

Air Pollution and Control
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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.

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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.

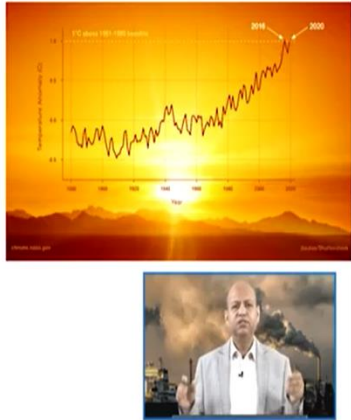
And then we will look into like what are different mitigation measures which can work for reducing the greenhouse gas emissions and we can curb this global warming related effects and we will conclude.

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Introduction: Global Warming

- Global warming is the **long-term heating** of Earth's climate system observed since the pre-industrial period (between **1850 and 1900**).
- Since the pre-industrial period, human activities have increased global surface average temperature by about **1°C or 1.8°F**.
- **Human activities**, primarily fossil fuel burning, increase heat-trapping greenhouse gases level in Earth's atmosphere.

Source: <https://climate.nasa.gov/resources/global-warming>



The slide contains a line graph showing global surface temperature from 1850 to 2020. The y-axis represents temperature in degrees Celsius, ranging from 10 to 16. The x-axis represents years from 1850 to 2020. The graph shows a fluctuating but overall increasing trend, with a significant rise starting around 1950. A red line highlights the temperature increase from 1850 to 1900, and a blue line highlights the increase from 1900 to 2020. A small video inset shows a man speaking, likely the presenter.

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 CO₂ etc. And they trap the heat which is outgoing from the planet, we will see how does this happen.

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Introduction: Global warming indicators

- Scientists have developed various indicators to see the intensity and possible impact of global warming, such as the Global Warming Potential (GWP), Radiative Forcing (RF), and Annual Greenhouse Gas Index (AGGI).
- This helps us to decide how much effort should be put into reducing the levels of different GHGs and allows emission-reducing strategies that target different gases while minimizing the economic impact.



Source: <https://niwa.co.nz/atmosphere> image: abcofagri.com

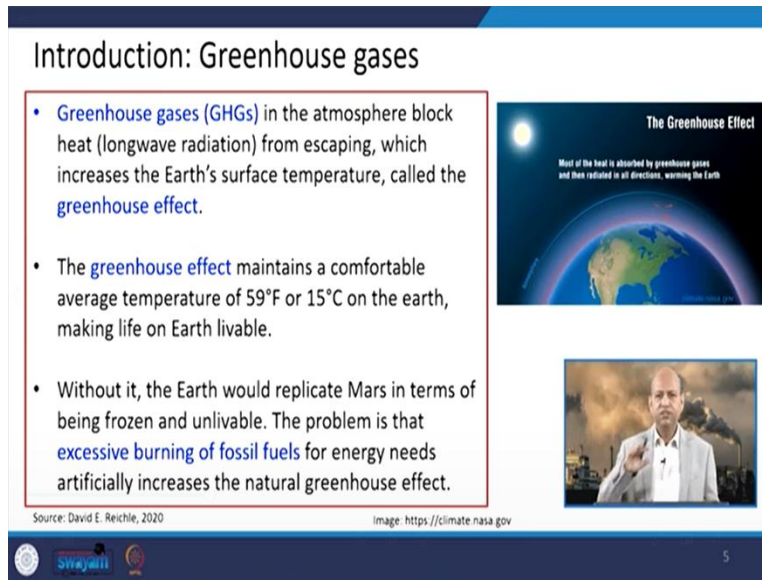
So, as I said that there are indicators like to measure the intensity and impact of global warming like Global Warming Potential (GWP) or radiative forcing or Annual Greenhouse Gas Index. So, we will discuss about these things later on. And they are needed because we want to study long term relationships 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.

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Introduction: Greenhouse gases

- Greenhouse gases (GHGs) in the atmosphere block heat (longwave radiation) from escaping, which increases the Earth's surface temperature, called the **greenhouse effect**.
- The **greenhouse effect** maintains a comfortable average temperature of 59°F or 15°C on the earth, making life on Earth livable.
- Without it, the Earth would replicate Mars in terms of being frozen and unlivable. The problem is that **excessive burning of fossil fuels** for energy needs artificially increases the natural greenhouse effect.

Source: David E. Reichle, 2020 Image: <https://climate.nasa.gov>



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.

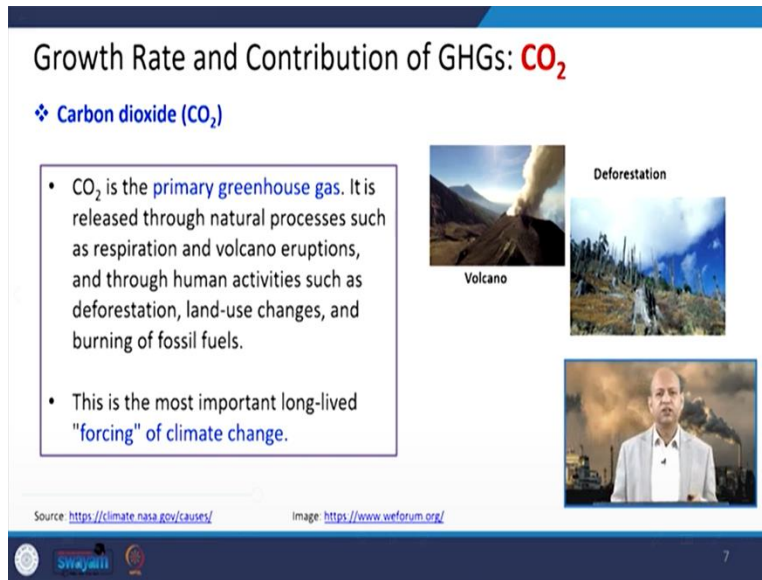
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Growth Rate and Contribution of GHGs: CO_2

❖ Carbon dioxide (CO_2)

- CO_2 is the **primary greenhouse gas**. It is released through natural processes such as respiration and volcano eruptions, and through human activities such as deforestation, land-use changes, and burning of fossil fuels.
- This is the most important long-lived "forcing" of climate change.

