Energy Resources, Economics, and Sustainability

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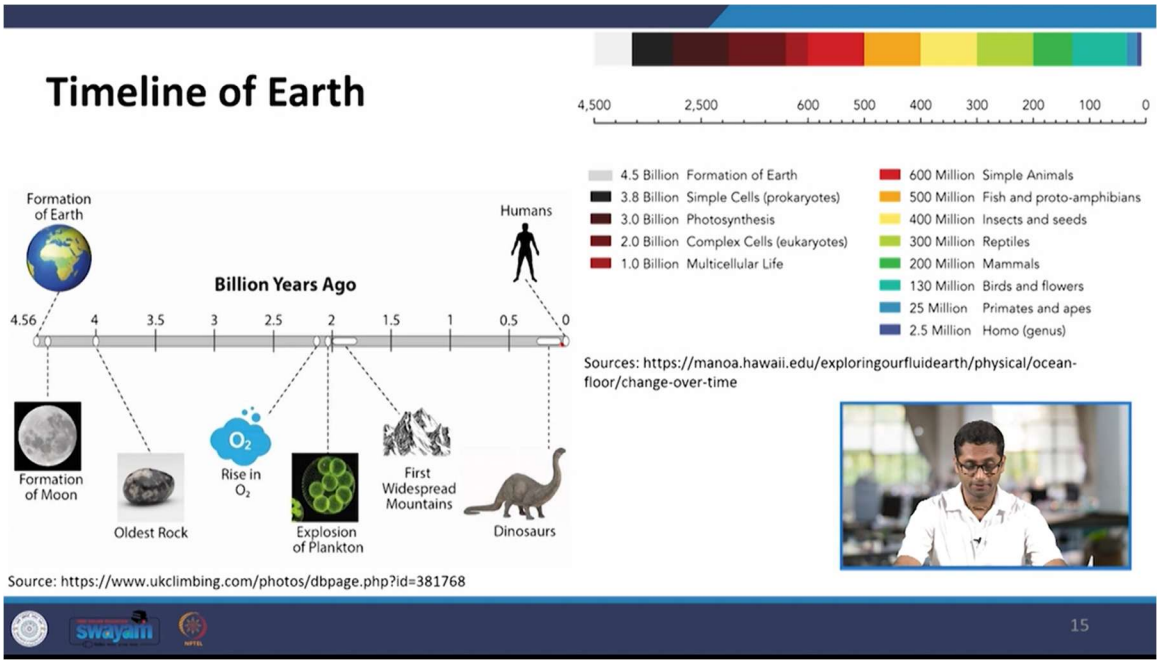
Week – 01

Lecture – 02

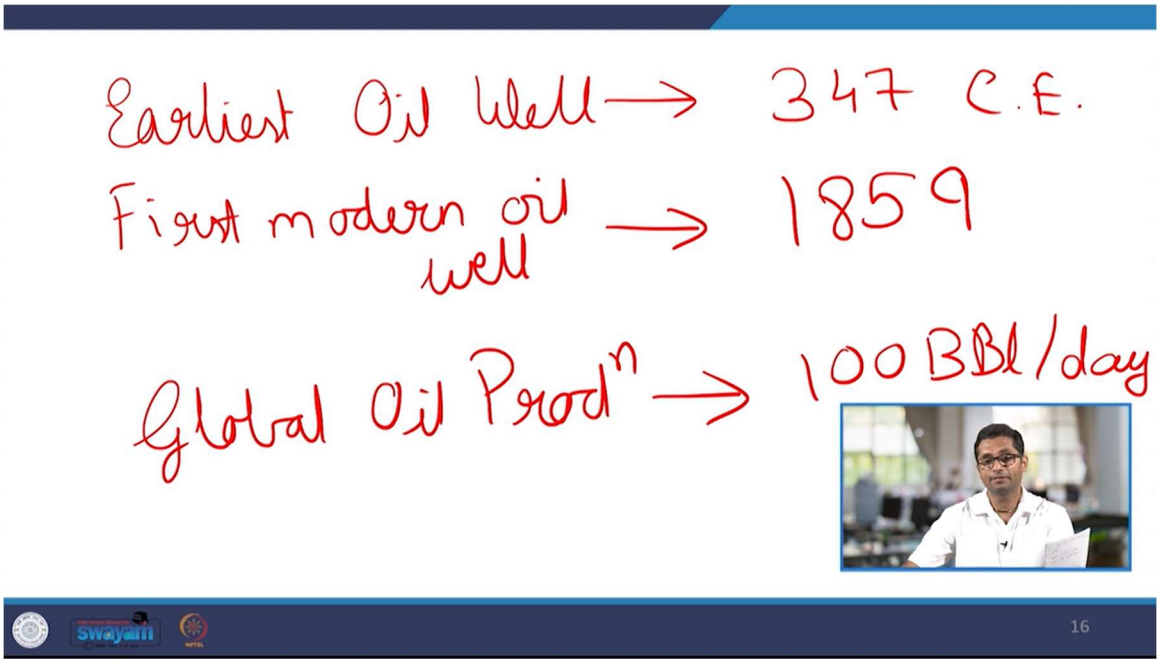
Lecture 02 - Introduction to Fossil Fuels

Hello everyone. Welcome to the second lecture of the course Energy Resources Economics and Sustainability. In the second lecture we are going to discuss some of the basics about the conventional sources of energy which are namely the fossil fuels. We will try to acquaint our self with the prevalence of the fossil fuels in the society and what are the associated impacts. So, I will try to make you familiar what are the fossil fuels, how deeply impacted our society is with the fossil fuels and what are the likely impacts that we can face in the future. So, these are some of the things that we will be discussing in today's lecture.



