INDIAN INSTITUTE OF TECHNOLOGY MADRAS

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NPTEL ONLINE CERTIFICATION COURSES

ECOLOGY AND ENVIRONMENT

Module on

Energy & Environment

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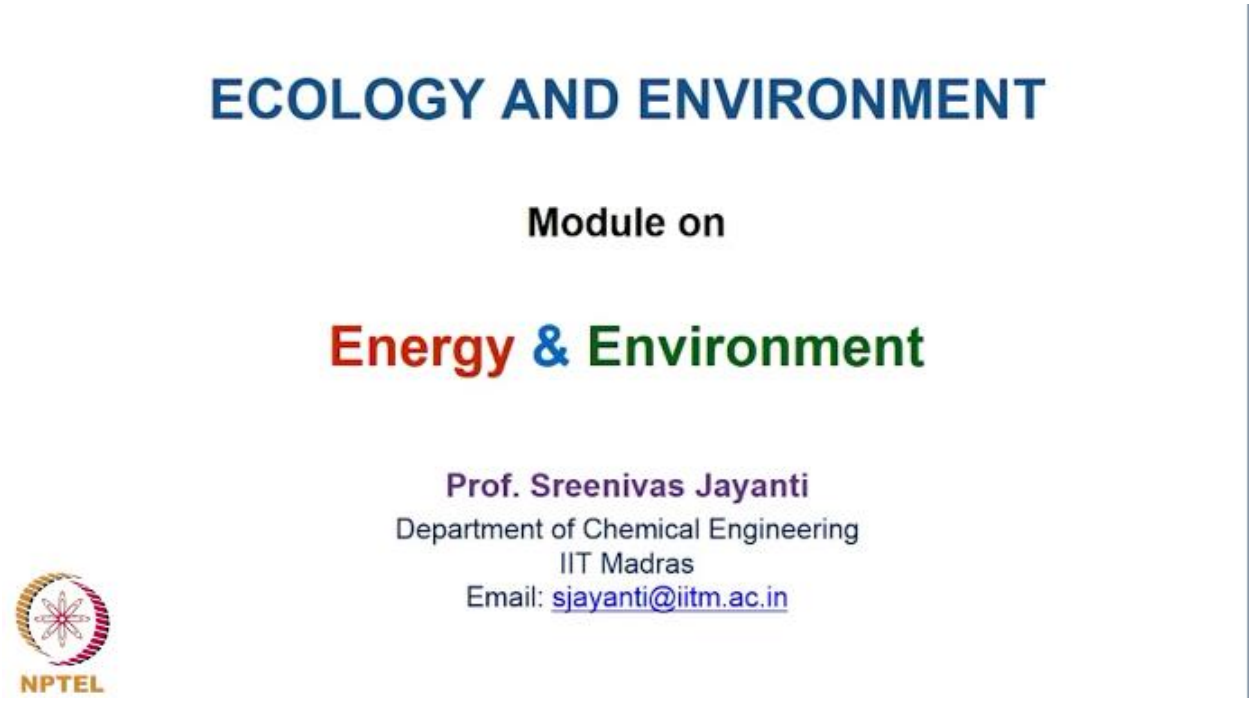
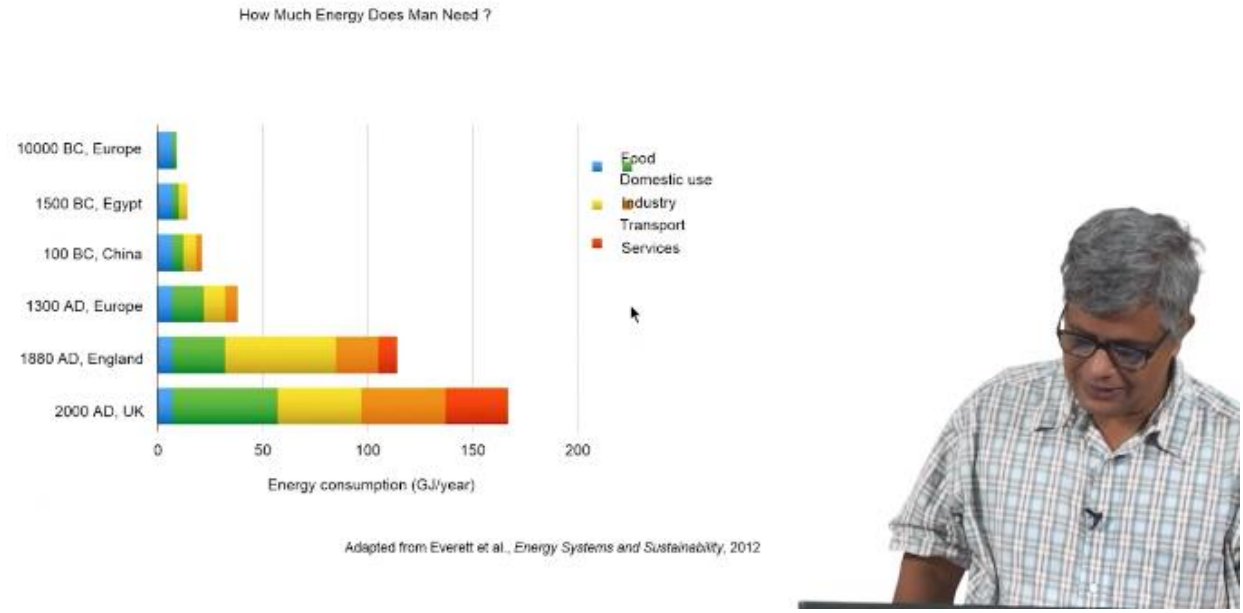


