Non-conventional Energy Resources
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Lecture - 02
Energy Usage by Humans: Estimate of Impact on Atmosphere

Hello. In this class we will look at Energy Usage by Humans, and in particular we will try to look at the impact that we have through our energy usage on the atmosphere. So, if you see a popular discussion, you see you know articles in you know newspapers, magazines, you hear a lot of discussion on you know what we need to do with respect to global warming and so on. A lot of that discussion is based on this idea that something that we do is impacting the composition of the atmosphere.

So, there is you know at least in the popular audience, there are some disagreements on the extent to which we make an impact on our atmosphere. So, what we are going to do today in this class is to basically go over a calculation a step by step calculation, where we will look at what is it that we are using and what kind of an impact that has on the atmosphere and you know how seriously we need to consider it. So, this is the kind of thing that we will look over in this class.

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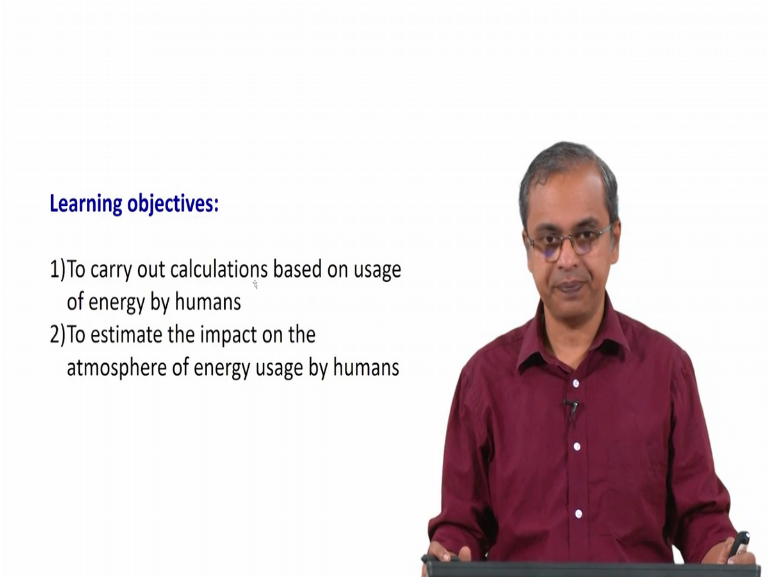

So, the learning objectives for this class are basically two fold; first of all is to our job is to our intention is to carry out a calculation based on the energy usage by humans. So, just that process, what is that process that we are going to go over to do this calculation is itself a sort of a learning objective for this class. So, that you get to get a sense of you know how to go about this kind of a calculation, and also in that process I will also try to highlight you know the kinds of approximations, we make and you know what assumptions we are making and so on, so that that is something that is I think of interest to look at. So, that’s a learning objective for this class.

So, that we will do and we would also like to estimate at the end of our calculation to estimate the impact on the atmosphere that energy usage by humans has. So, that impact on the atmosphere that we are creating as a result of our usage of energy is also something that we would like to figure out, and is also a learning objective of this class okay. So, with these two ideas in mind, we will begin our discussion on this topic.

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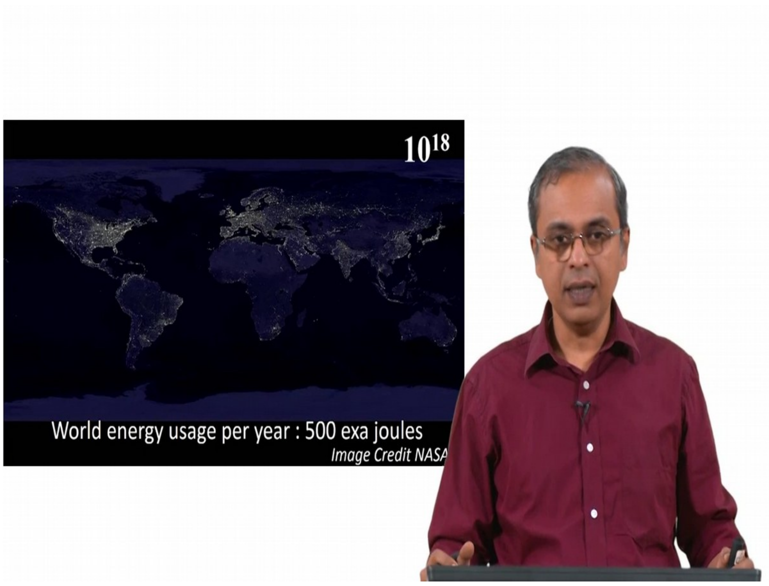

So, I think we looked at this in another class, but I will just highlight a couple of points here. So, the first is that there are estimates on how much energy humans are using per year as of now. As of now what is our annual energy usage and that is a value that is 500 exa joules okay.

Its 500 exa joules; so that is an exa joules is and the prefix exa is given if you have a 10 power 18 as the you know order of magnitude of that quantity. So, we basically have 500 into 10 power 18 joules being consumed every year. So, that is 500 into 10 power 18. So, 500 into 10 power 18 joules per year is what we are consuming. So, that is the number that we have to work with; that's a very important quantity that we need to keep in mind when we do this calculation this image of course, is courtesy of NASA it's an image produced by NASA using several hundred, maybe about 400 images individually located I mean gathered from around the world using their satellites, and then stitched together to create this image. It's a night time image which shows you how much of you know electricity is being used at various places and gives you an idea of how the energy usage is distributed across the world.

So, even as you look at this number, we also have to keep in mind that this is not uniform across the world, but regardless this is the energy that we are using as a species and so that's the number that we need to work with.

