INDIAN INSTITUTE OF TECHNOLOGY MADRAS

NPTEL
NPTEL ONLINE CERTIFICATION COURSES

ECOLOGY AND ENVIRONMENT

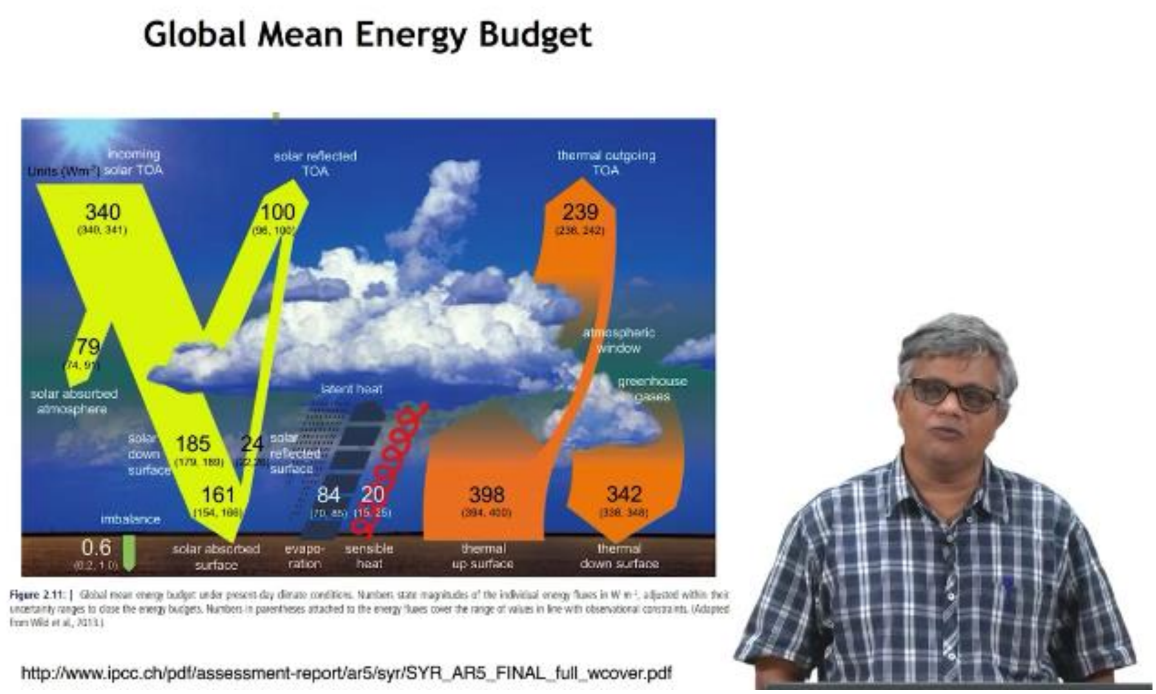
Module on

Energy & Environment

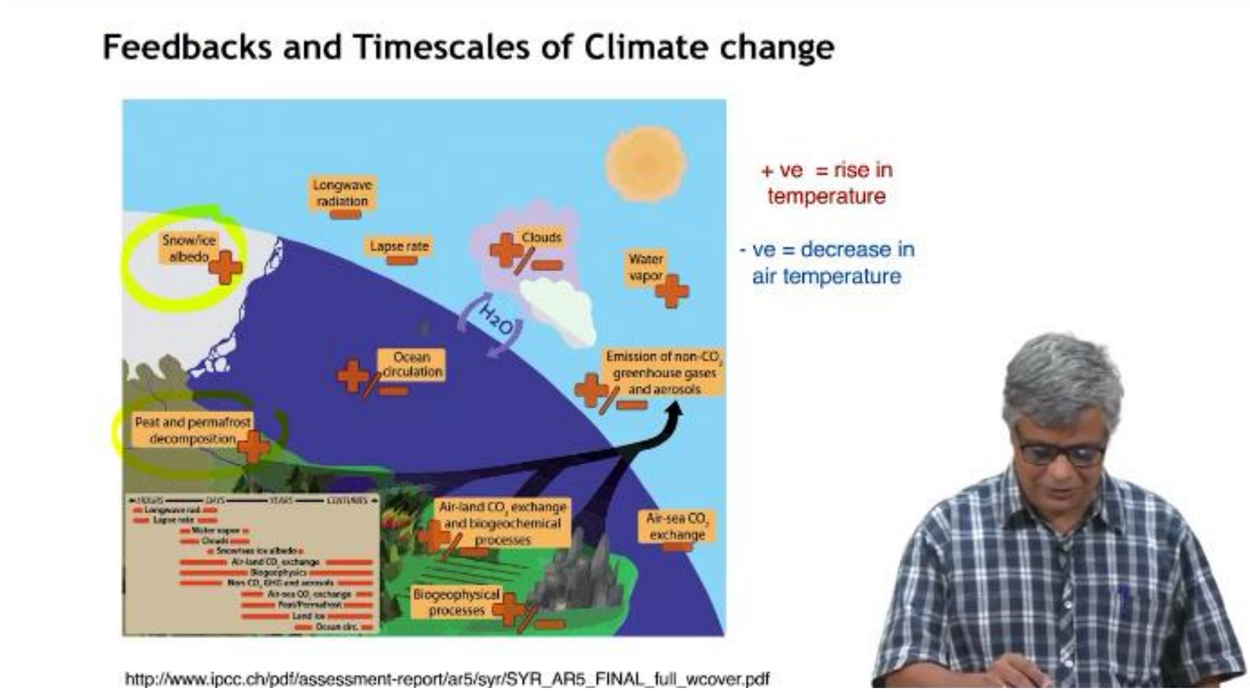
Prof. Sreenivas Jayanthi

Department of Chemical Engineering
IIT Madras
Email:- sjayanthi@iitm.ac.in

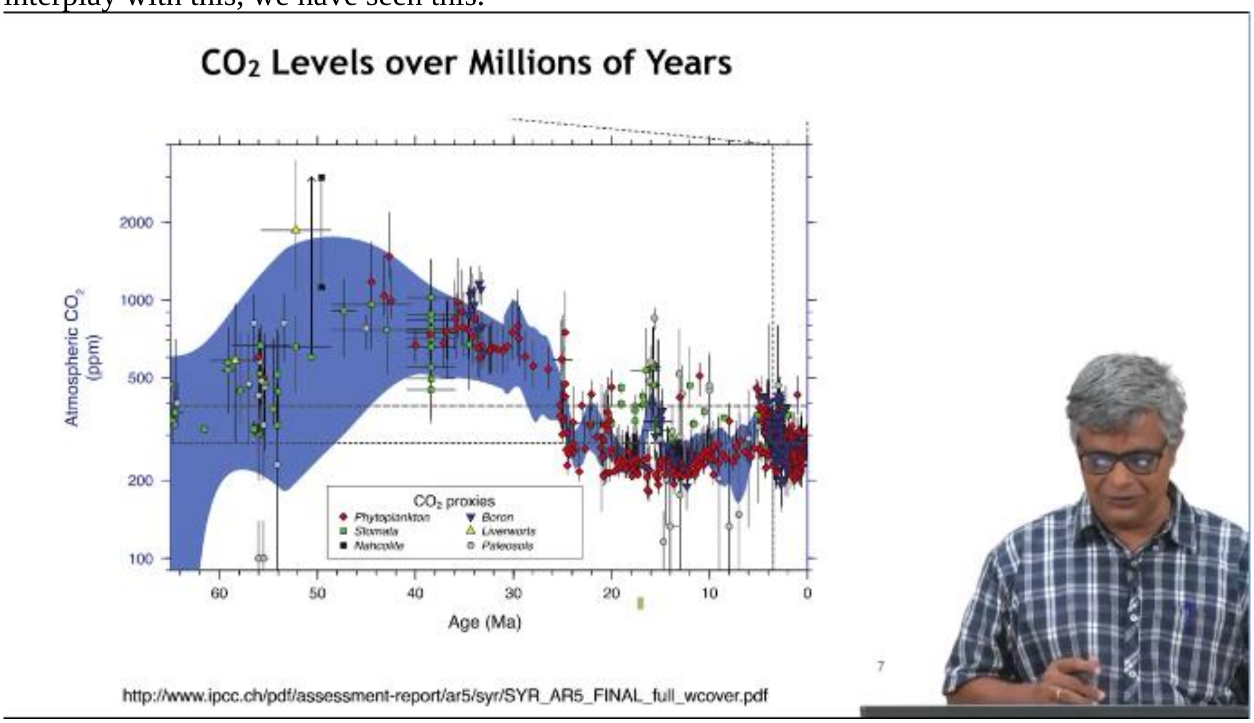
Okay, welcome to lecture number 5, on the module on Energy and Environment in the course Ecology and Environment. In the last lecture, we have looked at the global warming problem coming from an increasing amount of carbon dioxide emissions by a number of natural causes but also by anthropogenic factors.



