Energy Resources, Economics, and Sustainability

Prof. Pratham Arora

Hydro and Renewable Energy Department

Indian Institute of Technology Roorkee, Roorkee, India

Week – 06

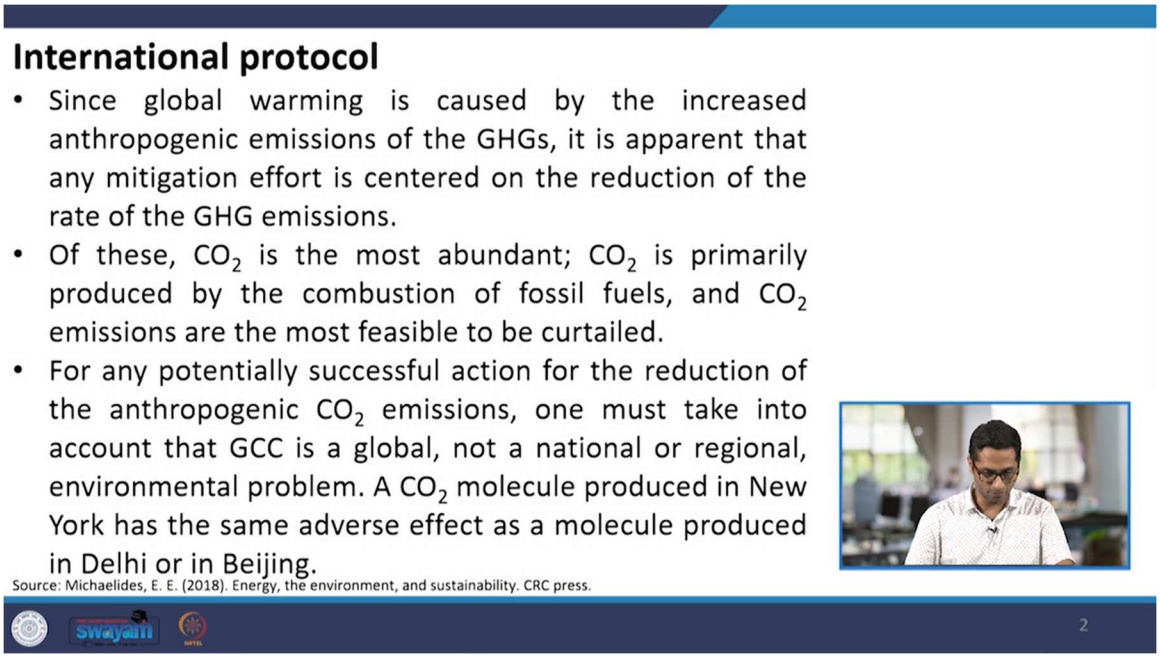
Lecture – 01

Lecture 27 - Global Climate Change Mitigation: International Protocol

Hello everyone, welcome back to the course Energy Resources, Economics and Sustainability. In the past few classes, we have been discussing the problem centered around the global climate change. We have been discussing what could be different mitigation options which could vary from increasing the efficiency to moving towards more renewable types of fuels, towards growing more trees, seeding of the oceans, using carbon dioxide for sequestration as well as for the utilization pathways. And we have also tried to discuss some of the advantages and weaknesses of these mitigation measures. It also becomes important to understand the major agreements, protocols or agreements that have been happening globally to counter this very specific problem of global climate change. We have heard about treaties, protocols such as the Kyoto Protocol or the Paris Agreement or the Gagli agreement which are centered around this very important issue.

So, let us in this particular class try to understand what were these agreements that were happening in the past, what were their specific objectives and what was it that these agreements wanted to achieve and what was the result of the agreement being in place. So, starting with again with the global climate change, we all understand this is more of a global problem rather than a regional problem. So, the earlier cases that we have discussed in case of the sulphur abatement, the lead abatement as well as ozone depletion were more regional in nature as compared to global. These are coming from few specific chemicals that were emitting because of the combustion of fuels but these chemicals were

very small in amount. But if we talk about the specific problem of global climate change, one of the major reasons for that are the greenhouse gas emissions, greenhouse gases and even among the greenhouse gases, CO2 or carbon dioxide plays a prominent role. And this CO2 has its major source in the combustion of fossil fuels. A majority of CO2 that we experience in the world today is being emitted because of the energy consumption that is relying on fossil fuels and because all of the fossil fuels be it be crude, oil, the coal or the natural gas are centered around carbon for a source of energy and the natural product for their combustion would be the CO2.



Further, it is also have been understood that anthropogenic emissions which is the emissions coming from the human activities are the major cause for the increase in the CO2. And CO2 to repeat again is more of a global problem.

If I release a molecule of CO2 in Delhi, it is as potent as CO2 molecule in Venice or in New York. There is going to be no major difference because the global warming effect that it is going to put is almost going to be similar. And this is what makes this problem a bit more important and a bit more difficult to tackle. And in the past because different scientific communities have been working towards advocacy of bringing the levels of CO2 down, there have been a series of agreements and first such agreement that was to take place was the Kyoto Protocol.

Kyoto protocol

- The Kyoto Protocol, created within the UN Framework Convention on Climate Change, was an agreement reached between several nations, for the reduction of global CO_2 emissions.
- The first phase of the protocol called for the industrialized countries to reduce their collective GHG emissions by an average 5.2% from the 1990 levels. It also made provisions for the transfer of energy conservation technology to developing nations and suggested restrictions for the growth of CO_2 emissions in the developed nations.
- Specifically, the Kyoto protocol stipulated 8% CO_2 emissions reduction for the countries of the EU, 7% reduction for the United States, 6% for Japan, and 0% for Russia. The protocol has been ratified by most (192) UN countries, with two notable exceptions: the United States and the People's Republic of China (PRC).
- Most of the signatories of the first phase, specially the EU and Japan, have taken significant and meaningful steps for the reduction of their GHG emissions, in the period of 1997–2010, the United States actually increased its CO_2 emissions by 16%, and the PRC, by 130%.

