INDIAN INSTITUTE OF TECHNOLOGY MADRAS

NPTEL
NPTEL ONLINE CERTIFICATION COURSES

ECOLOGY AND ENVIRONMENT

Module on

Energy & Environment

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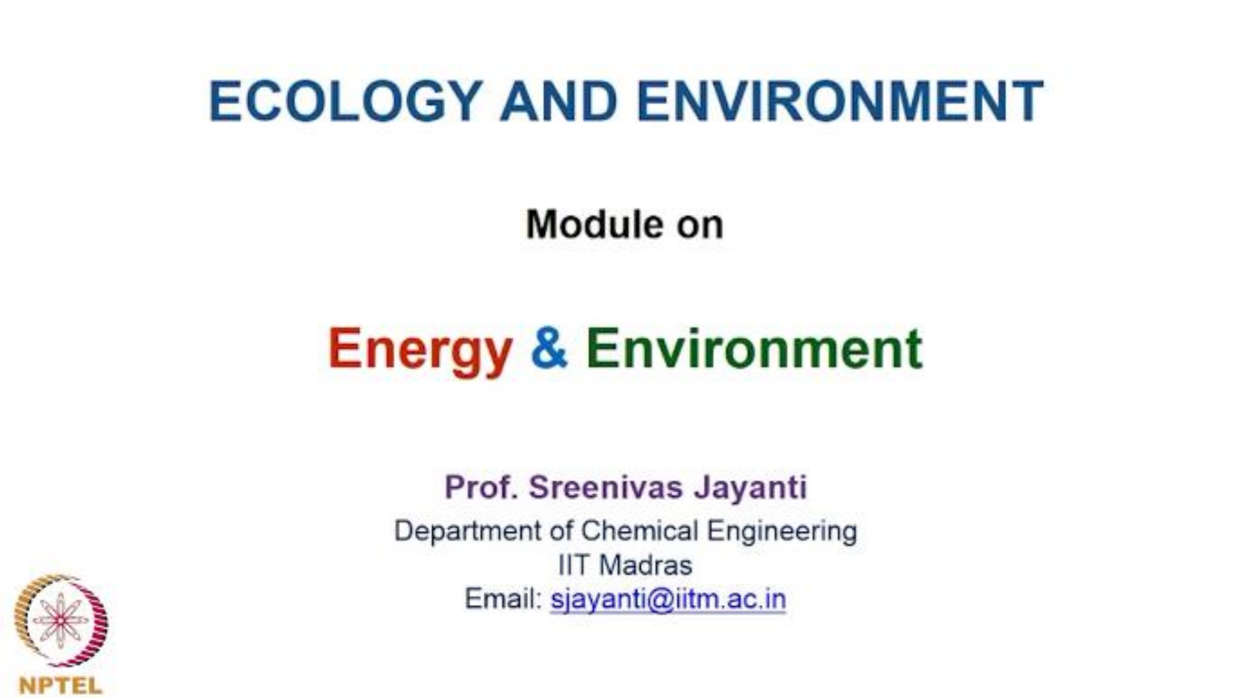
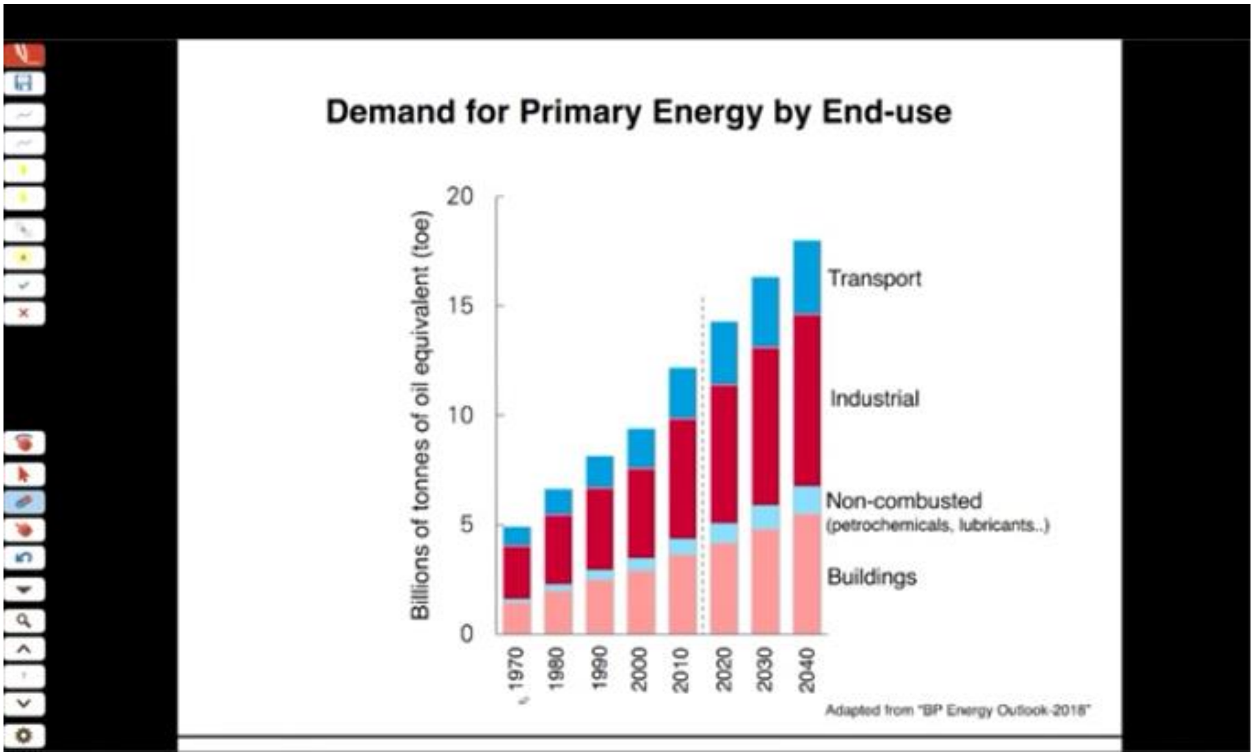
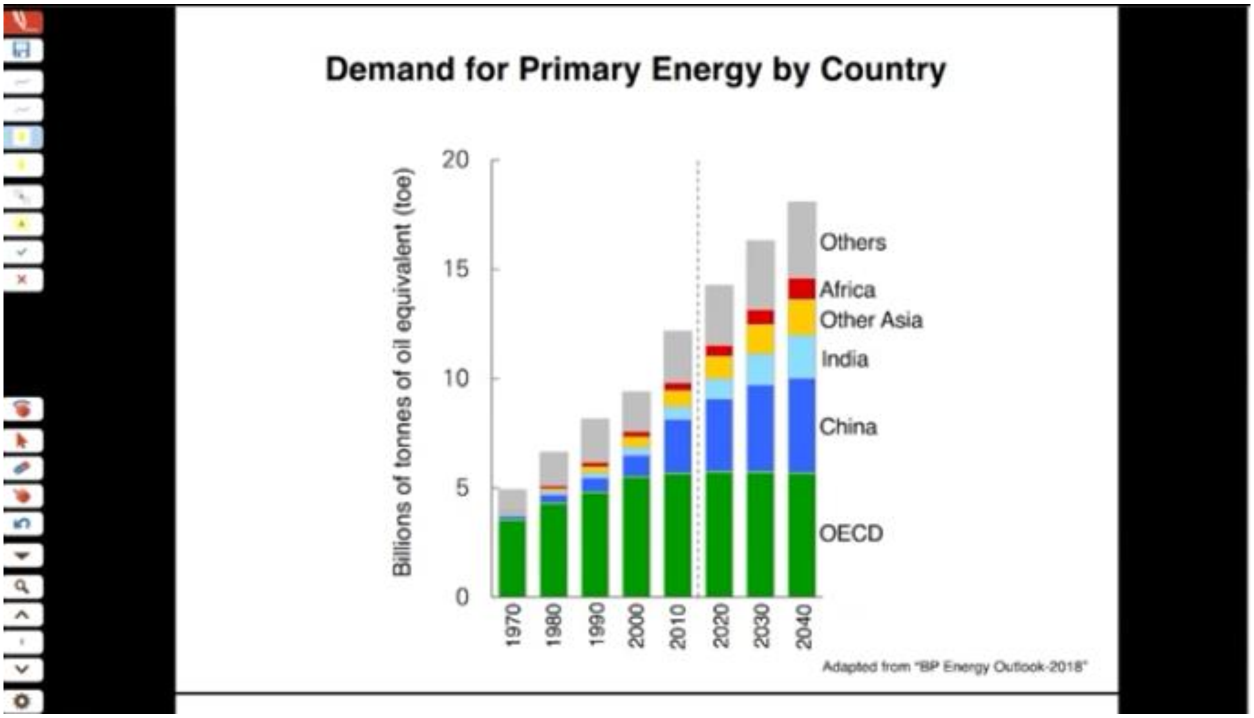
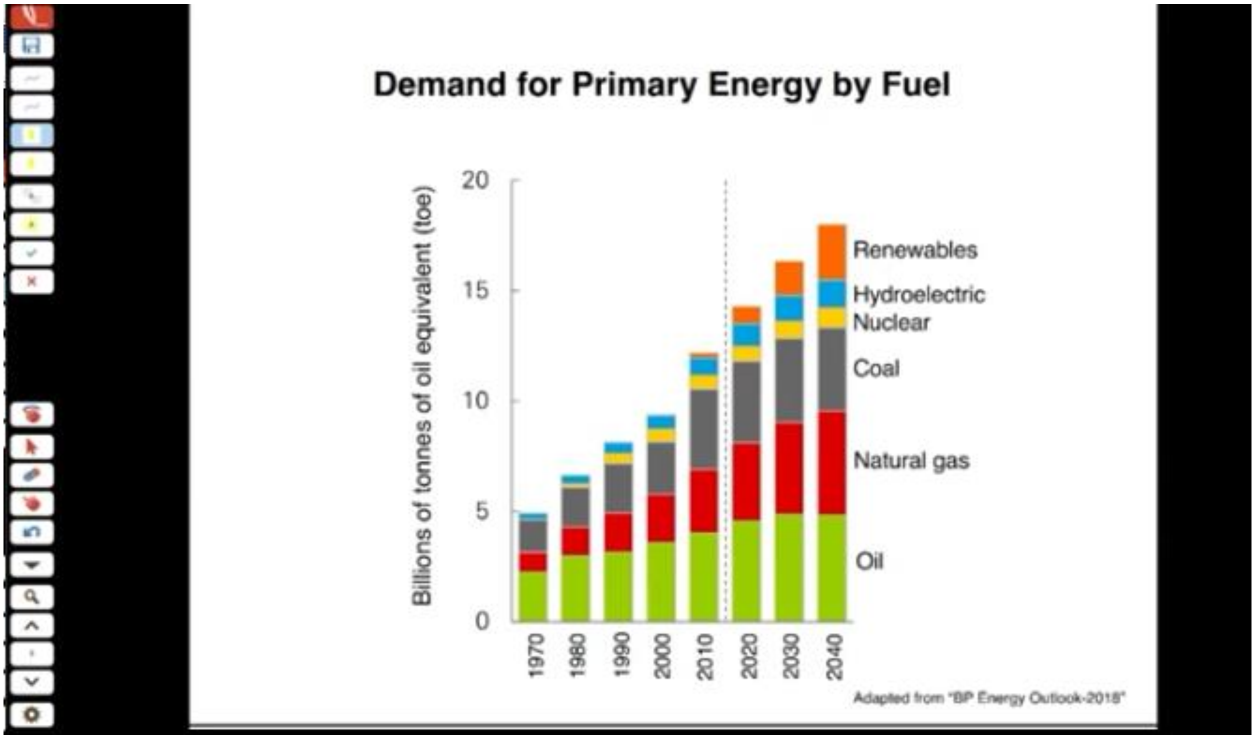