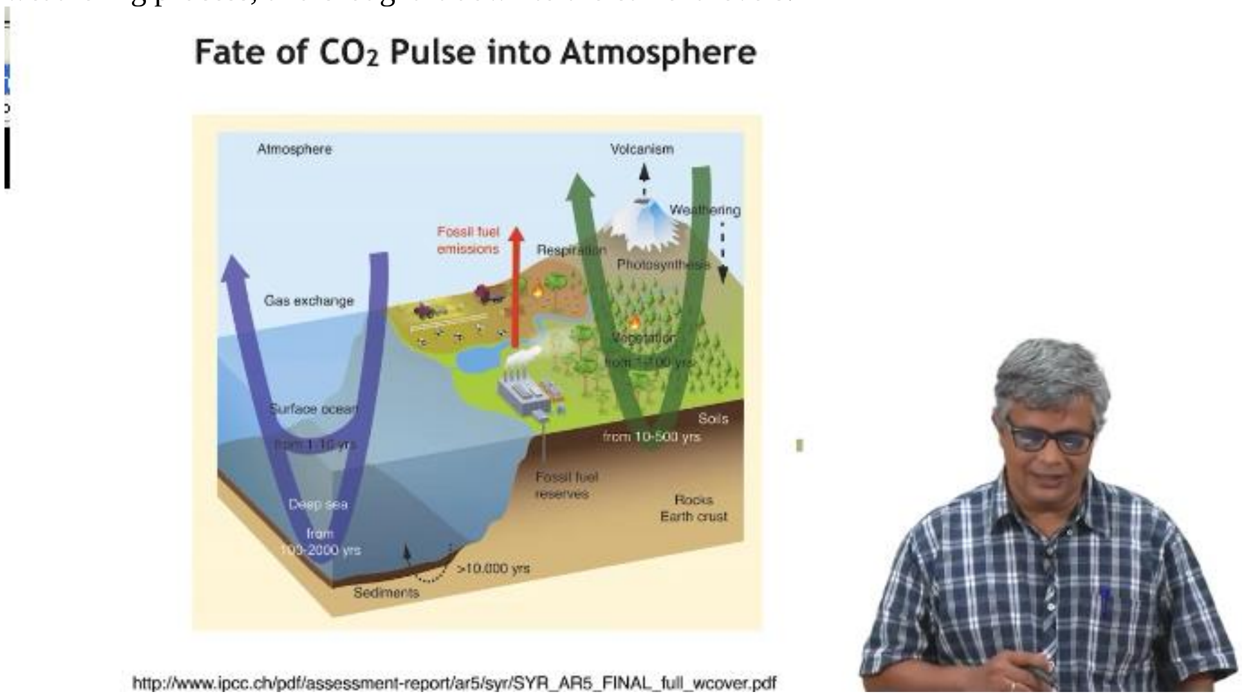
We saw the Global Mean Energy Budget in terms of how much energy is being received from the sun to earth and in what ways it is been modulated by the clouds, by the aerosols, by the atmosphere, by the surface, by the ice on the surface, water on the surface and all the other albedo factors that contribute to its modulation. And also how the energy emitted by the earth surface is being retained in the atmosphere by clouds and composition of the earth, some of the constituents of the atmosphere, and a number of factors which have a role in this in terms of the snow and ice that we have seen, that I mentioned here.



And then peat and permafrost ocean and clouds amount of water vapor and CO_2 gases and all these factors have a certain influence on the way the carbon dioxide and other greenhouse gases interplay with this, we have seen this.

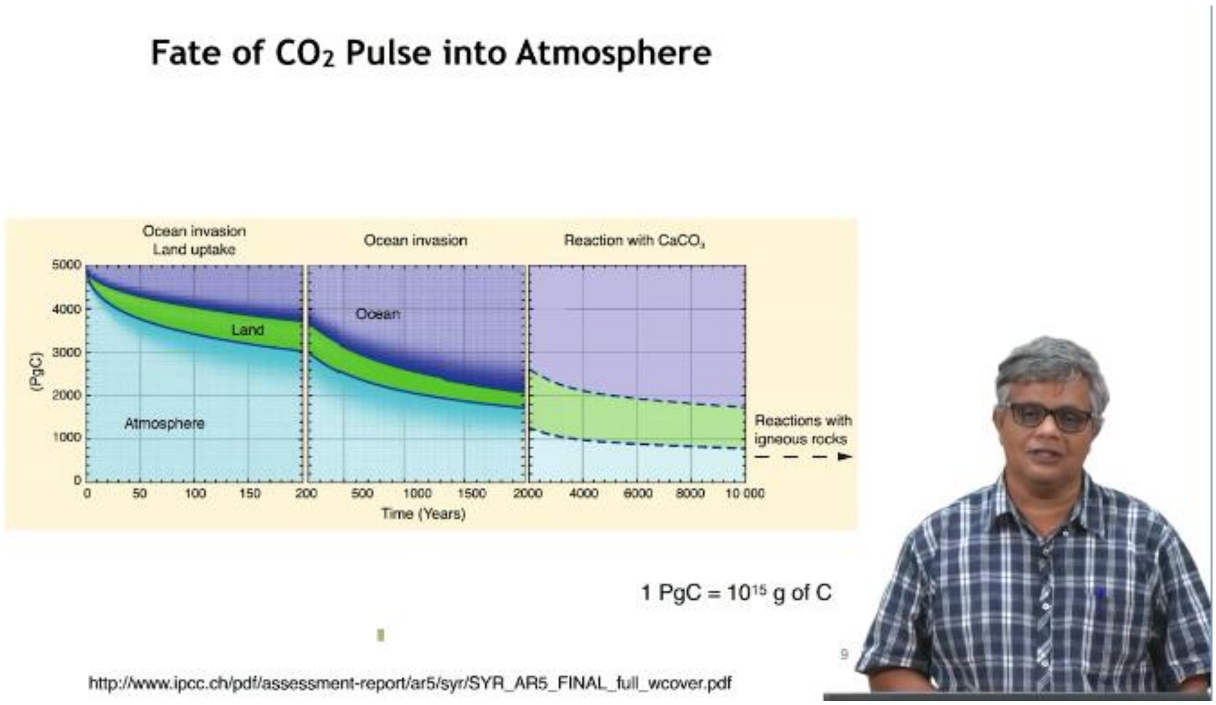


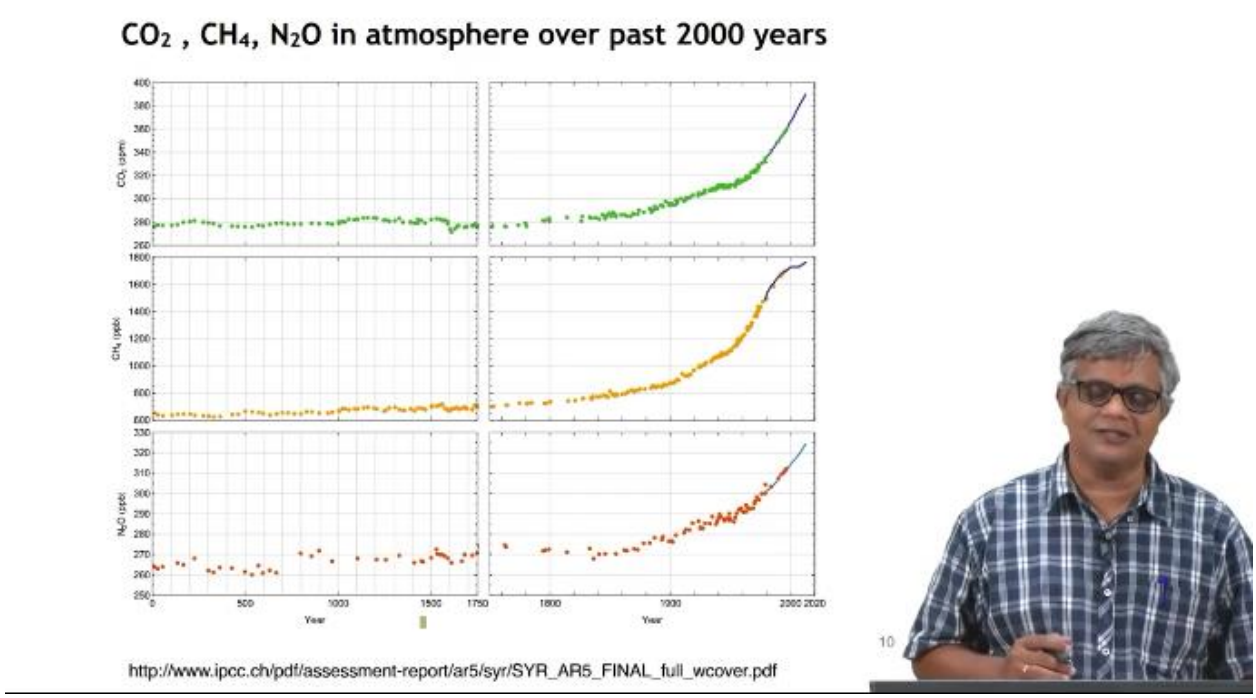
And how we have seen over the past 60 million years, how the carbon dioxide concentration in the atmosphere has been changing, and about 60 million years ago it was much higher than what it is between 500 and 1000 ppm. And how with the collusion of the Indian subcontinent with the rest of the Asia and leading to a large amount of subsurface solids being brought up in the form of Himalayan mountains has led to a gradual decrease in the carbon dioxide through the natural weathering process, and brought it down to the current levels.



