Energy Resources, Economics, and Sustainability

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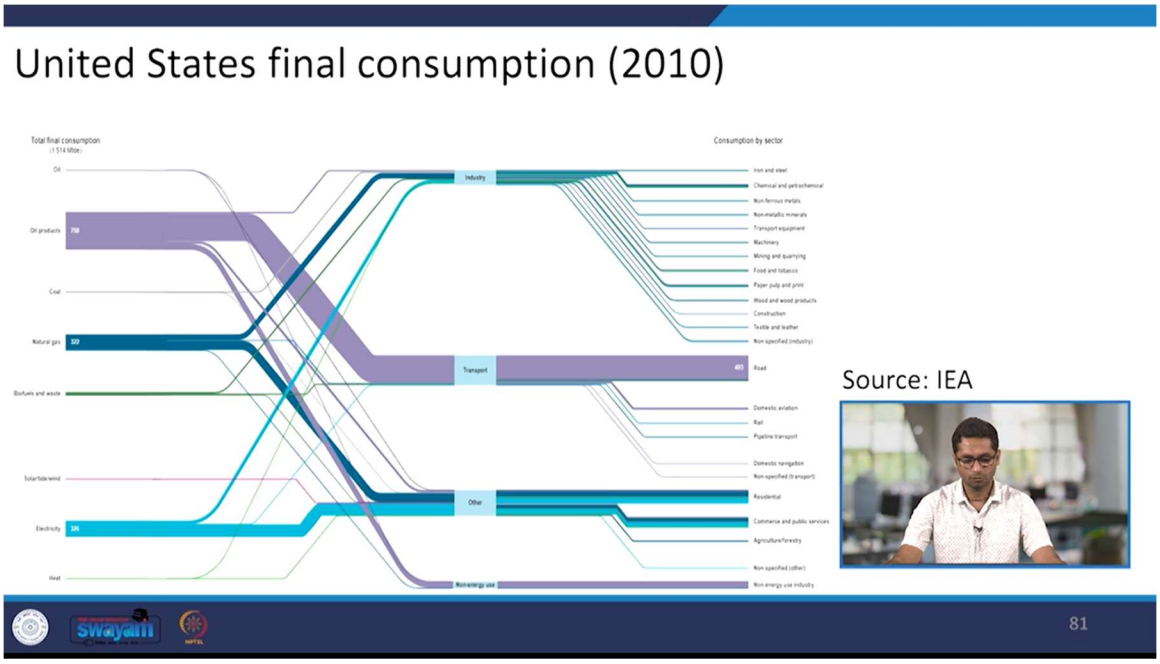
Week – 01

Lecture – 05

Lecture 05 - Energy Consumption in Different Sectors

Hello everyone. Till the last class, we have been discussing how the different countries consume the energy in different parts of the world. We saw that there are major differences in which a particular country would be consuming. There is a huge amount of difference in the absolute amount of energy consumed, the per capita amount of energy consumed and even in the per capita amount of CO2 emissions, which might be resulting from their energy use. In today's class, we will delve deeper into the different sectors, which are basically the residential sector, the industrial sector, as well as the transportation sector to understand the nuances that are associated with these sectors, how energy is consumed in the sectors and what could be the probable ways of improvement in the future. But taking a cue from the earlier class, I would also like to introduce you to something called as a Sankey diagram.



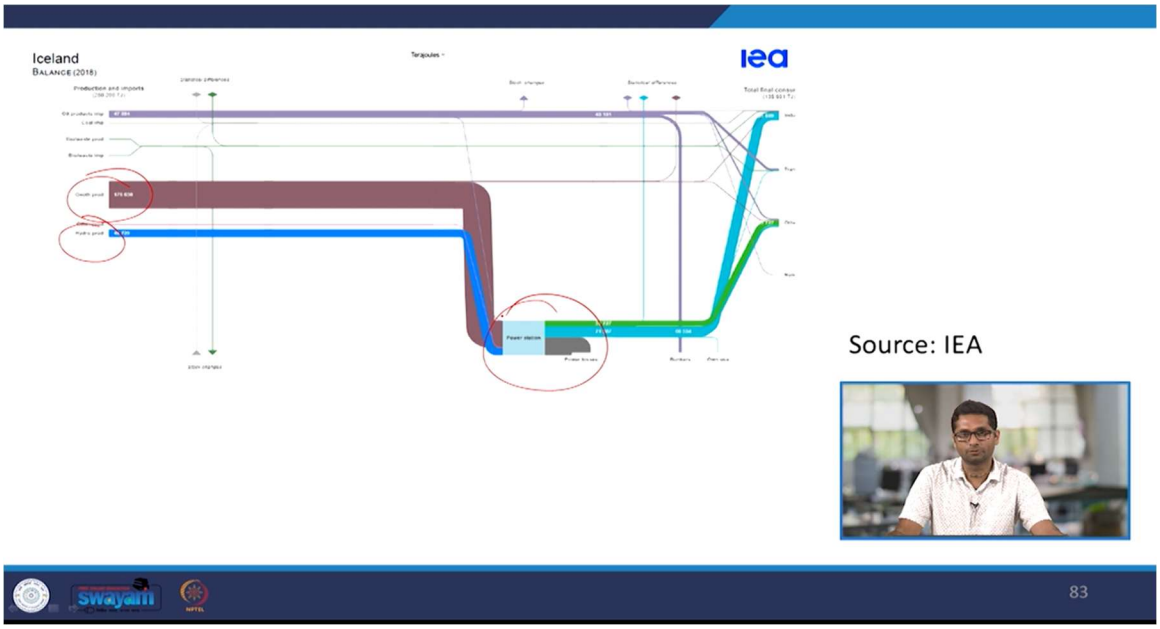
Now Sankey diagram is a sort of diagram that basically connects the production and the consumption of energy. So what you see on the left hand side is a typical Sankey diagram for the United States for the year 2010. And what you have is the different sources of energy that are used for the energy needs. It includes the oil products, the natural gas, electricity, the biofuels. And on the right hand side, what you see are the different industries or different areas in the residential or transportation sector that would be consuming this energy. So this is being quantified into industrial sector, transportation sector, non-energy use and other uses. The source of this data is the Sankey diagram tool by the IEA, which I would want all of you to explore. I would be giving the link for this tool as well. And you also see the link between the different sectors and the energy providers of the sectors given by the lines.

And the width of these lines basically tell you about the quantum of energy that goes from the production till the consumption. So here you can see that oil is basically going towards the transportation sector and it is consumed by the road sector. We have also seen in the last class that US as a country loves to ride by the road. Many people own a car there and this is one of the largest areas where energy is consumed there. If I talk about the industrial sector, it is not as big as the transportation sector and the major provider to that industrial sector would be natural gas.