Source:https://www.britannica.com/event/Kyoto-Protocol

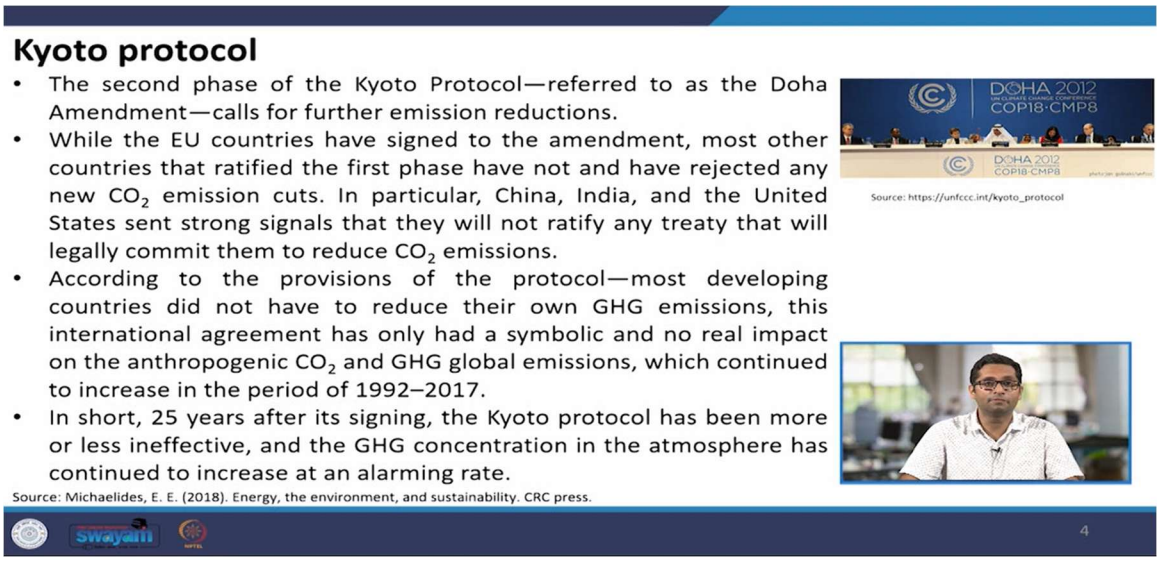
Source: Michaelides, E. E. (2018). Energy, the environment, and sustainability. CRC press.

It happened in the city of Kyoto in Japan. So, this meeting was held in the year 1997 and the signing parties agreed to put into practice their agreement from the year 2005. It was ratified by majority of countries of the UN like almost more than 150 countries and they all aimed at reducing the CO2 emissions. The emission reductions were much more stringent for the developed world as compared to the developing world. It also aimed at reduction of the total CO2 emissions by around 5.2% as compared to 1990 level.

And it also stipulated that around 8% CO2 reduction were to happen in the European Union, around 7% reduction in the United States, 6% in Japan and 0% for Russia. And as a success, this particular agreement was ratified means it was agreed by the voting in their respective parliaments by around 192 nations apart from two major ones and these were the US and the China. And if we see in the past trends of the CO2 emissions, we also understand these two are the leading producers of CO2 globally. So, this particular agreement was ratified by a majority of nations globally apart from two major countries which also happened to the major producers of CO2 and they were the US and the China. And we also see that there were major steps that were taken specifically in the EU, in the European Union as well as Japan. They made good steps towards reducing their CO2 emissions as a whole. But if we see the level of CO2 that was coming out from the two particular countries, the US and the China, they had a drastic increase. So, if we see the CO2 levels increase for the US specifically in the period of 1997 to 2010 which is the period in which a maximum progress was made under the ambit of Kyoto Protocol by

countries in the EU and Japan. The US almost increased its emission by around 16% and if you consider China it was around 130%. So, this was the period when China became the manufacturer of the world.

The growth was boosted by a lot of coal consumption or coal-based electricity production or coal-based energy production and it has a lot of emissions being produced in that particular period. So, there were a huge emissions that were taking place and they were by far like the emissions were too ahead of the reductions made by other countries in the form of Japan and the EU. And that was one of the reasons why we saw that the emissions of the CO2 in the past two or three decades have been consistently increasing, there has been no dip.



Further, there was a second addition to this particular protocol which is also called the Doha Amendment to the protocol that happened in the year 2012. It was specifically in the city in the Middle East and wherein there were further stringent guidelines adopted by the countries to further reduce their emissions apart from the ones laid down by the earlier Kyoto Protocol. But then again the protocol was not accepted by major countries including China, India and United States. Much of the developing world didn't want it to go for any binding agreements because this would involve doing away with the economic progress. We would have to understand that this was a major period of economic growth that the major countries were going through and going or adopting the reduction in GHG emissions meant putting a cap on the energy production which again meant capping the

economic growth of the specific countries. So most of the economic development as we have also discussed in the initial few classes is very nicely linked with energy consumption. So if you are capping the energy consumption per capita or the energy consumption by the industry, you are also putting a cap on the economic well-being of the people which they didn't much of the developing world didn't agree to.

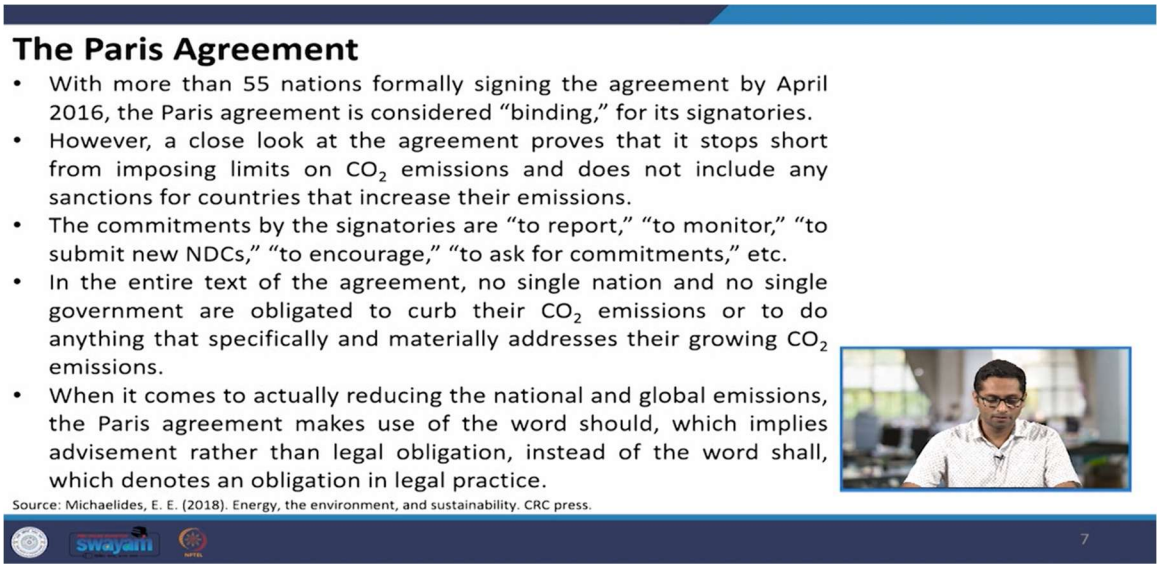
And we saw that the second amendment to the protocol didn't had much of an effect and the emissions continued to rise. So if we see for more than 25 years after the signing of the agreement like the Kyoto Protocol Academy said to be more or less ineffective. There had been significant emission reductions in a few countries specifically those of the European Union as well as Japan. But they were nowhere as compared to the emission increase that was happening in the US, the China and other parts of the developing world. So the GHG emissions as such continued to rise in the past three decades and that was happening at a very fast pace.

