Energy Resources, Economics, and Sustainability

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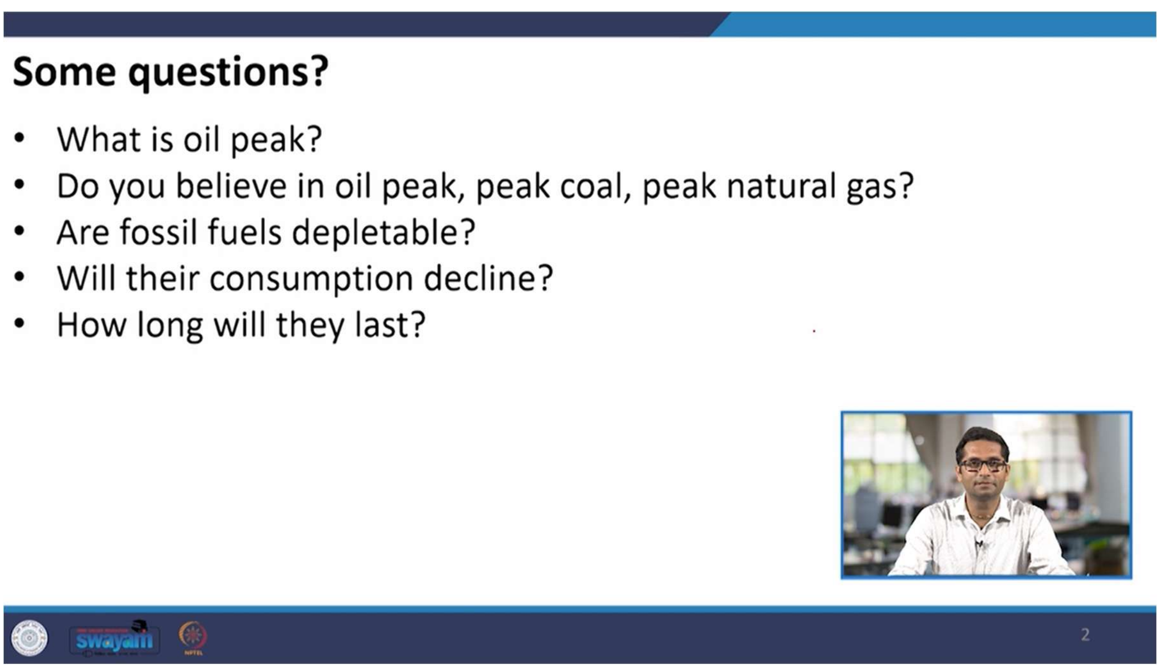
Week – 02

Lecture – 04

Lecture 09 - Fossil Fuel Resources-I

Hello everyone, welcome back to the course energy resources economics and sustainability. In the past few classes we have been discussing the energy value chain or the consumption of primary energy taking into account the different efficiencies that are needed for resulting into final energy. Now we will spend some time on understanding the fossil fuel resources of energy which are basically three coal, oil and natural gas. We will try to understand some of the basics of fossil fuels, some of the questions that we try to answer in the coming few classes would be what is peak oil?

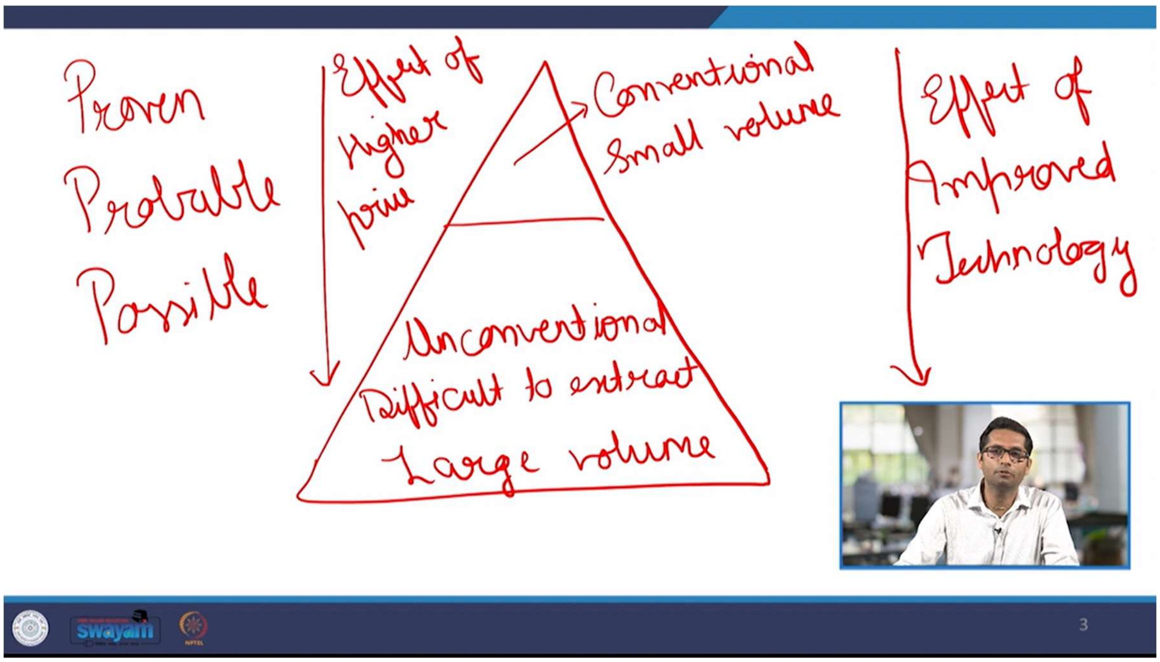


Do we believe in peak oil like or peak coal or peak natural gas for the sake? So what I mean by peak oil is basically the amount of any natural resource be it the coal, natural gas or oil is limited in the earth's crust. Someday it has to be depleted and before it gets depleted there is going to be a phase where the consumption is at its maximum and that maximum point would be called peak oil. So will we come across a point where the consumption of any of these three resources of energy would be max? There may or may not be a point like this but there are many people who talk about it.

Then are fossil fuels really depletable? We have been hearing about the depletion of fossil fuels since many decades. People have been saying about the doomsday is going to come at so and so year but no one has been able to predict it pretty well and the deadline or the timeline tends to be transitioning from one decade to another. Then finally will the consumption of these resources decline in the future? There have been theories but as we see the consumption has always been increasing. In a country like India which is having a good population growth we can see that the population has been exponential in the past few years.