Source: <https://climate.nasa.gov/causes/> Image: <https://www.weforum.org/>



Volcano

Deforestation

Water vapor (H_2O)

Nitrous oxide (N_2O)

Carbon dioxide (CO_2)

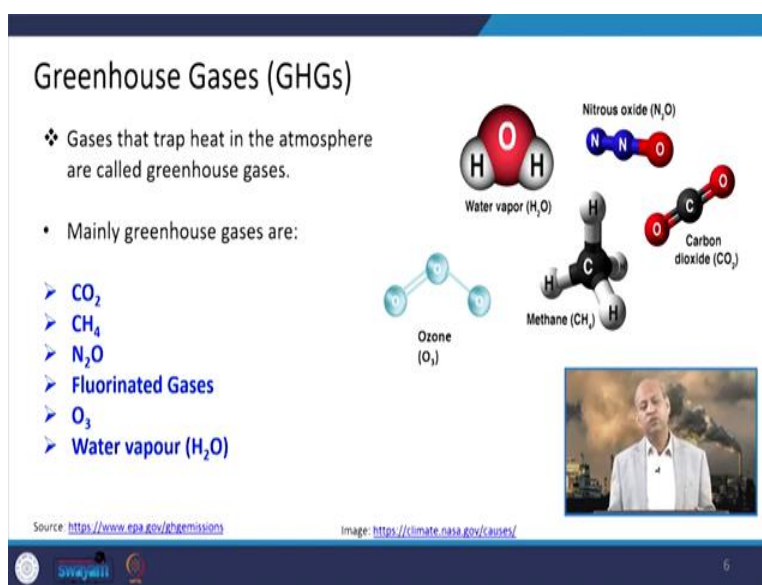
Methane (CH_4)

Ozone (O_3)

❖ Gases that trap heat in the atmosphere are called greenhouse gases.

- Mainly greenhouse gases are:
 - CO_2
 - CH_4
 - N_2O
 - Fluorinated Gases
 - O_3
 - Water vapour (H_2O)

Source: <https://www.epa.gov/ghgemissions> Image: <https://climate.nasa.gov/causes/>



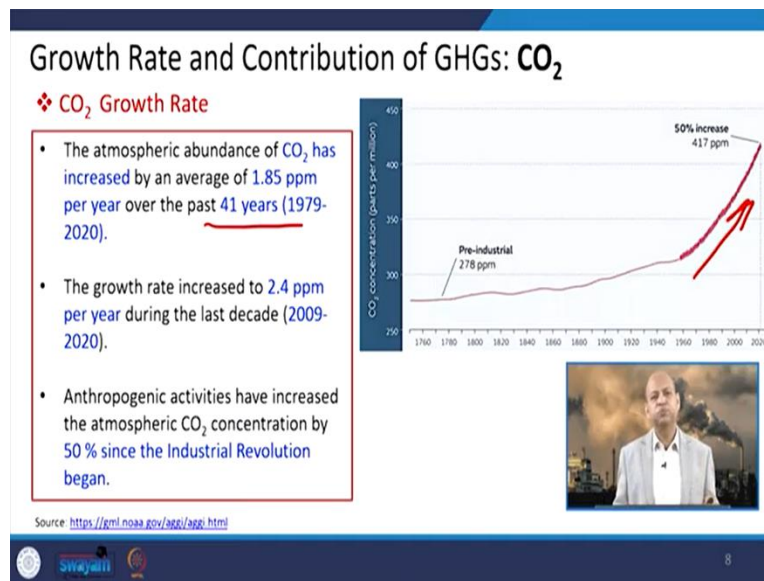
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So, when we talk about greenhouse gases, there are several gases which are having this kind of effect to absorb the infrared radiation or long wave radiation. And causing the heating effect basically, and these are like carbon dioxide, methane or nitrous 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 CO₂ and it goes into the atmosphere. And because, the lifetime of CO₂ 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 CO₂.

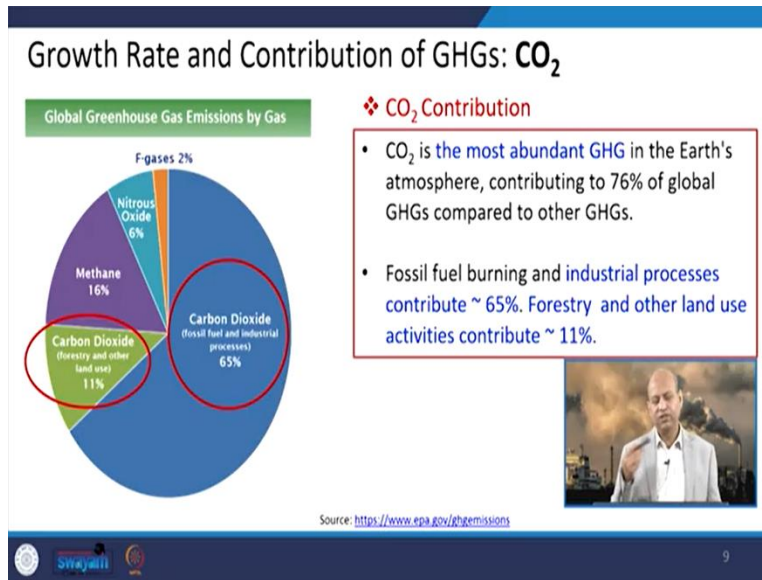
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Like, this atmospheric content or abundance of CO₂ has increased around an average around 1.85 ppm per year in the past 41 years from 1979 to 2020 this has been observed basically. And if you look into the last decade like 2009 to 2020 then it becomes rather more predominant like 2.4 ppm per year basically.

