Energy Resources, Economics, and Sustainability

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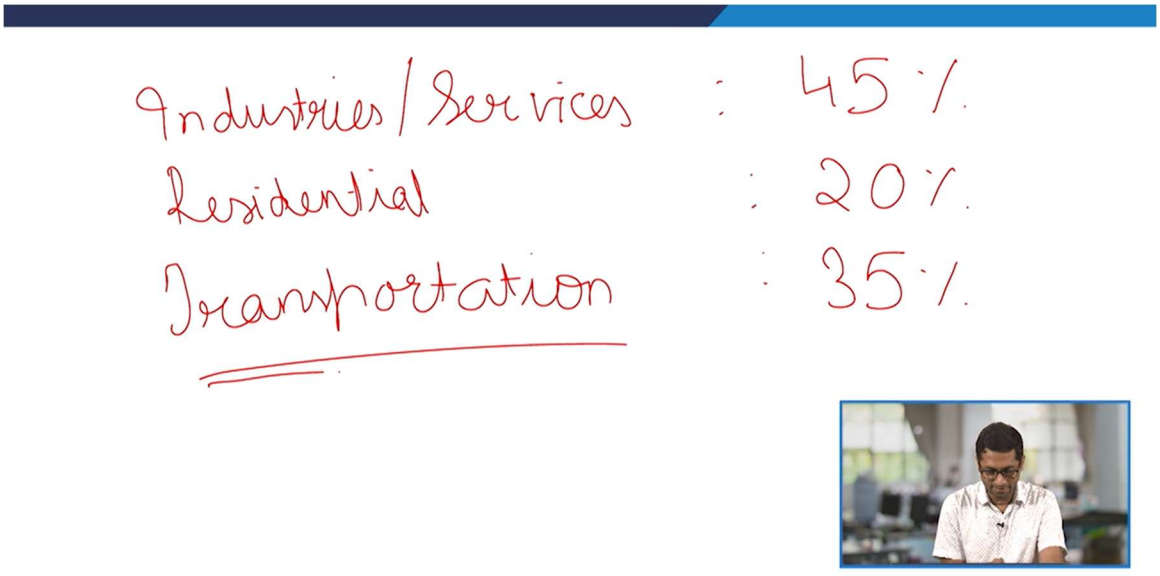
Week – 01

Lecture – 04

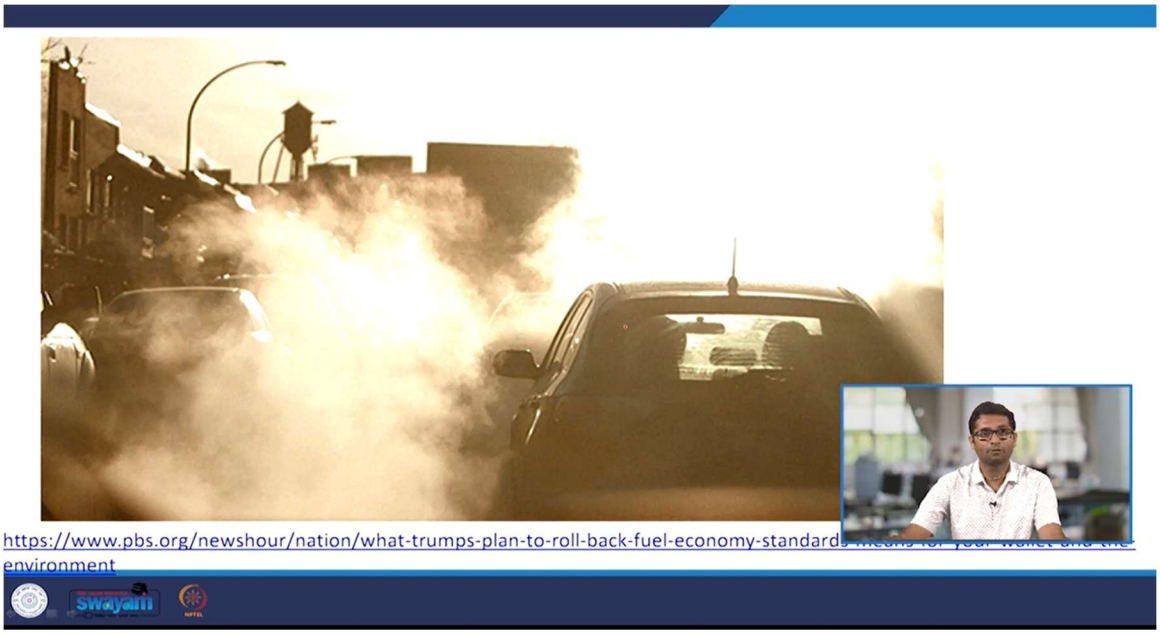
Lecture 04 - Energy Consumption in Different Countries

Hello everyone, welcome back to the course Energy Resources, Economics and Sustainability. Till now we have been discussing the different conventional and non-conventional sources of energy or renewable and non-renewable sources of energy. Today we will try to discuss how this energy is consumed in different countries in the different sectors. We will try to get a glimpse of what are the major areas where energy is utilized in the different countries. So if I take the generic distribution of energy resources globally, it could be divided into three major sources. The first one would be industries and services combined.

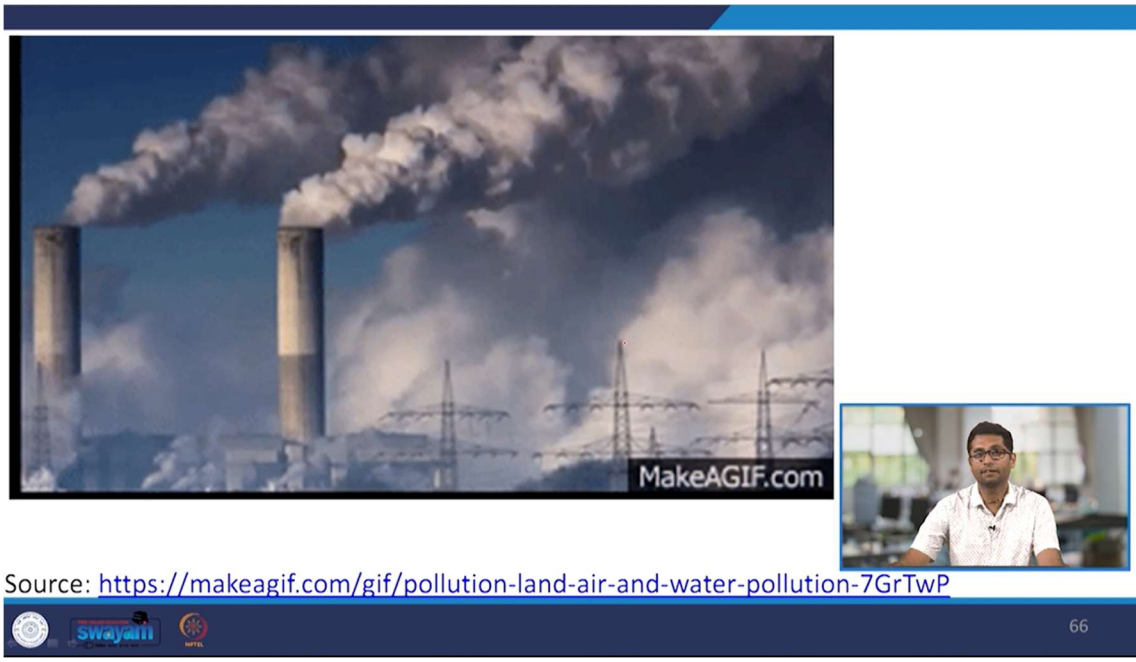


If I take the share of this particular aspect, it would be almost 45 percent. 45 percent of all the energy that is produced is consumed either in the industries or the services sector. Then we would have the residential sector which would consume another 20 percent of the resources. And finally we would have the transportation sector which would consume the remaining 35 percent of the resources.