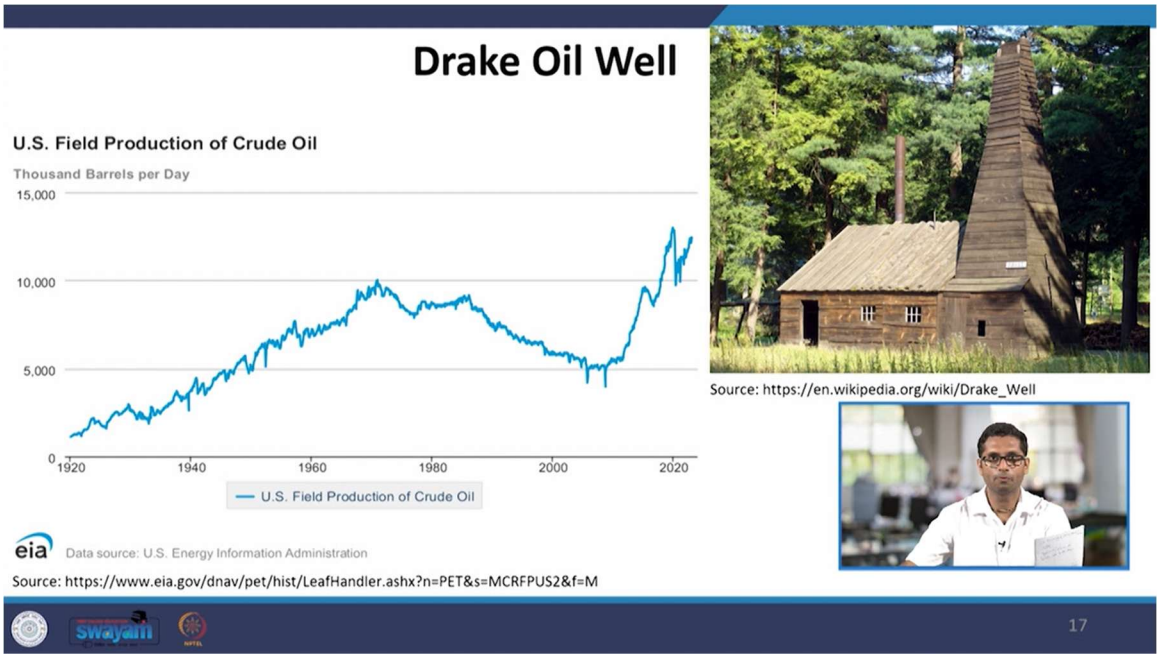
Before that let us try to understand a brief timeline of the planet earth. What you see in the figure on the left is a timeline of the planet Earth as has been deducted by different geologists. The life of the earth has been predicted to be around 4.5 billion years ago and life as we know came into existancel around 4 billions years ago and since then life has evolved into many complex species and humans as we see are a very recent phenomena.

We can see that like multicellular life being evolving around 1 billion years ago then fishes and insects roaming around the planet around 4 to 500 million years ago. So, this is a basic estimate of the life on planet earth. Now, interesting as it may be the major takeaway from this that I want to take you is that we have been consuming and using or acquainted with the fossil fuels at just a small dot here which is a very minute particle on the life span of humans on the planet earth. Whereas what it took to production of different fossil fuels including coal, natural gas, oil has been spending over millions of years. So, to this trajectory of events let me also add few more which include the first or known oil well.



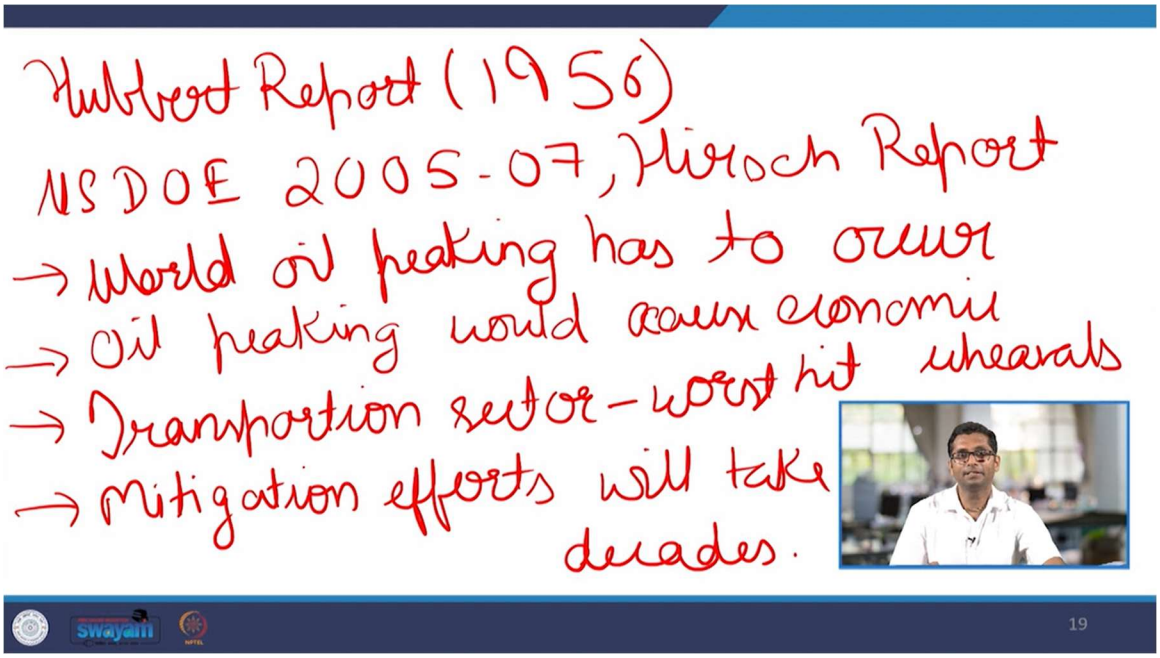
So, the earliest known oil well was discovered somewhere around 347 common era some people argue that was in China some argue that was in India, but this is the time span when it was discovered. Then the first modern oil well which has mechanization in it came into being around the year 1859 which was a Drake oil well in the country of the

United States. And finally if I talk about the global oil production in the year may be 2023 it stands roughly around 100 billion barrels a day. So, one barrel is roughly 159 liters, but this is where the oil production has been staying for the last 2-3 years. So, let us see go back to the slide we have seen that the history of planet earth spans over around 4 to5 billion years whereas if we compare that of oil it spans to just a few thousand years may be 2000 years and within the last 200 years or so we have been able to consume a major chunk of it which has been a major drastic effect. And just to remember if we see the timeline of the earth these different fossil fuels were produced by different geological effects which have spanned of millions of years. So, this was just to give you an example of the time span that it took for the creation of these valuable resources and the time span in which we have increased our production and consumption of these resources to not to add the different environmental effect that these resources cause.