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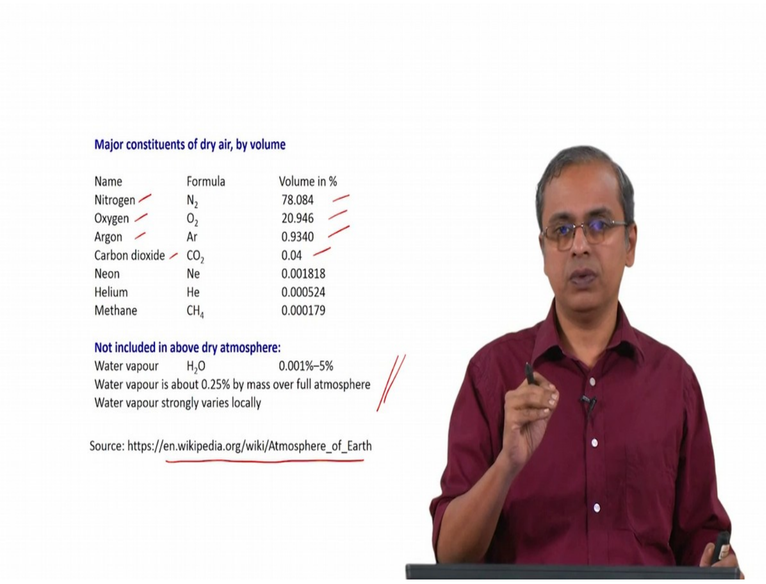

So, we will keep this number in mind and we will proceed on that basis. So, to do our calculation we have to have some starting points. So, the first starting point is to get a sense of what are the major constituents of dry air by volume. So, we would like to get a sense of what is the percentage of that constituent in the air and that's something that if we have as a starting point we can then compare what it is that we are doing and how much is it likely to change this composition ok.

So, the source for this data is Wikipedia, so that's the source you can go ahead and look at this source it gives you the same composition and of the various gases that are present in the atmosphere. So, if you look here we have the most significant constituent is nitrogen. So, that's about 78 percent of the atmosphere by volume is the nitrogen, the next major constituent is oxygen and that's about nearly 21 percent is oxygen. So, these are the two major constituents of air and that's what we are breathing in and out all the time. The other constituent which perhaps we don't talk about much at all is argon, that is 1 percent of nearly 1 percent of the atmosphere is argon, and then the 4 th major constituent is CO_2.

So, I think these are the ones that we really need to look at and particularly we are looking at CO_2, because that is the one that we are generating whenever we are consuming energy at least as of today, a large fraction of the energy that we use in fact, a very large fraction we will see the correct kind of numbers in another class, but essentially as long as you using any kind of a fossil fuel, you are using any kind of you know even if you are using electricity that has been generated using coal then essentially you are releasing carbon dioxide into the atmosphere. So, CO_2 is an ingredient that we need to keep an eye on, and today there is a lot of discussion about CO_2 being a prime contributor to global warming.

So, we got to have a idea of you know how much of CO_2 are we putting into the atmosphere, and how much of a difference is it likely to make and at what rate is it going to make this is the difference. So, I will also point out that we are not including in this calculation, the presence of water vapour. So, some of the things I will assume in this calculation as we do this calculation just to just so that we can have you know some control on what numbers we are dealing with here is that by and large I will assume all the other constituents are undisturbed by this calculation. We are only looking at C O 2, and we are not really looking at the effect of any of these other gases being present there we will just assume that they are all other inert or at least non-participating factors in this calculation.

So, we will leave that there and so there are some details with respect to moisture that are indicated here and particularly you also need to keep in mind that this moisture is not constant. Depending on whether you are at a desert kind of a location or you are at a sea coast, whether you are in winter kind of conditions or your are you know no hot humid conditions somewhere closer to the equator, based on these conditions the humidity in the air can be dramatically different. So, we are not looking at that we are not going to consider that as part of a calculation. So, we are just going to ignore that for the moment. They are simply going to look at the rest of the gases and particularly CO_2.

In principle the calculation we are going to do is actually quite simple, we are simply going to take the total amount of energy that we are using per year and see how much of CO_2 will be released into the atmosphere if all of this energy comes from a carbon based source that's all. That's all the calculation we are going to look at we are going to look at this total energy 500 exa joules of energy, and see how much of CO_2 let's say by you know per volume of CO_2, how much of CO_2 are we going to release into the atmosphere if we can get all of this energy using carbon based fuel. And just so we get an idea of you know how much of an impact it has, we are simply going to compare it against the amount of CO_2 already present in the atmosphere and we are just going to estimate approximately how many years or how long will it take for us to double the amount of CO_2 in the atmosphere simply because of our use of energy ok.

So, doubling the quantity of any gas in the atmosphere is a very significant you know impact on the atmosphere. We cannot you know look away that you know if there is from that parameter. If we know that you know we are suddenly going to double the concentration of something in the atmosphere and it's not just something inert it's doing certain specific things in the atmosphere, it could be anything it could be holding back the longer wavelength radiations etcetera any number of things it could be doing out there which we may not have complete control on. And so if you are going to double that quantity of that particular gas it's a reason for concern. Or it is at least a moment for us to reflect on and so that is all that we are going to do. We are going to see how much CO_2 is going to come out and how long it will take to double that amount of CO_2 present in the atmosphere assuming we continue to use energy at this present rate.

You should also keep in mind that they typically over the years our energy usage has only been going up. So, what is 500 exa joules now 10 years from now could be significantly different, chances are it is going to be much higher. So so, this calculation in that sense is even a conservative calculation, because we are only looking at today's usage.

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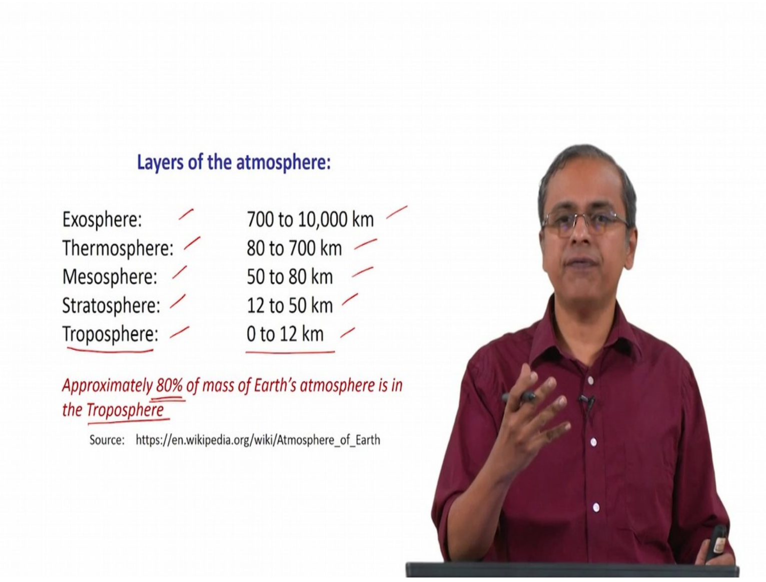

While we do this calculation, we need to understand what part of the atmosphere are we dealing with okay. So, the atmosphere is something that has many layers, people who know spend a lot of time on atmospheric signs, have actually looked at the layers of the atmosphere and have put different you know strata of the atmosphere for which they have names.

