount of heat into the atmosphere. These pollutants degrade the environment pose health hazards and cause various other problems. In that if you

see the emission of carbon dioxide is mainly responsible for the global warming. Coal, which is a valuable petrochemical, is also used as a feedstock material for various chemical, pharmaceutical and paint industries.

But from long term point of view, it is desirable to conserve the coal for the future needs. Similarly, the nuclear energy has safety and technical issues. Because the need of sophisticated technology and the skill manpower is essentially required for the operation of the nuclear energy plants. Health hazard from radioactive materials is another major drawback of utilization of nuclear sources for the energy purpose, even the limited resources. Environmental load of hazardous waste is one of the major drawback of utilization of nuclear resources for energy purpose.

Hydroelectric plants are cleanest, but large hydro reservoirs cause adverse environmental impact that is deforestation, ecological disturbances such as earthquakes. wildlife insecurity and rehabilitation problems. So, these are basically the major disadvantages associated with the use of conventional sources of energy. And all these factors have now led to the development of alternative sources of energy which are renewable and environment friendly.

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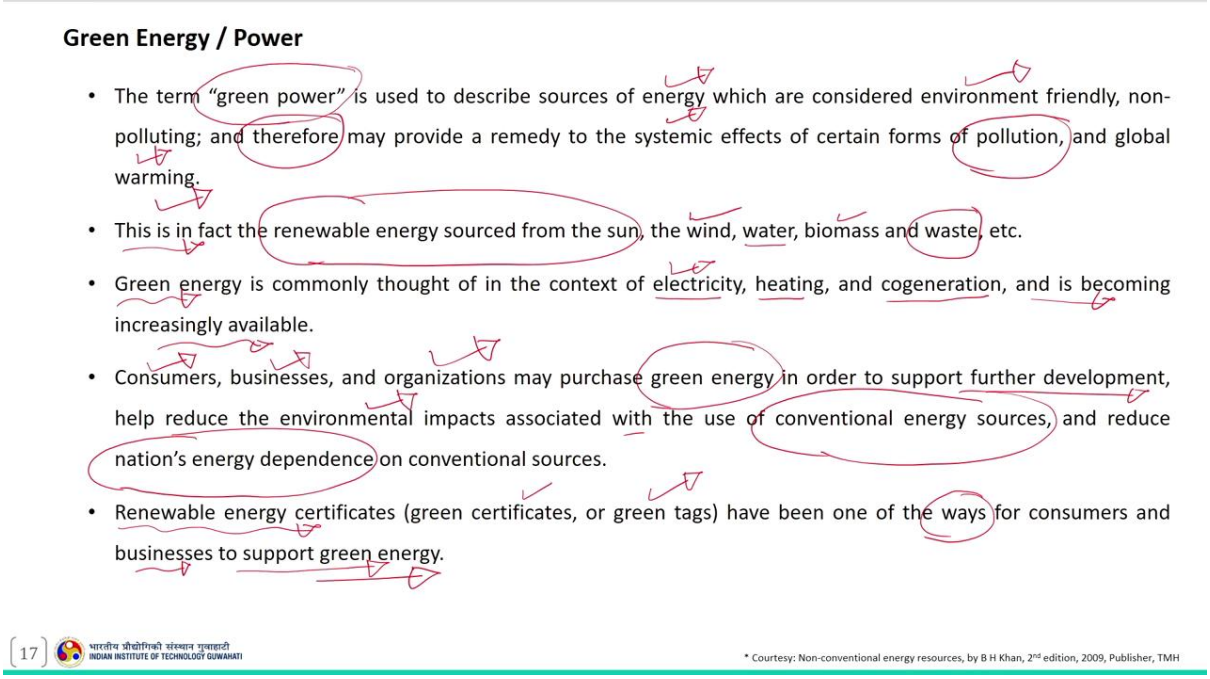

So, let us discuss about this renewable or green energy sources are also called as a green power. The term green power is used to describe the sources of energy which are considered environment friendly, non-polluting and therefore, may provide a remedy to systemic effects of certain forms of pollution and global warming. Green energy in fact, the renewable energy source from sun, wind, water, biomass and waste. Green energy here is commonly thought of in the context of electricity, heating, cogeneration and is becoming increasingly available to consumer. Therefore, the consumers, businesses and organization may purchase the green energy in order to support further development in the energy sector and also help to reduce the environmental impact associated with the use of conventional energy sources and reduce nations energy dependence on the conventional sources. Renewable energy certificates that is green certificates or green tags have been one of the ways for consumers and businesses to support this transition from conventional to green energy source.

So, in this lecture we discuss about the environment and ecology, greenhouse effect and global various pollutant and their harmful effect as well as the conventional energy resources, their importance and disadvantages. And all these factors have ultimately led to the development of alternate sources of energy which are renewable and environment friendly. So, with this we will end our lecture here. And in the next lecture we practice few examples on the concept discussed in this lecture as well as the concept discussed in this module.

Thank you.