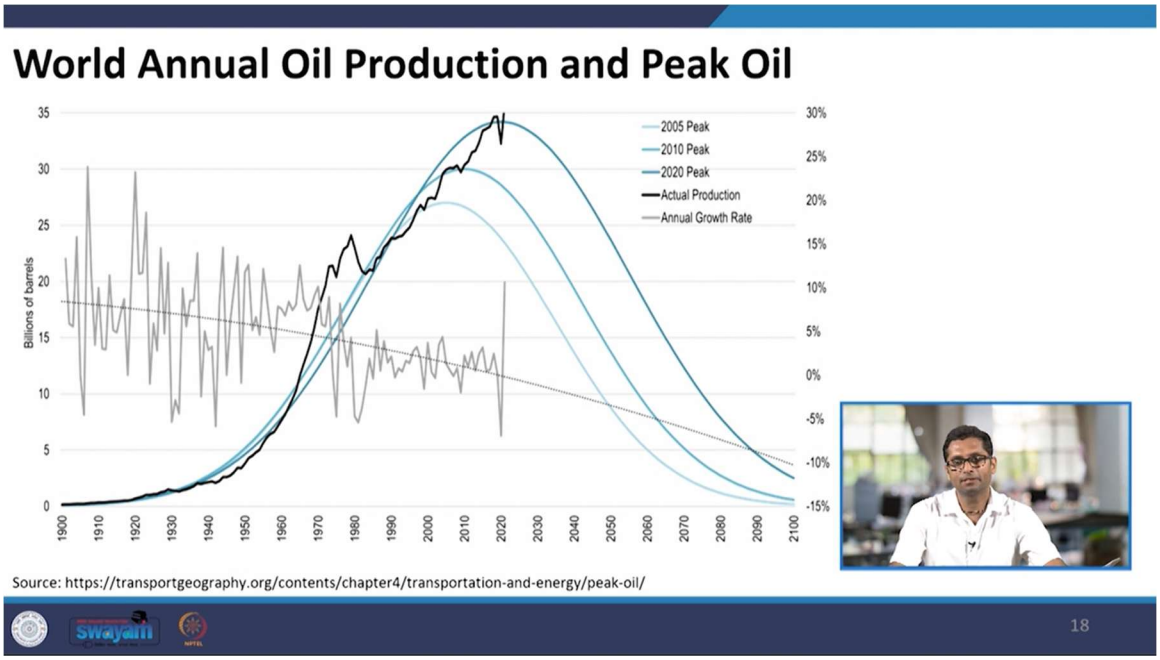
Now, what you see in the figure on the right hand side is the Drake oil well which I told was one of the major mechanized oil well that came up in the United States it did not look very mechanized at that point, but still it was and what you see on the left hand side has been the oil consumption in the US. So, as you see after the discovery of oil and the production of oil there has been a steady rise. It reached a peak around 1970s and 80s a dip and then again there has been a steady rise in the oil production. So, this is just the

case for the US. So, in the US different geologists have been coming up with different reports what will be the effect of different kinds of oil peaking and let us try to understand some of them.

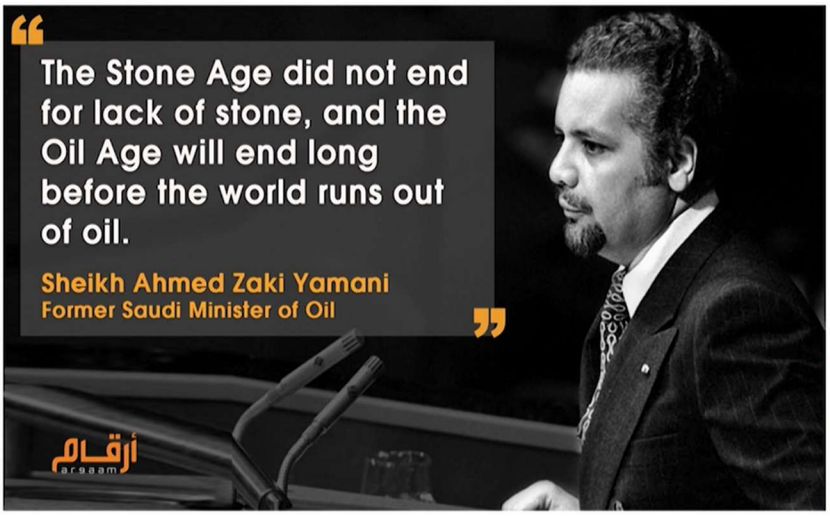


So, the first such report was by Robert Hubbert and it was called the Hubbert's report and this came up in the year 1956. Hubbert was a scientist at the American Petroleum Institute and with the help of simple mathematics he predicted that the oil peak for the US would occur somewhere in 1965 and 1970s. He just needed some simple calculations which we will be studying as we move further in the course, but he was quite correct in his prediction as we see in this graph the oil in the US indeed peaked at around that point, but that peak was not a sustainable peak that happened for long there was a dip, but the production again gained momentum and we have been increasing the consumption and production of oil since then. After that there have been another report by the US DOE or the US Department of Energy and that was in the year 2005 to 2007 and the report was called the Hirsch report. Some of the major pointers or the outputs of the report was that the world oil peaking has to occur. It is something that could be delayed, but cannot be denied. The amount of resources in terms of fossil fuels is finite and there would certainly be a day when the peaking is going to occur.