So, for example, the lowest level of the atmosphere is referred to as the troposphere. So, this is actually from somewhere between 0 and 12 kilometers from the you know; the entire atmosphere that is you know from the ground level to about 12 kilometers above the ground level is referred to as the troposphere. So, essentially a very large fraction of human activity is in this range, we are basically you know a very large fraction of our population is basically on the ground all the stuff that we do, all the work that we do, all the machines that we run are typically on the ground. We also have a fair number of you know aero planes which are flying in the sky, increasingly that is a significant number significant enough that we are looking at you know pollution impact of those vehicles in the in the air.

But if you basically are on a transatlantic flight for example, the most of these flights level off at about 10 kilometers of height. So, typically there are at 10 kilometers of height and about 1000 I mean 1000 kilometers per hour speed. So, 10 kilometers of height and 1000 kilometers per hour speed is roughly the kind of numbers that you are looking at when you are on a transatlantic flight, next time you are in one of those flights you have an opportunity to or even a long distance flight even within you know within your country if its long far enough that the flight reaches its a you know optimal cruising altitude, you will find these are the kinds of numbers that that are on display if you have such a display on the flight on in a display it front of you or if the pilot announces it to you.

So, just note for those look out for those numbers and those are the numbers you are likely to see. So, most of the jet liners; modern jet liners are flying around 10 kilometers altitude above the sea level and so, they are all flying in the troposphere. All the propeller planes the turboprops are all flowing flying much lower than that and for the most part this is all that human activity is. It stays within the troposphere; just to we do a little bit of things in the in higher altitudes as well. So, just for sake of completion we will briefly look at what what's going on at the other layers, but for the most part our you know direct involvement there is a bit on the lower side.

So, the next higher level is the stratosphere which is 12 to 50 kilometers from the ground. So, it starts off where the troposphere ends and then continues up till about a 50 kilometer altitude. And the ozone layer which is a very critical layer for us is in this stratosphere and so that's really the main thing that is present in the stratosphere that is of interest to us. A few of the jet liners will get into the are in a position to get into the stratosphere and, but for the most part our typical commercial flights are not really getting into the stratosphere they tend to stay in the troposphere. So, that's in the 12 to 50 kilometer you know altitude above the sea level.

Then we have the mesosphere which is 50 to 80 kilometers up from the ground, and this is where in fact, you know when you look up in the night sky and you see a meteor burning, up generally it is it is believed and estimated that this is the you know range of the atmosphere over which the meteors burn off. So, that's where this mesosphere enters into our frame of reference and where we even actually get to see it sort of indirectly when you look up into the sky, and you see this meteor you know a shooting star going through the sky, then it's something that's happening in the mesosphere. Above that is the thermosphere which is starts off at about 80 kilometers above the ground level and then goes up to about 700 kilometers above the sea level.

So, for us of interest in this thermosphere is the fact that let’s say the international space station, its situated somewhere in this you know range of distance from the ground its somewhere in the middle in fact, about you know 300 400 kilometers above the ground level is where the international space station is okay. So, this is how the various layers of the atmosphere are with respect to what the activities we do, much outside this is the exosphere which is finally, what merges with the open space out there and were you know solar wind then takes over. So, that is 700 to 10000 kilometers and beyond that the solar wind takes over and you are basically looking at you know open space well outside the realm of the earth.

So, these are the various layers of the atmosphere and this is how they stack up and for us of interest is this troposphere, which is 0 to 12 kilometer. And it is also of interest that you know for us to note that you know 80 percent of the mass of the earth’s atmosphere, 80 percent of the mass of the atmosphere earth’s atmosphere is in the troposphere okay. So, 80 percent of the mass of the earth’s atmosphere is in the troposphere. Therefore, we will restrict our calculation to this 80 percent. We will restrict our calculation to the troposphere. So, we are going to in any kind of a calculation of this nature, for us to do it in any you know reasonable framework of time, some number of approximations we need to make and it is for us to see if those approximations are reasonable and that they are not farfetched and also that we are not you know drastically changing the frame of reference of that you know system.

So, for now we will make this approximation that you know troposphere is where all of you know the earth’s activity is largely taking place, and that since 80 percent of the atmosphere is there let’s just stay focused on it let us not worry too much about we sort of assume that is our atmosphere, that we are not really worried about the rest of the atmosphere, and then within this troposphere is what we are going to do this calculation okay. So, all the calculation we will restrict ourselves to this troposphere. So, again this is the source for the data and you can also go and look it up.

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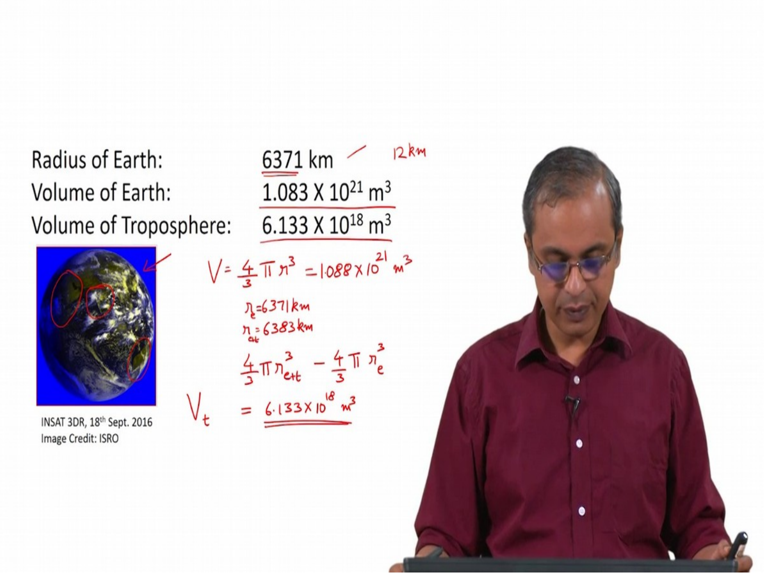

So, now let's estimate now that we have said that we are actually going to work with the troposphere, let's estimate the volume of the troposphere or rather will basically estimate the amount of the volume corresponding to the gas, that is held in the troposphere all right.

So, to do that let's look at a few simple numbers here we have here the radius of the earth, which is you know 6371 kilometers, again some approximations you have to make the earth is not a perfect sphere, but for the purpose of this calculation we will assume its a perfect sphere. So, again these are approximations that are reasonable and therefore, I think are just absolutely fine. So, if you simply do you know volume is 4 by 3 pi r cube and we use this 6371 kilometers as your r value of radius of r, then we get this answer of 1.088 into 10 power 21 meter cube as the volume. This value that you see here that's the value you will get as the volume of the earth. So, that is the volume of the earth. This volume is not immediately of importance to us we are more interested in the volume of the atmosphere that is just above this earth. And so, if you simply look at as we just saw in our previous slide, that the troposphere goes from 0 to 12 kilometers height.