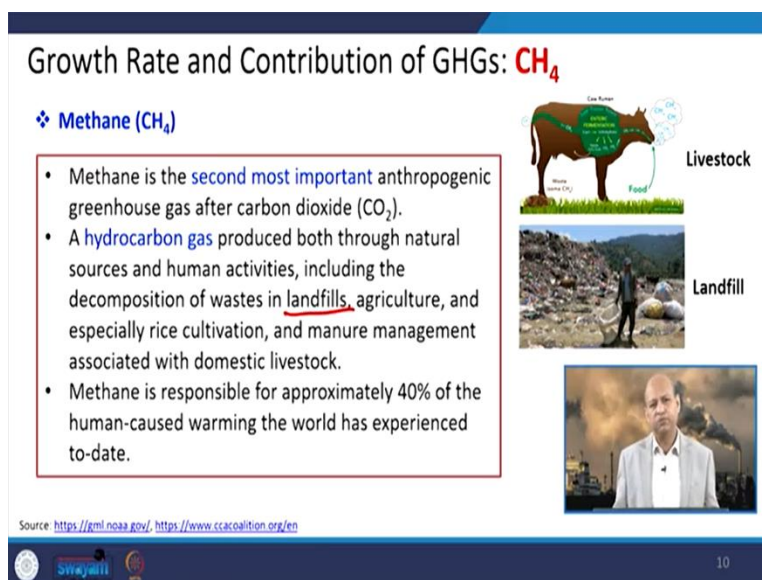
And this anthropogenic activities which are increasing the CO₂ concentration, they are like contributing in a large way and this huge steep increase of the CO₂ concentration in recent years basically. So, that is very problematic and 50 percent since the Industrial Revolution became so, that way the in a very small period a lot of concentration of CO₂ has increased, and that is the worrisome. Because, that has intensified this global warming phenomena, because of greenhouse gas effect.

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Well, when we look into the CO₂ 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 CO₂.

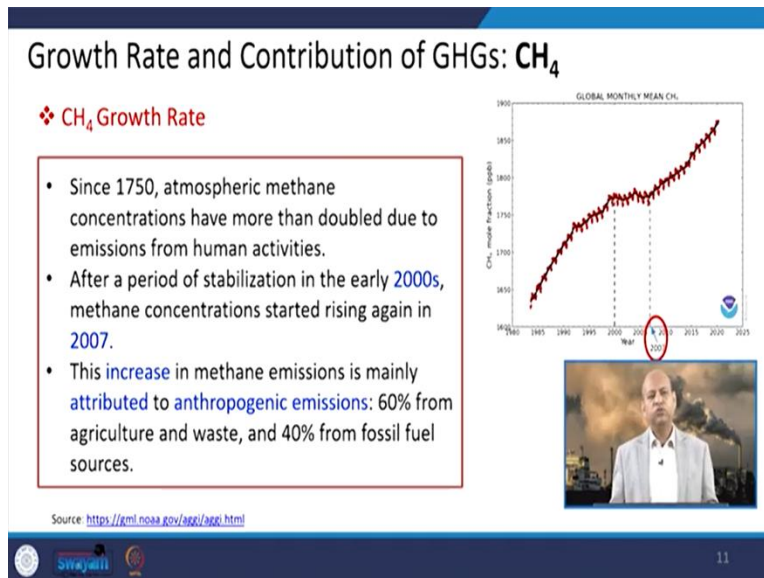
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When we talk about methane. So, methane comes from even natural sources like wetlands, etc plus these human activities like livestock and then these landfills where anaerobic digestion occurs or

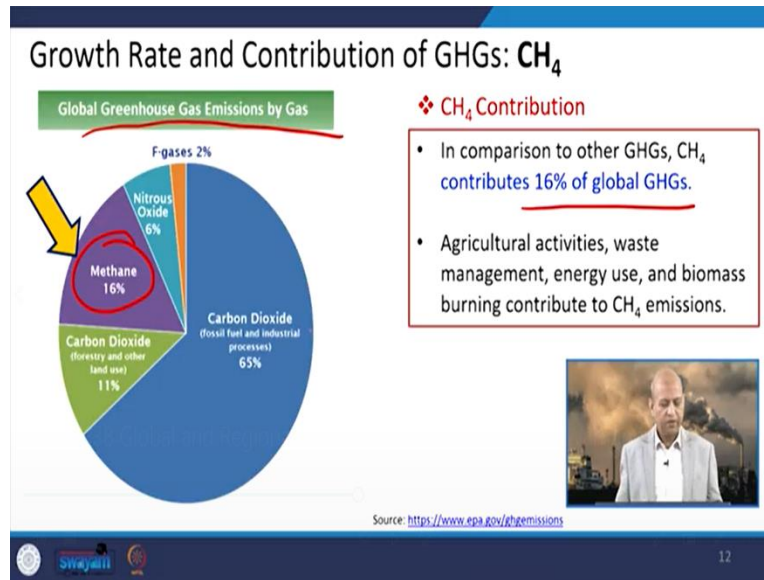
agriculture practices even rice cultivation etc they manure management all these activities contribute to methane emissions into the atmosphere. And this is responsible around 40 percent of the human caused warming means after CO₂ this is very important greenhouse gas in terms of global warming effect.

