INDIAN INSTITUTE OF TECHNOLOGY MADRAS

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NPTEL ONLINE CERTIFICATION COURSES

ECOLOGY AND ENVIRONMENT

Module on

Energy & Environment

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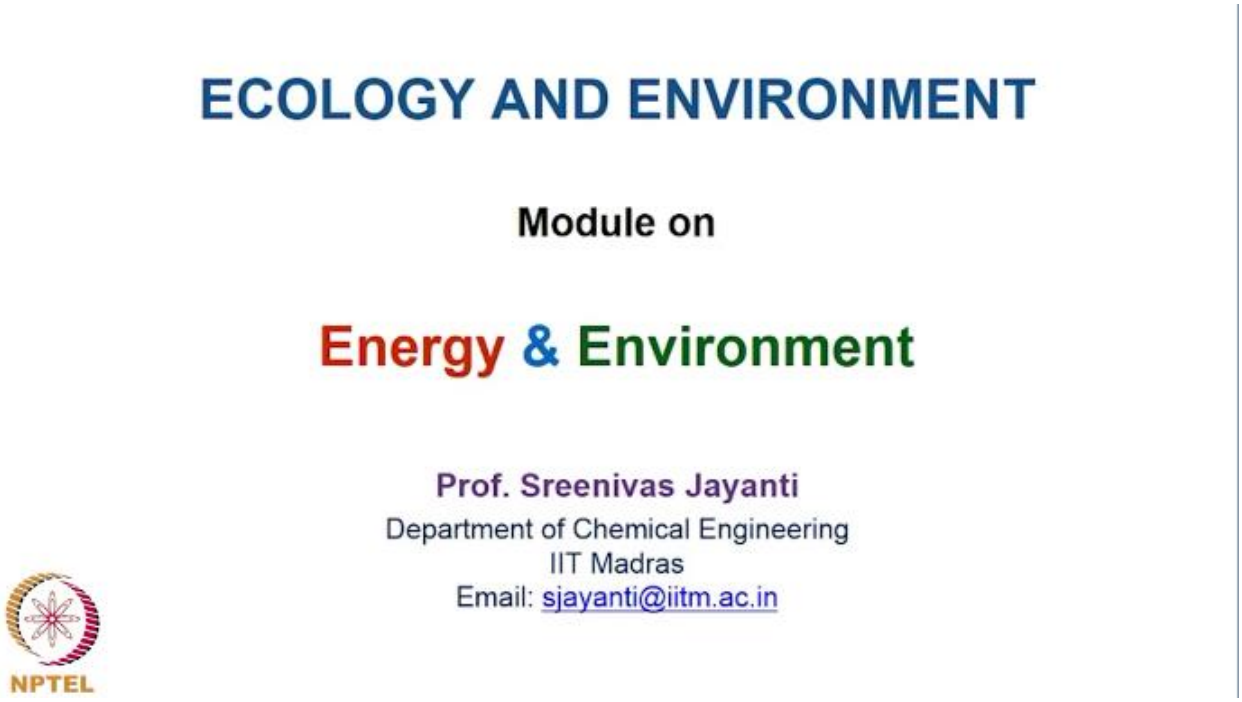
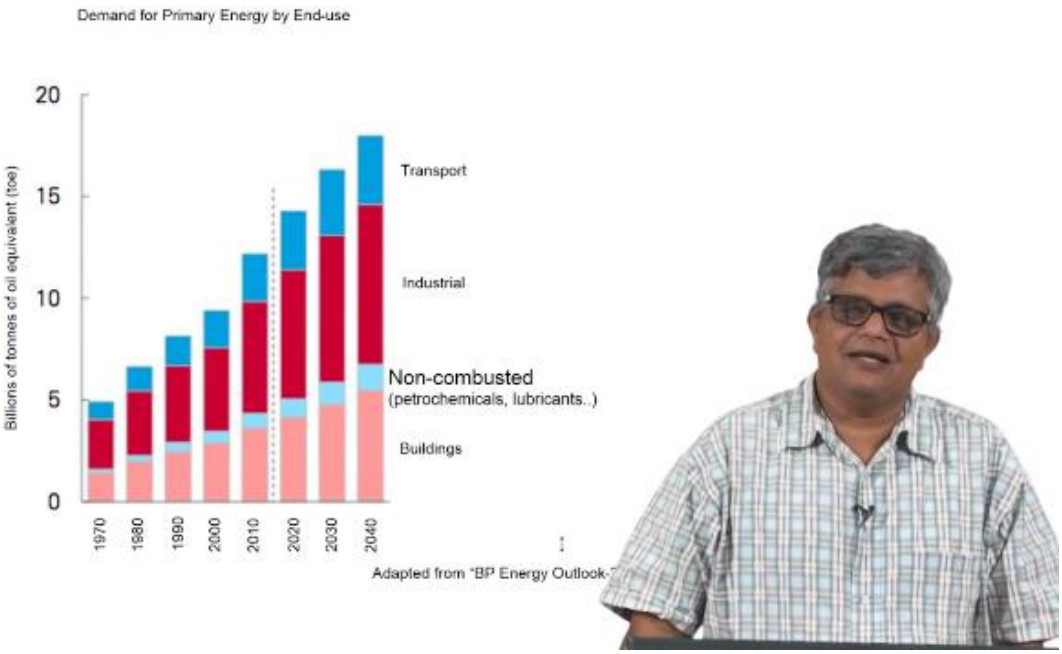




