Energy Resources, Economics, and Sustainability

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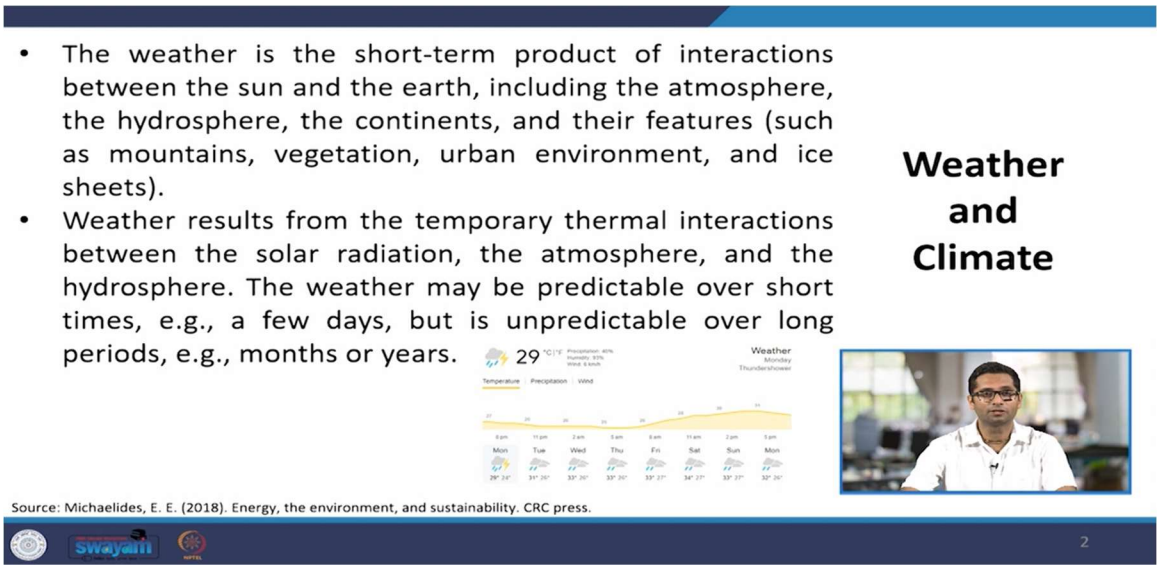
Week – 05

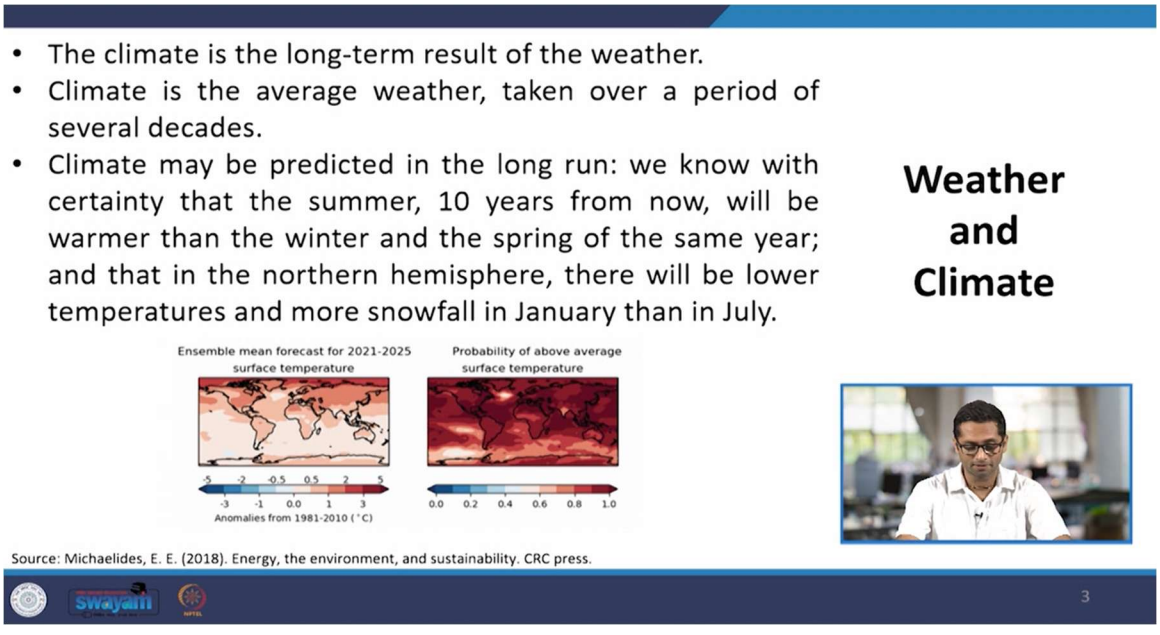
Lecture – 05

Lecture 25 - Global Climate Change Mitigation-I

Hello everyone, welcome to the course Energy Resources, Economics and Sustainability. In the last class we have been discussing the problem of the global climate change or GCC or we also know it with the names like global warming, climate change and we try to understand how this problem is very difficult from the problem that were seen earlier resulting from the use of energy sources. The problems were lead, sulfur oxides, acid rain, ozone depletion and these problems could be solved to a certain extent because of the policy measures that were taken. Whereas the global climate change provides us a very different challenge. We will continue with the same discussion where we keep on trying to understand like what are the major challenges posed by the global climate change and we will also start the discussion what could be the possible mitigation measures, what are the steps that could be adopted in the future that can help us tackle this big problem that stands in front all of us. So, let us start with our discussion where we try to understand first the difference between weather and climate. Often we see that these terms are used interchangeably but there is a difference in the meaning that is annotated to weather and climate.

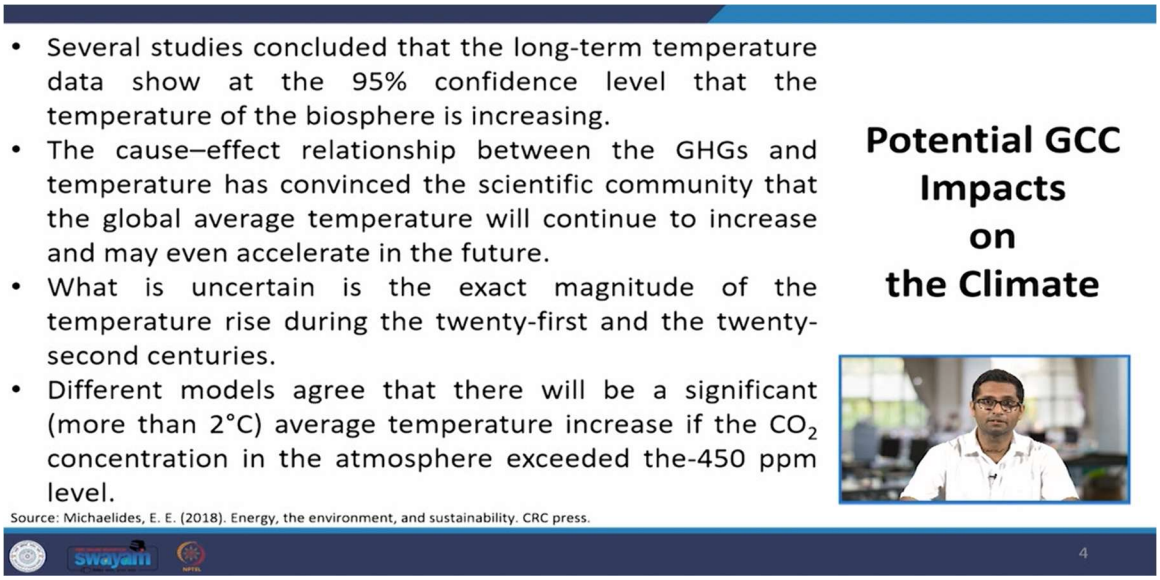


Weather basically refers to a short term product of the different interactions that happen between the sun, the different kinds of biospheres, atmosphere, hydrosphere and the different types of vegetation, mountains and the different kinds of geographies. It is basically a short term phenomena dealing with what is the temperature that is going to be in the next few days, whether we are going to get a precipitation, what are the likely wind speeds going to be, are we going to get enough sunlight or not and to some extent weather is predictable in the short term. All of us have been used to using apps in our mobile phone which predict whether it is going to rain today or not, what are the chances of rain, are we going to experience a sunny day or not, is it going to be cloudy, what is the temperature that I can expect in the daytime as well as the night time, what could be the typical wind speeds. These are some things that are predicted to a good extent and also we have the different weather channels predicting that this for different cities on the TVs as well as like of course everyone of us uses these features on our mobile phones. If I talk about the long term, maybe months or years, weather is not a very predictable thing, we can only predict these kinds of things for the short term, maybe few days or a week at max but if we talk about months and years, such kind of predictions are not very accurate.