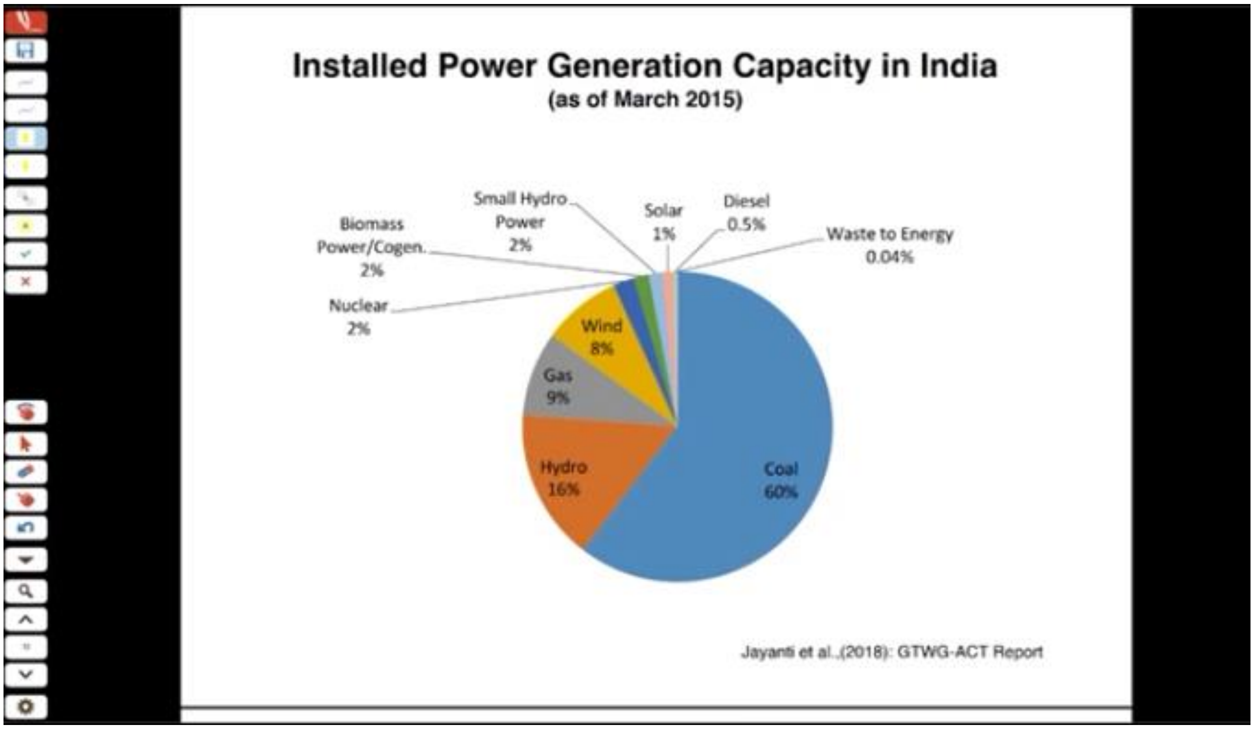
Welcome to the third lecture on the Energy and Environment module of Ecology and Environment course. In the last lecture, we have seen the demand for energy, and we have seen that the energy demand, we have seen that the energy demand has been increasing steadily over the past 40, 50 years. And as we can see in this picture where we have as a function of time, how the energy expressed in terms of billions of tons of oil equivalent has been increasing steadily, and in the near future going up to 2040. It is expected to continue to increase, spurt by demand from buildings, industrial output, and the transport sector. So, all this practice are causing an increase in energy consumption over the next 30, 40 years, when we look at the energy demand by country we can see that future increases of energy are coming primarily from China, India, and other African and Asian countries.



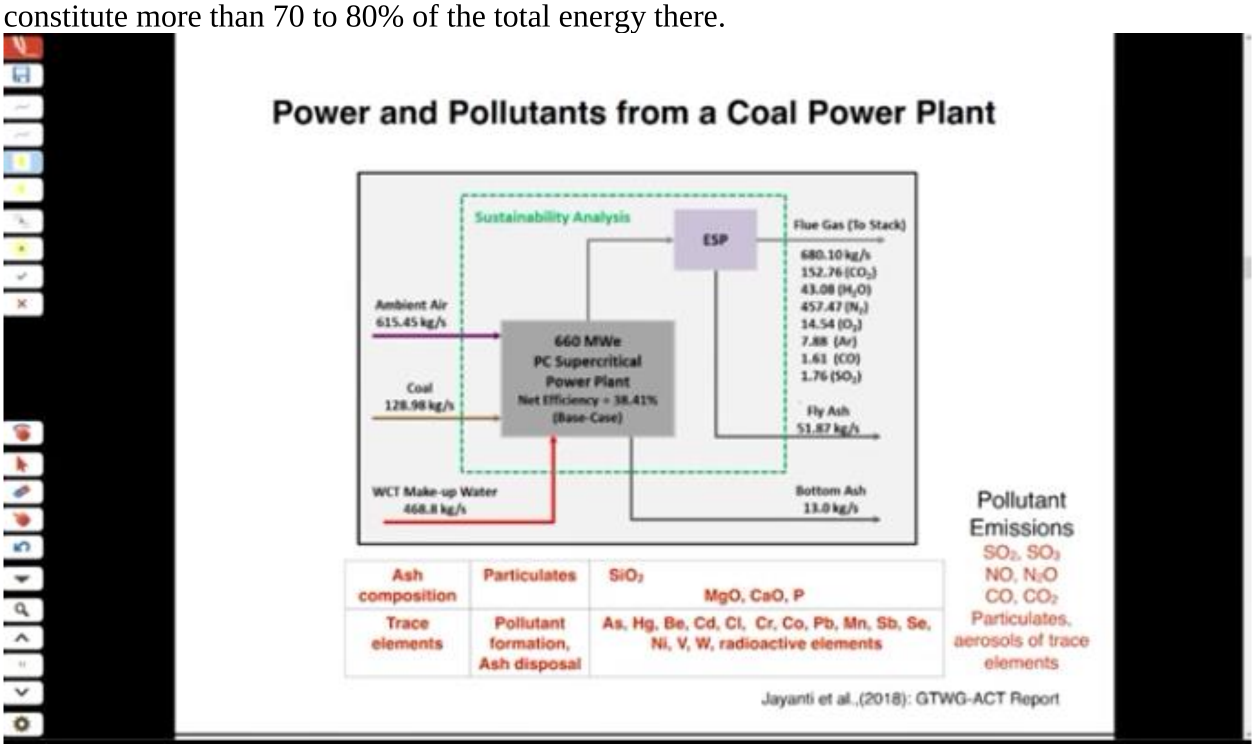
These have been traditionally the countries with low economic prosperity. We have seen that the energy consumption of a country and GDP closely linked, and these countries and the people there in seek economic prosperity then they have to consume more energy. And this is also one of the reasons why people think that energy is, energy is needed continuously. Whereas in the case of economically developed countries we see a flattening trend in the energy consumption.