Further comes the year 2015. We have the important countries or the leaders of the country meeting up in Paris and this is also commonly known as the Paris Agreement or the COP26, sorry COP21 when all the parties agreed to bring in their nationally determined contributions. Earlier it was the INDC which meant Intentionally Nationally Determined Contributions and finally when these were ratified by their respective decision making bodies they became the nationally determined contributions. The aim as

such of this agreement was that all the major countries came together which included the EU countries, the United States, India, China, Russia and others came in together to accept that they would have to keep the global temperature increase to below 2 degree Celsius and also make as much effort as possible to decrease that to 1.5 degree Celsius. Because that is one of the benchmarks that have been agreed on by the different global climate change models that beyond this there would be different natural consequences over the sea level rise that would have serious economic consequences. Further all the different countries or the signatories were given the freedom of choosing their binding commitments. It is not that it was the same commitments for each country but each country was basically encouraged to come up with their own binding constraints and also they were also expected to increase this NTCs or update this NTCs every five years. The recent update was also made by India in 2022 and all the signatories were also expected to report their emissions on a regular basis. India also published in the BUR or the Binaal Update Report and that puts into effect what has been the emission reductions so far since the signing of the Paris Agreement, what has been the progress, what is the target and how is India going towards achieving those targets.

Further it has also been putting in the obligations of the developed world to support the efforts of the developing countries. It was also understood that developed world has a major role to play in helping the developing world in terms of what technologies and the funding. So the developed world has certain technologies which can help in increasing

the efficiency as well as harvesting energies from new and renewable sources which is to some extent unavailable in the developing world. So it was also expected that around 100 billion dollars of funds would be available annually to support the developing world in terms of the research and the application of the new technologies and it also encouraged voluntary actions from the developing countries. Then there was also mechanism to address the laws and damage resulting from the climate change and it also made sure there was no double counting on reporting the international emissions. An example could be much of the manufacturing is now done in China so how would you basically put in the CO2 emissions for the product that is used in Europe but manufactured in China. So it made a first that the emissions are attributed to the right place and there's no double counting of the emissions.

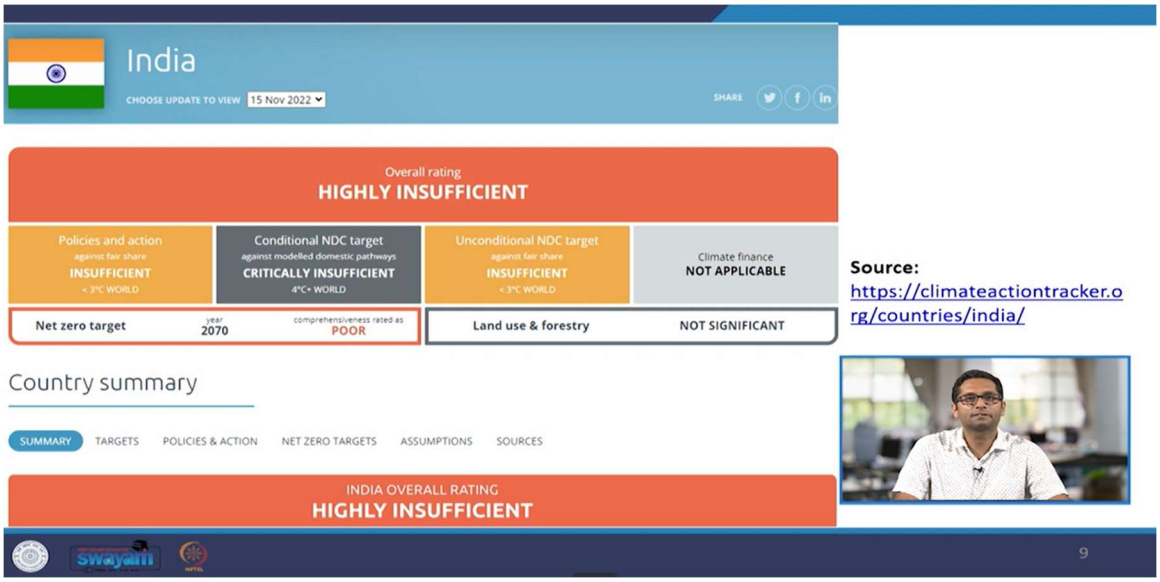


Further at the onset it was basically signed by more than 55 nations which in itself was a big achievement because till that point of time there was no major consensus taking place about the problem of climate change. We had major leaders denying its very existence but the Paris agreement being signed in the year 2016 was considered a big achievement and it is also considered to be binding for its signatory. This is what the official documents say but if you look closely at the language of the agreement or you closely analyze the objectives of the agreement this might not be true to the fullest extent.

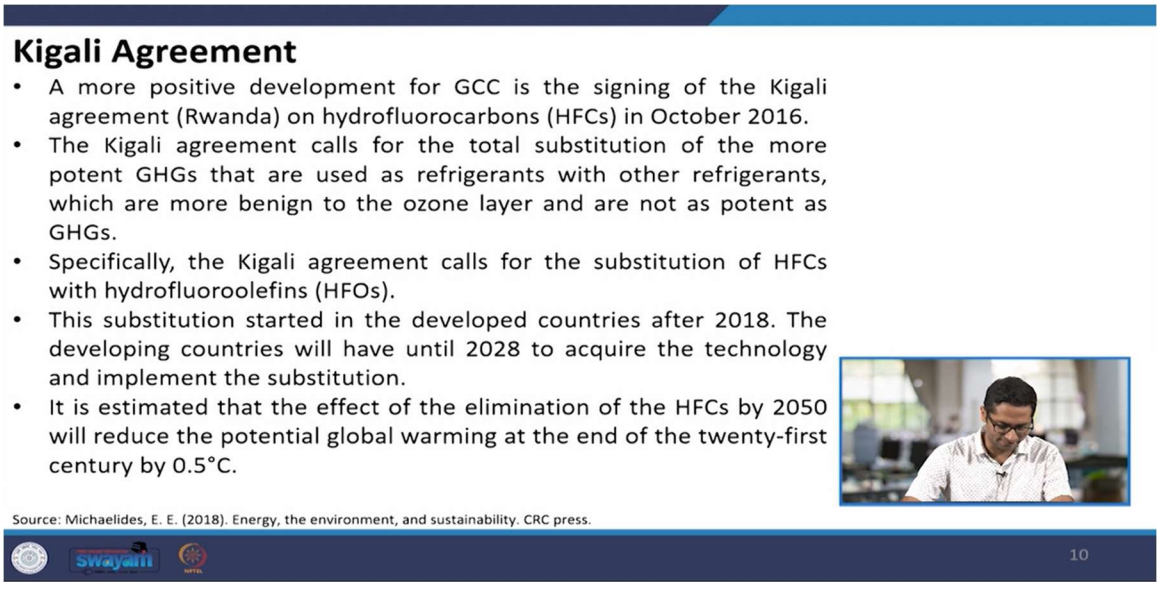
So if you have been noticing the different types of objectives in the previous few slides and the signatories were expected to report the emissions to monitor the emissions to

encourage to ask for commitments it was no way of saying a definitive action that was to take place. Further if you see the language of the document it uses the legal term shell which basically refers to an advice rather than a word okay sorry if you look at the official document it uses the word should which basically in legal terms means it's a advice rather than the word shell which basically means that there is an obligation and there could be some legal penalty if the country falls short of achieving the target. So if you see that there is no penalty imposed on any of the country if the country falls short of the target and again like if again to reiterate the point that no single nation or no single government is obligated to curve their CO2 emissions or to do anything specifically that address the growing CO2 emissions. So the result has been even after the signing of the Paris agreement quite a few years back the emissions have been increasing there has been a bit of decrease because of the pandemic that we have experienced in the 2020s but by and large the emissions have been increasing so far.