Welcome to the second lecture on the module on Energy and Environment in the course Ecology and Environment. My name is Sreenivas Jayanti. I am a professor in the Department of Chemical Engineering at IIT Madras.

In the first lecture, we discussed what we mean by the energy needs of man and how they have developed over centuries and millennia, and what are the needs of modern society. And we also looked at very briefly at where this energy is coming from, and we also saw the possible ill effects of using this harnessing this energy on the environment.

And now, we are going to take a fresh look at this energy and what will be the needs of energy? And how much energy do we need really? And especially because we know that harnessing energy also places stress on the environment.

So, we are going to start first of all with where the energy that we are extracting from the nature is going into in terms of our human society, and how it has been evolving over the past 40, 50 years. Here we have a slide where we are talking about the primary energy and how it has been evolving from 1970's and how it is likely to evolve over the next 20, 30 years. And especially how it is going into different uses by the human society. What we have on the Y-axis on the ordinate is billions of tons of oil equivalent, so it is not one particular form of energy, it is not one particular fuel, but all of those different forms of fuel and energy have been converted into the common denominator of tons of oil equivalent, TOE.

And what we have here is billions of tons of oil equivalent going all the way up to a total of 20 tons here. And we are distinguishing here four major uses of end users of energy. One is the buildings. Obviously we have for our house purposes, office purposes, and common living purposes, and also the roads and hospitals, all the service sector, all of that is there. And then we have an important aspect of the non-combusted form of energy; we made the earlier observation

that most of our energy is coming from fossil fuels. So, fossil fuels contain energy in chemical form and we extract it in many different ways, but we also make use of this fossil fuels for producing petrochemicals, lubricants, and other. For example, hydrogen is generated from natural gas, and this hydrogen is used in some other form to produce some other chemical or some other substances which the human society uses in some form. So, these are uses of energy for non-primary energy, non-use in the industry sector to fire their processes, but transport sector to drive the fuel, to drive the vehicles or for buildings here, okay.

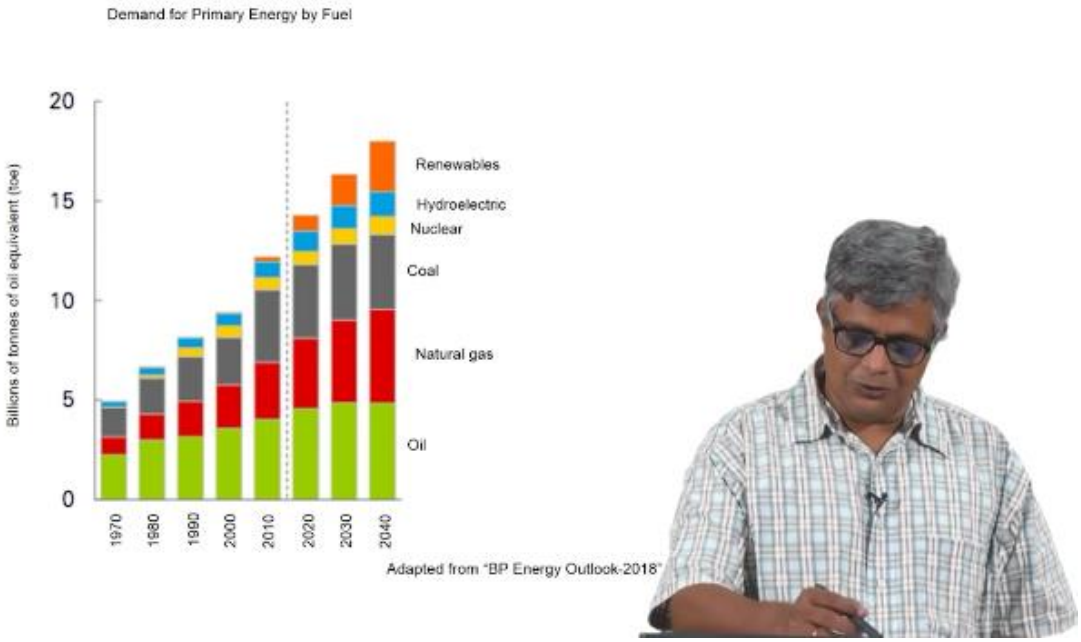
And then we have the industrial use, many industries produce many, many materials and devices that we use, and many of these processes require high temperatures, high pressures, very low temperatures, very low pressures, each of this requires a lot of energy. Okay. And so in order, if you want to make some computer terminal or some plastic thing, there is a lot of processing that goes on, and that processing requires a lot of energy, and that is where this industrial energy is going.