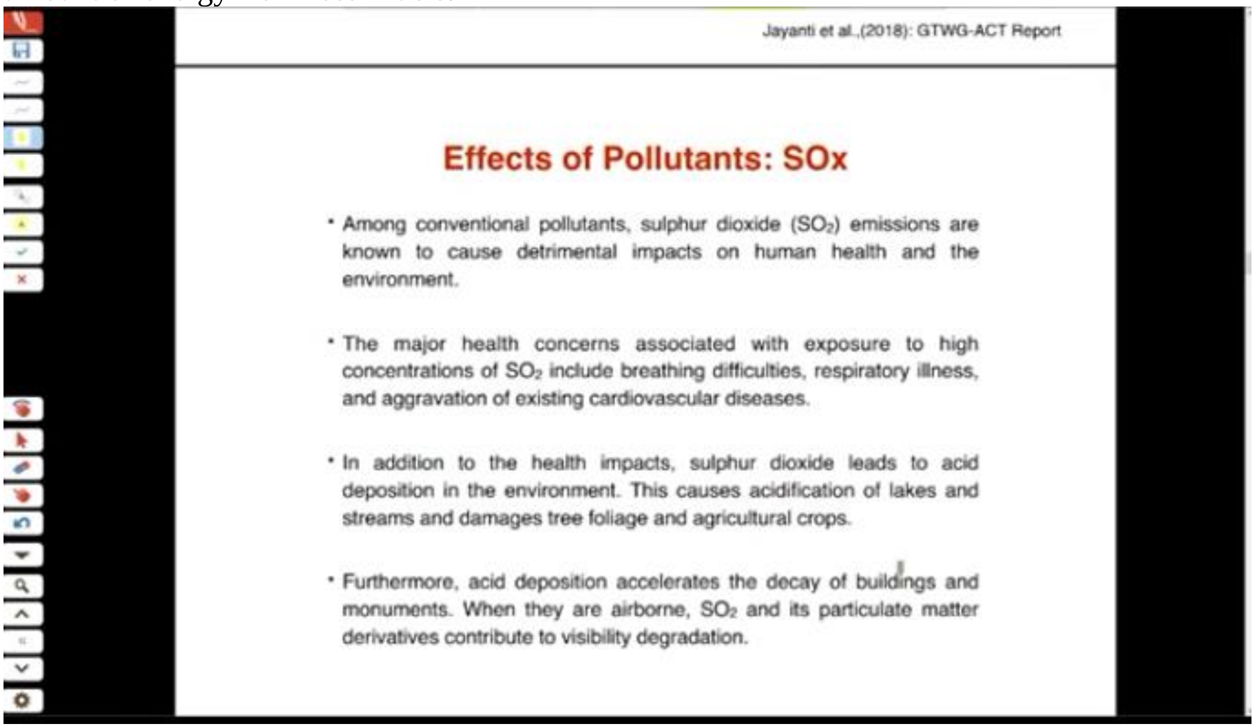
We also see how we have been drawing energy primarily from oil, natural gas, and coal for the past 50 years and this tendency is expected to go up, although we have an increasing contribution from renewable energies. We expect that in the near future for the next 30 to 40 years fossil fuels are expected to continue to contribute to the energy demand and also contributes significantly to the increased demand of energy. In this case, in such a scenario, why are we concerned, people talk about the finiteness of the fossil fuel reserves, but the reserves of whether it is oil, gas, or coal are such that they can easily see us through for the next one century, including oil. There are so many reserves of oil that at the current demand and the future expected demand, these fossil fuels can take us into the next century without any problem. So, the problem is not in terms of the finiteness, but in terms of the effect of drawing this much of energy from fossil fuels on the environment, and that is of primary concerned us, and this is what we are going to look at in today’s lecture.



If you look at the installed power generation capacity of India which is one of the major energy demanders currently and also of immediate future we draw a large amount, most of our energy is coming from coal in terms of installation. It is 60% in terms of actual amount of energy drawn it is more than 70% and much less in terms of gas and oil, but primarily coal and gas together constitute more than 70 to 80% of the total energy there.

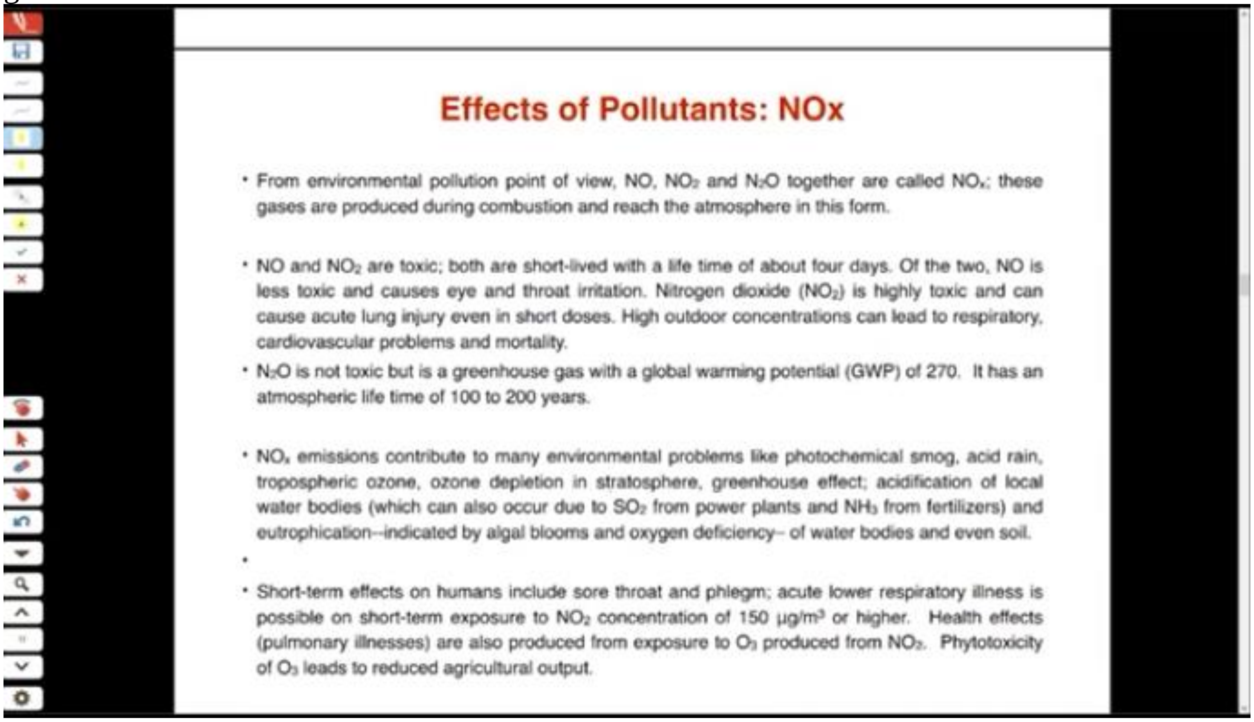


So, this is something that is of concern to us because as we have seen in the very first lecture, when we combust coal we not only get energy in terms of electricity, but we also get a lot of pollutants, and these are like oxides of sulphur, sulphur is present in coal in maybe 1 or 2% by mass, you have nitrogen oxides, carbon monoxide, carbon dioxide, particulates coming from ash, mineral matter that is present in the coal which can be significant in the Indian context. And aerosols of trace elements, many of which are environmentally harmful to the water bodies, to the air bodies, and to humans by direct ingestion and so on. So, it is the use of, it is the production of this pollutant that is causing concern in terms of drawing further energy, increasing amount of energy from fossil fuels.



Let us look at what these effects of pollutants one by one so that we can understand the gravity of the situation. When we consider sulphur oxides, we normally mean especially from our power generation type of situation, especially from coal and oil where they can be a significant amount of sulphur. Most of emissions will be in the form of sulphur dioxide and a small percentage maybe in the form of sulphur trioxide SO_3, and these are known to have a detrimental impact on human health and environment. So, the major health concerns associated with exposure to high concentrations of sulphur dioxide include breathing difficulties, respiratory illness, and aggravation of existing cardiovascular diseases. So, humans are directly influenced by this.