So again we have different kinds of portals giving the progress of different nations with respect to the CO2 emissions so this is one particular impact where we can see how like a majority of the world is doing very less as compared to the progress in terms of curbing the CO2 emissions.

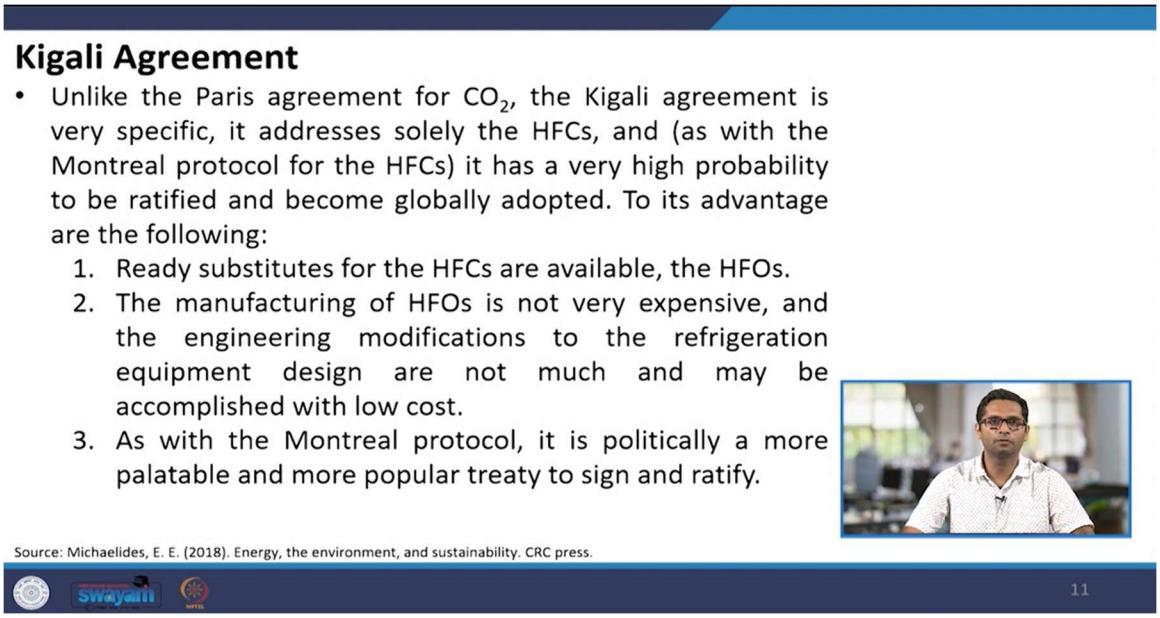


We see India in here doing quite well but if we go to another kind of ranking something like this and this is the ranking by the climate action tracker with which also says that the actions taken by India is highly efficient in order to meet the 2 degree Celsius target. So again we have a lot of our not widely accepted targets are there and of course there has been action but like that has been not up to the mark.

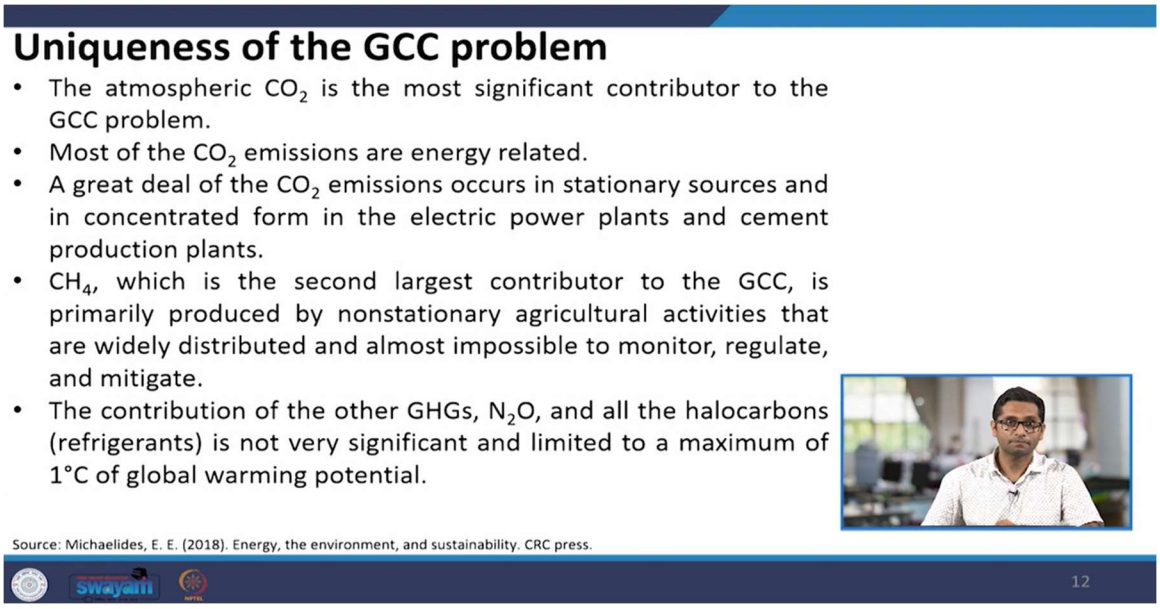


Further on a similar lines there was another agreement that was signed in the October of 2016 which was not much popularized and it is known as the Kigali agreement. It was signed in the city of Kigali in Rwanda an African nation and this particular agreement aimed at curbing of the HFCs or the hydrofluorocarbons. Now HFCs came into being to

