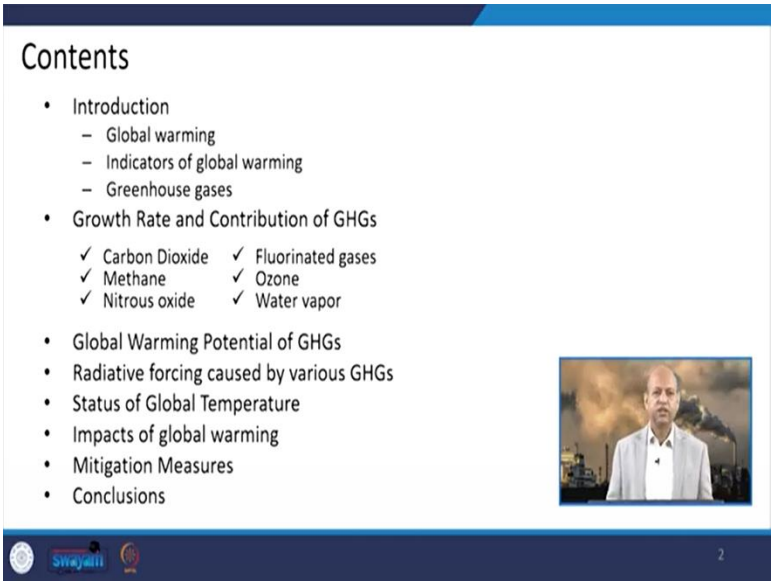
Air Pollution and Control
Professor Bhola Ram Gurjar
Department of Civil Engineering
Indian Institute of Technology, Roorkee
Lecture 38
Global and Regional Environmental Issues – Global Warming

Hello friends, you may recall that these days we are discussing about global and regional environmental issues. And in this series, we have already discussed about ozone layer depletion and today we will cover the global warming related issues. So, in this particular presentation or lecture, first of all we will very briefly discuss about what is global warming and the indicators which are related to global warming which represented in a better way so, that we can measure it track it.

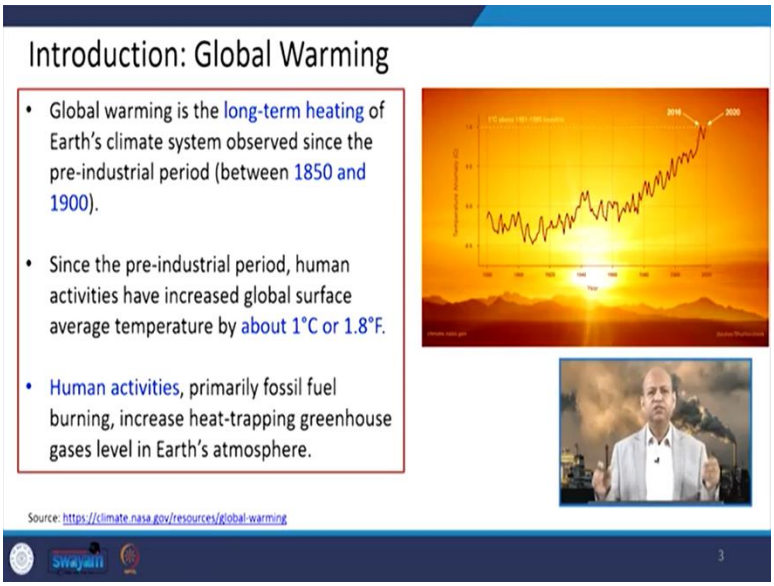
(Refer Slide Time: 01:01)



What are the greenhouse gases although you know about this, but briefly we will touch. And then we will see how much growth rate or contributions of different greenhouse gases is there. And then what is the global warming potential of the greenhouse gases and the radiative forcing which is caused by solar insulation. And then the what is the status of this global warming in terms of the temperature global temperature and impacts of different impacts of global warming because it is not only the global temperature increase, but other also like climate change related issues which we will see in brief.

And then we will look into like what are different mitigation measures which can work for reducing the greenhouse gas emissions and we can curb this global warming related effects and we will conclude.

(Refer Slide Time: 01:49)



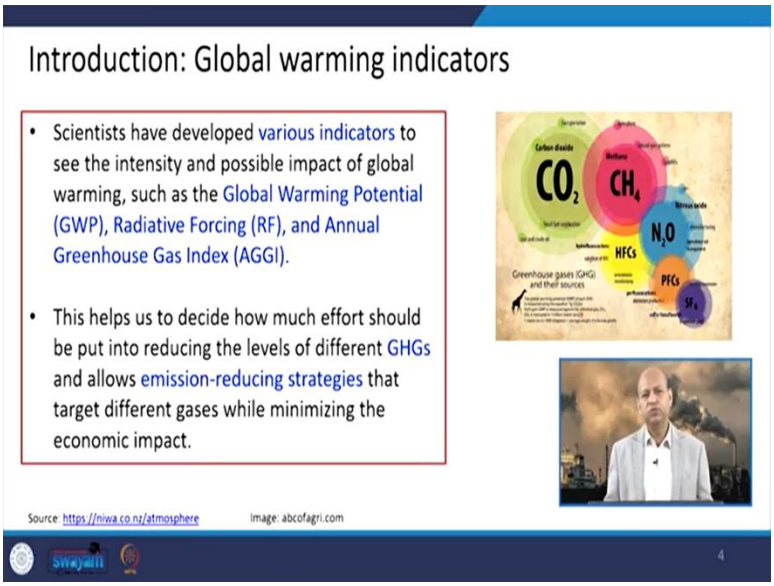
So, when we talk about global warming basically it is nothing but the long term heating kind of process of the Earth's climate system, which has been observed since the pre-industrial period like from 1815 to 1900 or so. Because before industrialization, this global average temperature was more or less up to a particular degree Celsius and it was for centuries all together.

But now, we have seen that since, when this industrialization has occurred, so, after this James Watt develop the steam engine, and then coal burning and other fossil fuel related burning activities we started. So, the greenhouse gases that means carbon dioxide etc they were pumped into the atmosphere and at the same time temperature of the global the planet temperature increased.

And we can see, here from 1880 to this to this present times the global temperature is basically increasing. And of course, there are different schools of thoughts, sometimes I discuss with you that some people say that this is because of just natural phenomena. But now, we have this international government panel of climate change, and they produce a lot of scientific evidences, which gives this evidence based conclusion that of course, the manmade or anthropogenic contributions are much more predominant in this particular global warming related issue.

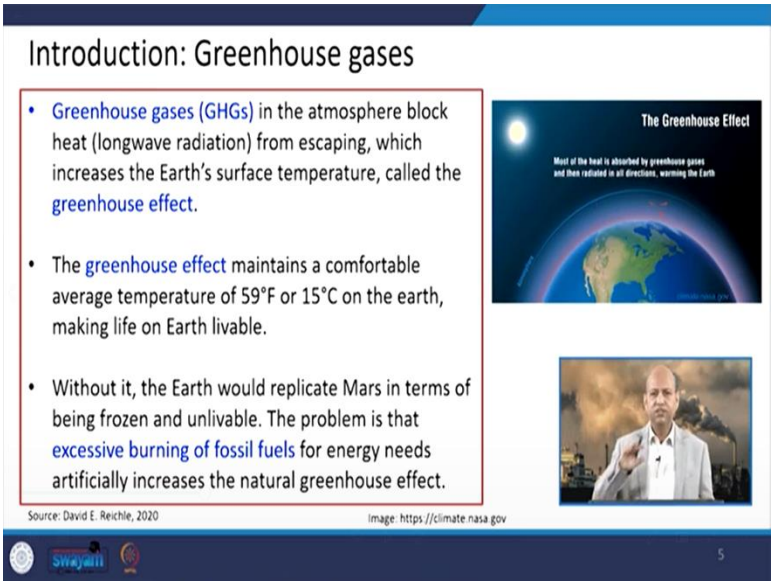
So, the since, this pre industrial era, when human activities started to contribute into global warming because of greenhouse gases emissions. So, the average temperature has increased about 1 degree Celsius, it looks very small, but basically in the Earth system, it means a lot it can change many things basically. So, the human activities, which are basically related to fossil fuel burning this has increased emissions of greenhouse gases like CO_2 etc. And they trap the heat which is outgoing from the planet, we will see how does this happen.

(Refer Slide Time: 04:06)



So, as I said that there are indicators like to measure the intensity and impact of global warming like Global Warming Potential (GWP) or radiative forcing or Annual Greenhouse Gas Index. So, we will discuss about these things later on. And they are needed because we want to study long term relationships between greenhouse gases and their impacts in terms of temperature or the heating kind of contribution. So, we need to measure those global warming potential etc.