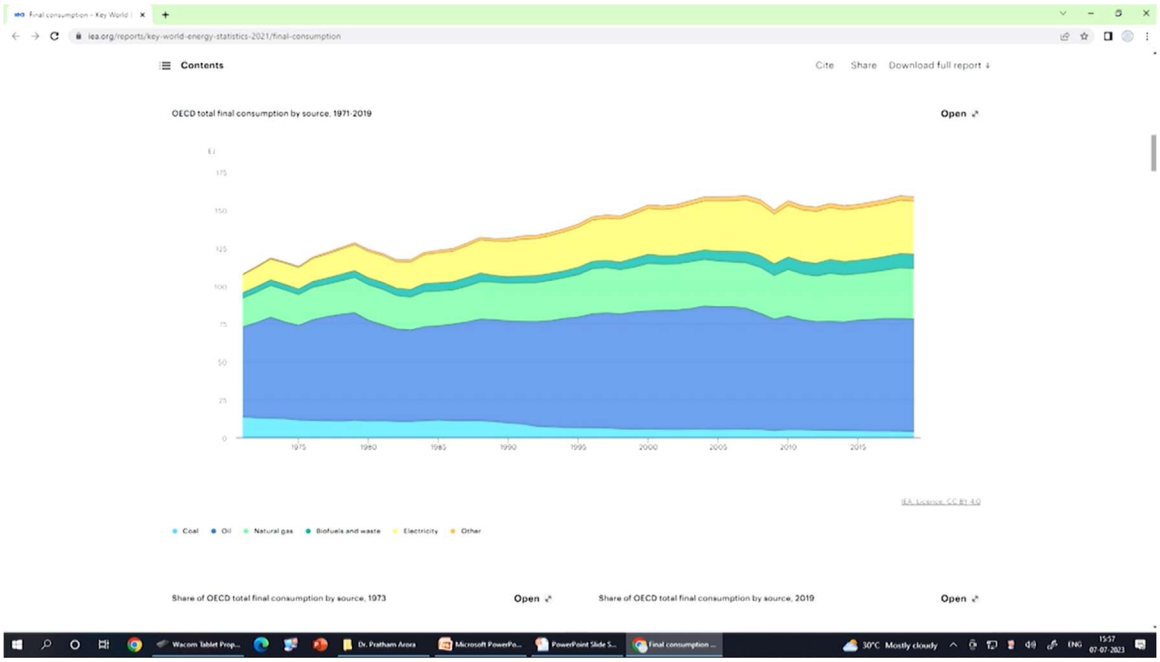
So this is again a global average and this would keep on changing as we proceed in time or we look at the past results. Again this is not a static value for different countries, this would be very different for different countries. But I have taken some generic values. Again if you refer to the different sources, the numbers would be very different. There would be different classifications. Sometimes the building sector encompasses both the services and the residential sector. There could also be a non-combustion sector which includes the use of lubricants or fertilizers or different chemicals. But nonetheless this is how the energy is divided. Majority of energy is utilized in the industrial sector. Then comes the transportation sector which includes all the different modes of transportation, road, railways, air, marine. And finally we have the residential sector which basically includes the homes, the buildings. It is very interesting to note that whenever we are talking about clean energy, green energy, sustainable energy, the focus in the popular media tends to roam around just transportation. They would be talking about EVs, they would be talking about hydrogen fuel cell vehicles, but not many people talk about industries or greening the residential sector. One might wonder why this is the case. One of the reasons is that the transportation sector is much more varied and available around us.



So if you stay in any of the metros in India you would come across this site very often where we have a lot of transportation causing a lot of not so good gases.

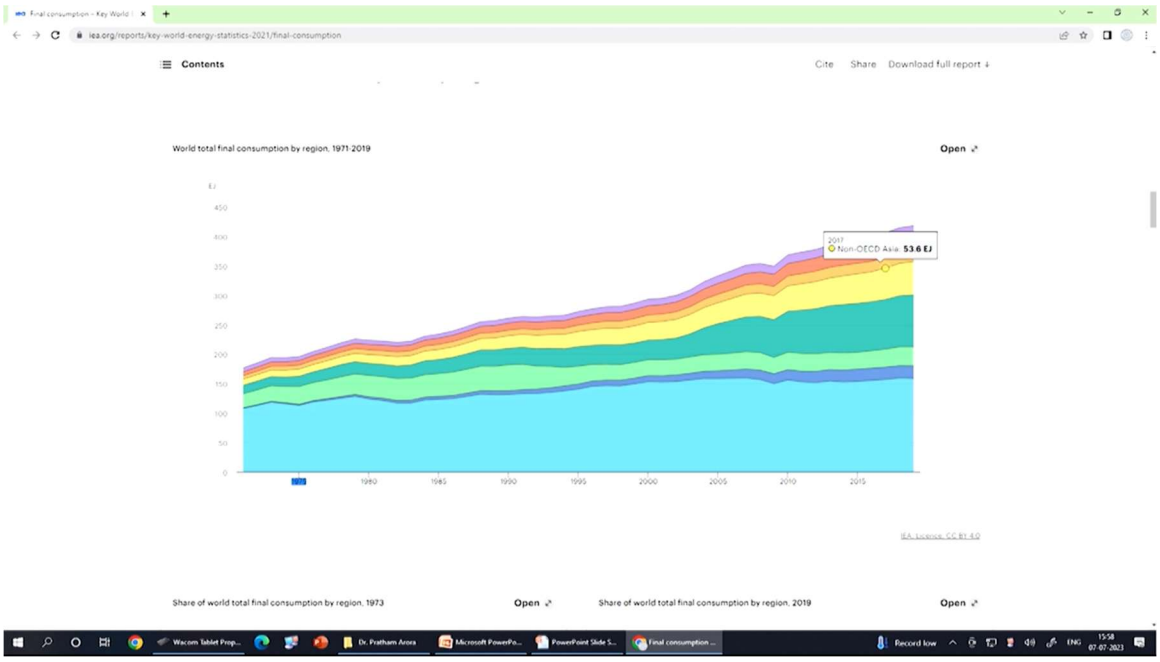


And we are not accustomed to see a site like this where we see huge industries which are creating a large amount of GHG gases and consuming a major chunk of the energy. And this is one of the reasons because most of us are staying in the cities and these sites are not very common around the cities. Further if we go across the IEA statistics we can understand how the different energy consumption varies in the different countries. And let us try to get a glimpse of it.



So what we will do is we will go to the IEA website which is the International Energy Agency and try to see some of the statistics. So this is one of the outputs by the different analysis that IEA does. It basically tries to quantify where the energy is produced, where it is consumed, what is the efficiency and come up with different results. So we are referring to one such of the analysis which was done for the year 2019. So first we analyze where the energy is coming from and in coherence with what we have studied in the past a majority of the energy that we utilize or have been utilized till lately was coming from fossil fuels.

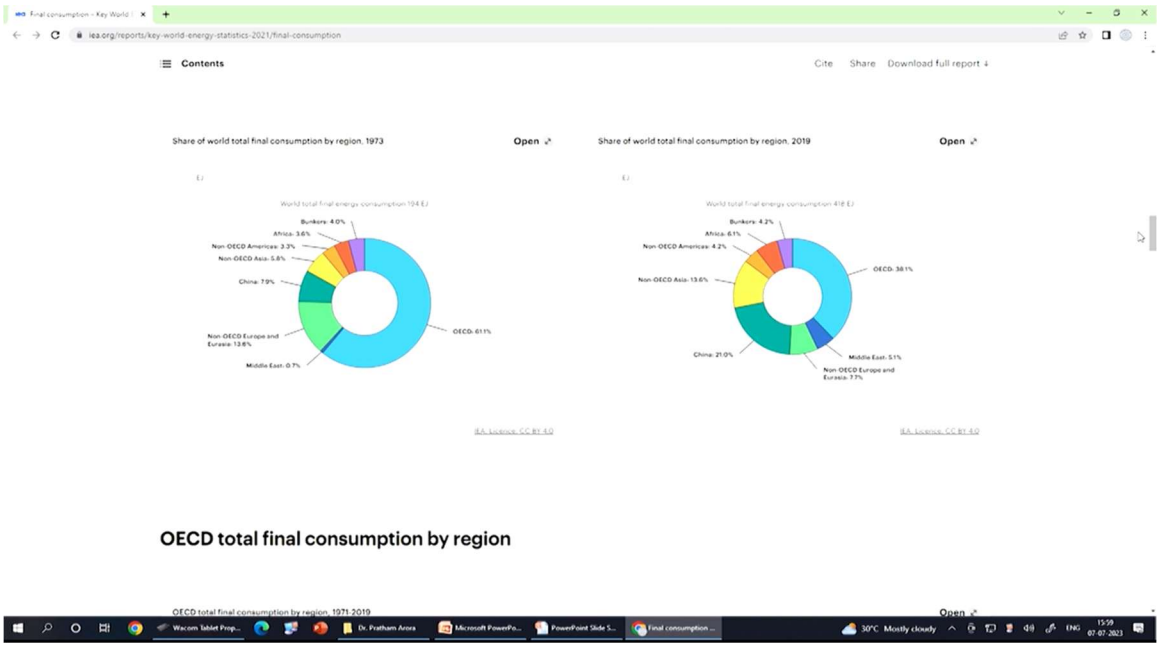
It was coal, oil, natural gas. Then a significant comes from biofuels or other kind of waste to energy processes. Then we have the electricity being generated both from renewable and non-renewable sources of energy. And then there are few others as well. Now if I proceed towards how the energy is consumed by the different regions we can also have a glimpse.