Welcome to the course on Ecology and Environment, and specifically to the module on Energy and Environment. My name is Sreenivas Jayanti, I am professor in Department of Chemical Engineering at IIT Madras. My email address is given here, in case you want to contact me for doubts, queries, comments etcetera. And we are going to discuss specifically the linkage between energy and environment, both of which are very important to us.

In this module roughly divided into 5 lectures, we are going to first of all look at what is this link connection between energy and environment? What are the main issues there? And what are the important factors? And followed by a brief lecture on what is the energy? Where it is coming from? And what are the needs of the society? And then closely look at what are the effects of energy harnessing on the environment? What stress does energy harvesting put on the environment? Why there is a conflict between this energy and environment?

And then we are going to look at - given that our environment is already stressed, we are going to look at what will be the future needs of energy, and how we can extract the energy from various sources in an environmentally friendly way. Okay, we are going to look at this in two different aspects, one is at the world level and secondly at in the Indian context.

And finally, in the last segment of this module, we are going to look at what we can call as the energy mix for specifically for India, and what we need to do in India so as to have both energy and environment for not only our generation but also for the future generations to come. So, that is overall structure of this particular module on energy and environment as part of the ecology and environment course.



So, let us start with essentially what is a need for energy? And how much energy does a man need? Okay, so when we talk about energy, we talk about energy in various forms, for the lighting, for example, for running various devices that we have, for transport application and also for growth of agriculture and other things that are essentially needed by us, by the human society, and number of other items which are part of our daily life and also the number of other services that are also part of our daily life. So, when we look at the historical, pre-historical needs of; man's need for energy, we have some interesting trends that we can see here.

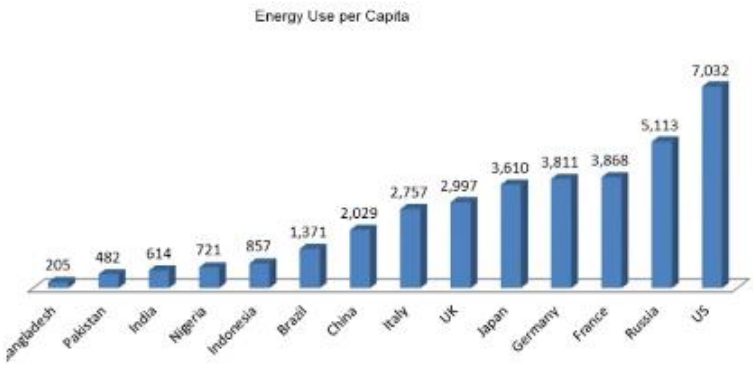
In this slide we have on the, here we have different eras going all the way from 10,000 BC to current 2000 AD. And here we have different colored segments indicating different ways in which energy is being used, for example, we have blue color representing food, the green color representing domestic use, the yellow color representing industry, orange color representing transport, and red color indicating services. And on the X axis here along the horizontal line, we have the amount of energy that is going into each of this different uses of energy over a period of time. If you look at maybe the pre-historic man in Europe, 10,000 BC, at that time, there is a need for human needs in terms of the food and the other things, and that would be slightly less than 10 gigajoules per year. You have the unit here, gigajoules per year, so, that is per annum, so