By peaking we mean the consumption has peaked and after that there would be a reduction in consumption. This oil peaking would hurt or would cause economic upheavals. Then further the transportation sector would be the worst hit and finally the mitigation efforts will take decades. They came up with an eye opening report which had the different scenarios what are the likely consequences if an oil peaking was to occur. And this oil peaking is something many people have been discussing in the popular media you would have been reading about when the oil peak is going to occur.



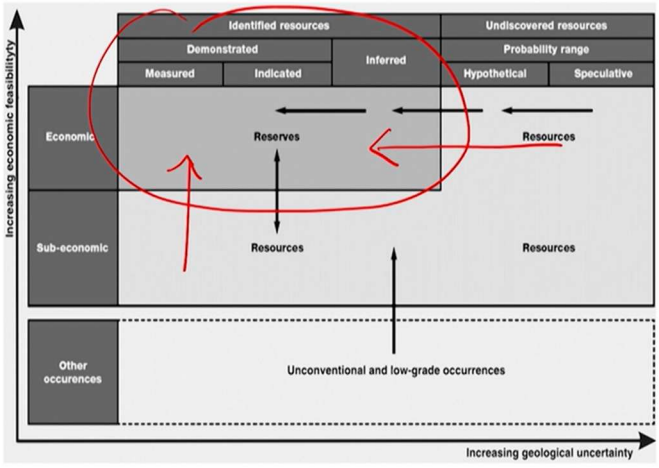
Till now we have been just waiting for it there have been different scenarios, different models which predicted like what if the oil was to peak in 2005, 2010, 2020. But the same you can see in the graph in front of you, but we can see that the oil production has only been increasing. So, this is the global oil production in billions of barrels and what you see on the x axis is the years. But it is something that cannot be denied it is only being delayed and there are reasons for that we will discuss that. But someday or the other this peaking has to occur and when the peaking occurs and as we go by the Hirsch report there going to be economic upheavals even today we understand that because of the disruptions in the oil economy we have disruptions in the normal life of day to day of humans.



Source: https://twitter.com/ArgaamPlus/status/1016593373648564225/photo/100

So, as we proceed let us read an interesting quote by one of the major countries that exports oil and this is the former minister of oil and what he suggested was that the stone age did not end for the lack of stone and the oil age will not end before the world runs out of oil. So, this is the perception of a major country that exports oil. Now, let us try to understand why the peaking has not occurred so far.

Mckelvey diagram



Source: Hein, D., & Karl, J. (2006). Landolt-Börnstein, Group VIII Advanced Materials and Technologies: Renewable Energy.

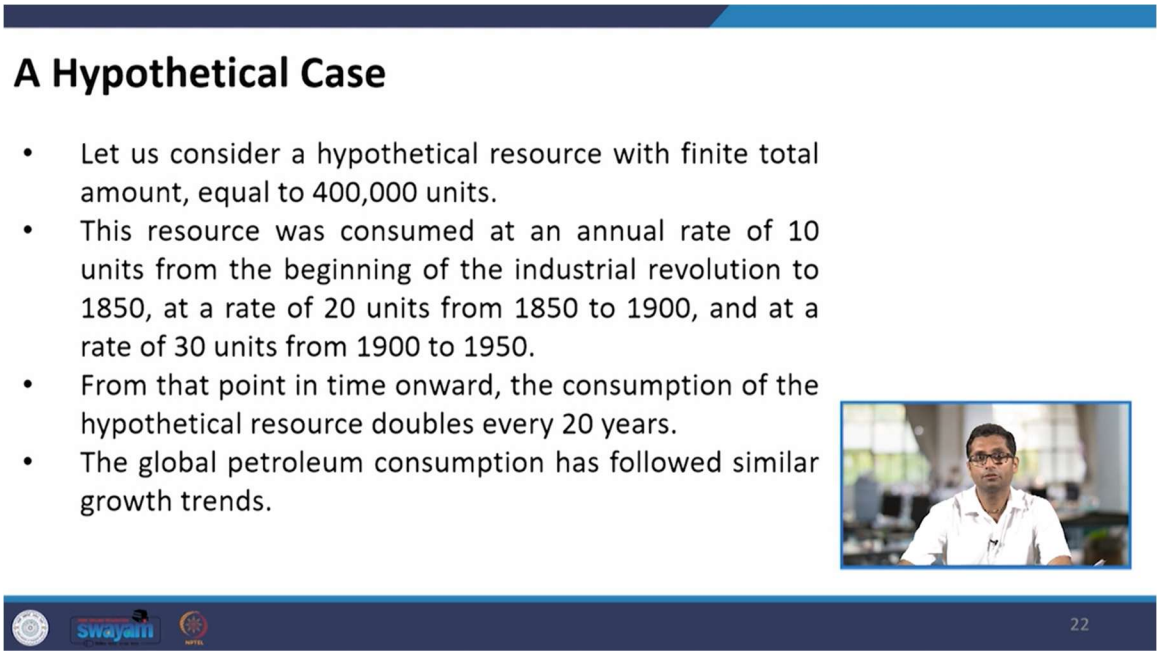
So, this phenomenon could be understood with the help of a McKelvey diagram which is basically coming from a geological sciences and named after the discoverer McKelvey. So, what we have on the x axis is the certainty with which a particular resource or reserve could be extracted.