So, we now need to look at a sphere where we use a value of r. So, for the value for earth we use r is 6371 kilometer and for the earth plus the troposphere we look at a value of r which is 6383 kilometer, and then when you subtract the two you subtract the volume of the largest sphere from the volume of the smaller sphere inside it, which is the volume of the earth then you get the volume of the. So, 4 by 3 pi r earth cube actually I should change this earth plus troposphere. 4 by 3 pi r of earth plus troposphere cube that is earth plus troposphere and this is only earth minus 4 by 3 pi r earth cube. So, if you do this then you will get the value that you see above which is 6.133 into 10 power 18 meter cube.

So, this is then the volume of the troposphere okay. So, this is the volume of the troposphere. So, by just quickly looking up simple values which is the radius of the earth, and the thickness of the troposphere and then calculating the volume of the earth plus the troposphere and then subtracting from that the volume of just the earth, we get the volume of the troposphere. So, this is the volume of the troposphere this value out here, 6.133 into 10 power 18 meter cube, that's the volume of the troposphere. So, you can run through these numbers and you should arrive at a value of this nature.

The image that you see here is courtesy of ISRO the Indian space research organization. So, its just an you know color image of the earth you can in fact, see I think I believe that is India right here, right here you will see the you see India and somewhere here is Australia and I think somewhere here you should see edge of Africa showing up somewhere there, but anyway. So, this is just the photograph of the earth, and more specifically I think what is of interest I just put this image up to just highlight one aspect of our calculation, which actually was very nicely stated in some other discussion that I had heard earlier which is basically that you know if you make a if you take a globe in your house, which let's say you have a sphere in your house which represents the earth and you have you know the map of the earth plotted on that sphere; then if you see here if you look at this value 6371 and the fact that the 80 percent of the atmosphere is within 12 kilometers of this ok.

So, that 12 kilometers is a very small you know dimension small distance relative to this 6371 kilometers. So, if you take a globe which is that size, then you know a coat of paint or varnish or whatever it is that you have put on the globe, it is really all there is in terms of the equivalent of the thickness of the atmosphere. So, the atmosphere is so thin relative to the you know the overall globe that we have. So you know, we think there is a big atmosphere up above us, it is large relative to us, but if you take into account the size of the earth it is really not that very large. It's a very thin layer and that was a very nice description I saw elsewhere, where they refer to it as you know not being thicker than the coat of paint or coat of varnish that is present on a typical globe, that you might buy commercially somewhere.

So anyway, so this is the value of the thickness the volume of the troposphere right. So, we will keep this number in mind.

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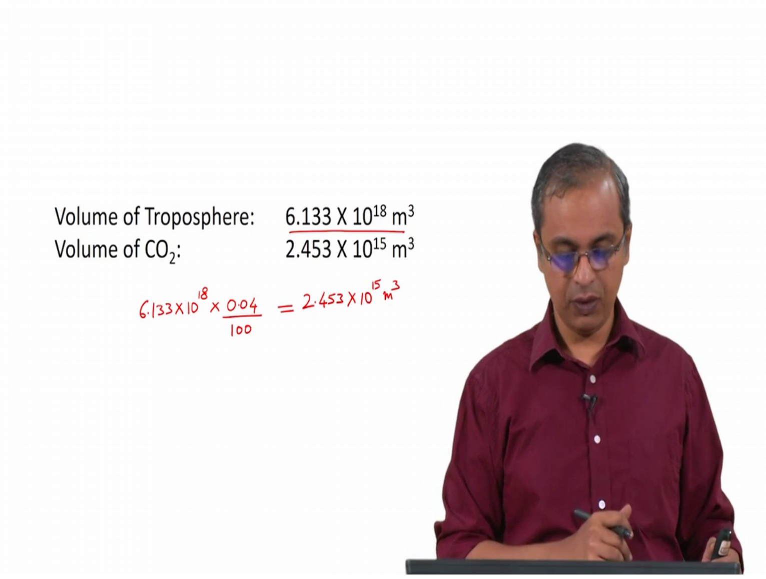

And let's now consider the fact that if you go back to the composition. If you go back to the composition of the air dry air then we find that 0.04 percent of this of the volume of the atmosphere is carbon dioxide okay. So, we will use the same 0.04 percent, and say that 0.04 percent of the volume of the troposphere is the carbon dioxide available in the troposphere. So, if you come here that is exactly what I have done, this is the volume of the troposphere and if I take 6.133 into 10 power 18 and multiply that with 0.04 by 100 you will get this value here ok.

So, that is the volume of carbon dioxide present in our atmosphere all right. So, we have simply just looked at the percentage and come up with this calculation, and you can just again as I said you know run through these numbers and you should see some number close to this. So, that's any interesting now in interesting quantity for us to keep in mind. So, we are as I said by the time we complete this discussion, we are sort of also curious to figure out you know what are we doing with you know with in comparison to this volume, and you know how quickly we may end up generating CO_2 which matches this volume, which means we have now doubled the amount of CO_2 in the atmosphere. So, that is something that is of significance and we are like we are trying to get a handle on or we are trying to get a feel for how long does it take for us to do something like this alright.

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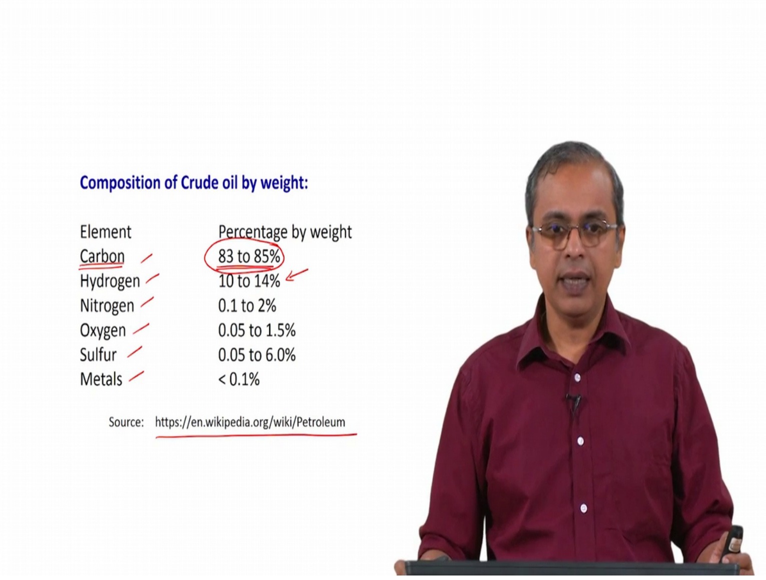

So, now we are now got this idea of how much carbon dioxide is present in the atmosphere. Now I would like to look at the second part of this calculation, which is that we are using some amount of energy how much carbon dioxide are we releasing as we use this amount of energy. So, that’s the second part of the calculation we have to do. For this again we have to make some assumptions.