And in addition to this common direct health impact on human beings in terms of immediate health concern, there is also undesirable consequences sulphur dioxide in terms of acid rain, which causes acidification of lakes and streams and damages tree foliage and agricultural crops. And acid deposition accelerates decay of buildings and monuments. The concern about Taj Mahal and other monuments that are being affected in North India by lot of pollution coming from power plants is an example of this particular case. And when airborne SO_2 and its particulate matter derivatives contribute to visibility degradation. This again is one of the problems fogs, smoke, and visibility problems especially in winter and especially in North India which leads to a lot of traffic congestion, train congestion and so on. These are all the immediate consequences that we have been facing, and whosever has been using coal has also been facing. In Europe and the US in early parts of the, in the middle of last century and currently in China and India we have this kind of problems associated with excessive usage of coal for power generation.



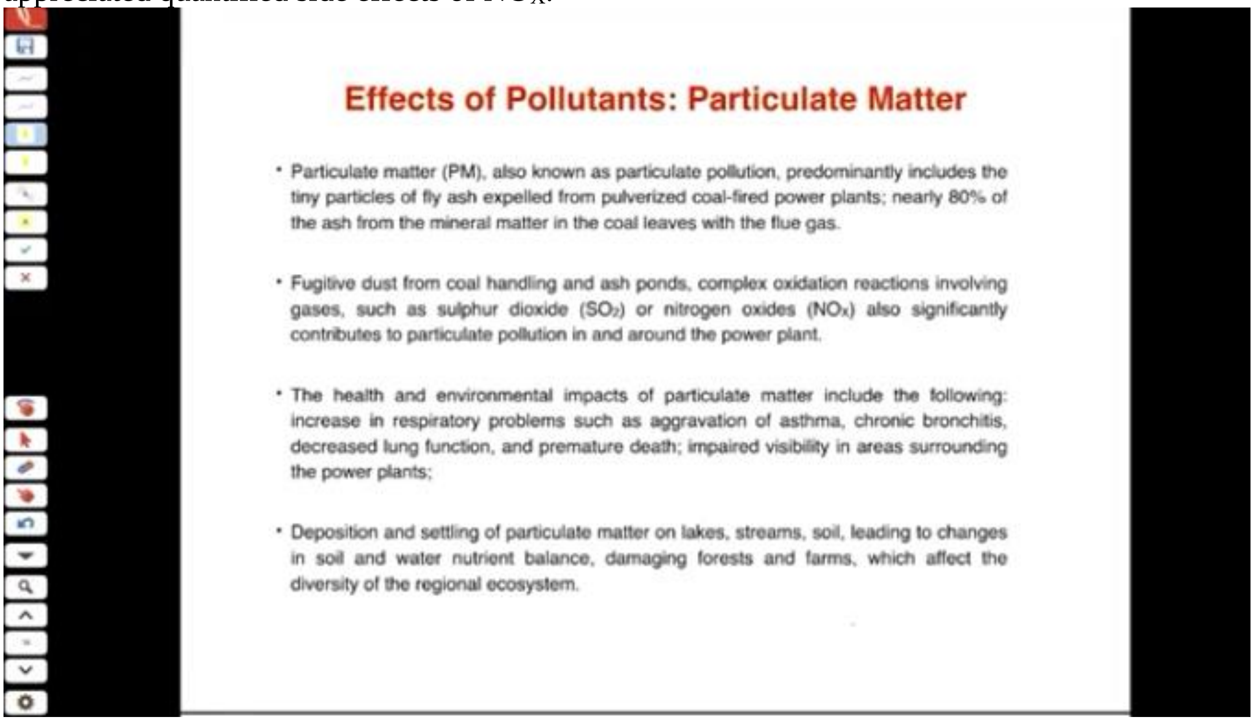
Another major pollutant that comes from coal and also oil and even from the use of natural gas, which is relatively cleaner fuel among the three coal, diesel and – coil, oil and natural gas. Natural gas is the cleanest, but even with natural gas you have NO_X problem, from an environmentally pollution point of view, NO_X includes the three nitrogen oxides, NO, NO_2 and N_2O these are together called NO_X. These gases are produced during combustion and reach the atmosphere in this form as NO, NO_2, and then N_2O, and then they go through transformations. Of these NO, and NO_2 are toxic, both are short-lived with a lifetime of about four days, and NO is less toxic and causes eye and throat irritation, in terms of immediate impact, Nitrogen dioxide is highly toxic, and can cause acute lung injury even in short doses. High outdoor concentration can lead to respiratory, cardiovascular problems and mortality.

N_2O is not toxic, it is not a toxic gas, but it is a greenhouse gas, with a global warming potential of 270, and it has an atmospheric lifetime of 100 to 200 years. So, if we are producing too much of N_2O from various uses of fossil fuels, whether it is for transport application or electricity generation or heat production, heat generation in industrial processes and so on. There can be production of N_2O which can be, can have a big impact in terms of greenhouse gas emissions, more about that shortly.

NO_X emissions contribute to many environmental problems like photochemical smog, acid rain, tropospheric ozone, ozone depletion and stratosphere, greenhouse effect, okay, acidification of local bodies and eutrophication indicated by algal blooms and oxygen deficiency of water bodies and even soil.

Short-term effects on humans includes sore throat and phlegm, acute lower respiratory illness is possible on short-term exposure to NO_X concentration of 150 micrograms per meter cubed.

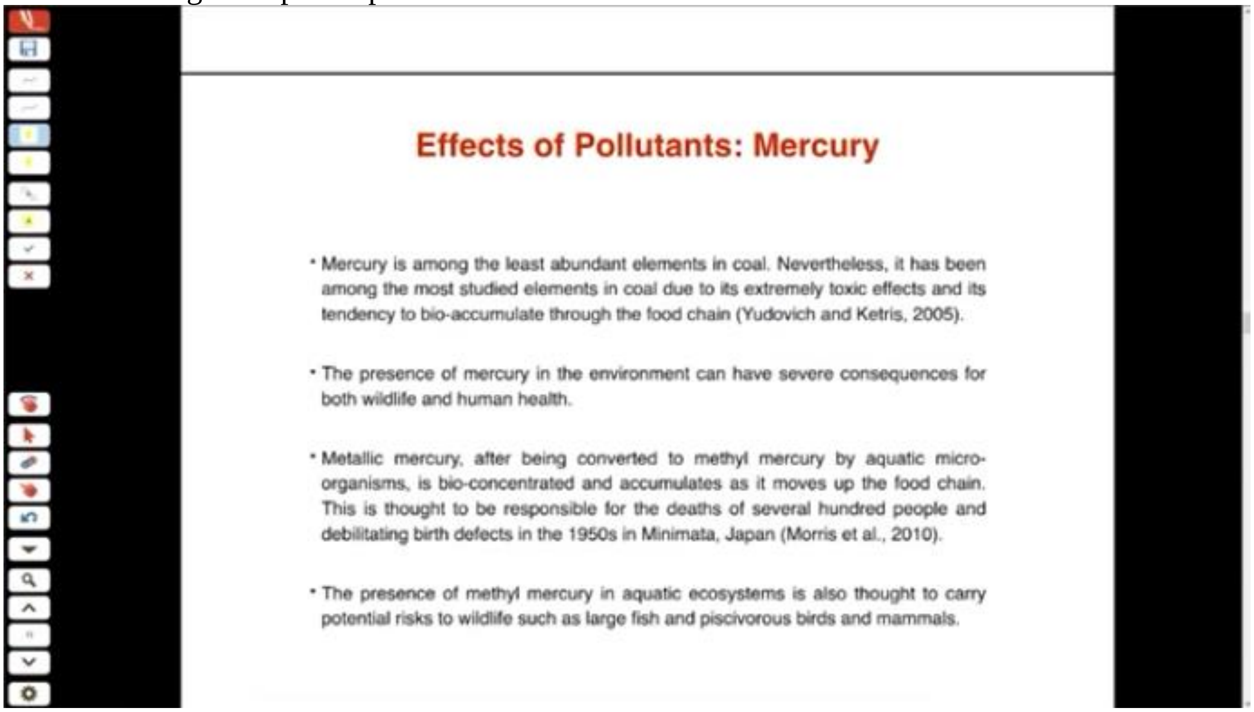
Health effects in terms of pulmonary illnesses are also produced from exposure to ozone produced from NO_2, Phytotoxicity of ozone leads to reduced agricultural output. So, NO_X has a number of bad effects all the way from immediate effect on the humans, and also long-term effect in terms of greenhouse gases, and in terms of ozone depletion, in terms of acid rain and also in terms of decreased agriculture output. So, these are all some of the known and appreciated quantified side effects of NO_X.