(Refer Slide Time: 04:40)

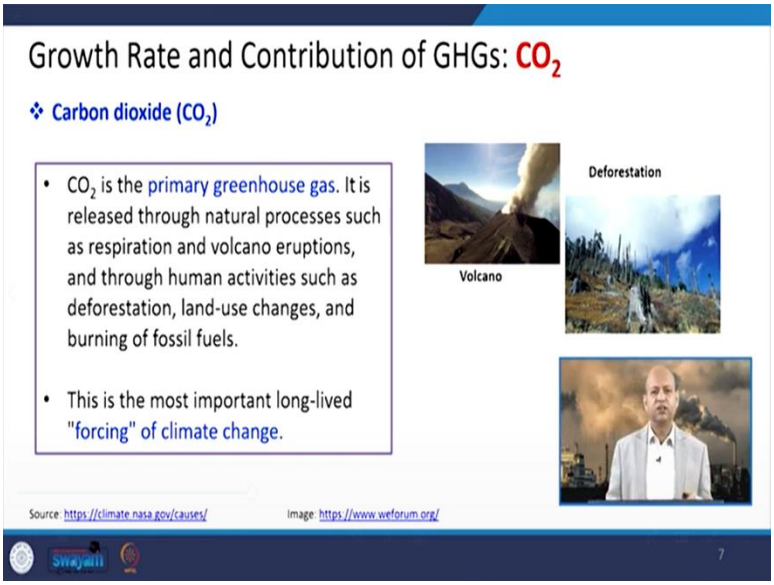


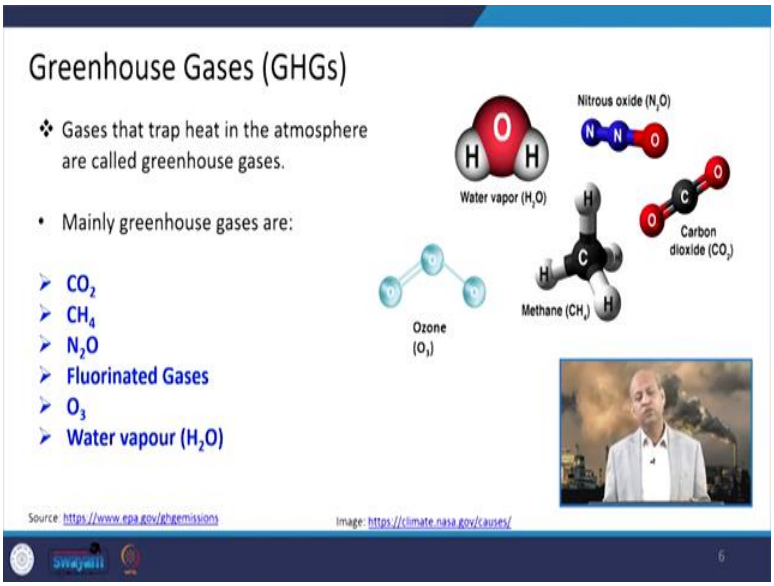
Well, when we look into greenhouse gases, so about this particular phenomena of the greenhouse effect in the sense because, it covers the planet these greenhouse gases like CO2, methane, etc. They are in the atmosphere and they basically do not allow the infrared radiation or long wave radiation, which goes out of the earth planet into the atmosphere into the space.

Because, a lot of ultraviolet rays or solar insulation comes to the earth surface and some a part of it is reflected some part of it is absorb and then it is emitted like a long wave radiation. So, this heating effect occurs because that long wave radiation is basically absorbed by greenhouse gases into the atmosphere and it acts like a blanket it does not allow it goes to pass and then heating effect occurs in the atmosphere.

And this although naturally greenhouse gas effect is very much required because due to this effect only we have certain temperature of the planet like around 15 degrees Celsius. And this makes the life possible otherwise, it will freeze and it will like mass, it will be completely frozen kind of planet which is not good for ecosystems which supports lot of varieties of life like us. So, we need this effect, but beyond certain limit, it is not good for us we which we will see how does that happen basically.

(Refer Slide Time: 06:17)



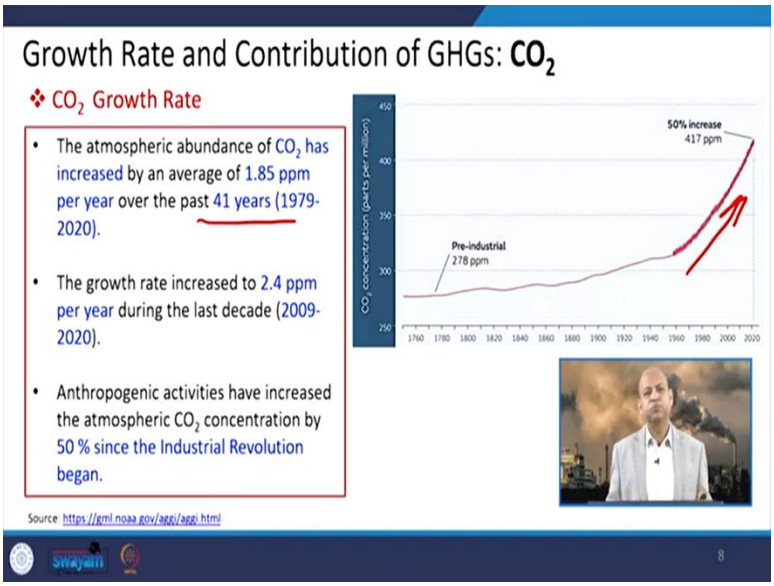


So, when we talk about greenhouse gases, there are several gases which are having this kind of effect to absorb the infrared radiation or long wave radiation. And causing the heating effect basically, and these are like carbon dioxide, methane or nitrous oxide N_2O, then there are certain fluorinated gases or ozone and even water vapor these all these gaseous components compounds they contribute into greenhouse gas effect basically.

When we talk about CO_2. So, it is basically the primary greenhouse gas and it is emitted in a very huge quantity whenever we burn fossil fuels, whether it is coal or whether it is diesel or gasoline because these are hydrocarbons basically.

And when we burn it, so, this carbon content is oxidized into CO_2 and it goes into the atmosphere. And because, the lifetime of CO_2 is for centuries, and that forcing the positive forcing means, increasing the temperature that kind of forcing occurs. And the reason is it is like, it comes not only from natural sources like volcanic eruptions, or even forest fire, but a lot of human activities, including land use change, when we go for deforestation or urbanization and various industrial related activities, they emit lot of CO_2.

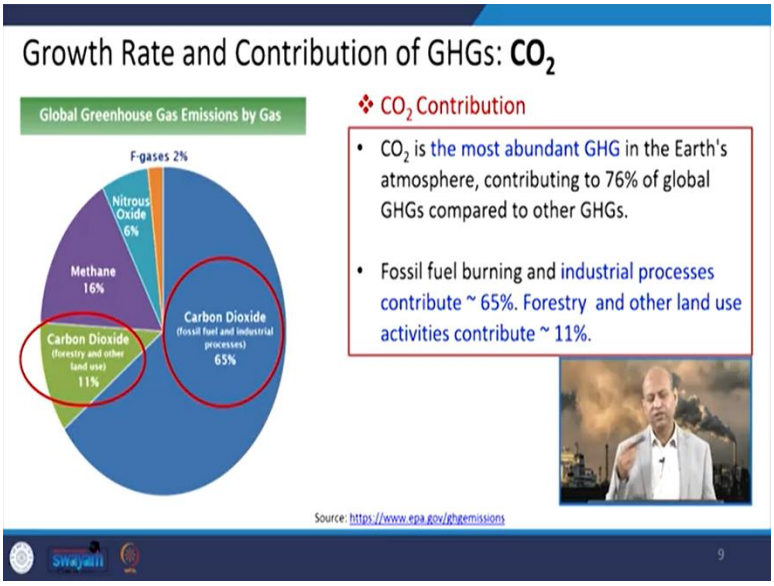
(Refer Slide Time: 07:50)



Like, this atmospheric content or abundance of CO_2 has increased around an average around 1.85 ppm per year in the past 41 years from 1979 to 2020 this has been observed basically. And if you look into the last decade like 2009 to 2020 then it becomes rather more predominant like 2.4 ppm per year basically.