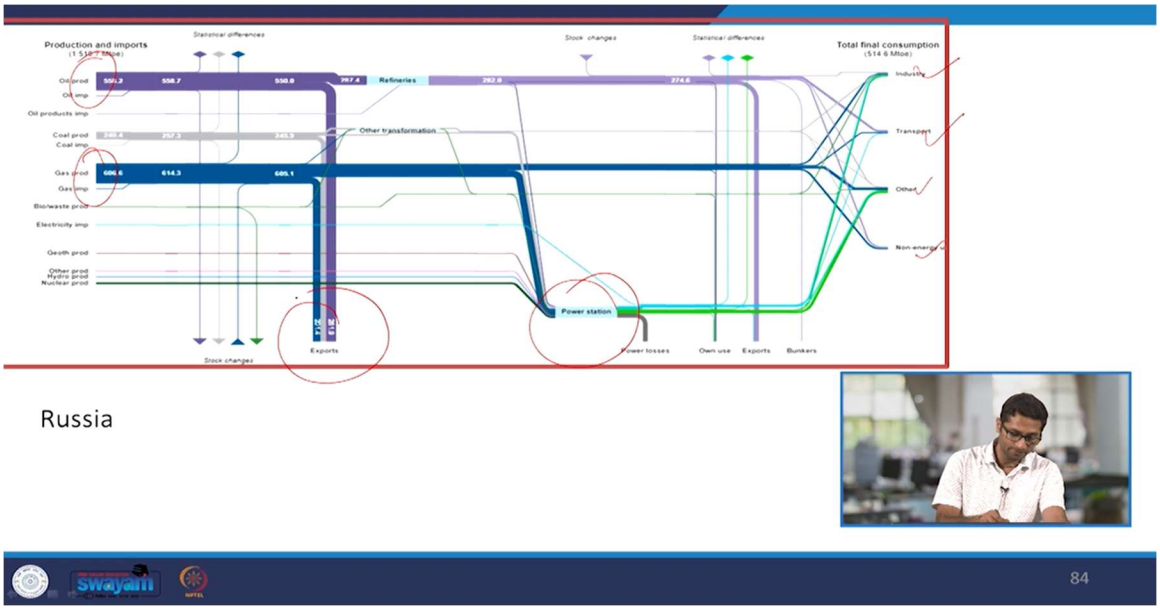
Where is this energy getting consumed? It is basically the chemical and the petrochemical sector. You can also see the electricity that is being generated from different sources ends up either in the residential sector or the commerce or the public sectors. So this is a very nice way to analyze how energy is getting produced, getting transformed or getting used in a particular economy. And we can also see how this would change with time. So we can see this data for the state of US for the year 2020 and we can see this has been changing since the year 2010.

Specifically, if you see the amount of natural gas that would have increased now. So in 2020 the amount of natural gas is 356, earlier it was 322. The amount of oil would have reduced. So the amount earlier they were using maybe 10 years back was around 758 million tons of oil equivalent which has now reduced to 668. So these diagrams are also helpful in understanding how the energy consumption has been changing in the different

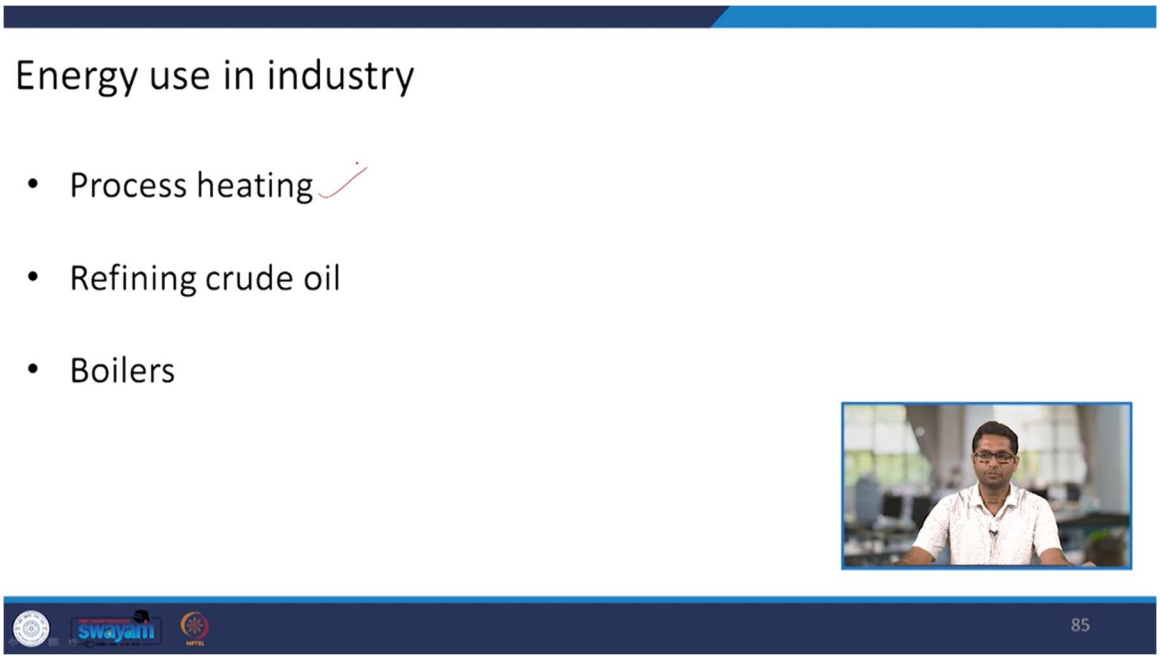
sectors both in the terms of where the energy is coming from and where the energy is getting consumed.



And we can also analyze the difference in different countries. I would just take you through a very different country in the form of Iceland. So if I see the data for Iceland for the year 2018 we would see that a majority of the energy is coming from geothermal energy. So almost 90 percent of the houses in Iceland are heated with the help of geothermal energy. And they also have a good hydropower. So Iceland as a country has one of the greenest grid in the world. And we also see that this energy is getting converted into industrial transportation and other sectors. And in the conversion of this geothermal energy into electricity we also have good amount of losses which end up into the atmosphere.



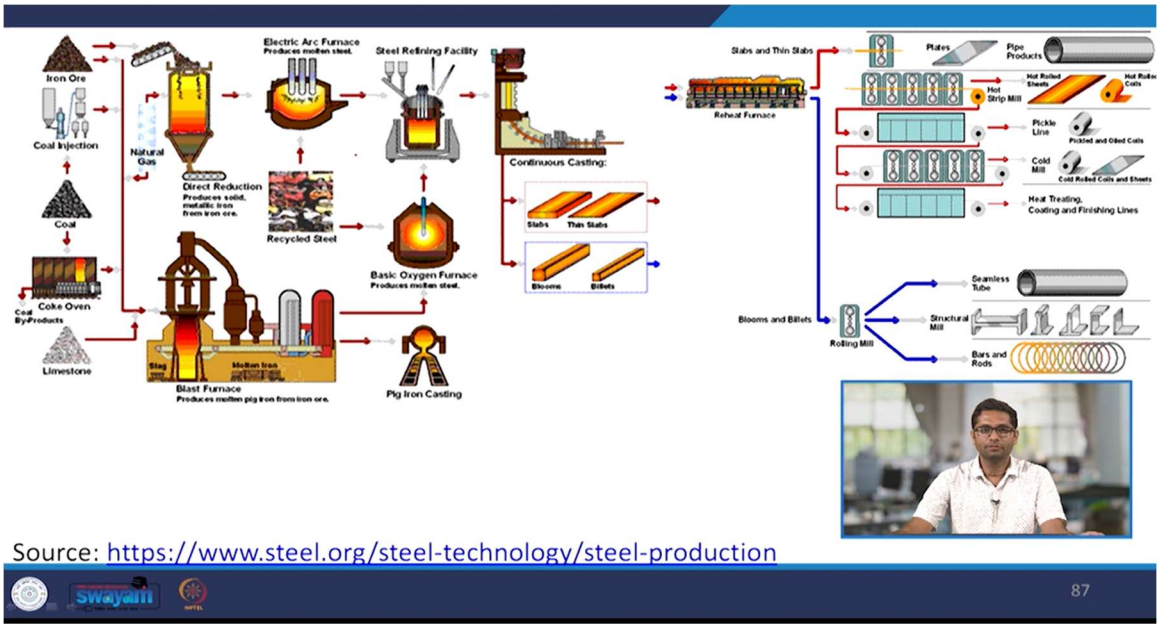
Comparing this to another country which is Russia, in the Russia you see there are huge amount of gas and oil resources. These gas resources are something that power their industry, their transportation and residential and non-energy sectors. They are using gas resources for producing good amount of their power. Compare that with India where a majority of our power is based on coal. We also see that they have huge amount of exports coming in where they are exporting both oil and gaseous products. I have intentionally not included a Sankey diagram for India because this is something that I want all of you to explore. I would want you to search for different tools. These Sankey diagrams are easily available on the internet. You can either visit the IEA website which I provide a link or you can also visit the NITI Aayog energy tool where they also provide how the energy scenarios have been changing in the past and what are the predictions in the future. Nonetheless this is a very important tool to understand how the energy economy for a particular country looks like. Now let us go into these sectors which are the industrial, transportation and residential sectors or the building sectors and try to understand how the energy is consumed in these particular sectors. If I talk about the industrial sectors, there are three major areas where energy is consumed.