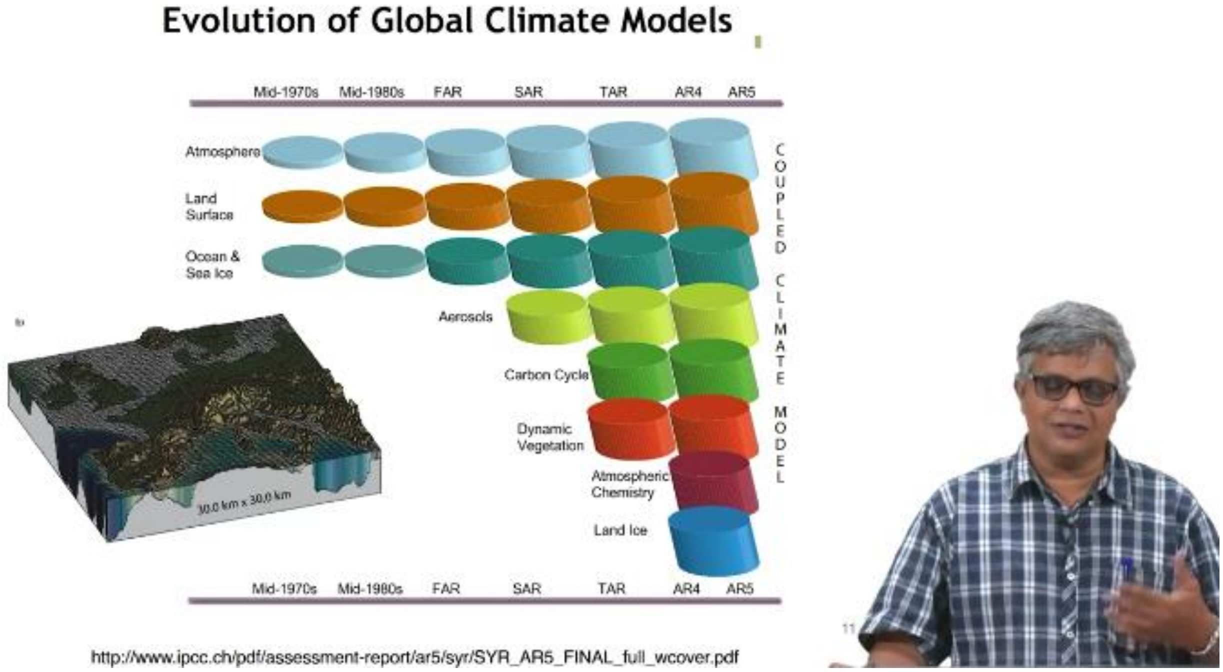
And how this has been changing in the recent past as a result of number of factors, again in terms of gas exchange between atmosphere and the ocean and between atmosphere and the vegetation here, and the exchange between the ocean and the earth's crust and between the vegetation and the biomass and the earth's crust and the recycling processes in terms of example volcanic emissions leading to a fresh influx of rock from the earth's crust, and also direct emissions of carbon dioxide.

And recirculation from the deep ocean to the ocean, upper ocean and then all these things, including fossil fuels from human activities, carbon dioxide emissions from human activities, range of activities, and we also take a note of the longevity of carbon dioxide in the atmosphere, if we release a pulse of carbon dioxide into the atmosphere today, it is going to last for a long time, 100's of years, and gradually, gradually it would be evacuated from the atmosphere by natural processes.

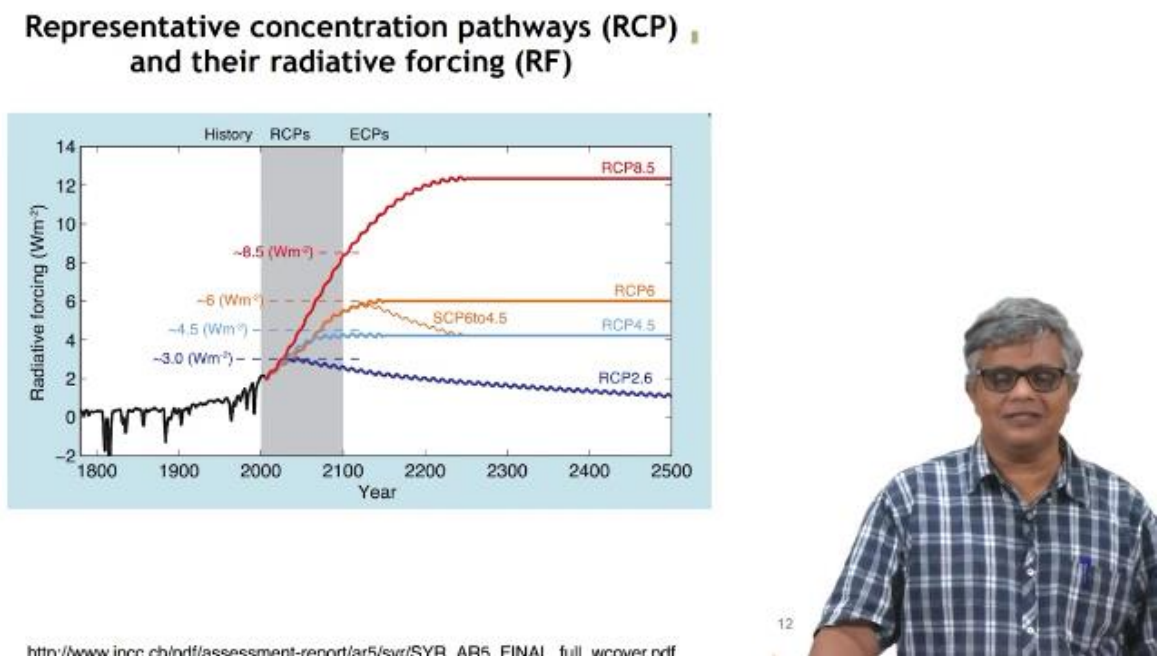




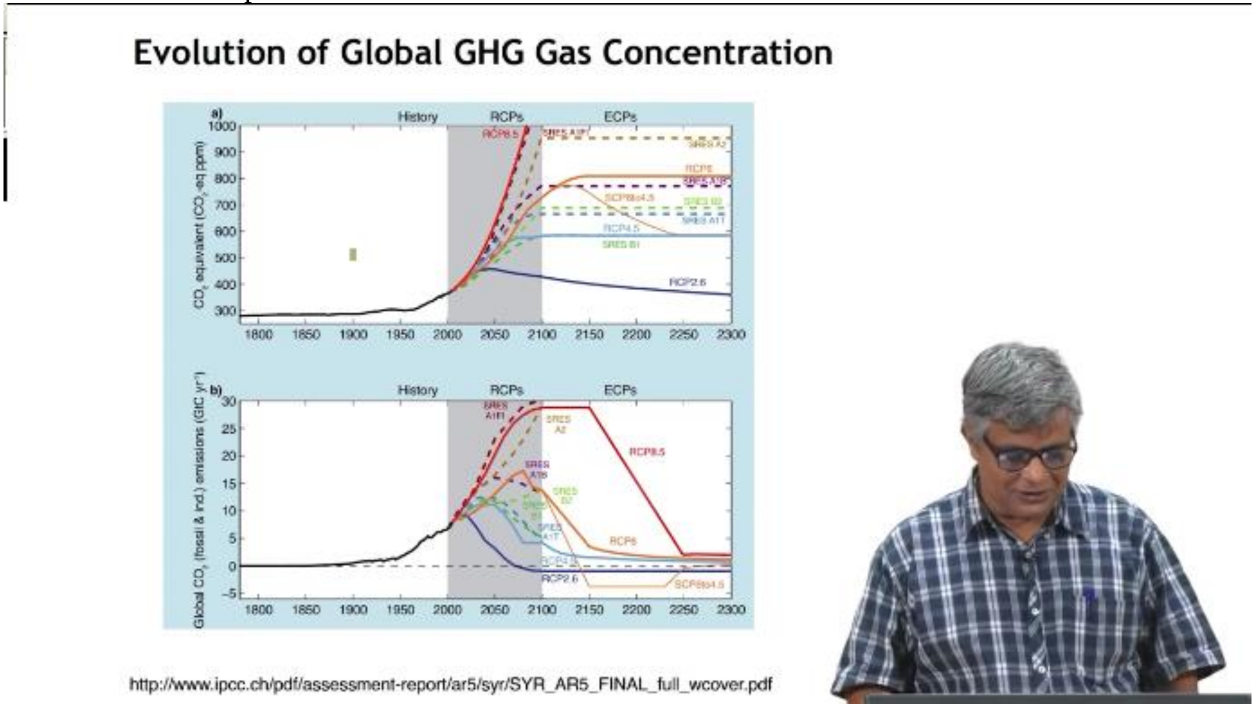
We have also seen that off late that is over the past 1000 years we have seen a quite a stable atmosphere in terms of concentrations of carbon dioxide and methane and nitric oxide, but in the recent 50 to 100 years there is been a tremendous increase in this, upsetting the balance that is been there for 1000 years.



And we have also seen how the inter-linking of various factors that contribute to the accumulation of carbon dioxide, the fate of carbon dioxide and the radiation budget and all these things are encapsulated in increasingly complicated global climate models.