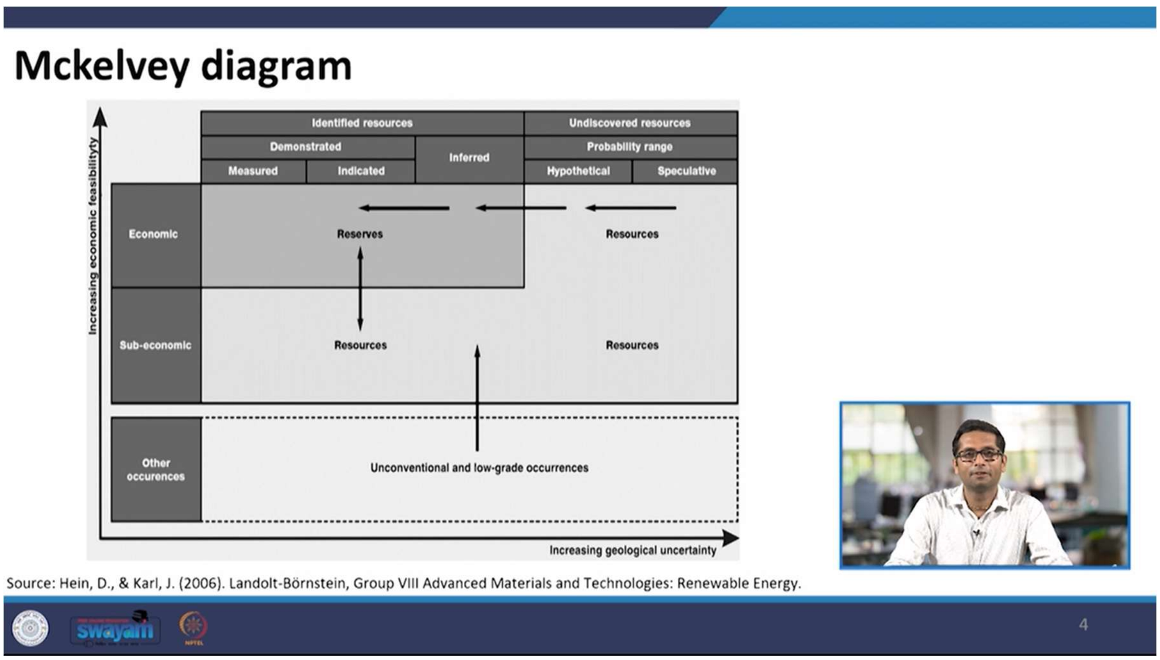
Then the million dollar question, how long will they last? 50 years, 100 years, 200 years, no one knows. If you remember earlier in the course we tried to understand if we keep on with the same consumption rate of fossil fuels the CO2 emissions that result from it might be able to double the CO2 concentration in the atmosphere in a fairly short amount of time. But we are still not aware like when, till when the fossil fuels are going to last. If we are not aware of how quickly they will get depleted why is there such a hurry to move towards renewable or clean or sustainable source of energy? This is something we will try to discuss in the present class. So first thing is like why is the oil not peaking up till now? So if we talk about the fossil fuels they have been broken down into reserves and resources.

So we have tried to understand in the earlier class that reserves basically refers to the oil or coal or natural gas that is available to us and we know with a certain amount of certainty that we will be able to extract that and extract it economically. Beyond that we also have a good amount of resources which would probably become available. So these resources might be known to us, might not be known to us. When they are known to us probably it is not very economical to extract them at the present moment. But as in the future the prices of oil would increase it might become economical. Further we might not have technology at present for extraction of those resources but in the future with the development of new and new tools we might come across a technology breakthrough that makes their exploration and use quite convenient in the future. So more and more resources would get converted into reserves. And even among the reserves they could be divided into either proven or probable and possible.



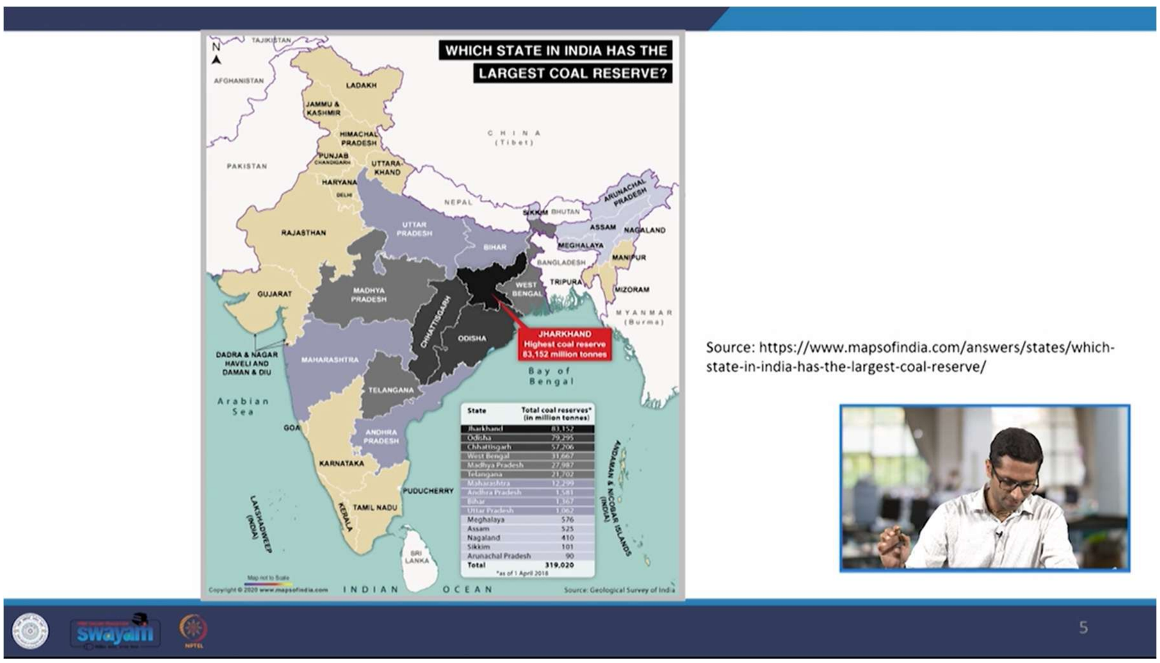
Again all the three go with that decreasing certainty with which we are able to predict that we can extract these oils. When it is a proven resource we are 90% sure that it should be able to get take a resource extract these resources economically. For probable it is around 50% and for possible it declines to 10% or so. So this is with respect to the resources which have been measured to some extent. Then beyond that we also have the reserves. So if I go with the different organizations which have been trying to basically budget these resources and they have tried to put all the resources that is available in the earth's crust in the form of a triangle. And on the top end of the triangle we will have the conventional resources by conventional I mean consisting of coal, oil and natural gas.

And this is somewhat of a smaller volume. Beyond this we also have the large base of the triangle which is the unconventional. Again I am referring to fossil fuels here. They typically difficult to extract and they also exist in large volume. And how do we move from conventional to unconventional resources? One is the effect of higher price. As we move in the future the price of these fuels keep on increasing and because of the price rise it becomes economical to extract something that was not very profitable in the past. Plus we also have the effect of improved technology. Sometime in the past offshore drilling was considered not to be a profitable option but if you see today there are a lot of offshore fields. Something similar could also be said about shale gas and shale oil which was not considered very profitable few decades back but now it has been a profitable industry.