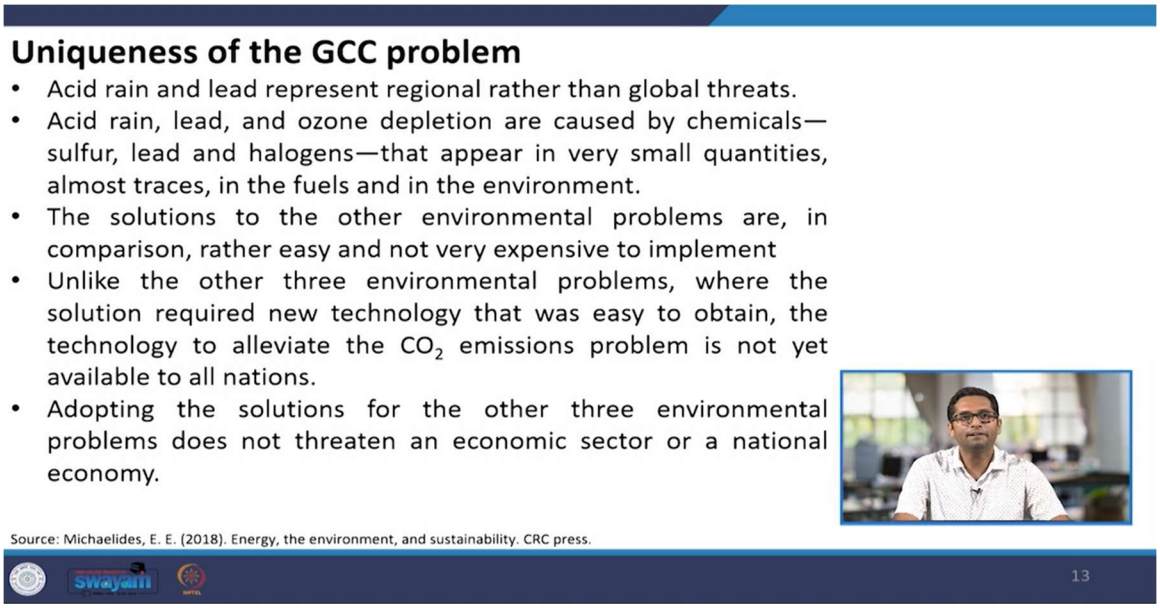
replace the earlier CFCs so if you remember the earlier classes and the example of ozone depletion potential we understood that the CFCs were used quite a lot in the refrigeration as well as air conditioning which were responsible for the declining of the ozone layer and to replace the CFCs it was the HFCs that were brought into the market they replaced the CFCs quite well but a problem with the HFCs were they were very potent greenhouse gases. Of course they had a very low ozone depletion potential or the effect on ozone depletion was quite less but if you consider the effect as a greenhouse gas that was quite high and to curb this the specific issue the Kigali agreement was signed which called for the countries throughout the world to substitute this HFCs with other specific chemicals and an example was the HF4s which was the hydrofluorolefins which had a low ozone depletion potential which means the effect on the ozone depletion was quite less and at the same time the greenhouse gas effect of these gases was also quite less and this was signed by a majority of developing and developed nations it was expected that for the developed nations the implementation starts in the year 2018 and for the developing world the implementation was given a bit delay of 2028 so that they can gather enough resources and there could be a transfer of technology that can happen from the developed world to the developing world and it is also estimated by the year 2050 because of the implementation of this agreement we can have the global warming being reduced by around 5 degrees celsius 0.5 degrees celsius and because these HFCs which are being emitted into the atmosphere are quite potent greenhouse gases.



So if we consider these two agreements we see that the Kigali agreement seems to be much more specific and it addresses the issue of HFCs to the core and it is also expected that it would be globally adopted and advantages could be felt quite nicely in the near future. The advantages or the reasons for it would be the substitutes of HFCs are available in the form of HFOs it doesn't have a very high economic penalty on the industries or the countries that will be adopting it so or the other way around it could also have some economic advantages in case of the improved equipment design and something similar to the Montreal protocol that happened in the 1990s it is a much more palatable or more popular treaty to sign and ratify so you don't have the public outcry that would be felt by the politicians who would be signing it and this agreement so far is considered a success in terms of curbing of the HFCs with better options like HFOs and based upon this it is also expected that it would be helping in curbing the global warming effect. Now if you compare the Paris agreement to Kigali agreement you see that the Paris agreement is looking at a much more bigger issue with of CO2 abatement which also means it has to be have different sources of energy available which was which is happening to some extent but is not widely adopted to say the manufacturing or the change to a renewable energy source is still very expensive it has economic penalties and it does have economic and issues for the population and it's not very palatable for the population of the countries of the developed world to move very easily towards more cleaner sources of energy.



So again if you look at the uniqueness of the global climate change problem it's that the CO2 is the most significant contributor and this CO2 majority of it is coming from energy-related operations and a great deal of the CO2 is again coming from stationary sources most of the power plants or industrial complexes like that of ammonia production or cement manufacturing or iron and steel industries are localized and it's easier to capture the CO2 from that places. The second major emission in terms of greenhouse gases is the methane and that basically comes from agricultural activities which is much more widespread. It's very difficult to capture the methane that is coming from the decomposition of animal dung whereas it's very easy to capture CO2 that is coming from a point source or a stationary source like the fumes from a power plant and the contributions of the other GHG specifically nitrous oxides and the other refrigerants in terms of HFCs is not very significant and it's expected that because of the Kigali agreement this would be taken care of. So again to repeat the problem of global climate change is much more different from that of the ozone depleting gases which were referred to in the Kigali agreement because it's more related to the lifestyle of the people the energy use of the people and it's coming a lot with the direct energy use it's not one of the side chemicals that is being used.



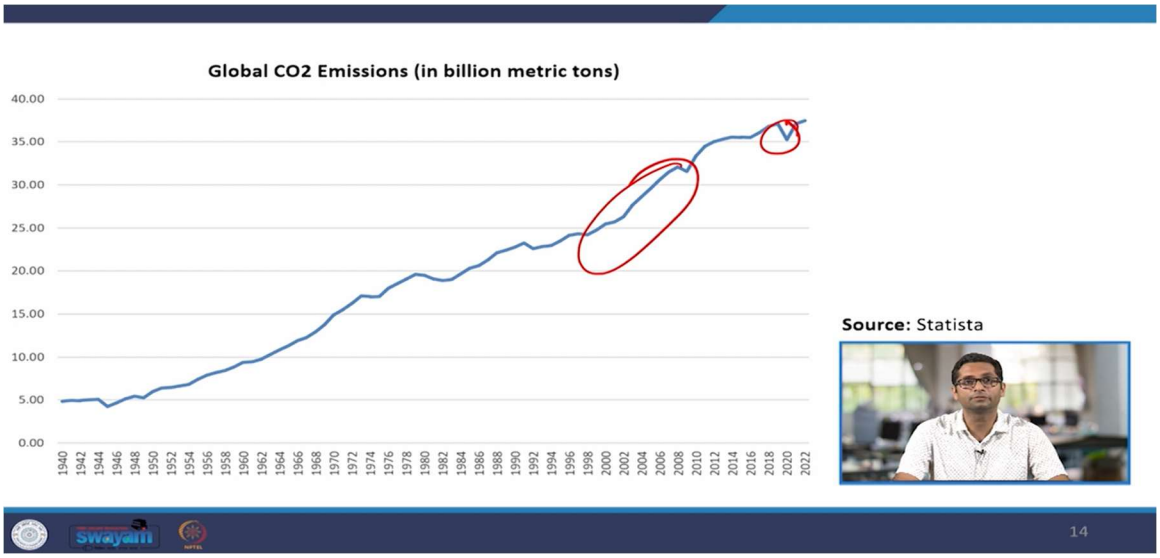
Again if you compare this particular problem with the that of acid rain and lead they were more regional problems than global problems. It was limited to few neighboring

countries and the agreements for those were quite easy to be signed. Further these were caused by certain specific chemicals like sulfur, lead or different halogens which were appearing in small quantities and as such their emissions were also not very large. You might want to refer to the question for the different kinds of SO2, NO2 and the CO2 emissions that we try to estimate for a typical 400 megawatt plant and there were orders of magnitude difference among the emission that result from a rather typical power plant.