Comparing this with climate, climate is more of a long term phenomena, it can also be said that it is like the average weather taken over a period of several decades and climate

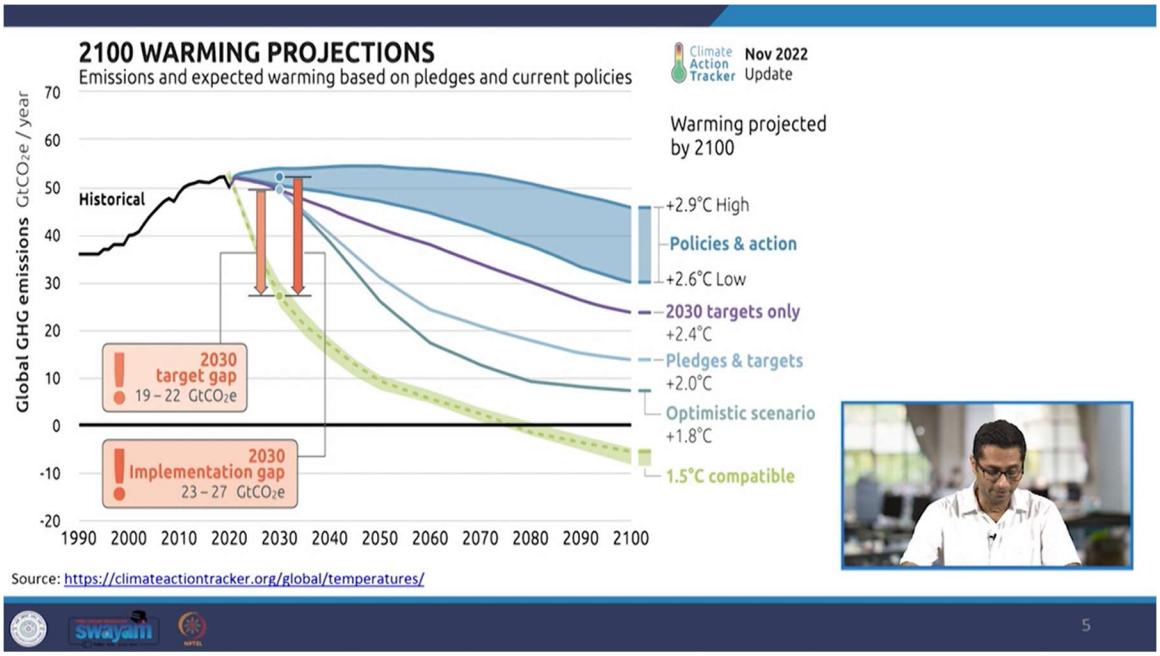
is something that we might be able to predict over the long run. We can say with a certain degree of accuracy that the summers maybe 10 years down the time are going to be hotter than the winters, this is the likely temperature that we can experience in the summers, this could be the likely average rainfall. So this is most likely giving us the average values that we would be able to experience in the future years given the prediction by the different kinds of global climatic models. There are a lot of them and based on different assumptions they give in different kinds of predictions and we have one such prediction that given the rise in the temperature in the past, we can expect the temperature rise to reach a so and so extent. An example is given in the figure at the bottom like we can expect how the temperature is going to rise, the average temperature is going to rise in the future because of the prevailing conditions.



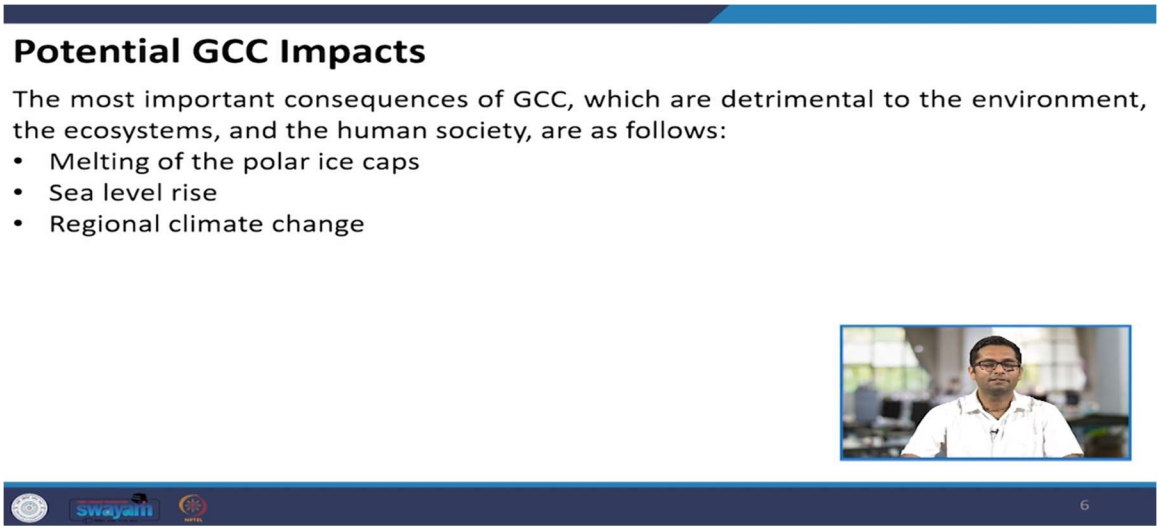
So climate yes it is able to be predicted over a long run and we have seen like or we have like the different kinds of climatic models have predicted with a good confidence level more than 95% that a great deal of temperature rise that is being experienced by the world today is because of the fossil fuel uses. It is because of the greenhouse gases that result from the combustion of fossil fuels which mainly are attributed to coal, natural gas and crude used in different energy applications and this CO2 and the light gases because of the greenhouse gas effect are able to capture the radiations from that rise from the earth surface and slowly and steadily they are warming up the earth surface. What we are not very certain about is the exact magnitude of a temperature rise that might happen in

the few years but the different type of climatic models are pretty much on the same page when it comes that a rise of maybe 2 degree Celsius or something similar is expected to have major catastrophic events in the future and this type of effect could be triggered by an atmospheric concentration of CO2 if that exists the 450 ppm level. So the current concentration of CO2 is somewhere around 4 or 10 ppm parts per million but it is likely to increase in the future with the rise in the CO2.

Also we understand that climate is something that can be predicted for the future and even a small change in this climate could have drastic effects on the vegetation patterns, on the lifestyle of the people, on the way the different economies work whereas a change in the weather maybe a few degrees here and there or a few centimeters of rainfall here and there might not make a drastic difference. So climate is something that we are much more worried about than weather. A change in the average climate by 2 degree Celsius can have a very good effect on the population it can lead to the submergence of many big cities under the water, it can lead to the disappearance of polar ice caps, it can also change the vegetation patterns, some of the areas which are known for their productivity of different types of grains might turn into deserts and there could be other way around as well. Deserts might receive good amount of rainfall and might become suitable for cultivation in the future.

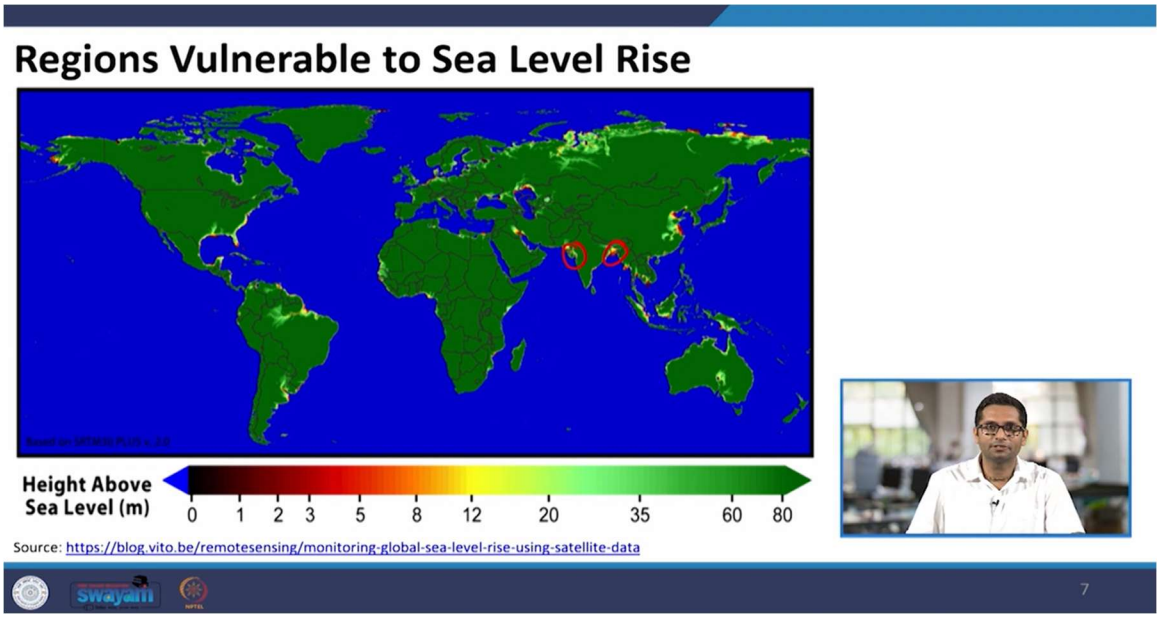


So just to give you an example this is one type of prediction like by one particular type of global climatic model it shows you like currently we are at a certain level of global GHG emissions in terms of giga tons of CO2 per year and based upon the trajectory that we achieve or the trajectory that we adopt we might reach different levels of temperature rise which could vary from anywhere from 1.5 degree Celsius to 3 degree Celsius. So based upon how good we can formulate policies for the reduction of the global CO2 emissions the future climate change that happens maybe in the span of the next 80 years or so could be a very different.