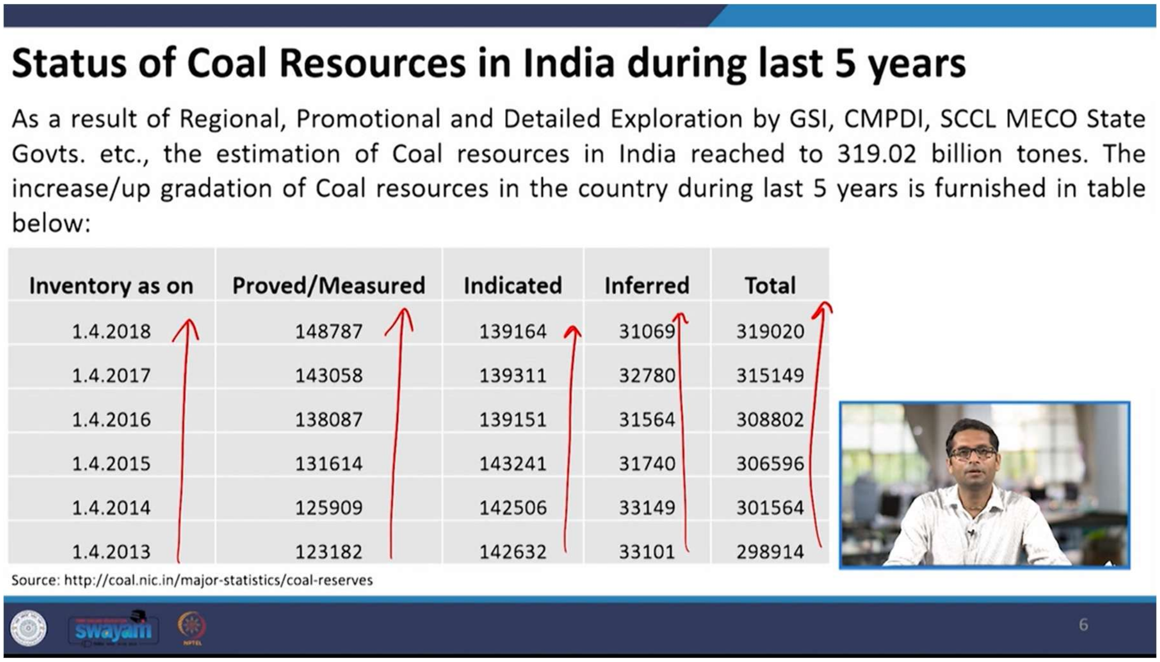


And a similar output is also given by something called as McKelvey diagram which gives us the same input that we have this reserves which have been quantified to some extent. But beyond these reserves we also have a good amount of resources. And among these resources either there are the sub economic and non economic ones and even in the undiscovered resources we would have hypothetical and speculative. But if you see the trends of discovery of new and new oil fields it has kept on decreasing now. Of course there was a phase when there was newer and newer discoveries being made. Even today there are new discoveries being made but the result or the amount or the absolute amount of oil being discovered has kept on reducing as we moving ahead with time.

And the resources again are being converted into reserves but the pace is slowly like dimming out. But this is one of the reasons why we have not been able to predict the peak oil and it also makes the things complicated. Again you can see there is one way movement from resources to reserves and among the reserves and resources there is a two way movement because it might happen some of the reserves when they are depleting they might turn into resources when it becomes uneconomical for them to extract them. So let us try to understand some of them from the Indian point of view. If you see the case of India there is one fossil fuel that is available in a good amount and that I would say is coal.

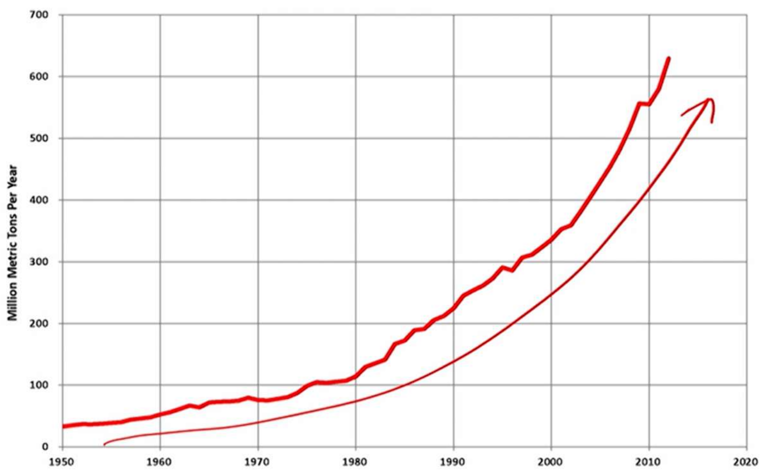


Coal is one particular resource that is available in India in a considerable quantity and this is specifically concentrated in the eastern or central states. So if you say like the largest producer of coal have been states like Jharkhand, Orissa and Chhattisgarh. Of course this is just a map to show you the relative amount and this keeps on changing like sometimes some state is ahead and sometimes some state is backward. But you see most of it is coming from the central or the eastern part of the country which has good amount of coal reserves. And I would say like coal is one of the resources that is available in considerable amount in India particularly also to say that the coal that we are getting is not of a very good quality and we as a country also import a good amount of coal because there are some industrial needs where you need high quality of coal and we do not have that.



Inventory as on	Proved/Measured	Indicated	Inferred	Total
1.4.2018	148787	139164	31069	319020
1.4.2017	143058	139311	32780	315149
1.4.2016	138087	139151	31564	308802
1.4.2015	131614	143241	31740	306596
1.4.2014	125909	142506	33149	301564
1.4.2013	123182	142632	33101	298914

But we do have significant amount of coal that is available in the country. And if I see the amount of coal that has been given on the website of Coal India Limited this is how the inventory looks like. So the inventory has kept on increasing in the past few years. So if you see like the inventory over the decades like how or the years how it has been increasing if I talk about the proven or the measured resources it has kept on increasing the same can be said for the indicated. The indicated might see a bit dip because some of it might have now moved to like the proven resources and then you can see a bit of dip in the inferred as well. But if I talk about the total which is a total of inferred, indicated and proven resources and this had seen an increase over the years and the data that I could get was for 2018. Of course you can go to the website of Coal India Limited or like the coal.nic.in and you can get the latest data. The point I wanted to make here is like not only the consumption has been increasing but also we have seen a drastic increase in the proven reserves or the measured reserves of coal in the country over the past few years.



Source: https://commons.wikimedia.org/wiki/File:India_Coal_Production.png

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And just to link it with the consumption, the consumption if I talk about it was around 60 or 70 in the 1950s and if we talk about today it is almost close to 900 and it is going to increase even more in the future. So we have seen an exponential rise in the amount of coal that would be utilized in the country and much of it is attributed like as our GDP is growing it is linked to the increased energy production and coal is one of the most easily available energy resource that we have and also one of the cheapest ones. So one would naturally would want to go for coal as a source of energy and this is what we have seen in the past.