It's the process heating. A majority of industrial processes takes place at elevated temperatures of the range of 800 degree Celsius, 1000 degree Celsius or even more. And

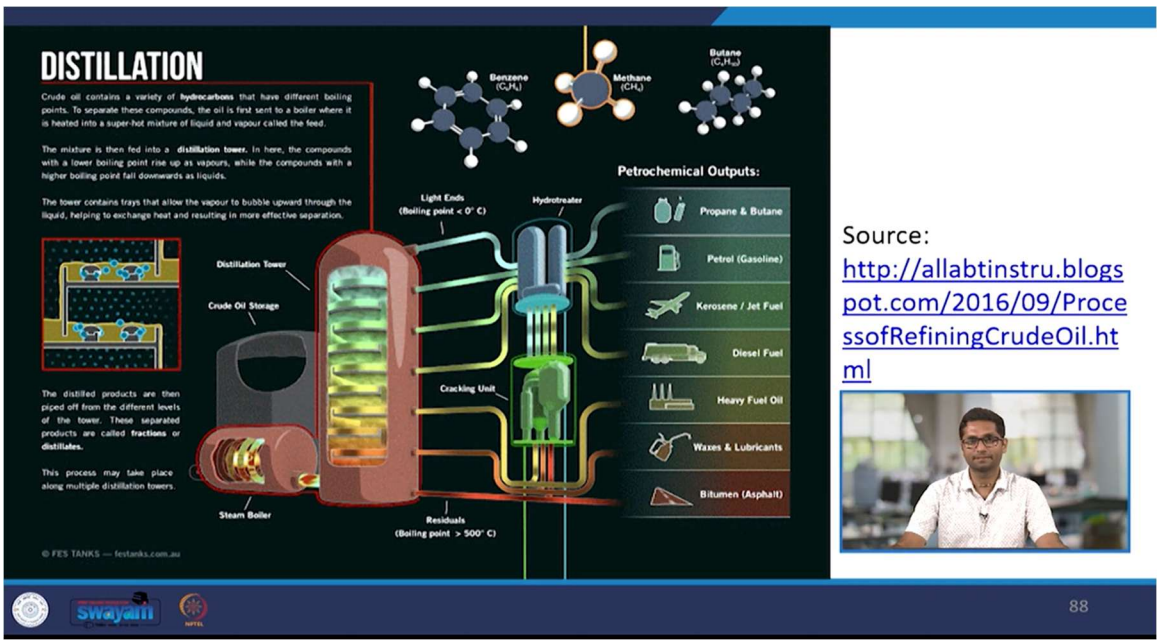
it becomes very difficult to use electrical heating in that cases and majority of these are powered in the form of different fuels like natural gas or coal. Then there's another sector which consumes a good amount of energy which is the crude refining sector which is also a sector that provides a majority of the polymers to us and many other products. If you talk about the petrochemical sector, just Google petrochemical sector and you will see that every other product that you use is basically linked to this particular refining sector. Additionally, we also have huge boilers in the industries which are producing good amount of steam and this steam is also again doing the similar task of providing heat or production of electricity.

Just to give you an idea, so this is a typical operation in the form in an iron and steel industry. You can see the hot iron being melted and putting into different bars and for raising or working at such high temperatures you need huge amount of fuel that is combusted and raising the temperature and so that these operations can take place. Again this is a typical flow sheet for an iron and steel industry. I wouldn't go into the detail, but I believe many of you would have studied the typical operation that take place in your school days or in your under graduation days. And what I would want to highlight there are number of operations where you would have huge amount of energy being consumed and a majority of this energy is being produced by direct combustion of coal or natural gas.



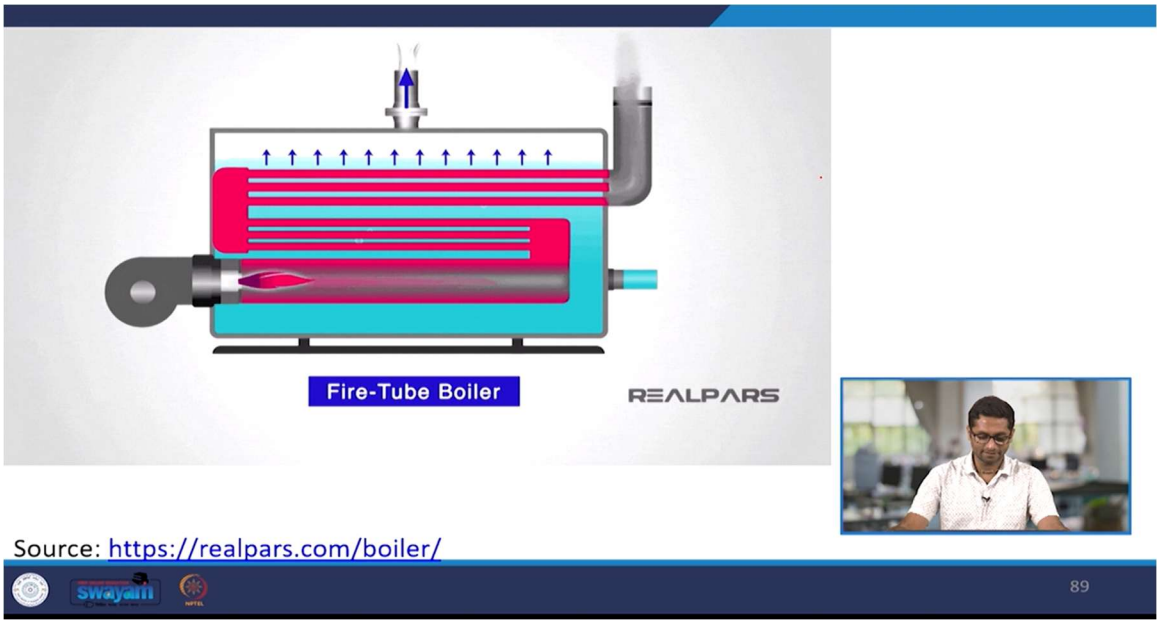
Source: https://www.steel.org/steel-technology/steel-production

And this is one of the reasons why a lot of people are now talking about hydrogen economy. The reason is that hydrogen as a fuel could be used to fuel these industries which are otherwise very difficult to decarbonize because such high temperatures are very difficult to be reached through electrical heating. And hydrogen as a fuel has that ability and this is again a reason why the iron and steel industry is now going towards a process called dry reforming of iron because the inclusion of hydrogen is quite easy in that particular industry. Also if you remember one of the earlier classes there was a case study that was taken for a startup that was able to produce high temperatures with the help of concentrated solar powers. And this is one of the applications of concentrated solar powers where huge or high temperatures could be reached easily.