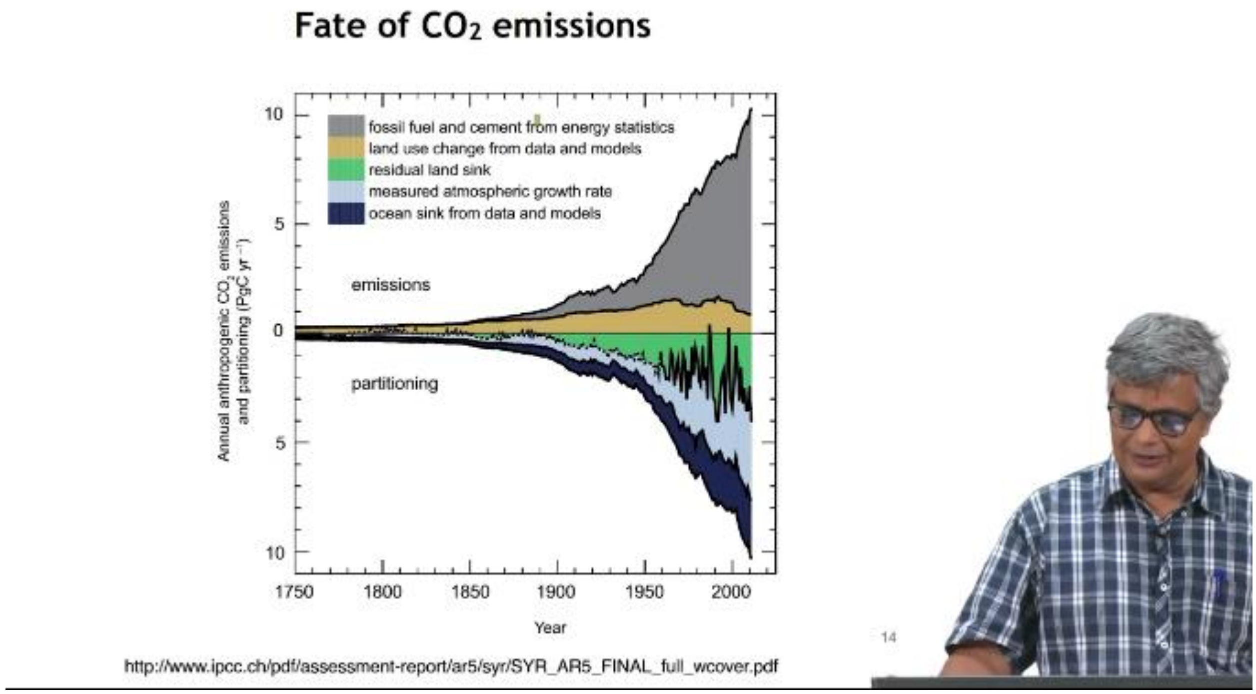


And how these have been predicting the increasing, large increasing concentration of carbon dioxide in the next few decades, leading to significant amount of positive radiative forcing, effectively the amount of heat that is retained in the atmosphere because of increase in greenhouse gas emissions and increasing usage of land in a way that would contribute to global warming. And most of these over the coming century, over this century, in fact, show that increasing amount of carbon dioxide in some cases going up to very large quantity, and having a possible radiative forcing of the order of 8.5 watt meter square. We have seen that about 2.4 watt per meter square has given rise to about 0.7 degree centigrade increase in temperature in earth's atmospheric temperature, and this is three times, four times that, so you can have quite a lot of increase in the temperature.

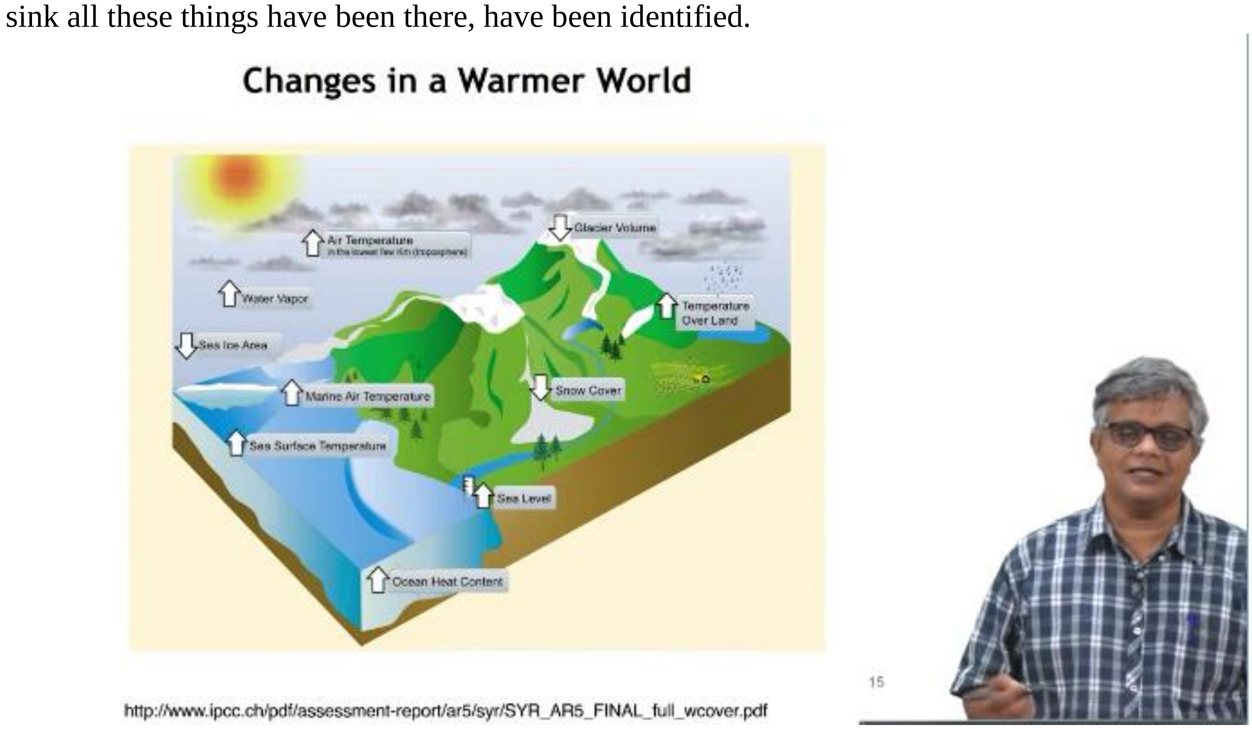


And there is also projections of carbon dioxide equivalent concentration reaching as high as 1000 ppm by 2070, if we let things be like they are and if we continue to draw increasing amount of energy needs from fossil fuel combustion which is what we have, and which will definitely last until the end of this century. And which are cheap known technology available to many people across the world, across national barriers and this fossil fuels also significantly spread all over the world.

In that sense, there is a more equitable distribution of this fossil fuels than some of the new fuels that new energy sources that we have. So, given all these factors if we go like as usual, we may end up with breaking the barrier of 1000 ppm in the not too distant future. And the rate of CO_2 emissions is also expected to go up significantly from around 8 which is what we have to maybe 3 times, 4 times that by 2050 to 2100 if we do not do anything. And something like that has a great impact on the atmospheric temperature, and there have been many projections and scenarios created whereby you can try to reduce the concentration of carbon dioxide over the immediate future which will give us only 2.6 watt per meter square of radiative forcing by 2050, 2070 like that. And then more delayed things so that we have continued increase of the rate of emission but gradually coming down in 2100 or 2150 like that. And all these scenarios have a corresponding radiative forcing and a corresponding amount of accumulation of carbon dioxide in various strata.



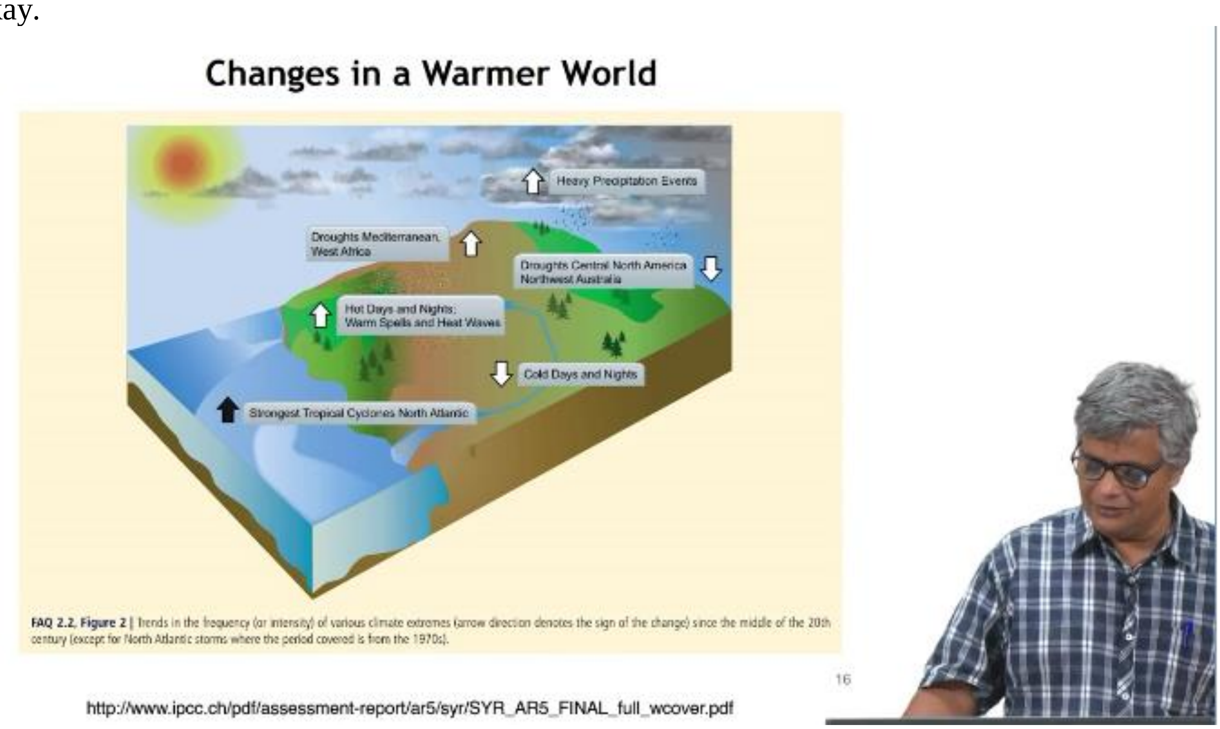
So, we have seen this particular picture right in the first lecture or the second lecture, where the partitioning of carbon dioxide into different sinks, ocean sink, and atmospheric sink and land sink all these things have been there, have been identified.