We also have transport or modern society has a lot of need for transport, we see an increasing number of vehicles every day, every week or at least every year on the streets. And then we all use vehicles for every small purpose, and then we also have exotic vehicles, promises of us being taken to the into the space, to the moon, maybe to Mars. All of which require a lot of energy, and so you have transport is another major consumer of energy. So, and all this constitute our future use of energy also, okay, so this is a kind of energy, this is what we need energy for and how it has been changing over the past 30, 40 years, is what is reflected in this.

So, if you go back to the 1970's, we have buildings, industrial use was the major part followed by heating and cooling purposes and lighting and all that within homes and offices and all that. In the factories and a small amount of thing for some products and then you have transport applications. And over the years, every decade each of this has been going, so not at the same pace, not in the same way, and you can see that industry, industrial consumption has not grown significantly here but here it has grown, and it is expected to grow at an increasing, at a steady rate in the next 20 to 30 years. And then we see transport sector increasing but depending on how for example the electric cars come up and then where we draw the energy from, how more, how efficiency evolves over this period, these trends may change.

And then we also have an increasing need for buildings as more and more people become more prosperous and then demand buildings and demand all creature comforts within that. We also have increase in needs. So, we can see a steady maybe accelerating increase for total energy among all these major sectors, and much of this is fueled, okay, by not by the economically developed countries but by recently developed countries like China, Korea, and by rapidly developing economies like India, Brazil and maybe Malaysia, Indonesia, and it is going to be fueled by countries which are still on the path of development, many sub-Sahara, and African countries. And all this, so these are the peoples who are going to require this increasing amount of energy. Okay, so, this means that although we know that energy generation is going to put a stress on environment, we see that demand is increasing even for the next 20, 30 maybe even 100 years. And so it is not going to fall so easily, so that is where the question of what stresses it imposes on environment and how we take it, how we tackle this is the real problem, so we cannot wish away energy, it is going to be needed by us, and it is going to be demanded by us.

And in terms of where we get this energy from because that fuel is important in terms of the kind of stresses it places on the environment.



Here we have, we are distinguishing in a similar way the total demand of primary energy of up to 20 billion tons of oil over this period from 1970 to 2040. We are distinguishing several different sources of energy, we have oil, crude oil, we have natural gas, coal, this have been with us from more than a century, and these have been the major providers of energy through this modern period periods.

