Petroleum Economics and Management
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Module - 06
Depletion and Rising Costs
Lecture - 27
Peak Oil

Hi everyone, I am Dr. Anwesha Aditya, your instructor for the course Petroleum Economics and Management that we are offering in NPTEL program. So, we are in module 6 of our course where we are analyzing whether depletion and Rising Cost can explain the oil price movement. So, this is the lecture number 27 of our course under module 6 where we are going to discuss a very important concept or hypothesis called the Peak Oil hypothesis.

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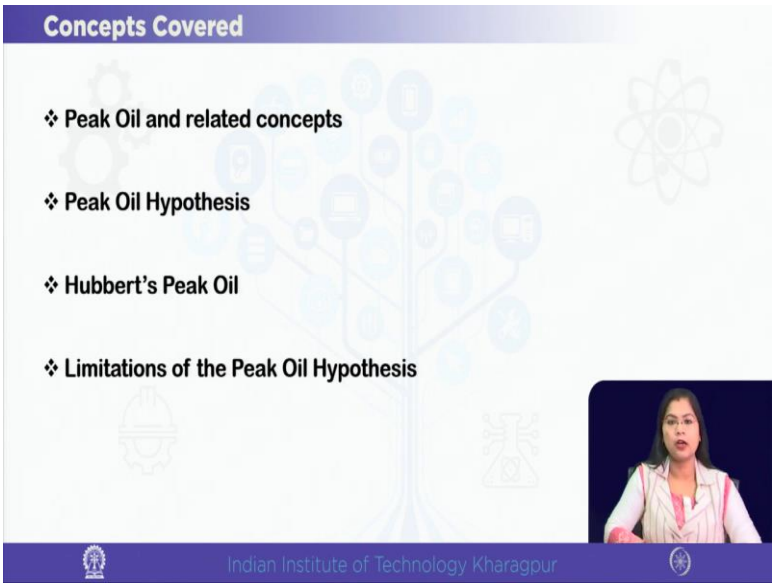

So, if you just briefly recapitulate whatever we have discussed so far, we see that we discussed in depth the oil price movement of oil in our module 4. In module 5 was devoted to explaining the oil price movement from the perspective of OPEC and Saudi Arabia and next in module 5 sorry in module 6 we are explaining the oil price movement from the point of view of whether petroleum is a depleting resource or not.

So, in the previous lectures of module 6 we have discussed in depth about the concepts related to reserve or depletion of a natural resource. So, if you remember we discussed about the concepts of a proved reserve, extractable resource, what are the stages of exploration and we analyze the whether petroleum is a depleting resource or not so, for that we use the R by P reserve to production ratio, but we found that if we compare petroleum with natural gas we did not find any sign of depletion at least for the next 3, 4 decades ok.

Because the R by P ratio tells about whether our resource is there inadequate or sufficient amount to maintain enough supply or undisrupted supply for the next 30 to 40 years ok. So, we saw that the reserve by production ratio of oil exceeded the reserve by production ratio of natural gas in 2017.

Now, in this context another very important related idea is to know about the peak oil because there was a very famous hypothesis called the peak oil hypothesis in which many economists who were supporter or proponents of peak oil hypothesis, they were quite pessimistic about the uncertain future of oil about the depleting nature of oil as a resource.

So, they were quite pessimistic, but we will discuss in to this class the peak oil hypothesis and the criticism or the limitation of the peak oil hypothesis. So, this is more or less how we have designed to this lecture.

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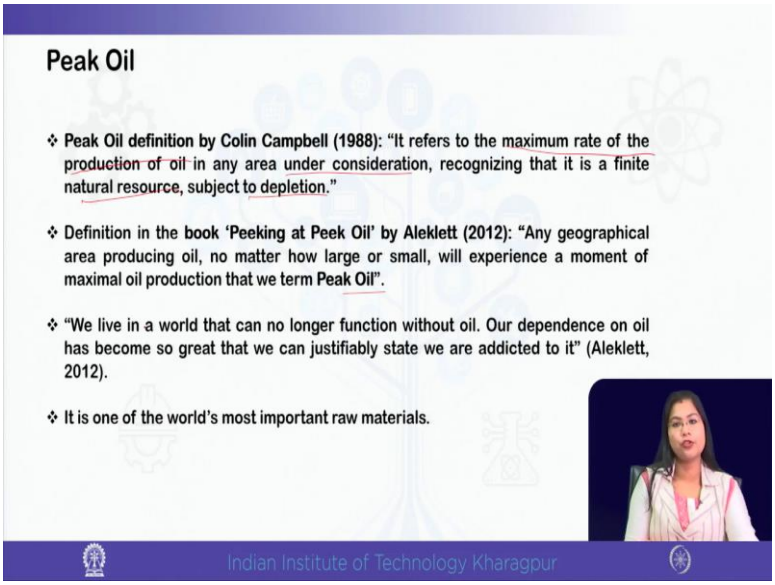

So, what is peak oil? First, we need to know that. So, peak oil definition was first proposed by Colin Campbell in 1988. So, peak oil as according to Campbell is refers to the maximum rate of production of oil in any area under consideration recognizing that it is a finite natural resource subject to depletion ok.