Finite Resource constraint?

"The total mineral in the earth is an irrelevant nonbinding constraint. If expected finding-development costs exceed the expected net revenues, investment dries up and the industry disappears. Whatever is left in the ground is unknown, probably unknowable, but surely unimportant: a geological fact of no economic interest"

-Adelman, 1990

Source: https://doi.org/10.2307/2109733

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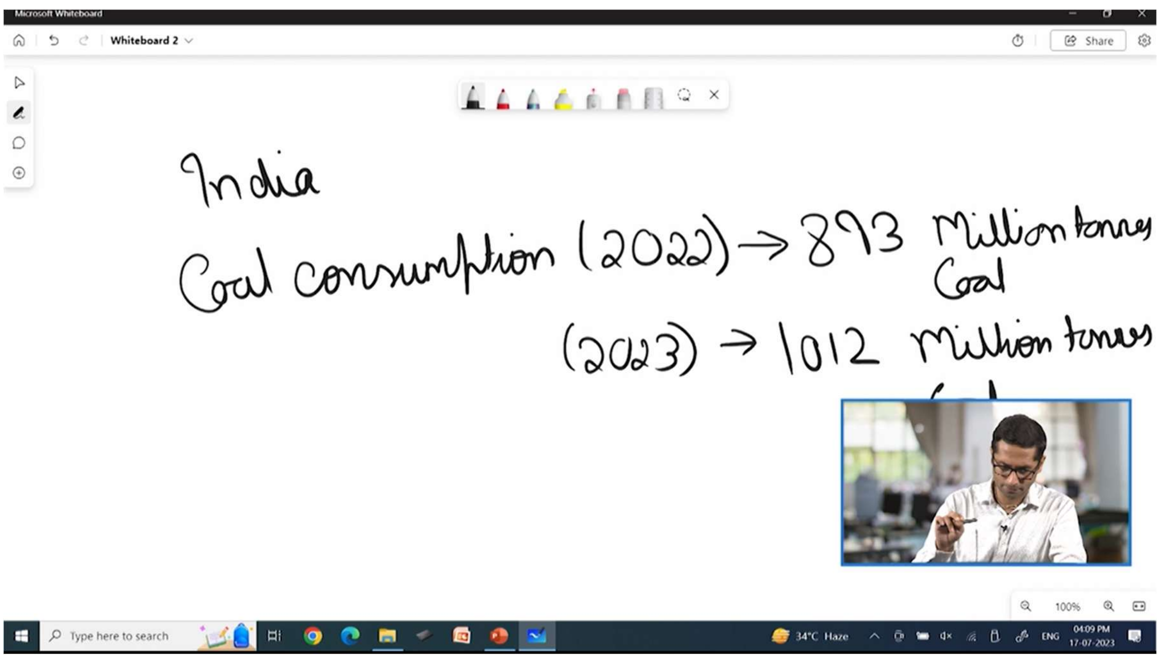
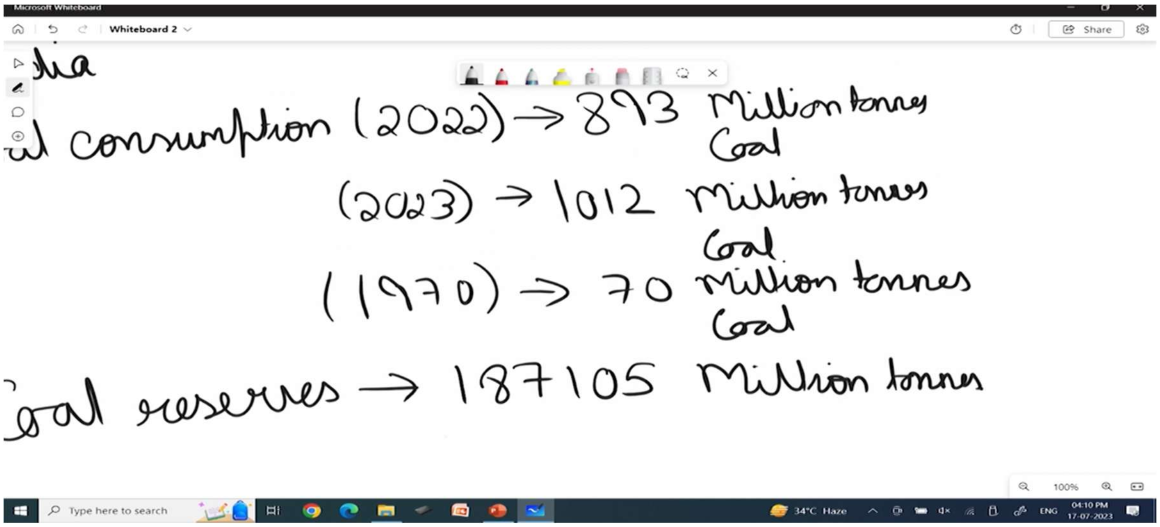
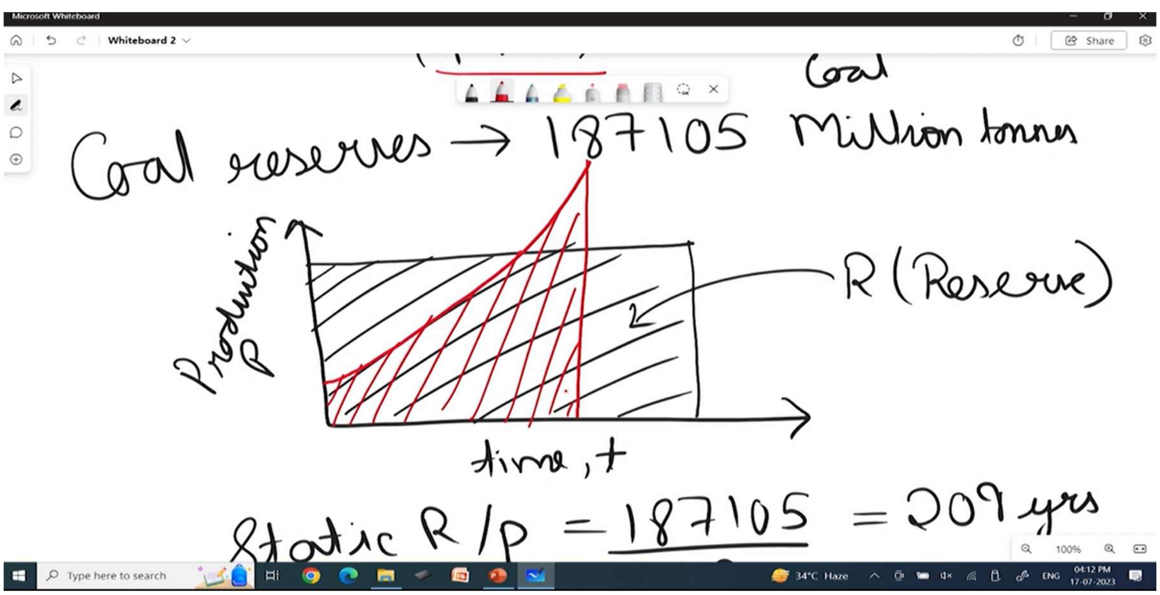
Now we also have a quote by one of the leading authors, his name is Adelman and what he said in one of the quote is like, the total mineral in the earth is an irrelevant non-binding constraint, If the expected finding development scores exceed the expected net revenues, investment rise up and the industry disappears. Whatever is left in the ground probably unknowable but surely unimportant, a geological fact of no economic interest. What he means to say is of course like someday the finite resource might come to an end but this end of the resource might not be linked to the disappearance of or the total utilization of the resource. What he means to say that at some point it might not become economical to extract that resource and the economy naturally transfers or organically transfer to another resource. So with these kind of understanding let us try to estimate the coal reserves in India and given the different models that are available how fast it is going to deplete. So let us go to the whiteboard and try to do some simplistic calculations.