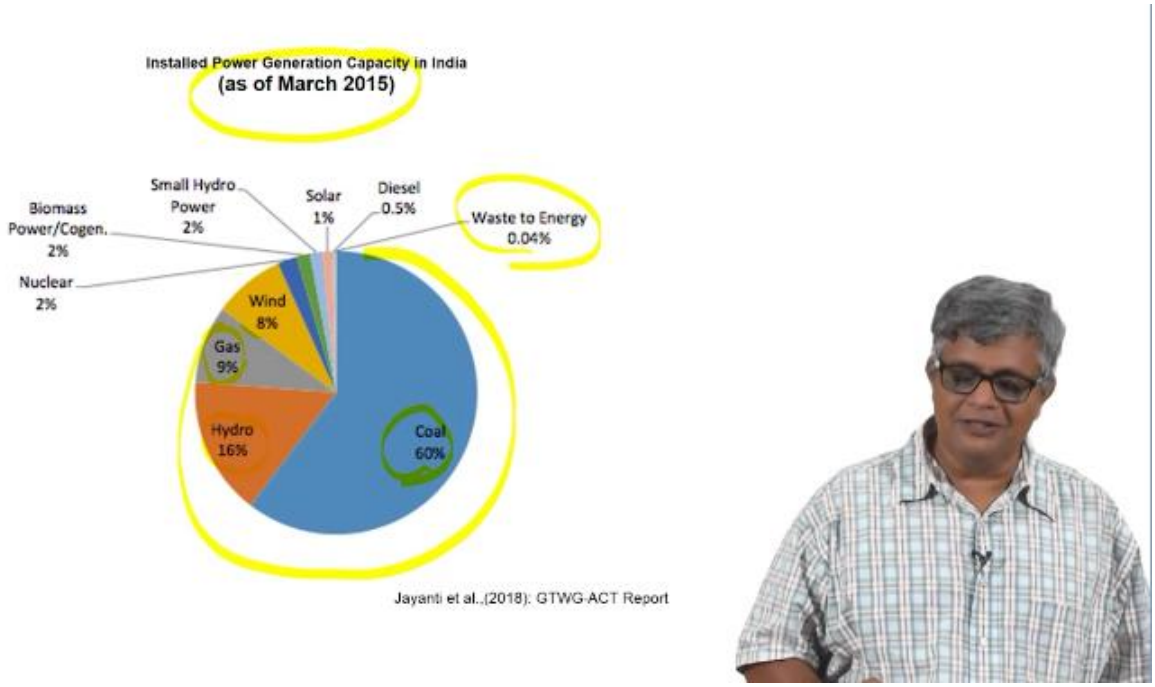
And then you have nuclear, a controversial fuel, hydroelectric which is also at one time seen as very clean fuel, efficient fuel, efficient energy generator, electricity generator, but nowadays it is myriad in many controversies. And then you have these renewables which are really giving us a lot of hope and promise. Okay, so if you look at this kind of energy sources, how have we been extracting energy from these sources over the past decades and what is likely to be the contribution of each of this.

If we have a contribution coming mostly from renewables, we are happy, because typically renewables do not have this immediate pollution that we have mentioned like SOx, NOx, particulates and all that, and they also do not produce other pollutants like greenhouse gases like carbon dioxide, methane, and those kinds of things. So, renewables are the clean sources of energy, we would like to take more and more from it, but what has been the trend over the past 50 years because the ill effects of fossil fuels have been known to the to the modern society from more than 40, 50 years. Okay, so right from late 1960's and 1970's people have been sensitized at least scientist have been aware of the climate change possibilities, but we are now much more concerned about those things, and in that context we are looking at where we are getting this.

So, coming back to this figure here, we can see that in 1970 we have about 5 billion oil tons, billion tons of oil equivalent of energy produced, and we are at this stage in the somewhere close

to 2020, so now we are producing about 14 billion tons, so our energy consumption has increased by more than factor of 2, close to factor of 3. And with all the concern that we have about energy and stresses on the environment, one would expect, one would hope that the energy consumption would be decreasing, but all projections this is not, this is one of the many projections of energy usage and need and all of them say that energy consumption is going to go up at least in the near future, at least up to 2050. And they all hope that eventually, it will go down and maybe even stabilize and then even come down somewhat. So, we see an increasing energy demand and increasing energy from conventional sources, we know that oil is not good, natural gas is not good, coal is not good, these are all fossil fuels and generate a number of pollutants including short-term and long-term kind of pollutants, but we see them increasing. The amount is increasing absolute times, and the proportion is not decreasing significantly over the next 20 years and even 30, 40 years. And we see that increasing energy share is been taken up not only by renewables here, renewables are definitely increasing the share, but there is not a rapid decrease in the fossil fuels. And despite so much of talk and so much of development and awareness and harnessing of renewables over the past decade especially, we see that the amount of renewable energy share is very small in the total energy consumption. So, we have a picture, later on, I think which shows that as of, in the year 2016, so that is a couple of years ago when we had full statistics, the amount of solar energy production, contribution was less than 1% globally. So, it is a very small amount, so renewables do not play a big part in our current generation consumption of energy, and it is forecast that this will not be producing contributing so much, even in the next 20, 30 years. So, the amount that they can contribute is is rather small.

So, this is one of the facts of energy consumption that energy consumption is going to grow for the next 20, 30, 40, 50 years and many projections say that fossil fuel role is going to decrease proportionately, but in absolute quantities in terms of how many billions of tons of coal is consumed and how many billion tons of oil is used, those numbers in terms of those raw numbers most of them will be increasing. Even nowadays when there is so much talk of decommissioning coal power plants we do not really know whether the next government in some country will follow that particular thing or maybe they will reverse the decision. Those kind of things are there, and it also depends on what kind of power plants you are shutting and how many you are shutting and what is the size, and what kind of consumption pattern there is and so on, so we can, we are saddled with the problem of having to generate more and more energy for our coming generations, for our economic prosperity, and that of other claimants on this earth, and we have no getting around at, okay.