So, towards the 0 the probability is more and as we move away from 0 the probability keeps on decreasing. What we have on the y axis is the economic incentives that we can derive from that particular resource. So, the higher on the y axis the more economic benefit is that you can derive from that particular resource. So, what we have in this particular diagram are two things one is the reserves and the other are the resources. Reserve is something that has been quantified that has been proven this much amount of oil or coal is present at so and so place.

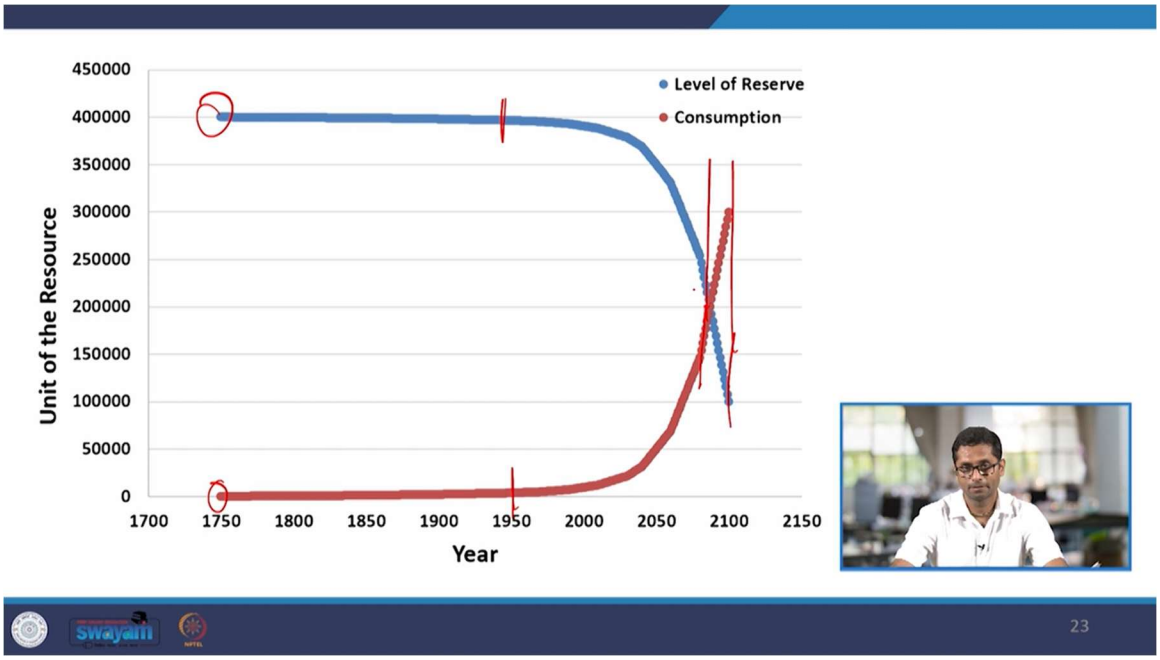
When I talk about resource, resource is something that we know with certain amount of probability that is there but we are not certain in the amount as well as how economically the resource could be extracted. So, when we are dealing with the different fossil fuels we are mainly concerned with the reserves. The reserves are something that is the amount of oil coal or natural gas that have been quantified and are known to be able to be extracted economically. What lies beyond is some of the features or some of the areas where the oil or natural gas or coal is present but it might be uncertain in the amount that is present. However, the technology that might be required for the extraction might make it uneconomic for their future extraction.

So, with this help we can either identify the resource as identified resource and reserves and undiscovered resources in terms of resources. So, when we are talking about the peaking we are mainly talking about these reserves and what is happening over the time we are continuously coming up with new resources which is increasing the amount of reserves as well as some of the resources which were uneconomical to get are becoming economical because of the increase or betterment of technology. So, let me repeat again there are different kind of resources that are present in the crust of earth some of them are economical to extract as of now and some of them are yet to be discovered or the probability with which they can be discovered is unknown and with the advent of time and the advent of technology many of these resources are being converted into reserves

and that is one of the reasons why the oil peaking has been shifting but nonetheless this shift is not something that we can avoid for long.



Now let us also try to understand this particular phenomenon with the help of a hypothetical case. Now let us assume the finite amount of any resource and I have given a value to that or of around 4 lakh units. Now let us suppose the utilization of that particular resource started in the year 1850s this is very close to the year when the first oil well or mechanized oil well came into being after that I have been using around 10 units of that oil or resource every year. From 1850 to 1900 I have been using 20 units beyond 1900 to 1950 I have been using 30 units and after 1950 the consumption has almost doubled every 20 years. So, this is basically reflecting how the oil consumption has changed for the planet earth for the past 150 years or so. So, from the beginning of the industrial evolution to around 1850s I am using around 10 units year then from 1850s to 1900 or 20 units from 1900 to 1950s around 30 units beyond that the consumption is almost doubling every 20 years. This is a simple calculation and I would want every one of you to do this plotting in a software like excel and the result that you would derive can be seen in the figure in front of you.



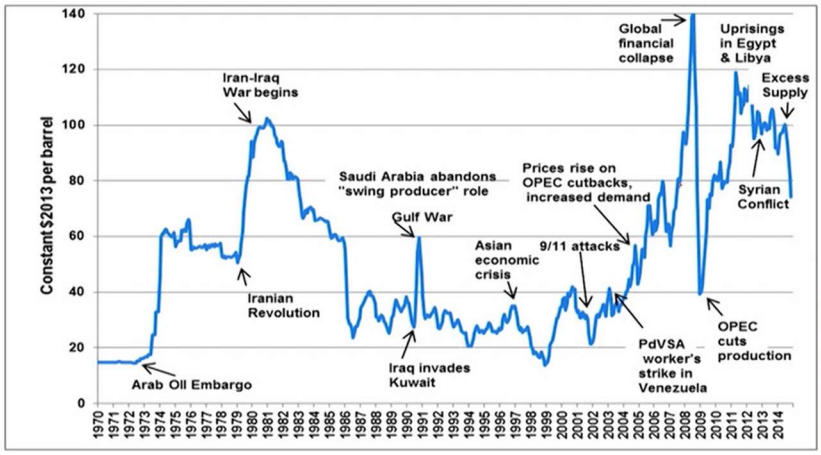
So, what you have on the x axis is the years which starts from 1750s from the onset of industrial evolution and what you have on the y axis is the consumption. So, we have taken a finite amount of resource which was 4 lakh units and the consumption almost started from 0. So, there are major takeaways from this graph. What we see is that for the next 200 or the first 200 years or so there is hardly any dent in the change or in the amount of reserves that have been utilized or produced. Similarly, if you consider the last 20 years you see a major change is happening almost half of the oil or the of this resource is getting consumed in the last 20 years.