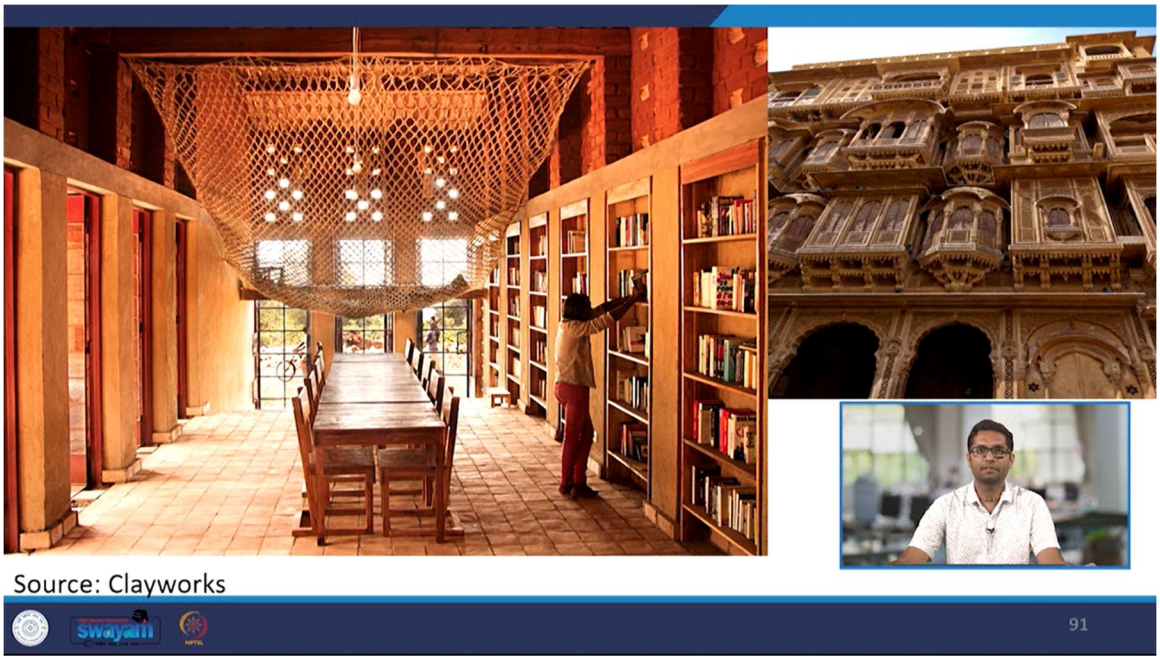
Source: http://allabtinstru.blogspot.com/2016/09/ProcessofRefiningCrudeOil.html

Another major sector that consumes a significant amount of energy is the petrochemical sector or the refinery sector which basically involves cracking the crude oil that is dig out of the Earth's crust into different fractions that could vary between the bitumins which are used for your road constructions, the different kinds of waxes, the diesel range fuels, the aviation fuels, the gasoline fuels or the gaseous fuels that you use in your kitchen as well as. So although the process in itself is producing different kinds of energy resources but in itself it also consumes a good amount of energy.



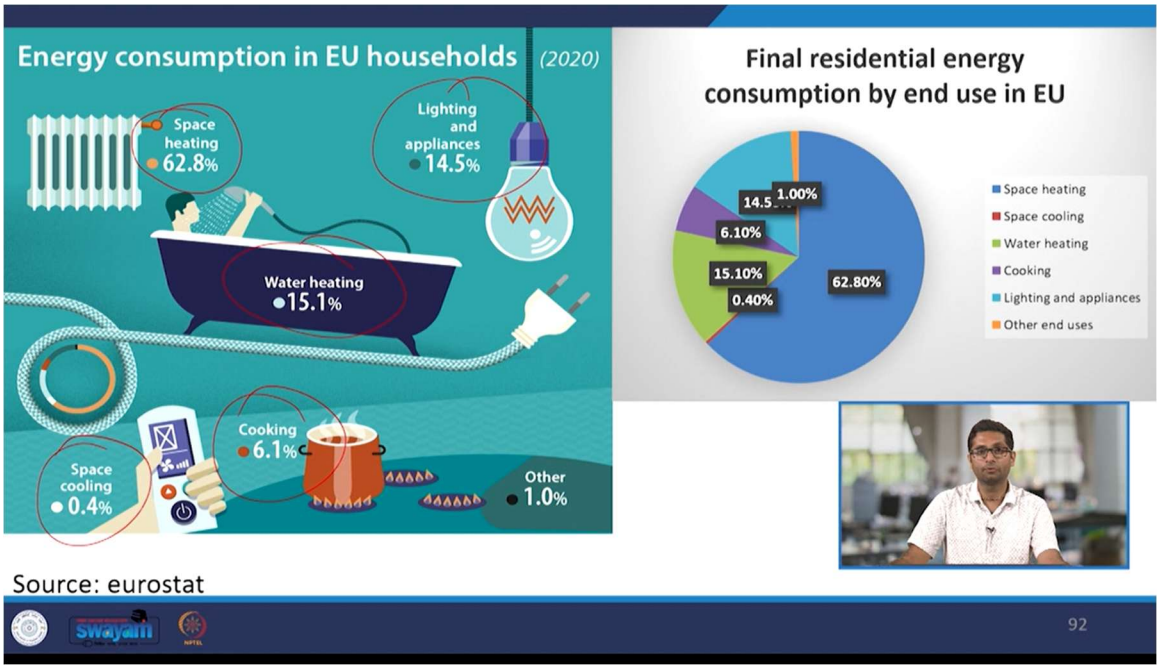
Then a significant of energy is also consumed in industries in the form of boilers where different kinds of fuels in terms of natural gas or similar fuels are burnt and they are used to raise the temperature of water and produce steam out of it and this steam is used for different applications which, to cater to the needs of the industry. But in industry if you see the majority of application of different fuels is basically in the heating sector.

Now coming to the residential or the building sectors there are different kinds of buildings would consume different kinds of energy and if I go with the different sources one particular sources is the EIA that I am referring to that gives us like what are the types of building that consume major amount of energy. So the major amount of energy would be consumed by the Mercantile, as a Service types of buildings. So when I talk about Mercantile this is basically referring to different kind of shopping malls. So just try to recollect when you visited last time a shopping mall there would be huge amount of lights glowing in huge amount of electricity being consumed. So as such they are one of the largest consumers of energy. So this is basically the capitalist or the consumeristic market they are referring to it but in doing so they are also consuming a lot amount of energy. Further a good amount of energy is also consumed in the offices which is basically the service sectors. The offices are normally equipped with different kinds of comfort, different kinds of lightning, different kind of cooling, heating and as such they consume a lot amount of energy. In the education sector also a huge amount of energy is concerned or if you see many of the universities in India are now going towards having good amount of solar power in different kinds of buildings. This is the reason because education institutes as such are also a major consumer of energy. We also have big hospitals or healthcare providers consuming good amount of energy and then we also have the simple lodging or businesses like hotels which give you residence and like they also consume a good amount of energy. But different kinds of buildings would have very different energy consumption.



Again we also see that even in the past people have been cognizant of this fact and they have been designing buildings like the one on the right is one of the buildings in Jaipur

which have been designed so as to minimize the cooling requirements. So as the air has been so directed that the places remain cool. The one on the left you can see is a building that is designed to minimize the lightning requirements. So as of now like things are again coming back where buildings are being designed to decrease their energy requirements both in terms of lightning or cooling or heating requirement. Again the buildings if we consider in different parts of the world or residential sector they would be very different in the consumption of energy.