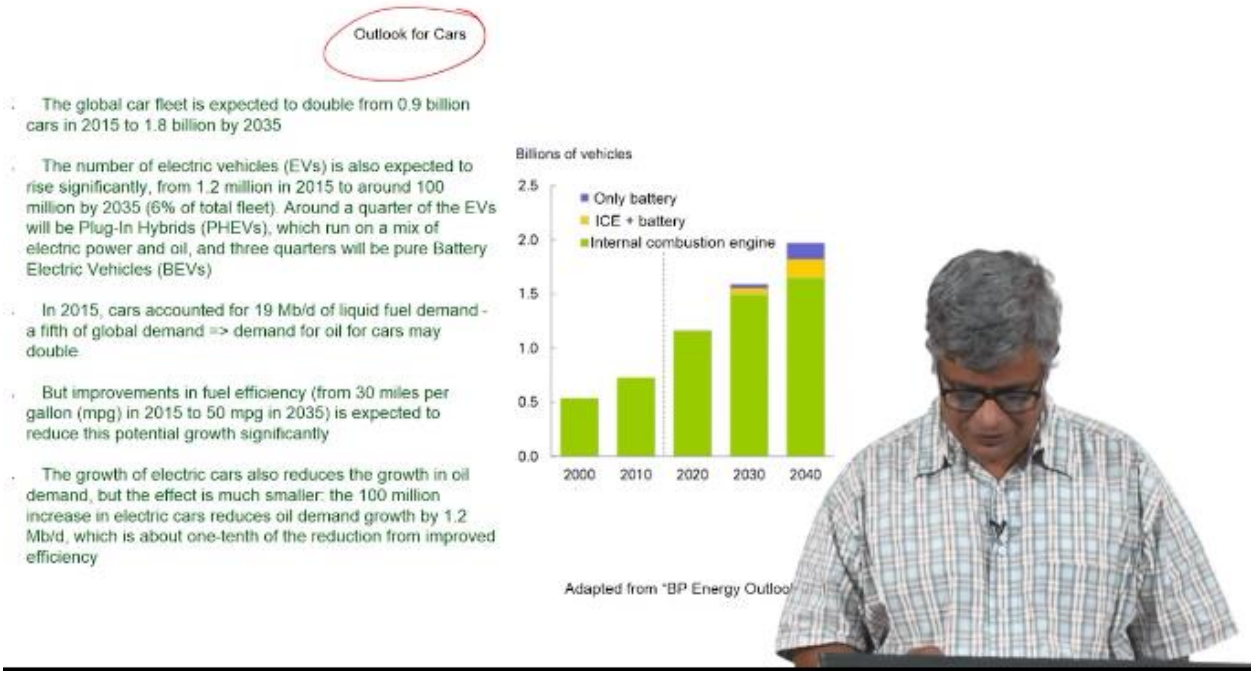


And we also have to live with the fact that more and more of this energy is coming from fossil fuels. And we have already seen this particular picture here, about the dependence especially in India on fossil fuels and I mentioned in 2015 the installed power generation capacity for solar is only 1% and typically with wind and solar type of power generation capacity, the capacity utilization factor is only about one third to one fourth, so that means that if you have a 100 megawatt solar power plant it's equivalent about 30 megawatt coal power plant or a nuclear power plant, so the installed capacity is different from number of maybe billions of units of electricity that are produced, so power, energy generation is different from installed power capacity, there is a vast difference between number of the sources. Fossil fuels are good from that point of view that you can hope to get 80% of the rated power from the fossil fuels, whereas conventionally new renewables like solar and wind will hardly give you 25 to 30% of the rated power in terms of energy realization.

The need for energy does not come only from power generation, we have also seen a significant proportion maybe 20% of the total energy need coming from the transport sector. And transport sector is even more crudely imbalanced among different sections of the world society. There are some countries which have as many cars as the number of people, and there are some other countries where the number of cars is maybe 1 in 100, okay. So, we know that there is a so much of pent-up demand for transport sector for personal transport, vehicles from many parts of Asia, Africa, and other places, and so it is expected that that demand for transport and therefore the demand for fossil fuels which drive this transport is going to be increasing more and more. And transport applications of fossil fuels generate different kinds and also similar kinds of pollutants like what we have seen, we have seen carbon dioxide, carbon dioxide is also generated from use of fossil fuels for transport applications, but in many cases incomplete because of incomplete combustion you can have carcinogenic hydrocarbons that are produced, and NOx is produced and maybe some ozone is produced, and very fine particulates and aerosols may be produced. So, there are other kinds of pollutants that emerge from transport use this fossil fuels.