And the third output that we can get from this graph is say I was in the year 2070 people are going to tell me I still have almost the same amount of reserves of a particular resource that I have consumed in the last 300 years or so. So, remember this argument you might have seen in the popular media people keep on saying that there are still more than half of the reserves that are remaining we have still not consumed almost half of the reserves. But if we carry on with the same pace the remaining half reserves could be exploited or could be consumed in a matter of 20 years or so. So, this indeed is eye opening. Ofcourse this is a very simple calculation whenever their peaking is going to occur the consumption is going to reduce and it is not going to get over in 20 years or so.

But this is an hypothetical case in which if I assume that the oil consumption carries on the same rate the remaining half amount of oil could be consumed in a matter of 20 years whereas the first half of the oil was consumed in almost 300 years. Now let us try to understand what dictates the price of oil.

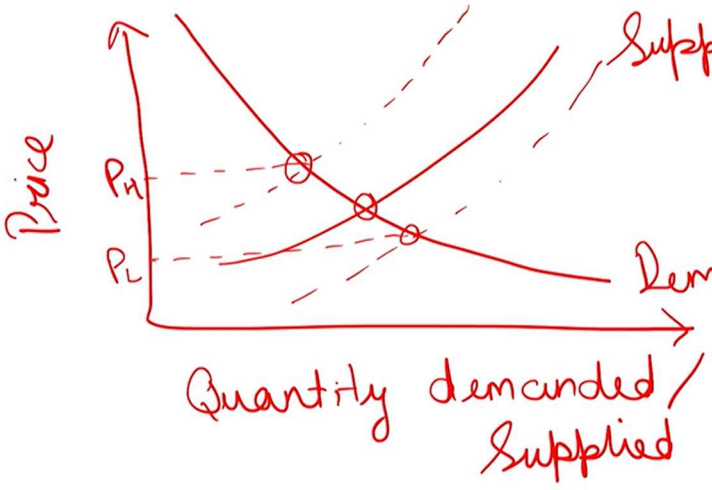
Now if I see the price of oil for the last 60 years or 70 years or so this is the trend that you see in front of you. There have been fluctuations ups and down what the unit normally is dollars per barrel. So, one barrel as I told you is around 159 liters. So, this is a normal unit for trading oil. So, what you have on the y-axis is dollars per barrel of oil and what we see is a fluctuation. The fluctuations we see there are arbitrary ups and downs and many of them we cannot explain or we have no control over. But if these fluctuations were to related with the major events which are the geopolitical events that are happening throughout the world we can easily correlate them. So, as you see in the figure in front of you that major wars that take place in the Middle East or in Europe have a drastic effect on the oil prices that we pay elsewhere and specifically in India.

Timeline: A Brief History of Oil Prices and Vehicle Technologies



Source: https://www.energy.gov/eere/timeline-brief-history-oil-prices-and-vehicle-technologies

Many of the geopolitical events that you see in front of us India had no or very little role to play yet we had to bear the consequences of the increasing oil prices which would again upset the economy or the decisions that the government make. Be it be the Arab oil embargo, the Iran Iraq war, the 9-11 attacks, the Arab springs the effect has been severe. One other important aspect that we find in here that after our increase in the amount of oil price that is normally followed by a subsequent decrease in the oil prices and this is again a very interesting economic phenomena.