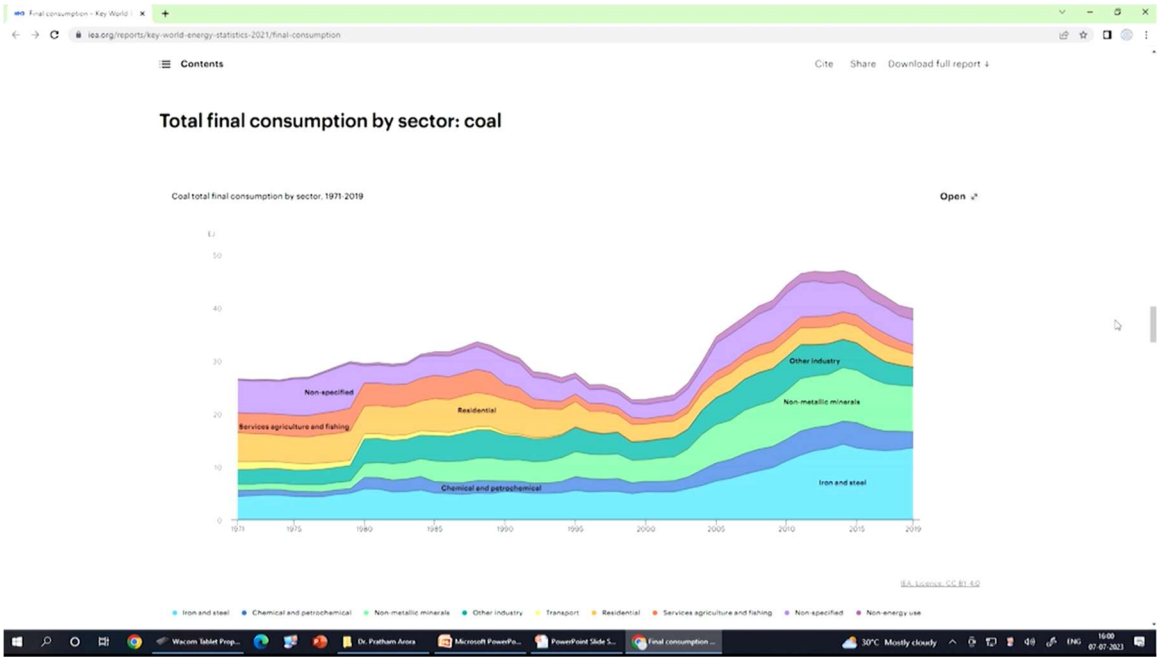
So if you see have a look at here we see that OECD region which is given in the light blue color consumes a major chunk of energy. It has been a major user or consumer of energy since the last 50 years or so. By OECD I mean it is the organization of economic cooperation and development basically referring to the developed world. Much of the countries of Europe, US, Australia, so these are the types of countries I am referring to.

And even today they consume a major chunk of the energy. But what we see their energy utilization has almost stagnated and this is attributed to two main facts. One is they are going more towards energy efficiency. More and more processes are becoming energy efficient. So even though the energy consumption might be increasing because they are going for efficient processes it does not appear. And finally many of these countries are also experiencing not a growth in population. So the population is becoming stagnant or decreasing. So the energy consumption is also not growing at a very fast pace. What we see a major chunk increase is the one in China which you see in here. It has been growing at a very fast pace for the past two decades. It has now become the factory of the world.

Any alternate product that you look at might be manufactured in China. And in this manufacturing process they are consuming a lot of energy. So this is in the dark blue color in here. We in India are a part of known OECD Asia and again we see that a major amount of energy is being consumed in here and is expected to increase in the future as well. But it is nowhere as compared to China or other OECD countries. But we also see that the major growth in the future is linked to these two regions China and non-OECD Asia. Whereas other regions are almost stagnant or the growth is not very much. So this is again why this course becomes important because we as a country would be increasing our energy consumption at a very fast pace and we need to be cognizant of the fact that we do so in a sustainable manner.



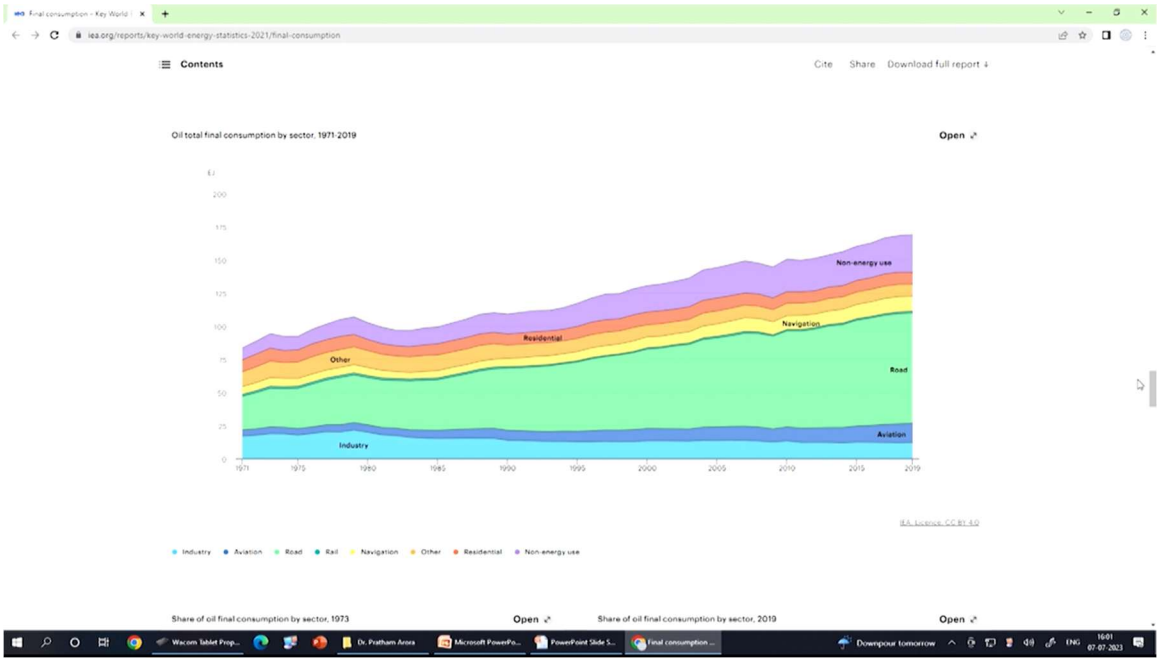
Further we can see that if we consider the years 1973 and 2019 the chunk of OECD has decreased from 61 percent to 38.1 percent. The non-OECD Asia which we are a part of is still 13 percent but expected to be a major player in the future.