So, since we are now looking at carbon dioxide as the aspect that we are focusing on, we will assume that the energy is coming to us through the use of you know fossil fuels, which are carbon based carbon based fossil fuels are being burnt to generate the energy that we are using as human beings and so on that basis we will figure out how much carbon dioxide is being released. So, is this an unreasonable assumption is the first question we have to ask ourself. So, actually it turns out that it is a very reasonable assumption, because in today’s world as of you know as we approach the year 2020 if you look at what is the you know source for the vast for a vast fraction of the energy that we are using.

The source for vast fraction of the energy we are using is coal. Its coal is what is being used in many many many places to you know fire up the power plants, and through that only we are getting our electricity. So, while we sit at home and we use electricity or we sit in our office and use electricity, the source of the electricity is often based on coal. Increasingly there are countries which are looking at other renewable sources of energy which is what we will see as we go through with our class. But today if you just look at the you know scenario of how much energy is being generated using a carbon based source, a very large fraction of the energy is being generated by the carbon based source.

And, so for all the energy that we use you know the 500 exa joules of energy that we use, significant fraction of that has come from coal and so for the purpose of our calculation we are just going to assume that all of it has come from coal okay. So, that that final you know approximation we are making, just for the purpose of our calculation just to get a sense of you know what we are doing with respect to it, and that is not a very unreasonable assumption. It’s a fairly reasonable assumption and we will see that in one of our later classes.

So, let’s now look at the composition of crude oil for example, again you know you take some you know hydrocarbon based source which typically comes from crude oil and then you are going to use it to generate you know energy. So, if you actually see a significant fraction of the crude oil, is carbon is based on is has carbon as this main element, which is present in the crude oil. Again this is the source for this data you can again look it up on your own as well. So, about 83 to 85 percent of what is present in crude oil you know which is being taken off of the ground at so many places is carbon. I will also point out that you know the exact composition of crude oil varies from location to location. So, this is only some kind of an approximation of the composition of the crude oil, but generally it is in this range and therefore, it is an acceptable number to go with.

So, you do have carbon, you have hydrogen, you have nitrogen, oxygen, sulfur even a very tiny amount of metal that is present in the crude oil, but a large fraction this 83 to 85 is carbon and so for our purposes, this is all we are going to focus on we are just going to focus on carbon. We are just going to say that in fact, technically you can be even be burning hydrogen 10 to you know 14 percent is hydrogen and that also is going to you know burn generate water and generate some energy, for the moment we are ignoring it. So, we are just basically looking at the carbon as the source. So, we may be off by about 10 percent in our calculation 10 - 15 percent in our calculation, but that’s not a big issue given the kind of numbers that we are dealing with. So, that is the point that I wish to make.

Keeping this in mind that is move to the next part of our calculation which is basically to look at the heat of formation of carbon dioxide.

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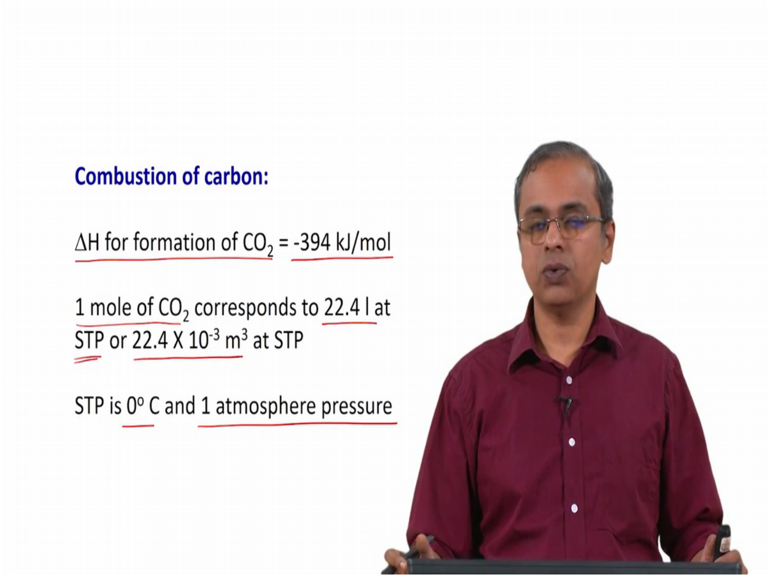

So, how do you look at what is the energy that you are getting from some fuel any fuel; you would you would you have some fuel that has some components in it they all get oxidized and that's how you release energy. So, how do you know what is that energy. So, people have done careful studies on this, and you have tables for these thermodynamic tables are available and they are in a position where you can go and look up the heat of formation of a compound. So, heat of formation of CO_2 starting from you know carbon which is in graphite form and then it reacts with oxygen and generate CO_2 for you, and in that case how much energy is it releasing right. So, you will see a number of this nature minus 394 kilojoules per mol is the typical number that you will see.

So, why is it minus? It is minus because that's the sign convention that is used it means that heat is leaving the reaction, that is it is an exothermic reaction right. So, if it is an exothermic reaction they put a minus sign in front of it. And so this is an exothermic reaction and that is exactly why we use it as fuel we use it as fuel because this is the amount of energy it is releasing, and then we are able to use that energy for a variety of different things.

So, this is the number amount in kilo joules; so 394 kilojoules per mol per mol of the carbon dioxide that is generated. So, a mol in this case you know if you take carbon one mol is 12 grams. So, every time you burn 12 grams of carbon this is the; you will get some corresponding amount of CO_2. So, you will get what 12 plus 32. So, you will get about 44 grams of CO_2, but basically you will you know you will release this amount of heat for that when you do that combustion process.