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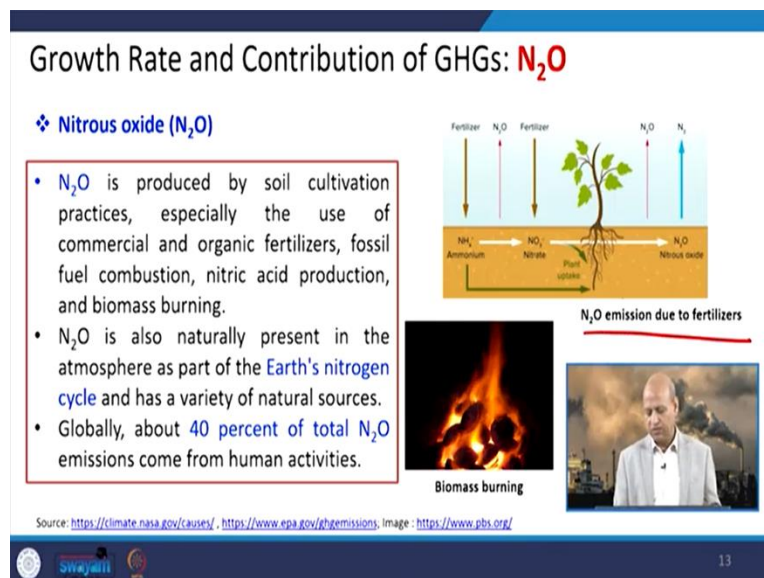
When we talk about its growth rate basically, from 1750 again we will see a lot of activities are there of human nature. So, this there was of course, some constant or little bit decrease, the increased rate but again from 2007 emissions of methane are increasing. So, they are related to several kind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

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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.

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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


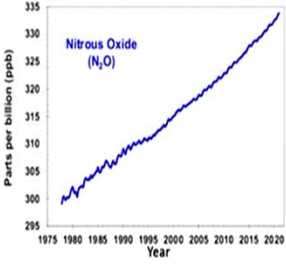
these kind of activities. And this is also very potent greenhouse gas and it contributes, although only around 2 percent.

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Growth Rate and Contribution of GHGs: N₂O

❖ N₂O Growth Rate

- The atmospheric burden of nitrous oxide (N₂O) grows over time.
- Furthermore, the annual increase in nitrous oxide's atmospheric burden, averaging 1.0 ppb yr⁻¹ over the past decade, is also increasing.
- The annual increase in 2020 was the largest recorded since measurements began.



Source: <https://gml.noaa.gov/aggi/aggi.html>

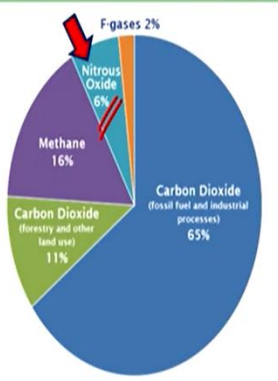
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But, as I said, because, this is also predominant after the methane. So, the growth rate it is increasing, because a lot of human activities are of that nature with contribution to the emissions of N₂O and it is around 1 ppb per year over the past decade, it is increasing, so, a lot of quantity of N₂O is coming out of these activities.

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Growth Rate and Contribution of GHGs: N₂O

Global Greenhouse Gas Emissions by Gas



❖ N₂O Contribution

- In comparison to other GHGs, N₂O contributes 6% of global GHGs.
- Agricultural activities, such as fertilizer use, are the primary source of N₂O emissions. Fossil fuel combustion also generates N₂O.

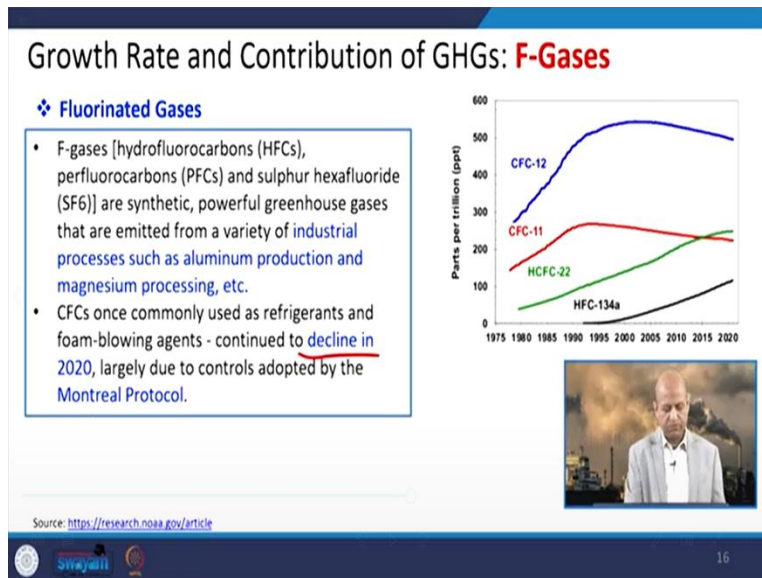


Source: <https://www.epa.gov/ghgemissions>

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And 6 percent around 6 percent of the greenhouse gases and is because of into this is the third largest contribution, CO₂, 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.

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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 CO₂. 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.