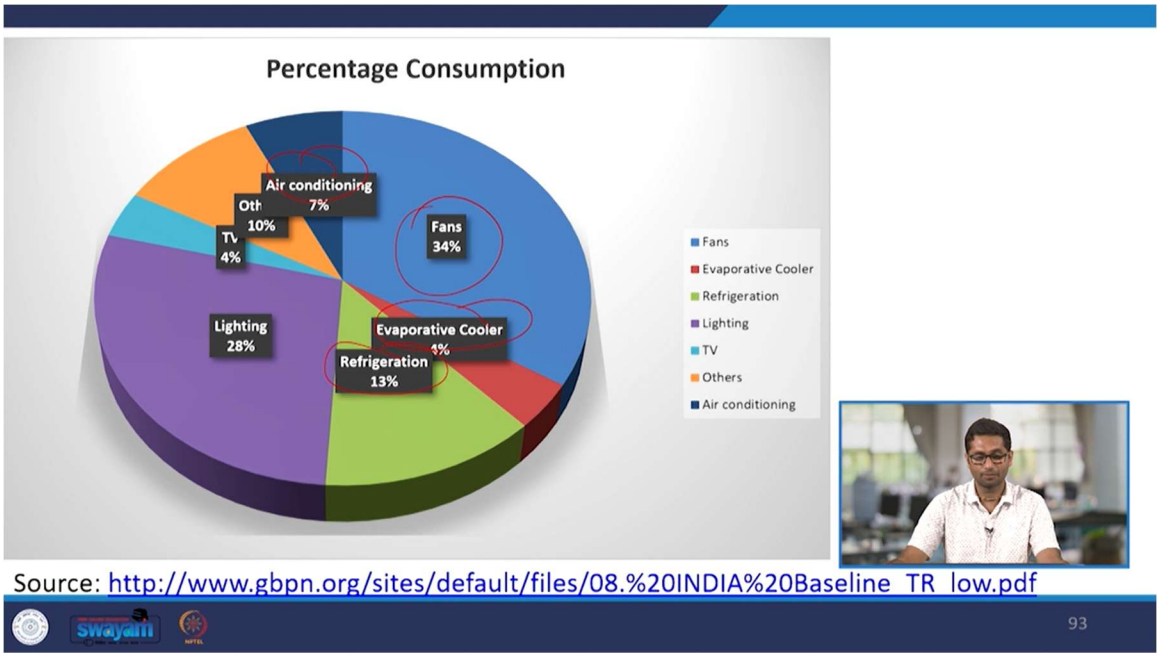


If I talk about a typical household in the developed world in Europe or in the US which is typically a colder country this is how the consumption would look like. A majority of their energy would be consumed in the space heating. So even though it is they are having a snowfall outside in the house a temperature of around 18 or 20 degree Celsius would be maintained.

Plus they would be using a good amount of energy in heating applications as well. So any place you go would have or has the ability to give you hot or cold water simultaneously. So nonetheless like this is consuming energy somewhere. Then we have the lightning and appliances. They have their cooking use as well which comes around 6 percent.

And given that majority of these countries are in the colder region the cooling requirements are not as much. So again to give you a majority of their energy

requirement goes towards heating both the space heating and the water heating. Compare that with a country like India.



So in India the majority of our heat goes towards fans or evaporative cooling or air conditioning or refrigeration. So we are typically a hot country and a majority of energy goes in the cooling applications. Since economically people are not very well off they go with a cheaper option like fan or evaporative cooler. Cooler is something that you find much in the northern part of the country and not very often used in the southern parts. Then again refrigeration we in India life love to cook a lot. So that is why refrigeration is used quite a lot. Plus if you see the lightning the energy consumed as a percentage of the total energy is quite high and as quite high as compared to that used in Europe or the US.

Further we have others which basically includes the cooking applications and others. The point I wanted to make here is among the different countries in the building sector you could have different places where you would be consuming a major amount of energy. And this would be primarily in space heating or water heating in the European countries. And the energy used would primarily relate to the cooling applications in a country like India. Further the change in the energy would be very different for the rural and the urban areas.

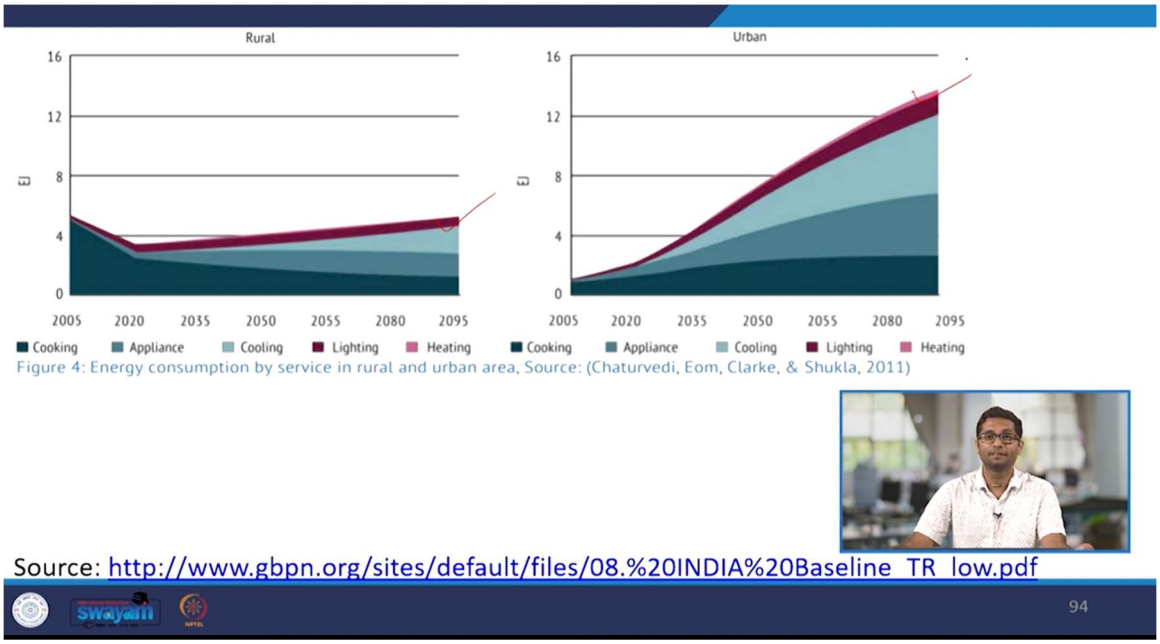
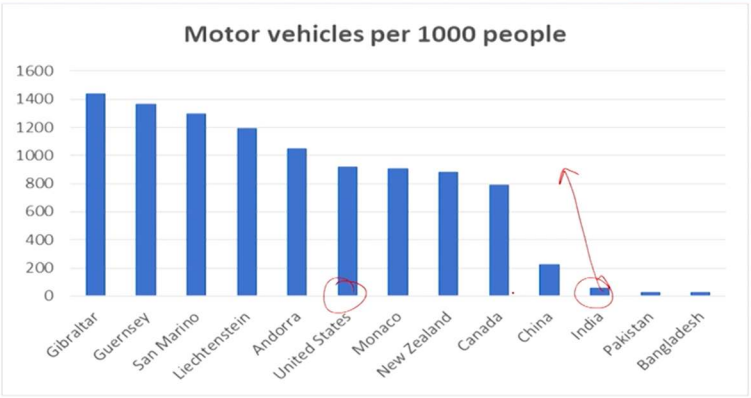


Figure 4: Energy consumption by service in rural and urban area, Source: (Chaturvedi, Eom, Clarke, & Shukla, 2011)

Source: http://www.gbpn.org/sites/default/files/08.%20INDIA%20Baseline_TR_low.pdf