So, maximum rate of production of oil in any area under consideration. So, in a particular area what is the maximum rate of extraction, maximum rate of production of oil in a particular area. Now, keeping in mind that it is a natural resource so, which is in limited stock and it is also subject to depletion.

So, as you are continuously using extracting or producing oil from that particular area it will be depleted over time because it is a natural resource which use at a particular point of time you start the given amount of resource right. So, if you consider suppose an initial time period. So, you have a fixed endowment of the resource because the rate of formation of new resource is very low.

So, if you are continuously using it you are depleting the resource ok. Now, there is a famous book by Aleklett in 2012 the book is named as Peeking at Peak Oil, ok. So, the book mentions that any geographical area producing oil no matter how large or small will experience a moment of maximum oil production that we can term as peak oil ok.

So, if the area which produces oil there will be a point on time where the oil production will reach a maximum level. So, this a maximal oil production we can term as peak oil following Aleklett (2012). So, you can see there is a book which is just entirely devoted to peak oil peeking at peak oil.

So, we live in a world that can no longer function without oil. So, we are dependent on oil and it has become. So, great that we can justifiably state we are addicted to it as mentioned by Aleklett 2012. So, it is one of the world's most important raw material we already know and that is why we have a course which is wholly dedicated to it.

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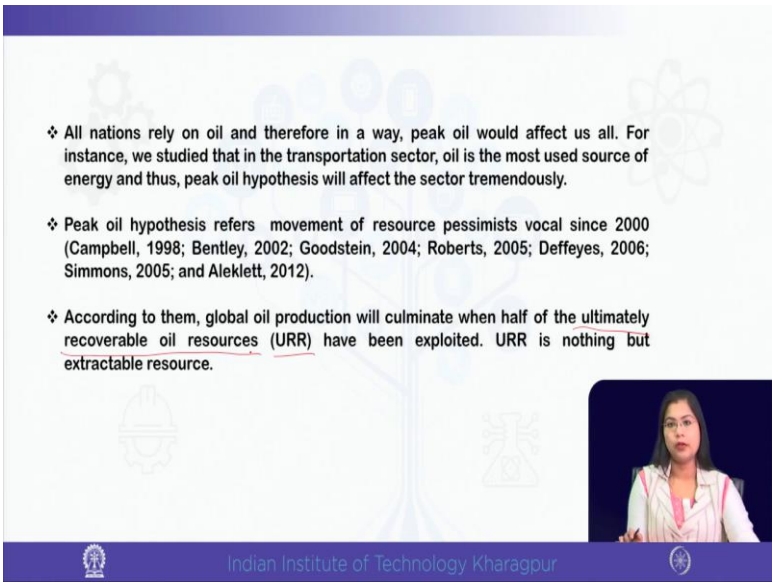

So, oil nations therefore, they are dependent on oil. Therefore, we can easily conclude that peak oil would affect all of us right. Peak oil means if you are extracting oil from a particular field a point in time will come where you are just using a maximum amount of production so, you will be depleting the resource.

So, from any area you are using obviously, a peak will reach you will reach the peak at some point of time right. So, peak oil would affect all of us because we are dependent on oil so much for our day to day life. We have already discussed the sector wise use of oil and we see that especially for transportation we are greatly dependent on oil.

So, as we have also mentioned that oil is the most used source of energy in the transportation sector so, that means, the peak oil hypothesis will affect the transportation sector tremendously. So, peak oil hypothesis refers to the movement of resource pessimist who have been vocal since the 2000 means late 1990s onward especially.

So, mainly Campbell (1998) Bentley (2002), Goodstein (2004), Roberts (2005), Deffeyes (2006), Simmons (2005) and Aleklett (2012). We have mentioned all the papers in the reference so, those who are interested for a more in depth understanding you can refer to the original research papers. So, here what we are doing in the class we are summarizing their views and very briefly because of our constraint in time.

So, the repeat we have discussed the concept of peak oil now what is the peak oil hypothesis so, this is the movement of resource pessimist who has been vocal since 2000 ok early 2000 or late 1990s. So, according to the believers of the peak oil hypothesis global oil production will culminate when half of the ultimately recoverable oil resources have been exploited.