We have also said particulate matter, this especially in coal combustion results from the mineral matter that is present, that is dug up along with coal and it can vary anything between 5% and 50% and especially in the Indian coal sites of the order of closer to 30 to 50%. So, that means that half the coal that is burnt will come out in the form of ash, either as a bottom ash or a fly ash. And fly ash where the particles are coming in extremely small sizes from fraction of micron to 10 microns or maybe higher. This is what we call us particulate matter pollution, it is also known as particulate pollution, predominantly includes tiny particles of fly ash expelled from pulverized coal fire plants, nearly 80% of the ash from mineral matter in the coal leaves with the flue gas.

Fugitive dust from coal handling and ash ponds, complex oxidation reactions involving gases, such as sulphur dioxide and nitrogen oxides also significantly contribute to particulate pollution in and around the power plant. So, the SO_2 and NO_X that are produced can also be converted into condensate matter, and they may come out in the form of particulate pollution. The health and environmental impacts of particulate matter the following, increase in respiratory problems such as aggravation of asthma, chronic bronchitis, decreased lung function, and premature death, impaired visibility in areas surrounding power plants.

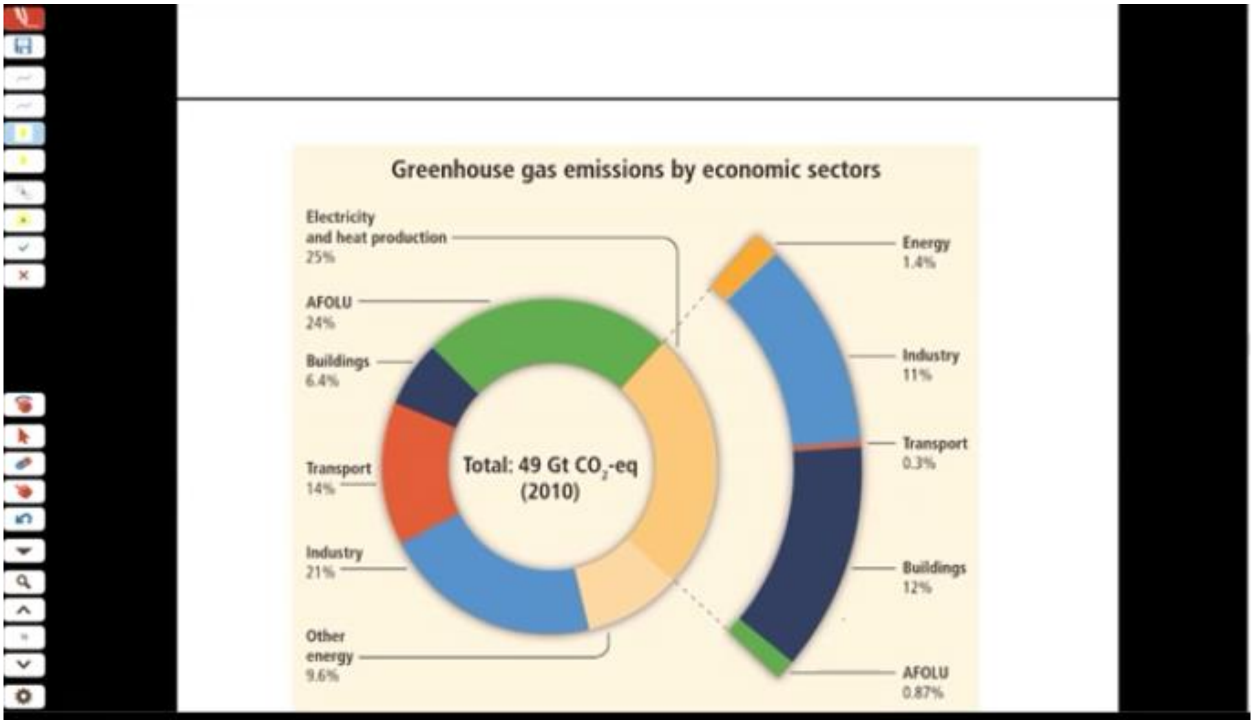
Deposition and settling of particulate matter on lakes, streams, soil leading to changes in soil and water nutrient balance, damaging forests and farms, which affect the diversity of the regional ecosystem. So, you name is whatever bad effects that we see are caused by this kind of pollutants that are coming from power plants.



We also have something that is not been regulated in many countries, which is the mercury emissions from coal power plants. Mercury is among the least abundant elements in coal, it occurs in trace quantities, ppm level, but it is among the most studied elements in coal due to its extremely toxic effects and its tendency to bio-accumulate through the food chain. So although it is in small quantities, its released in small quantities, it it can accumulate through the bio-route and then it can cause us harm.

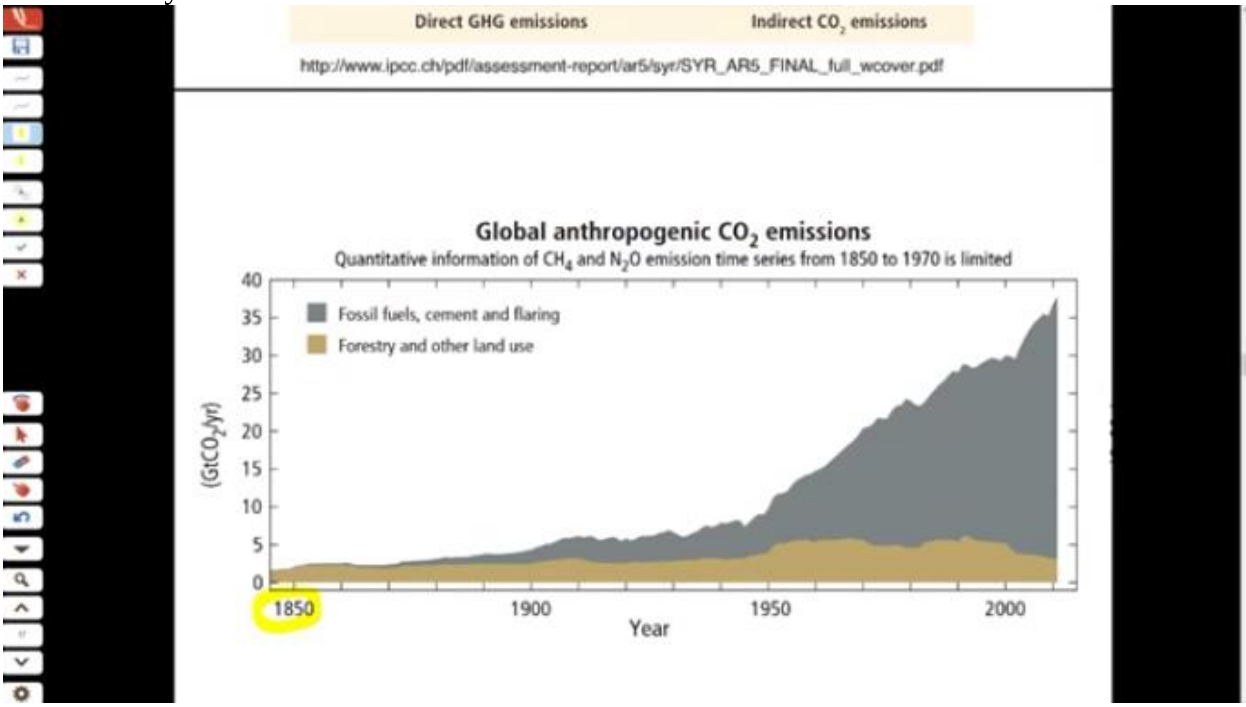
The presence of mercury in the environment can have severe consequences for both wildlife and human health. Metallic mercury after being converted to methylmercury by aquatic micro-organisms is bio-concentrated and accumulates as it moves up the food chain, this is thought to be responsible for the deaths of several hundred people and debilitating birth defects in the 1950's in Japan.

The presence of methylmercury in aquatic ecosystems is also thought to carry potential risk to wildlife such as large fish and piscivorous birds and mammals. So, again mercury is coming under increasing scrutiny of the legislatures and some countries have total limit on how much mercury can be emitted in the flue gases, but in many other countries it is not there, partly because pollution deduction technologies for mercury have not been so widely established on a plant scale, power plant scale.