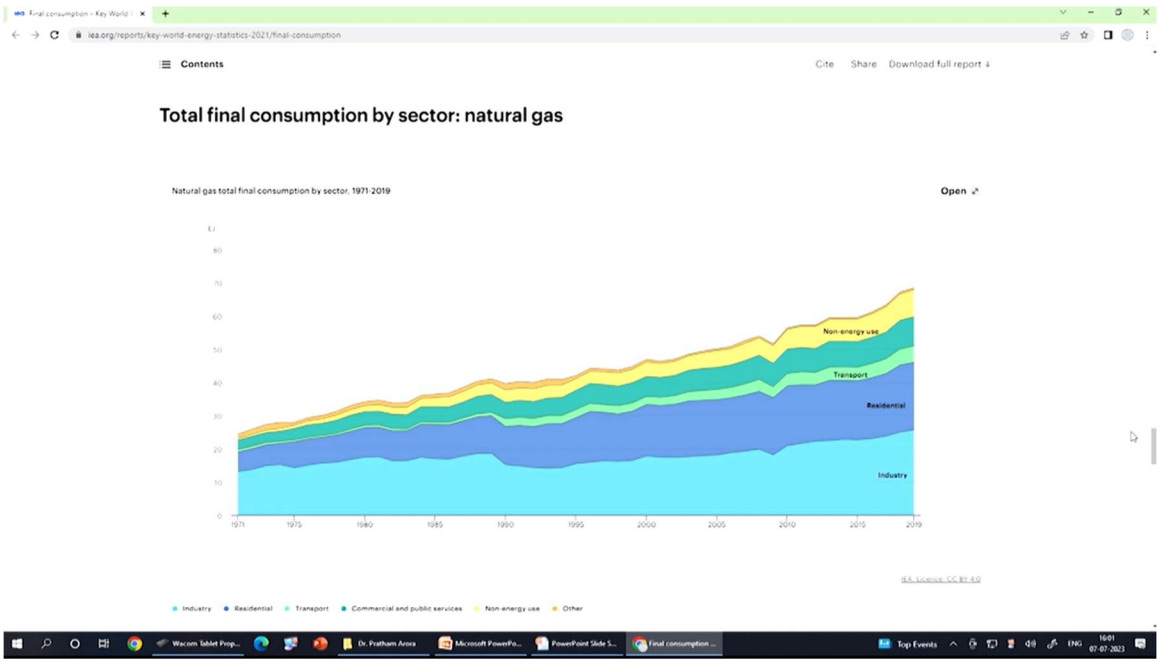
Further we can see how this energy was consumed by the major fossil fuels. So if I have a look at coal. So coal if you see the consumption has been varying a lot in the past. It had a peak in the 1990s and then there was a dip.

It again gained momentum around 2005 or so and this momentum was basically backed by the growth of China. So this was a time when China began a massive consumption of energy and massive production of goods and this is basically linked towards the growth in China and it has a big growth in them. Why we see a decline in 1990s? This was a time when major economies or the OECD world was shifting towards the use of natural gas as compared to coal. There are two reasons. It was economical and the second it was not leading to as much CO2 emissions as coal would have.

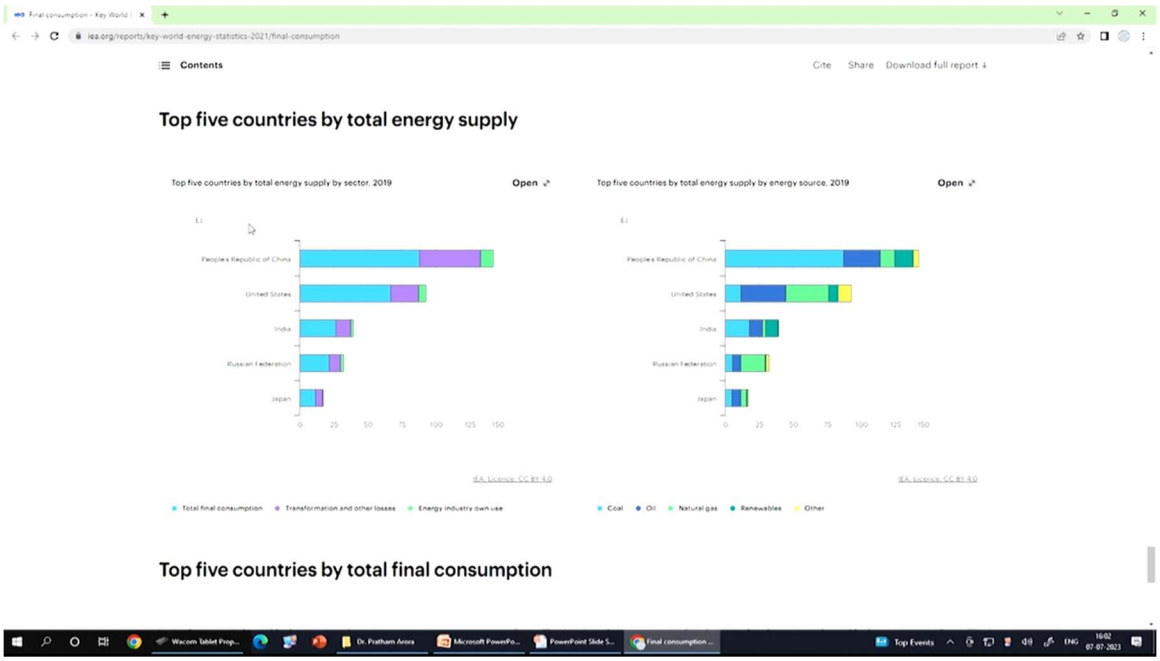
And we can see the consumption of coal could be linked to basically the iron and steel industry which is one of the largest consumers of coal. Then we also have the non-metallic factors. If we see the residential sector it is using some amount of coal but that is for heating purposes. Then we also have the use in chemical and the petrochemical industries. Coming towards the other fossil fuel which is oil.



Oil as most of you would have thought till now is majorly being consumed in the transportation sector and even in the transportation it is the road sector which consumes the majority of the oil. Then the other uses remain in the aviation sector but it is miniscule as compared to the transportation sector. Industries also consume oil mainly in the boilers but again that remains a small part.

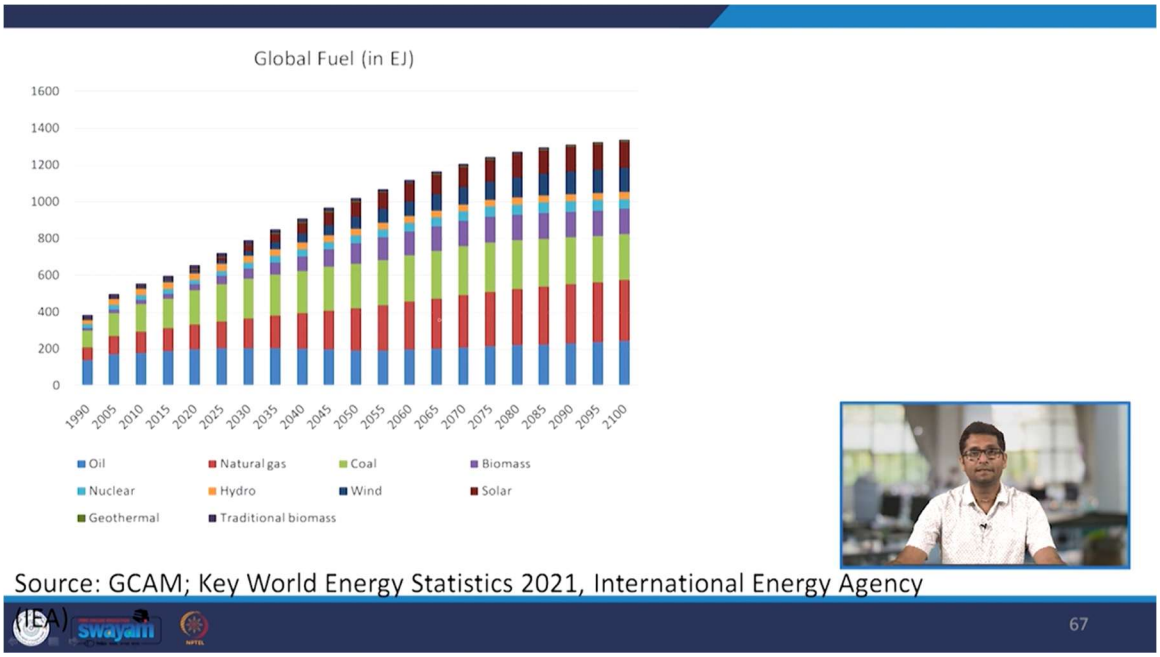


The other major fossil fuel remains natural gas. And if you see the natural gas consumption this has been increasing in the industrial sector as well as the residential sector. In the industrial sector as well as the residential sector the use is primarily for the heating purposes. The heating that is required in the industries normally of the tune of 1000 degree Celsius is supplied by natural gas based burners. In residential sector this is basically used for centralized heating in much of the colder countries. You also see a non-energy sector. So when we talk about a non-energy sector it refers to the sectors like production of hydrogen and ammonia which are primarily based on natural gas as a feedstock.