So, you see now you come across a new term which is called ultimately URR, ultimately recoverable oil resources URR, but it is a known concept to you because URR at a given point of time is nothing but extractable resource. So, in the previous lecture we have already defined what is proved reserve and what is extractable resource right.

So, URR is nothing but extractable resource. So, according to the believers of peak oil hypothesis global oil production will culminate when half of the extractable resources used up or exploited ok.

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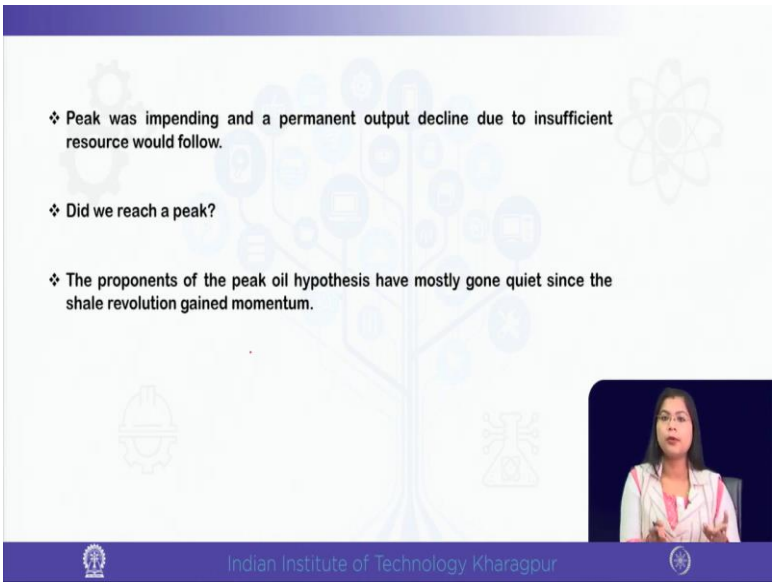

So, according to them in early 2000 peak was impending a permanent output declining due to insufficient or lack of natural resource would follow. So, they were very pessimistic about the future of oil according to them we actually used half of the extractable resource in oil.

So, there will be a permanent output decline that will set in. So, they were very pessimistic about oil. So, in future of oil the amount of oil endowment. So, now the

question in this context is after 2 decades have been passed since the early 2000s. So, we should now ask whether have we actually reached the peak. So, did we reach a peak that will be what we will be discussing in the remaining part of our lecture.

So, the, but the answer is that the proponents of the peak oil hypothesis they have become mostly quiet because of the very important event marked in the global oil industry in 2014 is the shale oil revolution right. If you remember the oil price movement, we saw that there is a global financial crisis in 2008 which started in US and then it percolated to other parts of the world.

But finally, with appropriate policies and overtime around 2012 the global economy could come out of the global financial crisis and oil demand started increasing. So, oil price also increased at that point of time. So, many believed that the oil price will increase very high, but they were not aware of the shale oil revolution because US already they invested lot in R & D they tried to find out some alternate some more.

So, types of oil. So, they came up with the shale oil with if in one of the lectures earlier if you remember we have discussed about shale oil in detail its characteristics how it was invented. So, but the thing is that shale oil is still mostly limited to US. So, but shale oil revolution actually changed the oil price trend.

So, suddenly oil price trend completely reversed in 2014 when US supplied additional amount of oil in addition to the existing supplies of oil from OPEC and non-OPEC countries right. So, the believers of peak oil they actually were just quite after the shale oil revolution because they did not know you see the timing. So, the shale oil revolution mainly these economists say Campbell 1998 and all other are early 2000 and Aleklett in 2012.

So, they believed that the oil price is so high that ultimately the oil production will culminate, but they were not aware of the shale oil revolution was coming up ok.

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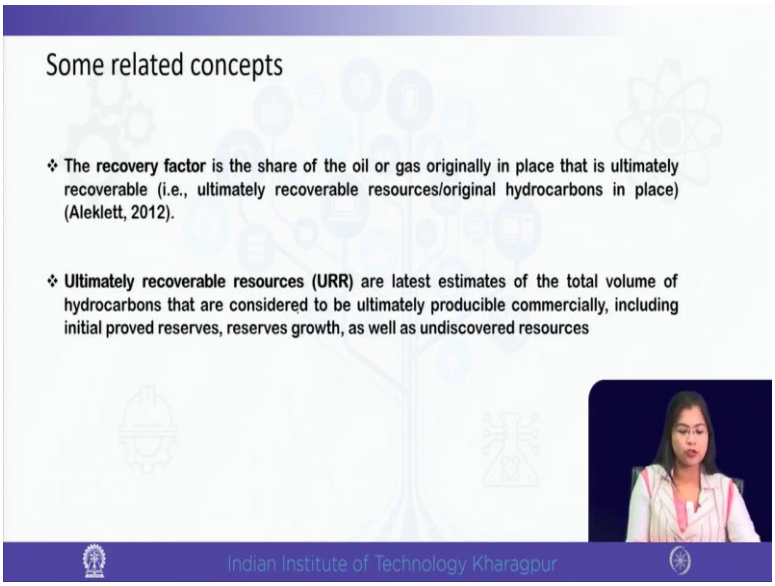

