Biomass Conversion and Biorefinery
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Lecture 01
Energy and Environment scenario

Good morning students. As you know, today is the first lecture of Biomass conversion and Biorefinery. As I told you in our introduction slide, we will be covering two lectures basically dedicated to introduction. So, today is the first one in which we will be covering world energy scenario, consumption pattern, fossil fuel depletion and environmental issues. A bit more elaborately I will tell you, how the fossil fuel depletion is taking place, what is the energy requirement, how renewables are taking shape into big component in the next few years of energy consumption as well as production and how the climate mitigation problems are also taking shape with respect to global carbon dioxide sequestration.

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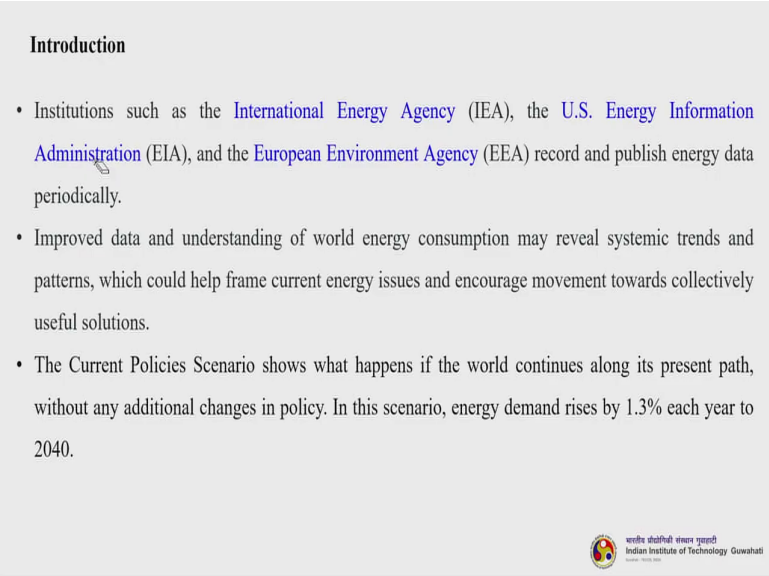

So, as you know, there are institutions such as the International Energy Agency (IEA), the US Energy Information Administration (EIA) and the European Environment Agency (EEA). These are the three Agencies which record and publish energy data periodically. You will get all these data, and, even whatever I am discussing today, mostly has been taken from their records. Improved data and understanding of world energy consumption may reveal systemic trends and patterns, which could help frame current energy issues and encourage movement towards collectively useful solutions. The current policies scenario shows what happens if the world continues along its present path, without any additional changes in policy. In this

scenario energy demand will rise by 1.3 % each year till year 2040. So, basically this is how it is being predicted.

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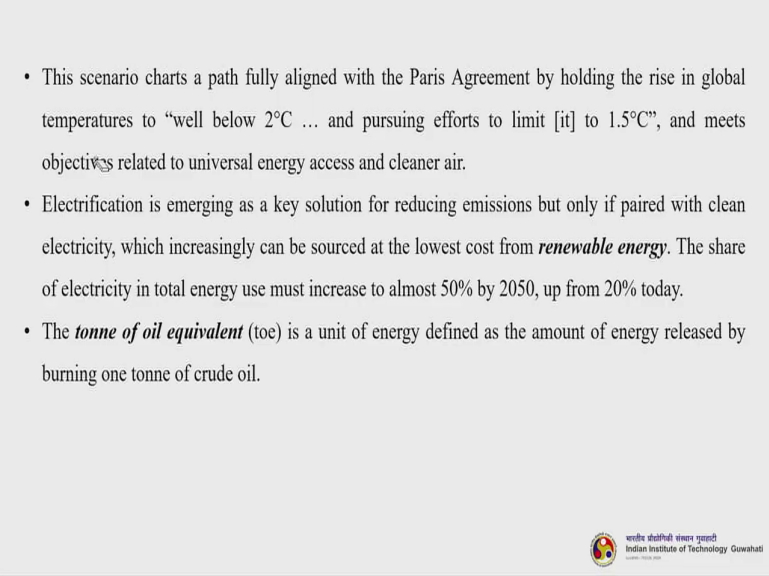

This scenario charts a path fully aligned with the Paris agreement by holding the rise in global temperatures to well below 2 °C. That is what the Paris agreement says about that temperature rise should not be more than 2 °C. And they are still pursuing efforts and convincing all the signatories of this agreement to limit it to 1.5 °C.

Electrification is emerging as the key solution for reducing emission. Now, you know that in many developing countries and rather underdeveloped countries, electrification is still a big issue; including India and most of the so-called Asian giants or giant/big economies. This is however taking shape in a very nice way and increasingly it can be sourced at the lowest cost from renewable energy. So, basically electricity from renewable energy; that is how it is being envisaged.

There is something called tonne of oil equivalent (toe) which is a unit of energy and basically defined as the amount of energy released by burning 1 tonne of crude oil.

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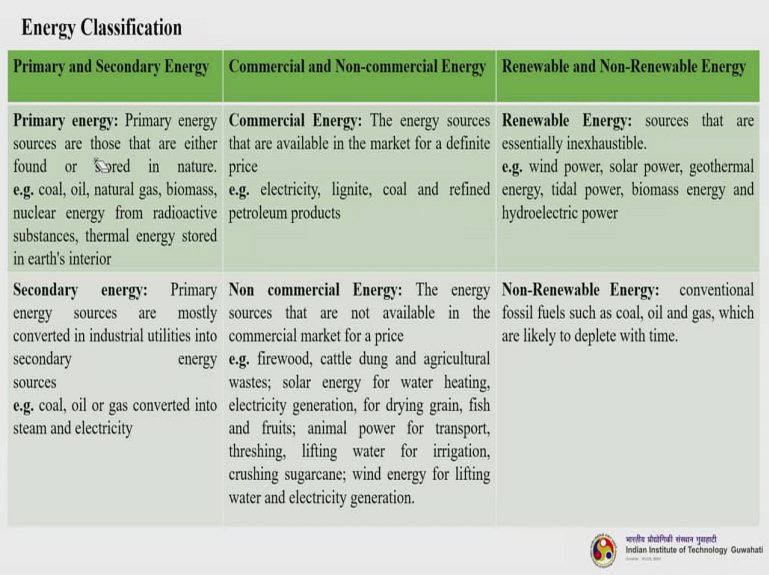

So let us understand the energy classification or how energy is being classified. So, primary and secondary energy, commercial and non commercial energy, renewable and non-renewable energy. Primary energy sources are those that are either found or scored in nature, e.g. coal, oil, natural gas, biomass, nuclear energy etc. Secondary energy is mostly converted in industrial utilities from other sources of energy (such as) coal and oil, all these things.

So when you talk about commercial and non-commercial energy, in commercial energy it is electricity, lignite, coal which are commercially available. Non-commercial energy is basically fire wood, cattle dung, agricultural waste, biogas etc. It also includes wind energy.

Then comes renewable or non-renewable sources. The renewable sources are essential inexhaustible. E.g. wind power, solar power, geothermal, tidal, biomass and hydroelectric power. Non-renewable energy are conventional fossil fuels such as coal, oil, gas which are basically depleting with respect to time.

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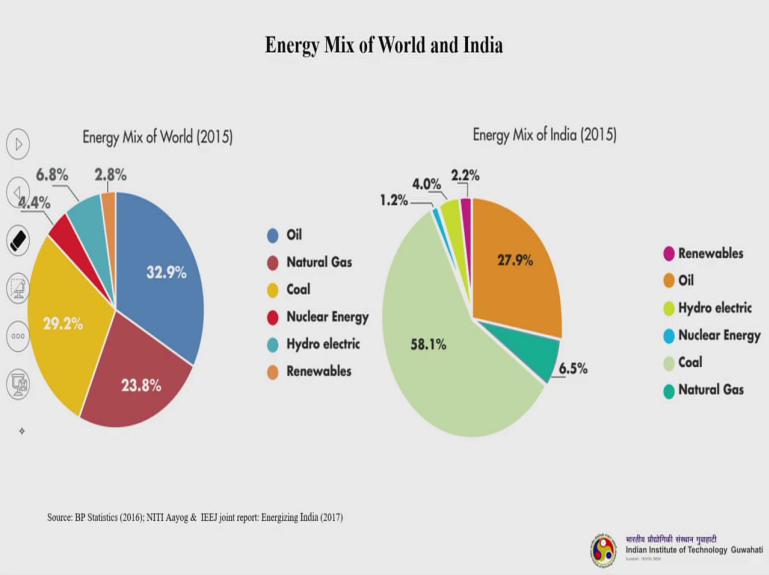

So, if you look at the energy mix of world and India, I will be showing so many of these statistics which are taken from these environmental energy associations and other societies. This is from Niti Aayog. So, you can see in the energy mix of the world how much is actually being consumed in the entire world in the form of oil and coal. So they are the most important.

So if you look at India, 58.1 % comes from the coal and it is a very big number. The rest is from oil and very few from hydroelectric and other sources. Now, renewables as you can see is 2.2% and it is slowly increasing. We project that around 2035-2040 it will be more than 10 to 12%.

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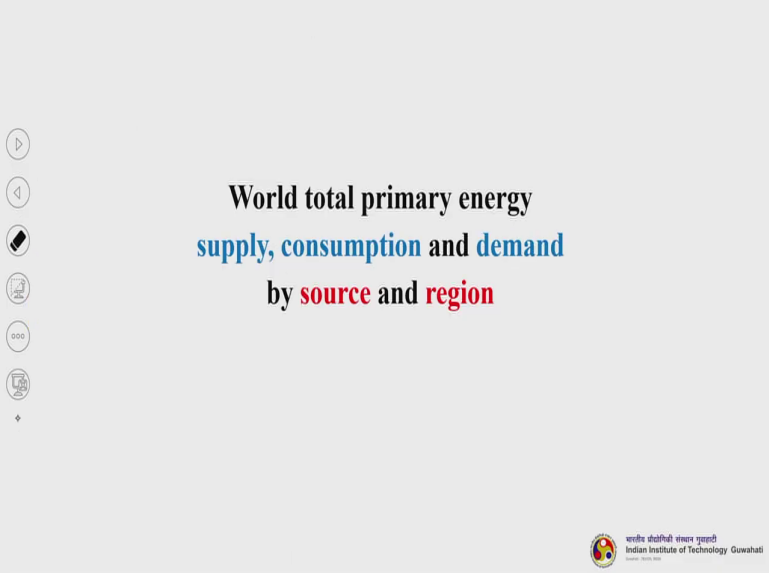

Now let us understand the world total primary energy supply, consumption and demand by source and region.

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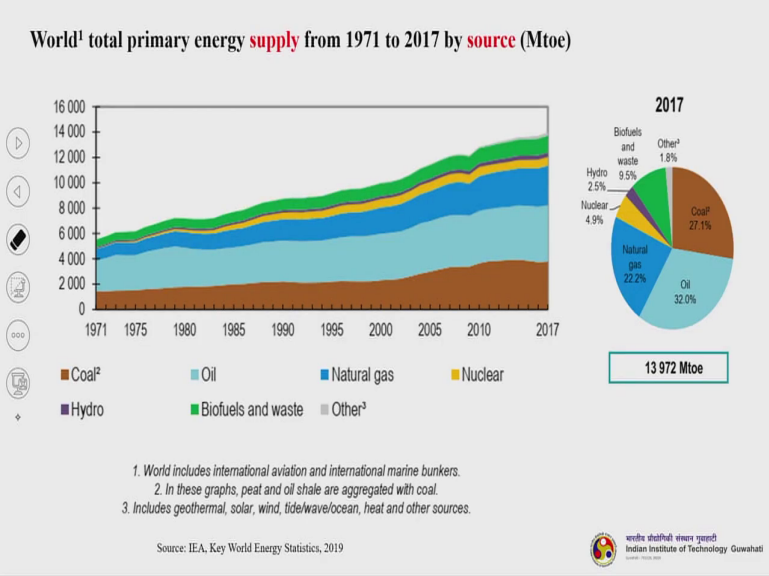

This is the world primary energy supply from 1971 to 2017 by source. If you see that round 1 (pie chart), you can see that in 2017 coal is 27%, oil is 32%. These two are more than 50%. Rest are natural gas, bio-fuel wastes and other sources such as hydro and nuclear sources.

Similarly, if you see by source, again you can see that oil is the major one. This is the consumption pattern by source. So oil is the major followed by natural gas, electricity and bio-fuel.

So this is the supply in terms of region. You will see that there is something interesting. You can see from the round 1 (pie chart) that only China accounts for 22% and OECD countries for 38%, India actually lies in the red zone, which is non-OECD Asia. It accounts for 13.5% out of which India is almost more than 50% which is a very significant number.

So China and India together are supplying a huge amount of energy required in the total Global energy supply.

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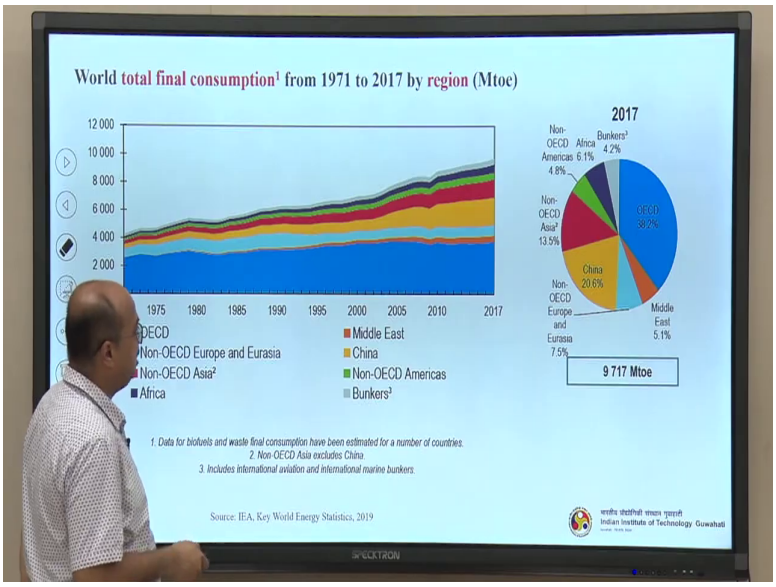

So if you talk about the final consumption, again OECD is followed by China and the non-OECD countries, the same pattern. The energy consumption pattern as well as the energy supplied pattern is almost same.