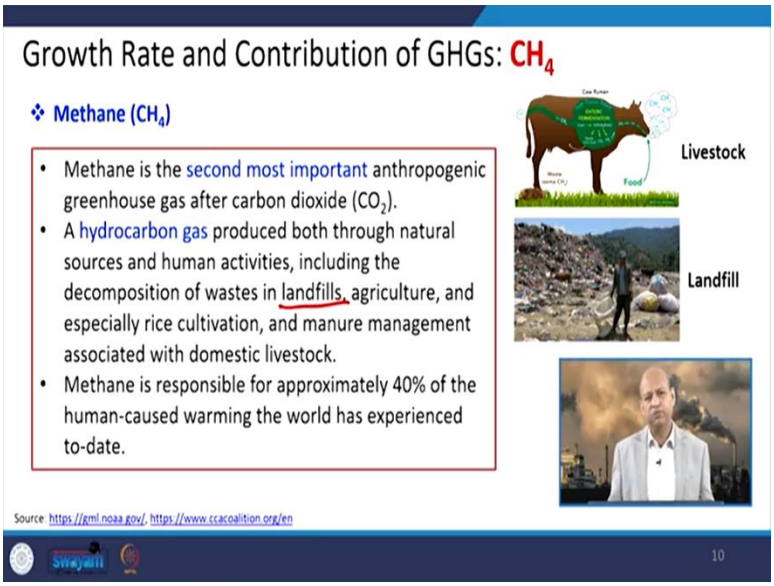
And this anthropogenic activities which are increasing the CO_2 concentration, they are like contributing in a large way and this huge steep increase of the CO_2 concentration in recent years basically. So, that is very problematic and 50 percent since the Industrial Revolution became so, that way the in a very small period a lot of concentration of CO_2 has increased, and that is the worrisome. Because, that has intensified this global warming phenomena, because of greenhouse gas effect.

(Refer Slide Time: 08:56)



Well, when we look into the CO_2 contribution from different segments or domains, so, like fossil fuel and industrial processes, they contribute around 65 percent and carbon dioxide from forestry and other land use like deforestation or etc that is around 11 percent so total 76 percent from these kinds of activities goes to the atmosphere basically. And this fossil fuel burning industrial, processes where they consume lot of coal or gasoline, diesel, etc and they contribute a lot of CO_2.

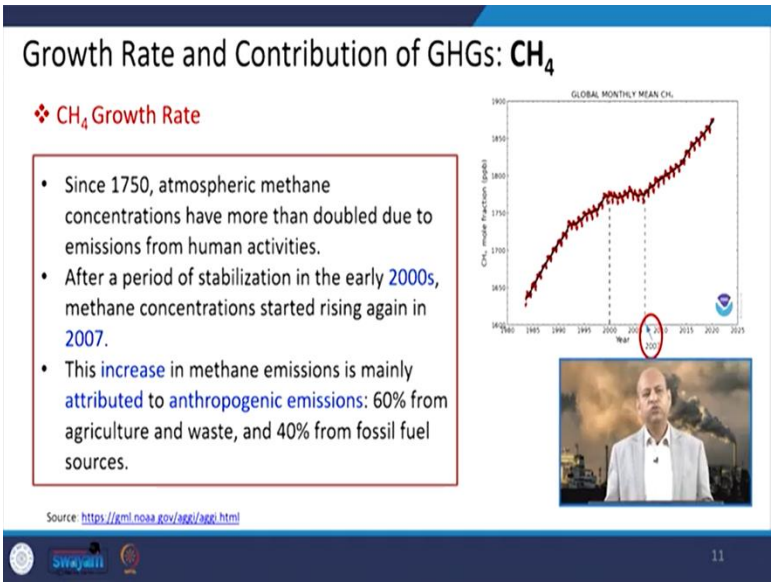
(Refer Slide Time: 09:40)



When we talk about methane. So, methane comes from even natural sources like wetlands, etc plus these human activities like livestock and then these landfills where anaerobic digestion occurs or

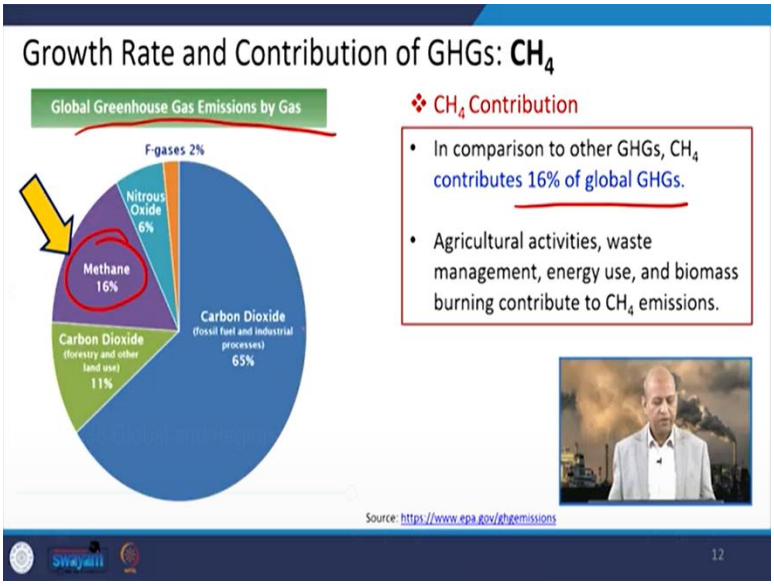
agriculture practices even rice cultivation etc they manure management all these activities contribute to methane emissions into the atmosphere. And this is responsible around 40 percent of the human caused warming means after CO_2 this is very important greenhouse gas in terms of global warming effect.

(Refer Slide Time: 10:21)



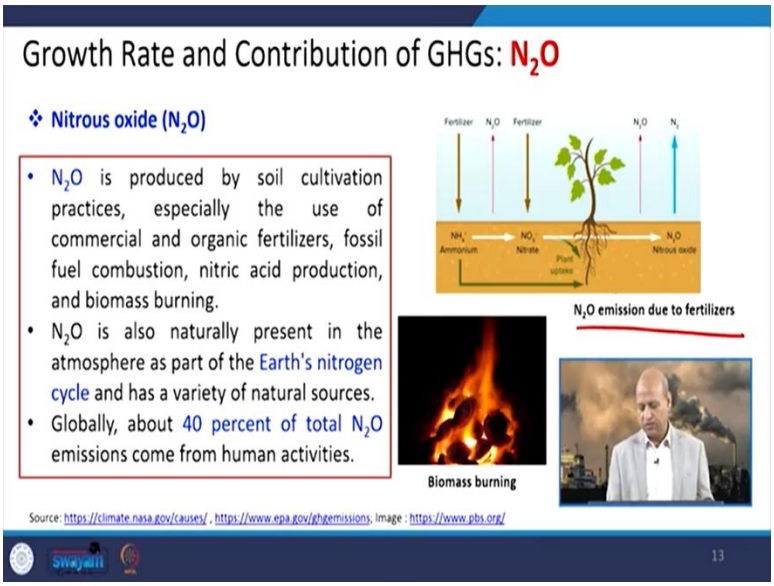
When we talk about its growth rate basically, from 1750 again we will see a lot of activities are there of human nature. So, this there was of course, some constant or little bit decrease, the increased rate but again from 2007 emissions of methane are increasing. So, they are related to several kind of human activities and technologies basically.

(Refer Slide Time: 10:48)



Now, if you talk about contribution, so, 16 percent of global greenhouse gases this comes in terms of methane basically. So, 76 percent is this greenhouse gas emissions in terms of gaseous components is CO_2 and 16 percent is methane basically, and then we will see other contributions of like nitrous oxide.

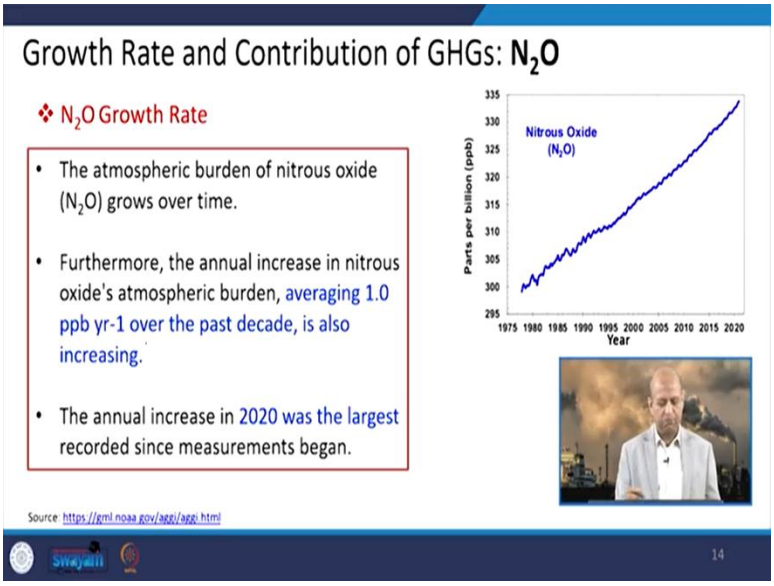
(Refer Slide Time: 11:12)



So, nitrous oxide also comes from different kinds of activities, like organic fertilizers or fossil fuel combustion, nitric acid production, and also agriculture related activities basically, it comes from