Now, one mol of CO_2 corresponds to 22.4 liters at STP. Remember that this is STP or in other words if you want since other calculations we have done are in meter cube, the volume of the troposphere that we calculated was in meter cube. I will simply convert this liters into meter cube 1 liter is 10 power minus 3 meter cube. So, 22.4 liters is 22.4 into 10 power minus 3 meter cube. Okay so, that many meter cube is what one mole of carbon dioxide will correspond to at STP. Now STP is defined as 0 degrees C and one atmosphere pressure actually one atmosphere is now a little bit of an approximation.

So, but in any case we can assume that to be the correct definition as of now it is 0 degrees c and one atmosphere pressure, that's a pretty good number to go with a set of conditions to go with. So, that under those conditions at 0 degree centigrade and one atmosphere of you know our atmospheric pressure, one mol of carbon dioxide will occupy 22.4 into 10 power minus 3 meter cube or 22.4 liters. Now you can ask yourself the entire country is not sitting at 0 degree C if you take India for example, it's definitely not sitting at 0 degree C for the most part maybe a few places you know up north if you cross Delhi and start going further north, as you get into the winter seasons temperatures can drop to 0 degrees C can go below 0 degree C.

There are places in the world which are sitting you know which are well below freezing conditions where there is lot of snow. So, they are definitely below 0 degrees C and more importantly that is just the surface of the earth. If you start climbing up from the surface of the earth as you go to higher and higher altitude, the temperature above outside the temperature at those altitudes it keeps getting lower and lower and lower certainly this is so, in the troposphere.

So, that is why when you are in a flight, if you are you know flying in a aeroplane somewhere high up in the sky, you will often have you know halfway into the flight the pilot will come on and give you some idea of you know where your destination is, how far you are from the destination and usually they will also give you some idea of what's the you know speed they are traveling with. And the temperature that is outside. Invariably you will find the temperatures that they will be referring to will be well below 0 degree centigrade, that they will say you know temperature outside is such and such temperature. So, the point is the temperatures that we are dealing with in the troposphere start off in the surface, you know at various locations on the surface of earth at you know several tens of degrees centigrade and as you go up into the higher ends of the troposphere, you have a temperature which is in the several tens of degrees in the below 0 degrees.

So so, say minus 20, minus 30, minus 40 degrees C and on the plus side you will have plus 10 plus 20 plus 30 kind of degrees C as the range of temperatures. So, say minus 40 to say plus 30 is the kind of range of temperatures that you are looking at for the you know atmosphere the troposphere across various locations. So, given that this is the range we just take you know 0 degree C as somewhere in the middle and then we will assume that that's representative of this entire troposphere. So, again there is an approximation there and we will assume that this approximation is valid. So, that is the way we are going to go about it. Therefore, so if you actually have completely different conditions of temperature and pressure this number that we are talking of 22.4 will not be actually correct.

But we are just assuming that this number is representative, the conditions we of 0 degree C and 1 atmosphere pressure are representative of the circumstances, that we have atmospheric pressure in fact, is going to decrease as you go up, but regardless we will assume that this is the number that we are dealing with; so again an approximation for you to keep in mind.

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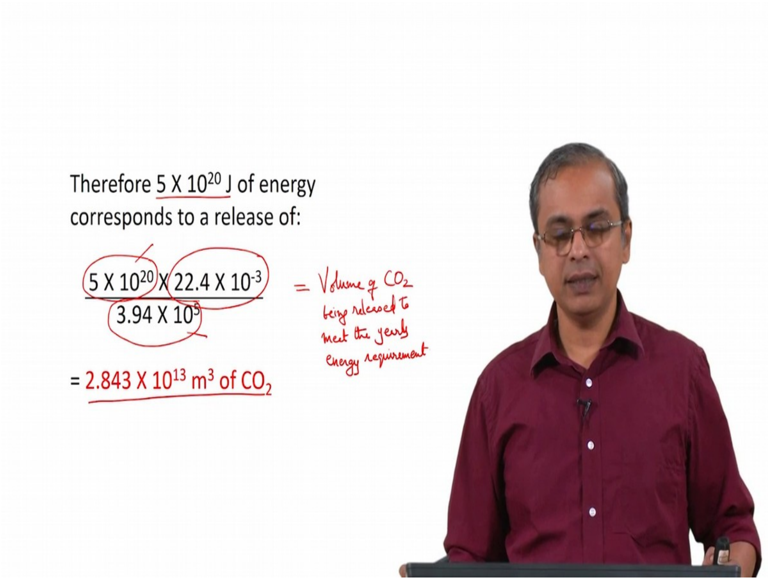

So, given that we have this information let's look at what we are dealing with. As I said we have 5 into 10 power 20 joules of energy that we are consuming per year all right. So, if you go back here the heat that is being released when you burn 1 you know gram of carbon or you release 1 mol of CO_2 in the process of releasing a mole of CO_2, the amount of energy that is being released is 394 kilo joules or 3.94 into 10 power 5 joules per mol.

So, if you take the total energy that is required and divided by the amount of energy that is released, the total energy that is required here and you divide that using the amount of energy that is released per mol of a CO_2 that is released, between this these two you will get the total number of mols of CO_2 that is being released into the atmosphere right. You will get the total number of moles of CO_2 that is released into the atmosphere, as a result of the total energy that we are demanding from the system and the energy being released per mol of CO_2. And every mol of CO_2 occupies 22.4 into 10 power minus 3 meter cube therefore, if you do this calculation, we will get the total volume of CO_2 being released to meet this energy requirement to meet the yearly energy requirement.

So, this is the total volume of CO_2 that is being released to meet the annual energy requirement of the humans human beings. So, for all of us put together this is the total volume of CO_2 that is being released. So, that is this number that you see here; 2.843 into 10 power 13 meter cube of CO_2 is being released or will need to be released if the entire 500 exa joules of energy, that is being used by mankind is released by combusting carbon. So, that's the number now we have arrived at. So, we have now gone through a calculation, where we have made a bunch of approximations, we have assumed that the earth is spherical, we have assumed that all the atmosphere is only that which is within the troposphere we have assumed that the conditions STP will hold for this entire set of you know this is the thickness of atmosphere. And and also that we have we have assumed that all the energy is now being released from carbon combustion.

So, if we do that we come with this come up with this number of 2.843 into 10 power 13 meter cube of CO_2 that is going to be released per year, to meet our energy requirements. So, now, it is of interest to compare this number with the amount of CO_2 that is actually already present in the atmosphere. So, let's do that.