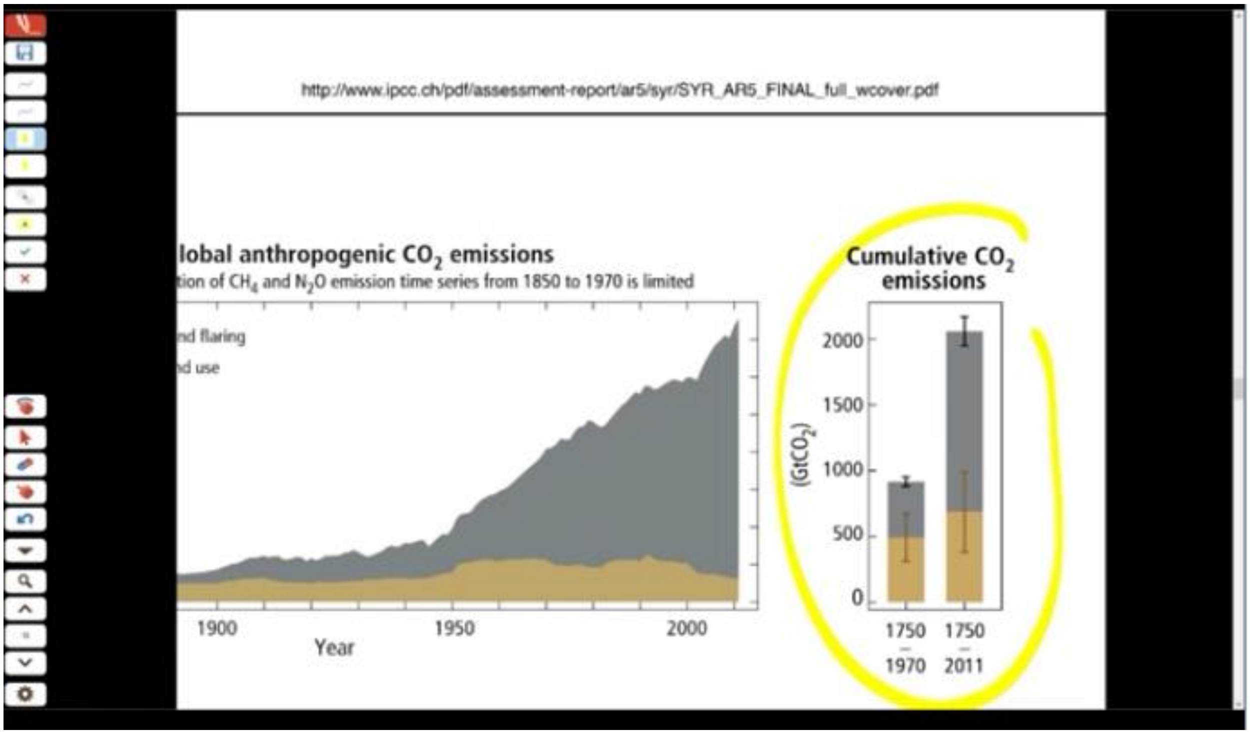
So, when we look at fossil fuel combustion, they generate a lot of pollutants which have immediate consequences both in terms of time and also in terms of the zonal dependence. If you have a power plant in Delhi then people of Delhi are going to suffer, maybe surrounding states and villages and towns, but there is also another aspect of fossil fuels combustion which results in a global problem, which is emission of carbon dioxide and other greenhouse gases. And carbon dioxide is a global problem because its concentration currently is very low despite what people are claiming, it is very low, but only as far as direct impact on human health is concerned, we are not affected by the small fractions of percentage of carbon dioxide concentration, but in terms of other effects that it has in terms of especially the global warming point of view it is a major concern for us. And it is seen us a challenging problem associated with energy, there is been a concerted effort over the past 50 years on understanding the carbon dioxide causes and then greenhouse gas emissions, and a number of studies have been made. And so because of this carbon dioxide emissions has become one of the primary problems associated with fossil fuel combustion, and energy generation.

If you look at the 2010 global emissions of carbon dioxide we have released all over the world. In 2010, so that is about eight years ago, 49 gigatons of carbon dioxide equivalent, so that includes methane and whatever other N_2O, all these gases together in terms of the carbon dioxide equivalent in terms of greenhouse gas contribution is 49 gigatons. And if you look at where this is coming from, every aspect of the human societal sector has a contribution, transport has 14% of this emission, buildings; so all the heating and cooling, and other domestic use of energy, electricity and heat generation for industrial things contributes about one-quarter of this. Industry which is essential for our current human society, the advanced stage of human society contributes 21%, so and out of this electricity and heat production you can see that industry consumes 11%, people buildings consume 12%, and so in that sense, these are also essential parts of our thing. So, that is the very life of our society is full of carbon dioxide emissions and it it is present in almost every sphere of human activity. So, to cut down on carbon dioxide becomes very difficult for us.

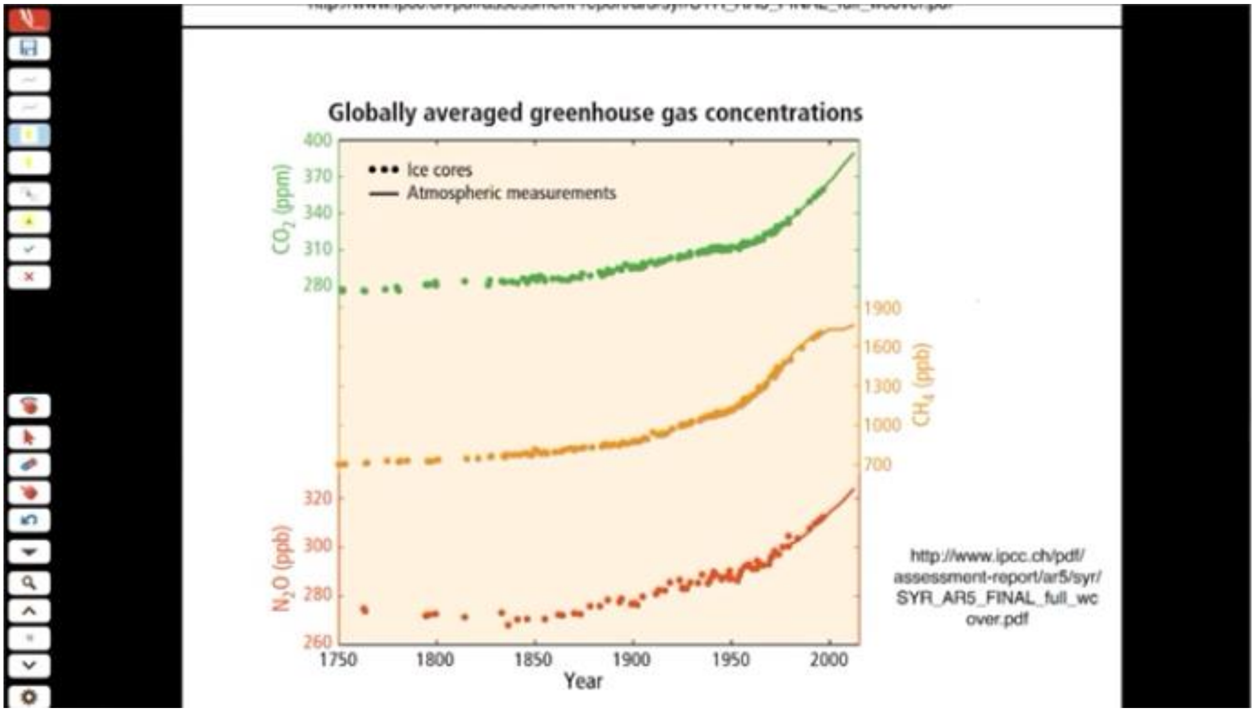


But we have to cut, that is because if you look at the carbon dioxide emissions, global emissions all the way from 1850, so that is about 150 years ago, 170 years ago to what it is currently, we have here a distinction between carbon dioxide emissions, global anthropogenic carbon dioxide emissions, carbon dioxide emissions resulting from human activities and you have CO_2 emissions from fossil fuels, cement and flaring. Flaring is that you have, in the oil production and gas production you may have some excess gas which cannot be done with, and then you burn it, so that continues to burn as long as oil is drawn from that those wells.

And cement generations, cement productions, steel production all these activities generate a significant amount of carbon dioxide. So, for this kind of activities which are, which can be associated directly with our human society and human industry oriented towards humans, we can see that over the past century 1850 to 1950 there is been a small contribution of it in terms of gigatons of carbon dioxide per year, a very slow increase. But over the last 50 to 70 years there is been a rapid increase in this, and you can see compared to what we have been emitting in 1850 to what we have been emitting in the year of 2010, there is been a huge increase in terms of carbon dioxide emissions coming directly from this modern industrialized lifestyle of humans. Whereas forestry and other land use have contributed relatively, okay, there is a small increase, but it is not that much, okay. So, it is this part associated with the industrialized society of the current human lifestyle which is causing a lot of concern.