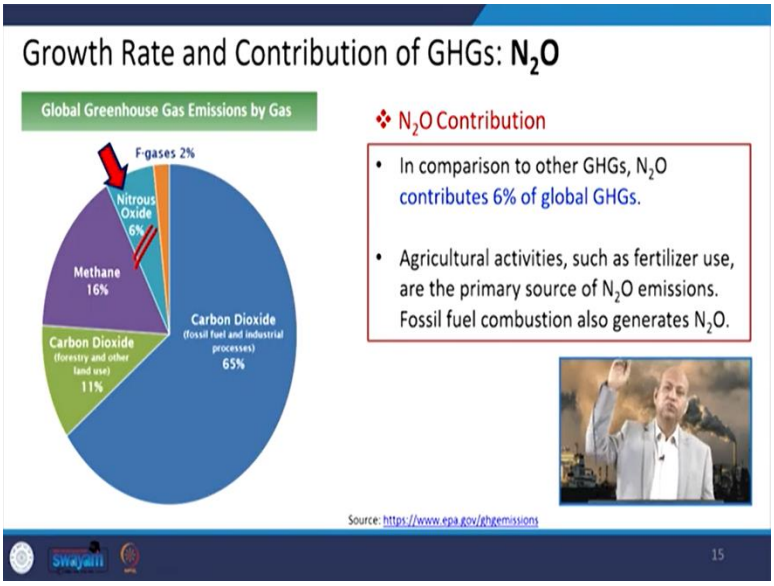
these kind of activities. And this is also very potent greenhouse gas and it contributes, although only around 2 percent.

(Refer Slide Time: 11:40)



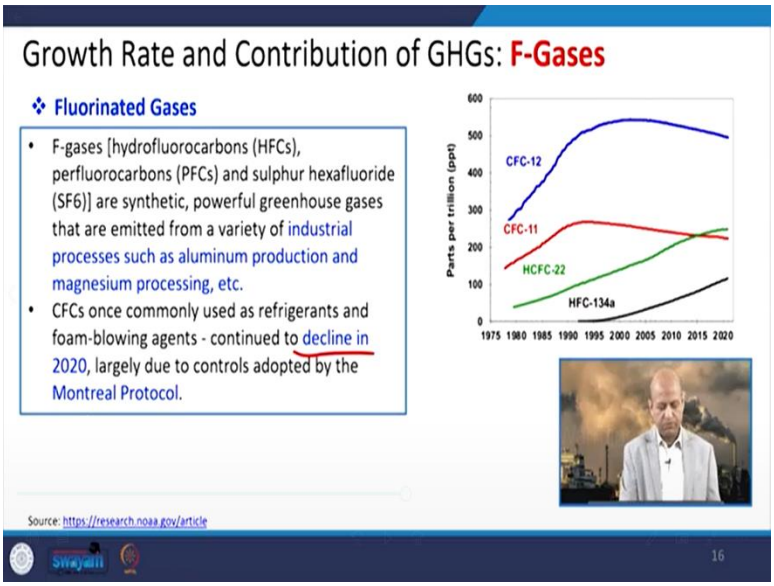
But, as I said, because, this is also predominant after the methane. So, the growth rate it is increasing, because a lot of human activities are of that nature with contribution to the emissions of N_2O and it is around 1 ppb per year over the past decade, it is increasing, so, a lot of quantity of N_2O is coming out of these activities.

(Refer Slide Time: 12:03)



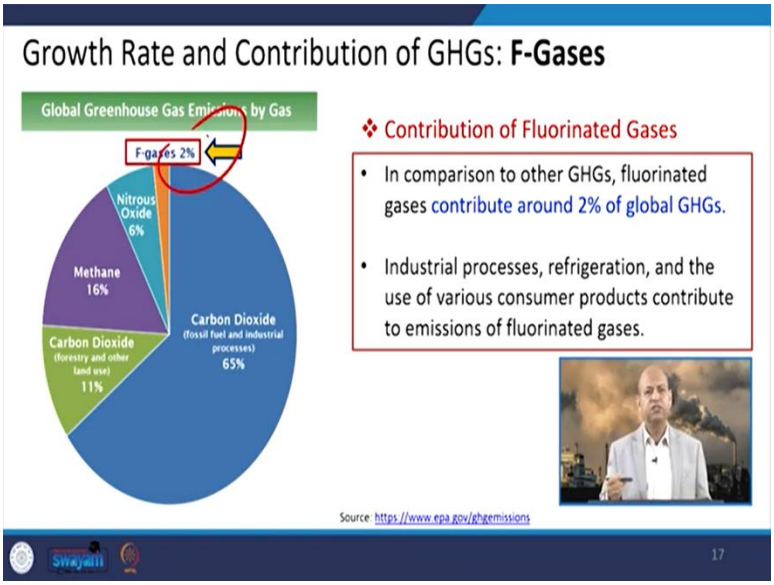
And 6 percent around 6 percent of the greenhouse gases and is because of into this is the third largest contribution, CO_2, methane and nitrous oxide basically. Nitrous oxide is also problematic, because it may reach to the stratosphere and it can contribute to the ozone layer depletion, you might recall that kind of thing.

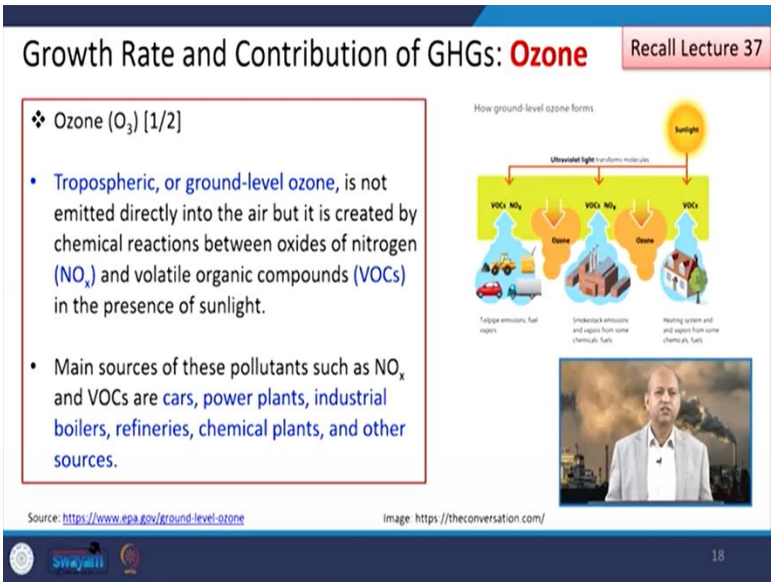
(Refer Slide Time: 12:26)

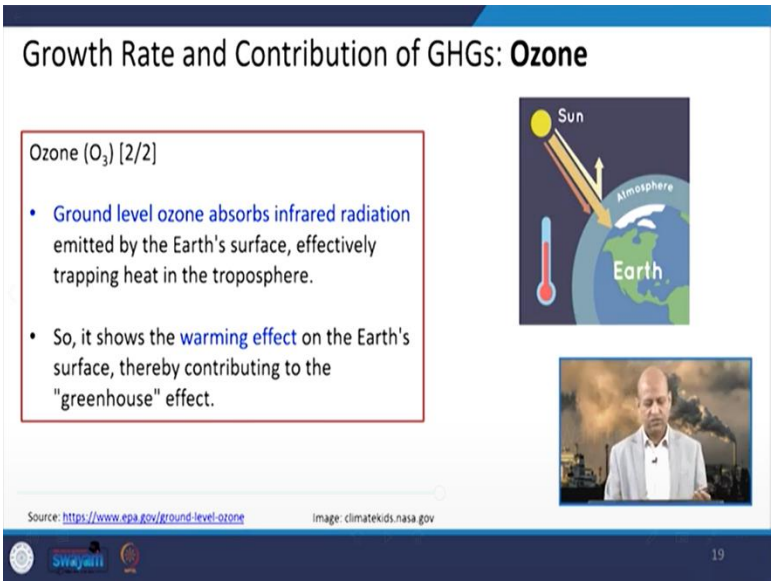


Then there is this fluorinated gases, they are very small in quantity, but their potency is very high, we will see how potent they are thousands time then the CO_2. So, even though their quantity is very small, but because of their global warming potential is very high, it is kind of worrisome, and also they contribute into this ozone layer depletion. So, it is good that through Montreal protocol, we are reducing their production and that we are going to control it. So, the decline trend after 2020 because of Montreal protocol so, that is a good thing.