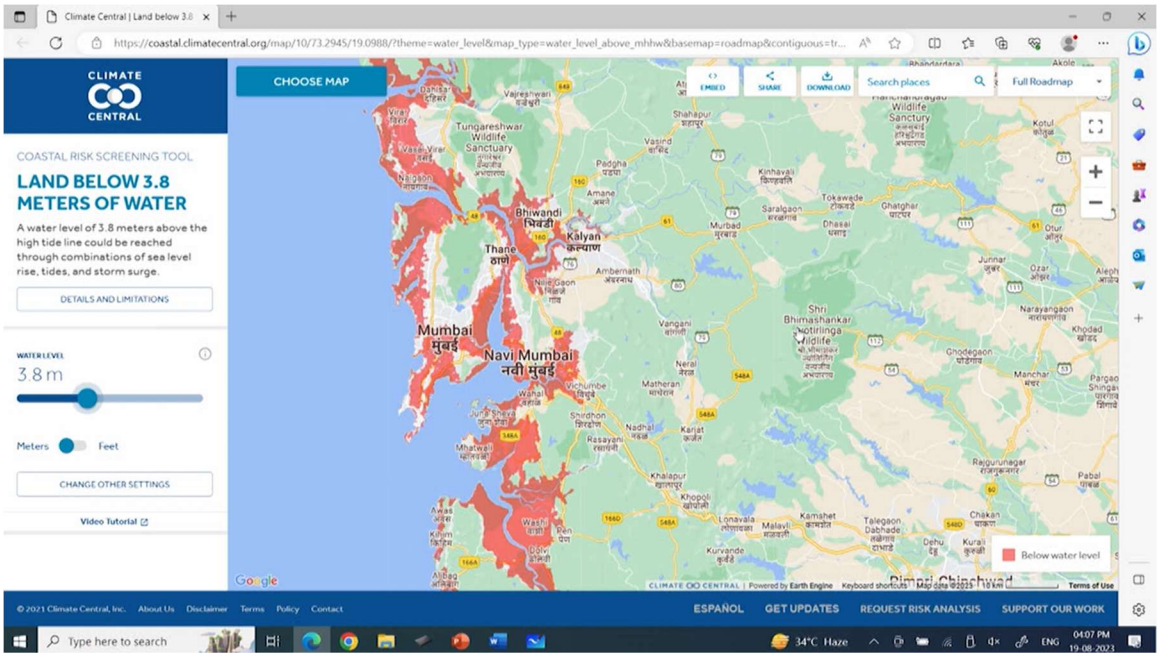


So if we talk about what are going to be the likely impacts of global climate change, the major impacts could be clubbed into three, one would be the melting of the polar ice caps. So we have a good amount of surface of earth that is covered by ice, a majority of it lies at the two poles the Arctic and the Antarctic and also we have the mountains covered with ice. The advantage of the surface covered with ice is that it is able to reflect more than 90% of the insulation that we receive from the sun. So that is good in the point of that we are not capturing much heat. But if there is a rise in the temperature of the earth which we have been experiencing many of these ice caps might melt and because of the melting the surface below the ice caps which is normally rock and darker in color might get exposed and these kind of surfaces in turn would have a lower reflectivity of the sunlight which might lead to more absorption of sunlight which further initiates more temperature rise. So it is like a feedback loop that was going to exaggerate the temperature rise if it is not checked. Further another problem that is linked to these kind

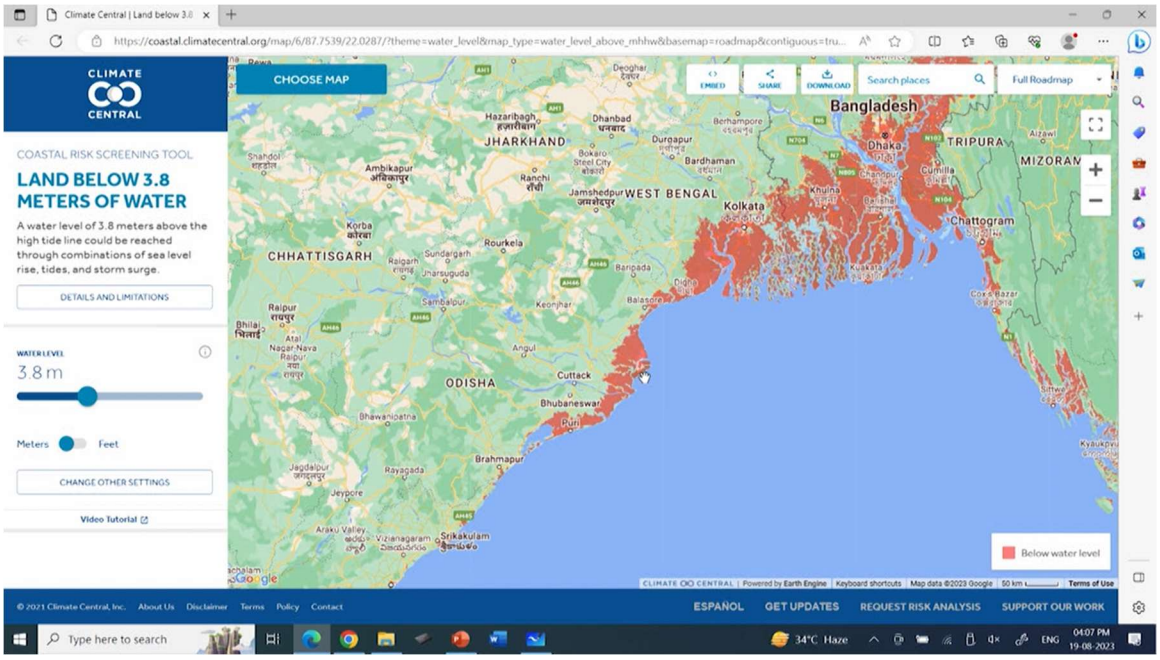
of melting would be the sea level rise. All the ice when it melts is ultimately going to enter into the seas and it has been estimated that if a major part of the western Atlantic ice is to melt the sea rise could be of the tune of around 5 meters as compared to the present level and if there was of all the ice that is there on the earth was to be melted it would raise the sea level to almost 60 meters above the present level and that could have huge implications. Further the sea level rise happens due to two reasons one is the melting of the ice and further because of the global temperature rise we also have the expansion of the water bodies because the volume as a function of temperature as we have increasing the temperature the volume occupied by a certain quantity of water would also increase and that is also a reason why we are experiencing a great fear that a temperature rise might lead to drastic effects in the future in the form of sea level rise. Further these kinds of impacts can also lead to regional climate changes and the prediction of these kinds of changes is not very accurate to say because this depends on many different phenomena but it is estimated that the temperature is going to play a major role and it has been suggested that some parts of the world might become very different from what they look to today there could be rainforest turning into deserts and vice versa it is going to change the vegetation pattern and with this is also linked the way people interact with each other the way economic policies are formed the way businesses are performing and it could have significant influence on the different supply chains be it be the food supply chain or the different raw materials so this the effects could be very drastic in the future.



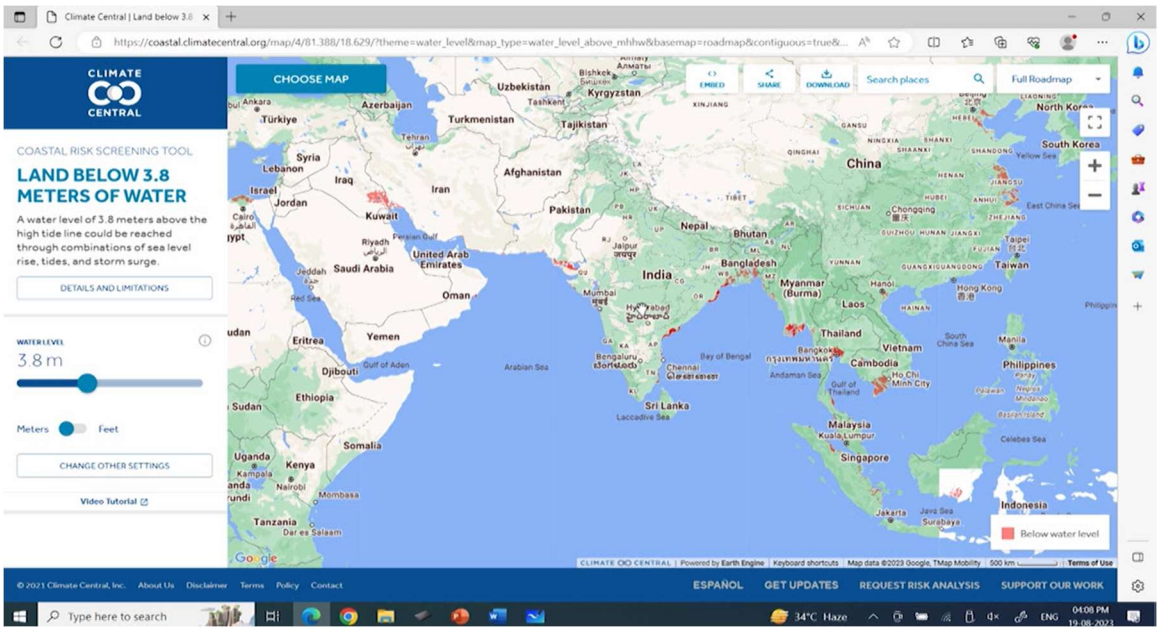
So just to give you an example this is one figure which gives you the area which are the most vulnerable to the sea level rise so on the bottom what you see is the level of sea that is rising above the level of the 1990s and a one meter rise could be a problem for Indian cities like specifically the major cities like Bombay or Calcutta and then we also have major parts of the world or the major cities of the world around the coastline and they could be sure and if there is a rise to up till 80 meters or so which is which is not like expected to happen in the near future but still it can lead to submergence of great parts of the world.