Also we can see what are the five major countries which are the largest consumers of energy. It is the People's Republic of China, the United States, India, the Russian Federation and Japan. These five are the major consumers of energy and we will be returning them back to them. But we can see that the energy consumed could be divided again into three factors.

One is the total consumption. Then the transformation of the energy is almost every time related or coupled with losses as well. So there is a good amount of energy that is lost. And then there would be captive requirement by the industries as well. But these are the five major countries which are the major consumers of energy.

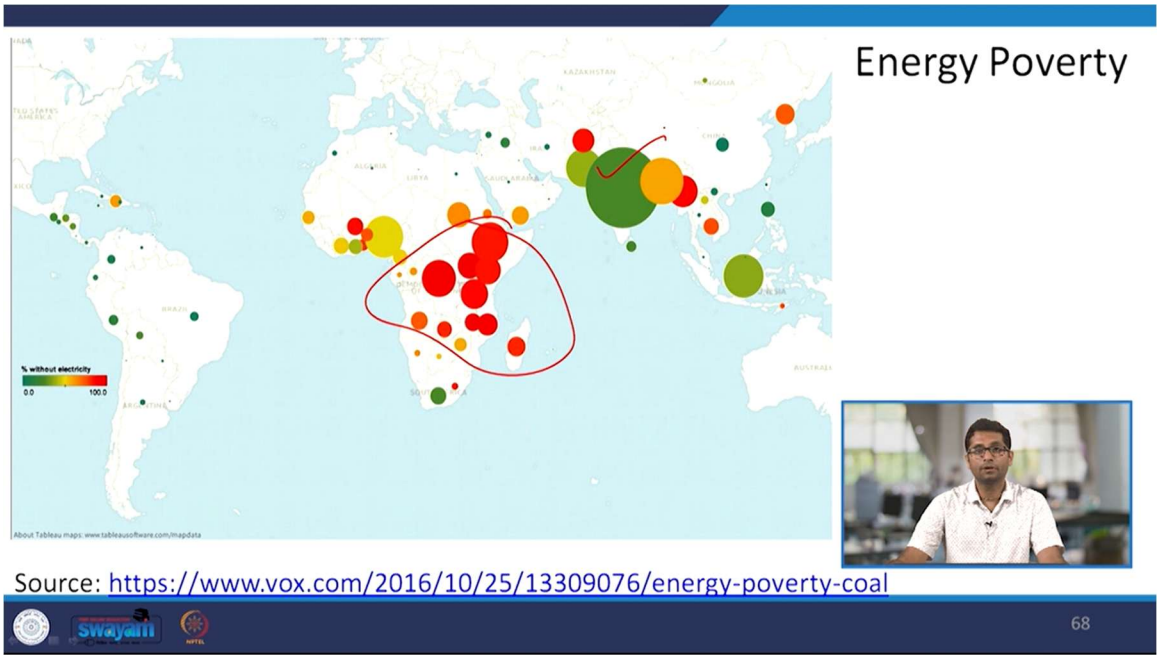


Now coming back to the slides. So we have been studying how the growth of different fuels energy consumption is expected till today's time. And there have been different models which have tried to predict how energy use is expected to change in the future. So one such model is GCAM which is a Global Change Assessment Model which has been developed by the PNNL which is Pacific Northwestern Laboratories in the US. And we have tried to study some of their analysis and this is one such projection for the future use of different kinds of fuels for powering the energy needs. And this is the scenario which was before the different countries announcing their net zero targets.

So this is the business as usual scenario. In the absence of any major policy of implications, this is how the energy consumption is going to change in the next 80 years or so. We can see if there are no major policy implications, fossil fuels in the form of coal, natural gas and petroleum are going to dominate. We would also see the renewables kicking in but they would not be more than 50 percent. So this also brings out that how good policies and good government interventions are needed for a greener future.

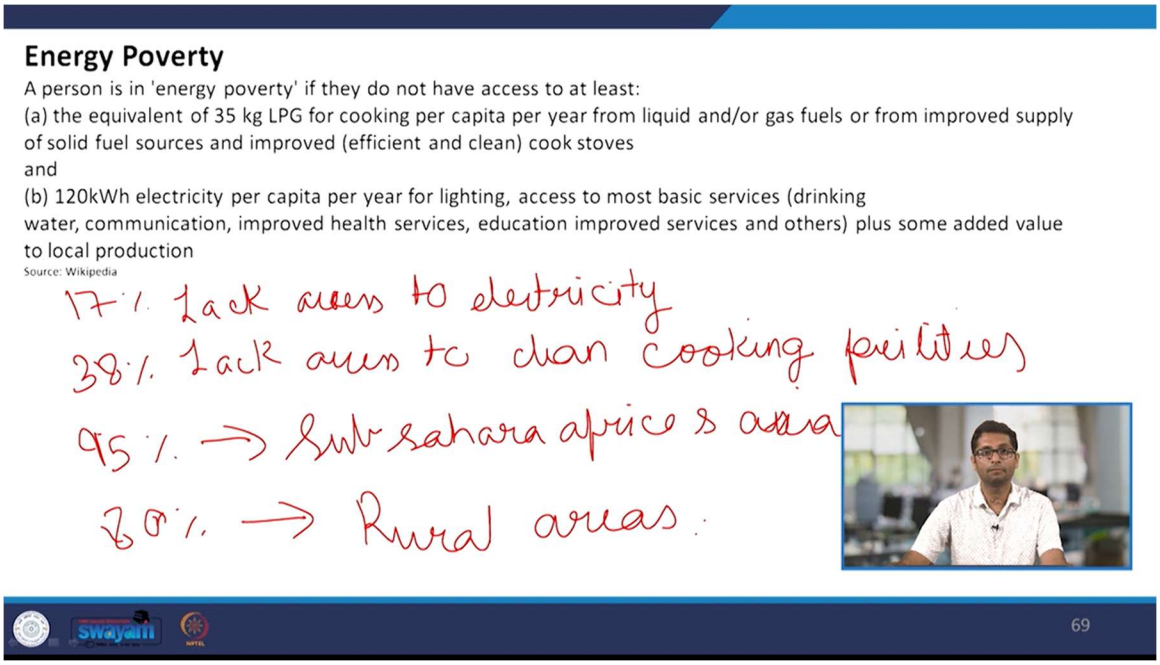
And this results again I would say are before the different countries announcing the different policies or the net zero targets. This is how if we continue with the same pace and the same policies, the energy consumption is going to change in the future. Now with this let me also introduce you to a term called energy poverty. Energy poverty is basically

referring to the lack of clean cooking facilities as well as electricity. And there are many countries of the world which are termed as energy poor.



One such infographic is something that you see in the screen in front of you where you see the percentage of people with access to electricity in the form of the colours. If a country has a reddish tone or the deeper the red colour, the more population of it doesn't have access to electricity. And if it is towards the green, it is basically having more and more people have access to electricity. Plus the diameter of the circle basically tells you the absolute number of people who don't have access to electricity. So, we can see much of the Africa falls in this region where majority of population don't have access to electricity.

But we shouldn't be very happy in our country either. Although the number seems to be very green, so which means that almost more than 95 or 99 percent of people would have access to electricity. But even the people who don't have access to electricity may come major chunk such that we have the largest number of energy poor people living in our country. If I go with the one of the definitions of energy poverty, of course there are different agencies who come up with the definition. And one such definition is that people don't have access to even 35 kgs of LPG which is a clean cooking facility or any other clean cooking facility per year.