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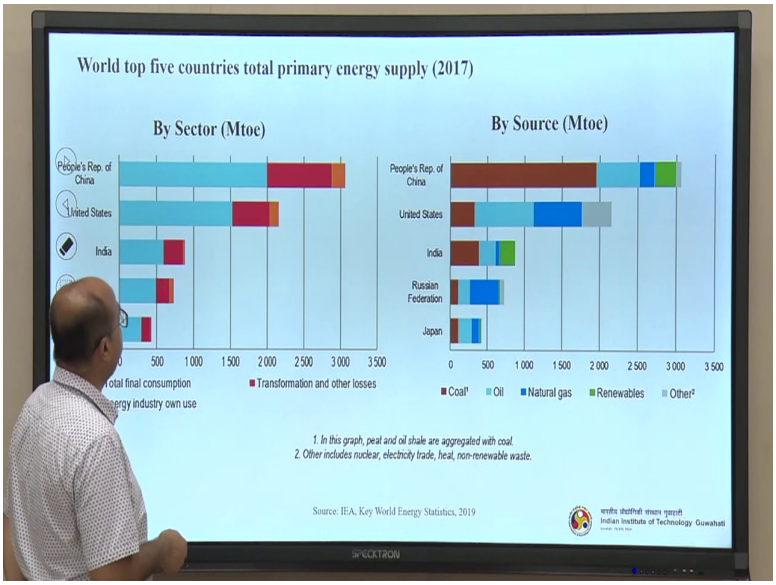

So if you look at this particular slide, this talks about the top five countries total primary energy supply. So, if you go by sector then you can see that the People's Republic of China stands first followed by United States of America, India, Russian Federation and Japan. Now if you look at the second plot that side, you can see that China's steel consumption is actually hugely dependent on coal followed by oil, natural gas and renewables.

And India almost follows the same pattern. However, you can see that in India the renewables are increasing day by day. That is very interesting and that is because the

Government of India has so much of thrust and excellent policies on actually renewables. So if you look at this again, top 5 countries total primary energy consumption, you will see that China's iron and steel is followed by chemical and petrochemical, followed by non-metallic minerals. These are basically industry based consumption patterns. And India also is following the same trend except that the chemical and petrochemical is a very small one and in non-specific industries it is more. Because of these non-specific, under that basically small-scale industries comes up and you know in Indian economy small scale industries play a very big and crucial role.

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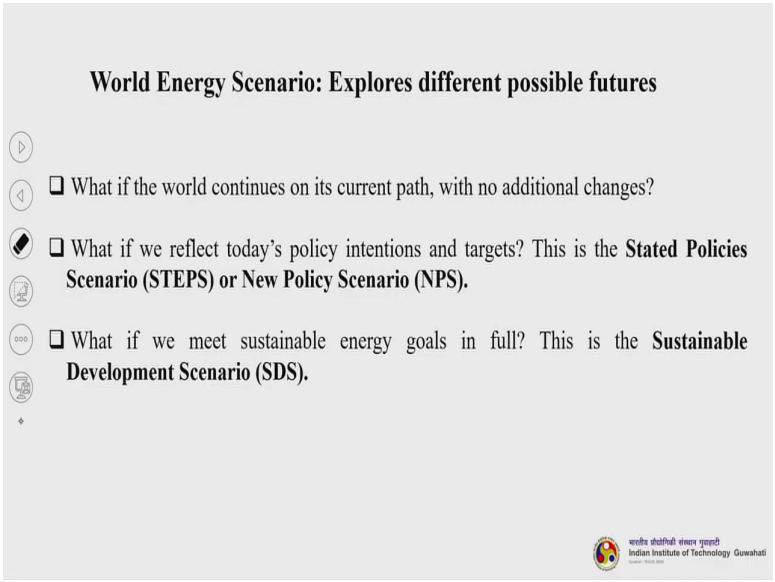

So, what if the world continues on its current path with no additional changes? So, what if we reflect today's policy intentions and targets? This is the Stated Policies Scenario (STEPS) or the New Policies Scenario (NPS); what we are going to adapt basically, the NPS. There is something called the SDS, which is basically meeting the sustainable development goals. We call it the sustainable development scenario. So, whether it is NPS and SDS or both, this is how actually now things are being decided.

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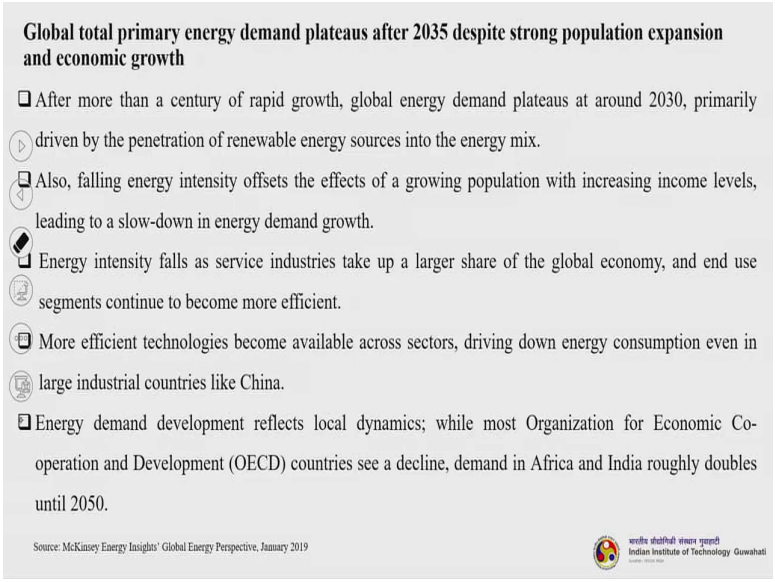

So, if you look at the Global total primary energy demand, that is going to have a plateau after 2035 (projection basically), even if there is a strong population expansion as well as economic growth. So, if you look at this, the Global total energy demand will have a plateauing effect at 2035 or beyond 2035, primarily driven by the penetration of the renewable energy sources into the energy mix.

As more renewables are coming into picture, they are taking a big thrust of the entire energy supply as well as consumption pattern. So, you can understand, that is why actually there will be a plateauing effect after 2035. So, also falling energy intensity offsets the effects of a growing population with increasing income levels, leading to a slowdown in the energy demand growth.

So, energy intensity actually falls as service industries take up large share of the global economy. That is what is happening in most of the developing countries, where the service industries are playing a big role in the economy as well as in Energy consumption basically.

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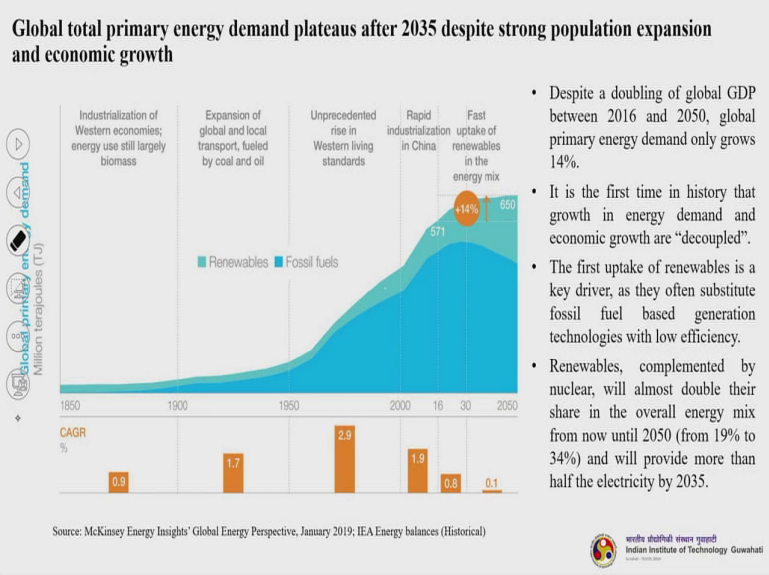

So, if we look at how the projection looks actually; so you can see that there is something interesting here; despite a doubling of global GDP between 2016 and 2050, the global primary energy demand actually grows by 14%. So this is a projection towards 2050, which you can see here. So, it is the first time in history that growth in energy demand and economic growth are decoupled. So, this is very interesting. The first uptake of renewables is a key driver as they often substitute for fossil fuel based generation technologies with low efficiency.

So, renewables complemented by nuclear, nuclear power, basically, will almost double their share in the overall energy mix (from 19% to 34%) and will provide more than half of the electricity by 2035. So, what we understand from this particular slide is that, renewables along with nuclear power is going to substitute almost 50% of the total energy supply after 2035 in most of the countries.

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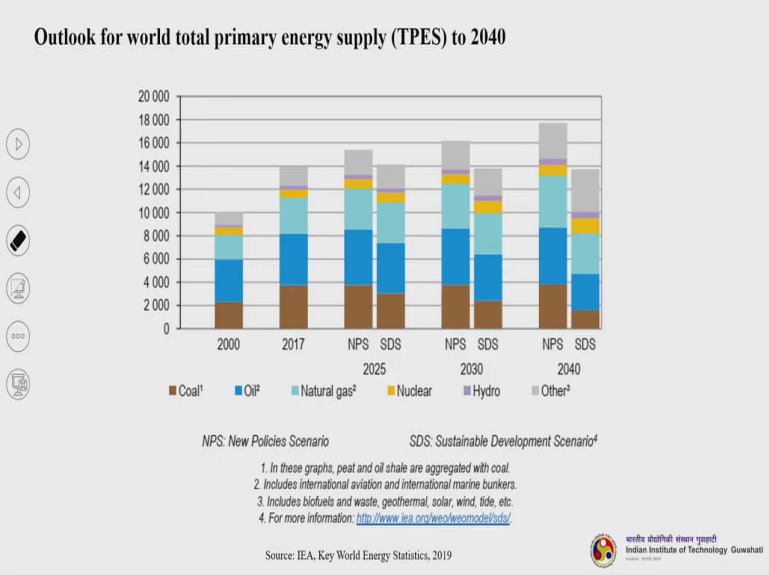

So if you have an understanding of the total primary energy supply by 2040; this is a prediction. You can see that, if you look at this slide, coal is continuously getting depleted. And similarly, the natural gas though it is taking a shift after 2035. It will slowly it will come down. Similarly, there are other sectors also.

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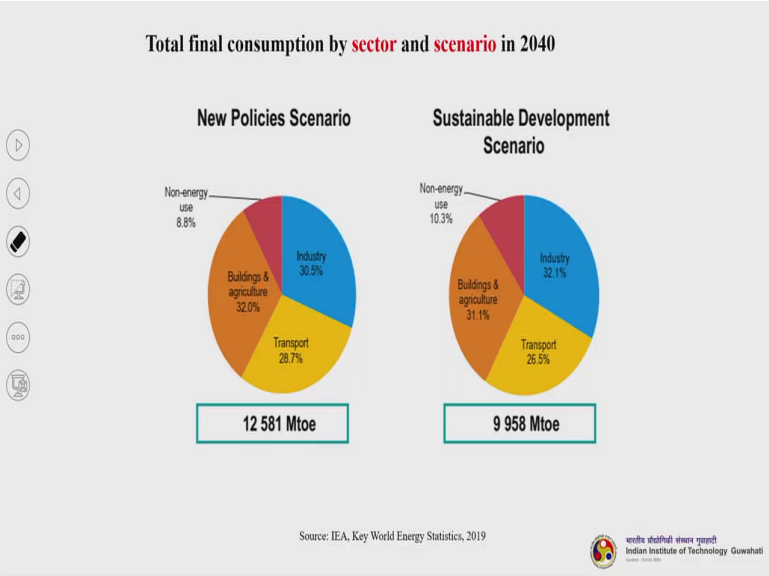

And if you look at the sector wise, so we will understand that in a sustainable development scenario, industry, transport, building and agriculture, these are the major shares. And if we look at the new policies scenario, it is all the same thing; only the net amount or the net percentage varies a little. Otherwise they easily complement each other.

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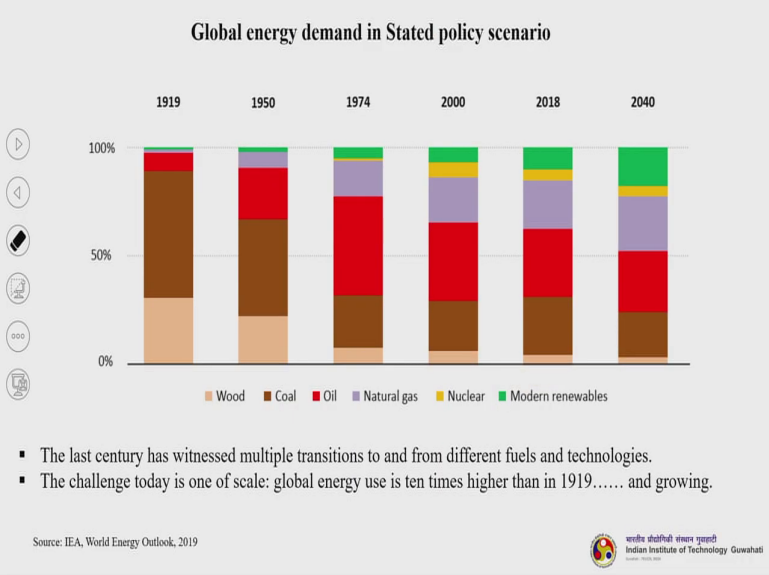

So this is the global energy demand in stated policy scenario. So you can see that, there is something interesting, how the wood is getting decreased. Initially, long back when we started 19th or early 18th century, so you can see that the wood was the primary source of energy. Slowly it gets depleted and the use of coal has increased. Then oil has come into picture and now slowly fossil fuels are depleting. So we have to depend more on the nuclear and modern renewables. And those are taking the major amount of the energy supply and of course demand also.