So, they become mostly quite after the shale oil revolution actually took place. Now, here we need to know some related concept to for proceeding further. So, one such concept is the recovery factor. So, what is that this is the share of the oil or gas which is originally in place that is ultimately recoverable.

So, basically this is the ultimately recoverable resource or original hydrocarbon in place. So, this definition was provided by Aleklett 2012 and ultimately recoverable resources. These are the latest estimates of the total volume of hydrocarbons that are considered to be ultimately producible commercially ok.

Including initial proved reserve commercially means it should be producible economically or profitably and including the initial proved reserve growth and undiscovered resources ok. So, these are this is what is the URR.

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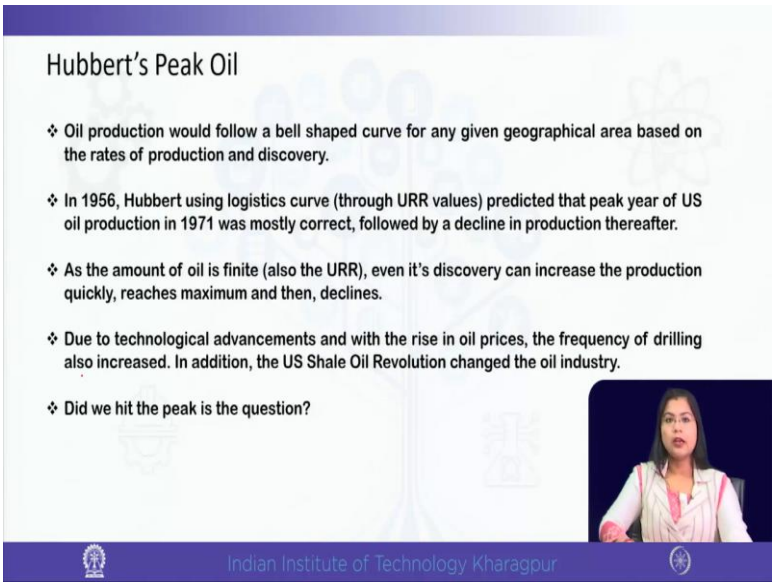

Now, here we have a very related concept of Hubbert's peak oil and that was a proposed by Hubbert a long ago in 1956. So, according to this Hubbert's peak oil theory the oil production would follow a bell-shaped curve for any given geographical area based on the rates of production and discovery.

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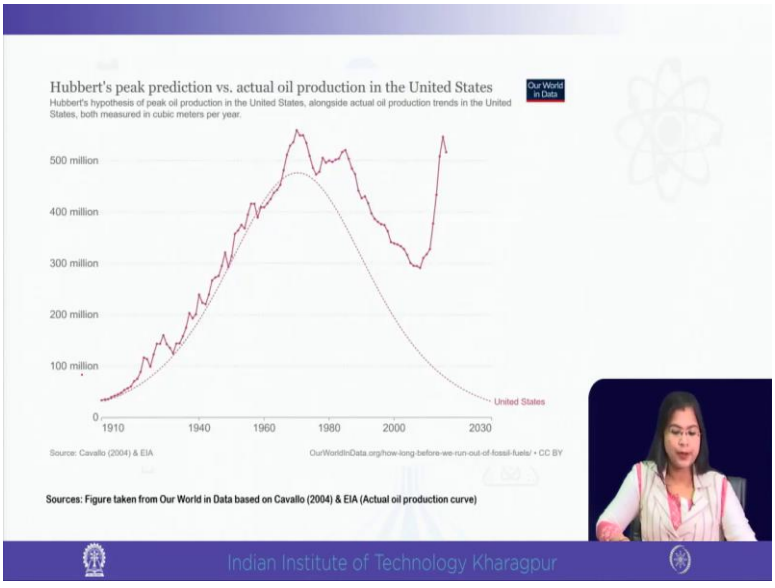

I will show you the peak oil the peak prediction by Hubbert. So, you see this is the predicted value. So, the Hubbert's paper was in 1956. So, Hubbert predicted the oil

production and you can see the red dotted line is the prediction and the red solid line is the actual value.