And so all these are likely to increase the temperature of the earth’s atmosphere in a significant way, maybe by 2 degrees, 3 degrees, 5 degrees like that, okay. And the carbon dioxide concentration may go up to 1000 ppm, now as we have said earlier it is not the absolute values of carbon dioxide concentration or even methane concentration or even the temperature increase that matter to us because this kind of changes we see in our everyday lives. Temperature changes a much bigger order there as a consequence of seasonal changes and climatic changes. And we have also seen an increased amount of carbon dioxide concentration, after all, it is going from 0.04 to 0.1% and something like that can happen if you are there in a close room with a number of people and listening to lecture, okay. So, this kind of things are, it seem normal to us, but when you look at the fine balance in which the current climate is ensconced, then we see that small changes of the order of few degrees in temperature can have fairly serious consequences, and what happens in a warmer world is what is shown here.

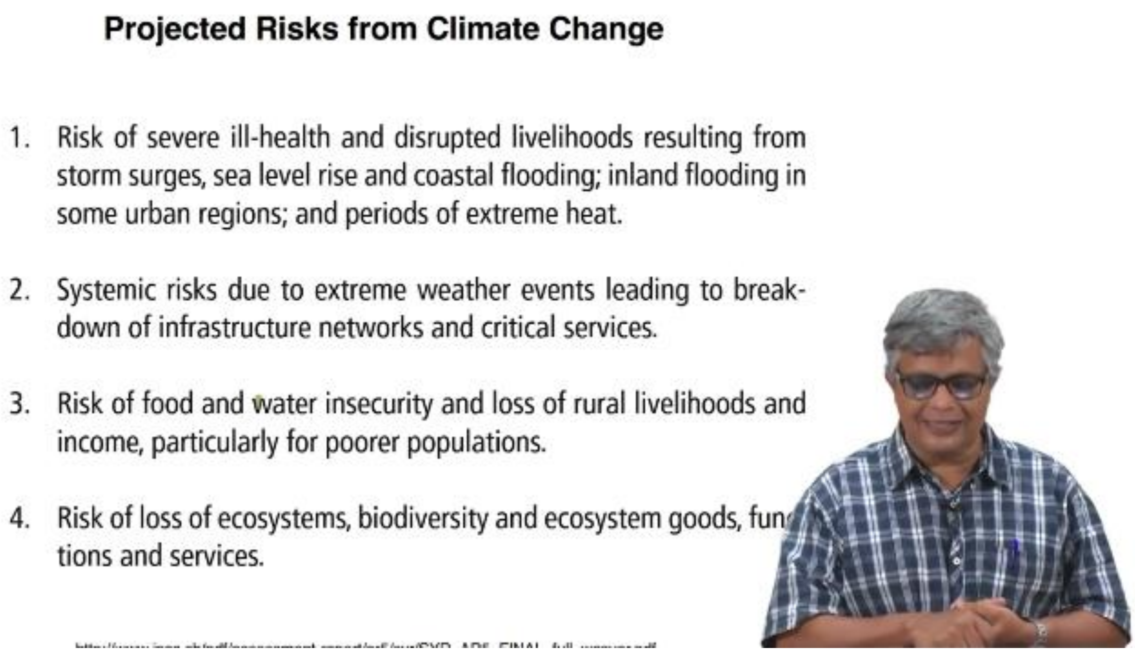
For example, glacier volume is expected to reduce, and glaciers are the major suppliers of fresh water to many populist countries like China and India. And temperature over land will increase, snow cover decreases, and this could mean threat of livelihoods of people in, for example in Europe and North America, this were who depend on for their wellbeing on the, for example, winter sport activity which depend quite a lot on the on the snowfall and all these things.

Marine air temperature is expected to increase, sea surface temperature is expected to increase, and both of this have a significant effect on the formation of cyclones and other precipitation and evaporation events which lead to, for example, the monsoons which bring in a lot of rain for us in India. And then you have sea ice area decreases and ocean heat content increases, sea-level also increases. So, these are some of the consequences, but the consequences that are also very important to us are the immediate consequences of these in terms of changes in the climate, okay.



So, we can have as a result of this rather small magnitude where changes of a few degrees temperature or in the atmospheric temperature, we can expect heavy precipitation events, so that is incessant rain, dumping of huge quantities of water in a very short time, this has this been happening, where you have a year supply of rain is done maybe in a few days' time. And then you can also have droughts in Central North America, Northwest Australia where some, while some areas have too much rains, some other areas have too little rain, you have cold nights and days decreasing, hot days and nights increasing, warm spells, heat waves, these these can be a problem, and droughts in the Mediterranean and West Africa, and the strongest tropical cyclones in North Atlantic, we have we are seeing some evidence of that. So, these are all the things that are very quick responders to small changes in the climate conditions.

We also have much slower response of the sea-level rise. Over the past century it has risen by 20 centimeters, in the next century it may go up by 50 centimeters if things continue like how they are, and these are all slow responses. But the but the effect of these cyclonic storms through increased sea-level on storm surges and then inundation and all those things can be quite dramatic. And one of the features of the modern society, human society is that most of us is concentrated along the sea coast for whatever reason, whichever country that has a seacoast if you take a look at the population concentration we see that large number of people are there in and around sea coasts. We have huge commercial, industrial, capital locked up in the seashore areas in the form of industries, in the form of trade, goods and all that. So, all of this kind of things are going to be affected significantly, and the water supply and this kind of things are also expected to be severely influenced in a bad way by this.

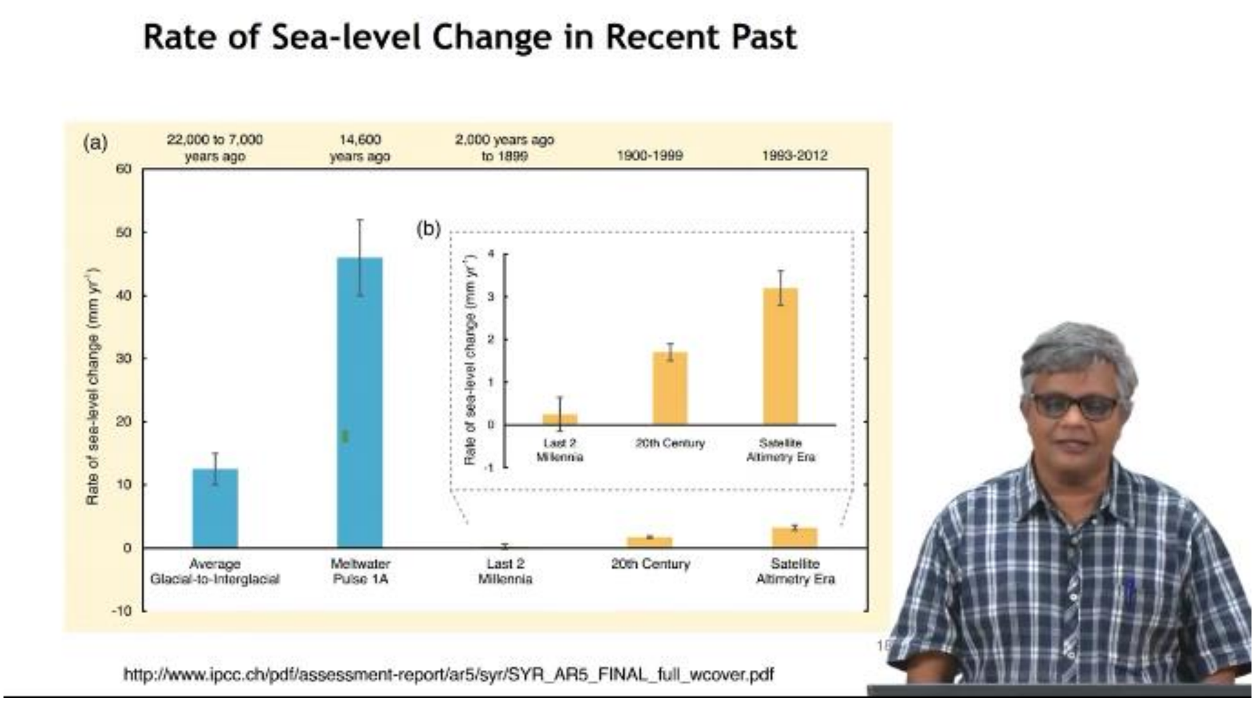


So, the projected risk from small changes in the climate change that are very much possible given are rate of carbon dioxide emissions and given the longevity in the in the atmosphere are risk of severe ill health and disrupted livelihoods resulting from storms surges, sea level rise and coastal flooding, inland flooding in some urban regions, and periods of extreme heat.