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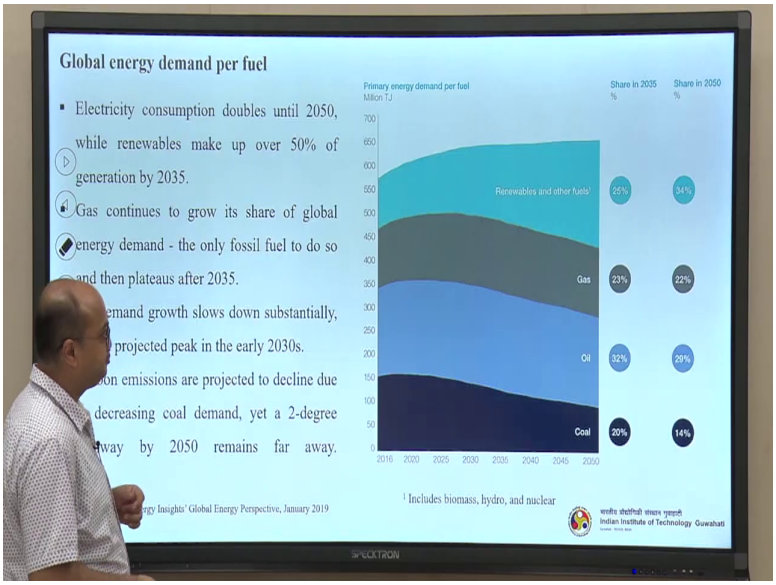

Global energy demand per fuel, if you look at, you see that in this particular plot, you see that renewables and other fuels after 2035, here, every other thing, whether it is gas, oil or coal, it is getting depleted or getting a plateauing effect after 2035. But renewables are increasing.

So, this is what it tells us that due to the policy intervention by most of the governments across the world, there is more focus on the development of renewables.

So that is why renewables and other fuels are taking a steady curve or the curve is increasing and not depleting.

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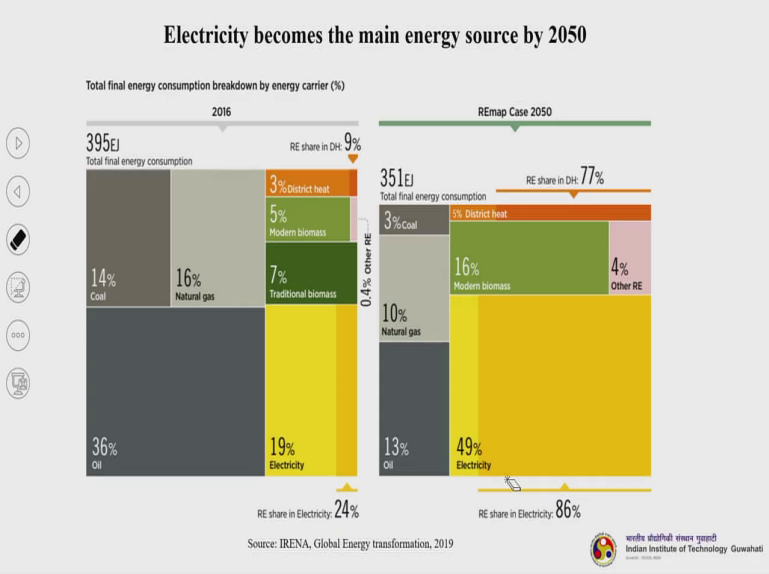

So this is interesting. If you look at this, it is about electricity. So, if you look at this particular slide, this and this, you just understand that 36% of oil, 14% coal, 16% of natural gas and only 19% electricity. As you move beyond 2016, this is up to 2016. And as projected up to 2050, you can see electricity is going to take the centre stage with 49%. See it is 50%. Half of the main energy source will be by electricity. Followed by the modern bio-mass, bio-energy, what we are going to discuss in our lecture, basically in this course. So you can understand how the policies are actually driving all the Global major economies, including the small economies also across the world to focus on the renewables and including electricity. So mostly it will be electricity. And again, electricity can be hydropower, it can be nuclear power and it can be from other renewables also.

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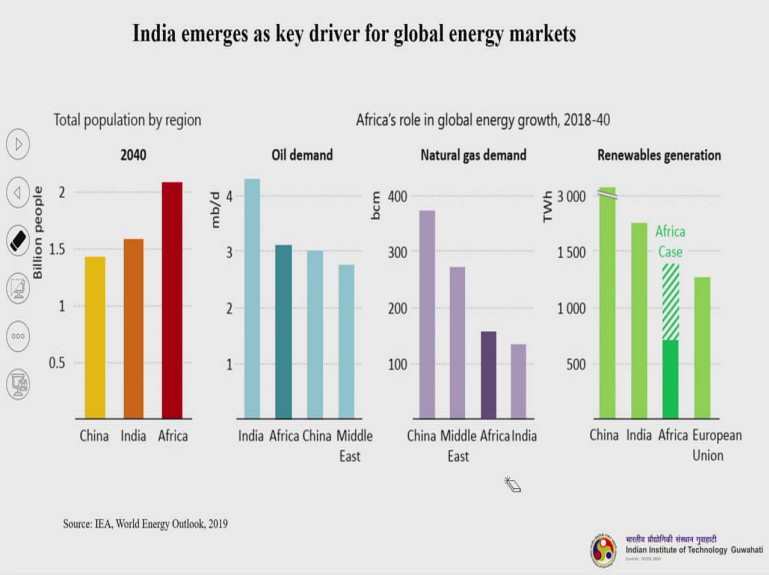

So, this particular slide tells us that India along with China emerges as the key driver for global energy market. Another interesting observation is about Africa; the entire African countries, in the last one (bar graph) as you can see here. You can see here, how China and India are taking shape in 2040 (this is a projection till 2040). This is total population by region. So in China, India and Africa (Africa means African continent and not South Africa), you see their projected oil demand, see their natural gas demand. India is falling in the natural gas demand because we are not yet moving into the gas natural gas. However, China has surpassed all of us. And if you look at the renewables, you see that India is playing an interesting role, a very big role. And of course Africa also.

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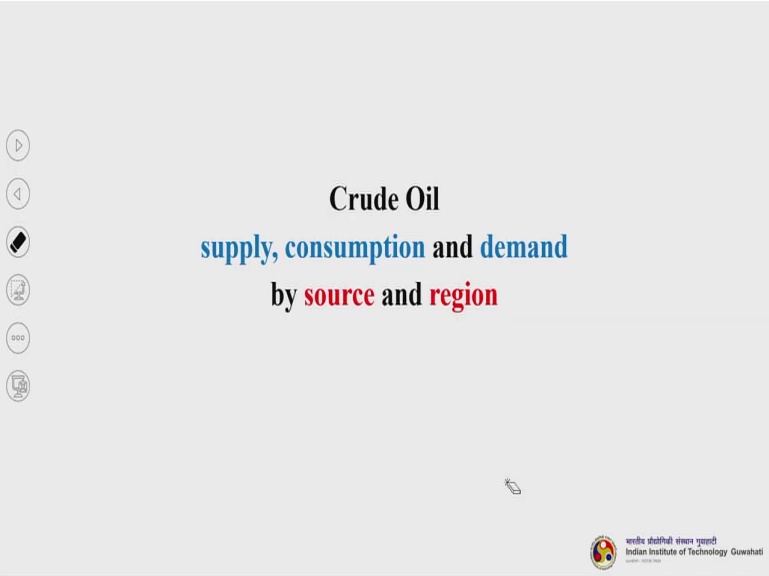

So, we will see different energy sources, their supply, consumption and demand by source and region. We will just quickly glance through it. So the first one is crude oil.

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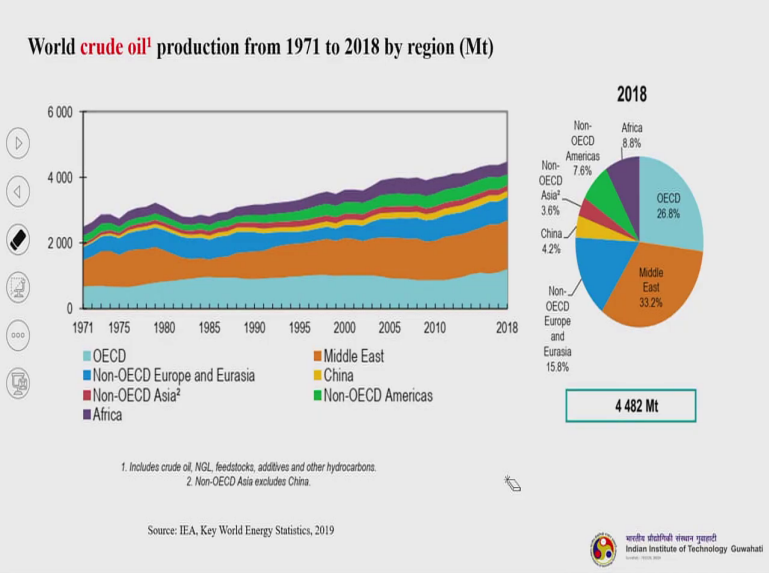

So you can see the world oil crude oil production from 1971 to 2018 by region. And you can see that, OECD is of course 26.8% and Middle East (33.2%). So OECD and Middle East is close to almost 60%. The rest is non-OECD Europe and Eurasia, then China, Asia and other countries.

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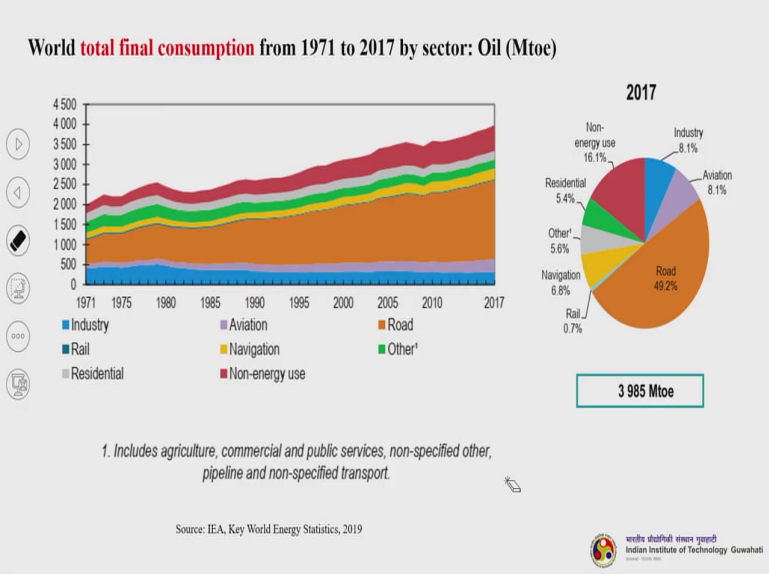

So mostly it is coming from the Gulf countries and OECD countries. If you see the final consumption from 1971 to 2017 by sector, you can see that road, or the transportation sector basically is almost 49.2%, followed by navigation, aviation and non-energy use sector.

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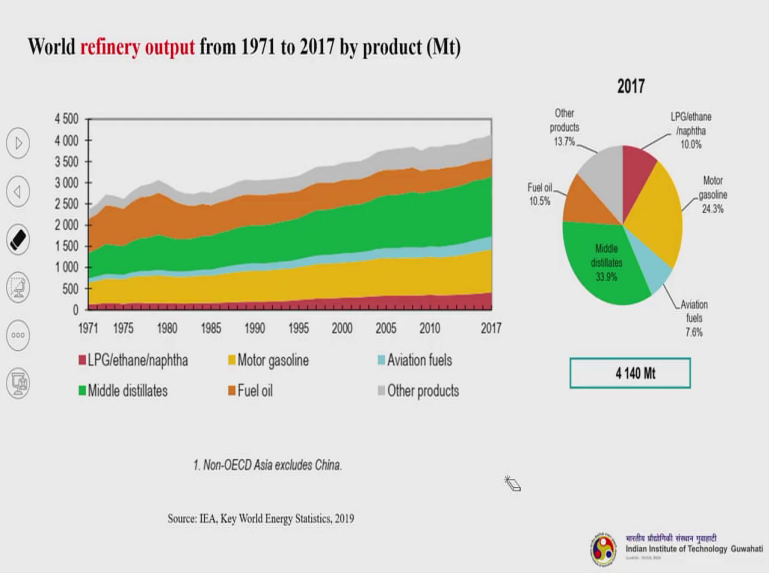

So, similarly if you see the refinery output, you can see that mostly it is coming from the middle distillate, followed by the motor gasoline, fuel oil and then LPG, ethane, naphtha and other products.