(Refer Slide Time: 13:01)



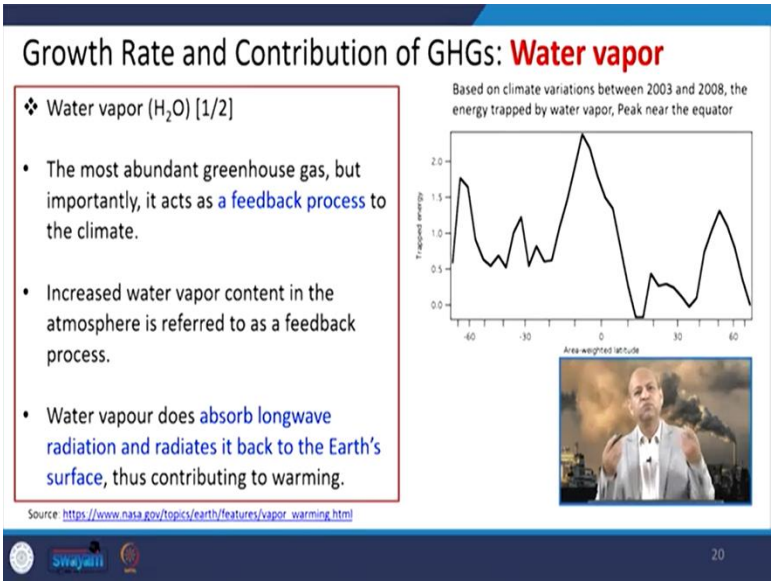


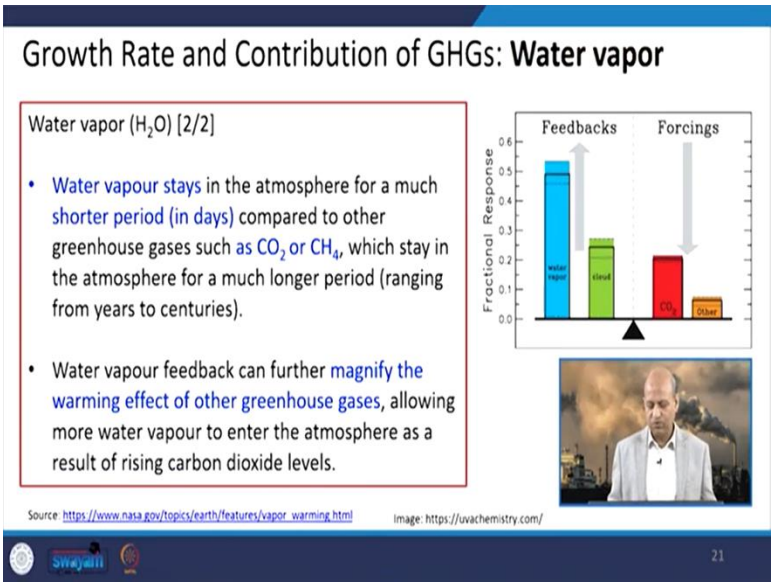


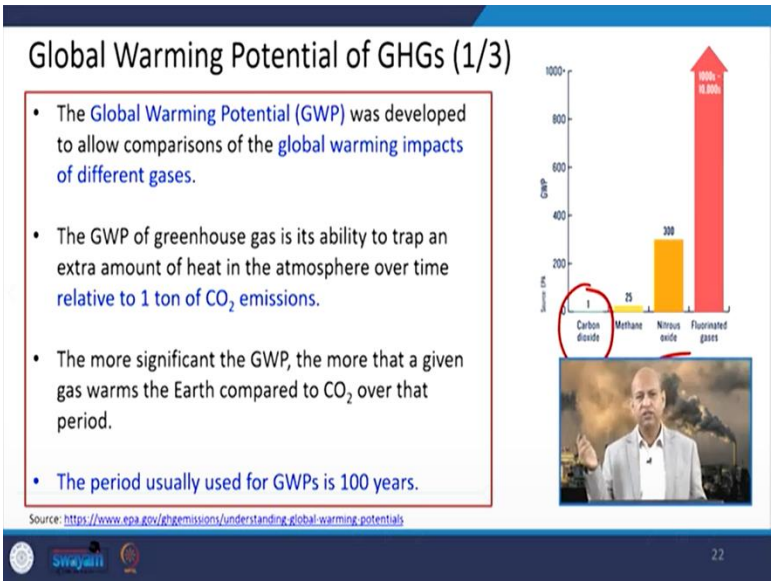
Well, the growth rate only this 2 percent was the contribution and it is declining, because we are replacing it with better chemicals. When we talk about the ozone as ozone in troposphere, acts like a greenhouse gas although in the stratosphere it is good, because it protects us from ultraviolet rays. But in troposphere, it is not only toxic gas, but also having the greenhouse gas effect in terms of that increasing the temperature. So, basically it is not emitted directly as this is the secondary pollutant and the precursors of ozone are like VOCs volatile organic compounds or the NOx emissions hydrocarbons etc.

And because of in the presence of sunlight due to this photochemical reaction ozone is produce. So, if we can control the precursors, we can control the ozone basically, and these VOCs, NOx etc, they come from again several kinds of human activities like industrial boilers, refineries, chemical plants, etc. Well, this the effect of the ozone as I said, this is shown here, it gives the warming effect in the troposphere, because of absorbing the solar radiation. Well, not the solar radiation, exactly the outgoing radiation basically.

(Refer Slide Time: 14:18)





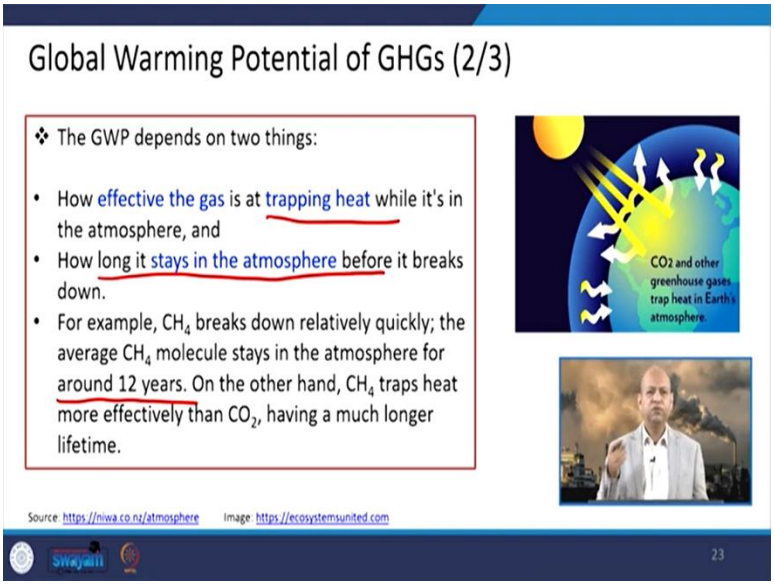


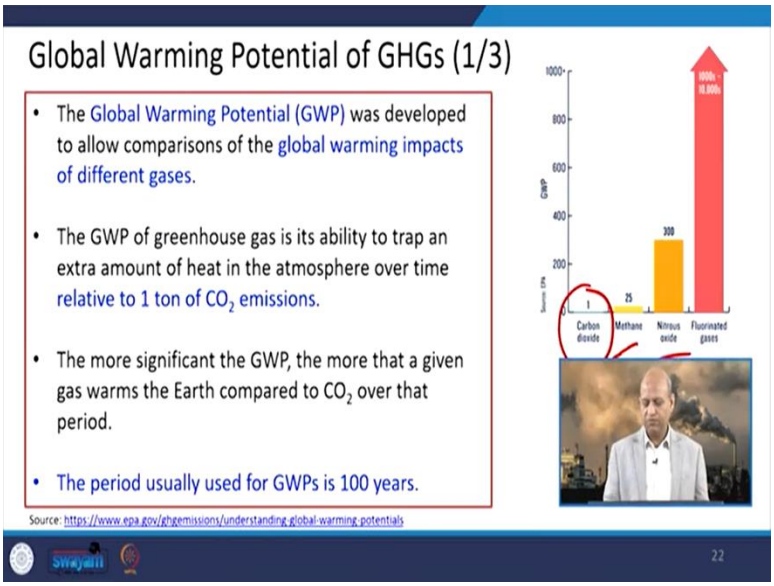
Then, we talk about the water vapor, water vapor is this is a kind of feedback effect. So, at such because of global warming vapor occurs vapor is produced and it goes to the atmosphere and then it also absorbed the outgoing radiation.

So, basically, it is a kind of vicious cycle, , because, as it goes, it contributes to the global warming effect or because of greenhouse gas effect. So that way means more temperature, more vapor and more again that this greenhouse gas effect. So, feedback mechanism is there and then the forcing of these CO_2 etc, we can look into.

Well global warming potential if we talk about so, this is one indicator which can compare which can help us to compare the potential of the different greenhouse gases. Like if you talk about like carbon dioxide for 400 years or so, if it is the unit 1, then the methane is 25 times then the carbon dioxide nitrous oxide is around 300 times. So, see means like unit potential of carbon dioxide of the same quantities 400 years is around 1, then 300 times is the this nitrous oxide. And these fluorinated gases they are 10,000 times even 1000 to 10,000 depending upon different these greenhouse gases, but thankfully, they are reducing in quantity.