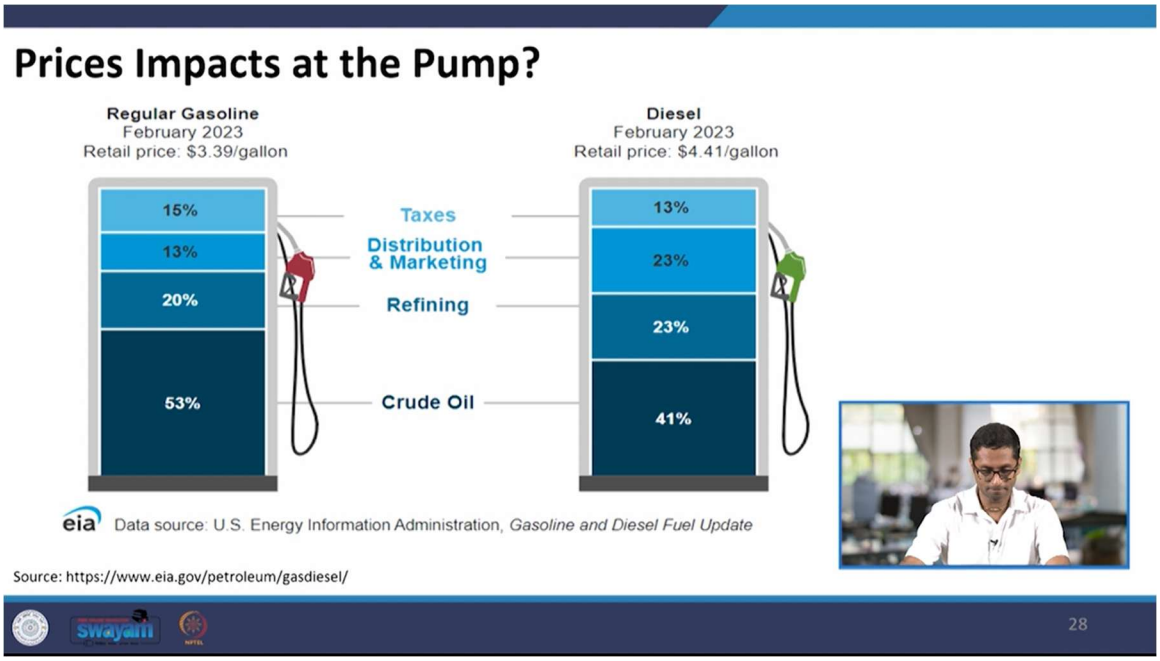


We will try to understand this with the help of a simple figure or what is known as the demand or the supply curve. So, let us try to understand this with the help of a curve. So normally the demand of any particular resource is inversely proportional to the price. So, what I have on the y axis is the price and what I have on the x axis is the quantity demanded or supplied. So, the demand for any particular resource is inversely proportional to the price. The greater the price of a resource the less people would want to buy it and that is why we have this inverse relationship and this is also called as the demand curve. At the same time we also have a supply curve which means because the price of a commodity has increased there would be more and more suppliers in the market who would want to supply that commodity and would want to make profit out of it and this is called as the supply curve.

Let me repeat it again as the price of a commodity increases in the market more and more players would want to jump in the market so as to make profit by selling that particular item and at the intersection of these two is called the equilibrium that decides the market price of a particular commodity and something similar is also experienced in the case of fossil fuels. Now let us consider a major war taking place somewhere in the world that would affect the supply of oil. What that is going to happen or that is going to affect is it is going to shift the supply curve. So, the supply curve is going to be shifted a bit towards the left so that the new equilibrium has a higher price which is called PH. So because there was a major political or geopolitical event that happened somewhere the price of a commodity has increased the supply curve has shifted towards the left and we have a new equilibrium being reached.

Now since the commodity of that fossil fuel has increased people would want to try out with new sources an example could be the case of shale gas that was having huge reserves in the US but because the technology was expensive it was not making into the market but with time as the price of fossil fuels increased and the advent of technology the resources became explorable and it now is being used in the market. So now the price of that commodity has increased new and new players would want to jump into the market and what that is going to affect is it is going to shift the supply curve on the right and we would have a new equilibrium as PL. So all those such events would increase the price of a commodity in the market but eventually with the jumping of new market

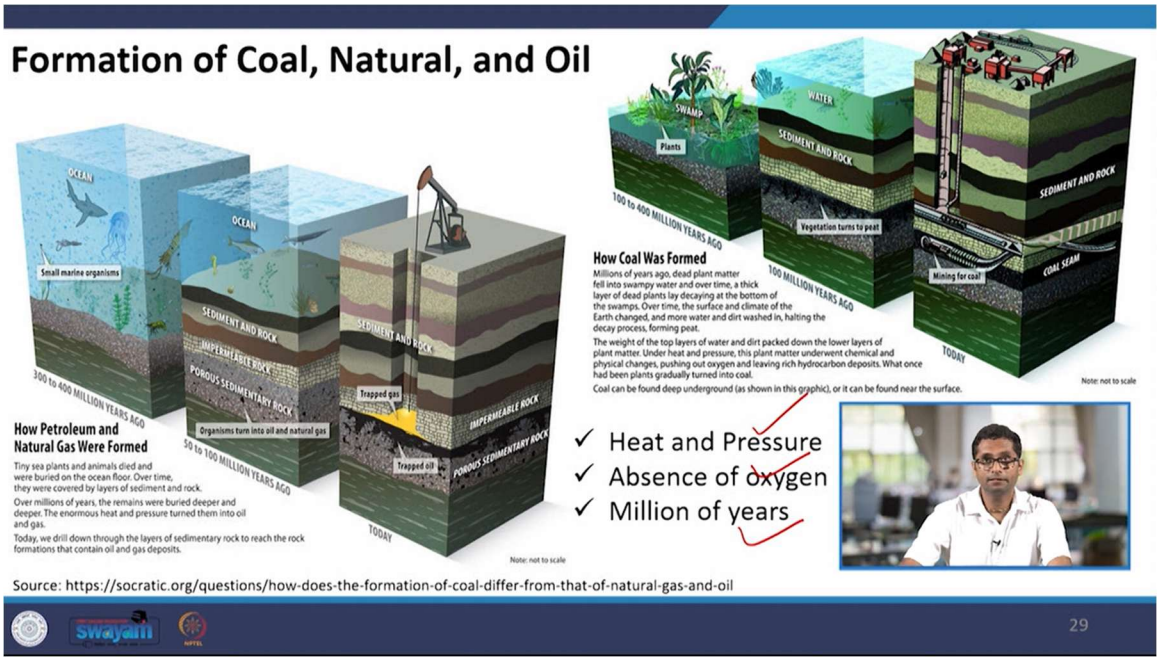
players there would be a lower price and this is what has been seen quite often in the case of fossil fuels. So important takeaway from this discussion is that the price of fossil fuel is something that is dictated by major geopolitical events or a cartel known as OPEC, Organization of Petroleum Exporting Countries and we in India have very little control over the price of oil. We have to go by whatever the pricing is decided by the global market.



Now let us also try to understand what is the normal price of oil composed of. So this figure basically shows the component or the percentage of different aspects that make up the price of oil at an oil pump. These figures are basically for the US but this would not be very different for other countries including India. So almost 50% of the cost goes towards the crude oil, the buying of the crude oil from the different countries that are producing it. Then around 20% of the cost goes towards the refining.