So, there is a there is a lot of concern about this unbridled consumption of oil and governments are helpless in reducing the dependence of on this oil especially for transport and automobile applications. So, out of this, there is a ray of hope these days for the past few years in terms of electric vehicles, clean energy sources, okay, it is such that it has made the automobile industry topsy-turvy as we see here in this slide. We have the automobile industry, and I put a reflection of this to show it is topsy-turvy, and it is being appended by major headlines like these from major automobile manufacturers, Volkswagen to go all electrical by 2020. All Volvo cars to be electric or hybrid from 2019, and between 2019 and 2021 the firm will introduce five 100% electric models, Big EV plans from Renault, Nissan, and Jaguar Land Rover to make only electric or hybrid cars from 2020. So, there is a huge revolution that is expected to take place in terms of electric vehicles, okay.

So, this is good in a way if it happens, when it happens, as it happens, especially from the immediate environmental problems that we have like the smog, the pollution, the breathing problems that we have from all those things there can be relief. But in terms of the economic climate in which these kinds of ambitions can be realized, in terms of long term effects of these electric vehicles and the sustainability of this, there are still major questions, and that one really needs to answer those kind of things. And so this there we can get a feel for this in terms of a short extract again from this BP Energy Outlook 2017, not 2018, and this is outlook for cars, okay.



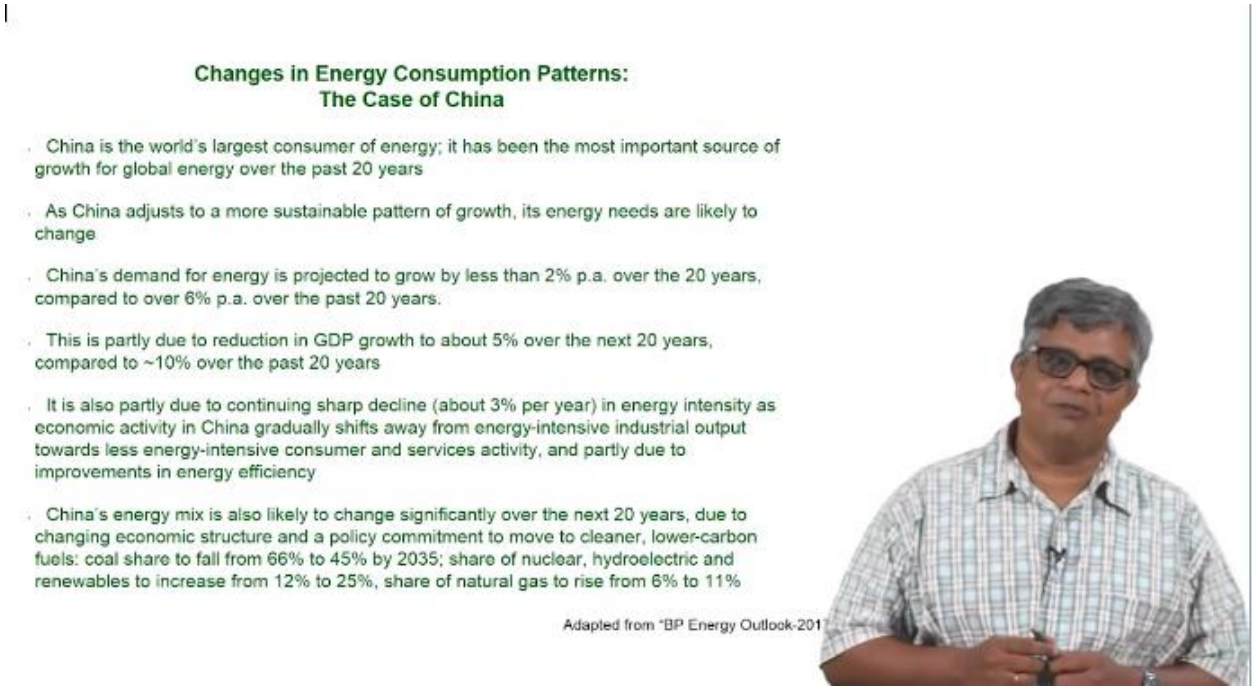
So, here we have much more recent statistics going from 2000, 2010, 2020, 2030, 2040 and here you have billions of vehicles, so you can see vehicles are in terms of billions and human population is also in terms of billions. So as per this we have, we will have by 2040 one car for every three citizens or maybe for four people on earth. Current carpool fleet in 2015 is 0.9 billion cars are there, and it is expected to double to 1.8 billion by 2035. So, the number of cars is going to double and if all of these were to run on crude oil derived fuels then the amount of pollutants produced from these things will also increase tremendously. We hope that with newer regulations, stiffer regulations some of the conventional pollutants will be decreasing, but especially the greenhouse gas emissions especially carbon dioxide will continue to increase. So, that is one thing, one aspect of it, but the picture is not so simple, and I made the mention in the first lecture that each of this is a complicated issue and some of that complication is something that we can see here in this-this thing. So, one would expect that if the, as a number of electric vehicles increases we expect that the emissions will come down and all that, but that picture is not so simple as that, okay. Because car companies are continuing to increase their efficiency of conversion of chemical energy into motive power, and the mileage in terms of number of kilometers or miles traveled per liter or gallon of fuel, okay. So, that has been steadily increasing, so it is expected that improvements in fuel efficiency in cars will make cars go from 30 miles per gallon in 2015 to 50 miles per gallon in 2035, because of the pressure exerted on the automobile companies to reduce emissions by the society and by the governments, okay.