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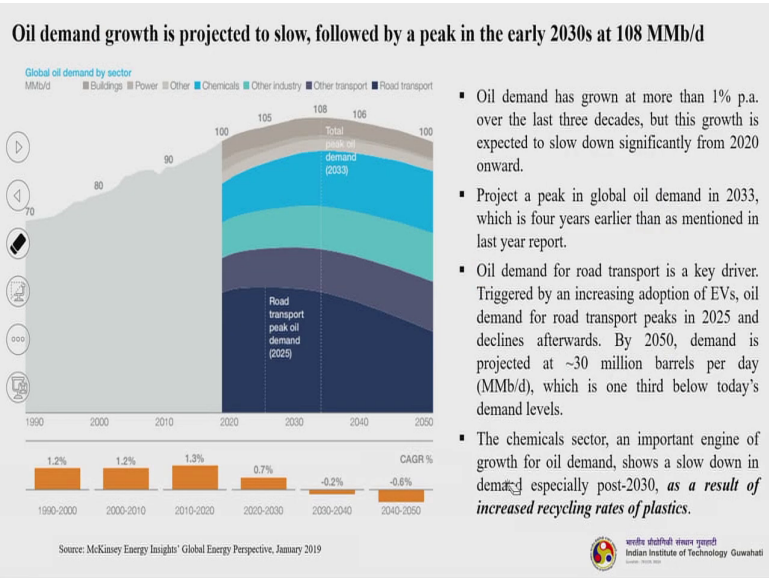

Let us now understand the oil demand growth, how it looks like beyond 2030-35 and till 2050. So you can see that oil demand has grown more than 1% per annum for over the last three decades. But, this growth is expected to slow down significantly from 2020 onwards. So from the current year onwards. The reason is due to the (fact that) more and more recent development of the electric based systems or we are depending more on the electricity rather than other sources of energy.

So there is a projection of a peak in 2033. Beyond 2033 there will be a plateauing effect again. So, by 2050 demand is projected at almost 30 million barrels per day (bpd), which is one-third (times) below today's demand as of now. So, the chemical sector which is an important engine of growth for the oil demand shows a slow down with respect to post 2030 projection.

Why? The reason is that, there is an increased rate of plastic recycling. That is also very interesting now. So you know that more and more plastic recycling is happening. So that is why there will be a plateauing effect after 2030 specially in the chemical sector.

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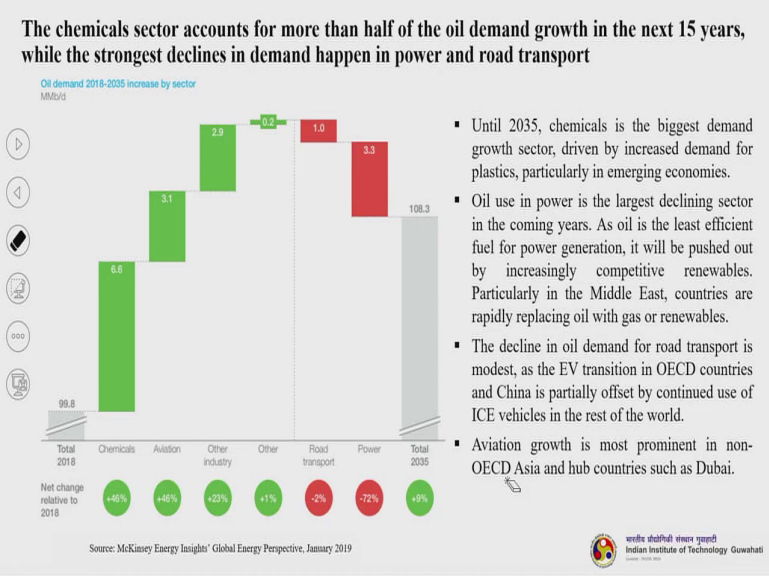

Now when you talk about the chemical sector, more than half of the oil demand growth will be for the next 15 years. Until 2035 chemicals is the biggest demand growth sector, and then there will plateauing effect. So, oil use in power is the largest declining sector beyond 2030-35. So the decline in oil demand for the road transport is modest as the EV is coming into picture.

There are 2 things, first is EV (the electric vehicles basically). Mostly it is a huge transition in the OECD countries. They are almost going for EV (they are already doing it). And China is partially offset by continued use of the ICE vehicles. Though the OECD countries are going more into the EV; however, China being one of the largest economy in Asia as well as by population or by energy use and as well as by consumption, still China is going to continue the ICE (that means the internal combustion engine) vehicles. So that is why in Asia it will be

little less. Aviation growth is most prominent in non-OECD Asia and hub countries such as Dubai.

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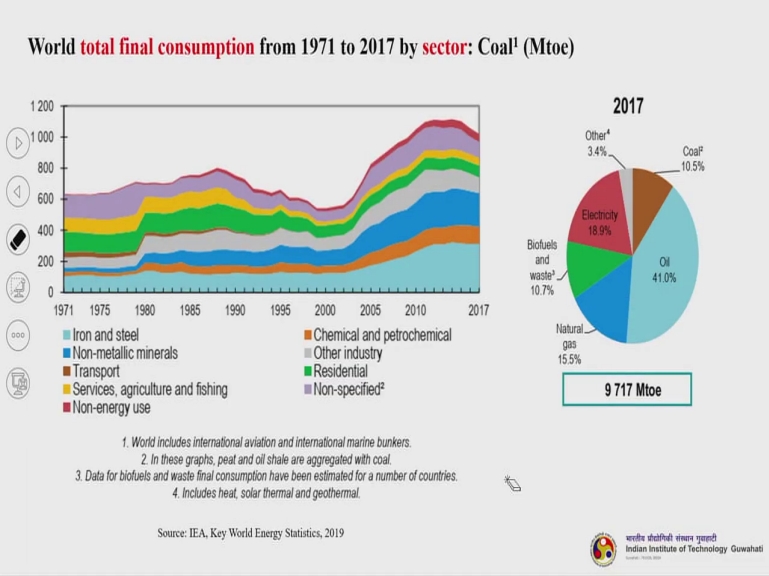

Then, let us understand coal. So, if you look at the total final consumption from 1971 to 2017 by sector, you will see that oil is 41%, followed by electricity, natural gas and interestingly you see biofuel, 10.7% (it's a big one). So it is up to 2017. So understand that, beyond that how the biomass based industries, bio-fuels that are coming from (different) other sources (waste sources) is going to shape up our economy.

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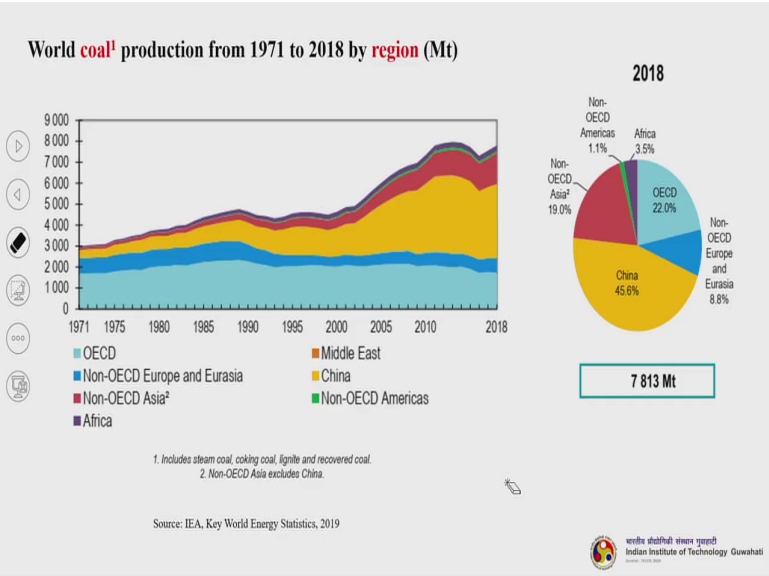

So, the world production of coal by 2018, if you look at this round one (pie chart), you can see that China is almost half (45.6%). India comes under the non-OECD Asia (this red

portion) (almost 30% to 35% under that is from India) and of course followed by the OECD and other countries.

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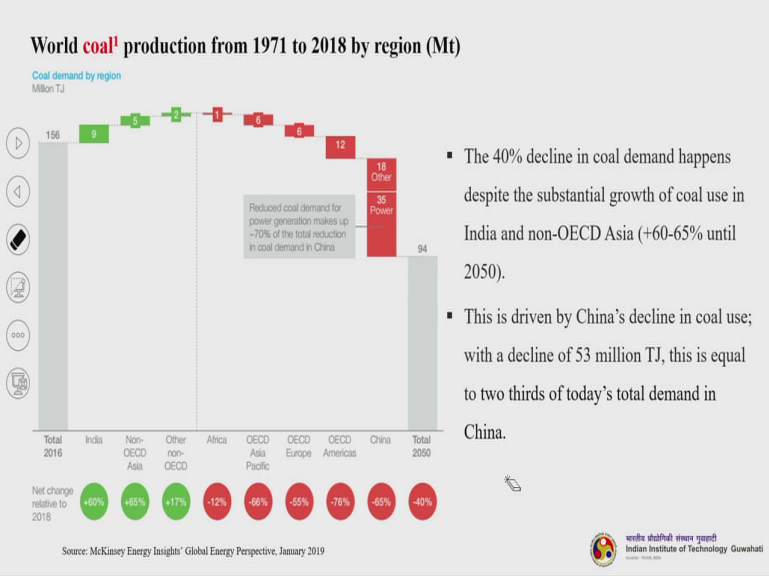

So here, if you look at this particular slide, you can understand that 40% decline in coal demand happens despite the substantial growth of coal use in India as well as other non-OECD Asian countries. This is basically driven by China's decline in coal use. So that is also very interesting right; with the decline of 53 million TJ, this is equal to two thirds of today's total demand in China. So, all these things have driven our focus towards renewable.

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Then again, we will quickly understand natural gas, the way we have discussed about coal and oil. So Natural gas supply, consumption and demand.

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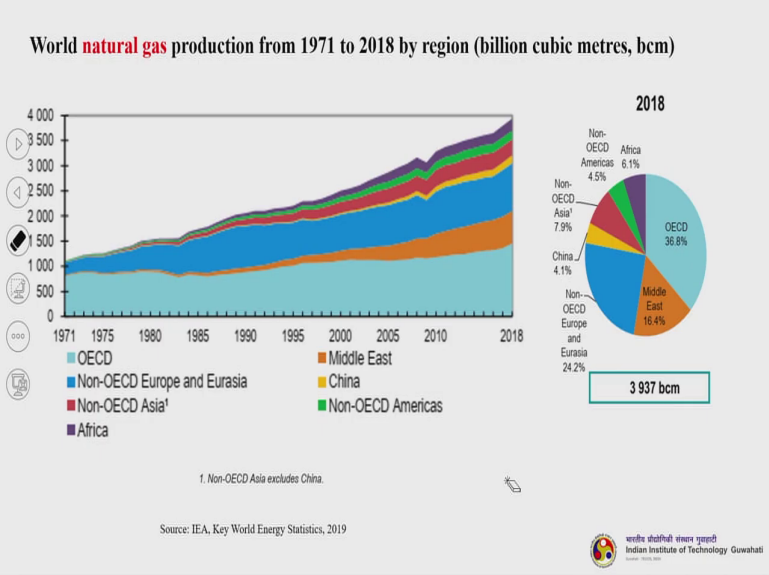

So, here you can see that natural gas production~~. So,~~ mostly ~~it~~ is by the non-OECD European countries and OECD countries (close to 60%). And India has a very minimal role to play here.

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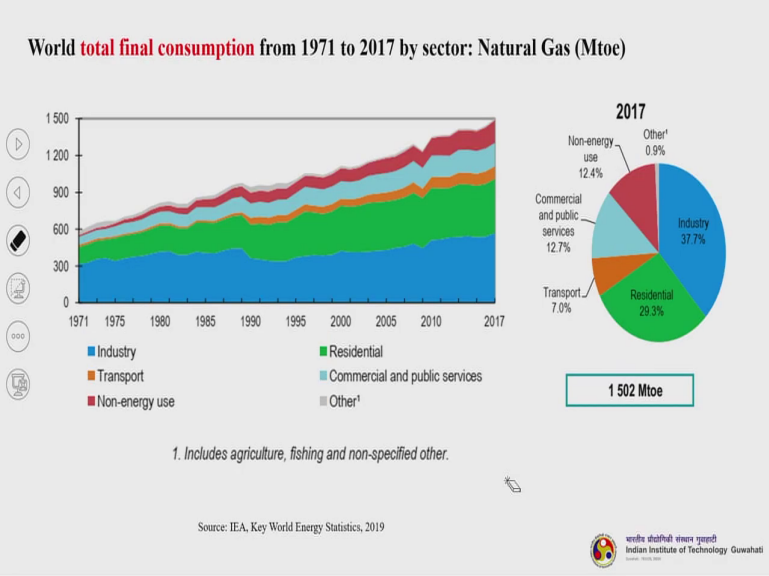

So, for the final consumption; of course industry is the most important one, followed by the residential areas and then commercial and public services.

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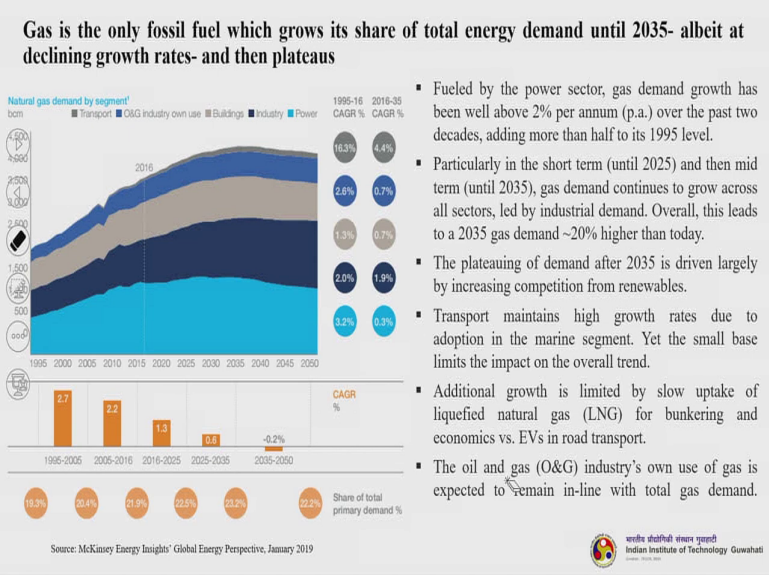

Then, when you talk about natural gas, ~~so~~ it is the only fossil fuel which grows its share of total energy demand. You must understand that, among all the fossil fuels this is the only fossil fuel (natural gas) whose demand is continuously growing for the various advantages it has over other fossil fuels. So, particularly in short-term till 2025 and mid-term (2035) gas demand continues to grow across all sectors led by industrial demand.