So, we can see that to a large extent the actual oil production actually followed the bell-shaped curve right. But there has been divergence in the post 2000 means at least from the 2010 era and mainly it is marked by the shale oil revolution. So, in 1956 Hubbert used a logistic curve through the URR values and predicted the peak year of the US oil production in 1971.

So, in 1956 Hubert predicted the oil production of US of 1971. So, that was a prediction and that was mostly correct when in 1971 it was checked and it was found that the Hubert's prediction was mostly correct and this was followed by a decline in production thereafter. So, as the amount of oil as well as URR is finite or limited ok.

Even it is discovery can increase the production quickly and it can reach the maximum and then it can decline. You see because the amount is fixed it is in limited quantity because the current rate of addition is very low ok. So, we can consider at a given point of time this type of non renewable or exhaustible natural resources are in fixed supply ok.

So, it is discovery a new discovery can increase the production quickly. But again, if we keep on using that we will reach a maximum and then it will decline right. So, due to technological advancement and with the increase in oil price the frequency of drilling also increased. In addition, we also know that the shale oil revolution took place in 2014 and that changed the oil industry. So, the question is, Did we hit the peak that is our interesting question.

So, we can see that for a very long time you see at least till mid nineteen 1970s you see till 1960 almost the actual oil production and the prediction by Hubbert they moved almost together. 1970 you see the actual oil production actually increased. So, that is we already discussed the reason because of the increase in oil price. So, we know the oil price shock of 1970s right.

The first two oil price shock was in 1970. So, oil price oil production increased the actual production was greater than the prediction, but the trend is same because the peak of the bell shaped curve also was predicted to occur during 1970. So, that happened you see

after that the oil production the predicted value also declines after reaching the peak as well as the actual value also has declined after reaching the peak.

It increased during the time of great price collapse because we have already discussed that Saudi Arabia increased their oil supply they abundant the high price policy. So, at that time you can see that oil the actual production increased. But the trend was more or less followed, but the trend actually changed due to the shale oil revolution and you can see the technological improvement.

So, actual oil production actually diverts from the predicted value. So, the predicted value of the post 2000 shows a declining trend the Hubbert's prediction, but the actual value in the post 2010 has increased. So, due to technological improvement and the shale oil revolution. So, this figure is taken from our world in data which is a very relevant data source for our purpose and this is based on Cavallo 2004 and EIA actual oil production curve.

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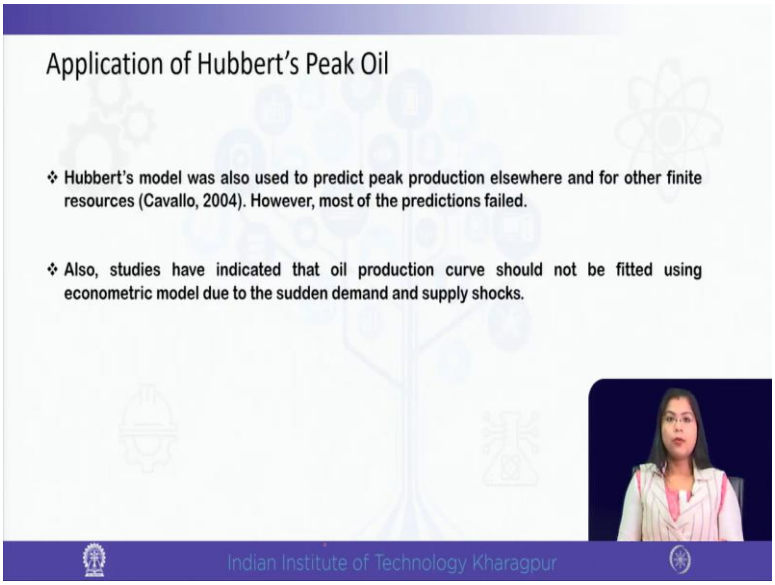

Now, what are the application of Hubbert's peak oil? So, Hubbert's model was also used to predict the peak prediction in other cases apart from oil industry and for other finite resources like Cavallo 2004 also used Hubbert's peak oil theory and for other metals and minerals. But however, most of the predictions failed.

Also, studies have indicated that the oil production curve should not be fitted using the econometric model because you see we know that the oil market is subject to lot of shocks both in the demand side supply side which is often beyond the control of the oil suppliers. So, fitting an econometric model is may not be very wise decision to study the oil production because there are shocks which are just completely exogenous. So, it is very difficult to predict using econometrics.