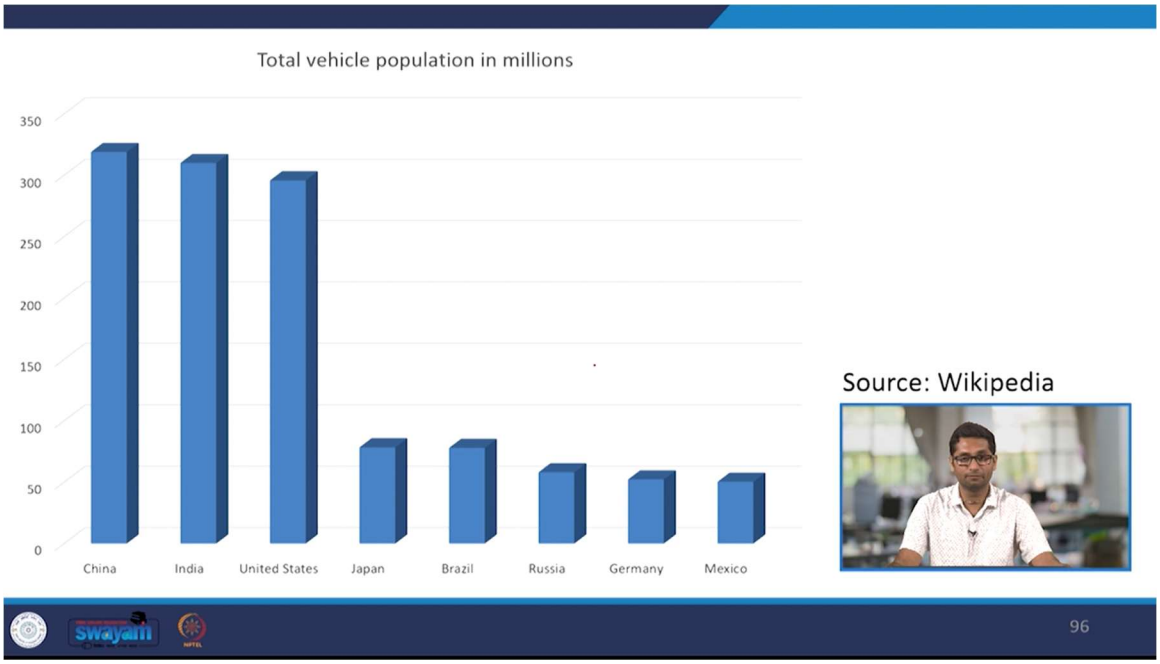
And then I am referring to a study that did an analysis how the energy consumption would be changing for the 90 years among different applications in India. And they have given the projections how the energy would be changing in the rural and the urban areas. So again they have given the bifurcation between the different applications which includes cooling, cooking, lightning, heating. And we see that there is a huge amount of difference between both the rural and the urban areas. Urban areas as such tend to consume much more than the rural areas and this should also be an area of concern. And the difference between the two needs to be minimized as much as possible.



Source: Wikipedia

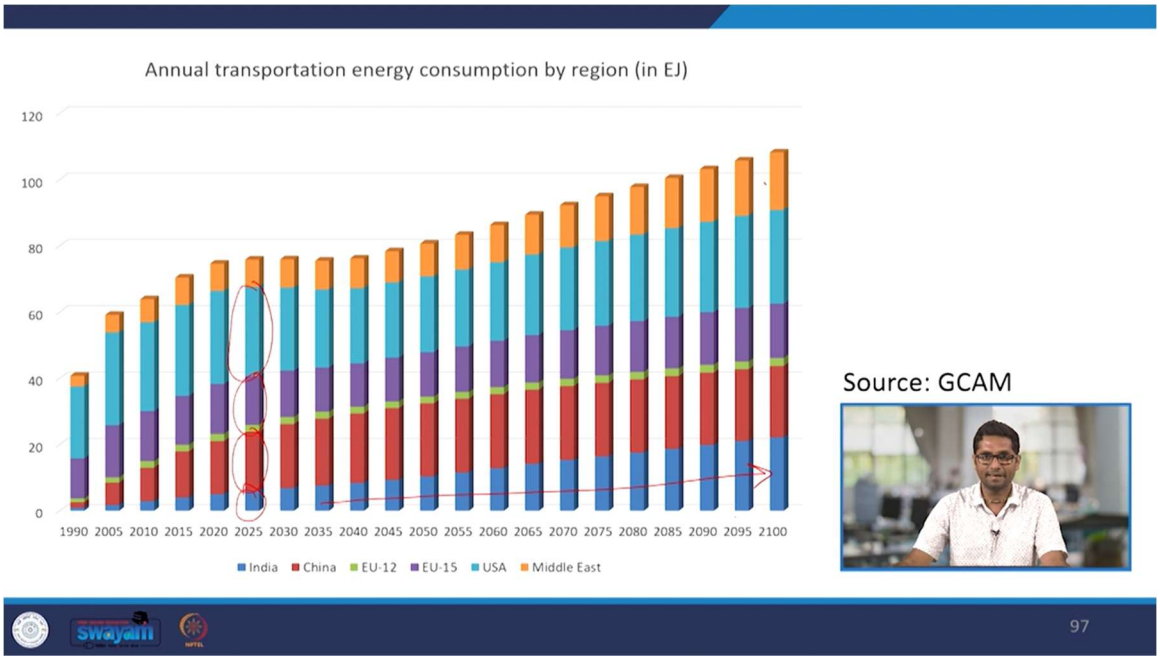
Further coming to the last aspect of energy consumption which is the transportation sector. So if I look at the number of motor vehicles per 1000 people, so this is the normal

matrix in which the number of vehicles is given for the different countries, the number of vehicles that are there per 1000 people. This is how the different countries would stand in. We have countries like Gibraltar, San Marino, maybe Monaco which most of you might be hearing for the first time. These are small countries but as such they have huge amount of vehicle population. So if we talk about a typical developed country like US, it has the vehicle population of almost 900 per 1000 people. So it would basically translate to that if you have a family of 4 people every person has his or her own vehicle. Compare that to a country like India where this number would come around 60, 50 or 60. So for every population of 1000 people we just have 50 cars or 60 cars on the streets. So this is way lesser. And we in India are aspiring for a lifestyle that is equivalent to that of US or any other developed world and we would want to increase the number of cars here. To say at like the particular extent like it is a very difficult thing to achieve given the infrastructure is already crumbling among with the type of car networks that we have and even in the future if this was to increase this would could have drastic consequences. China is somewhat better than us but it is way lesser than what we see in some of the developed countries like US or New Zealand or Canada where the number of cars are way higher. And this is again the reason why in India and China people are using good amount of public transportation and we are quite better if you consider our immediate neighbors like Pakistan or Bangladesh. If we talk about the total vehicle population in terms of millions India is probably at par with US or China.