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Growth Rate and Contribution of GHGs: F-Gases

Global Greenhouse Gas Emissions by Gas

Gas	Contribution (%)
Carbon Dioxide (fossil fuel and industrial processes)	65%
Carbon Dioxide (forestry and other land use)	11%
Methane	16%
Nitrous Oxide	6%
F-gases	2%

❖ Contribution of Fluorinated Gases

- In comparison to other GHGs, fluorinated gases contribute around 2% of global GHGs.
- Industrial processes, refrigeration, and the use of various consumer products contribute to emissions of fluorinated gases.



Source: <https://www.epa.gov/ghgemissions>

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Growth Rate and Contribution of GHGs: Ozone

Recall Lecture 37

❖ Ozone (O_3) [1/2]

- Tropospheric, or ground-level ozone, is not emitted directly into the air but it is created by chemical reactions between oxides of nitrogen (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight.
- Main sources of these pollutants such as NO_x and VOCs are cars, power plants, industrial boilers, refineries, chemical plants, and other sources.

How ground-level ozone forms

Ultraviolet light transforms molecules

VOCs, NO_x → Ozone


VOCs, NO_x → Ozone

VOCs → Ozone

Tailpipe emissions, fuel vapors

Smelterstack emissions and vapors from some chemicals, fuels

Heating system and vapors from some chemicals, fuels



Source: <https://www.epa.gov/ground-level-ozone>

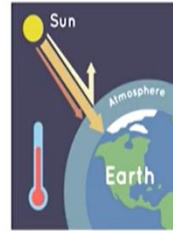
Image: <https://theconversation.com/>

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Growth Rate and Contribution of GHGs: Ozone

Ozone (O₃) [2/2]

- Ground level ozone absorbs infrared radiation emitted by the Earth's surface, effectively trapping heat in the troposphere.
- So, it shows the **warming effect** on the Earth's surface, thereby contributing to the "greenhouse" effect.



Source: <https://www.epa.gov/ground-level-ozone>

Image: climatekids.nasa.gov



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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.

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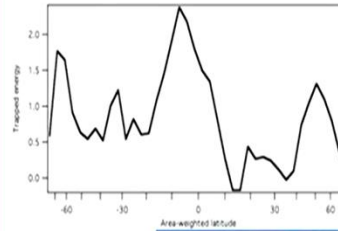
Growth Rate and Contribution of GHGs: **Water vapor**

❖ Water vapor (H₂O) [1/2]

- The most abundant greenhouse gas, but importantly, it acts as a **feedback process** to the climate.
- Increased water vapor content in the atmosphere is referred to as a feedback process.
- Water vapour does **absorb longwave radiation and radiates it back to the Earth's surface**, thus contributing to warming.

Source: https://www.nasa.gov/topics/earth/features/vapor_warming.html

Based on climate variations between 2003 and 2008, the energy trapped by water vapor, Peak near the equator



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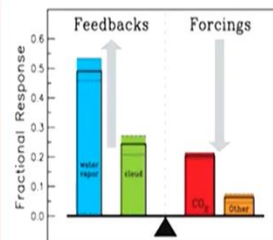
Growth Rate and Contribution of GHGs: **Water vapor**

Water vapor (H₂O) [2/2]

- Water vapour stays in the atmosphere for a much shorter period (in days) compared to other greenhouse gases such as CO₂ or CH₄, which stay in the atmosphere for a much longer period (ranging from years to centuries).
- Water vapour feedback can further magnify the warming effect of other greenhouse gases, allowing more water vapour to enter the atmosphere as a result of rising carbon dioxide levels.

Source: https://www.nasa.gov/topics/earth/features/vapor_warming.html

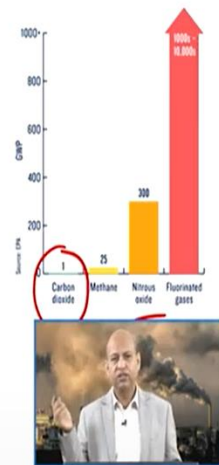
image: <https://uvachemistry.com/>



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Global Warming Potential of GHGs (1/3)

- The Global Warming Potential (GWP) was developed to allow comparisons of the global warming impacts of different gases.
- The GWP of greenhouse gas is its ability to trap an extra amount of heat in the atmosphere over time relative to 1 ton of CO₂ emissions.
- The more significant the GWP, the more that a given gas warms the Earth compared to CO₂ over that period.
- The period usually used for GWPs is 100 years.



Source: <https://www.epa.gov/ghgemissions/understanding-global-warming-potentials>



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.

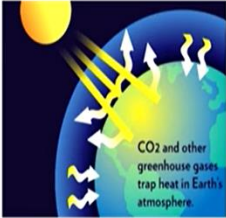
So, basically, it is a kind of vicious cycle, , because, as it goes, it contributes to the global warming effect or because of greenhouse gas effect. So that way means more temperature, more vapor and more again that this greenhouse gas effect. So, feedback mechanism is there and then the forcing of these CO₂ 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.


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Global Warming Potential of GHGs (2/3)

- ❖ The GWP depends on two things:
 - How effective the gas is at trapping heat while it's in the atmosphere, and
 - How long it stays in the atmosphere before it breaks down.
 - For example, CH_4 breaks down relatively quickly; the average CH_4 molecule stays in the atmosphere for around 12 years. On the other hand, CH_4 traps heat more effectively than CO_2 , having a much longer lifetime.



CO₂ and other greenhouse gases trap heat in Earth's atmosphere.