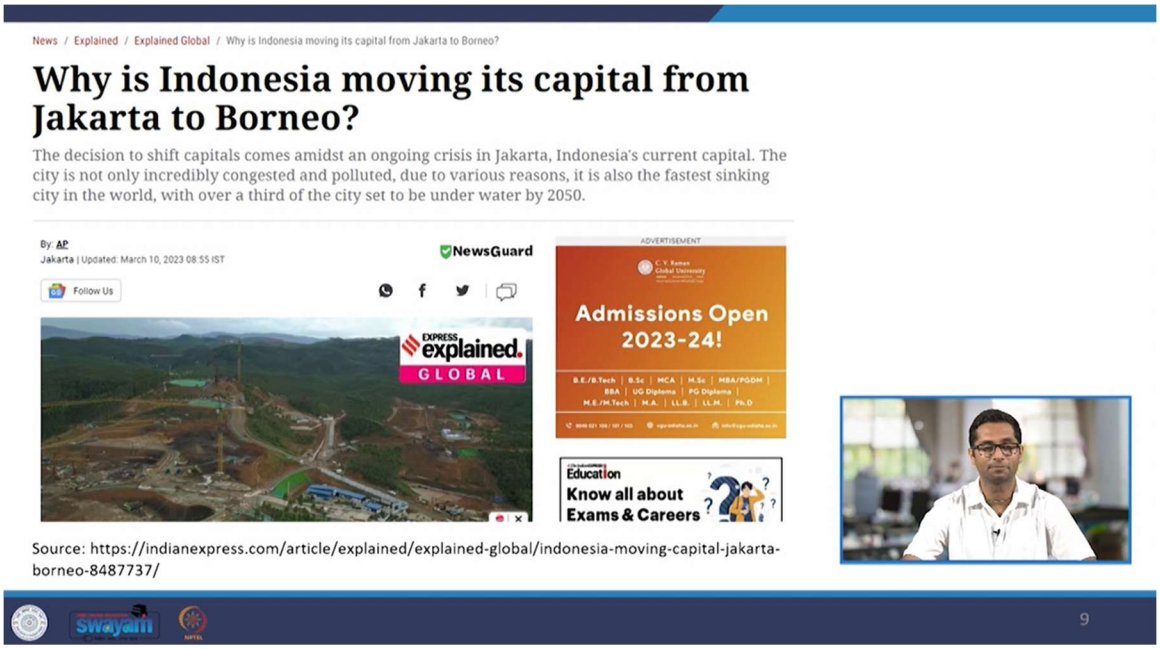
To gain a better perspective maybe I will just take you to a simple tool so this is just a simple tool there are many such tools available on the internet so it is just for the understanding so here we are focusing on Mumbai and it and the color in the red basically shows the areas of Mumbai which becomes vulnerable to rise in water levels so if I select a water level of maybe 3.8 meters we can see great deal of Mumbai getting submerged so given that it is the economic capital of India great part of the GDP of the country arise from this one particular city this could have many drastic consequences we can also zoom out and see the effect on the whole country.



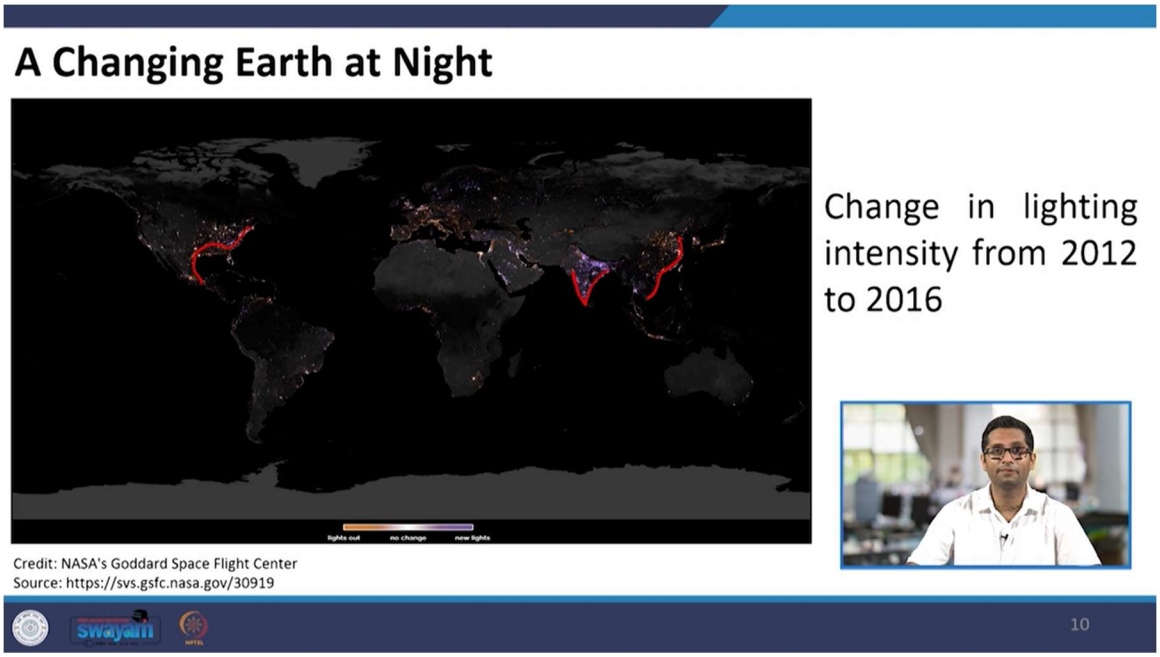
So it is not only the Mumbai that is going to submerge but it is the effect is also going to be felt in cities like Kolkata which is again a major metro city we can see a great part of the state of West Bengal and Orissa being lost.



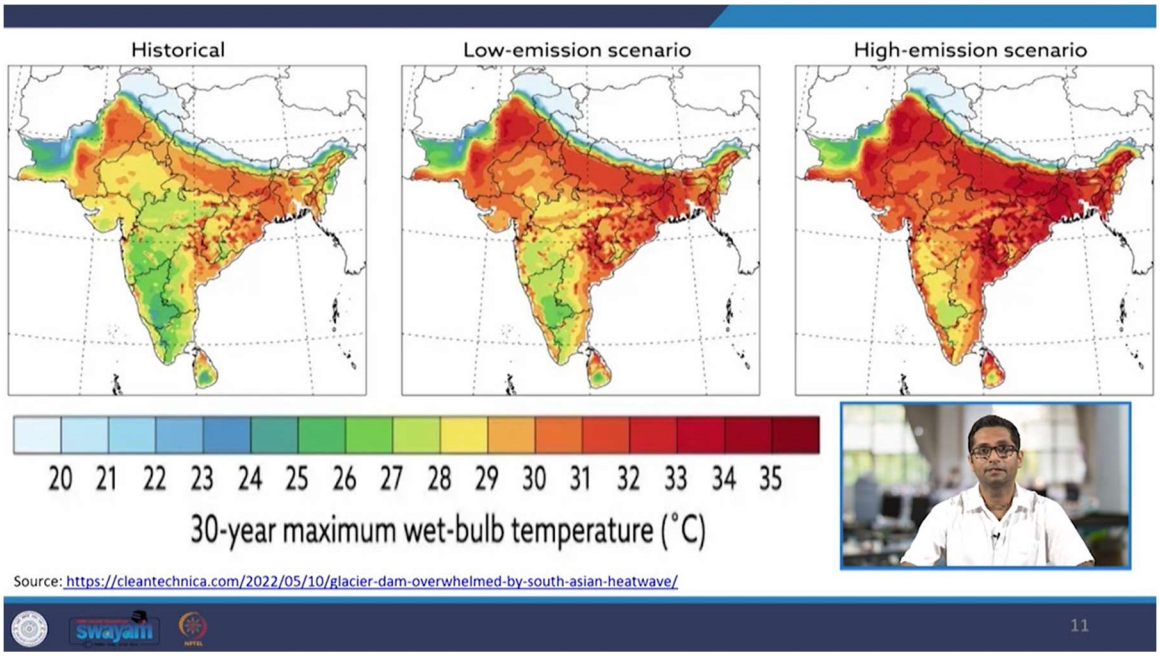
And something similar can be seen in the south as well another major metro in the form of Chennai is going to be affected by that and if we see India as a country like it might not appear to be drastic but we can see that three major cities three major metros would be at the blunt of sea level rise in India.



Further like let me also show you like this was this was a recently in the news that Indonesia which is again a major country in Southeast Asia is now considering moving its capital from Jakarta to Borneo again one of the major reasons for this shift is like because the rising sea levels and it is expected by the year 2050 a great deal of city would be underwater so they don't want to take any chances and they want to start as soon as possible so this the for so their the aim of shifting the capital from one city to another city has already been initiated.

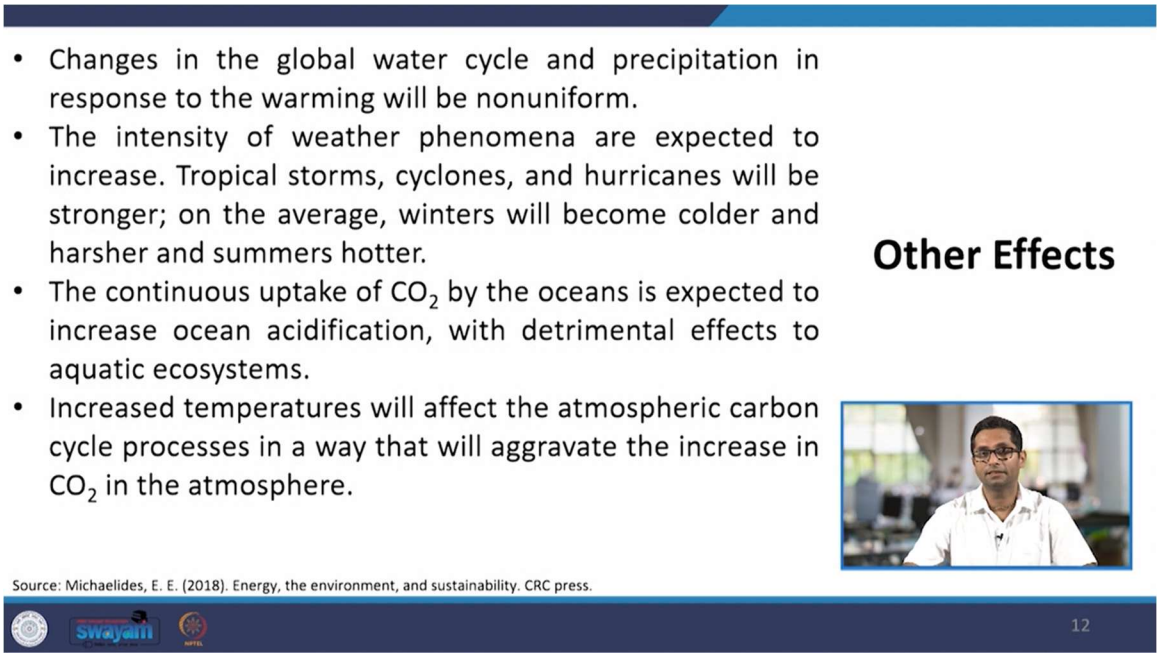


And further reiterating the earlier point that if you again analyze the global population and this is again one of the figures that we have discussed in the past as well you will see a great deal of the global population looks lives around the course so you can see the China even in India the US a great deal of population so it is almost estimated that almost 75% of the world population or more than 70% of the world's population lives within 60 meters of any coastline so that makes the situation even worrisome that we have a huge people a huge number of people living near the coastline and there are different reasons for that and and they all become vulnerable to a sea level rise which could which could have drastic consequences in the future in the future some of the city some of the countries like Maldives or other island countries might cease to exist if there is a considerable sea level rise that happens in the future.