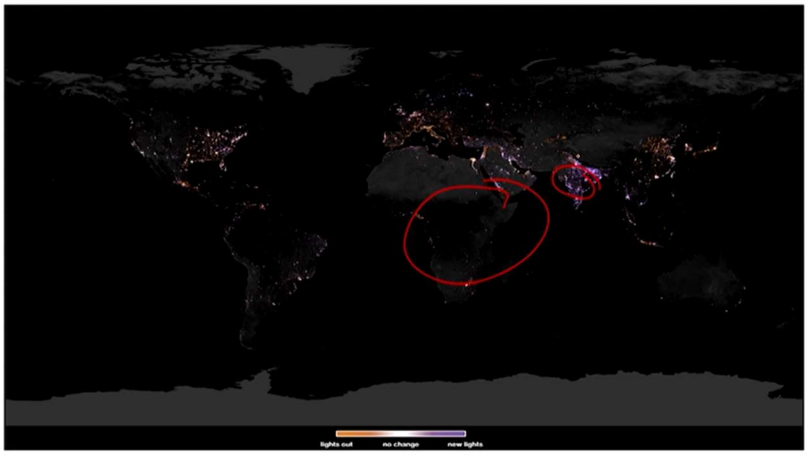


Or people are derived of access to 120 kilowatt hour of electricity per capita per year. So, you can just check in the number of units that you consume in your monthly bill and you will come to know if this number 120 kilowatt hour is very big or very small. Plus I would also like you to introduce you to some statistics. This is regarding energy poverty and it says that 79 percent of world population lack access to electricity. Again 38 percent lack access to clean cooking facilities.

Almost 95 percent of these people are in sub-Saharan Africa and Asia. And 80 percent of these people are in rural areas. So, we can see that how diverse is the access to electricity among the different regions of the world. A good chunk of people even today don't have access to electricity and clean cooking facilities. And much of these people stay either in sub-Saharan Africa or Asia.

We in India also have a major chunk of people who don't have access to these facilities. Plus rural areas are one of the areas which have lack access to this electricity. Let us come back to one of the figures that we have studied in one of the earlier classes where we saw that the energy distribution throughout the world in the form of the lightning as a night sky that has been taken from NASA. We can see that there are places of the earth which are more brightly lit than the others. There have been changes, significant changes in the past five years or so.

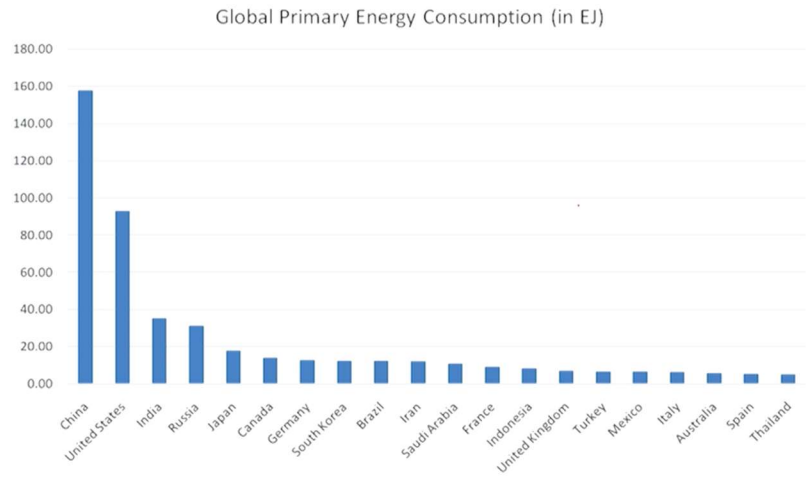
A Changing Earth at Night



Change in lighting intensity from 2012 to 2016

Credit: NASA's Goddard Space Flight Center
Source: https://svs.gsfc.nasa.gov/30919

But we can see again there is much of the Africa that stays in the dark. Much of it could be attributed to the non-liveable condition in the form of deserts and forests. But again we also have a good amount of energy poverty that is dominant in these areas. Even in our country which is very brightly lit, we again have a good amount of people which are energy poor. And in the future the governments would aim that these people who have been derived get their due and become or have a reasonable amount of energy to live a sustainable life in the future.



$1\ EJ = 10^{18}\ J$

Source: BP

Now let us also try to understand the largest primary energy consumers in the world. So this is the list of different countries given by the amount of energy they would be consuming. So China tops this list. So these are the numbers in terms of exajoule which is 10 to the power of 18 joules. China by far is the largest energy consumer of the world.

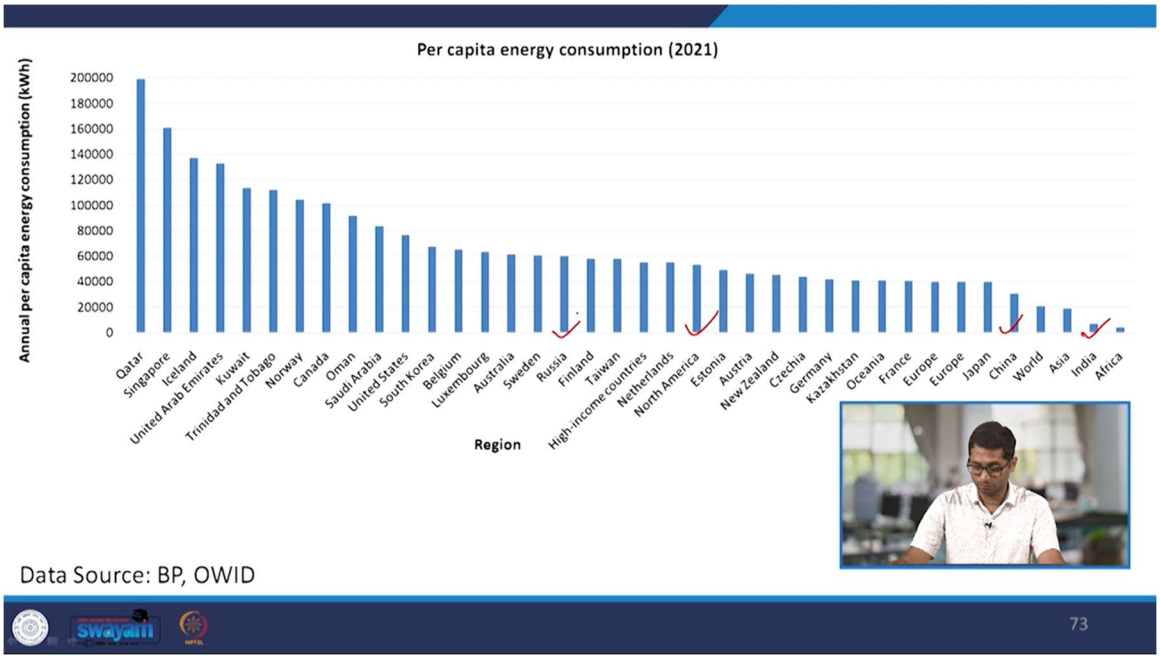
It is also the factory of the world. It produces almost all of the manufactured goods or any other manufactured goods that you would be using would be produced in China. Then we also have the US. We in India stand at the third point. We have Russia coming in, then it is Japan, then Canada and then many of the European countries coming into play. So if we try to count the energy consumed by the top five countries which is China, US, Russia and Japan say China consuming around 155 exajoules, then we have the US consuming around 90 exajoules, India again around 35 something similar for Russia, Japan consuming around 18 exajoules.

If you total it, the total would come around to be 330 or 340 exajoules. Remember in the earlier class we have told you that the total energy consumption globally was around 600 exajoules and here we see that the top five countries consuming more than 50 percent, almost 55 percent of the total energy being consumed in the world. At first point this might seem to be like a disparity, just five countries in the world consuming more than half of the total energy of the world. But we also need to look at the population of these countries. Among these five countries we have the two of the largest populous countries being India and China.

India has just overtaken China being the most populous country. Then we have China, Russia again has a good amount of population, sorry not Russia, it is the US that has a population of around 30 CR, then we have Russia and we have Japan. So if you see the population that is in these countries again that would be nearly half. So it makes sense that half of the world's population consuming half of the world's energy.

So far so good. We have half of the world's population living in these countries and it would consuming half of the energy. But it becomes interesting if we see the per capita energy consumption in these countries. So here you can see have a look at the per capita energy consumption of these countries. So let us try to find these five countries that we

were mentioning in the earlier slide. So we would have North America here which is part of like US and Canada.