many 10 to the power 9 joules is what is needed, and that blue color is what man needs in terms of calories, so as to sustain his daily life and all that. And since man has not evolved that much over the past 12,000 years, that part remains the same all the way from 10,000 BC to 2000 AD. Okay, but other parts which support human life as we see it and as we have evolved over this particular period have undergone drastic changes, and this has called for vastly different amount of energy over this period.

We can see that the green color domestic use is very little in 10,000 BC, but 1500 BC maybe at the height of Egyptian civilization, a slightly more 100 BC China that is also well developed, but may be isolated society, independently grown society. And by then you not only had significant component of domestic use but there is also some development in industry and some requirement for transport. We have all these things coming by 100 BC in China. And 1300 AD Europe is the, maybe around the dawn of industrialization or dawn of modern civilization and there is a lot of connectivity, kingdoms have been developed and lot many more people are there, and lots of activities, human comforts have started gripping in, and so you see a significant amount for domestic use, maybe for heating and cooking and all those things. And also industries beginning to take shape and increased amount of transport maybe from city to city by ordinary people is also becoming common, and 1880 AD is the height of industrialization in England you can see a big amount of increase here for big amount of increase here for industry and also much larger amount here for transport, and services are beginning to also take significant amount.

And the modern man of our generation in 2000 AD has not only a small component for basic human needs fairly large amount of close to 50 gigajoules per year for domestic use for all our air conditioners and fridges, TV's and sound systems and all those things, and a large amount of industry, industrial use but which we see is less than what it was at the height of industrialization that is because of the efficiency gains that have happened over this period and also the way the industry has developed. Okay, so we are moving from very heavily energy intensive industries to less intensive industries.

And then large amount of transport-related energy because the common man can also spend significant amount of travel in all forms. And then finally you have a burgeoning service sector which is also calling for large amount of energy. So, the modern man has close to 170 gigajoules per year of energy compared to less than 10 gigajoules per year for the pre-historic man. So, that means the factor of 17 times the energy requirement is there per person over the years, and we need so much more, and what is the another big difference between 10,000 BC and 2000 AD is the number of people that are there. So, this has meant this big increase in the demand of energy by the modern human society. Okay, but this particular demand is not uniform across the world, it has never been uniform, and even now it is not uniform, although we are much more open and closer to each other in this world, spread all over the globe here.