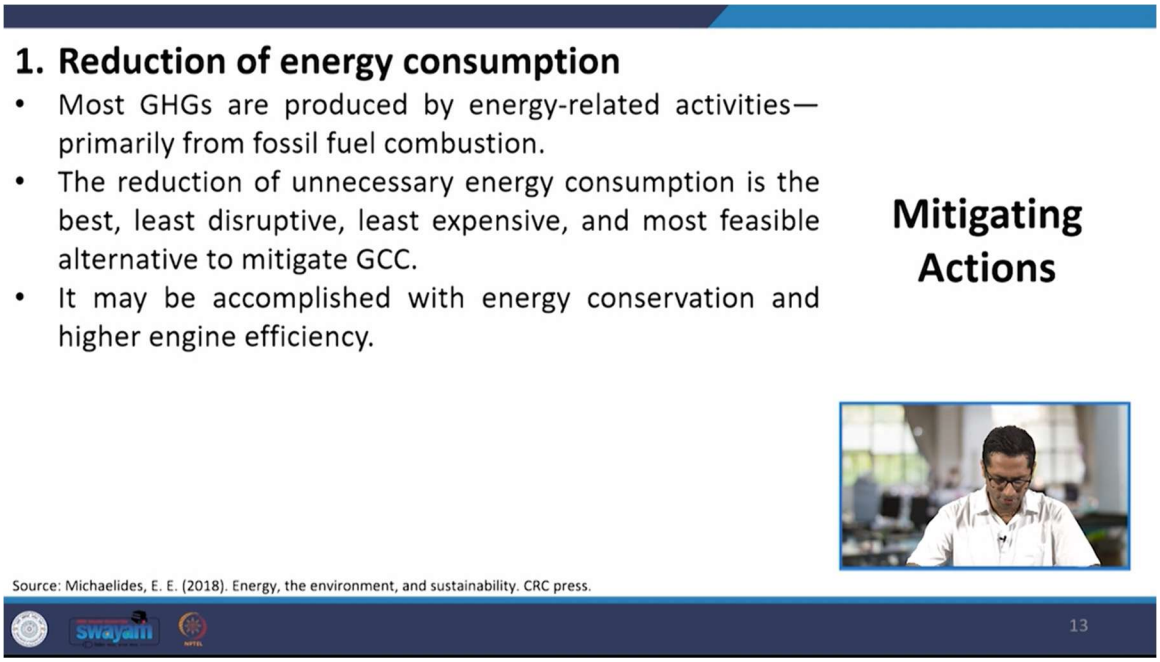
So again these are some predictions for India how the local climate is going to change in the future so this is the wet belt temperature prediction for the 30 years and given the like we can see there is a significant rise in the average temperature which is a part of the climate given the different scenarios so no matter if we are going for a low emission scenario or a high emission scenario there is going to be a temperature rise that we would be experiencing in India and that could lead to different changes the change in the weather pattern the change in the monsoons we wouldn't go into the details but like given

our agriculture is a lot dependent upon the rainfall this could have significant consequences for us as a country now we have got some understanding of the problem now let us also spend some time in discussing what could be the possible mitigation measures what are the different mitigation measures that have been suggested by the different types of scientific communities and let us try to analyze the pros and cons of each.



So before that like there could be some other effects there could be some other effects of climate change which have been told it could be the change in the global water cycle as well as the precipitation there could be change in the how and the quantity of rainfall that we receive another major consequence that we are currently facing is the intensity of the tropical storms cyclones and hurricanes the intensity and the number of incidents is on a rise if you compare to the history and much of it is attributed to the change in the climatic conditions that we are experiencing further a great intake of CO2 by the oceans is also expected to increase the acidification or the acidity of the oceans which would again affect the aquatic ecosystems there might be a change in the food chain which basically feeds the different kinds of organisms and again the increased temperatures of the atmospheric like CO2 also exaggerate the release of CO2 in the atmosphere so this is basically a feed forward loop in which greater the amount of CO2 the processes are tuned

in the such a way that it only accelerates the CO2 that would be coming in the future so that basically exaggerates the problem and with this we have tried to understand like what could be the possible consequences of CO2 that is going to atmosphere but let's also try to understand what could be the different mitigation measures and these mitigation measures are suggested by the different scientific communities and let us go further and try to understand what could be the advantages and drawbacks of some of these measures so let us try to understand and or educate ourselves with some of the key mitigation methods that have been suggested to tackle the problem of global climate change.



So one of the first measures that have been suggested that came in early why don't we reduce the energy consumption itself our energy consumption has been rising exponentially in the past few decades let's go for the low-hanging fruit energy consumption is the key source energy consumption entails use of fossil fuels fossil fuels entail release of the CO2 in the atmosphere so why why don't we go with more energy efficient pathways which is the least disruptive least expensive and the most feasible alternate and it could help us in clearly like both have a saving in the environment as well as the cost saving as well because the money it would have its monetary benefits as well so let us try to do a simple example to understand what could how we can bring in energy efficiency into being.

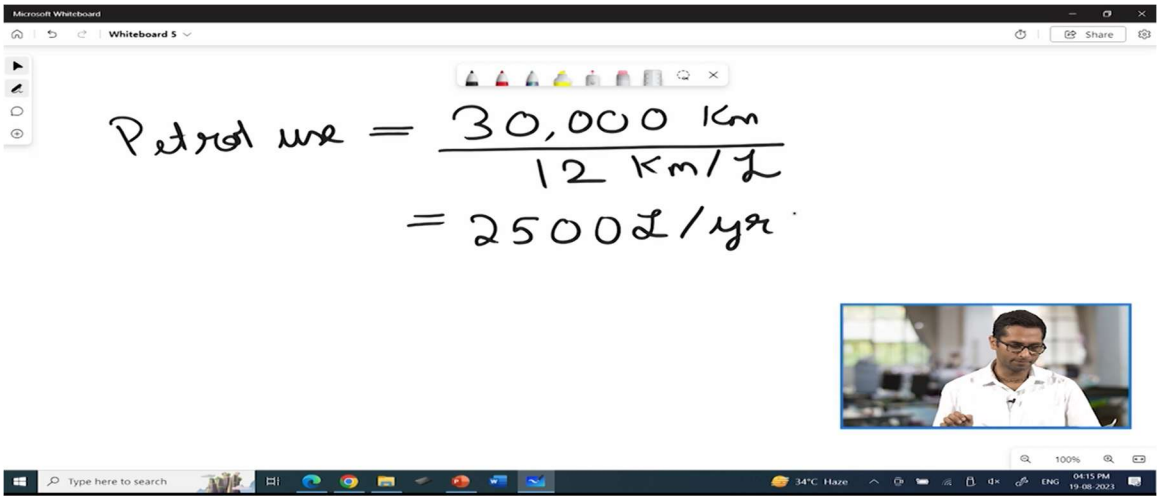
Example:

A delivery agent does 30,000 km/year and uses a light truck that travels 12 km per litre. How much CO_2 does this truck produce per year? It is suggested that the salesperson substitute the truck with a small car that with 25 km/l consumption. How many litres of gasoline will be saved annually and what will be the reduction in the CO_2 emissions? You may assume that the gasoline is composed solely of octane (C_8H_{18}).