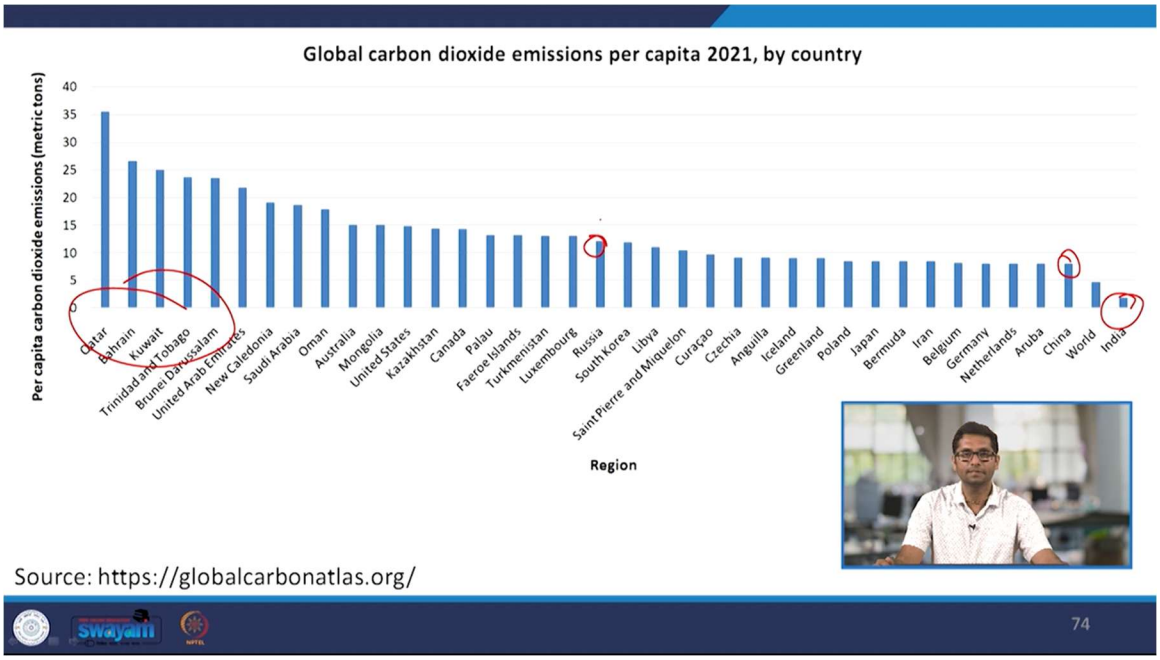


We would have China here, India is in here and Russia is again here and yeah I am unable to locate Japan but it makes up for it. So we see that the energy used per capita is not evenly distributed. Even if China is the largest consumer of the world, per capita consumption comes out to be very less. It is way lesser than what a country like Qatar, Singapore or UAE which are very rich in energy resources would consume, almost one fifth of the energy.

If we talk about India, we are way below the world average. So almost one third of the world average is something that a normal citizen in India consumes as compared to a normal person in the world. And what we would want to do, we would want to reach at least the place of this developed world. We would want to at least make our energy consumption five times. This is again in line with the earlier graph that we have studied that the rise in GDP for any country is linked with the energy consumption.

So we in India would want to come in here. The same goes with China, they would want to increase the energy consumption till the world level. And although they are the largest producer, sorry the largest consumers of energy, they would still want to increase energy consumption. And the same goes with India. Although we are the third largest consumer

of energy globally, we would still want to increase our energy consumption. And it becomes important to decide where this energy is going to come from.

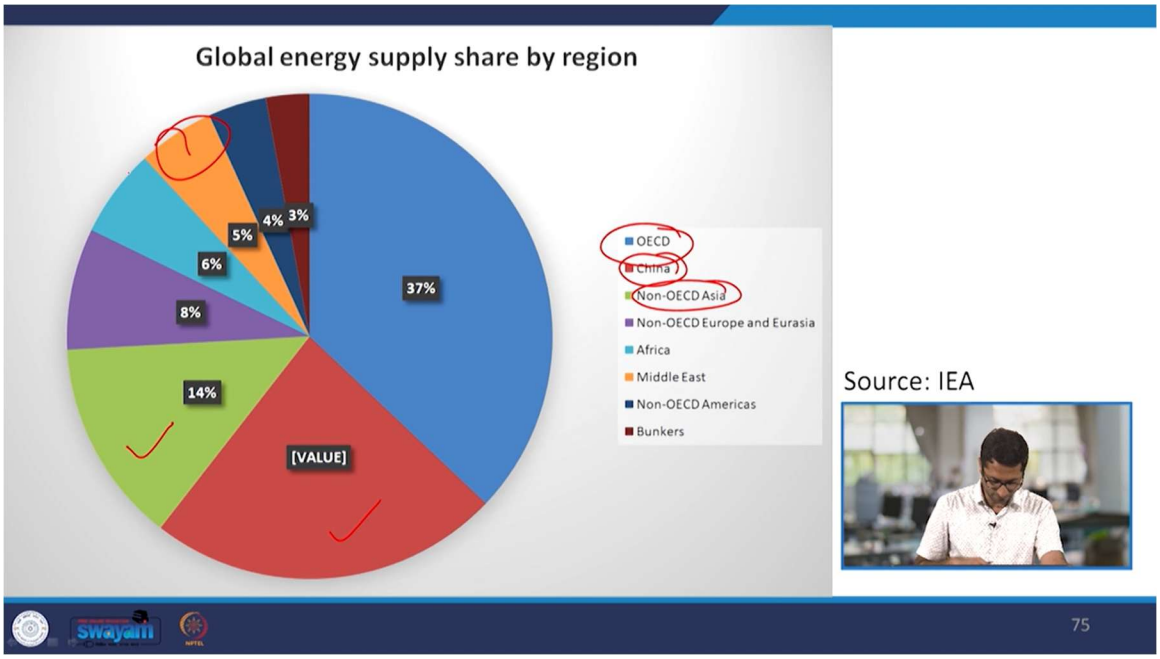


Now we also need to study the CO2 emissions that come with the per capita for the different countries. And again this has many different aspects to it. Of course, we would have many of the Middle Eastern countries which have huge reserves of oil and natural gas and they consume it like anything which are one of the largest producers of CO2 per capita. But we see that we in India do not have very high CO2 emissions per capita as well. It is way below the world average, almost one third again the world average.

So if we are consuming or we are increasing our energy consumption, even the CO2 emissions would increase if we go with the same amount of fossil fuel use. And we can see that China again is near the world average. We could also have different countries in here like which we are referring to like say Russia is here which is again consuming at par with the developed world. So the important point that I wanted to make in here that there is huge amount of difference within the absolute amount of energy that is consumed by any country, the per capita amount of energy that is consumed and the CO2 emissions that are a result of the energy consumption.

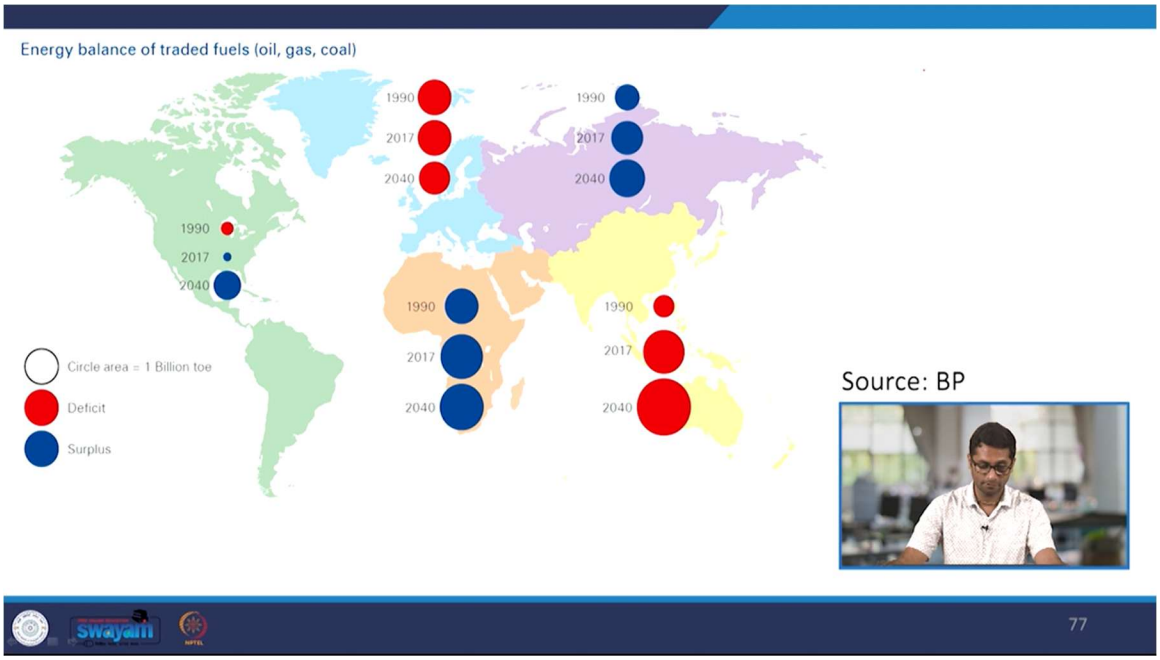
The CO2 emissions would also result with the major source of energy. If the source of energy is natural gas, the emissions would be lesser as compared to a country which is

consuming a good amount of coal. So these things make the problem of cleaner resources and CO2 abatement a very dynamic problem.