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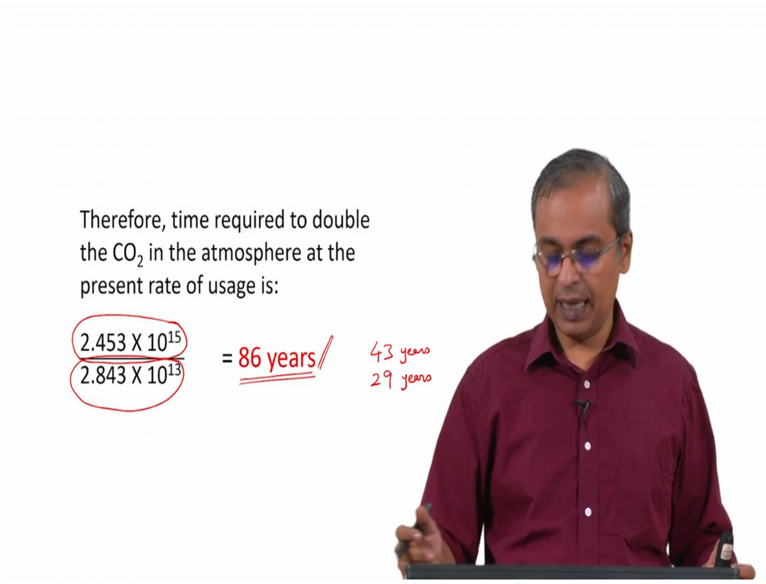

So, the total amount of CO_2 that is present in the atmosphere is this number that you see here in meter cube okay. So, that is the volume of CO_2 present in the atmosphere in meter cube, and that is simply the 0 point you know 0 4 percent of the volume of the troposphere okay. So, that is just 0.04 percent of the volume of the troposphere and that is the amount of CO_2 that is present in the atmosphere as of now.

The denominator is the rate at which we are releasing CO_2, based on our annual energy requirement okay. So, based on our annual energy requirement this is the amount of CO_2 we will release into the atmosphere every year. So, if you compare these two numbers if you take the total amount of CO_2 present in the atmosphere, and divide that using this amount of CO_2 that we are releasing every year into the atmosphere, we get a number of 86 years. So, in the present rate of usage of energy if all of the energy is being released using carbon based sources, in 86 years we will double the amount of CO_2 present in the atmosphere okay.

So, that's a phenomenal increase in the amount of CO_2; please keep in mind that you know our planet has been I mean our solar system has been around for a few billion years, and you know we have had evolution occurring over several millions or tens of millions of years, human beings have around been around for several tens of thousands of years in various you know states of evolution and in if you take all of that into context; if you take all of that into context 86 years is nothing. I mean 86 years just disappears 86 years is virtually a fraction of a second of existence in terms of you know the entire evolution that has happened in humankind right.

In you know on the planet of which we have ourselves been in a very large you know significant period of time, relatively I mean the grand scheme of things even our presence is not a very large fraction of time, but even with respect to our existence alone, 86 years is nothing I mean it its well within you know most of us these days if you look at the lifespans of people around the world at least in the you say developed countries or where or at least in countries where there is better medical facilities, better health conditions many people are living to be 80-90 years old right.

So, within the lifetime of a single human being, you are doubling the amount of carbon dioxide present in the atmosphere you know as a species we are doing this. So, that is a phenomenal thing that I mean phenomenal way in which we seem to be interfering with what is you know some kind of an equilibrium, that has evolved over you know millions of years of evolution in the atmosphere right.

So, lot of things are happening in the atmosphere, I mean CO_2 is being released from various sources and the plants are you know capturing the CO_2 and then you know refreshing the atmosphere etcetera. So, when we do something which is outside this scope of operation and suddenly start increasing the amount of CO_2 present in the atmosphere, we cannot assume that the atmosphere will somehow take care of it. It doesn't happen that way we have to have some way of handling this at the moment we have not really consciously looked at it, but when we look at a number like this and we see that we know within the matter of 86 years, we are actually going to double the amount of CO_2 present in the atmosphere it is definitely a cause for concern. We cannot just look the other way we cannot pretend that this is a non issue. We have to at least we have to at least make a good attempt to understand what is the significance of having double the amount of CO_2 in the atmosphere ok.

So, lot of people link this to global warming a lot of scientific reports link, the amount of carbon dioxide present in the atmosphere directly to the temperatures that are present in the that are being experienced across the earth and therefore, if you double the amount of CO_2 you are bound to have a significant impact on the temperature profile of the planet. And so it is not something that you can ignore.

Also remember, one other approximation which we made which I said at that point I highlighted at that point is a conservative estimate, is the fact that I am using today's energy usage which is 500 exa joules per year, and exa joules per year and this is something that has only been increasing okay. So, what is 500 exa joules here per year today maybe 10 years from now may be double in terms because our population is only increasing, even if our population levels off at some point the you know the amount of development that's happening across the population is increasing. Legitimately we want more and more people to have better quality of life.

Generally better quality of life means they are going to use more gadgets, they are going to have houses that are better equipped and consume more electricity consume more energy that's the general trend. I mean unless and until we can think of some better way of you know enabling higher quality of life without correspondingly increasing the amount of energy usage across everybody, including the people who already have this facility. Until and unless we figure something like that out as of today the path is that for development to occur more energy usage will be there, most people will consume more energy. And therefore, given that you know you could see even right in the very first slide that I showed you, where you saw energy usage across the world. There are significant fractions of the world which are still not using anywhere close to the amount of energy that the so called developed regions of the world are using.

Naturally when the rest of the world also starts using the same amount of energy as the developed world, the amount of energy that we will use in the world goes up significantly. So, going up by a factor of 2 or factor of 3 its not at all impossible even you know in the just extrapolating what we are doing right now. Okay so, going up by a factor of 2 a factor of 3 is not at all impossible. Please keep in mind if our energy usage goes up by a factor of 2 or a factor of 3, these 86 years will come down by a factor of 2 or factor of 3. So, suddenly you are looking at 43 years or you are looking at something even less you are looking at something like you know say 29 years.

So, imagine this instead of instead of doubling the amount of carbon dioxide in 86 years, you could suddenly start doubling the amount of carbon dioxide in 49 years, you could double the amount of carbon dioxide in 29 years and that is alarming 29 years is nothing. By the time you are you know son or daughter if you have a son or daughter who is just born, by the time they reach you know they just complete their college they are and start going into their first job there are 29 years or something of that nature 25 plus years of age. And so even in that short timeframe if you suddenly double the amount of CO_2 in the atmosphere, and if that has a major impact on the you know temperatures across the world that is something that we need to be concerned about. We cannot just look the other way I mean it is quite irresponsible for us to just look the other way if that's the rate at which we are you know making a difference to the atmosphere.