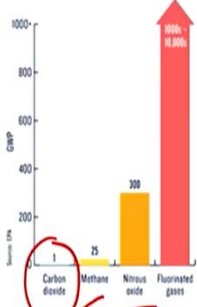


Source: <https://niwa.co.nz/atmosphere> Image: <https://ecosystemsunit.com>


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Global Warming Potential of GHGs (1/3)

- The **Global Warming Potential (GWP)** was developed to allow comparisons of the **global warming impacts of different gases**.
- The GWP of greenhouse gas is its ability to trap an extra amount of heat in the atmosphere over time **relative to 1 ton of CO₂ emissions**.
- The more significant the GWP, the more that a given gas warms the Earth compared to CO₂ over that period.
- The period usually used for GWPs is 100 years.



Gas	GWP (100 years)
Carbon dioxide	1
Methane	25
Nitrous oxide	300
Fluorinated gases	1000 - 10,000



Source: <https://www.epa.gov/ghemissions/understanding-global-warming-potentials>



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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 CO₂ 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.

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Global Warming Potential of GHGs (3/3)

- Having a **standard scale** for all greenhouse gases allows comparisons between emissions from different activities or sectors.
- This helps us to decide how much effort should be put into **reducing the levels of different greenhouse gases**.
- GWP allows **emission-reducing strategies** that target different gases while minimizing the economic impact.

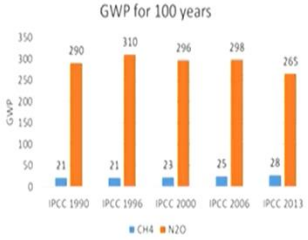


Source: <https://www.epa.gov/ghgemissions/understanding-global-warming-potentials> Image: <https://culturesconnection.com/>

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GWP of GHGs compared to CO₂ (1/2)

- **GWP100**: total warming of a greenhouse gas compared to CO₂ after 100 years. This one is the most widely used.
- The majority of studies and agreements use the 100-year time horizon. Also, the Kyoto Protocol and the Paris Agreement are based on GWPs from pulse emissions over a 100-year time horizon.



IPCC Report	CH4 GWP	N2O GWP
IPCC 1990	21	290
IPCC 1996	21	310
IPCC 2000	23	296
IPCC 2006	25	298
IPCC 2013	28	265

- As per IPCC, changes in the **GWP values** are made time to time due to improved scientific knowledge and updated estimates of the energy absorption, lifetime, impulse response functions.



Source: <https://www.epa.gov/>, <https://climatescience.org/advanced-greenhouse-gases>, Timma et al., 2020

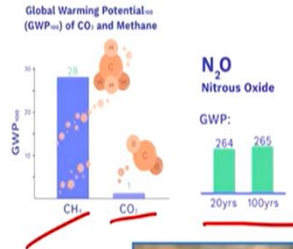
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Well, when we talk about different kind of scales, so, emission reducing strategies are needed for that particular purpose. And if we talk about this GWP 100, so, total warming of greenhouse gas compared to CO₂ after 100 years, so, this one is the 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 N₂O is 296 or 310. In different reports the quantities is varying, because scientific evidences are refining their potential that way the variation.

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GWP of GHGs compared to CO₂ (2/2)

- Different greenhouse gases stay in the atmosphere for different amounts of time, their GWP can change a lot depending on the time frame (e.g. 20 or 100 years).
- For example, the GWP₁₀₀ of methane is 28, meaning that one tonne of methane would have 28 times the warming impact of one tonne of CO₂ over a 100-year period.



Source: <https://www.epa.gov/>, <https://climatescience.org/advanced-greenhouse-gases>



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GWP of Fluorinated Gases

- Chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), hydrochlorofluorocarbons (HCFCs), and sulphur hexafluoride (SF₆) are sometimes called high-GWP gases because, for a given amount of mass, they trap substantially more heat than CO₂.
- The GWPs for these gases can be thousands or tens of thousands.

Greenhouse Gases	Lifetime (Years)	GWPs (time horizon: 100 years)
CFC-11 (CCl ₃ F)	45	4700
CFC-12 (CCL ₂ F 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



Source: <https://www.epa.gov/>, (Xiao et al., 2018)



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Radiative forcing caused by various GHGs (1/5)

- We know that when **energy from the sun** reaches the Earth, the planet **absorbs** some of this energy and **radiates** the rest back to space as heat.
- The Earth's **surface temperature** depends on this balance between incoming and outgoing energy.
- Average conditions tend to remain stable unless the Earth experiences a force that shifts the **energy balance**.



Source: <https://www.epa.gov/climate-indicators/climate-change-indicators-climate-forcing>