So there could be different methodologies in terms of estimating how the coal that we have in India is going to deplete in the near future. So let us try to do a calculation with the most basic approach. So if I talk about India as a country and if I talk about the coal consumption and let us take the data for the year 2022 and this data as is available is roughly 893 million tons of coal. We also have a projection for the year 2023 and this projection gives us a consumption of around 1012 million tons of coal. Further if I go back in the history and see the whole consumption in the 1970s the consumption was barely 70 million tons.

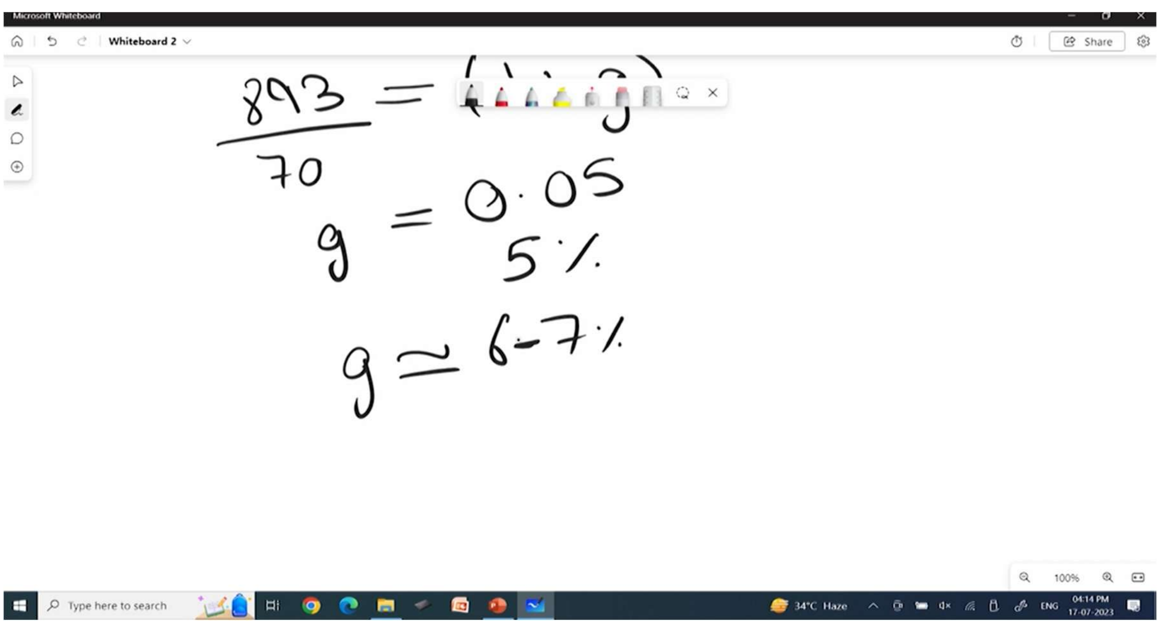


We can see we have been increasing exponentially and if I talk about the present coal reserves that we have I am just talking about the proven resources. So the estimate that we have is around 187105 million tons. So one way of calculating how long the coal is going to last is that like I know my present consumption of the year 2022 and this comes around to be 893 I know the final reserves that are known to me in the year 2023 and I just divided. So basically what I am doing is I am considering a basic case where I know what the production is. So if I have the production on the x axis let me say it P and this is the time on the x axis.

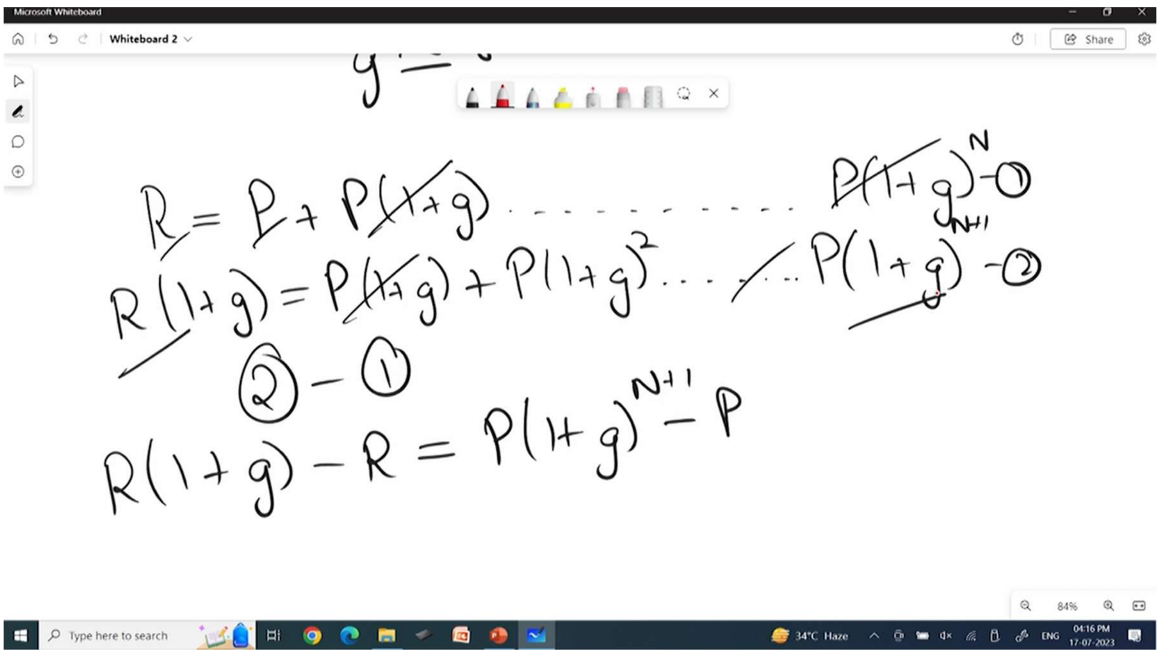


So I know I am keeping the production constant and at some day the reserves are going to deplete and that would be the time at which it is utilized. So if I have this as a graph the area under this curve is basically the total reserve and how can I calculate that? I can just do a static R by P ratio so this particular method is called static R by P and what do I take? I know the total availability of coal currently which is 187105 and I divide that with 893 the result that I am going to get is roughly 209 years. So if I freeze the consumption of coal to around 893 million tons per year and I also know what is the total amount of coal that is available to me probably I am going to run out of the total reserves of coal in 209 years. So that seems to be pretty long amount of time and gives us a feeling that we should not be worried about this. But the problem here is that the coal consumption has always been increasing in the past and as we have seen in the statistics the coal consumption was nearly 70 million tons in the year 1970s and it is poised to be around 1000 plus million tons in 2023.