The plateauing of demand which is happening after 2035, as we can see here, almost there is a plateauing of demand here. So, it is driven largely by the increasing competition from the renewables. So, the Oil and Gas Industries' own use of gas is expected to remain in line with the total gas demand.

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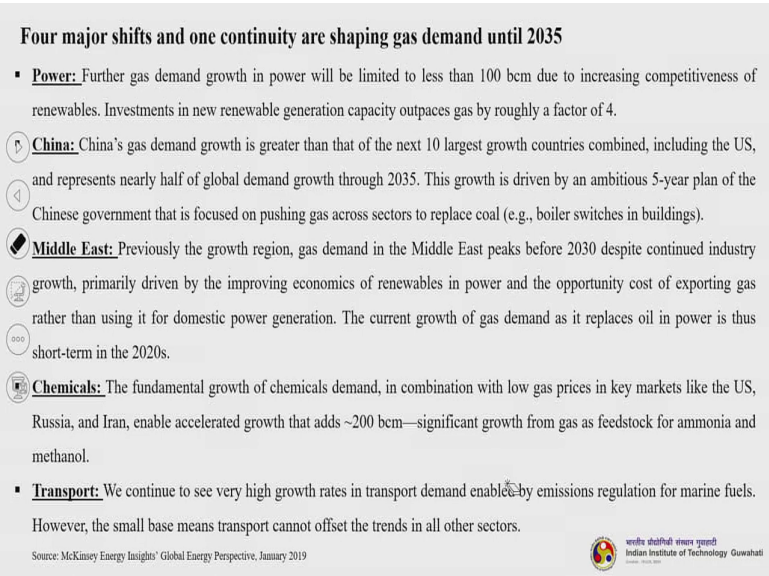

So these are certain things (points to be noted on) how the gas demand is going to take shape up to 2035. So in the power sectors China's gas demand growth is much higher than any other countries (including the US). In the Middle East (previously the growth region) gas demand peaks before 2030. Then there is chemical sector and there is transport sector.

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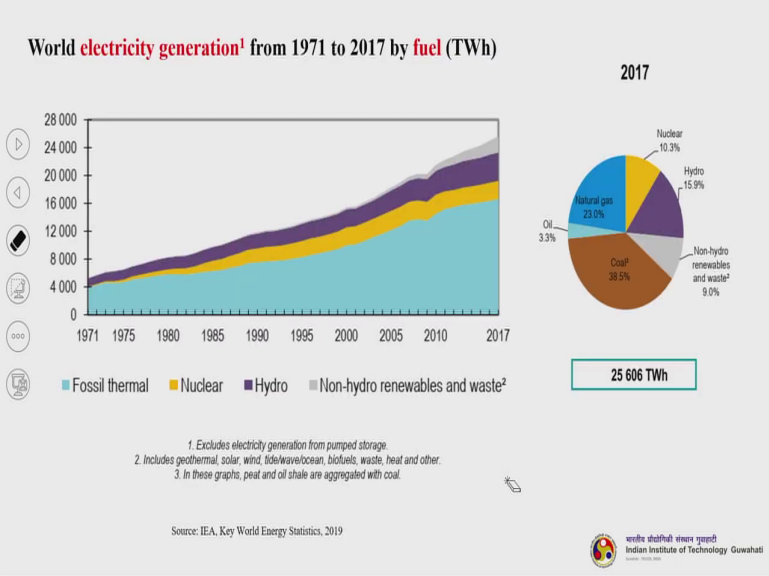

The next (topic) is World electricity supply, consumption and demand by source and region. So, this is the world electricity generation from 1971 to 2017 (by fuel). So, mostly it is from coal; just like in India, it is the National Thermal Power Plant, they supply a major portion of the electricity followed by hydro, natural gas and nuclear. In India also nuclear is slowly taking shape.

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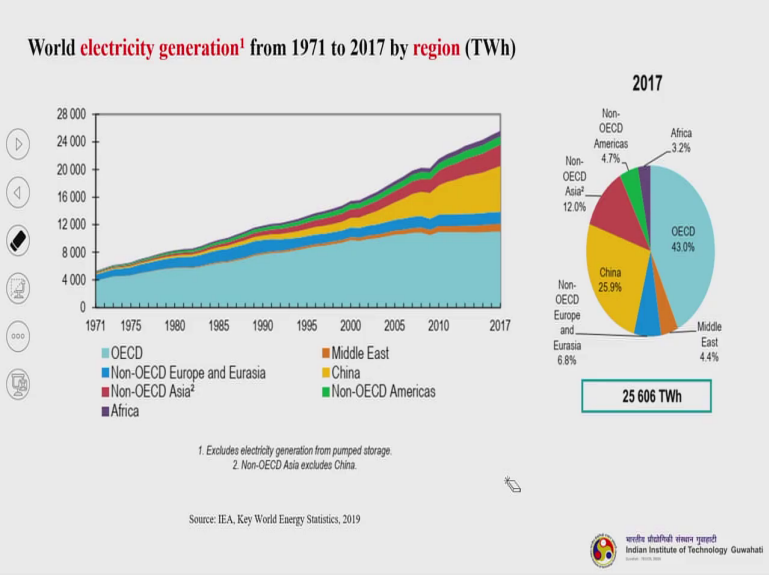

And (for) the electricity generation by region: if you look at (this slide), OECD is the major (contributor) (43%), followed by China. So OECD countries and China is almost (accounts for) more than 60%. India comes under the non-OECD Asian countries.

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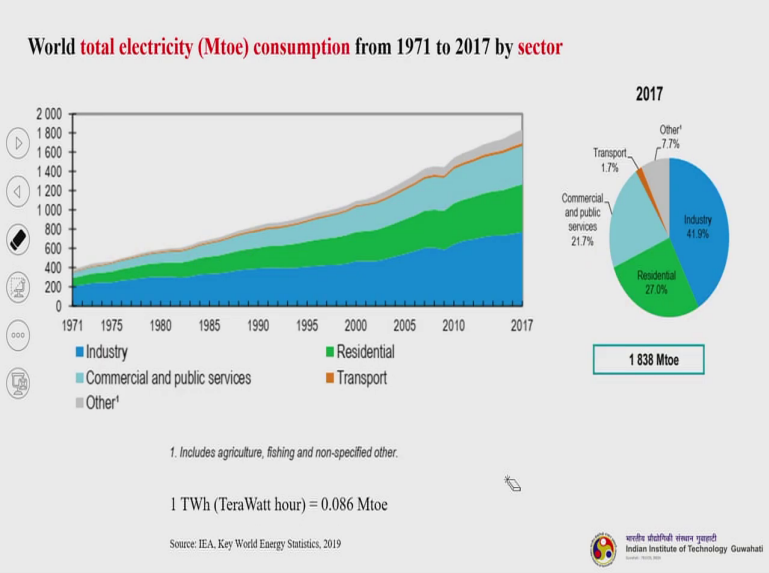

This is the total electricity consumption by sector. So the industry of course (consumes) close to 42% and rest almost 50% is (consumed by) residential, commercial and public services (sectors).

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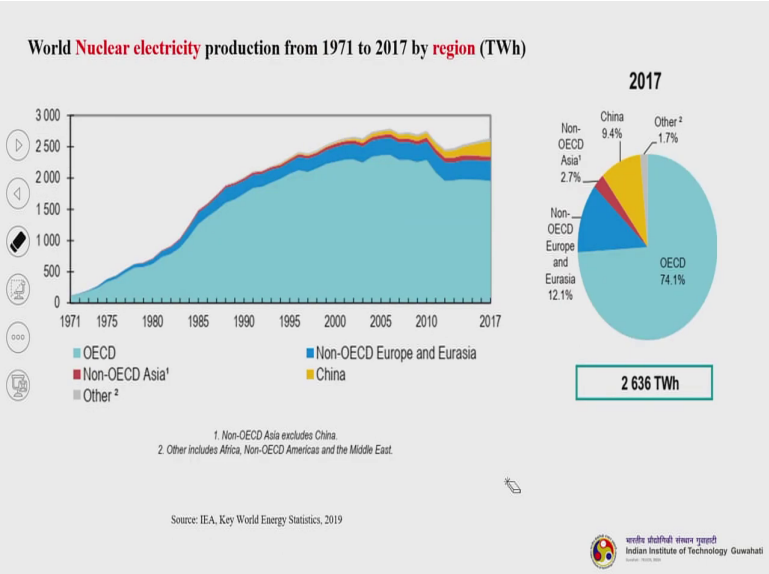

So if we talk about nuclear electricity production, you can see that close to 75% is by OECD countries, i.e., mostly the European countries including the United Kingdom, France and other countries and as well as the United States also. And non OECD Europe is almost 12%.

Asia is lagging behind in this nuclear power sector, but slowly China, India and other countries are developing their nuclear power sector.

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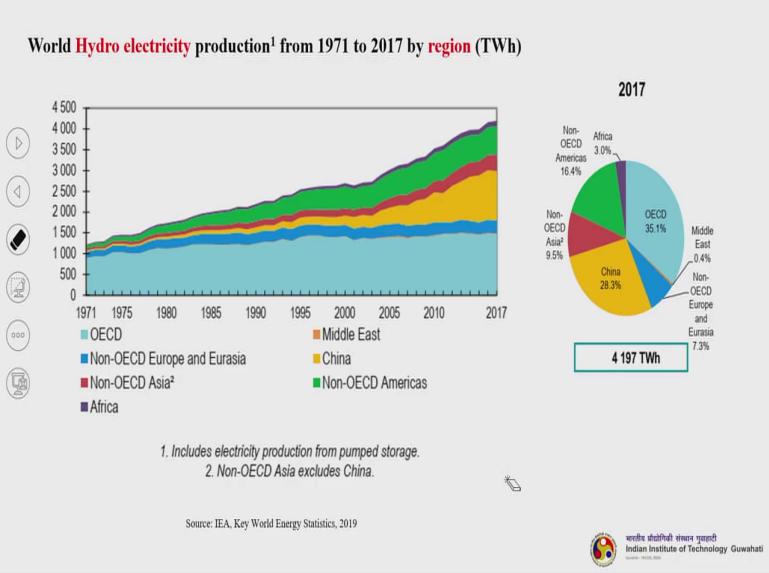

So this is hydroelectricity (power production). Here also, you can see that OECD and China takes the centre stage, followed by the non-OECD Asia, in which India comes into picture and other American and African countries too.

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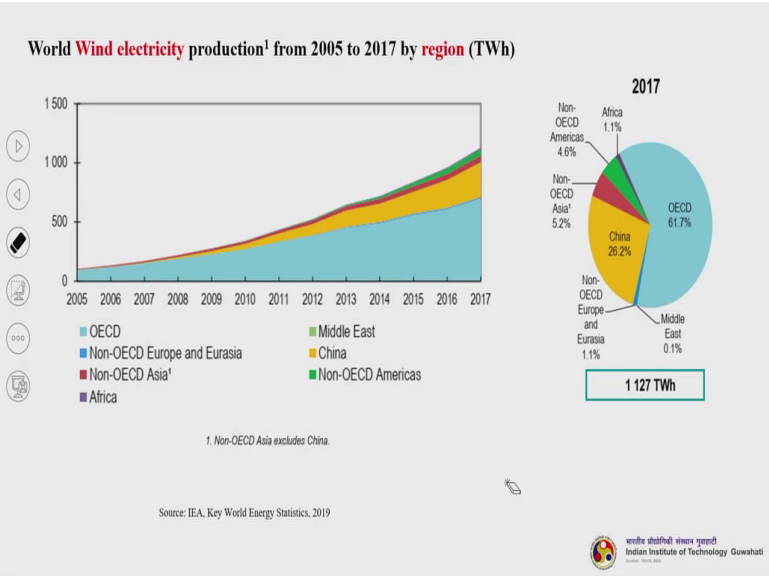

So this is wind electricity. Again here also, OECD takes the major share. Now, what we understand from these few slides is, basically, when we talk about renewable electricity, the OECD countries have already taken the lead. Now China is following them and India is also following them. And we are sure that beyond 2035 you will see a huge change in the total energy consumption pattern as well as source.

So this is solar PV (photo voltaic electricity). This is one sector in which the government of India is giving a lot of emphasis. There are a lot of subsidies available to set up a solar PV system, including the small ones in the household sector too. Awareness is also increasing and the Government of India is playing a big role in shaping up that particular sector.

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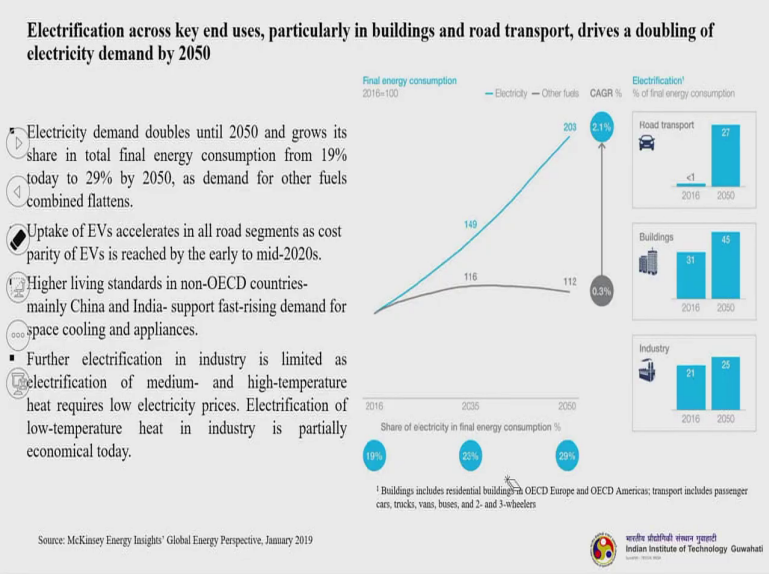

Then, let us understand about the electrification areas across the key end uses. If you see this particular slide, you can understand that electricity demand doubles until 2050 (this is how it has been projected) and the policies are also like that. And it (electricity demand) grows its (share in) total (final) energy consumption from 19% today to 29% by 2050 as demand for other fuels are flattening (other fuels means the fossil fuels).