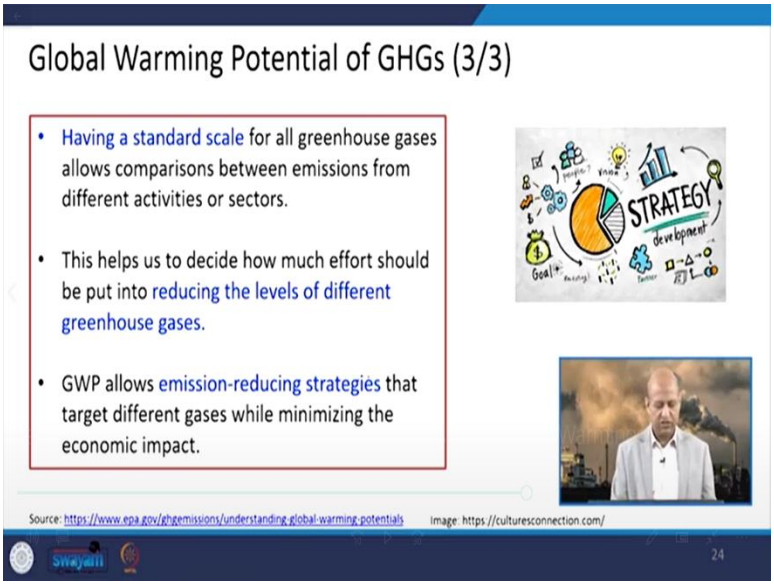
(Refer Slide Time: 15:56)

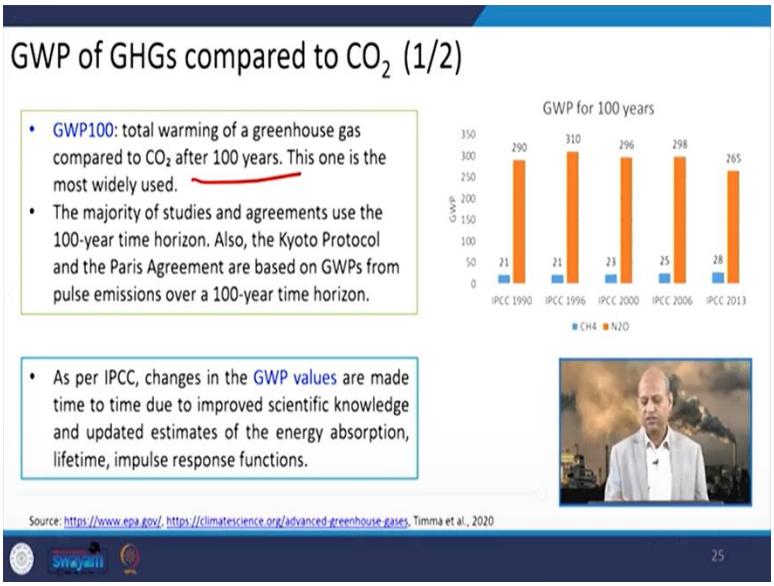




Then we talk about this global warming potential basically, as you as because different lifetime span is there for different gases. So, it will depend it will depend upon the these kind of two things like the trapping of the heat, how long this is stays in the atmosphere, how much intensity is it captures that potency. So, those things are there to decide whether it is very going it is going to intensify the global warming effect or not. Like methane stays around 12 years in the atmosphere, where a CO_2 can go for centuries. So, that will be effect, but because of their phenomena of capturing the heat as we have seen it is 25 times the methane. So, even like smaller in quantity, it will have more effect.

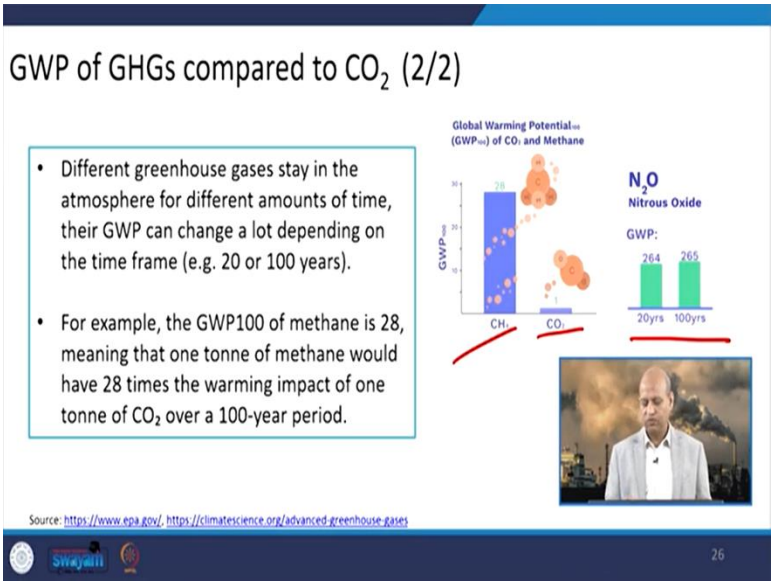
(Refer Slide Time: 17:01)

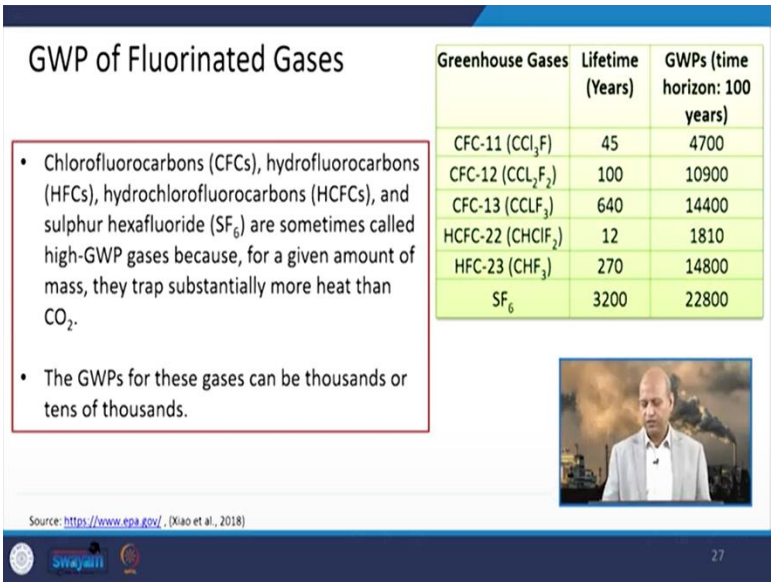




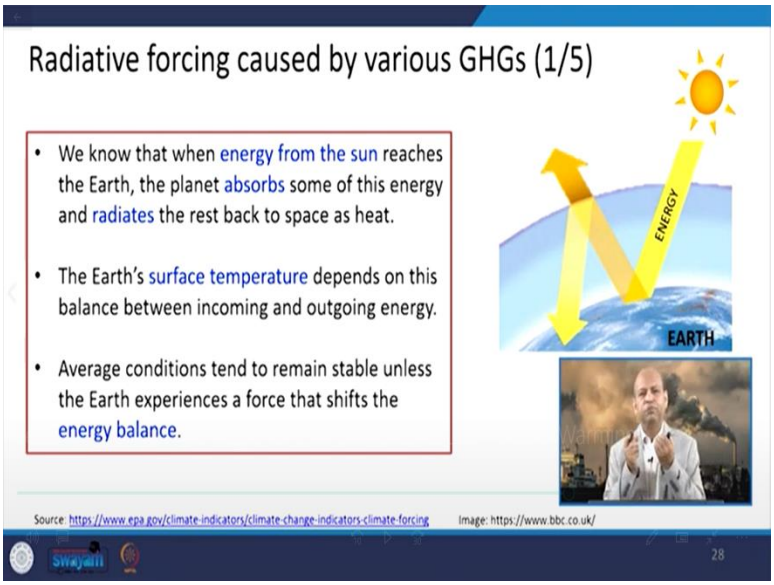
Well, when we talk about different kind of scales, so, emission reducing strategies are needed for that particular purpose. And if we talk about this GWP 100, so, total warming of greenhouse gas compared to CO_2 after 100 years, so, this one is the most widely used kind of thing. So, if you compare like different kinds of studies have been there through IPCC, so this meeting only 21 or so, and N_2O is 296 or 310. In different reports the quantities is varying, because scientific evidences are refining their potential that way the variation.