So, that means that gas-guzzling cars are no longer to be sold, and if they are sold, they will be sold at very heavy taxes and so on. And so, because of this increase in the mileage of the cars we expect that even though the car population is doubling from 0.9 to 1.8, we expect significant reduction in the additional consumption of oil, okay. In 2015 cars accounted for $19 billion per day of liquid fuel, okay, and if we double it, it should go up to 38 but because of the fuel efficiency and all that it is going to come down to, the additional amount is going to come down to only about 2 to 3 million barrels a day, okay. But projections are, for example by 2030 you have large amount of conventional internal combustion engines and then a small amount here of internal combustion plus battery which is known as plug-in hybrid vehicles. And only battery vehicles, which is roughly shown in that indigo color, purple color kind of thing here and that is a small percentage, by 2040 is going to go up to higher value, but it is expected to go from 1.2 million in 2015 out of 900 million, so that is the percentage of electric vehicles as of now is less than 1%, and it's going to go from 1.2 million to about 100 million by 2035. So, almost a 100 fold increase, some estimates put this at 300 million, but even 300 million out of 1.8 billion is still about one-sixth. So, in the next twenty-thirty years we are still going to have a large number of internal combustion engines going around, partly because of the age factor and partly because these are the most convenient, and partly because the new electric vehicles do not measure up to the standards expected by automobiles, of automobiles by people, in terms of the range, in terms of the ease of operation, ease of the fueling, and all those issues.

So, it is expected in 2017 that 60% of the total fleet in 2035 will be electric vehicles, okay. So, and around a quarter of this electric vehicles should be plugin hybrids which means that which run on a mixture of electric power and oil, so that is the internal combustion plus battery here, and so they will be producing still some of the pollutants associated with the internal combustion engine. Whereas the rest of them will be purely battery vehicles, so provided the charging energy from the battery is free of pollution, that is again is a question mark. You will have reduced amount of pollution here. But the complicating or interesting thing is that if we have a large number of influx of electric vehicles produced by the very same automobile companies that are producing current generation of internal combustion engines, then the resources spent on development of this electric vehicles will be taken away from the resources spent on fuel efficiency and so on. So, as a result of that the fuel efficiency or the miles per gallon of conventional automobiles will not go down to 50, maybe it will go down to only 40. So, that means that the corresponding savings in oil consumption will not be as much. And so even though you are gaining some of the emission efficiencies in terms of electric vehicles, the overall effect of this, of electric vehicles on emissions is going to be pretty small. So that is something that, that shows the linkage, the connection between the demand for energy and the use of energy and what that demand and meeting the demand in newer and cleaner ways put on other sectors of the society, in terms of the investment, in terms of the skills, in terms of materials, processes, and effort. All of this are diverted from some other thing and brought towards this, and because of this something else changes, the earlier benefits will not be coming up.

So, in that sense, the effect of the growth of electric cars is supposed to be very small. The 100 million increase in electric cars reduces oil demand growth by 1.2 million barrels per day which are about one-tenth of the reduction from improved efficiency. So, this is where I say that the energy issue, okay, and the environment issue and the measures that we take as individuals, as

societies and all those things these are not complicated issues you press here, somewhere else the pressure will come in some other things, so in that sense that there is a complication that arises from this.