Around 15 to 20% of the cost further goes towards distribution and marketing and finally we have around 15% of the taxes. Now these taxes is something that is a matter of debate, some countries have less, some countries have more, even in India we have different states having different taxes but this is how a normal oil price is made up of. So if you are paying Rs 100 per litre of oil or gasoline or diesel this is what you can expect the breakup of the cost to look like. Now let us also try to understand how oil was

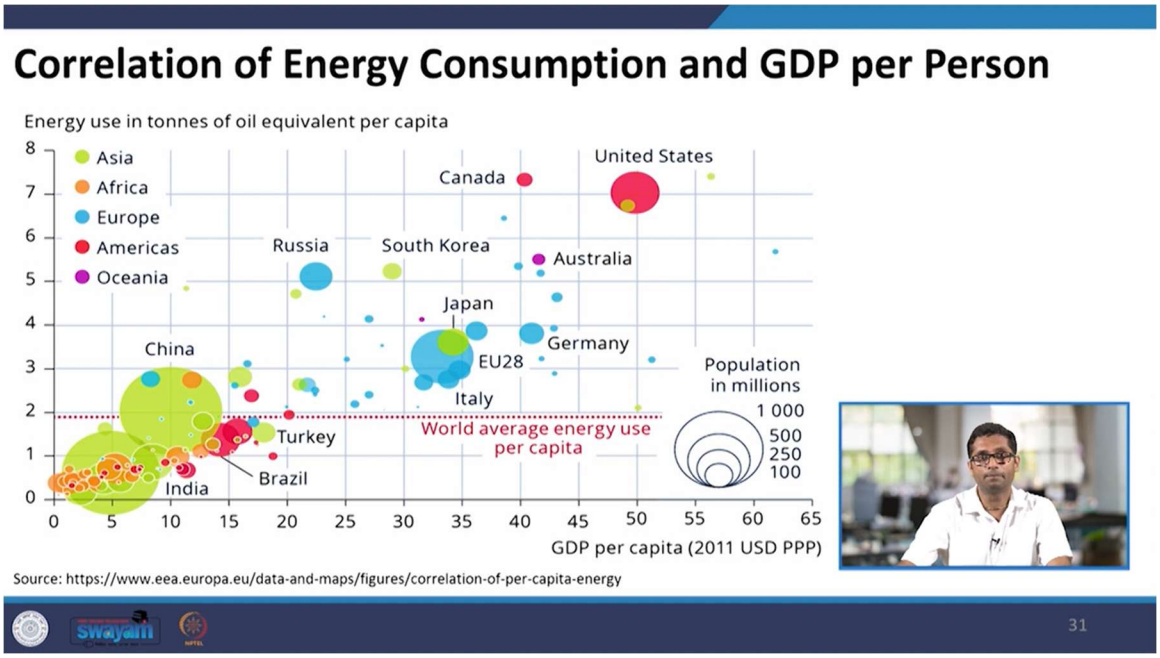
produced at the first instance. So if I talk about coal and petroleum you can see how the basic production came into being.



So there were marine organisms as well as plant species that were there around millions of years ago probably 400 millions years ago or something similar. They got buried under the different layers of the earth due to different geological formulations and remained so again for millions of years. As today we dug into the earth either into the ocean floors or beneath the deserts and the coal and the oil that has been formed because of heat and pressure, the absense of oxygen and millions of years is being extracted by the different digging or extraction technologies. So let me repeat it again, we had millions of years ago around 400 millions years back a lot of live species that were running around the earth with the advent of time these species could no longer survive they were buried under the different layers of rocks and sediment which caused the condition necessary for the conversions of these organic matter into what we known as coal and oil. And one of the major reasons was the heat and pressure that was applied, the absence of oxygen and millions of years.

Now if I go back to the price of oil one would like to think where is the price for the heat and pressure that was applied over millions of years, the absence of oxygen and millions of years. So it seems that we are taking this aspects for granted and we are not taking the

value of these things which eventually led to the formation of this valuable resources. It's not that we cannot produce oil from different biomass sources or different organic sources, we have processes like hydrothermal liquefaction or similar things which apply huge amount of heat and pressure and could lead to the formation of bio-crude. But the only thing that is holding these technologies back is the economics and there is huge amount of resources or energy that goes into the conversion of any organic matter into resources like coal and natural gas and oil. So we would also like to discuss the correlation between consumption or energy consumption and the GDP per person.



So this is an interesting infographic that I would want you guys to spend some time on. What we have on the x axis is the GDP per capita. So this GDP per capita is in terms of 2011 US dollars on purchasing power parity and what we have on the y axis is energy use in tonnes of oil equivalent. So when we are talking about a course in energy we would be using different types of units and tonnes of oil equivalent is one of them, other could be tonnes of coal equivalent, quads, so get used to these all units but basically they are representing the amount of energy that would be utilized. What we see here are the different countries being represented.

The size of the circle representing a particular country basically represents the population of that particular country. So what we have for India is a big circle in here then we have

one for China, we have one for US in here and the European Union group of 28 countries have been taken in here. A simple understanding that we derive from this particular graph is as our GDP grows our energy consumption is very nicely linked to it. There has been a very nice trend between the growth of GDP and the growth of energy use. We can see the countries which are part of the developed world basically the US, Canada, Australia, much of the Europe high up and having a high amount of energy use as well.

Whereas we in India are quite at a lower end. We are imagining that our GDP would be growing substantially in the years to come. Much amount of population is living in a poor background and they deserve a much better lifestyle but this would be very closely linked with energy consumption because the rise in the GDP is closely linked to the energy use. And if this energy was to come from oil it means that we are becoming more and more dependent upon the geopolitics and also we are paying for something we have no control over. So this lecture was basically to help you explain what are the major nuances that are associated with the use of fossil fuels apart from the environmental effects which they have. There are major geopolitical effects which we want to decouple ourselves with and that is again one of the reasons why the different governments of the different countries are pushing towards renewable or sustainable fuels.

So with that we end today's lecture. Thank you.