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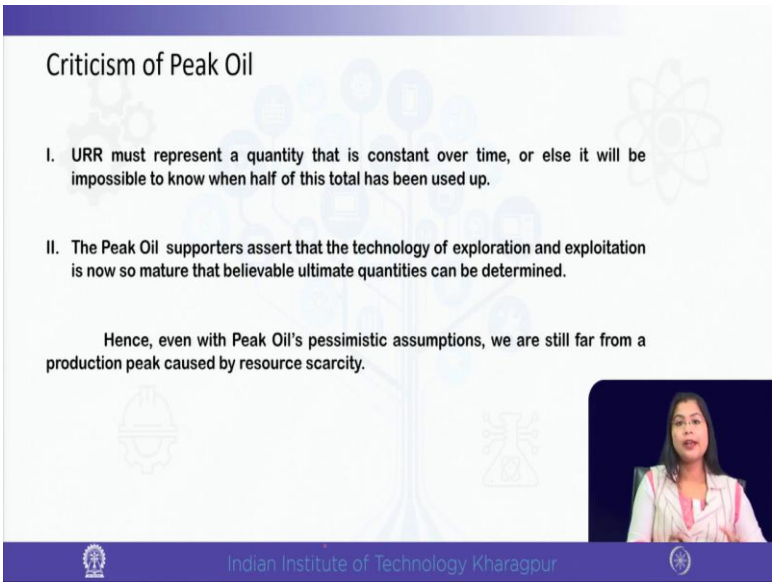

So, these are the some of the criticisms of peak oil are also there. So, we are looking at means the application and criticism. So, should we rely on the peak oil? So, one criticism is that we already have seen that the shale oil revolution has made the proponents or the believers of peak oil hypothesis mostly quiet and the second criticism is that. URR, the concept of URR ultimately recoverable resource.

It must represent the quantity which is constant over time. Otherwise, there will be it will be impossible to know when half of the URR is actually used up. But you see you already discussed that this URR may not be constant right because it also considers the reserve growth the appreciation in reserve that occurs during the phase of extraction.

Because we just discussed that during the phase of extraction and exploration which occurs for a period of say 30 to 40 years there are reserve growth because technological improvement is there. So, you come up with new reserve ok reserve appreciation takes

place. So, URR may not be constant, but the peak oil says that URR for peak oil hypothesis, URR should be means you should know when half of this URR is used up.

But how do you know if half of the URR whether it is used up or not because URR may not be a constant ok. And third criticism because the first is the shale oil revolution we already discussed the second criticism is the URR is not a constant may not be a constant and the third criticism is that the peak oil supporters they believe that the technology of exploration and exploitation is also very mature.

That the exact amount of the ultimate quantities believable ultimate quantities can be determined. But you see we know that it is completely uncertain because even with a very improved technology you cannot definitely say how much of oil is there ok. So, uncertainty is always there and that makes the global oil market subject to so much volatility.

So, oil the amount is uncertainty you do not know the exact amount. So, even with a very better technology you cannot say definitely right. So, even with peak oil pessimistic assumption what we can conclude is that we have not yet reached the peak which is caused by scarcity of resource. We are yet to reach a peak because the one of the reasons is as we have seen the shale oil revolution.

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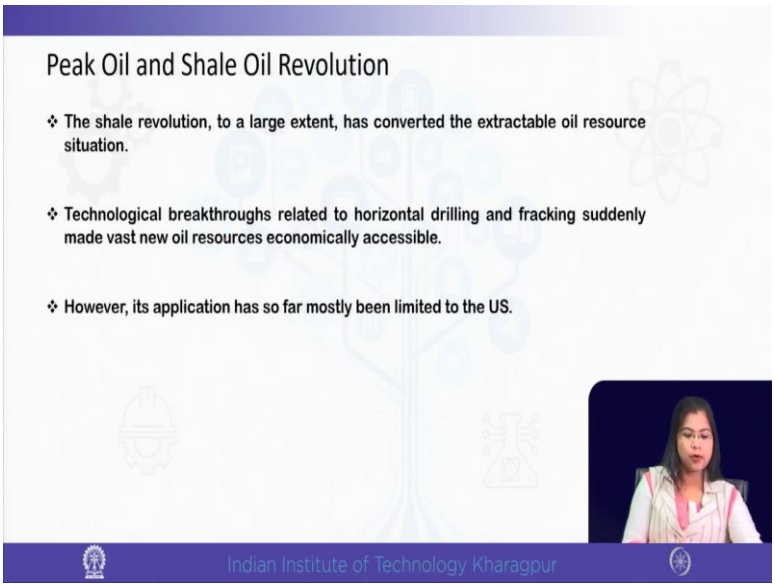

So, the shale oil revolution to a very large extent it has converted the extractable oil scenario right. And the technological breakthrough related to horizontal drilling and fracking they have made vast new oil resources economically accessible, economically means profitably ok.