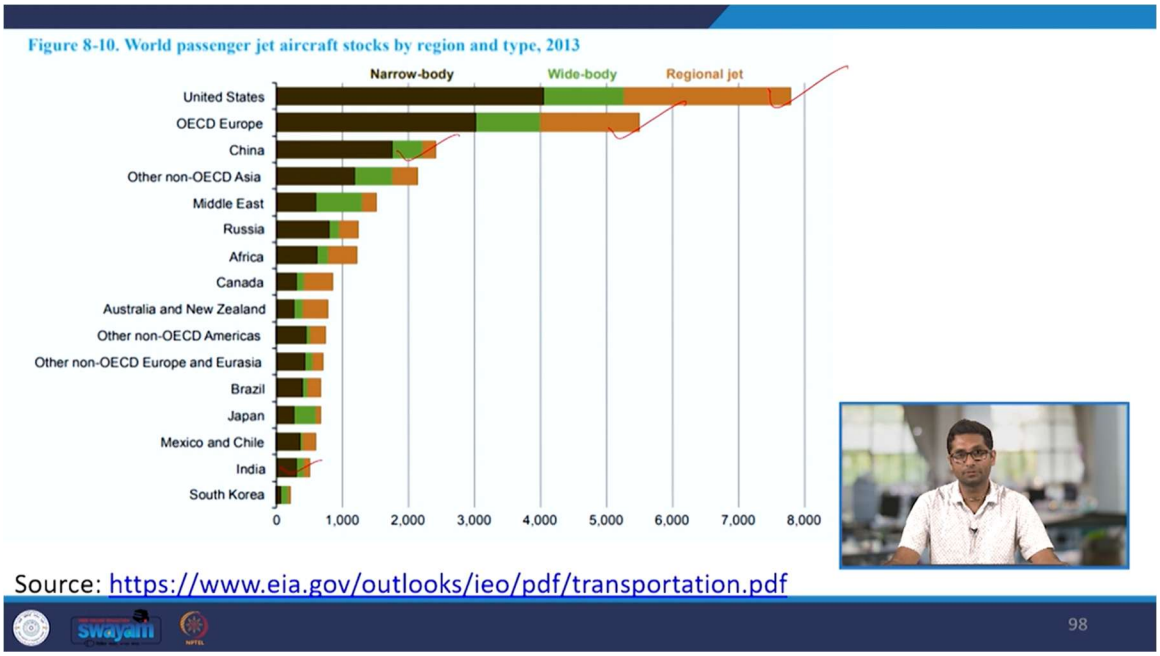


So this is again something interesting to note that although the per capita or the number of vehicles per 1000 people is somewhat lesser if I talk about the total vehicle population we are almost equivalent to that of China and US. And this is again a reason that people

would want to go towards combined or public transportation or ride sharing facilities in the future because the infrastructure that we have would not have the ability to sustain the amount of vehicles that are there on a per capita basis in developed country like New Zealand or Australia or the US. So this gives us an important perspective that although the absolute amount of vehicles could be large the number of vehicles that are there on a per 1000 capita basis or per capita basis is very less in a country like ours.

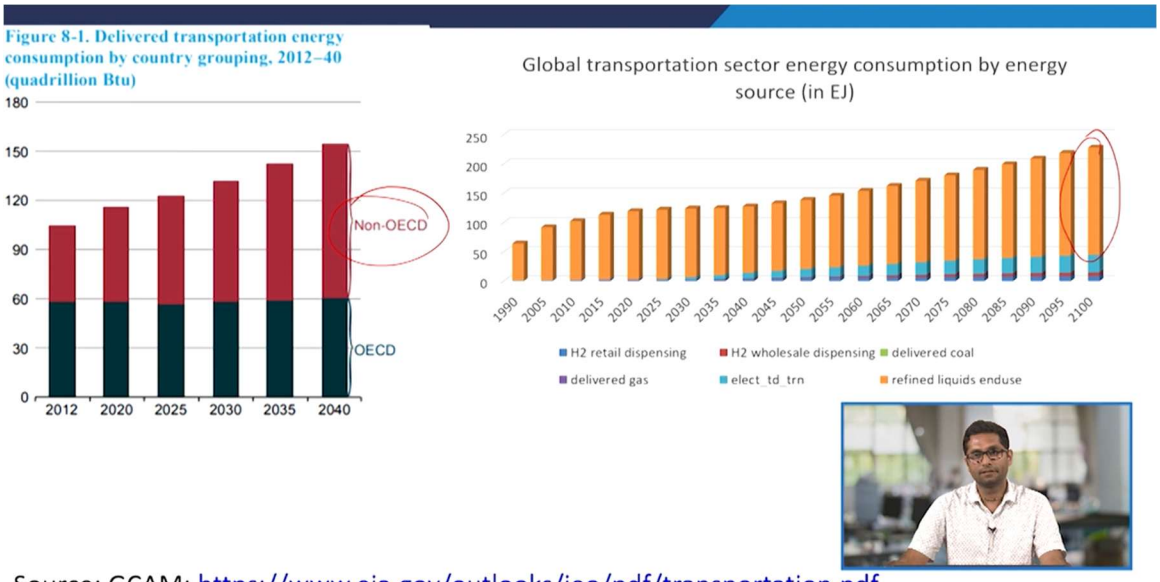


Further if I talk about the transportation energy consumption by region we can see that so this was again done in-house by our team we see that in the year 2025 we are quite minimum. So the amount of energy is being consumed by China and as well as the European countries we also have the US consuming a major chunk of energy in the transportation which is by far the largest consumer of energy as well as transportation is consumed. But if we see the next 70 years or so our transportation energy is expected to increase at a very fast rate. Interestingly China is going to remain almost stagnant or slightly reduced. Something similar is expected for the US as well but it is interesting to note that most of the increase in the increase in the transportation energy would be powered by India and other Middle Eastern countries. So this is something that we should be alert about. Of course we would want to increase the number of vehicles but again that needs to be done in a sustained fashion.



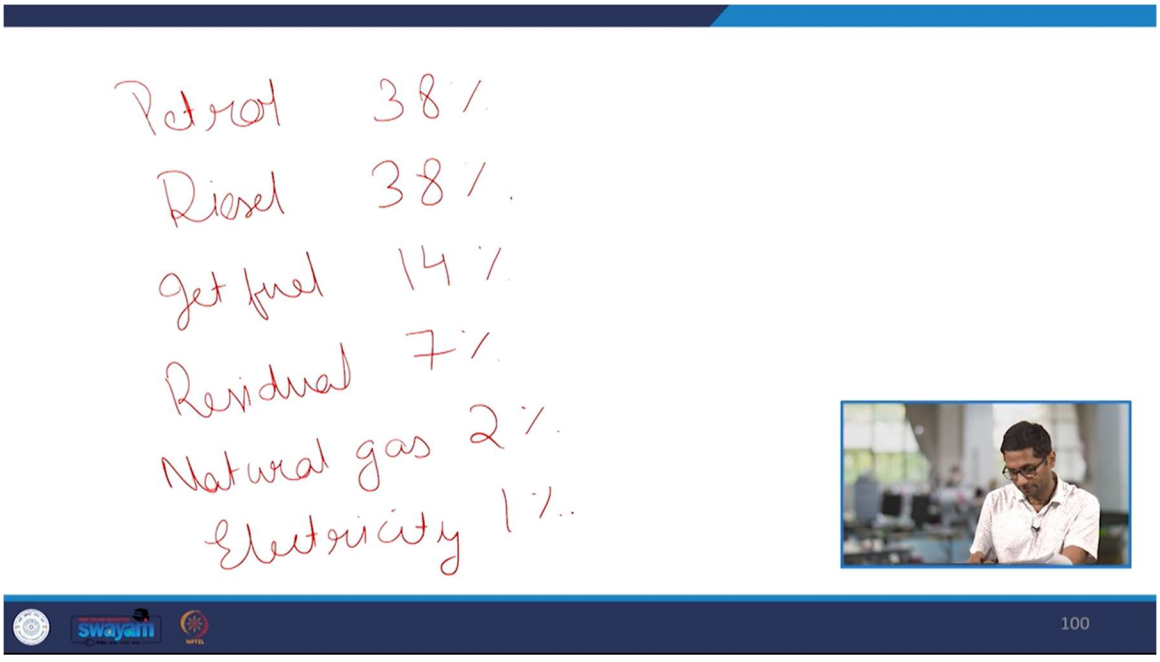
Source: https://www.eia.gov/outlooks/ieo/pdf/transportation.pdf

Further we can also have a look towards the air transportation. If we try to compare the number of aeroplanes in terms of the regional jets and the wide body jets as well as narrow body jets US leads the race by far then we have the European countries, China picking in. India is still way back the number of airliners that we have in India is way less. The transportation using the air pathway is quite less and this would increase in the future as well. So we need to be careful of the fact that we should not be in a blind race to follow the developed world to increase the air transportation because that would have its own implications.