Further the solutions for these environmental problems was available and it was easily developed and it was not very expensive to implement. On the other hand it also led to efficiency increase and also gave nice benefits to the implementers which is not the exact case for the global climate change because the solutions in terms of renewable energy of course we have economical options like solar and wind available but still if you consider the round the clock operation or the round the year operation we still have we still see that the fossil fuel based sources still continue to have an edge and the major issue that is stopping or that differs the global climate change from the other three is that it doesn't these three problems earlier did not threaten the economic sector of the national economy.

So suppose a particular country or a group of countries want to adopt maybe a target that they would want to go for green energy from so and so year onwards of course they can do it but what is going to happen is because this energy is coming at an expense it would be borne by either the industries or the people in general. So this means the industrial products that are generated by that particular country become expensive and they might not be able to compete with their counterparts in the global market. So now we are in a world of globalization where we would have the chief substitute of any particular products available. So if a country goes with curbing its CO2 agreement CO2 emissions by going towards a greener source of energy it is expected to pay an economic penalty. So either in its production or the people would have to pay an extra cost which meant which also means that they would have to give some of the earnings which they were happily earning in the past and to this majority of people are not very amenable or very or they are they are not very enthusiastic about the same and that is one of the reasons that is holding this particular problem behind and since it's a global issue there has to be a global decision that has to be doing it that has to be adopted by all the nations together so that it

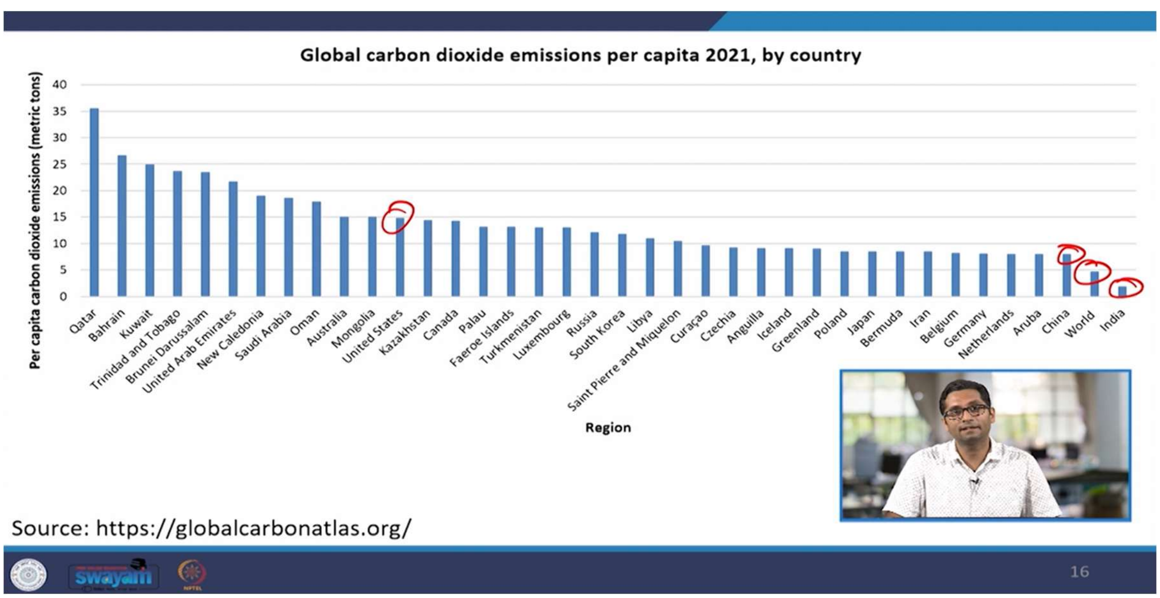
doesn't happen that the countries who on moral grounds might adopt and the CO2 emission reduction potential but they end up losing economically in terms of people losing the economic advantage or the economic benefits that they have been deriving in the past.



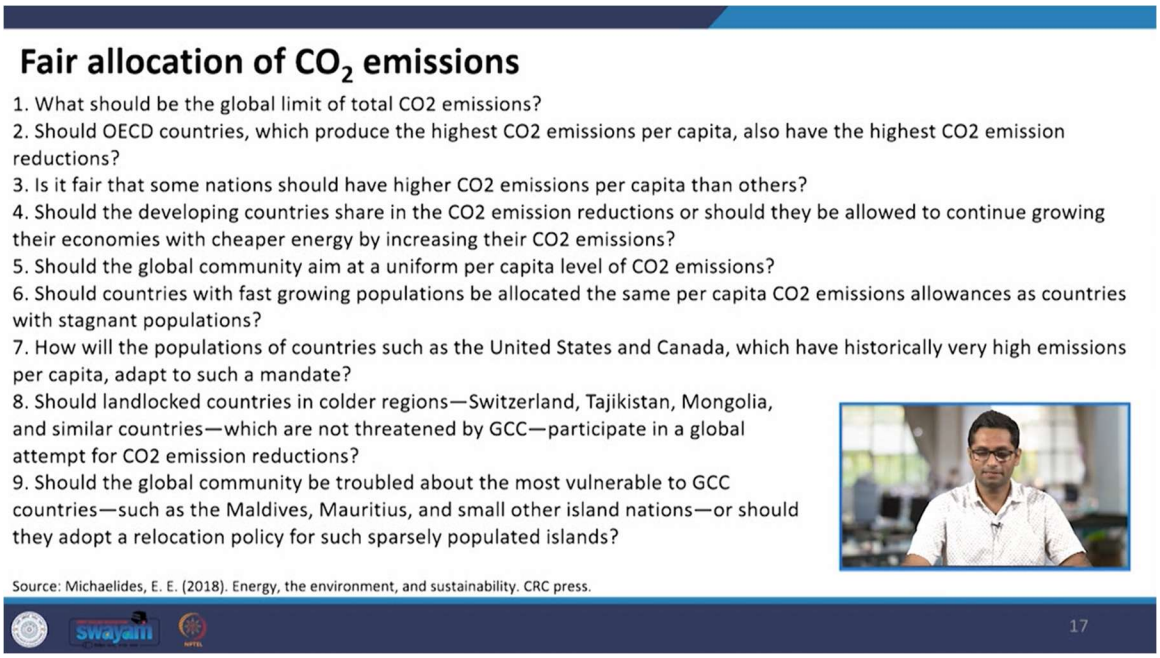
Further just to put in the same points and the the CO2 emissions if you have a look towards it they have been continuously rising for the past many decades we will see a dip in here that was more attributed to COVID and the loss of the economic activity that was happening but by and large the emissions have been rising and we see a specific rise in the years 2002 to 2012 this is the years when the Kyoto Protocol was in practice we see significant reductions were happening in the European Union and the Japan but if you see the overall emissions they have been continuously rising and it is also attributed a majority of it is also attributed to the rise of the economies of the developing world specifically China, India, other parts of Southeast Asia which have been increasing its energy consumption and energy production so there have been a somewhat a reduction that is happening in other parts of world but it was very less as compared to the increase in energy production that was happening in other parts of the developing world and given that a majority of the population is living in in China, India and other parts of Southeast Asia this also makes the problem even more complex because the number of people that are living in this part of the world are quite high and even a small rise in the energy consumption could have a big rise in the cumulative CO2 emissions.