(Refer Slide Time: 17:46)



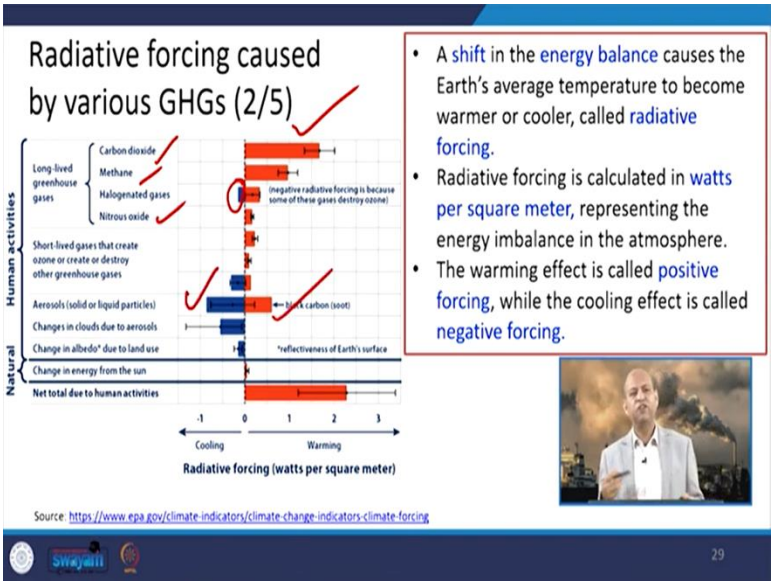


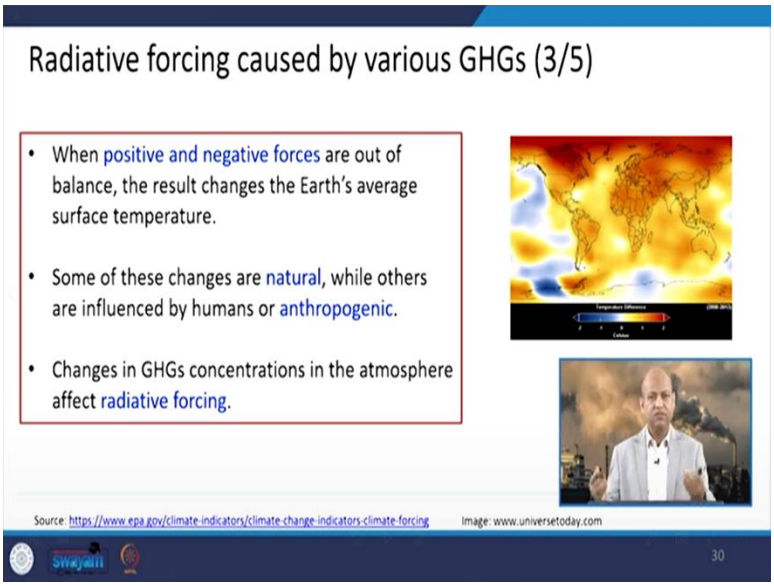
Greenhouse Gases	Lifetime (Years)	GWPs (time horizon: 100 years)
CFC-11 (CCl_3F)	45	4700
CFC-12 (CCL_2F_2)	100	10900
CFC-13 ($CCLF_3$)	640	14400
HCFC-22 ($CHClF_2$)	12	1810
HFC-23 (CHF_3)	270	14800
SF_6	3200	22800



Well, when we talk about global warming potential, again, the $CO_2$and methane around 28 times or 25 times and these N_2O can have different like 20 years or 100 years so, different values may be there. Well fluorinated gases, we have seen like 100 years, its potential may vary from 5000 to around 23,000 depending upon different coordinated gases. Well, radiative forcing is like how much positive or negative effect is there for example, clouds are reflecting the solar insulation which is coming. So, it will reflect so, it is causing cooling effect it so, its value is negative. When black carbon or some aerosols which capture the radiation then we call it positive forcing. So, that way greenhouse gases are having positive forcing.

(Refer Slide Time: 18:41)

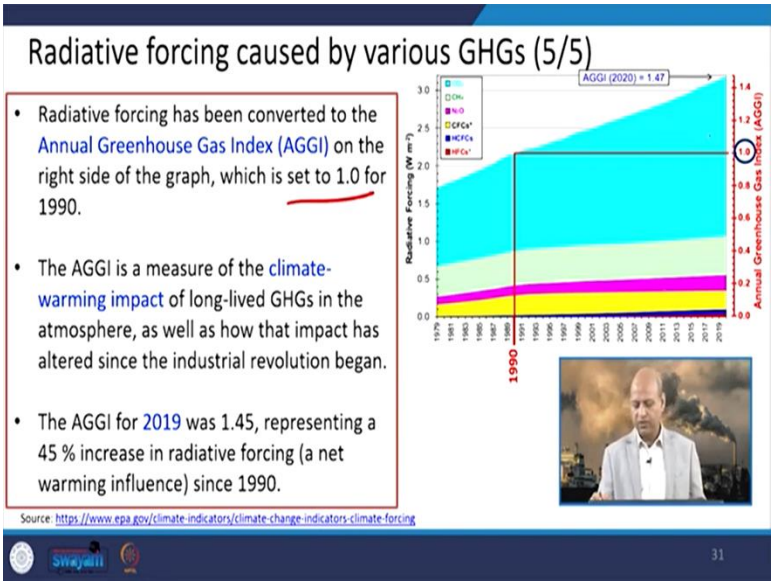


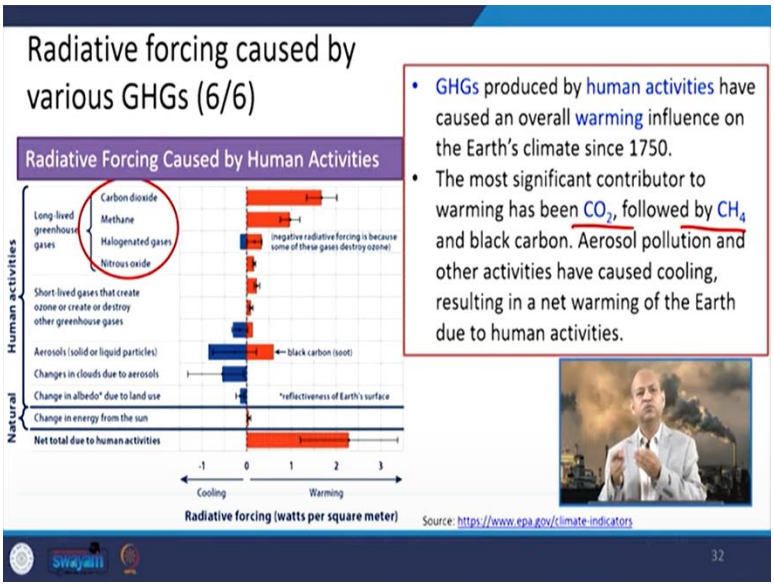


Carbon dioxide, methane all these nitrous oxide they are having positive forcing. Although, this negative radiative forcing is because of these gases destroy the ozone. So, that is why some part of these halogenated gases is having the negative impact because of contribution in destroying the ozone otherwise it is having the positive forcing.

Similarly, these aerosols like sulfate etc they are reflecting kind of nature. So, they have this negative and the black carbon aerosols they are having positive. So, but the net effect is positive forcing basically, which we if we add everything then we get that all these things add up into the positive forcing that means, they will increase the temperature because they will capture the heat.

(Refer Slide Time: 19:34)



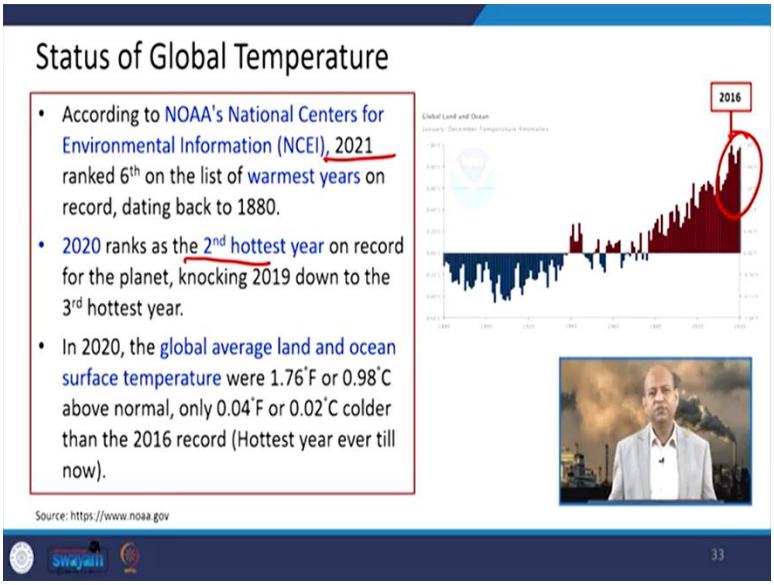


Then, if you see these radiative forcing, because of in terms of Annual Greenhouse Gas Index, so see over the years like 1990 if we take as 1 then in comparison to that, in 2019 it became around 1.4. So, that way because their concentrations are increasing their index related values are also increasing.