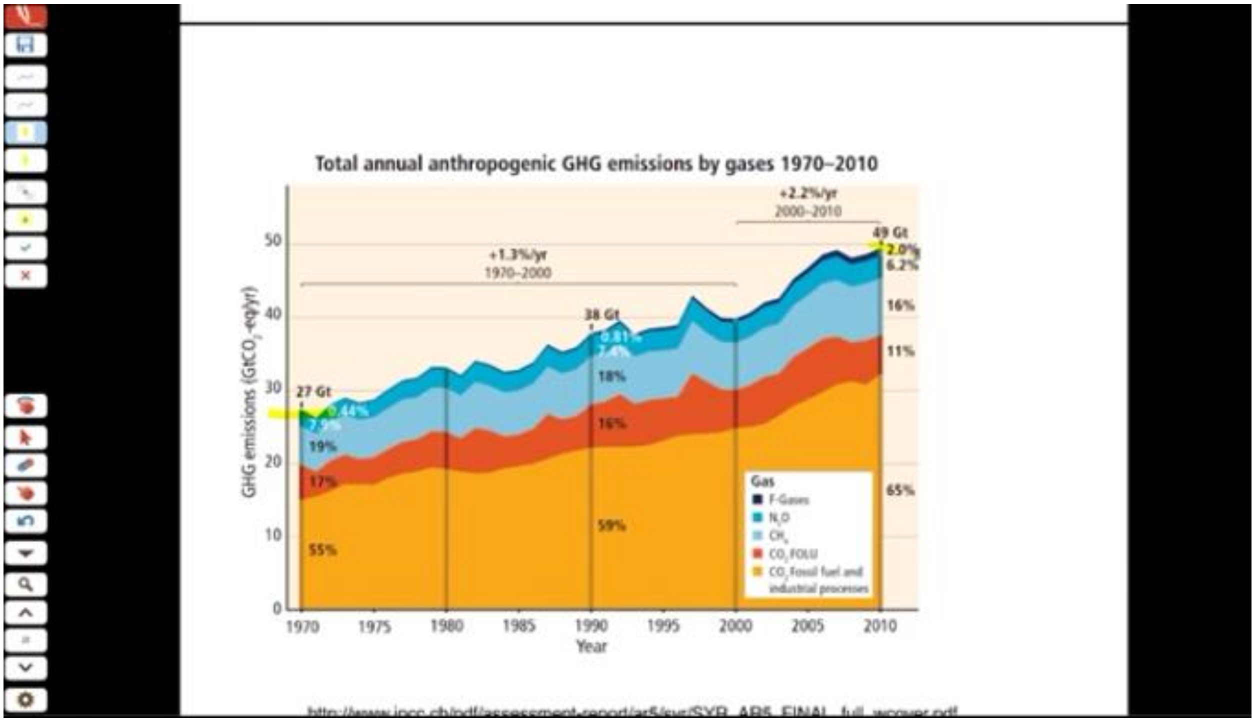


When you look at it in a different way here, in this graph, you have cumulative carbon dioxide emissions, the total amount of emissions of carbon dioxide and here we have, in the period between 1750 to 1970; 220 years. In this, we have had about 500 gigatons of carbon dioxide total emitted from forest and land use that is the pre-industrialized way of human life, and about less than that maybe about for another 400 gigatons from energy use from this, whereas between 1750 and 2011, so that is over this 40 years here. We see that there is a large amount of carbon dioxide emission that can be attributed to the modern industrialized energy-intensive process that we have in our current life. And you can see that the total cumulative CO_2 emissions has gone beyond 2000 gigatons of carbon dioxide, okay.

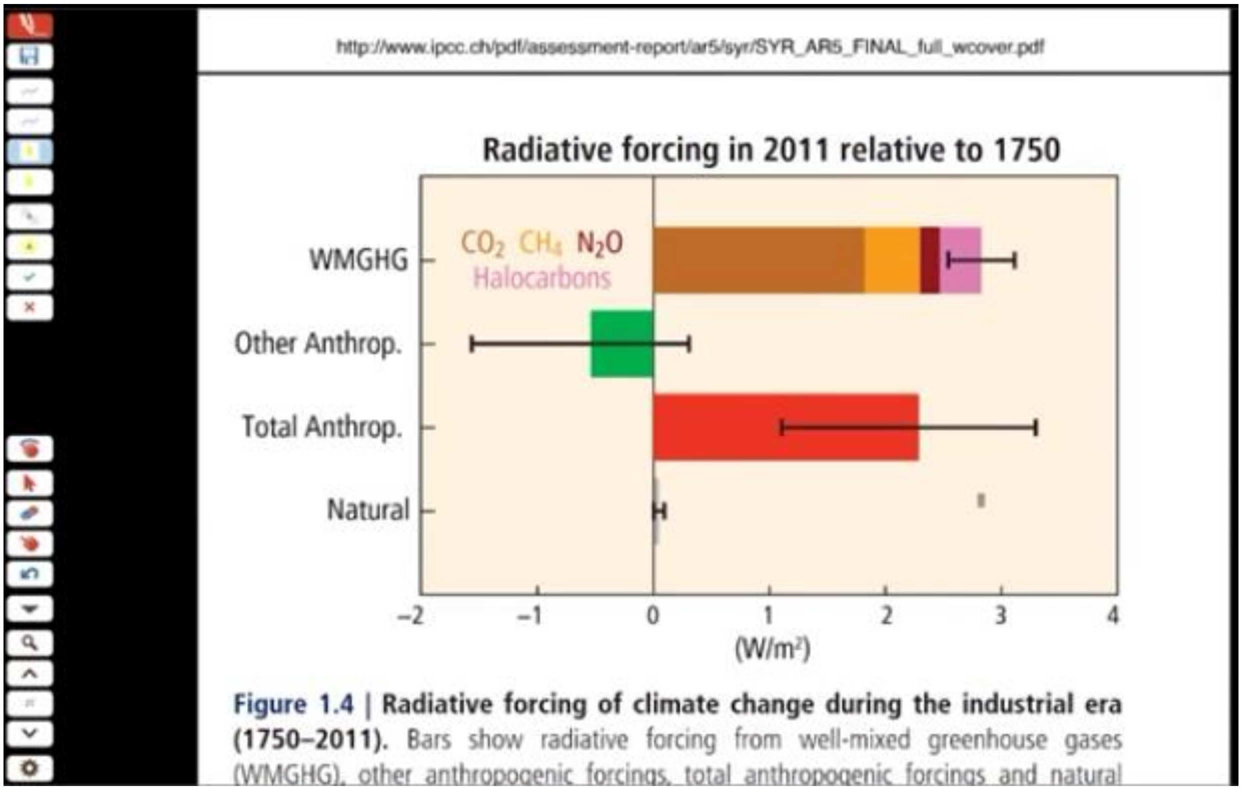


So, over the last 50 years, 60 years we have been emitting carbon dioxide at an accelerated pace. This has had an effect on the carbon dioxide concentration and other GHG gas concentrations, in the atmosphere. And here you see three of them, carbon dioxide in terms of ppm in green here, methane which is not produced by combustion, but it may be produced by other activities related to humans, and it is also produced naturally by number of causes. And also N_2O which is in ppb and CH_4 is also in ppb, so it means that it is one-thousandth of the concentration of this in terms of raw numbers. So, this is, for example, carbon dioxide is between 200 and 400, and N_2O is between 260 and 300, so in terms of numbers CO_2 is thousand times more than N_2O, but the global warming potential, the harm that N_2O does with respect to relative to carbon dioxide in the atmosphere is, we have seen is about 270. So, that means that these numbers are almost comparable, so if we divide the N_2O concentration by four, then we get the CO_2 equivalent of N_2O from that point of view these numbers are not very small.

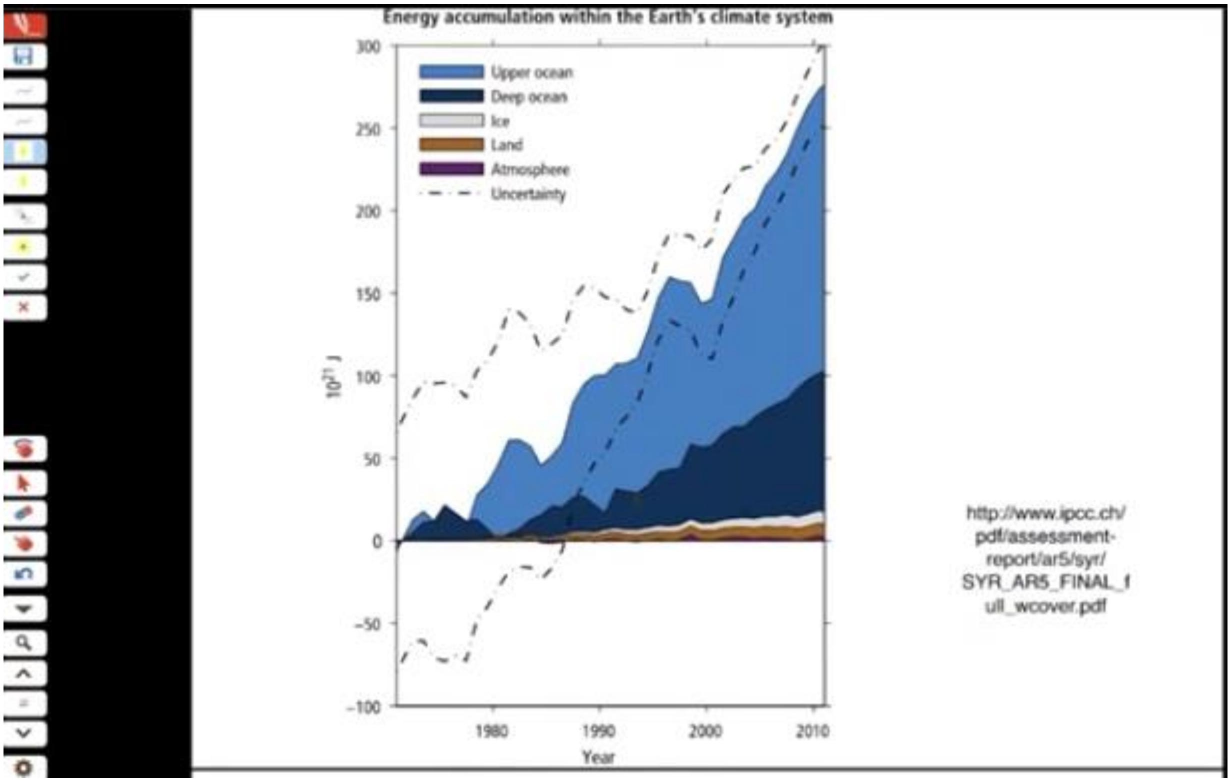
And similarly, methane also has a very large global warming potential and so these are these are not insignificant contributors to the global warming, but what we see here is that carbon dioxide concentration has been steady, but of late it has been increasing rapidly. And if you go back to a millennium, that is going back to 1000 AD, 500 AD then the concentration from various proxy evidence, okay, at those times we did not have direct measurement of carbon dioxide and all that, but there is a lot of proxy evidence which shows that over the past 1000 years it is been before the pre-industrialized days it has been pretty constant. All the three have been pretty constant in the atmosphere, but of late they have been increasing at accelerated pace, and we can see N_2O increasing and carbon dioxide increasing, but not so much as methane because these two have produced in the energy generation process, combustion produces very little of methane. So, to that extent, although there is some increase here, it is not as much as it is in the case of carbon dioxide.