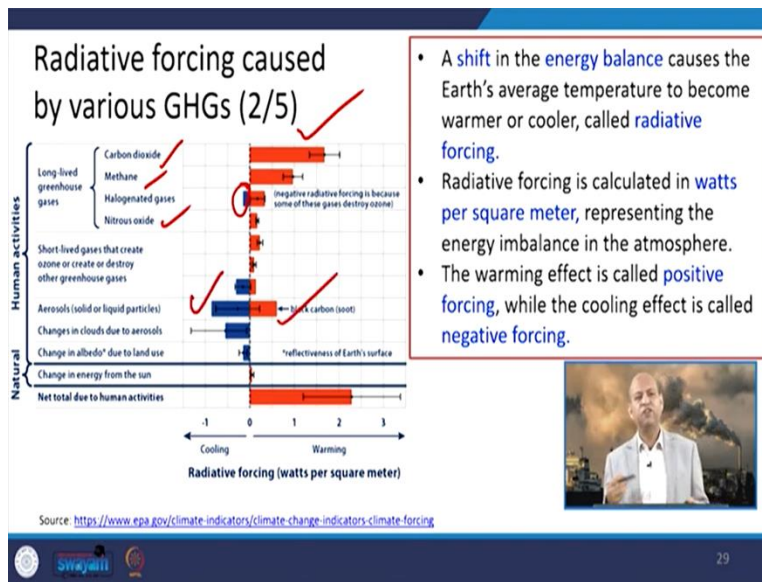
Image: <https://www.bbc.co.uk/>



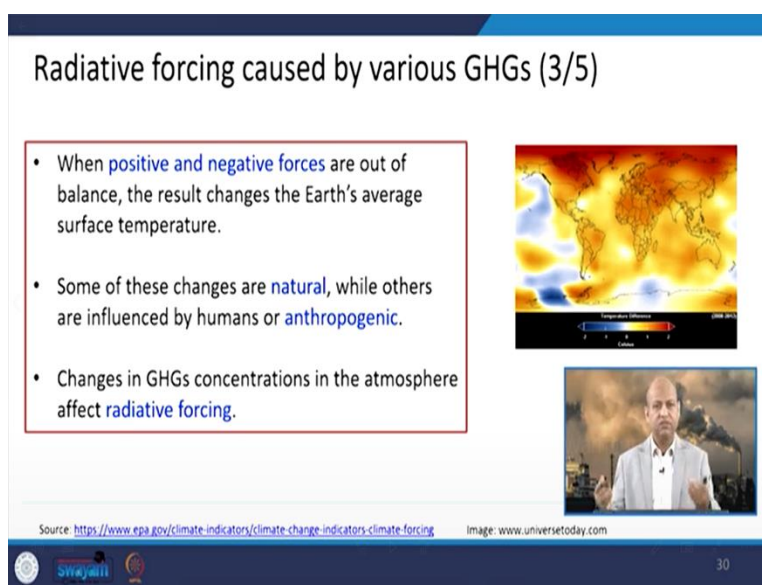
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Well, when we talk about global warming potential, again, the CO₂ and methane around 28 times or 25 times and these N₂O can have different like 20 years or 100 years so, different values may be there. Well fluorinated gases, we have seen like 100 years, 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.

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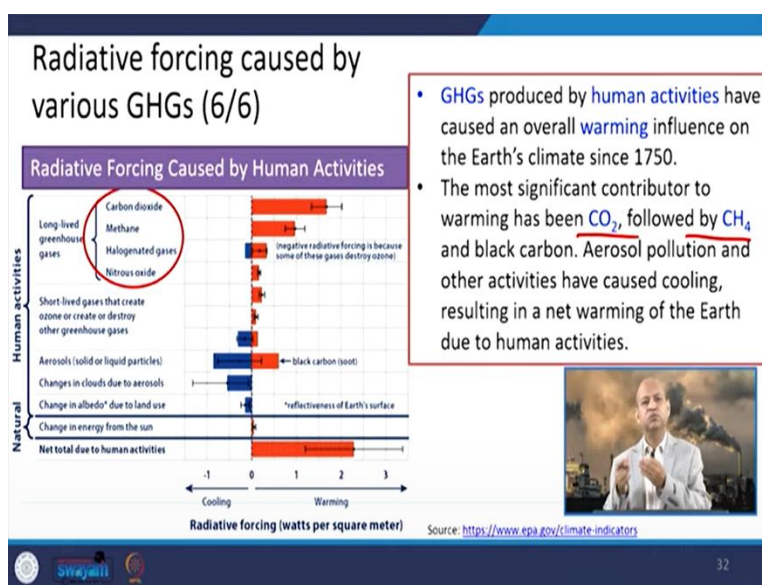
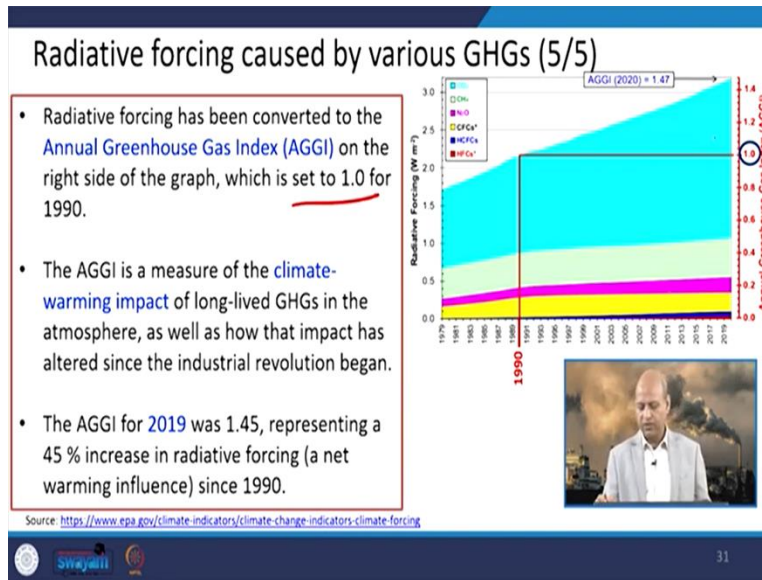
- A shift in the **energy balance** causes the Earth's average temperature to become warmer or cooler, called **radiative forcing**.
- Radiative forcing is calculated in **watts per square meter**, representing the energy imbalance in the atmosphere.
- The warming effect is called **positive forcing**, while the cooling effect is called **negative forcing**.



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.