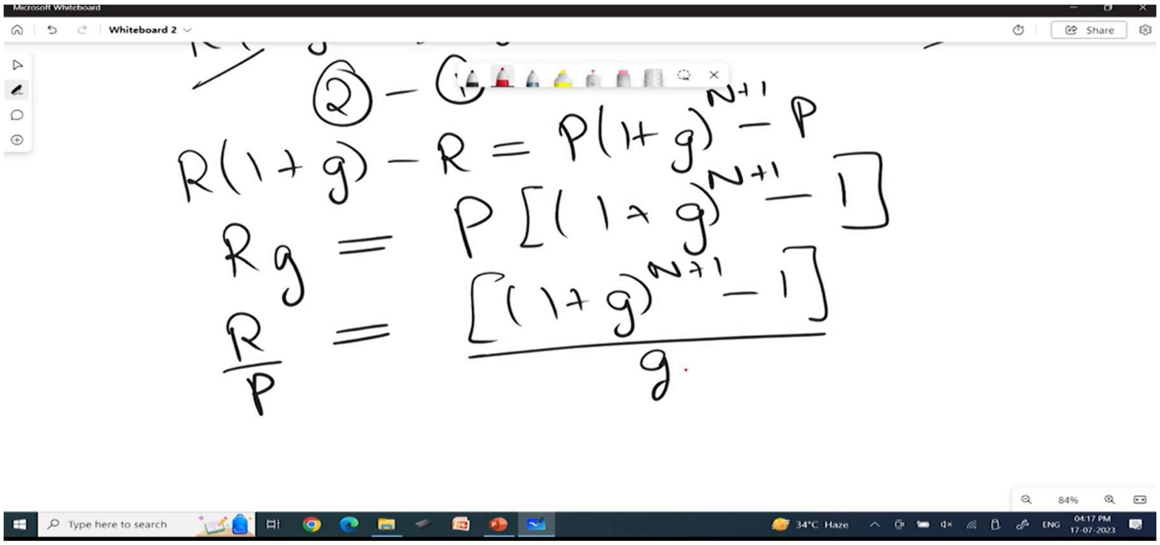
So there has been an exponential rise so if I see this case and if there is an exponential rise probably the coal consumption would be increasing an exponential rate and be over before the static R by P ratio. So the curve should be something like this in this case. So let us try to do this calculation again.



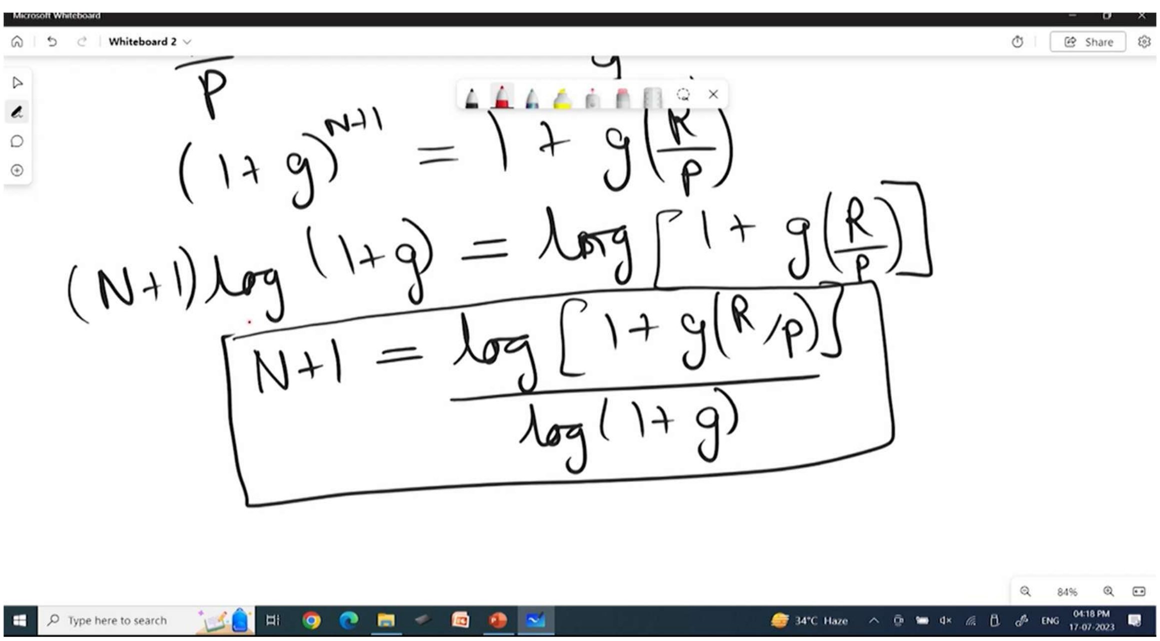
So I know the two values that is available to me. So for the year 2022 and 1970s which was 893 and it was around 70 million tons in the year 1970. If I have to estimate the growth rate I can do simple calculation it is 1 plus G is the growth rate and raise to power 52 which is the difference in years. I can do this simple calculation and the value of G here would turn around to be 0.05 or 5%. So overall the consumption of coal in the country for the last 50 years or so have been increasing at a rate of 5% and even if you consider the different databases maybe by the planning commission or the NITI Aayog the growth rate had been of the range of 6 to 7%. So that justifies that there has been an increased consumption of growth rate of coal in the past and now let us try to estimate if this growth rate was to continue in the future as well how soon are we going to exhaust the coal resource or the reserves that we have currently.