Please also keep in mind a lot of people have opinions on this and you can certainly look up a lot of scientific literature on this. Generally the scientific community is convinced that you know having more CO_2 in the atmosphere results and global warming, and when you have global warming it leads to extremes in environment. It doesn't necessarily mean the whole place becomes hot. It generally seems to result in extremes in environment. So, you have snow storms that are very severe you have cyclones that are very severe you have you know droughts that are very severe. So, each of these weather phenomena tend to become more severe.

So and therefore, the ability of the you know population to deal with it becomes harder and harder, they have greater hardship in dealing with this population with this extremities in atmospheric conditions.

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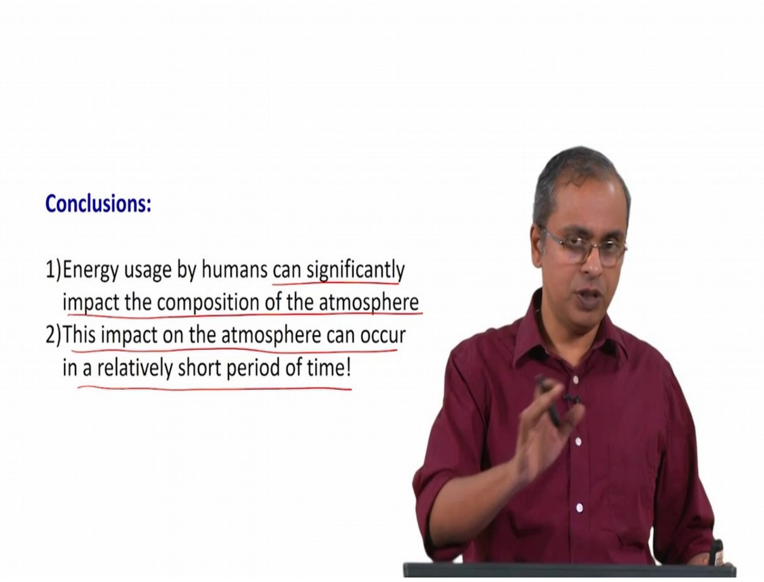

So, in conclusion we can see through our calculations that first of all the fact that energy usage by humans can significantly impact the composition of the atmosphere. So, I think that itself is a very important conclusion to focus our thoughts on, because there is at least I mean in the popular perception there is at least some number of people have this idea that the atmosphere is huge, and there is no way that you know a bunch of us sitting on the ground can actually make a difference to the atmosphere.

And therefore, this whole idea of global warming or that you know the amount of carbon dioxide in the atmosphere being high etcetera is all not really true, is the kind of idea that some number of people have. But, we have just gone through a you know basic calculation looking at some some of the basic parameters that are involved in this process of course, making some approximations which at each stage I try to explain to you what are the approximations we are making. And based on this we can understand that, we can easily we are easily doing things that are that is changing the composition of the atmosphere significantly in a small timeframe not a very large timeframe. In the grand scheme of thing I said as I told you it’s a fraction of a second in the grand scheme of evolution that we are changing the composition of the atmosphere.

Naturally that is not something that is likely to be a safe thing to do. And the fact that this impact on the atmosphere can occur in a relatively short period of time, this is exactly what I was just mentioning the timeframe is very short that this is just a momentary thing in the grand scheme of evolution that we are making this difference.

Please keep in mind many approximations we made, I will also add one more word of caution here I spoke about you know how our energy usage is just going up and then. And therefore, going up by a factor or 2 of 2 or 3 in an energy usage is not so, farfetched, which means this 86 years is going to come down by a factor of 2 or factor of 3. There is one other parameter that we are ignoring here which is actually making this calculation I would say on the you know little bit on the relaxed side it may be actually more severe than this and that is how we are treating our forests.

We depend entirely on our forest to fix the CO_2 right as of now; we don't people are looking at new technologies to capture the CO_2 etcetera that is a different issue, and we have to see how far that can go. As of now we are depending on nature we are depending on the trees and plants and vegetation around us to help us capture the CO_2 and uniformly across the world you will see that forests are being cut down. People are have you know become very alert to it and a lot of people have stepped up saying you cannot cut down forests cannot cut down trees.

And so, there are significant movements around the world to protect our environment to protect the forests because that's all we have to protect the atmosphere that we have to live with. So, that is a moment that is definitely there, but despite that moment if you just see the general trend, you will see that you know because there is an industry associated with wood or with that need for firewood etcetera for a wide range of reasons in general at least in the last several years forests have been massively cut down.

So, we are actually affecting ourselves, we are basically you know suffocating ourselves on two fronts. A we are using so much energy with the only source or primary source being carbon and so, we are putting more carbon dioxide into the atmosphere. And we are taking away that one thing that the nature has which helps us protect ourselves from this carbon dioxide which is the plants. We are just cutting them down indiscriminately and naturally we are only worsening this situation for us. So, when I come to a you know calculation which arrives at 86 years, you can see that you know that itself is you know a number that is on the I would say on the larger side, chances are we are working with numbers that are actually much shorter.

So, in summary this is a calculation in this class we have gone through a calculation which tells us what is it that way what is the status in the atmosphere, with respect to carbon dioxide what is it that we are doing with respect to you know our energy usage, how does that impact the atmosphere and throughout this calculation I have shown you tried my tried to alert you to all the approximations that are there. Primarily because if you are interested you can take up this calculation in much greater detail or you can look at literature where they may have perhaps done this in much greater detail, where perhaps they make you know much better estimates of specific quantities and then go about the calculation.

However, this calculation we have done its still reasonably good to give us an order of magnitude estimate of what we are dealing with, and that number as we came up with was well under a 100 years. And therefore, is something that we should be interested in looking at and interested in reflecting on.

As we go through this course, we look at a lot of renewable energy technologies, basic idea being that you know we can move away from this carbon based energy source and see if we can use other sources, where we can meet our energy requirements without doing this impact on the this negative impact on the atmosphere. So, we would then have those technologies leading us to a path of good comfort with good environmental impact and therefore, a positive way to go about our existence. So, we will see that in our subsequent classes.

Thank you.

KEY WORDS:

Energy usage; Impact on Atmosphere; Dry Air Constitution; Carbon dioxide; Atmosphere; Troposphere; Stratosphere; Mesosphere; Thermosphere; Exosphere; Troposphere Volume; Carbon dioxide release; Crude Oil; Global Warming