So, the increasing adaptation of the electric vehicles is also leading to this particular surge in electricity demand.

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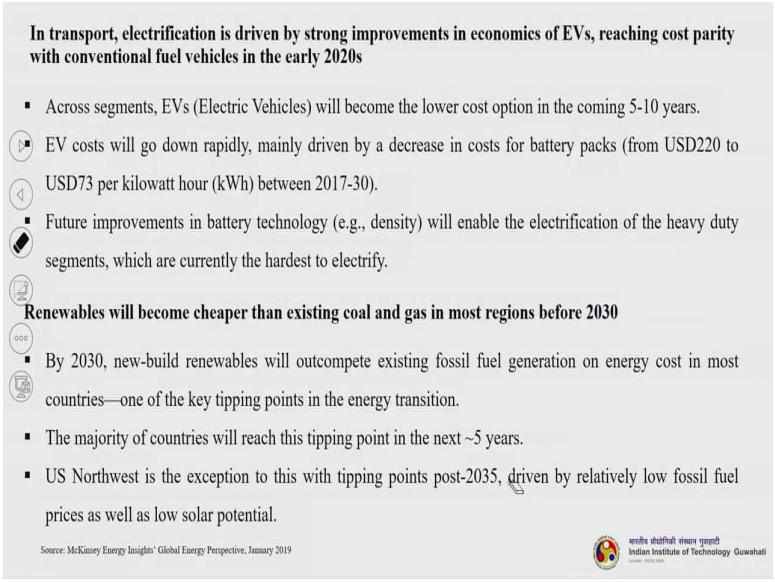

So, in transport sector electrification is driven by strong improvements in economics of the electrical vehicles, reaching cost parity with conventional fuel vehicles in the early 2020s. This is what, is the actual aim of the OECD countries. They want some sort of trade mark or cut off with the cost in comparison to adaptation of EV's or electric vehicles. So, you can see that, for future improvement in battery Technology, (that is that is also very important) huge amount of research is still going on. This will enable the electrification of the heavy-duty segments which are currently the hardest to electrify. So renewables will become cheaper than existing coal and gas in most regions before 2030. Then you will be forced to switch over to renewables even if you are not ready to adapt. So, that is going to happen by 2030. So a majority of the countries will reach this tipping point in the next 5 years including India. But anyway; in India we are already into renewables and our renewable production is also much higher than other developing countries.

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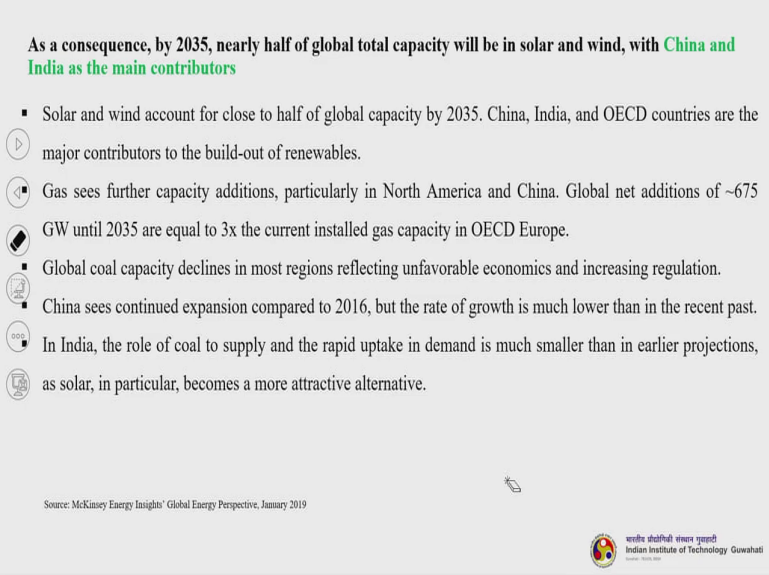

So as a consequence, by 2035, nearly half of the Global total capacity will be in solar and wind, with China and India both taking the centre stage or they will become the main contributor (that is very interesting). So solar and wind account for close to half of the Global capacity by 2035. China, India and OECD countries are the major contributors.

Natural gas sees further capacity additions, particularly in North America and China. So Global net additions of ~675 GW until 2035. So coal capacity declines, because in most of the countries there is a decline in production of course, (that is true) as well as a decline in adaptation or use. In India, the role of coal to supply and the rapid uptake in demand is much smaller than in the earlier projections.

So that is actually good as solar in particular becomes more attractive alternative. As I told you, that Government of India has given (emphasis on) the use of this policy as well as (the government) giving so much of subsidies to setup solar PV systems, including the rooftop solar PV systems for use in the households also.

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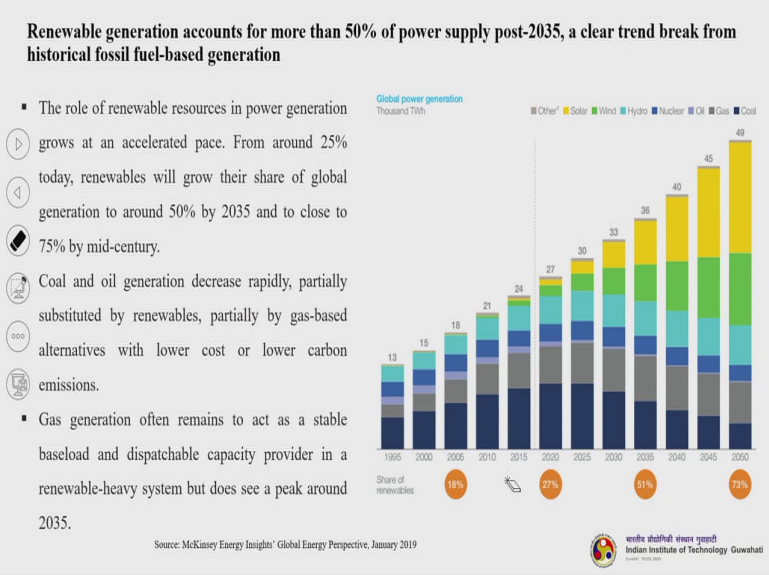

So, renewable generation accounts for more than 50% of the power supply post 2035. This is where the NPS and SDS both complement each other. So in this particular slide, you can see, how from 2030 onwards there is a huge increase in the Solar. You can see that yellow ones (yellow part of the bar graphs) are the Solar and how it is increasing followed by the wind and hydro. So this is how we are going to focus, including India. The major focus will be mostly on the Solar PV systems. Then of course solar thermal is also there, wind energy, hydro energy and nuclear energy. So all renewable sources.

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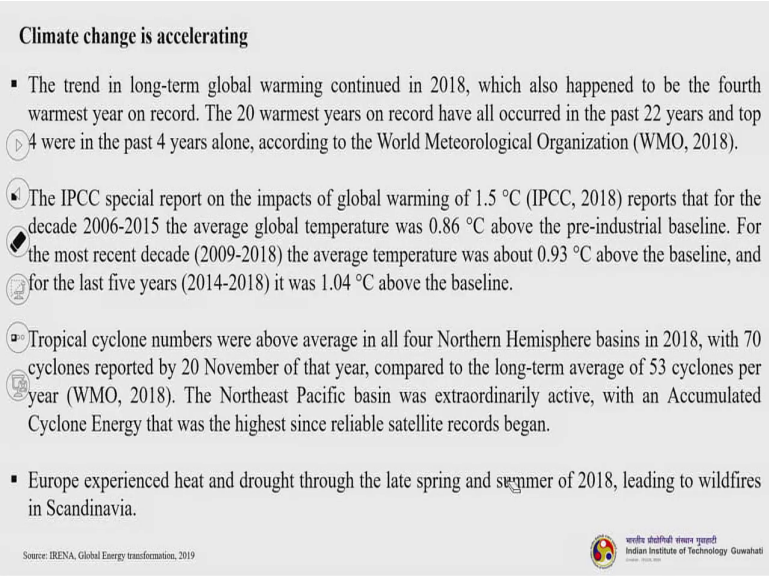

Now let us just quickly understand (since this is introductory class) about the global environmental issues. So we will talk about only the carbon dioxide emissions and climate change.

So the trend in long-term global warming continued in 2018, which also happened to be the fourth warmest year on record. So, you know, since the last ten or twenty years the warmest years basically occurred in the past 22 years. And the top four were in the last four years alone. So that is very bad. This is according to the WMO or the World Meteorological Organisation.

The IPCC special report on the impacts of global warming of 1.5 °C reports that, for the decade, 2006 to 2015, the average Global temperature was 0.86 °C above the pre-industrial baseline. For the most recent decade, i.e., 2009 to 2018, the average temperature was 0.93 °C. So it is almost going to be 1 °C.

And for the last five years 2014 to 2018 it is 1.04 °C (above the baseline). So the last four years consecutively 2019, 2018, 2017 and 2016 are the hottest or warmest years till date. So as a result of this, there is a huge increase in the number of cyclones that is affecting the entire northern hemisphere and north east Pacific basins as well as Indian Ocean sides also.

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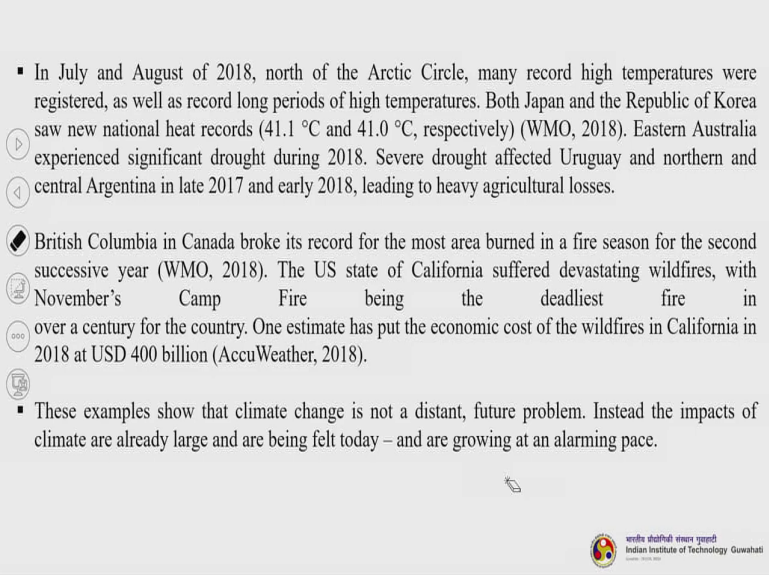

So in July and August of 2018, north of Arctic circle, many record high temperatures were registered, as well as record long periods of high temperatures. Japan and Republic of Korea saw new national heat records 41.1 °C and 41.0 °C. These are huge temperatures; they have never witnessed in their entire life span, (I mean) the people (of) who are currently in Japan and Korea. Eastern Australia also experience significant drought during 2018. Severe drought affected Uruguay and northern and central Argentina in late 2017 and early 2018 leading to heavy agricultural losses.

Now British Columbia, Canada broke its record for the most area burned in the fire season for the second successive year. The US State of California also suffered devastating wildfires. These are the things we already know, right. These have all been reported in the news and we know all these things. So these examples show that climate change is not a distant or future problem, rather it is happening (now), since almost 2 to 3 decades.

And now this is the peak time that we are facing and so much of global climate change is taking place.

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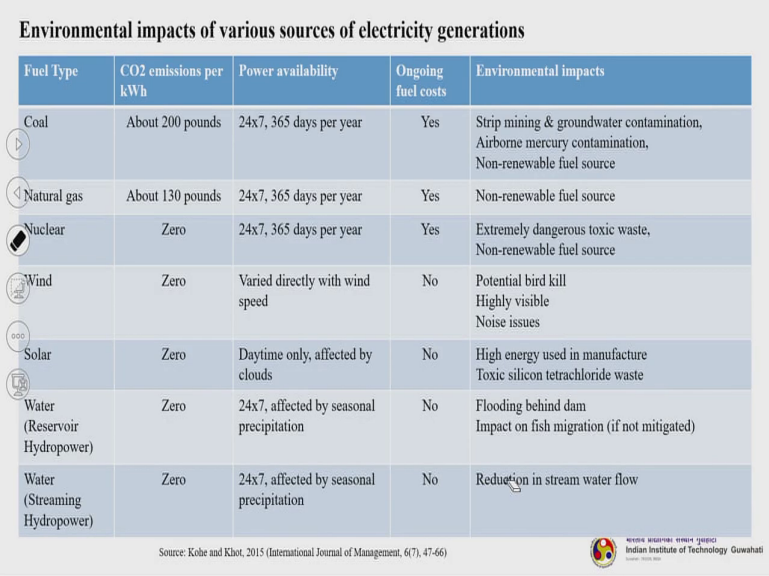

Now, this slide will basically tell you the environmental impacts of various sources of electricity generation. So coal, natural gas, nuclear, wind, solar, water (basically the reservoir hydro power) and then again water (that is the streaming hydropower). So what are the Environmental effects? If you look at wind, there is a potential of bird kills, the wind turbines are highly visible and noise issue is also there.

Similarly, if you talk about solar, though it is very good, but there are issues regarding high energy used in the manufacturing process when you make solar PV and then there is a toxic Silicon tetrachloride waste. Similarly, flooding is a problem in hydropower dams; but you know, all these so-called environmental impacts also can be properly minimised (mitigated) if we take sufficient precautions. That is what is being done now-a-days by most of the countries and they adapting the safety measures and latest technologies so that the impact on the environment will be very minimal.