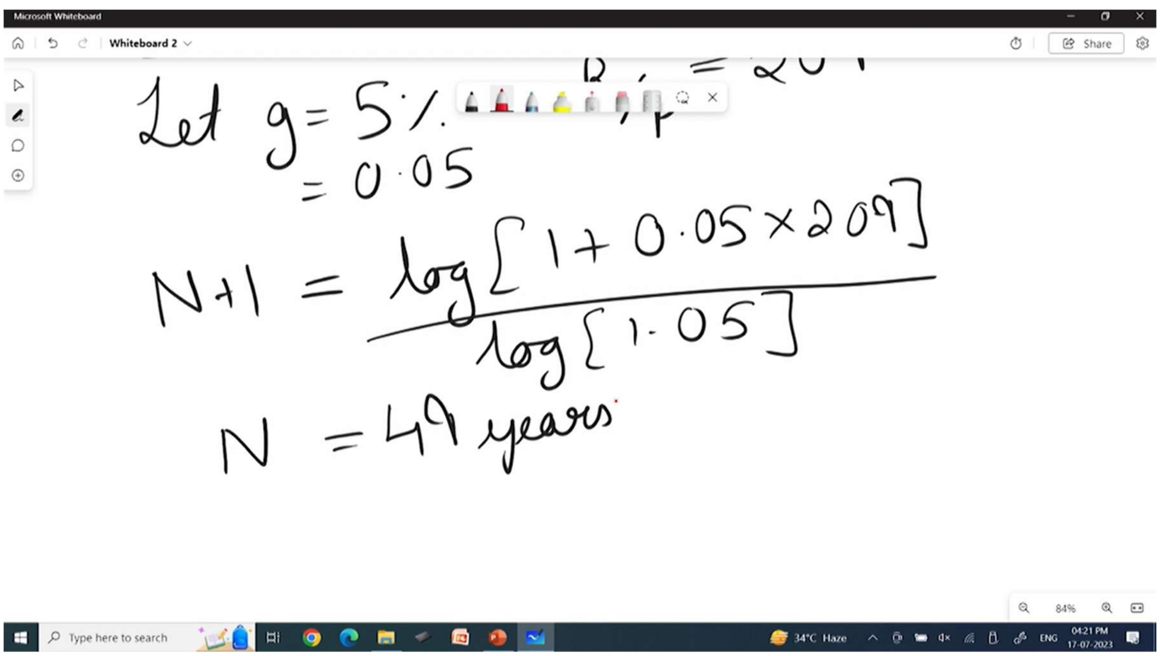
So let us try to do that calculation. So I proceed with the simple calculation that the reserves that I have the total reserves would be an addition of the production that has been continuing from today and every subsequent year there is an increase of 5% say which is given by the growth rate and it increases till the year N when I run out of my total reserves which is the nth year. I can write as another similar equation where I am multiplying both sides with 1 plus G a factor of 1 plus G and this would be plus P into 1 plus G square all the way till P into 1 plus G raise to power n plus 1. So let me put this as equation 1 this can be equation 2, I subtract equation 2 like equation 1 from 2 and what I get as a result is the reserves into 1 plus the growth rate minus R would be equal to the production into 1 plus G raise to power n plus 1 minus P. So if you see that equations above all the consecutive terms cancel out each other so we have like this term cancelling out this and every consecutive term would cancel out the one before.



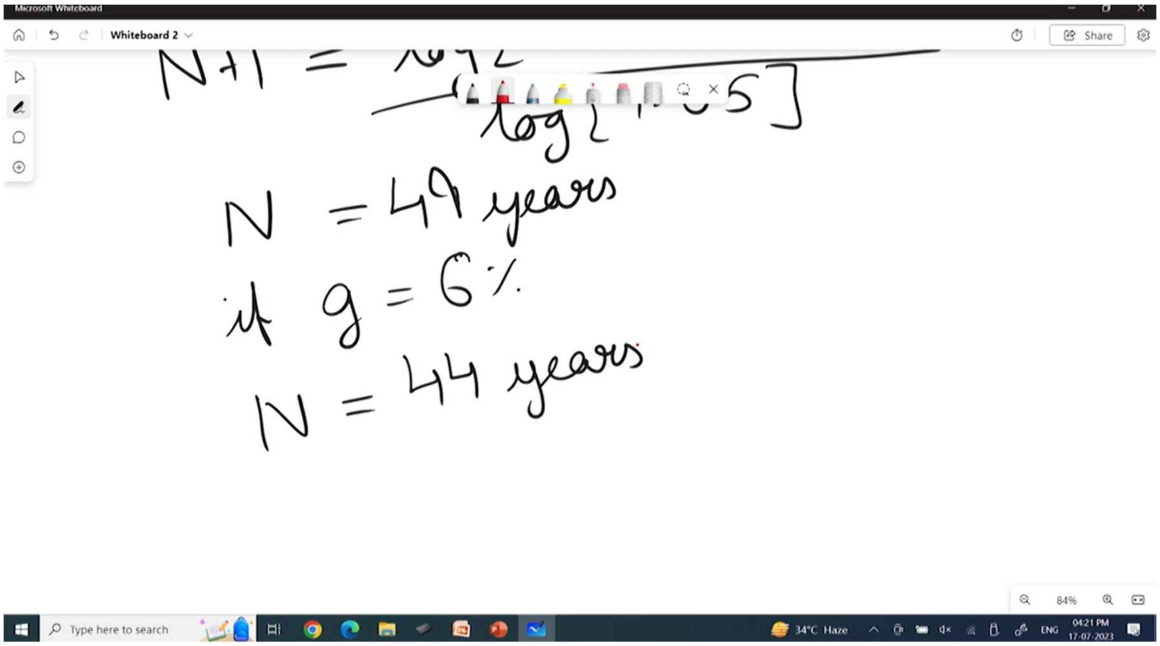
So the only thing that remains are the terms R, P, this and here and this is what I have written in the equation. So this is an algebraic equation which I can try to solve so again R and R gets cancelled again so it is R into G giving P which is the production rate and 1 plus G n plus 1 minus 1 so this is what I get. Again I can do some more modification which is R by P, P I have taken on the left hand side and this would be 1 plus G n plus 1 minus 1 and divide by the term the growth rate. Further I can do a few more modification to this I can take this 1 plus G n plus 1 term on the left hand side and this gives me 1 plus G R by P. I can take a logarithmic or natural log on both the sides and this gives me n plus 1 you put this in a bracket 1 plus G and this would be equal to log of P.