Source: GCAM; https://www.eia.gov/outlooks/ieo/pdf/transportation.pdf

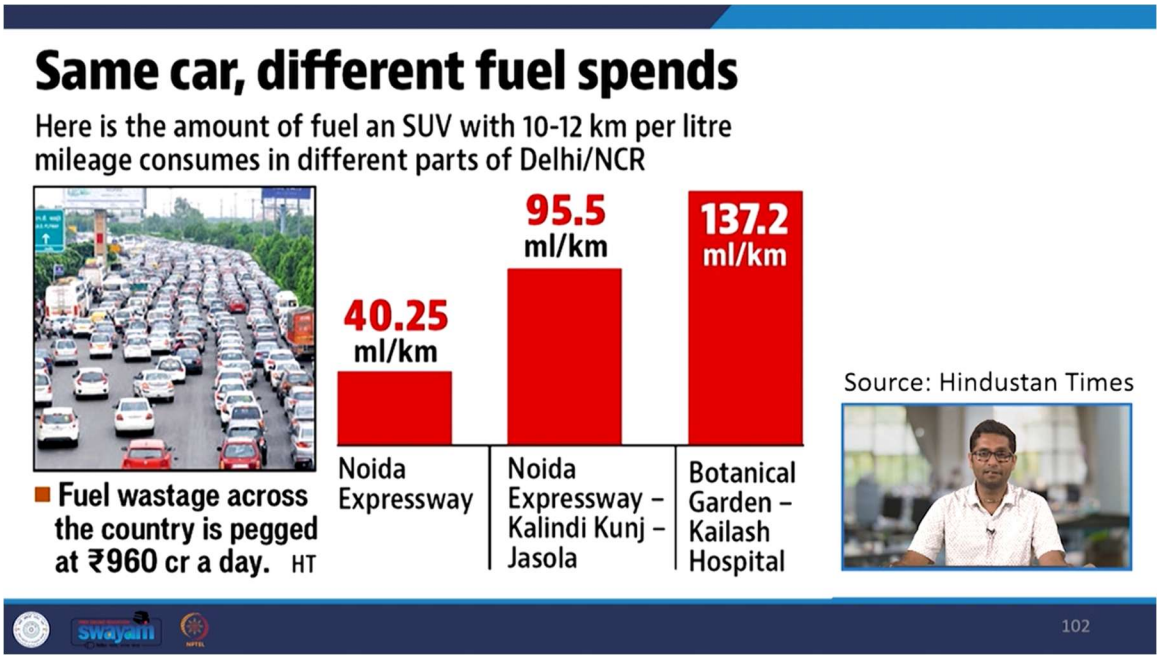
Further we can see that most of the growth for the transportation sector in the coming future would be propelled by the non-OECD world which would be basically led by India and the other Asian countries. Among the transportation sector if I go with the scenarios that does not take into account the use of alternate fuels like EVs or hydrogen at a much faster rate, we see that for the coming 80 years or so we would be highly dependent upon refined liquids in the form of gasoline or diesel. So this calls in for a policy shift where advantages or subsidies or incentives are given to people for adopting cleaner sources of energy in terms of EVs or hydrogen because if that is not done given the expected increase in the transportation sector that can have significant impact on the environment given that most of the energy would be coming from the crude oil. If I talk about the present use of different kinds of fuel globally we can see that petrol is used to power around 38% of the vehicles.



Almost similar amount of vehicles are powered by diesel almost 38%. Jet fuel which is used for the aviation industry consumes almost 14% of the energy. Residual fuels make up 7%. Natural gas around 2% and electricity is roughly 1%,might have grown a bit but no matter how much we hear about EVs the penetration of electric vehicles and the use of electricity for running the vehicles is not very significant till date. We are expecting that

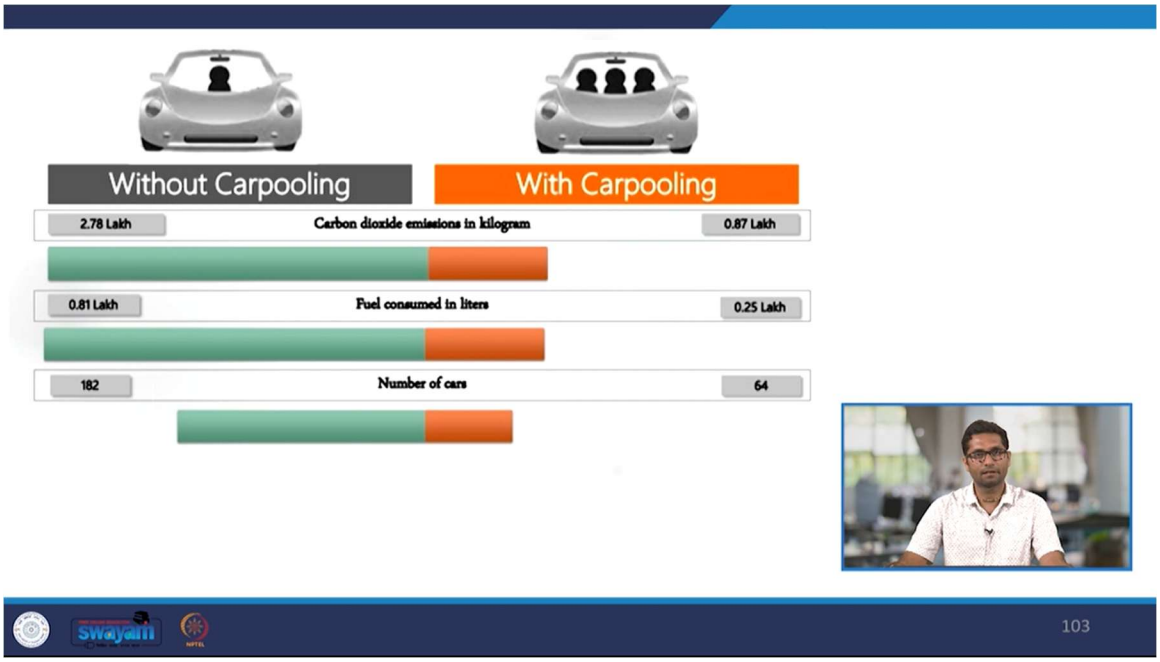
to increase in the future and this is what calls for the different policies or incentives by the government to take it.

Further we also need to understand the infrastructure is a necessity for the transportation sector. So this is a typical site in any metro in our country we have huge amount of traffic jams and these traffic jams not only lead to waste of time but a good amount of waste in energy as well. So there was a study that was done by the Hindustan Times.



So they proposed that if considering three different stretches in the national capital region which was the Noida Expressway, Noida Expressway to Kalandikunj and another pathway through Botanical Garden to Kailash Hospital which is a very congested pathway different vehicles would have different fuel economies.

So if I go with the expressway which the vehicles have a free flow and not many jams happening a typical vehicle would utilize only 40 ml of fuel for a kilometer. This could almost double for a congested pathway like one which is the Noida Expressway, Kalandikunj and Jasola one and this could further increase for a more congested pathway. So we should be aware of the fact that increasing the vehicles might not increase our comfort but might lead to wastage of time as well as the wastage of the precious resources and which can also end up in the harmful release of the different GHG gases which would have a significant effect in the future.



So here there have been aspects regarding the advantage of carpooling because if you go with carpooling we are making an efficient use of the same resource and at the same time emitting much lesser for the same kind of resources. So with this we would like to end this class where we have tried to discuss the implications of different sectors in the use of energy.

We have discussed the three major sectors which was the industrial sector, the transportation sector and the residential sector. We have tried to understand how energy is consumed in these sectors, what are the different nuances, what could be the future pathways and with this we take a break. Thank you.