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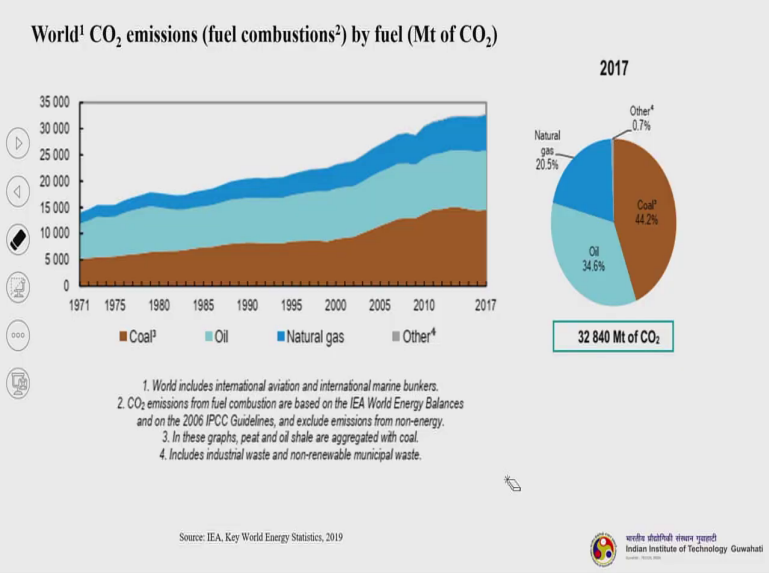

If you look at the world carbon dioxide emission, you will see that oil and coal are the major emitting sectors followed by natural gas. And China and OECD again (because they are the largest consumers of course) are the largest emitters.

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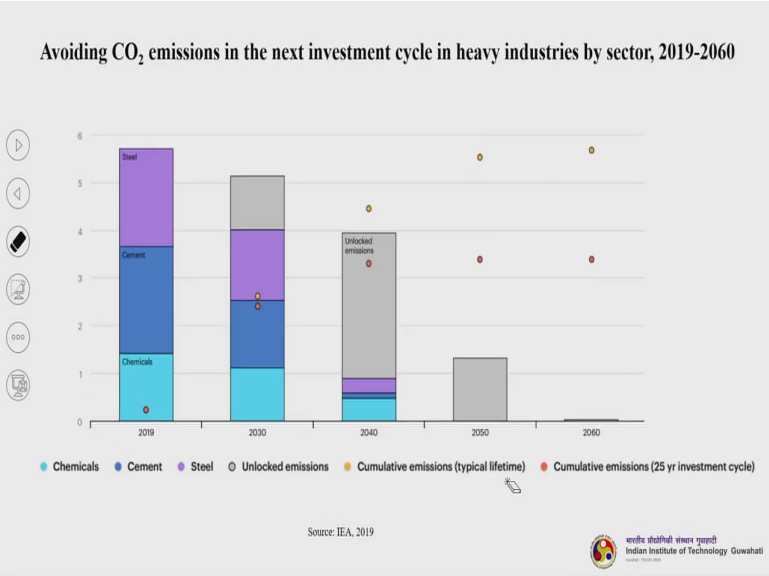

So (now), if you look at the heavy industries sector, the projection from 2019 to 2060; (let us see the from the first one 2019, 2030, 2040, 2050 and 2060), you can see that the industries which are unlocked emissions that is increasing. See that these are all Industries which are emitting hugely. Slowly it (emissions) is decreasing and unlocked emissions are increasing. Then all (only) unlock emission increased (remains). And in 2050 all (other emissions) this is gone and 2060 that is also gone (all emissions are reduced). This is how it is projected.

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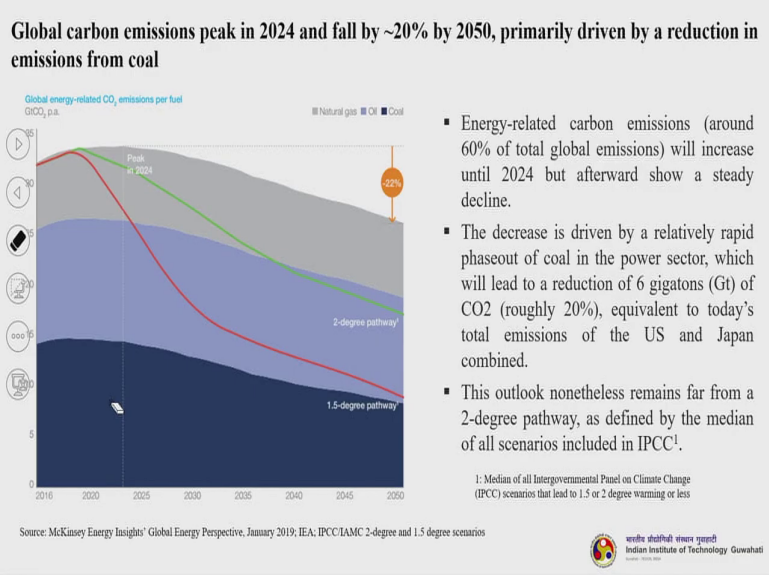

So if you look at this particular slide, it says that Global carbon emissions peak in 2024 and there is a fall by ~20% by 2050, primarily driven by the reduction in the emission from the coal. So coal emission is gone. Once that is gone, almost 20% to 30% of the Global carbon dioxide emission will drop immediately. So there will be an excellent balance of the carbon dioxide that is actually being emitted by the developed and the developing countries.

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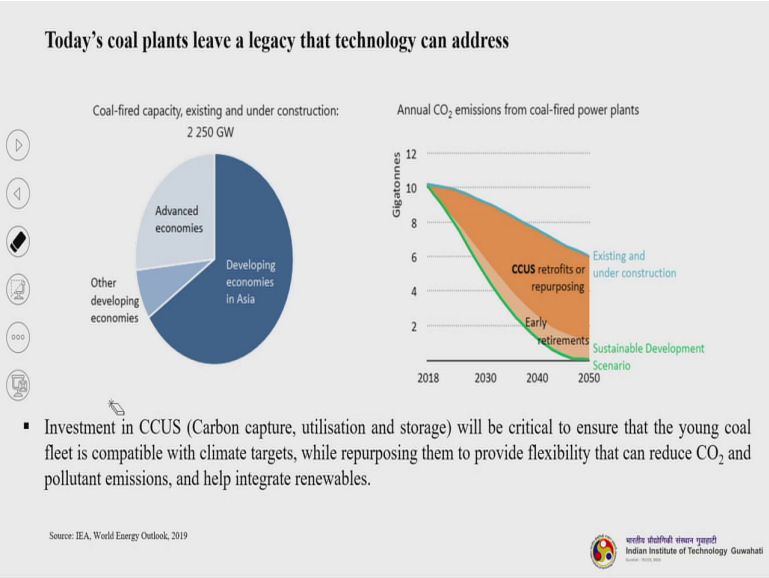

So if you look at the developing economies in Asia, there is a huge percentage (statistics wise), other developing economies and advanced economies. So these coal based plants basically.

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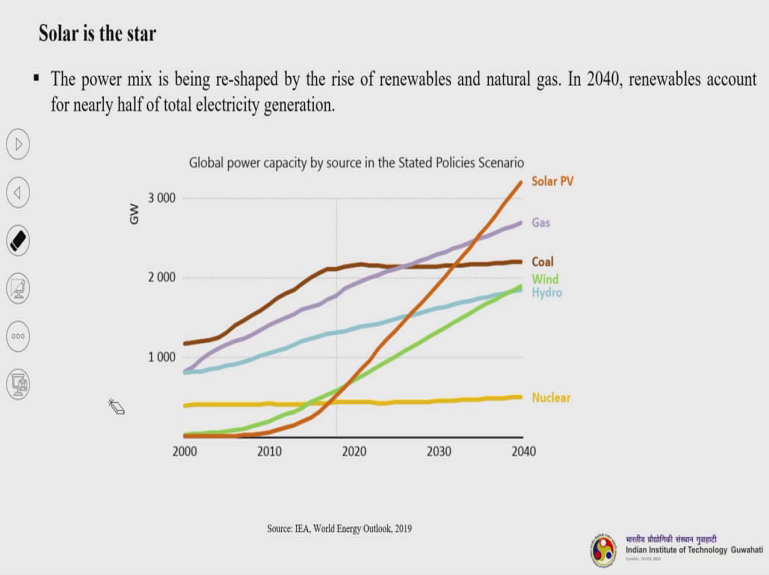

And solar is becoming the star. So you can see, this very interesting to see the how the curve is actually increasing from 2000 to 2040 (it is prediction basically, which is going to be absolutely true as it is). There will be absolute, the unit values may differ, but the curve will remain so. And apart from this there are others such as wind, hydro and nuclear. Here, the biggest problem in nuclear are the safety issues as well as the installation cost. It is a very costly technology. But once established it is very good.

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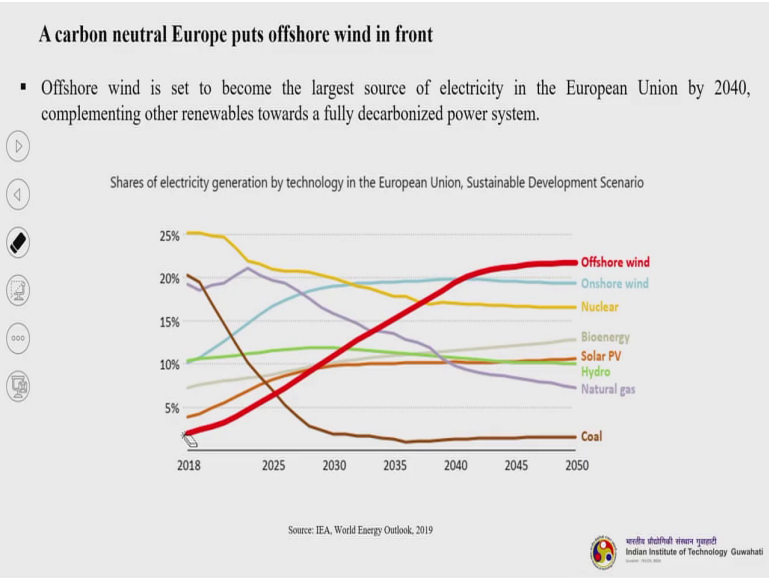

So, a carbon neutral Europe puts offshore wind in front. So this is about Europe. You see here, in Europe there is something interesting about this bio-energy. From 2018 you see how it is slowly increasing till 2050. Though, not a very significant jump, but the adaptation and maintaining it is also very important. So, in Europe, the offshore wind is going to take a major role. Solar will be less, because in Europe, you know that availability of the solar

power or the sunlight is much lesser than other countries, especially, with respect to the Asian countries.

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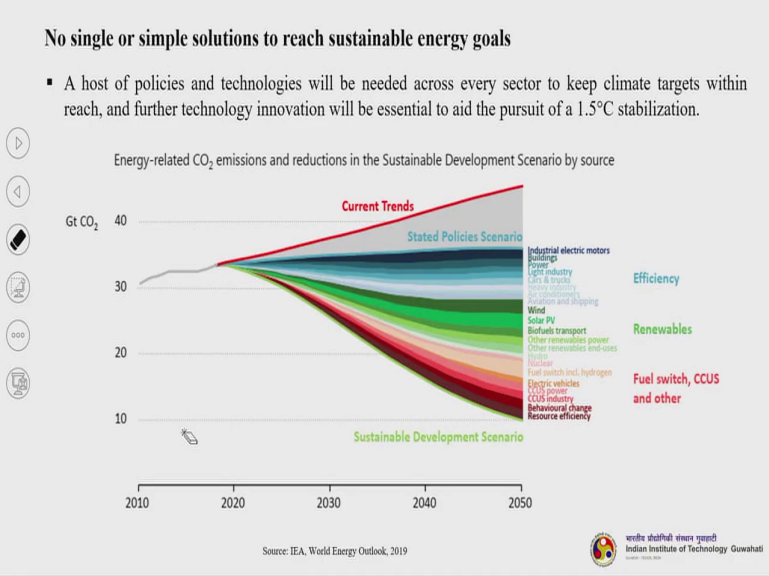

Having said that, there is no single or simple solution to reach a sustainable energy goal. Every country is putting their efforts. A host of policies and technologies are required and it is already there. Policies are there, technologies are also there. So to keep the climate change targets within reach, and further technology innovation will be essential so that we do not go beyond 1.5 °C. Though the Paris agreement says 2 °C, however most countries have agreed that will they will try to keep it not more than 1.5 °C.

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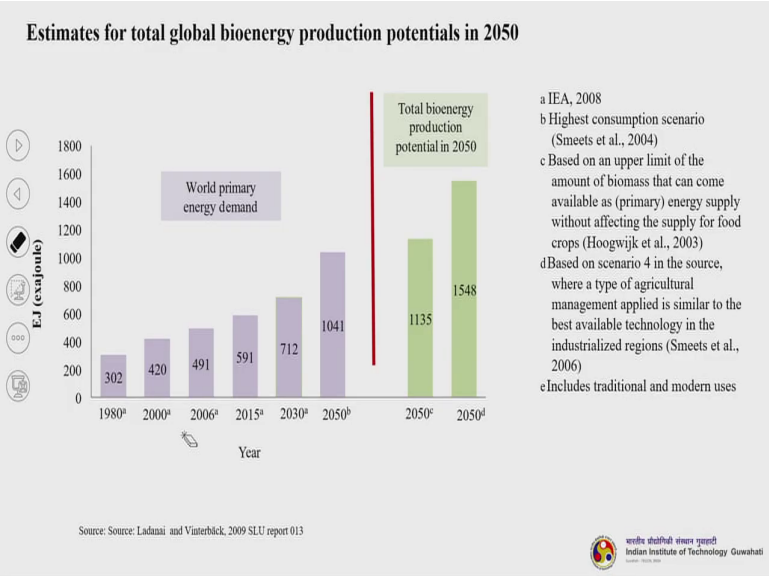

So before we end up our lecture we will quickly understand the focus of our course, i.e., the biomass energy or the bio-energy. Let us understand what is the bio energy potential across

world. So, you can see that in 1980 what it was, 2015 what it was, and 2050 what it will be. This is the worlds' primary energy demand. And this is the bio-energy demand (its projected). 2050^{c} and 2050^{d}, c is based on the upper limit of the amount of biomass that can come available as a primary energy supply without affecting the supply for food crops (basically from agricultural residues and all).