Region	2020	2025
China	3430.132	3709.162
USA	1439.008	1435.325
India	871.398	1112.742
EU-15	810.8868	780.1659
Middle East	566.1289	585.603
Russia	512.4527	505.9739
Southeast Asia	378.6731	432.0417
Japan	334.7609	324.6962
EU-12	217.2813	224.0822
South Korea	185.2929	185.6186
Canada	170.6243	173.3625
Indonesia	163.0429	192.541
Africa_Northern	159.0739	175.247
Central Asia	154.7156	165.8971
Mexico	141.3372	150.2544
Europe_Non_EU	139.9443	150.5432
Brazil	137.2336	146.6995
South Africa	134.2601	138.9456
Australia_NZ	128.779	135.587
Europe_Eastern	83.10036	83.71125
Taiwan	81.18258	82.44669
South America_Southern	65.55812	71.98303
Central America and Caribbean	59.12243	62.34729
Pakistan	55.16593	60.883
Argentina	52.9848	57.64429
Africa_Western	51.69698	59.18318
South Asia	47.01748	58.56099
Africa_Eastern	28.99329	34.06412
South America_Northern	28.19809	28.31491
Colombia	28.05368	31.61697
European Free Trade Association	22.6112	21.37442
Africa_Southern	20.65899	24.32064

Further if you look at the countries with respect to the specific CO2 emissions we can see that China is now the one of the largest emitters of the world followed by US then India then the European countries the group of 15 countries in the Middle East and then Russia so these are the major countries and you can see others as well in here and we can see in the future and the emissions for India are expected to rise that for China are rising at a smaller level for US it's almost stagnant we can see a bit reduction happening in the Europe for the Russia again somewhat rising and something almost stagnation sorry it's rising for Middle East and somewhat of stagnation for Russia but this is what I am talking about the total emissions.



If we talk about the per capita emissions this tells a very different stories we have the countries from the Middle East which are by far one of the largest consumers of fossil fuels as well as the emitters of CO2 if you see the see countries like Qatar or Bahrain so if you see Qatar which is emitting almost 7 times in the world average if you see a country like Kuwait or Bahrain it's almost 5 times something similar can be said about the US as well almost 3 times the world average so the world average is around 5 tons of CO2 per person and compare that with China almost 1.5 times and India it's very less so again India might be one of the largest emitters in terms of the cumulative or the total CO2 emissions but if you go with the per capita emissions it's quite less and this is what makes the situation very complex so how do you reach at an optimum or a fair deal where we have some countries which have been emitting a lot since the past and currently their emissions are multiple times the global average and then there are countries like India which are maybe less than half of the world average and they would want to grow in the future.



So that calls for like the questions like fair allocation of CO2 emissions and this is what has been a matter of debate and these are some of the questions that we should be asking of course there is no one answer to these questions but like these are the questions that are of importance like should there be a global limit on the CO2 emissions is that possible

because we have seen in the history there have been countries which have been emitting a lot more than their counterparts we know that the developed world or the OECD countries have been producing the highest CO2 emissions per capita and so should they be liable to for the highest CO2 emission reduction as well and there have been a debate on that where the developing world says they should but the people who live in this country don't want to lose their affluence and they would certainly not agree to it.

Then is it fair for some nations to have higher CO2 emissions than the others again a moral question for which we would have to come together as a society to answer and should the developing world share in the CO2 emission reduction be lesser or should they share equal responsibility now again that is a growing matter of debate can there be a uniform per capita level of CO2 emissions can there be a cap to which and the developed world has to reduce an emission and a cap to which the developing world is allowed to raise its emission. Then we have also certain countries with a very fast growing population so should they be allowed to have much more CO2 emissions than the others because they have a greater population and a greater rate at which their population is growing to be catered to. Then how would the populations of countries like the US or the Canada which have historically being very high emitters would want to adopt to such a mandate like how would the population of these countries react because they have been used to living a life of comfort which again entails a lot of energy consumption. Further we also know there are many landlocked countries like Switzerland the Pakistan Mongolia which would not have any problem from the global sea rise even if there is rise of few couple of meters it wouldn't affect their economies or the people as such. So why would these countries want to commit to any particular action because they have nothing to lose and on the other extreme are the countries which are the island nations like the Mauritius or the Maldives.

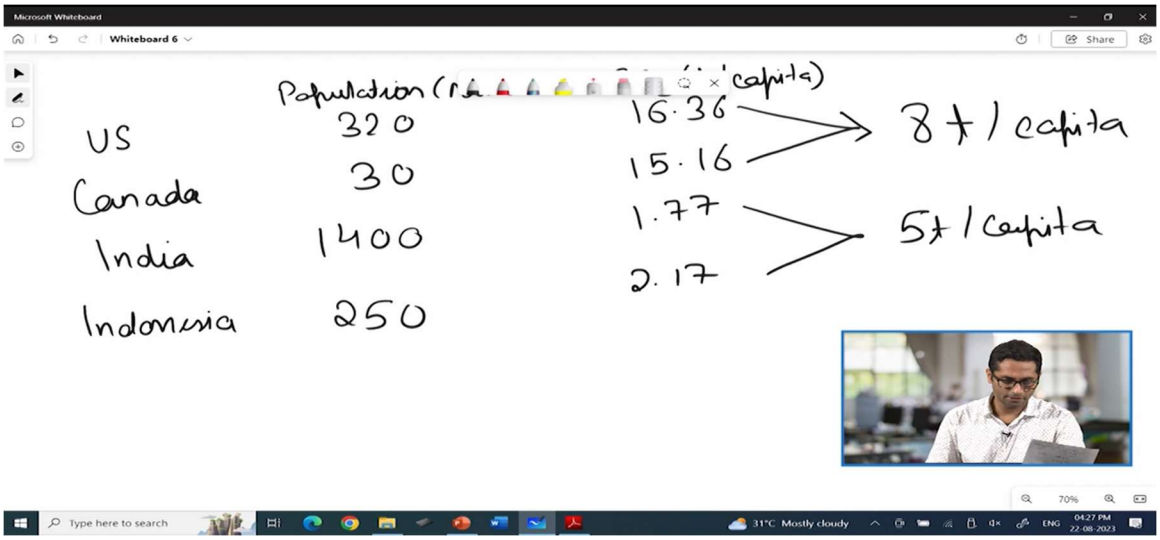
These would probably be the first few countries to disappear if there is a sea level rise of a particular meters and should the other parts of the world have sympathy on them and should there be policies so as to relocate the location or relocate the population that these countries are housing because these are the first ones who are going to be at the blunt although they might not be one of the biggest emitters of the CO2 but these are the countries who are going to face the consequences.