And you can also see from 1970 to 2010 so over the past 40 years, carbon dioxide equivalent emissions of greenhouse gases per year at, in 1970 they are about 27, and 2010 they are 49. So, again there is a total gradual increase, steady increase and of this carbon dioxide from fossil fuel and industrial processes is given in orange color and this is also been increasing steadily. And then methane and N_2O are also increasing, have also been increasing and carbon dioxide from fossil fuel and industrial processes which are directly related to the energy generation and energy consumption account for two-thirds of the total CO_2 produced. So, this is a major problem for us.

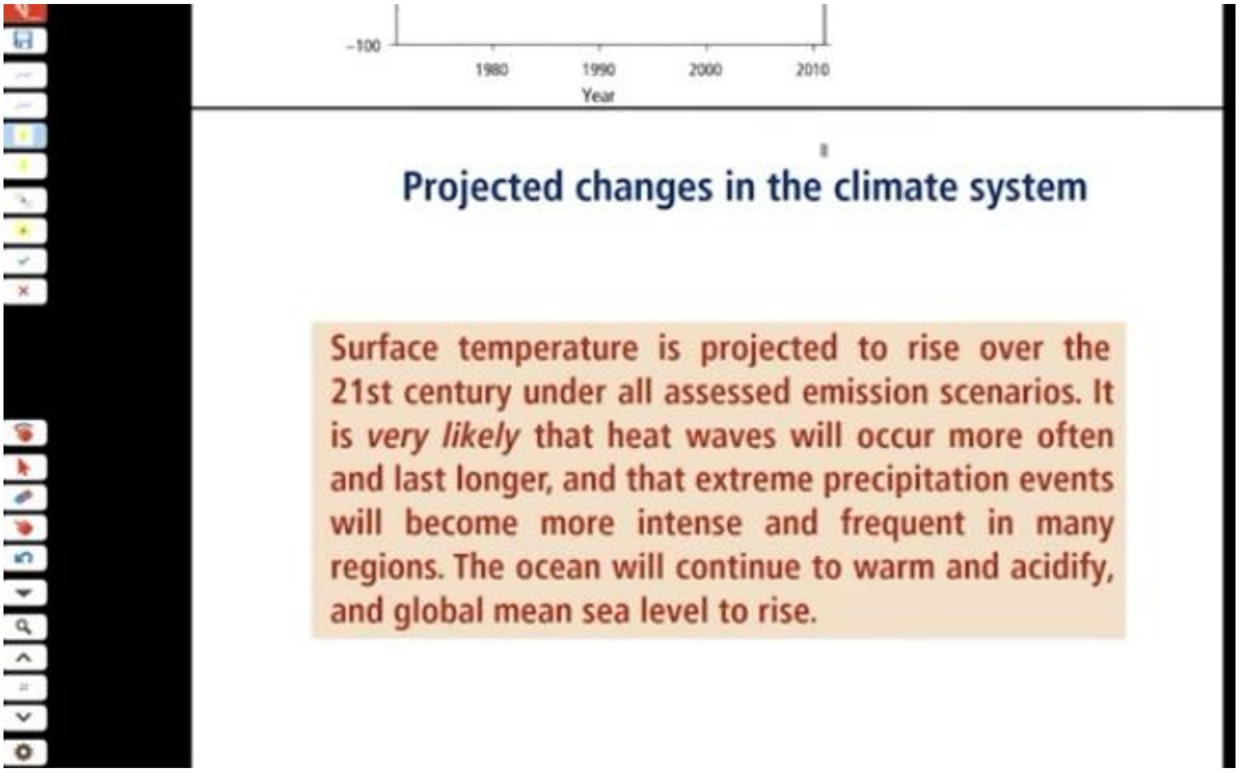


And this is expressed in what is known us the radiative forcing, the amount of heat that has been retained in the atmosphere compared to 1750, the amount of additional heat that has been retained in the atmosphere and it is given in terms of watt per meter square. And it is small in number like 1, 2, 3 watts per meter square compared to about 200 to 300 is what we get from the solar and energy is about 100 times this. But in terms of its impact on the atmospheric temperature and so on, and also on the climate it can be devastating as we will see. And you can see that well mixed, WM stands for well-mixed greenhouse gases, these are gases which have a long lifetime in the atmosphere, and so that they get very well mixed in the atmosphere up to height of maybe 100 kilometers, and so their concentration is more or less the same globally. It is not that if you have power plant here, immediately there is a carbon dioxide concentration going all the way up to the end of the atmosphere, these are well mixed within this 10 to 100 kilometer range of this atmosphere and you can see that these gases have contributed a net of about 2.5 watt per meter square. And other anthropogenic things have contributed a negative value of about 0.5, and this other thing can be a number of other processes like increased or differential land use and then crops, road laying, and whatever else that you can think of. All these things have usually some effect on the solar energy budget, and those kind of activities have actually resulted in this., so that you have a total anthropogenic radiative forcing of about 2.2 watts per meter square, as of 2011. And there is also a lot of, the uncertainty in these estimates is actually given by these numbers, you can see that uncertainty is large, but still, there is a net positive anthropogenic radiative forcing.



And you can see that the radiative forcing associated with natural causes is a minuscule percentage, if we did not have this anthropogenic causes then because of this natural causes there can be minute changes in the carbon dioxide and other gases concentration, but because of these natural actions, because of the human lifestyle related actions we have increased radiative force, these are all estimates, but these have been in the making for the past 50, 60 years in various activities, and scientific activities and we can see the consequent effect on the energy accumulation within earth's climate system, in terms of joules on the Y axis and over the past 40 years, from 1970 to 2010.

And here we have the amount of heat that has been contained in the upper ocean, deep ocean, ice, land, atmosphere are the five elements that five different sectors that have been identified. We can see that as of 2010, you have a large amount, more than half of this has been retained in the upper ocean, so that means that the temperature of the seas has increased slightly, and ice which results in the melting of the ice is a small quantity, but you can see that it is been widening, increasing, and that will lead to melting of the ice. And then the deep ocean there will be currents and transfer of heat from the upper to the lower oceans that has also been rising gradually. And then you can see the atmosphere is this much, it is a very small quantity, but it takes relatively small quantity of heat to increase the temperature of air. So, that is why the temperature is caused by the atmospheric accumulation here is as significant in terms of heat as it is in terms of upper ocean.



So, this is a major concern for this, and the projected changes in the climate system are that surface temperatures it projected to rise over the 21st century under all assessed emissions scenarios. This is from IPCC on climate change panel, international panel and it is their assessment, the latest assessment, it says that surface temperature is projected to rise over the 21st century under all assessed emission scenarios. It is very likely that heat waves will occur more often and last longer, and that extreme precipitation events will become more intense and frequent in many regions. The ocean will continue to warm and acidify, and global means of sea level to rise.

So, this is a major global concern of increased energy use from various sectors. So, and these are the short-term effects associated with fossil fuel combustion and the long-term effect in terms of global warming are the major threats to increased energy use, but also there are other consequences on biological systems, water bodies, and so on that are associated with energy use. And some of these are expressed, explained in other modules. So, in the next lecture, we are going to look at what kind of solution, therefore, we have to finding equilibrium between energy and environment, is what we will see in the next lecture.

Thank you.