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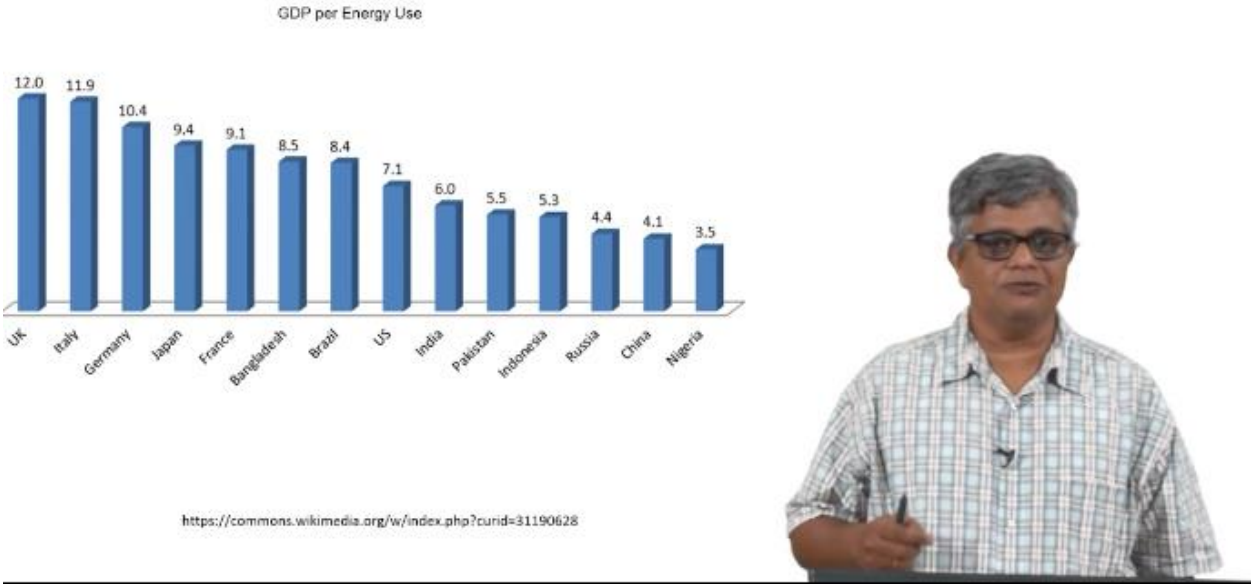
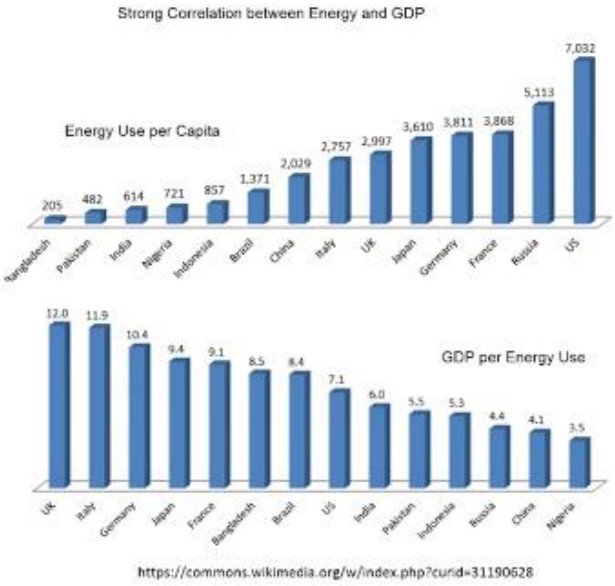
We still have many huge disparities, and this actually has a very strong impact on, not only what the current needs of the human societies for energy, but what will also be the future needs of energy. Here we have energy use per-capita, per person what is the amount of energy usage here and you can see in relative units there is a wide disparity between Bangladesh which has 205 and the US which has 7,000, and India is 614, and China is 2,029. So, that means that India is consuming about one-third of China's per-capita energy use. And many of the European countries and Russia and the US have much larger, maybe 10 times larger the per-capita energies, and this is an important disparity, and this disparity is accentuated by other aspect of energy as to why we need energy and why we will not have energy.

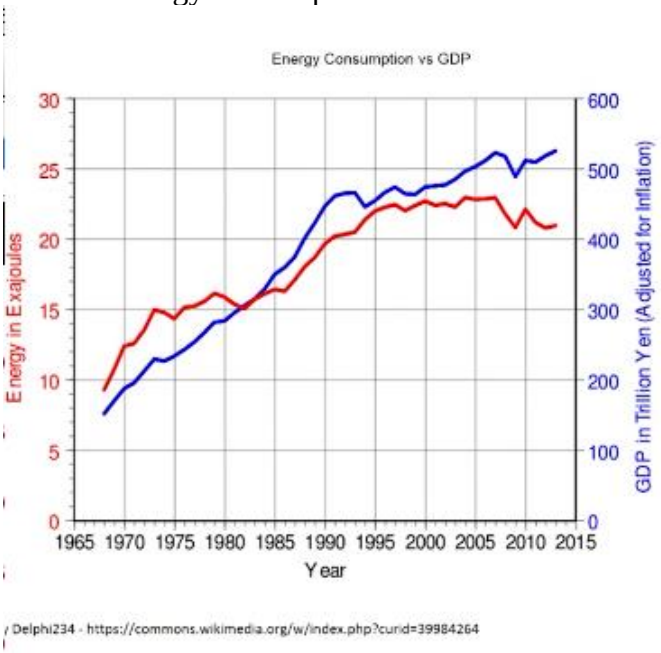


And here we have another interesting statistic, where we are looking at gross domestic product. Okay, so essentially the income generated by a country and in terms of in relation to the amount of energy that is spent. Okay, so how much, how many joules of energy produces, how many how much of dollars of income. Okay, so that is what we are looking at,.The higher the income that is generated per unit energy that is spent, the more will be the prosperity gained, to be gained by spending more energy.