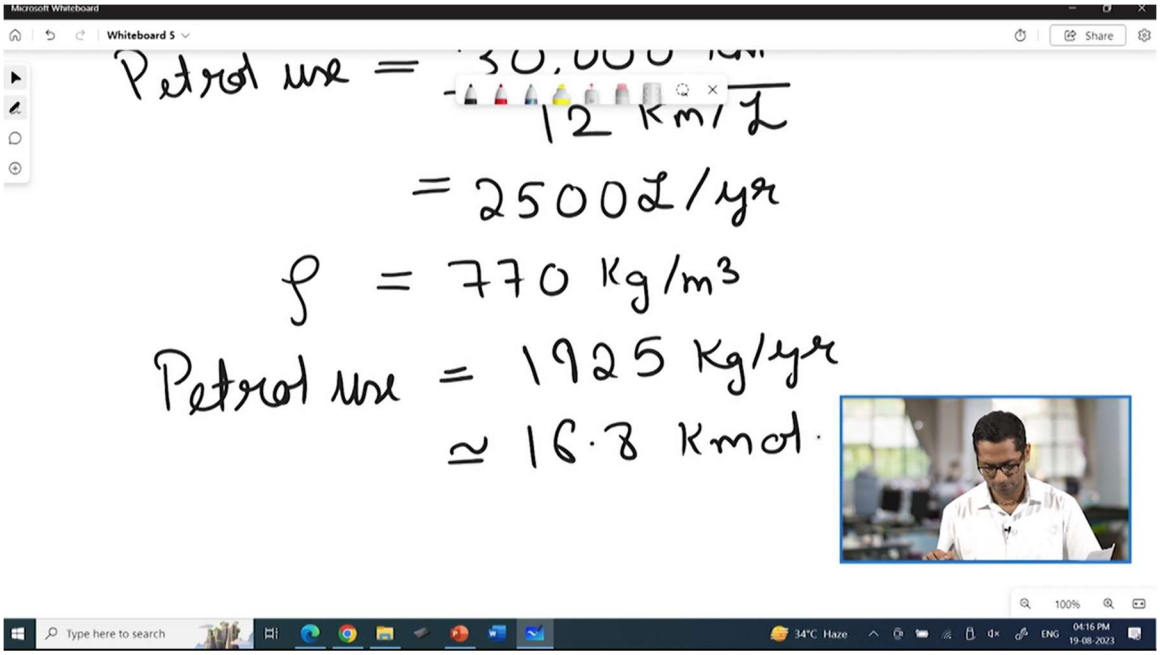
- Density of gasoline is 770 kg/m3

Mitigating Actions

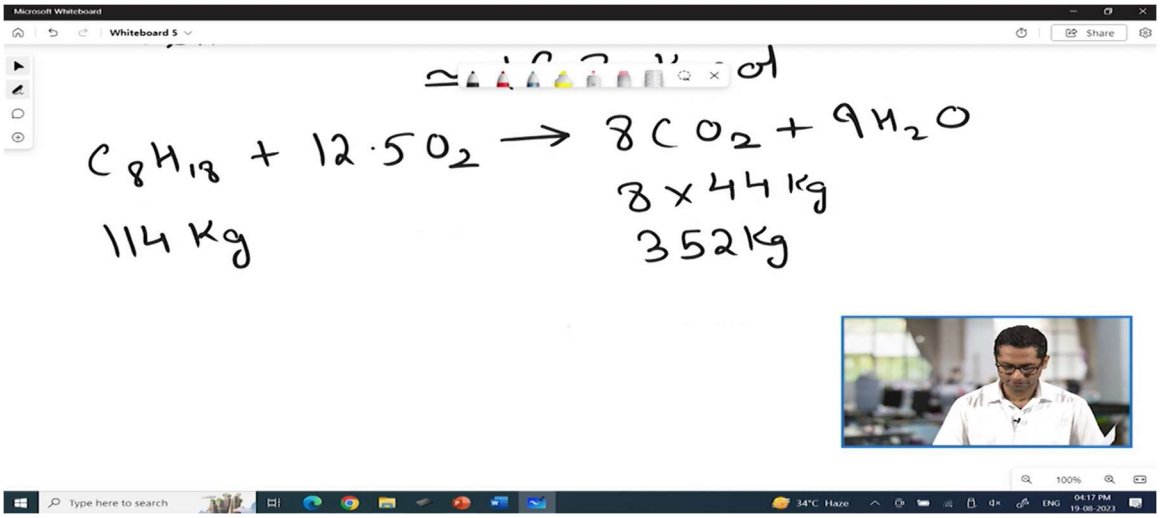
So let us take the example of a delivery agent who is working for any of the companies an example could be amazon or something similar so the delivery agent would is expected to travel around 30,000 kilometers a year and we are expecting that and this the so-called agent is currently using a light truck and the mileage could be around 12 kilometers a liter we would want to estimate how much CO2 does this truck produce every year and it is also suggested that what if the salesperson would want to substitute this truck with a smaller car maybe a hatchback and and the the efficient or the and for this car and the mileage could be 25 kilometers so let us reduce to 25 so 25 kilometers/litre and we would want to understand how many liters of gasoline will be saved and what could be eventually reduction in CO2 emissions and we may also want to assume that gasoline is composed only of alkanes whereas it has many hydrocarbons let us for this critical calculation let us say it's only obtained and the density of gasoline is also known to us as 770 kgs per meter cube of gasoline.



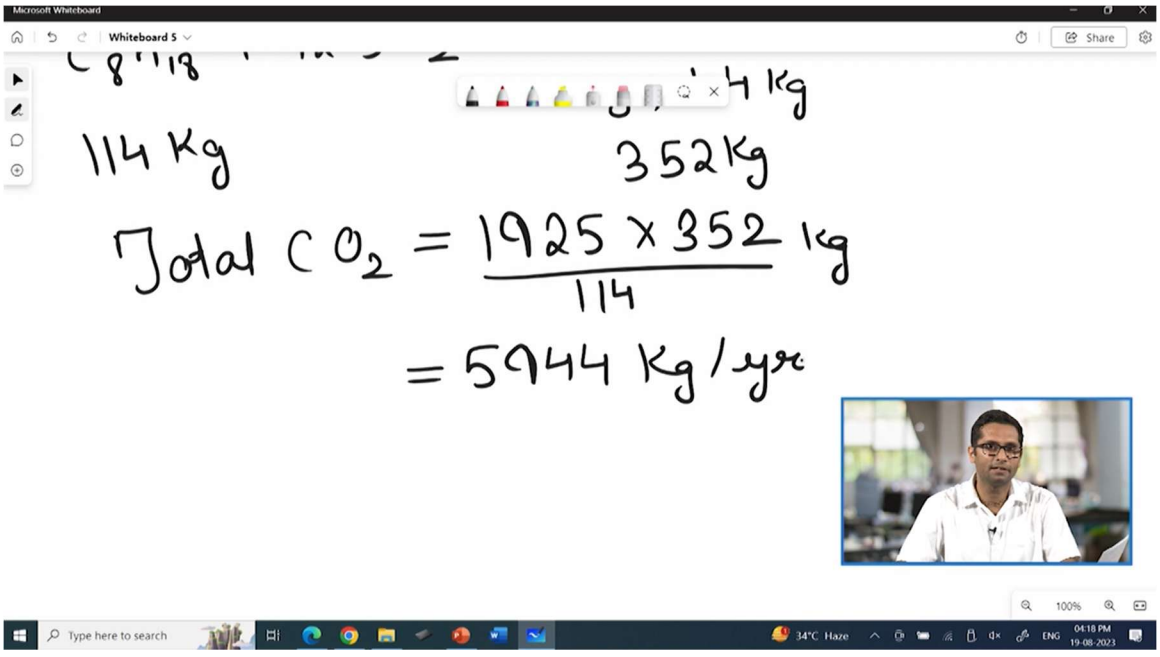
So let's go to the whiteboard and try to do the simple calculation so first let us go with the petrol use so we are traveling around 30000 kilometers and the mileage is almost for the small truck is 12 kilometers per liter so we do this and division and we come to the conclusion that this would be consuming almost 2500 liters of petrol per year.



The density of petrol is also known to us in the form of row and this is given to us at 770 kg per meter cube I can multiply this with the above figure and the petrol use would come out to be roughly 925 kgs per year I can also divide this with the molecular weight of octane and this would be roughly 16.8 kilo moles of fuel that would be used now.

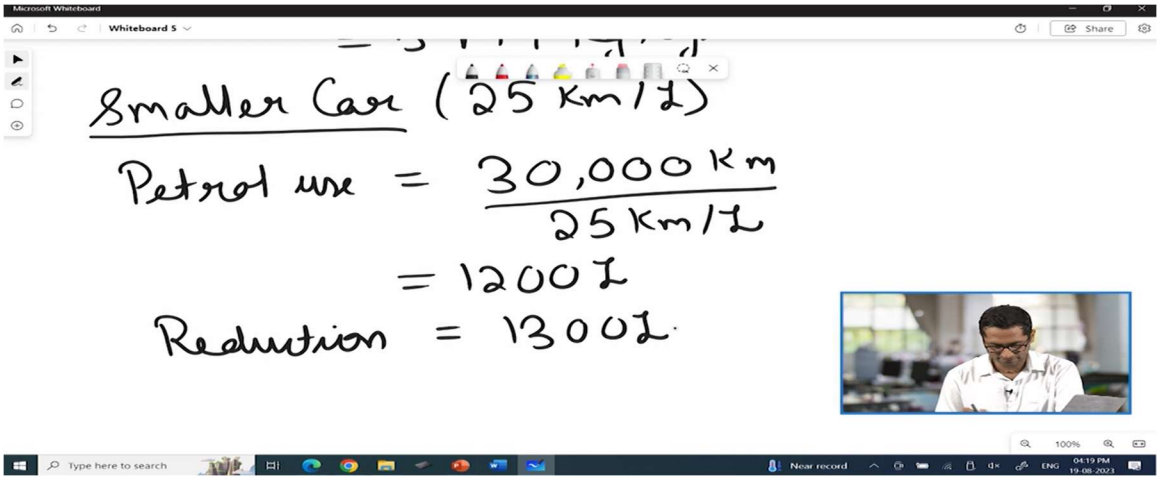


Octane we understand can be given by the formula C8H18 this would eventually combine the 12.5 moles of O2 or oxygen and eventually lead to production of 8 moles of CO2 plus 9 moles of water or I can also say 114 kgs of octane which is the molecular weight of octane is going to lead to 8 into 44 kg which is the molecular weight of CO2 and eventually this would come out to be 352 kgs of CO2 getting produced.