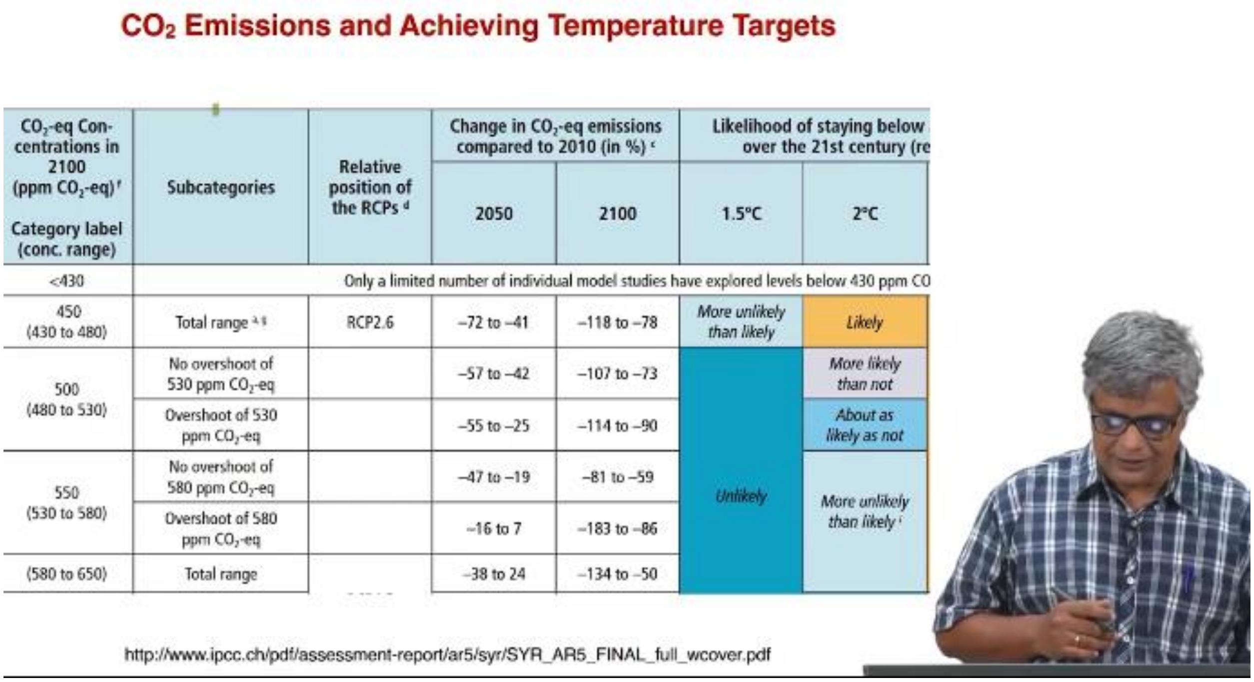
Systemic risks due to extreme weather events leading to breakdown of infrastructure, networks and critical services. So, this also we have seen in recent cyclonic storms, many villages and many towns have been wiped out, and they have been blacked out in terms of absence of power, and we know electricity is the is a major lifeline for us and if we do not have it, number of things that we take for granted are no longer possible for us.

Risk of food and water insecurity and loss of rural livelihoods income, particularly for poorer populations. This again is one of the social factors of climate change, in the sense although climate change affects all the countries in the same way in terms of carbon dioxide concentration, the corresponding changes in terms of local temperature variations are very, very different across the globe and the subsequent changes in terms of whether it is a drought, whether it is an extreme precipitation, cyclonic storms, and storm surges, all these things are even more varied.

And in many cases, it is the vulnerable section of the society, the poor people, the old, the infirm people these will be affected by the changes much more strongly. And if things continue like this, then we would be seeing large-scale migration of people from one area to another area. And that again is one of the major problems for us because we have a number of political barriers, we have created invisible walls across countries, and in states, in countries like India we also have invisible walls between states, between one state and the neighboring state and we also have not only to humans, loss of ecosystems, biodiversity, and ecosystem goods, functions, and services. So, all these factors caused by changes in the climate, resulting potentially from increased amount of carbon dioxide concentration, where carbon dioxide is being generated at a much faster rate than it can be accumulated, it can be evacuated from the atmosphere through natural causes. So, this is what is actually causing us a lot of concern and worry for people across the globe, almost every one of us will be affected, sometimes in a good way, sometimes in a bad way. And given our concentration and barriers that are already there, this can be severe, this can lead to a lot of severe stress in terms of how we manage with this, okay.



So, this kind of things have happened as we mentioned in the past, these have happened as recently as 14,600 years ago in which we had a huge amount of sea level rise at the rate of more than 40 millimeters per year compared to the 20^{th}-century value of few millimeters per year, okay. Here we have 20^{th}-century average is one and a half millimeters per year, okay. And some other estimates put this at 3 millimeters per year, but that is a very small quantity compared to what happened from 15,000 years ago where it was as high as 40 millimeters per year. And the average sea level rise between 22,000 and 7,000 years ago was about 13 millimeters per year. So, it is not unthinkable that sea level would be rising quickly, it has happened in the recent past, and so given that we are concentrated around the course, this can have severe consequences.



CO_2 Emissions and Achieving Temperature Targets

CO_2-eq Concentrations in 2100 (ppm CO_2-eq)[f] Category label (conc. range)	Subcategories	Relative position of the RCPs[d]	Change in CO_2-eq emissions compared to 2010 (in %)[c]		Likelihood of staying below over the 21st century (re	
			2050	2100	1.5°C	2°C
<430	Only a limited number of individual model studies have explored levels below 430 ppm CO					
450 (430 to 480)	Total range[a, g]	RCP2.6	–72 to –41	–118 to –78	*More unlikely than likely*	*Likely*
500 (480 to 530)	No overshoot of 530 ppm CO_2-eq		–57 to –42	–107 to –73	*Unlikely*	*More likely than not*
	Overshoot of 530 ppm CO_2-eq		–55 to –25	–114 to –90		*About as likely as not*
550 (530 to 580)	No overshoot of 580 ppm CO_2-eq		–47 to –19	–81 to –59		*More unlikely than likely*[i]
	Overshoot of 580 ppm CO_2-eq		–16 to 7	–183 to –86		
(580 to 650)	Total range		–38 to 24	–134 to –50		

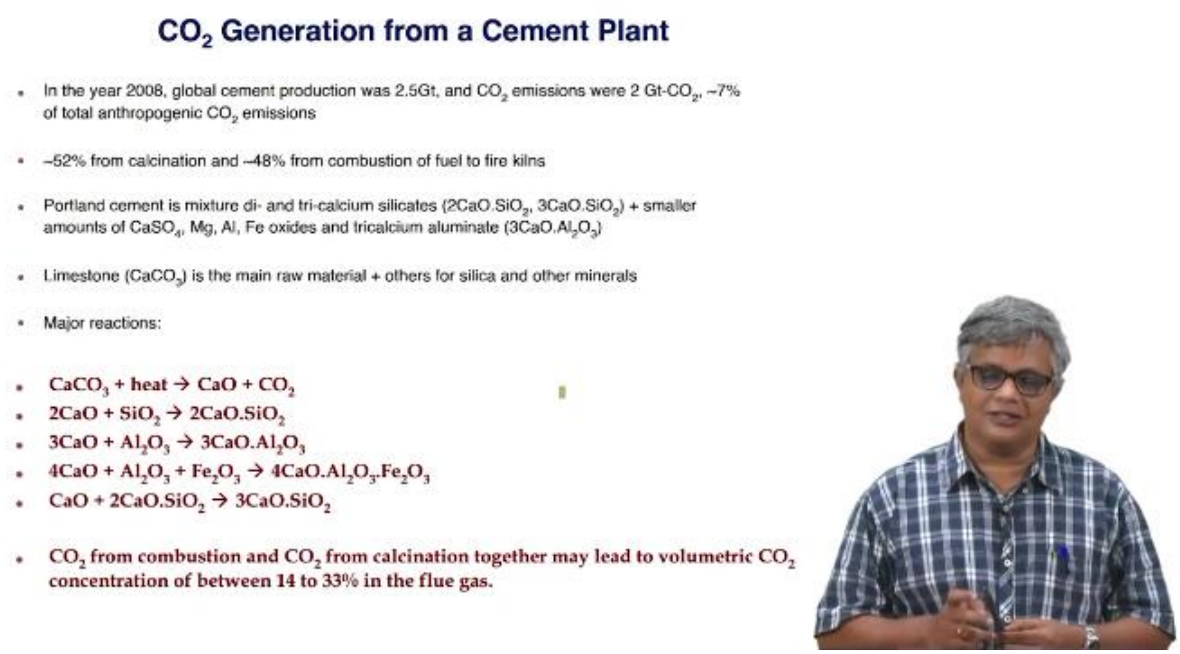
http://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf

So, there is a call from some action to be done, and what action can be done? Given that we are emitting a lot of carbon dioxide from fossil fuel usage, this is the one that is, and given the quick linkage between the carbon dioxide concentration and the amount of heat it retains in the atmosphere, the radiative carbon dioxide that we emitted, emit today gets well mixed within the atmosphere maybe up to 10 kilometers, 100 kilometers in a matter of 1 or 2 weeks. And once it is there, it is going to interact with the radiation to retain more of the heat and cause radiative positive radiative forcing. So, given this strong linkage and given that we as humans have been emitting an increased amount of carbon dioxide, this obviously becomes one of the target targets for us in terms of what we need to do, okay.