So, technological improvement has also led to increased supply of oil as well as the shale oil revolution. Shale oil revolution is mostly limited to US. So, that is one limitation of shale oil. But technological improvement has been going on for other parts of the world also right.

So, therefore, you see from 2000 post 2010 onward the actual oil production and the prediction by Hubbert has diverged. And mainly these are the two reasons shale oil revolution and the technological improvement in drilling and fracking to be more specific horizontal drilling and fracking.

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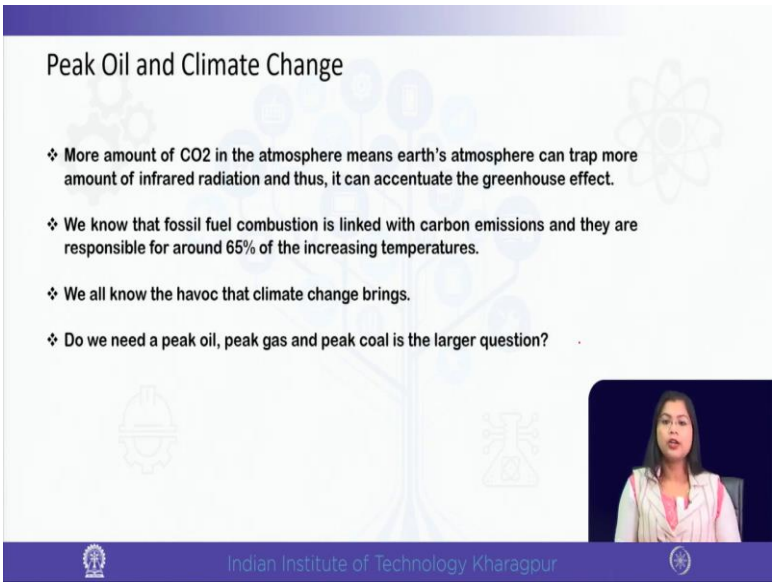

Now, another related aspect is peak oil and climate change. Now, you see as you are using more and more of oil so, you are reaching the peak or not only oil any type of fossil fuel or any type of resource which actually leads to greenhouse gas emission and so, and climate change. So, as you increase the production you reach the peak. So, what happens?

You emit more greater amount of carbon dioxide CO2 in the atmosphere means atmosphere can trap more amount of infrared radiation and that it can accentuate the greenhouse effect. So, you are nowadays so, concerned about the climate change and the greenhouse gas effect. You remember we have also discussed about the Paris agreement in the very initial classes of our course.

So, we know that fossil fuel combustion is linked with carbon emission and they are responsible for around 60 percent of increase in temperature. So, we all know that climate change will play a havoc. So, we can fill the consequences of climate change. So, that is why now the question is do we actually need a peak not only of oil for other type of resources also let us say gas or coal.

So, that is the larger question because if you are actually reaching a peak what happens that leads to more of CO2 emission. So, that will accentuate the problem of climate change that will increase the main global temperature that will aggravate the problem of greenhouse gas emissions right. So, do we actually need a peak oil peak gas or peak coal?

So, that is the broader question we should be concerned about because we have to be careful about the environment and sustainability. We have discussed all these in our very initial lectures because as you are using more and more of fossil fuel. So, we are emitting lot of CO2. So, if you are reaching the peak actually that will also lead to greater greenhouse gas emission and that will be responsible for climate change and increasing global temperature.

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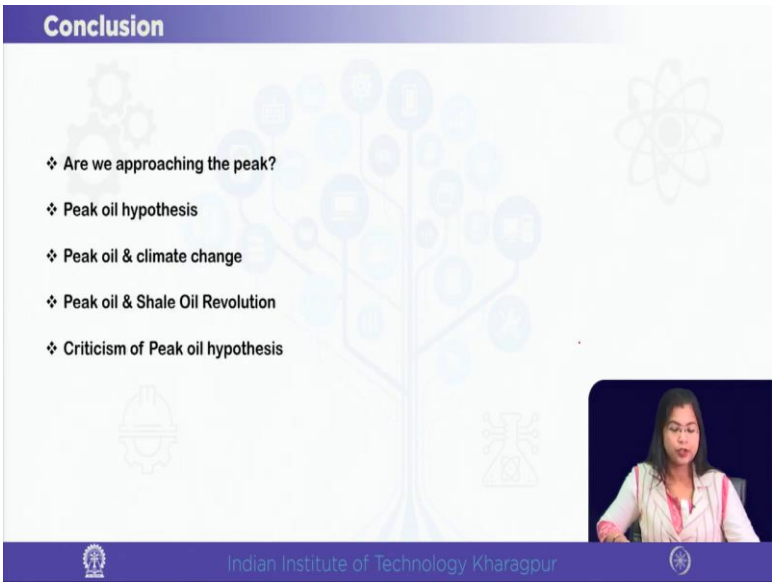

So, in today's class what we have discussed is that we answer to the question that are we actually reaching the peak. So, we started by defining what do we mean by peak oil and then we discussed the peak oil hypothesis, we discussed the criticism, we pointed out the criticism of the peak oil hypothesis and we plotted the Hubbert's peak prediction and compared it with the actual oil production.