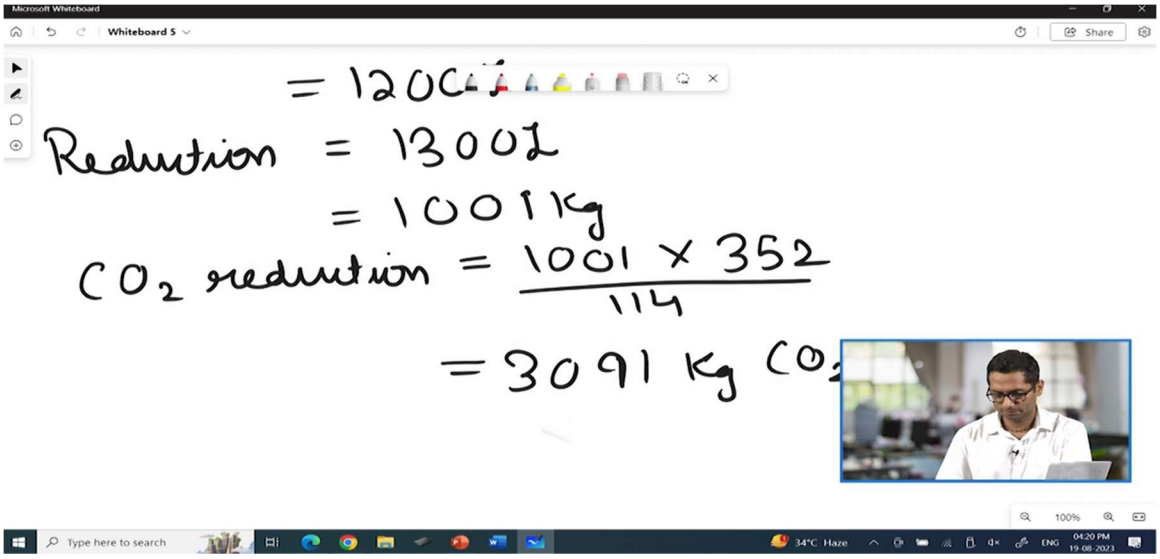


So if I was to estimate the total amount of CO2 that is getting produced this will be equal to the fuel that was being used 1925 into 352 which is the CO2 and divided by 114 in the form of kgs and the answer would be 5944 kgs. So a typical truck small truck riding around 37 kilometers is going to release almost 6 tons of CO2 in a year which is not very

much and if I am going to replace this vehicle with a smaller car and I am taking the mileage of a smaller car to be 25 kilometers per liter.

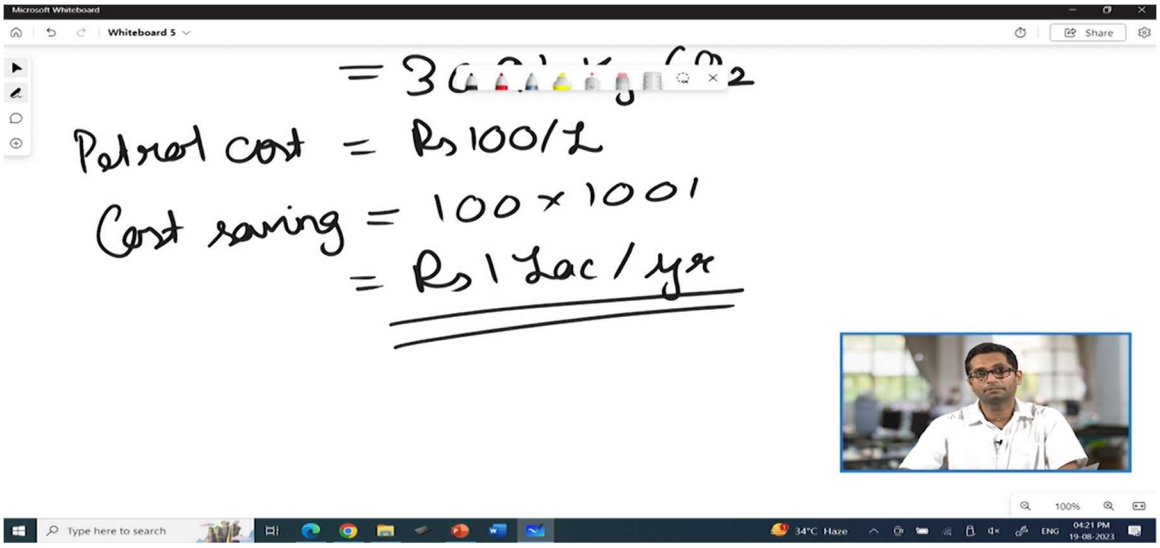


So if we can see the use of petrol this would be the 30,000 kilometers again divided by 25 kilometers per liter and this would be coming around to be around 1200 liters of fuel compared to earlier earlier we are using 1925 so we are using good amount of petrol and the reduction sorry earlier we were using almost double 2500 liters so the reduction I would say is almost 1300 liters and we can also estimate the amount of CO2 that is getting reduced and this reduction is also equivalent to a 1000 kgs or so.



So if I talk about okay maybe I can say 1001 kg just multiply that with the density if I talk about the CO2 reduction that would be coming from this change this would be 1001 kgs of fuel that is saved multiplied by 352 divided by 114 and this would be roughly

around 3091 kgs per CO2. So this small change of going to a more efficient vehicle can help us save around 3 tons of CO2 for a year and this is just for one salesman and not only this is also going to be accompanied by a saving in the cost.



So we can also assume that the typical petrol cost at the filling station could be around rupees 100 a liter and the cost saving that the salesperson could incur would be around 100 into 1001 so roughly 1 lakh rupees a year. So there could be some significant cost saving that also comes in with the increase of the efficiency of the process but again this might limit the carrying capacity of that particular salesperson the amount of goods he or she can carry becomes limited as well. So there is another trade-off there. So we can see we can make some amount of carbon reduction if we go towards much more efficient processes but given the extent of CO2 emission that we are experiencing this might not be able to make a worthwhile dent.

So if you go back to the slides then another pathway that could be adopted would be substitution of the coal-based power plants with nuclear or hydro-based production technologies which are much more like which have been used in the past as well and there has been a good amount of experience. So for nuclear we can say that it has been used in the developed world for the past 60 years or so the experience is very good like there have been technologies that have been there around.

2. Substitution of coal with nuclear fuel for the production of electricity:

- The nuclear reactor technology is well advanced, and the OECD countries have had more than 60 years' experience inoperating such reactors.
- However, before this solution becomes widely adopted, we will have to address the environmental problems of nuclear energy, most notably the long-term storage of nuclear waste.

Mitigating Actions

Source: Michaelides, E. E. (2018). Energy, the environment, and sustainability. CRC press.
https://www.needpix.com/photo/1851593/nuclear-central-energy-radiation-fireplace-contamination

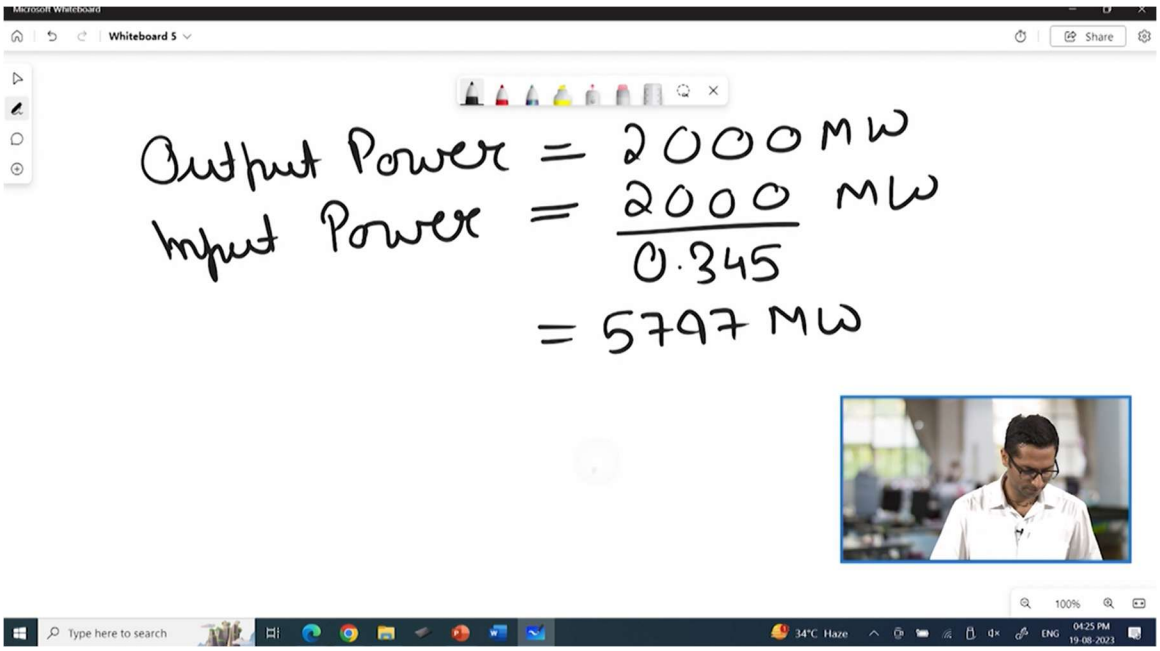
There have been major incidents like the Chernobyl or the Fukushima disaster and that is something that has created a perception of a negative perception for the nuclear fuels and this is something that needs to be well addressed if these kinds of technologies are to be propagated in the future. So we have had major environmental disasters resulting from these kinds of power plants although the probability is quite less but these kinds of disasters have happened and they could happen in the future. So we would have to look towards the long-term safety as well as we would also have to look at the storage of the nuclear waste that is created. So this nuclear waste needs to be stored and it needs to be stored for a quite a time in the future so that it does not come in contact with the living organisms and that is again a big issue. And let us try to understand the applicability of these kinds of alternates with the help of another example.