So, one of the things about climate change is that there are changes happening at a very slow rate over a very long drawn out period, because of causes that are not really in our control. But our way of lifestyle and increasing release of carbon dioxide into the atmosphere is making things worse by, and if that can be mitigated then the consequences of this can be mitigated within our generation and within the next few generations to come. And this gives this gives us a breathing time to address the long-term change in the climate arising from a lot of other, other factors.

So, if you are looking at what can be done to prevent, to keep carbon dioxide concentration to within about 450 ppm, currently it is very, very close to 400 ppm by the end of the century then the change in carbon dioxide emissions as compared to 2010 should be 40 to 70% less. So, that is by 2050 we have to reduce carbon dioxide emissions by 40 to 70% less, and we have to continue to do that at an increasing rate so that by two thousand one hundred (2100) we have to make it almost 90%. So, we have to go down to at 10% carbon dioxide as has been emitted, as was emitted in the year 2010 by 2100, two thousand one hundred, in another eight years. If you can reduce our carbon dioxide emissions to 10% of what they have been currently by 2100, then there is possibility to keep it within 450 ppm and this scenario given all the factors it contributes to carbon dioxide emissions is considered to be very unlikely, okay.

So, this is more unlikely than likely and likelihood of staying below 21st century of 1.5 degrees centigrade is considered to be unlikely. And if you want to retain it at 500 then slightly more relax conditions are there, okay. But all these projections say that it is very unlikely that we will be able to keep the temperature rise to 1.5 degree centigrade over the pre-industrial area by the end of 2100. Under certain conditions maybe it is possible to go up to 2 degrees, and that is why Paris meeting which happened very recently, plus concentrating on what can be done, what can governments do and what can people do to reduce the carbon dioxide concentration to no more than 500 ppm or so. So, that we can keep the atmospheric temperature increased to only 2 degrees. And if you want to do that, then we have to reduce carbon dioxide emissions by anything between 30 and 50% by 2050, and by 50 to maybe 100% by 2100. And what can we do, what can be done to make this?



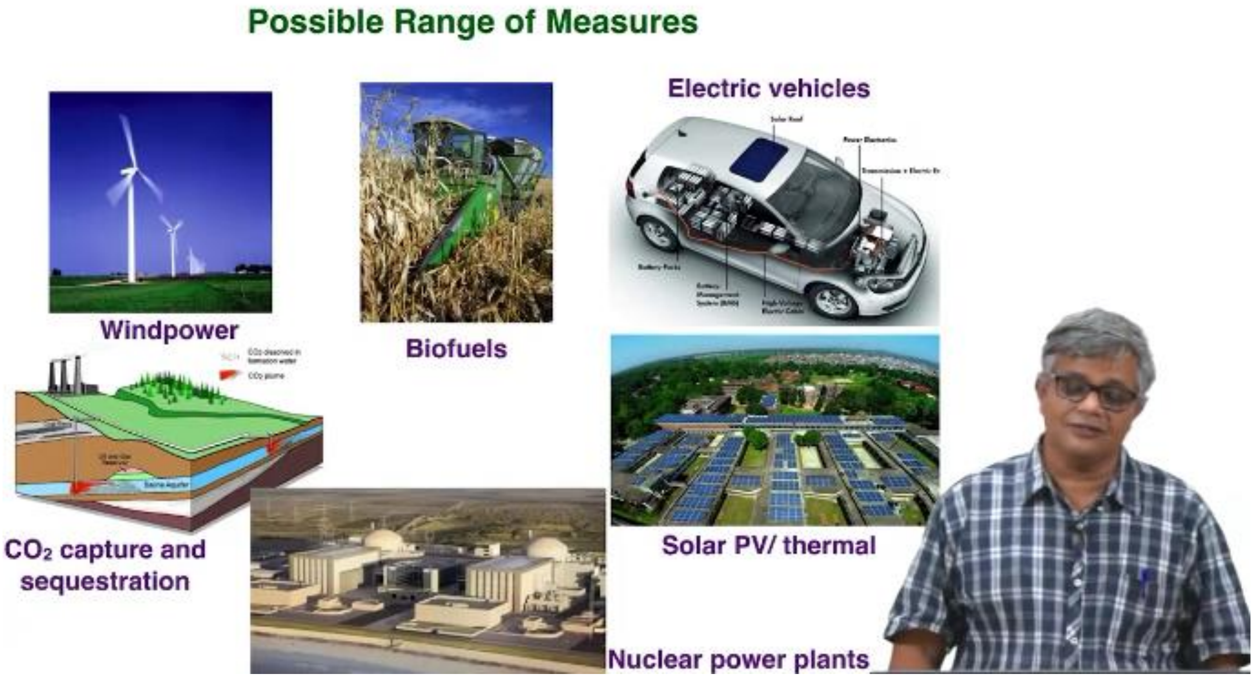
Okay, unfortunately, we have seen in one of the slides earlier that carbon dioxide is being emitted from all activities, whether it is industrial activity, whether it is home activities, whether it is service sector or whatever that we do we are emitting carbon dioxide in different rates. If you go by a train it is different if you go by flight, it is much more, if you go by your own car, it is much more than if you go by a bus, okay. So, these are some of the everyday activities that we indulge in which result in carbon dioxide emissions, and there are other activities where we really cannot do much about carbon dioxide emissions, okay. So, when we look at carbon dioxide emissions we would like to reduce, we would like to reuse, and we would like to recycle, okay. And or we would like to substitute, so that means that we try to reduce the consumption of energy, and we would like to reuse or recycle material so that we do not spend more energy and more carbon dioxide emissions in creating these things. And we would like to substitute a process which is CO_2 intensive or a product which is CO_2 intensive which something that is less CO_2 intensive, okay.

Given this kind of things, there are some of activities that we indulge in which have to keep generating carbon dioxide in the very process of their existence. For example, if you take a cement plant that cement plants, cement is actually made of calcium, alumina, silicates and their mixture, and the basic raw material for this is calcium carbonate, $CaCO_3$, and other raw materials. And we decompose calcium carbonate to produce calcium oxide which is then combined with silica and alumina and other things to finally produce different forms of raw materials which make of the cement. So, in the process of decomposing calcium carbonate, we are releasing carbon dioxide, okay.

So, that means that if you want to have cement you have to decompose calcium carbonate, and therefore you have to release carbon dioxide, and not only that all these processes require a very large amount of heat, and many of these processes have to be carried out at extremely high temperatures, 1300, 1400 degree centigrade, and so when you want to create high temperature you have to burn fuel and then you have to create that, so that itself produces lot of carbon dioxide.

So, in that sense, some processes through the very nature will have to release carbon dioxide, and it is estimated that in the year 2008 global cement production was 2.5 gigatons, and carbon dioxide emissions were two gigatons that is about 7% of total anthropogenic CO_2 emissions which is from cement production.

Similarly, steel which is used by us for so many things including cars and construction of various things, and manufacturing lot of goods is again carbon dioxide intensive process. Again there in the very process of reducing iron oxide into iron to make steel, we make use of carbon monoxide or carbon, and that gets converted into carbon dioxide, so that means that if you want to make steel you have to release carbon dioxide, and again steel is something processed which happens at very high temperature. So, that means again you have to increase the temperature, and therefore you have to burn fuel to create those furnaces, and that emits lots of carbon dioxide. And if you look at it steel, and cement are the basic building blocks of our modern society, if you make a big skyscraper so that people can live comfortably, then they consume a lot of cement and lot of steel, okay. And how can we not do with this, given that our population is increasing and given that more of us will want to live in urban environments with lot of creature comforts. So, there are, these kinds of challenges that we have.