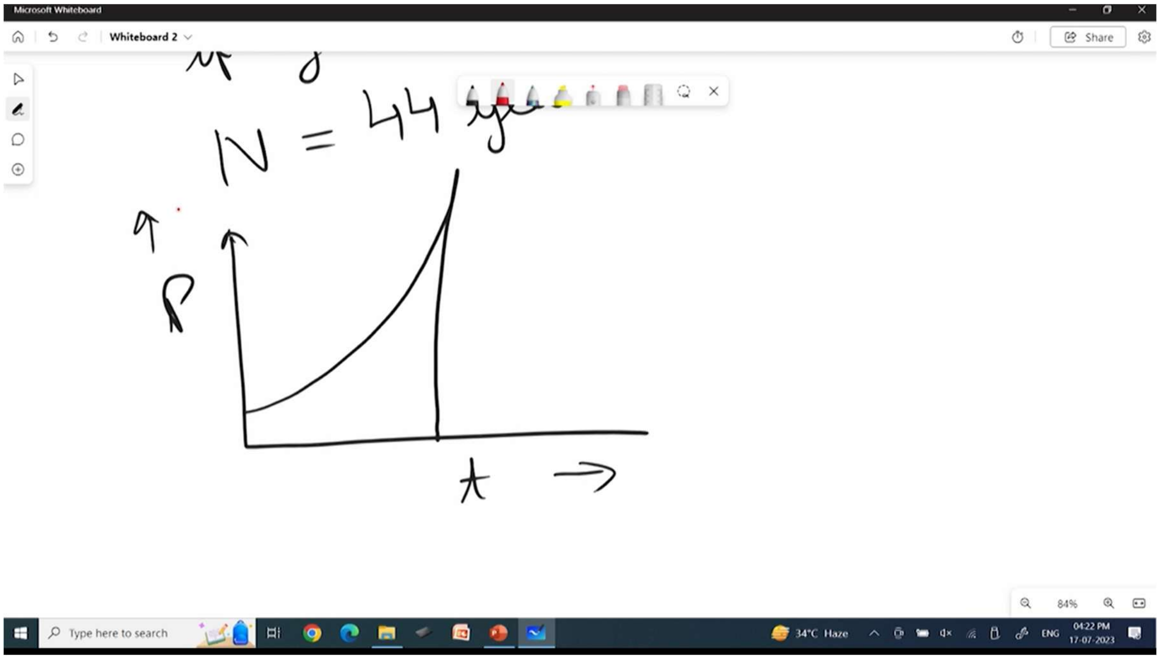
So this would be 1 plus G R by P bracket close and I can just retain the term n plus 1 on the right hand side and the other terms can be transported on the right hand side. So it would be 1 plus G R by P and divided by log of 1 plus G again and this would be 1 and I can use this particular equation to get the number of years when I will exhaust my resources given that I start with the production P and I have been increasing the production with the growth rate of G for the coming few years. So I can use this equation so this is a simple equation I know what is the growth rate which I can take it to be around 5% then I also know the reserves which are around 187 I have taken that in the previous case it is 187105 the production of around 893 million tons per year and our R by P of around 209 so I can put this value in directly. So let us try to do this calculation let me assume growth rate of 5% or 0.05 in here and on the static R by P ratio and which is similar to the earlier case and this would come around to be around 209.



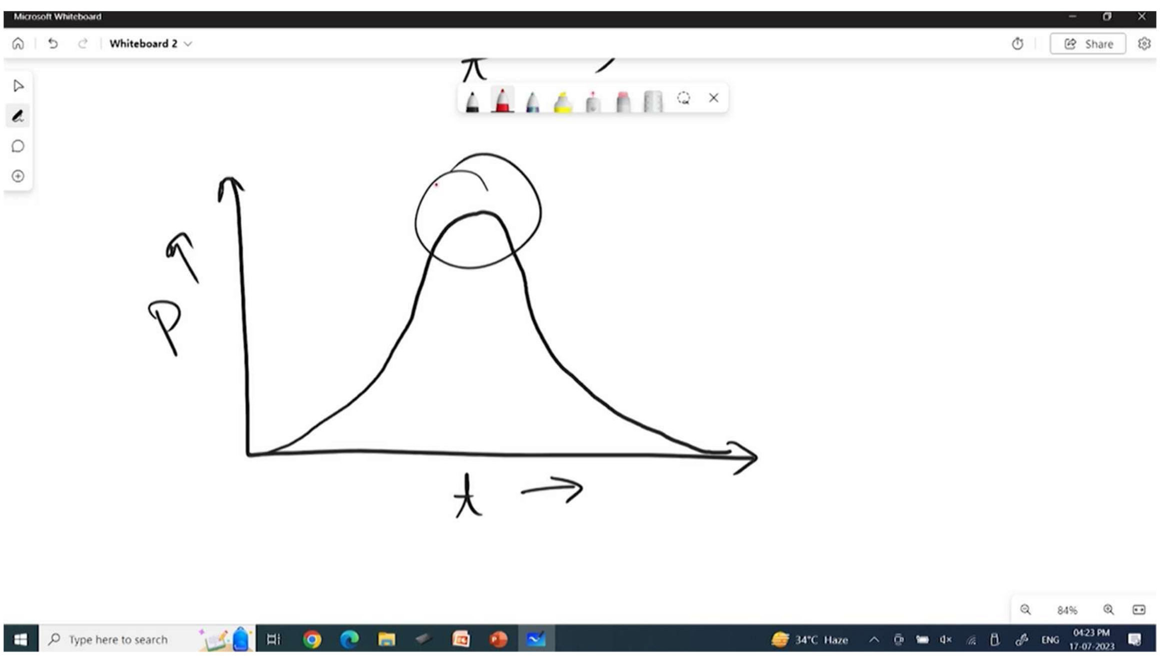
I can input this values in the same equation which would be n plus 1 is equal to log of 1 plus 0.05 into 209 and I divide this with log of 1.05. I do this calculation and the final value that I should be getting from this calculation. So if you do this calculation the value of n would come out to be roughly 49 years and that is a significant difference from the earlier calculation of around 209 years or so it is almost one fourth of what we have like calculated earlier so that you can see like how fast and the resource could be depleting if there is an exponential growth that is happening. Further like we have assumed a growth rate of 5% if I was to assume growth rate of around 6% the number of years becomes even lesser and you would get an answer of around 44 years.



So as the growth rate keeps on reducing the number of years in which we are going to exhaust our coal reserves is also going to become lower and lower and lower or becomes smaller and smaller. And of course like we also need to understand that in the present decade or in the coming decade our energy consumption or the consumption of resource like coal would grow at a much more faster rate given that we are putting we are growing at a very fast pace. So this is the other extreme in which we are considering the exponential rise but as many of you would have understood that this is not a true case either that in a real scenario it might it would not happen that we would be increasing the production till at one day it becomes extreme and comes down. So of course like this is the answer that we have tried to calculate but this might not be a true replica of a present of the scenario in which of particular fossil fuel is going to deplete. So what people have postulated or many scientists or many scientific communities have postulated that a trend for the depletion of a finite resource might follow a trend in which you would have an exponential rise of a resource for a few years it peaks stays there for some time and then there is a similar decline in the future.



So on the x axis we have the time and we have the production on the y axis. So this is how the different scientists have came up with the postulation like this is how the reserves would be declining or being used in the future and what I mean by peak oil or peak coal or peak natural gas is the production at this particular level and this is something that is of interest and we will be discussing that in the future classes.



So in today's class we have discussed the basics of the fossil fuel reserves and taking a case study of India we have tried to understand how fast we might be able to deplete our resource if we are keeping the production stagnant or if we are exponentially increasing the production of coal and we got some important insights and we will continue this discussion to the next class as well where we are going to understand the implication of a more realistic model where there is an exponential rise of a resource and then a stagnation and finally an exponential decay that is happening. Thank you.