Example

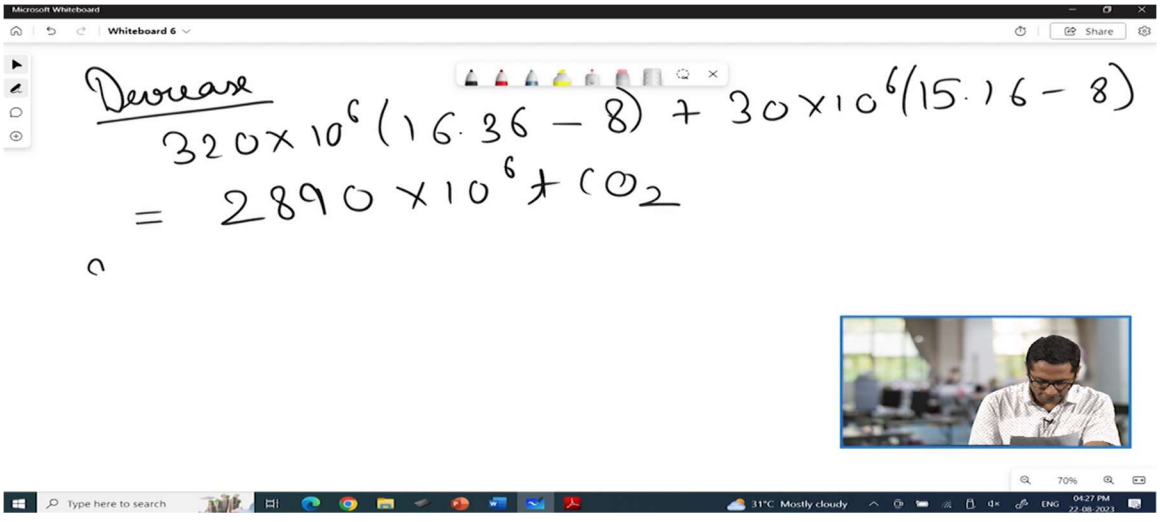
- The populations of the United States, Canada, India, and Indonesia are approximately 320, 30, 1,400, and 250 million. Assume that the United States and Canada agree that no more than 8 t of CO_2 per capita should be emitted by any nation, effectively halving their CO_2 productions from their current levels, while India and Indonesia raise their CO_2 production to 5.0 t of CO_2 per capita. What will be the net effect of these changes?

Maybe to understand the specific concepts let us try to understand this with the help of a simple example. So let us consider that the populations of four major countries in the US, Canada, India and Indonesia and the populations are approximately 320 million, 30 million. We in India around 140 crores currently and 250 million for Indonesia again a very populous nation and let us assume that the United States and the Canada agree that they would want to limit their emissions to around 8 tons of CO2 per capita. So currently their per capita emissions are close to 15 or so let there be policies where these two major countries want to bring in their CO2 emissions to almost half in terms of 8 tons and at the same time it is allowed that India and Indonesia which are two developing nations can increase their CO2 emissions to close to global average of around 5 tons of CO2 per capita.

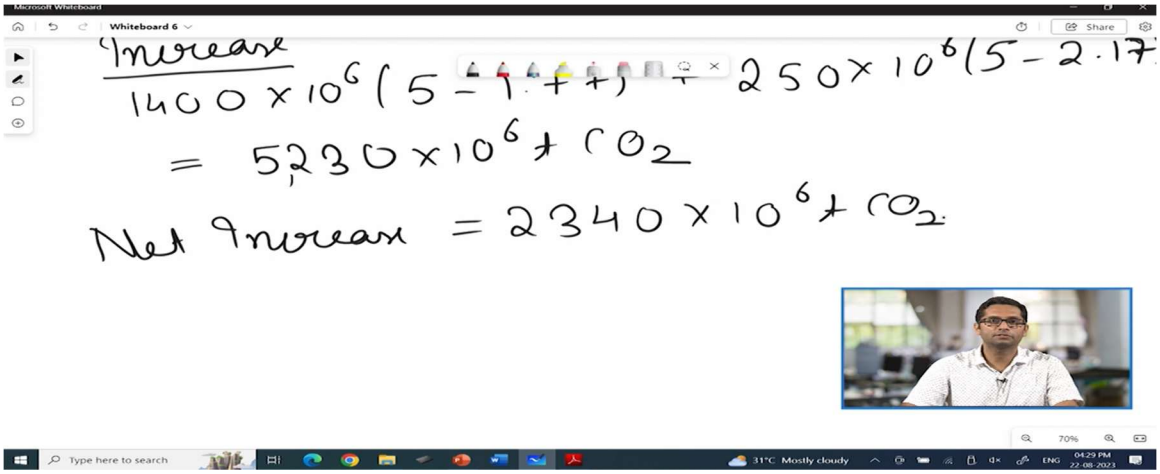
So the current CO2 emissions for India stands around 1.77 and around 2.7 is something for Indonesia. So let us try to do this simple calculation and try to see if these what the dynamics to happen like we have two major countries putting in or reducing their emissions from 16 tons of CO2 per capita to 8 tons and we also have two other developing nations India and Indonesia which are allowed to increase their emissions to around 5 tons of CO2 per capita what would be the result of these changes. So let's go to the whiteboard and try to explore this.



So let me list down the major countries we have the US, the Canada, India and Indonesia. Let me put in down the population. So let's say we have a population of about 3.2 million and this is in millions and I'm also putting in the CO2 emissions in tons of tons per capita. So if I go with the current statistics the population is around 320 million for the US, 1400 we are almost 140 crores and 250 for Indonesia. If we go with that current emissions in terms of tons per capita it's 16.36 for the US for the Canada somewhat similar 15.16. India this figure stands at 1.77 and around 2.17 for Indonesia. So let us take this as a base statistic and try to see if there is a reduction that is happening in the two countries and then there is an increase. So we would have the US and the Canada coming at to around 8 tons per capita and we would have India and Indonesia increasing their emissions to around 5 tons per capita.



So we can do the simple calculation let's first calculate the decrease in emissions that is basically because of the US which is 320 is the population into 10 to power 6 this is the millions 16.36 minus 8 plus I would add 30 into 10 to power 6 and 15.16 minus 8 and if I do this calculation the total result would come around to be 2890 into 10 to power 6 tons of CO2. So around 3000 million tons of CO2 emissions would be reduced at the same time there is expected to be an increase in the emissions of India.



So this would be around 1400 into 10 to power 6 and this is 5 minus 1.77 are the current emissions plus that of Indonesia into 10 to power 6 and they have slightly more emissions as compared to India on a per capita basis and if I add these two values together this comes out to be 5230 into 10 to power 6 tons of CO2. If we see or compare the two values there is going to be a net increase and this net increase is going to be approximately equal to 2340 into 10 to power 6 tons of CO2.

So even if we see there is a drastic reduction in the emissions by the two major countries that is US and Canada and at the same time we bring India and Indonesia some things closer to the world average there is going to be a drastic increase in the total emissions of the CO2 somewhere of the term of the order of 2000 million tons of CO2 emissions and this is why this problem should be tackled by the developing and developed world together because the actions if they are taken solely by the developed world might not suffice and this calls for all the countries of the world to come together and try to solve this important issue. So with this we end today's class. In the next class we will be discussing some of the myths and realities that are associated with this important issue of global climate change. Thank you.