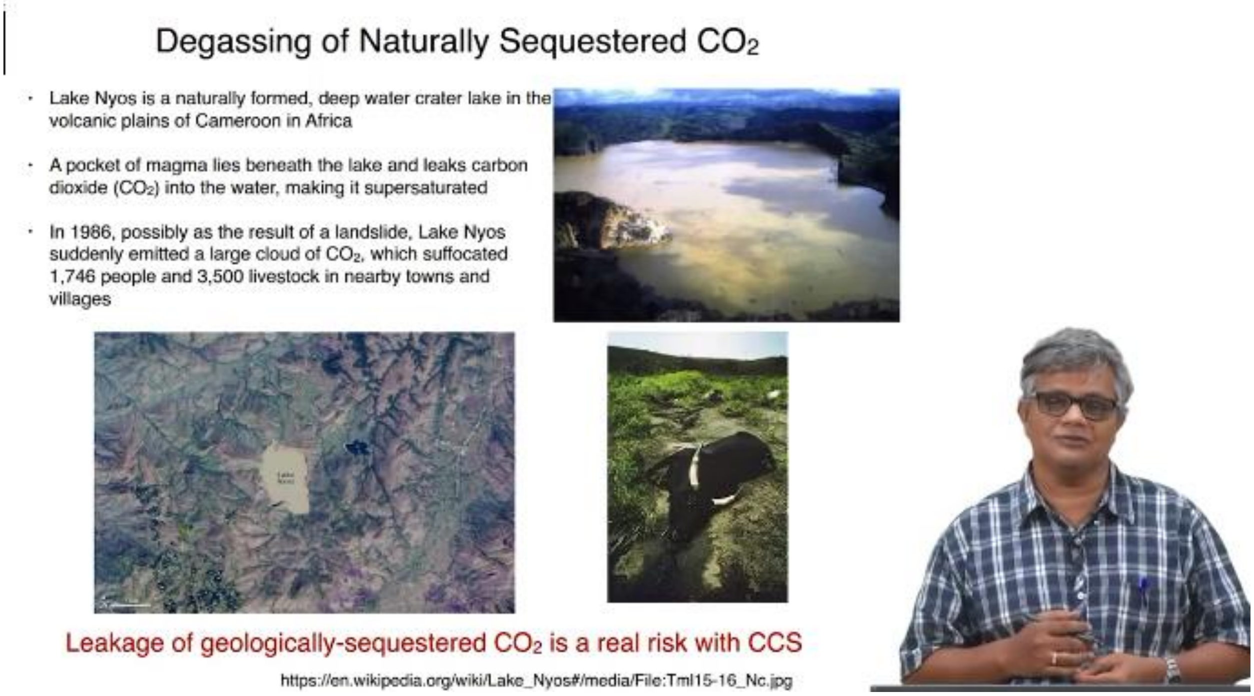


So, the possible ranges of measures what we can do is to substitute carbon dioxide emitting process that are within our control, with processes and products which do not depend on carbon dioxide, and this is where electricity generation becomes a major target because we know that the world over, more than 60%, 70% of electricity is generated in fossil fuel combustion. And so that makes it a lot of carbon dioxide emissions, and if we can produce electricity in other ways, then we could make a huge dent in terms of carbon dioxide emissions. And the other possibility especially is the transport sector which also accounts for a significant portion maybe about 20%, if we can replace fossil fuel guzzling cars with electric vehicles, battery vehicles, and carbon dioxide less exhaust as in fuel cell cars and all that. Then there is a possibility, but of course, we have to see from where we get electricity, how we generate the electricity to charge up this cars and to create hydrogen for fuel cell vehicles. And if you make use of biofuels to produce petrol like diesel like fuels, then that would be one possibility, because biofuels in the process of growth of this plants they will be absorbing carbon dioxide. So, you could reduce your carbon dioxide footprint by using biofuels, but how much you can produce and how many crops can you produce in order to feed these 1.8 billion cars which are expected in 2035 which we saw in our first lecture, okay, so that becomes a big question, we have limited possibilities.

We have wind power, which can be used to generate electricity and there has been a quiet and increasing trend in terms of wind power harnessing across the globe, and nowadays wind power is cost competitive with conventional fossil fuels and cost that are also trembling. And then we have solar PV systems, portable tax systems, and solar thermal systems which can be used to generate electricity without producing carbon dioxide during production stage, both wind and solar PV are very good fuels from global warming point of view, but the question is that what do you do when wind is not there? What do you do when sun goes down? So, we need to have for these things complimentary energy storage technologies. And energy storage is a biggest problem for us in terms of making full use of this and transforming ourselves into CO_2 free emissions from electricity generation point of view, and that is really a big technical challenge for us.

We also have nuclear power plants which do not emit carbon dioxide and which are which can be worked day and night, year and year out for number of years, even tens of years, several tens of years. They have their own problem and if you look at how much you can produce from nuclear power and what you do with nuclear waste those are also questions for us. There is also something else that is been mentioned very much, this is known as carbon dioxide capture and sequestration. When you have a stationary large source of carbon dioxide, for example, of power plant or a cement plant, or a steel plant usually there are a finite number of stacks or places from which carbon dioxide and flue gases, exhaust gases are released into atmosphere, and these may contain anything between 5% to 50% of carbon dioxide concentration, okay.

So, since these are well-defined sources of carbon dioxide it is possible to separate carbon dioxide from this mixture of gases through number of chemical means, chemical engineers know how to do this, they have been doing this for 20, 30, 40 years. And if you can take this and then sequestrate it, so that is keep it out of harm way, keep it out of atmosphere, keep it underground which is known as geological sequestration, keep it dissolve it in seawater which is known as ocean sequestration or use some raw materials to accelerated weathering. Just as in a cement plant you are decomposing calcium carbonate to produce calcium oxide, you can make use of some natural occurring oxide minerals to convert them into carbonates in a reverse process of decomposition, so this is known as this what happens naturally. When the Himalayas came out on to the surface many of this oxide bearing minerals were there, and they gradually reacted very slowly reacted with carbon dioxide and the atmosphere, and they reduced the carbon dioxide concentration from above 500 ppm to closer to 300 ppm, but over millions of years. If we accelerate the process in an industrial context, then we could imprison carbon dioxide in solid form, so that it cannot come out. So, these are possible techniques, carbon dioxide capture, and sequestration by which it is possible to capture a significant portion of carbon dioxide that is being released from a number of stationary resources including power plants and cement plants and steel plants, refineries and all these things.



Technology is known but to put that into practice will take a lot of money and number of other process and also fears about what happens to carbon dioxide that is sequestrated. And this is one particular case of degassing of naturally sequestrated carbon dioxide, so carbon dioxide that has come out from possibly volcanic emissions. And in this particular case we are looking at Lake Nyos which is a deep water crater lake formed in the volcanic plains of Cameroon in Africa, and underneath this lake, there is a mild volcanic activity because of which some carbon dioxide is coming, and this is a deep water lake, I think close to 280 meters. And there is thermal stratifications so that you have upper layers of water which are stable which are less dense compared to the lower layers and because of temperature gradient this has been in the stable form for millions of years. But occasionally you can have mixing of the top layer and the bottom layer. Bottom layers are rich in carbon dioxide, they are supersaturated in carbon dioxide, and the top layers do not have so much of carbon dioxide, but because top, bottom layers are at pressure, they are in 200 meters in deep water the pressure is excessively, it is very high there and carbon dioxide is retained in dissolved form, but if you have a landslide, if you have volcanic eruption, and there is water comes up, okay, maybe because of a local tsunami that is created maybe because of some spilling over and those kind of things then it is possible for the dissolved carbon dioxide in the water to degass, to come out into the outside into the atmosphere, and something like that happened in 1986.

In that case, there is a possibly because of a landslide, some of the bottom water containing more amount of carbon dioxide came up as a result of which the pressure decreased, as a result of which carbon dioxide came out into the, in a big cloud. And it flowed down the slopes of the mountains, in invisible form it enveloped, displaced air at ground level and it many people were suffocated, cattle was suffocated and in this particular event in 1986, 1746 people were supposed to have died and 3500 cattle were also supposed to have died in a matter of minutes over a radius of 25 kilometers from this lake, okay. So, something like this happened in 1984, another event happened, and there are other areas in which this kind of sequestrated carbon dioxide, in this case, it is sequestrated in water of about 200, 300 meters deep.

Ocean sequestration can also have this kind of consequences, if we store it in geological formations as shown here in saline aquifers then essentially you drill maybe 1000 meters deep into this, into this porous rock and then you inject carbon dioxide at high pressure for a period of 30 to 50 years that maybe the lifetime of a power plant or steel plant like that. So, during this entire period the carbon dioxide which would have gone into the atmosphere through your chimney would be separated from the rest of the gases, it would be concentrated to maybe 95%, 98 pure percent purity, it would be compressed to maybe 200, 300 bar and then pushed into the rock, continuously for 30, 50 period, year period and then the rock is, the pipeline is closed and left there, and will be left there and gradually, gradually carbon dioxide flume will spread through this, this porous rock and the pressure will decrease, and above this porous rock you have an impermeable layer of rock, so that this gas cannot escape, and this gas will slowly over a period of thousands of years and tens of thousands of years it will slowly react with the surrounding media and then it may become permanently captured. But in the meantime if you had an earthquake, and if there is a cleavage of some of this impermeable layers then it is possible for this point flume of carbon dioxide gas which is injected into that, in to the brine water can actually come up and then slowly leak out, leak out into water bodies and make them acidic or it may come up all the way into this surface and then it may displays air and create that Lake Nyos kind of event.

So, these are some of the possibilities, that is why when engineers talk about carbon dioxide capture in geo-sequestration they look for sites in which you have many, many layers of this impermeable rocks. So, you have a layer here and then some sediment, porous sediment, another impermeable rock, and another sediment, these are all things that have happened over millions of years due to very natural processes. And if you have several such layers then you would dig down deep into that into the third or fourth layer and then you would store your carbon dioxide because of which you will have one layer and then the next impermeable layer and then the next impermeable layer all these things are trying to retain carbon dioxide, even in the case of small fissures. But if you have a very big earthquake and then over this 1 kilometer, 2 kilometers depth there is a fissure that happens then it is possible for a significant amount of captured sequestrated carbon dioxide to come out and cause damage, so site selection is very important in terms of carbon dioxide capture in sequestration.

So, these are some of the things that are being discussed, and these are being studied, some of them being implemented in the world stage to reduce carbon dioxide emissions from all over the world. Many of these methods are costly, and many of these things are dependent on technology, and therefore some countries would take advantage of this, and some other countries would suffer from having to learn new technology without the resources to create those kinds of technologies. So, there is all kinds of things that happened, and the distribution of carbon dioxide consumption or energy consumption across society, within society, across different strata of the society is uneven. So, who pays for the cost, who bears the responsibility for reduction of carbon dioxide emission is all a matter of debate discussion and negotiation. So, all these kinds of activities are happening on the world stage.

So, in the next lecture, we would like to look at what is there in it for India? What can we do in India about this? What kind of challenges we face? And what kind of solutions that are likely for us, in the context of energy harnessing so that our economic prosperity can continue unabated, at the same time we can continue to protect and improve the environment in which we live. So, this question of energy versus environment in the Indian context is what we are going to discuss in the last lecture, sixth lecture of this series.

Thank you.