And d (which is this one) is based on the source where a typical type of agricultural management applied is similar to the best available technology in the industrialized regions. So, you can understand that there is a huge upsurge in the biofuels and bioenergy based supply.

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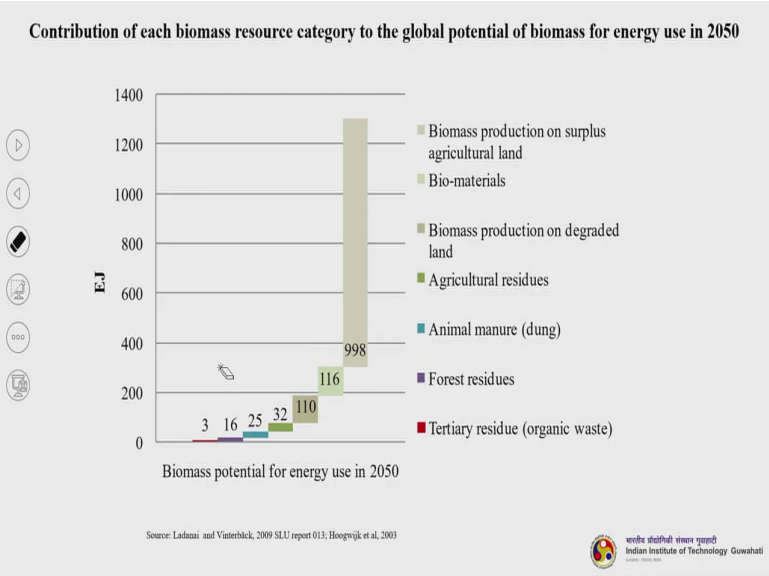

So this is the contribution of each Biomass resource category to the Global potential of biomass for energy use in 2050. What are these different types of feedstock. We can talk about feedstock. So, biomass production on surplus agricultural land, bio-materials, biomass production on degraded land, agricultural residues, animal manure (dung, where you go for biogas basically), forest residues, tertiary residues (organic waste).

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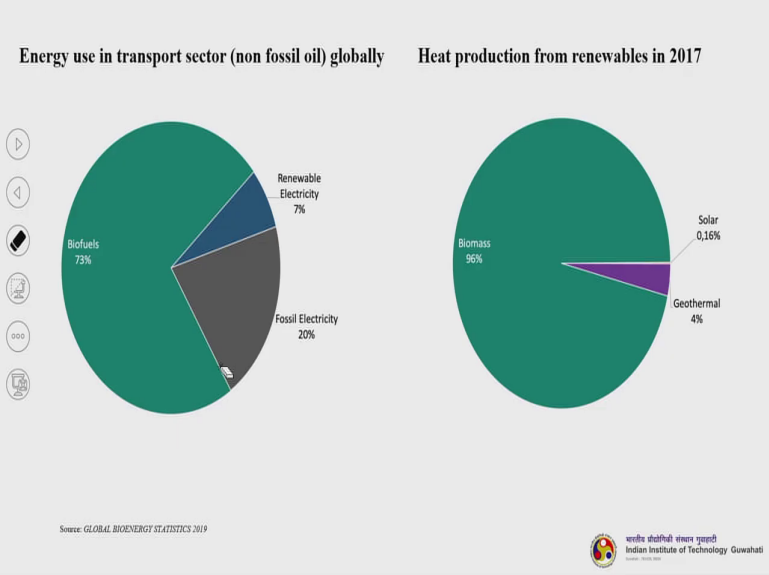

Then you can see that energy used in the transport sector, non-fossil globally. So bio fuel is going to take almost 73% beyond 2050. Similarly, heat production also 96% (it is a huge number) from renewables; this is 2017 data.

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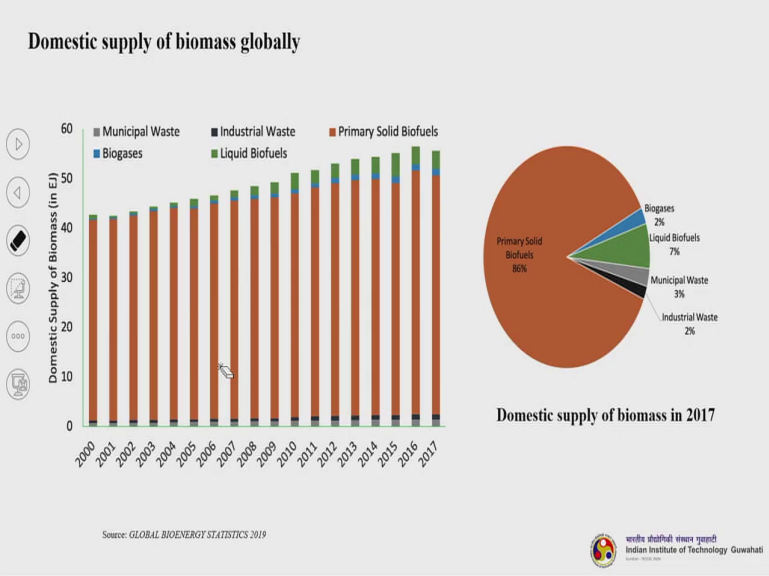

Domestic supply of biomass globally; so you can see how it is. So, primary solid bio-fuel is 86%, still it is same. Slowly bio-gas and liquid bio-fuels are coming into picture. So, liquid bio-fuels are gaining more importance because of its availability. Actually availabilities can be round the year rather (when compared to) than Biogas. Biogas, during winter has a depleting supply.

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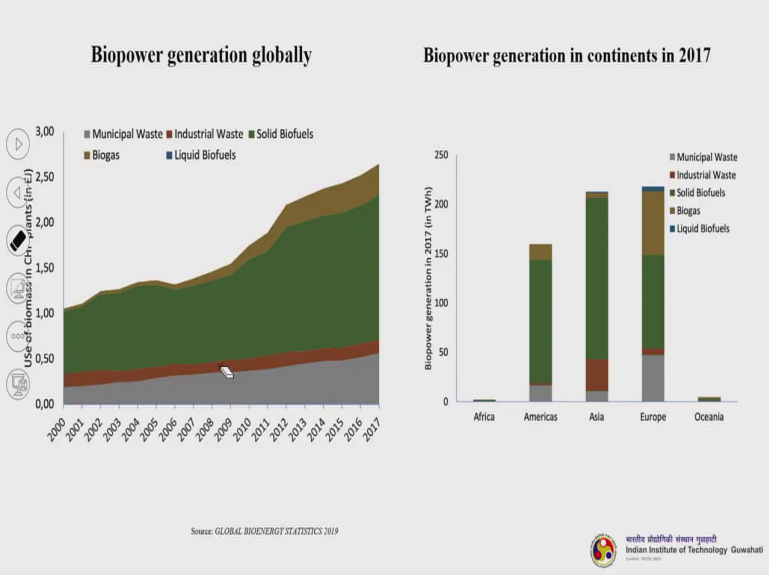

So biopower generation globally; you can see that this is till 2017. You can understand that the components that are being considered are municipal waste, industrial waste, solid bio fuels, biogas and liquid bio fuel. You see, solid bio fuel is taking the centre stage. Now slowly liquid bio fuel will also be coming into the picture, especially in the European countries. Whereas, in Asia it is very less, however, slowly the Asian countries also will catch up.

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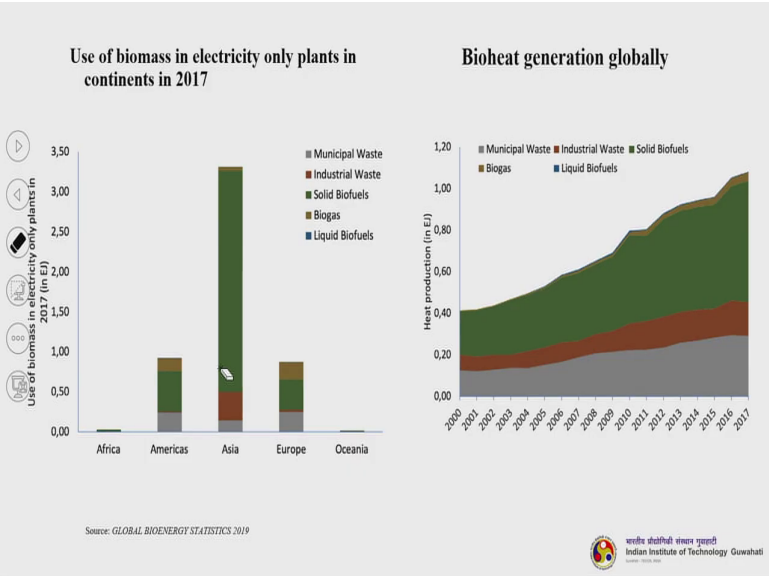

Use of biomass in electricity only plants in continents in 2017. You can see that in Asia for solid bio-fuels again there is a huge surge. And heat generation globally.

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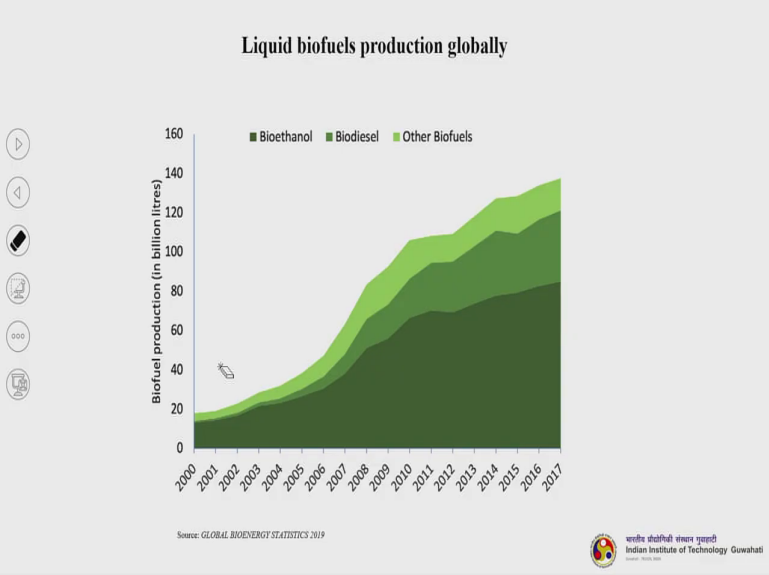

With this we will wind up. This is liquid bio fuel production globally. So you can see bio ethanol, bio diesel other biofuels. So this is bio ethanol, this is biodiesel. And then other biofuels. Other biofuels can be bio oil, it can be bio ethanol, it can be bio butanol and other bio fuels. So what we understand from today's lecture is that, no single or simple solution exist to reach the sustainable energy goals.

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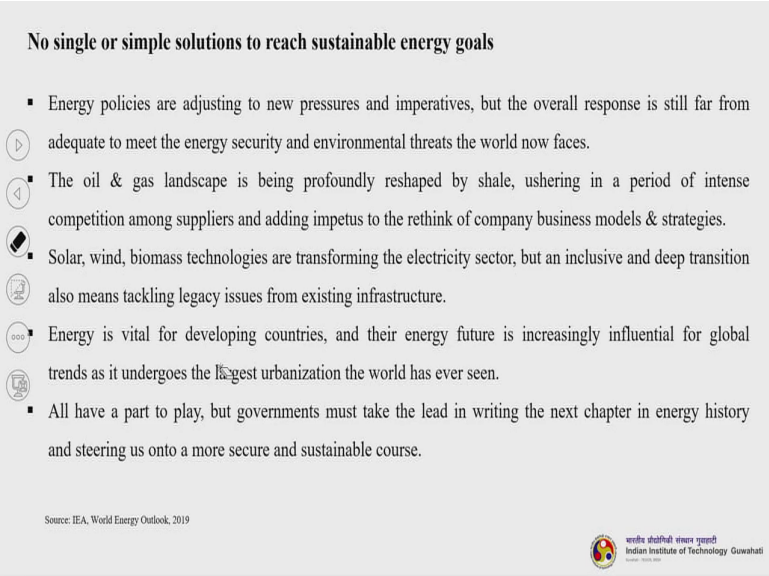

So, energy policies and adjusting to new pressure and imperatives, but the overall response is still far from adequate to meet the energy security and environmental threats the world now faces. The oil and gas landscape is being profoundly reshaped by shale, ushering in a period of intense competition among suppliers and adding impetus to the rethink of company business models and strategies.

Solar, wind, biomass technologies are transforming the electricity sector, but an inclusive and deep transition also means tackling Legacy issue from existing infrastructure. Energy is vital for the developing countries, and their Energy future is increasingly influential for global trends as it undergoes the largest urbanisation the world has ever seen. One classic example are the African countries. The way the urbanisation has taken place in African countries after 2000 is phenomenal.

And, all have a part to play but the governments must take the lead in writing the next chapter in energy history and steering us on to a more secure and sustainable course.

So, thank you students. Thank you for listening. So the next class will be again introduction. In the next class we will understand about Biomass, what is actually Biomass and what actually bio mass based Industries looks like and bio-refinery concept. I will explain the bio-refinery concept.

Thank you very much. In case you have anything to ask please feel free to write to me at kmohanty@iitg.ac.in or please post your questions in the NPTEL Swayam portal. I will be happy to answer that. So thank you very much.