And, these various like CO_2, CH_4, all these are having because of human activities they are coming and then the aerosols are also being emitted. And it is said that because of health related issues we are reducing emissions of these particulate matter like $PM_{2.5}$, PM_{10}. So, there are some studies

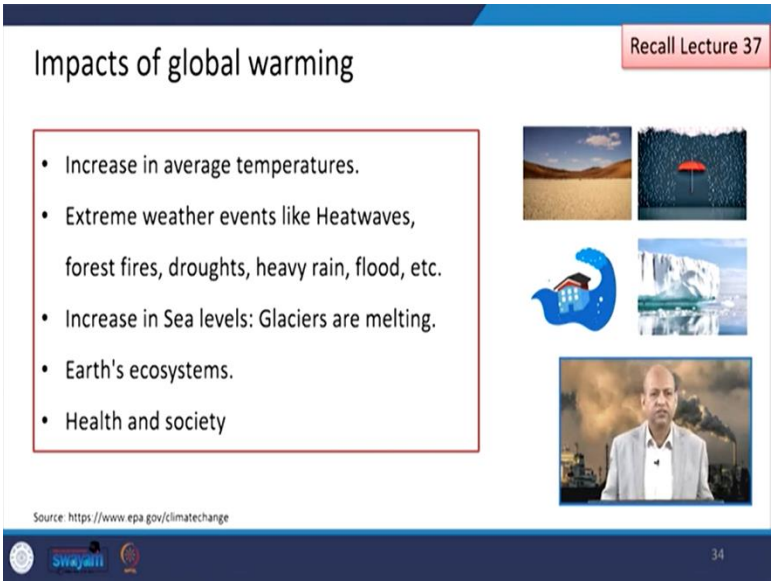
which say that, because these aerosols must part of these aerosols are having cooling effect. So, if we reduce then maybe more warming effect may be observed in future.

(Refer Slide Time: 20:32)



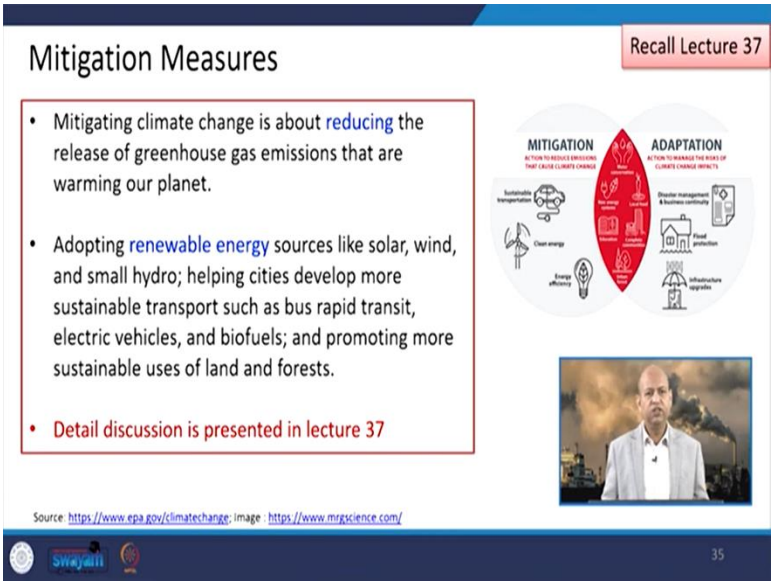
Well, if you talk about the status of the global temperature it is increasing in 20th century it is increasing and then 21st century the hottest these years have been observed. Like in 2016 the hottest day have been observed or the highest temperature have been observed the temperature. So in 2020 it ranks around second hottest year 2016 was the first one 6th is 2021 So, after 2002 the temperature is rather very high. So, it is a very worrisome phenomena, we have to really capture it or control it otherwise it would be difficult.

(Refer Slide Time: 21:15)



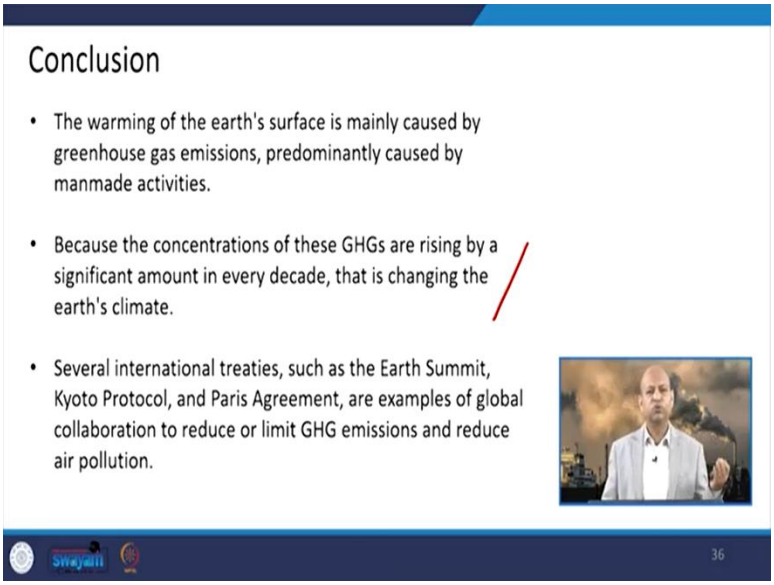
Then there are several impacts of the global warming, which has been discussed like in lecture 37 you can recall like it will not only increase the average temperature. But it will also increase into like heat waves or flood related phenomena, drought related phenomena, precipitation variation, extreme events of the precipitation or then the storms etc sea level rise, ecosystem will be disturbed, because temperatures are increasing in certain ecosystems, then it will disturb is complete, that balance. And then the Health and Society are affected, because, suppose in higher latitudes, and if temperature is increasing, then malaria related problems may also increase in those regions.

(Refer Slide Time: 21:59)



Well, if you talk about the mitigation, then the best way is to reduce greenhouse gas emissions, that means, we have to change our energy sources. So, that is why a lot of efforts are being made at the global level different countries are going for a different kind of renewable energy sources. In India, you might have seen a lot of emphasis is there on solar radiation or other kind of renewable resources, even mobility like we are going for e-mobility in a big way. So, that way we are going for reducing the emissions of greenhouse gases.

(Refer Slide Time: 22:36)



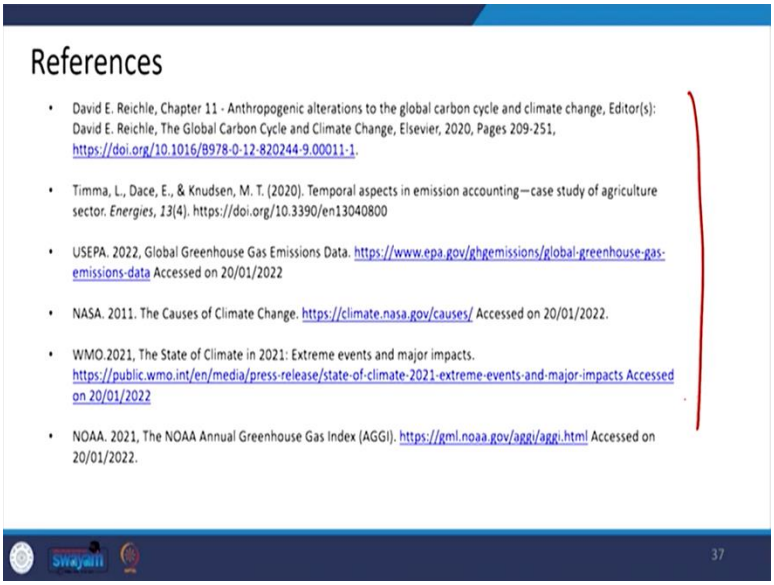
Although there are issues like some people talk that if we go for in a lifecycle assessment, then situations may be kind of different, but it is still in the mode of the research and there are two schools of thought, but at least when urban emissions are reduced, then health effects related issues will not be there.

But from global warming point of view, we have to see only those kind of technologies, which really helped us in reducing the greenhouse gas emissions. So that is we have to go for and like the concentrations have been rising since the pre-industrial era and they are increasing because of population is increasing, urbanization is increasing, industrialization is increasing.

So, if we have to reduce these emissions of greenhouse gases, then we have to go for better energy sources, which are not dependent upon fossil fuels, or we have to capture them, like carbon sequestration phenomena you might have heard. So we have to avoid them to go to that atmosphere that is the key thing.

And several agreements have been there at the global scale like earth's summit, Kyoto Protocol, Paris Agreement, etc. So, they are for capturing or reducing the greenhouse gas emissions so that we do not have this global warming effect, or we do not have the climate change related issues.

(Refer Slide Time: 24:03)



So thank you for your kind attention. And these are the references for additional reading for you. You can read it at leisure. And let us meet in the next lecture. Thanks again. Thank you.