Now let us also try to understand how this supply of energy is coming from. Of course we have studied like which countries are consuming a major chunk of energy, but there would also be countries who would be producing and supply these values. So major amount of energy is being produced by China which is one of the largest producer of energy. And then we also have the OECD world which is the developed world which is basically many countries coming together. But China remains one of the largest producers of energy. We are a part of the known OECD Asia. And then there are other chunks as well which are producing Middle East is also in here.

If I have to name the different countries by their ability to produce the energy, the list would go as China, United States of America, Russia, Saudi Arabia, India, Canada, Indonesia, Australia, Iran, Brazil. So what we see in here that there is a mismatch between the largest consumers and the largest producers of energy. Say take the case of a Middle Eastern country like Saudi Arabia, we do not see that in a major consumer of energy, but it is a major producer of energy. Something similar could be said for Canada or Australia. In that sense like they are not a major consumer of energy, but they are major producers of energy. So the thing to understand here is there is a big mismatch where the resources are available and where the resources are being consumed.



This could also be seen or understood with the help of this interesting infographic which shows in the energy surplus for the different regions. So the world has been divided into five different regions which includes the Americas, the North and South America, much of the Europe, Russia, the Indo-Pacific as well as the Middle East and Africa. So we can see the different regions have undergone different types of dynamics. If we see the Americas, they were energy poor. So basically if the color of the circle is red, this refers that the energy is, the total amount of energy is deficit.

The region is deficit in the amount of energy. It is not able to produce all the energy that it has been consuming. If the circle is blue, it means the energy is surplus. It would be

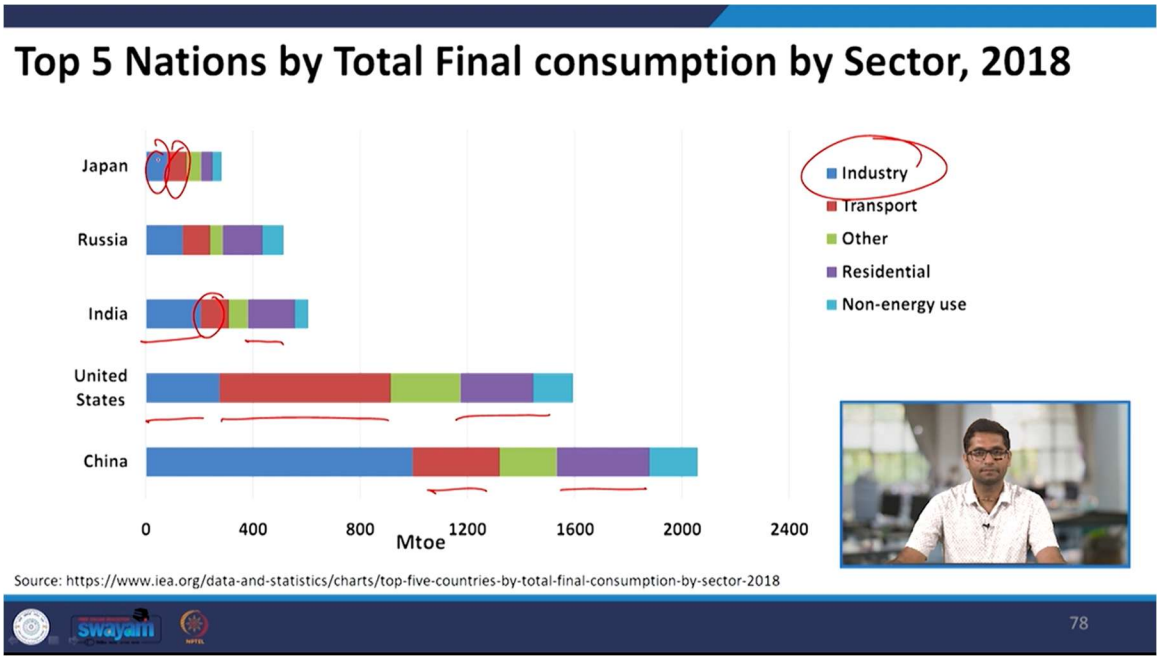
exporting the excess energy that it produces. And further, the larger the diameter of the circle,the larger the absolute amount of deficit or surplus.

So if you see the Americas, it was a deficit in the 1990s. But with time it has become energy surplus and it is expected to become even more surplus in the coming few years. One of the reasons that attribute to this fact is the discovery of shale oil and shale gas, which was earlier not economical, but has become now economical and expected to increase in the future. Take the case of Europe. They have been one of the largest consumers of energy. They were energy deficit in the 1990s. They are still energy deficit and in the future also they are expected to be energy deficit because they consume a good amount of energy being the OECD world, but they do not have inherent resources for that. And this is something that you also read in the popular literature about the implications of the current war that goes on between Ukraine and Russia and the suffering that are, the implication that the Europe is having because of that war. If you talk about the Middle East and Africa, there are energy surplus to say, they have been energy surplus and in the future, they are also expected to be energy surplus. The same can be said for the Russian region as well. It was an energy surplus and in the future, it is expected to increase its energy production and would be exporting that to the different parts of the world.

If I talk about the Indo-Pacific, which we are a part of, it was energy deficit. It also is homeland to two of the most populous countries of the world. The energy consumption of which is expected to increase exponentially in the future. And this is, we see that if we talk about the deficit, our region is going to be the energy deficit or the most energy deficit in the future. And this is something that should keep us worried. We should be finding other sustainable source of energy because we cannot just remain dependent on the different sources of oil, natural gas and coal for this because that is not going to help us in the future as the energy consumption increases in the future.

We can also try to understand how this energy is consumed by the different sectors in the different countries. So, let us try to analyse the five major consumers of energy and how do they consume their energy. Let's start with China, which is the largest consumer of

energy. A majority of energy, almost 50% of the energy in China is consumed in the industrial sector.



So, this is, this is like, this is I believe intuitive. It is again like one of the largest producers of any manufactured product and that industries consume energy. The another major consumer of energy is the transportation sector in China. And finally, they also have a good amount of residential sector consuming energy. Coming to US, the results are a bit different.

In the US, the transportation sector is the largest sector. One of the reasons why it's the largest sector is because US is primarily a service based economy. It provides more and more high end services. And when you're talking about high end services that also involves a good amount of travel. Further, people in US love to travel as a hobby. Most of the people would be driving from one end of the country to the other end of the country.

And they would, they would hardly go or use public transportation, which is quite different to the conditions in India or China, where people would love to use public transportation. And this is the reason why transportation is one of the major areas where energy is consumed in the US. Further, they also have a good amount of industry and the residential sector is equally big as well. Coming to India, we have now become our have

a population that is almost equivalent to that of China, but still in the residential sector, the energy consumed is almost half of that.

And again, one of the reason is that it's energy poverty. Much of the people that we have are living in energy poor regions. Plus, in India, a lot of people due to different reasons would love to travel with public transportation. And this is again a reason why the transportation sector is not as big as compared to US or in China. In India, again, we have a good amount of industrial sector.

But it's quite small as compared to US and China. Something similar could also be seen in the case of Russia, which would have a similar distribution among the different sectors. But given the population, it still consumes much larger amount of energy as compared to India. And finally, we have Japan. Japan again has a good amount of energy being consumed in the industrial and the transportation sector.

So with this, we take a break for today's class. In today's class, we have tried to understand how energy is consumed by the different countries and in different ways. So different countries consume different amounts of energy in terms of the absolute amount of energy as well as per capita basis. Further, the implications or the sectors in which energy is consumed is very different in the different countries. And this is dictated by a lot of factors, which includes the social factors, the economic factors, the cultural factors. So this is an interesting thing to understand that different countries would consume energy in different ways.

In the future classes, we will try to understand where is an energy consumed in this particular sectors. Thank you.