And we saw that shale oil revolution along with technological improvement has actually led to a diversion in the actual oil production after 2010 with the Hubbert's peak prediction. So, and we also answered the broad question of do we actually need a peak because a peak means we are actually reaching the peak point of the bell shaped curve as predicted by Hubbert not only of oil of coal, natural gas, but that also leads to a huge amount of greenhouse gas emission and may not be good for environment in the long run.

So, we have to also think that we should not reach the peak of peak use of any resource that will not only have implications from the point of view of depletion of the resource, but that will also have implication from the point of view of environmental consequences which is a means a greater concern for the entire globe, entire world and the ecosystem also.

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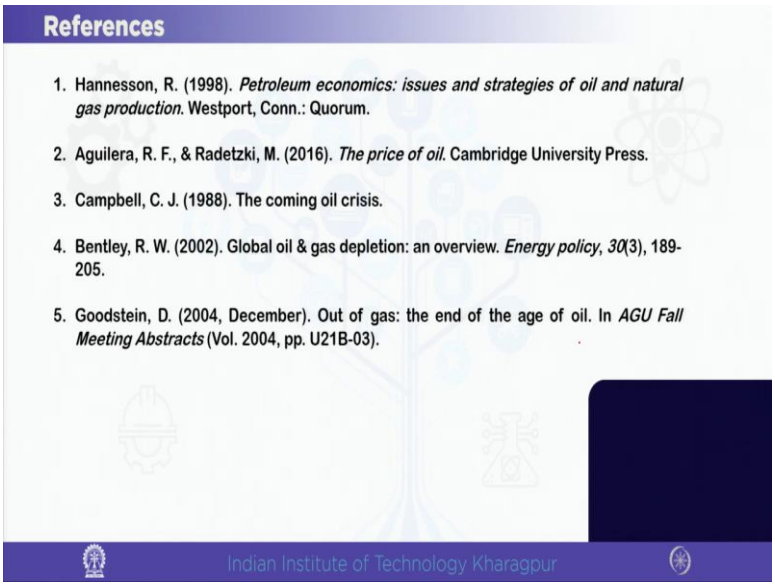

So, with this I finished today's lecture and we have used many references for today's lecture as you can see apart from the two books of petroleum economics, we have to also refer to all the research papers that have actually used the concept of peak oil and they the economist who are proponents of peak oil.

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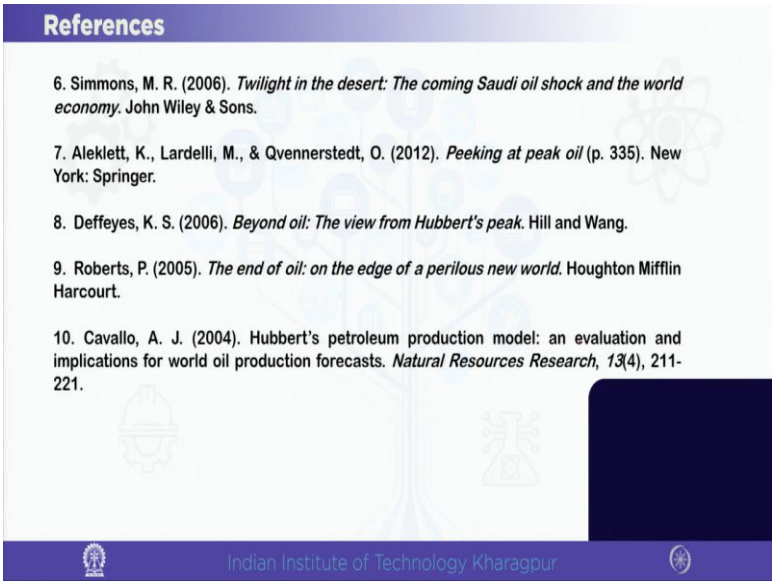

So, we refer to all the papers of peak oil hypothesis the starting point was Campbell's paper in 1988 and then we also mentioned the other books and papers we have used for today's lecture.

So, with this I thank you and see you in the next lecture.