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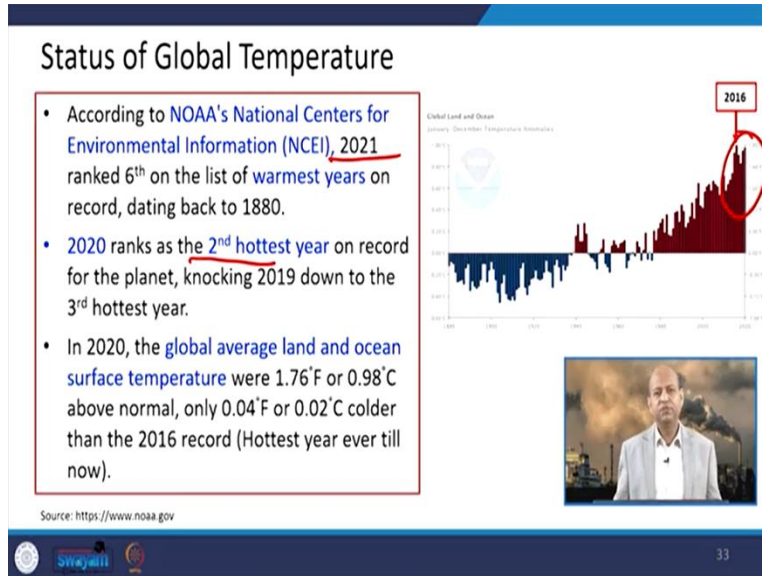


Then, if you see these radiative forcing, because of in terms of Annual Greenhouse Gas Index, so see over the years like 1990 if we take as 1 then in comparison to that, in 2019 it became around 1.4. So, that way because their concentrations are increasing their index related values are also increasing.

And, these various like CO₂, CH₄, 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}, PM₁₀. 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.

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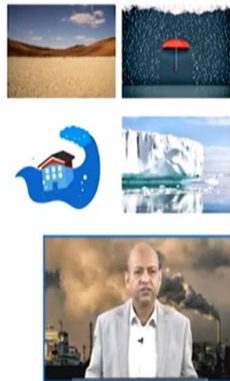
Well, if you talk about the status of the global temperature it is increasing in 20th century it is increasing and then 21st century the hottest these years have been observed. Like in 2016 the hottest day have been observed or the highest temperature have been observed the temperature. So in 2020 it 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.

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Impacts of global warming

Recall Lecture 37

- Increase in average temperatures.
- Extreme weather events like Heatwaves, forest fires, droughts, heavy rain, flood, etc.
- Increase in Sea levels: Glaciers are melting.
- Earth's ecosystems.
- Health and society



Source: <https://www.epa.gov/climatechange>

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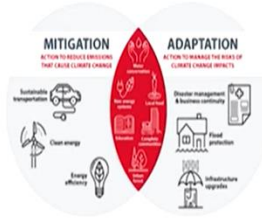
Then there are several impacts of the global warming, which has been discussed like in lecture 37 you can recall like it will not only increase the average temperature. But it will also increase into like heat waves or flood related phenomena, drought related phenomena, precipitation variation, extreme 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.

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Mitigation Measures

Recall Lecture 37

- Mitigating climate change is about **reducing** the release of greenhouse gas emissions that are warming our planet.
- Adopting **renewable energy** sources like solar, wind, and small hydro; helping cities develop more sustainable transport such as bus rapid transit, electric vehicles, and biofuels; and promoting more sustainable uses of land and forests.
- **Detail discussion is presented in lecture 37**



Source: <https://www.epa.gov/climatechange>; image: <https://www.mrgscience.com/>


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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.

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Conclusion

- The warming of the earth's surface is mainly caused by greenhouse gas emissions, predominantly caused by manmade activities.
- Because the concentrations of these GHGs are rising by a significant amount in every decade, that is changing the earth's climate.
- Several international treaties, such as the Earth Summit, Kyoto Protocol, and Paris Agreement, are examples of global collaboration to reduce or limit GHG emissions and reduce air pollution.



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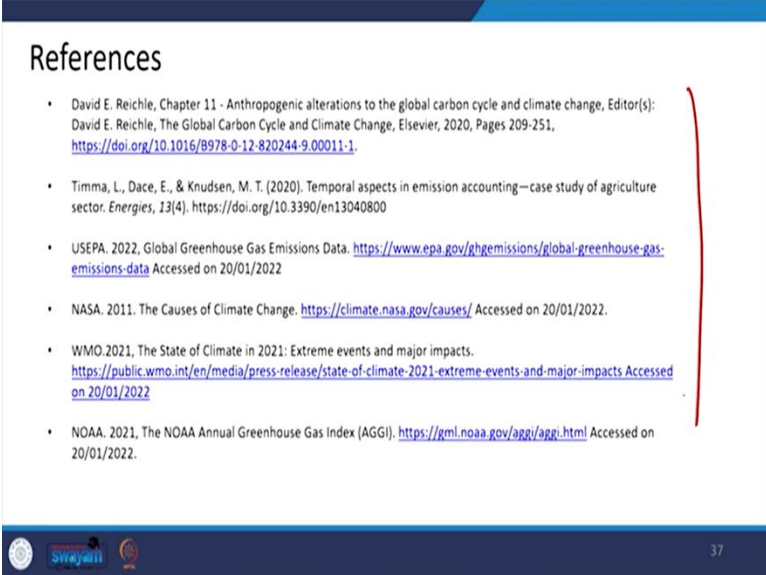
Although there are issues like some people talk that if we go for in a lifecycle assessment, then situations may be kind of different, but it is still in the mode of the research and there are two schools of thought, but at least when urban emissions are reduced, then health effects related issues will 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.

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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.