Example:

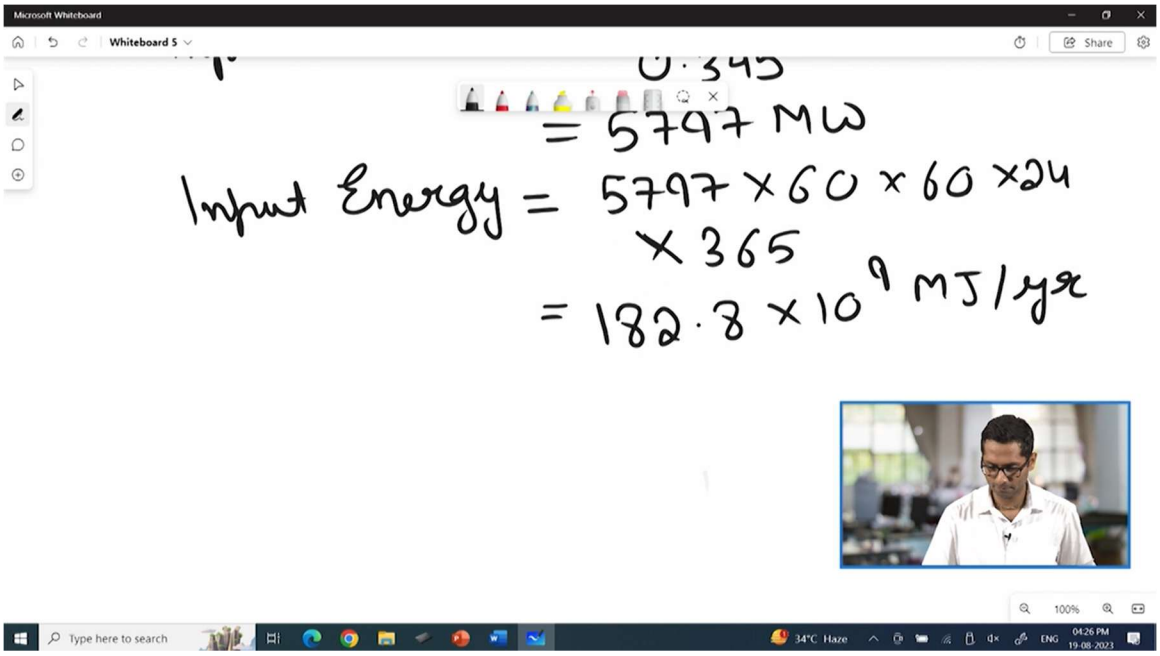
It is suggested that five older coal power plants with a total 2,000 MW capacity be substituted by two 1000 MW nuclear power plants. The average thermal efficiency of the older plants is 34.5%. Determine the annual CO_2 emission reduction. Heat of combustion of carbon is approximately 32,800 kJ/kg.

Mitigating Actions

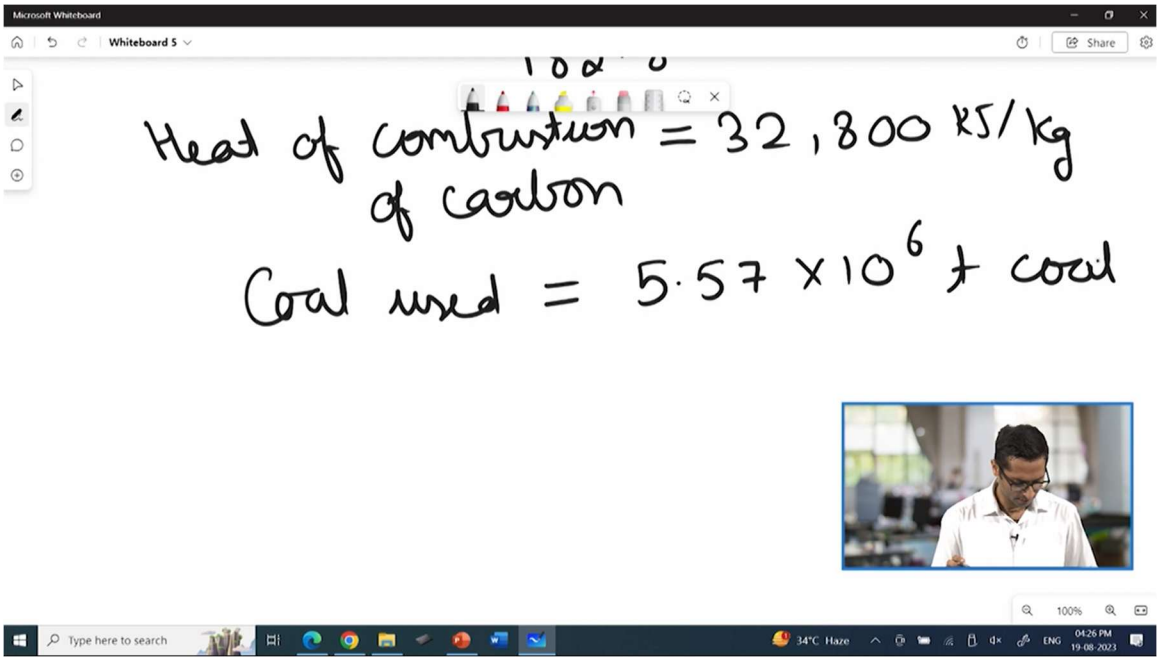
So let us suggest that we would want to suggest our retired 5 old coal power plants that have been into operation for quite few years and they were in totality they were providing a power range of around 2000 megawatt. We would want to now replace these power plants by 2000 megawatt nuclear power plants. The average efficiency of the older plants I am assuming to be around 34.5 percent. Let us determine the amount of CO2 emission that they were producing and given that we will take an assumption that all of the energy is coming from coal and the coal is composed of 100 percent carbon. So let us and we also aware that the heat of combustion of carbon is approximately 32,000 kilojoules per kg. Again I am considering a high grade coal to be used in this particular case. So let us go to the whiteboard again.



So let us try to understand that the output power that I am looking for in this case is equal to 2000 megawatt and the corresponding input power that I would have to put in would be 2000 megawatt divided by 0.345. So this is the typical efficiency of the coal based power plants that I have assumed and this number would come around to be 5797 megawatt.

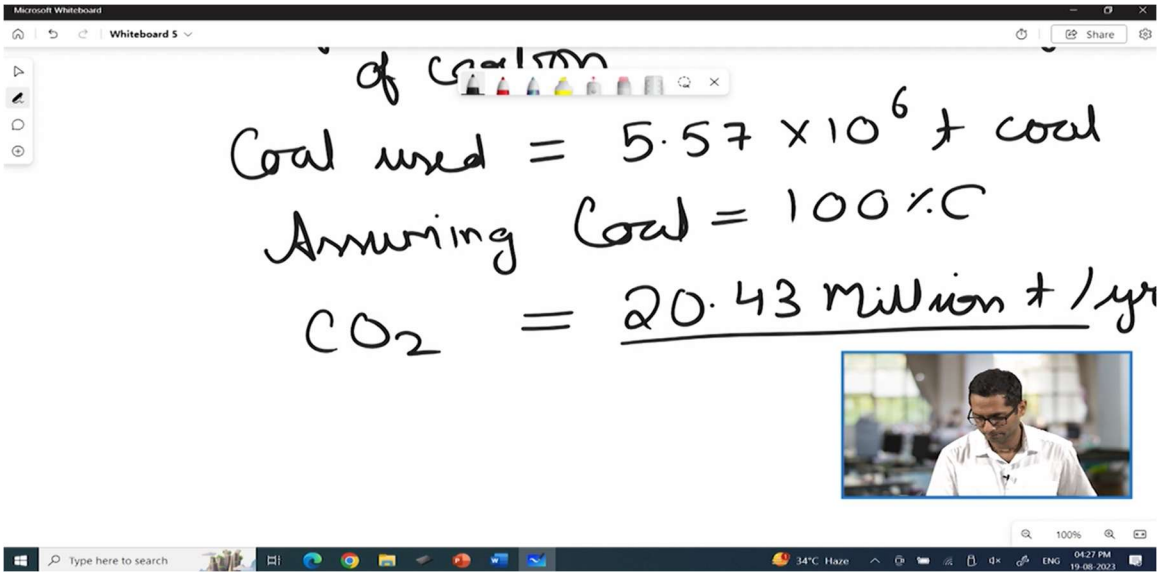


If I talk about in the energy terms the input energy that I would need would be is 5797 into 60 seconds 60 minutes 24 hours and 365 days. Assuming that this plant is operating throughout the year and the input energy would be roughly 182.8 into 10 to power 9 megajoules per year.



So this is the amount of energy that I would require and I also know the heat of combustion of carbon and this is known to me as 32,800 kilojoules per kg and I divide

the two values and divide the total energy by the heat of combustion of carbon and this would give me the coal that would be used and this would come around to be around 5.57 into 10 to power 6 tons of coal and.



Assuming that coal is 100% carbon I can calculate the amount of CO2 that would release and the CO2 that would be released would come out to be around 20.43 million tons and this is per year. So you can see that a change in one of the major power producing plant to a technology that would not have carbon emission can help save a lot of a lot amount of CO2 because these are the point sources of CO2 where the CO2 is concentrated and the production happens at a very fast pace. So and these kinds of changes could have much greater relevance as compared to the efficiency change where the use would be widespread much more decentralized and varied and if we go towards a technology that could be like nuclear or renewable we could have enough savings in terms of the carbon dioxide release on an yearly level. So these this we have discussed two major mitigation measures what is the efficiency increase and the other is updating the technology to nuclear or maybe hydro.

We will continue on with this discussion in the next class as well where we are going to discuss some other measures like carbon sequestration or the carbon utilization or growing more trees seeding of carbon dioxide with oceans or it could be the redirect air capture and we will try to understand how does those methodologies compare to these one. With this we end today's class. Thank you.