If we look at one more example of this complication here, in terms of changing energy consumption patterns and we look specifically at the case of China. China is a very important role model for us to understand this linkage between the society aspirations and the energy consumption and the consequent effects on the environment and also how the energy usage develops, all these things are, the case of China is an interesting example. And China is also the largest consumer of energy now. So, there is one more good reason for studying energy, okay, so China is the world's largest consumer of energy, it has been the most important source of growth of global energy over the past 20 years. So that over the past 20 years China has been driving the demand for energy, it has been buying up all kinds of resources renewable and non-renewable for the past 20 years on the global market, minerals market. And as China adjust most sustainable pattern of growth, its energy needs are likely to change. We have mentioned that economic prosperity and energy consumption are strongly linked. And with economic prosperity, the population patterns will change, and that puts different kinds of demands on further use of energy and demand for energy, and that itself plays out in a different ways, okay.

And as the economic prosperity increases, in the early days, you can have double-digit growths, but you cannot continue to have double-digit growths for a very long period because then you will be hitting limits coming from natural resources. So, in the case of China, we can see that China's demand for energy is projected to grow by less than 2% per annum over the next 20 years compared to over 6% per annum for the past 20 years. So, we are talking about the energy demand, right throughout the last two, three decades or more. China has been, having a double-digit growth, so that is more than 10% growth for 20 consecutive years, 25 or 26 consecutive years. China had a double-digit growth in economy, in GDP, so that meant also a very strong demand for energy. And you could see that as 6% over the past 20 years, but now that it has reached a certain economic level now that per-capita energy consumption of China is more than

the world average and three times the per-capital energy of India in terms of energy consumption. Its demand for further energy is reducing, and it is expected to be more like 2% per annum for the next 20 years compared to 6% for the past 20 years, and this is partly due to reduction in GDP growth to about 5% over the next 20 years compared about 10% over the past 20 years. So, there is the linkage between the energy consumption and GDP.

It is also partly due to continuing sharp decline about 3% per year in energy intensity, okay, so energy intensity is a concept where what is the amount of energy that you are spending in order to produce so much of GD, how many dollars of GDP can you get per so many megajoules of energy that is spent. And that depends on how you are generating that money, if you are generating that GDP dollars by making process which are heavily energy intensive then your energy intensity of the GDP will be high, okay. But as the society matures and as the labour market becomes costlier than some of these energy intensive, labour intensive process will go to other countries, and so you will be looking more at the services and other kind of things which do not require as much of energy as some of the manufacturing processes take. So, that means that you may continue to increase a GDP but not at the same rate of energy demand. So, this reduction in energy demand, significant reduction 2% to from 6% is due to continuing sharp decline in energy intensity as economic activity in China gradually shifts away from energy-intensive industrial output towards less energy intensive consumer and services activity.

It is also partly due to improvements in energy efficiency, okay. So this is also, and the very same pattern of energy demand and then economic prosperity and the shifts in energy-intensive process we have seen in the many European countries and the US and other things, and we are seeing that in China and we are seeing some of those things in India, okay. So, this also tells us what kind of pattern of energy demand will be there in India for us.

China's energy mix is also likely to change significantly over the next 20 years. So, energy mix is where we draw energy from what source we have to draw from, and that depends partly on what the source is that that are at your disposal, what is the cost in terms of dollars, and what is the cost in terms of environment, how much you need in, how you can allocate. So, all those issues coming to picture. And this change is partly due to changing economic structure and a policy commitment to move to cleaner and lower carbon fuels. So, China has jumped on to the world commitment towards reducing carbon dioxide emissions, we will see more of that in another lecture, and as a result of this the dependence on coal is likely to be is going to become lesser and lesser.

Recently China was consuming 46% of the total world production of coal, so that is every other kilogram of coal was being consumed in China, okay, this is set to go down. And coal share in the energy mix is going to go down from 66% to 45% by 2035, it still is a large part 45%. Share of nuclear, hydroelectric and renewables is to increase on 12% to 25%, China is the world leader in terms of renewables, but even that kind of thing sustain for the next 20 years is going to increase the share maybe to 25% only and that is not coming just from renewables but also from hydroelectric and especially nuclear. And share of natural gas, natural gas is a much cleaner fuel compared to coal, and that is going to increase although it is a fossil fuel and GHG, greenhouse gas emission fuel, its share is going to increase some 6% to 11%, okay. So, why this is so, and all that is another part of the story, we won't really look at that, but we can see a change in the way

that energy is consumed, and partly because of concern about this greenhouse gases, partly because of the changes in the society, and so many things. So, these are some of the factors that come into the demand for energy, and how it changes and how it is likely to emerge over the next short term of 20 to 30 years and over the next long-term of 50 to 100 years. And there is a lot of concern about short-term immediate pollution from energy generation using a number of fuels, and there is also equally strong concern about longer term, 50 to 100 years in terms of the global warming scenario. So, these are the two issues that we are going to look at in lecture 3, to look at what are the concerns from the environment point of view of energy generation and energy demand.

Thank you.