And what we see here, there are certain European countries here which have very high values 10, 12 like that, but Bangladesh which was consuming very little energy is not far behind, it is only 8.5 versus 10 here, and countries like US 7.1, India 6, Pakistan 5.5, here this particular thing indicates even Nigeria which is 3.5. So, that means that in terms of energy usage per GDP is not that much differential as it is in terms of raw energy consumption per head itself.

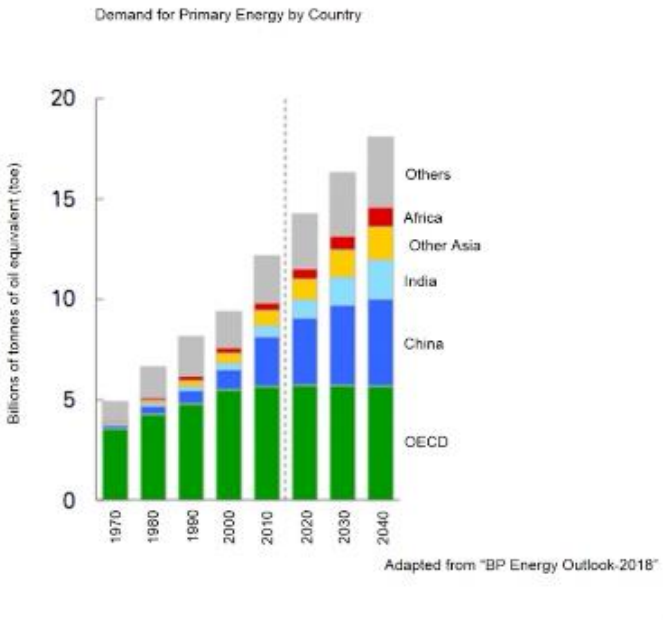


What this means is that when you put this together, this would actually translate that first figure would also translate into the GDP per-capita. And what this means, therefore, is that these countries have very low GDP and these countries have very high GDP, these countries have high economic prosperity, and these have very low economic prosperity. This particular linkage between energy consumption and the GDP also comes out in different figures.



This is one particular figure spread from 1965 to 2015. So, almost 50 years of data, and energy usage here in Exajoules and GDP in trillion yen adjusted for inflation. So it is a good figure that we can compare yen with yen or dollars with dollars, or dollars of yen of 1960's can be compared with yen of 2015 on this figure. So, this is adjusted for inflation, and what we see is

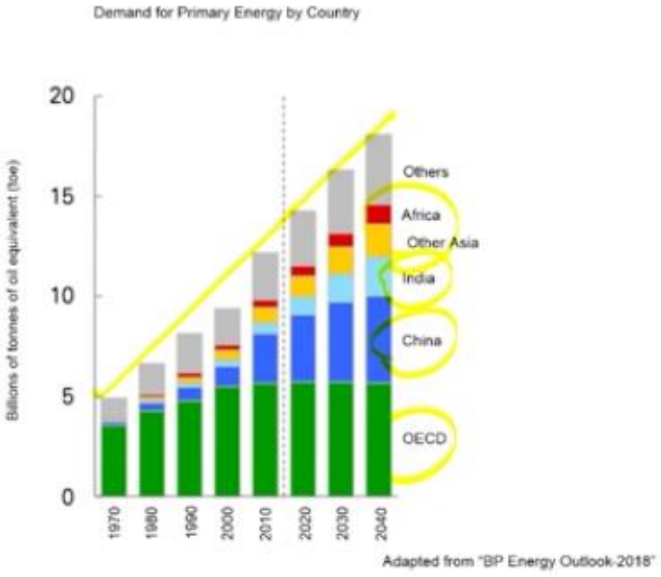
that in the blue color is the GDP growth, and red color is the energy growth. So, over this 1960's all the way into 1990's, 2000 and maybe even more, there has been a steady co-increase of both energy consumption and GDP. So, there is a strong correlation between the GDP of a country and the energy that the people of that particular country consume for various pieces, okay.



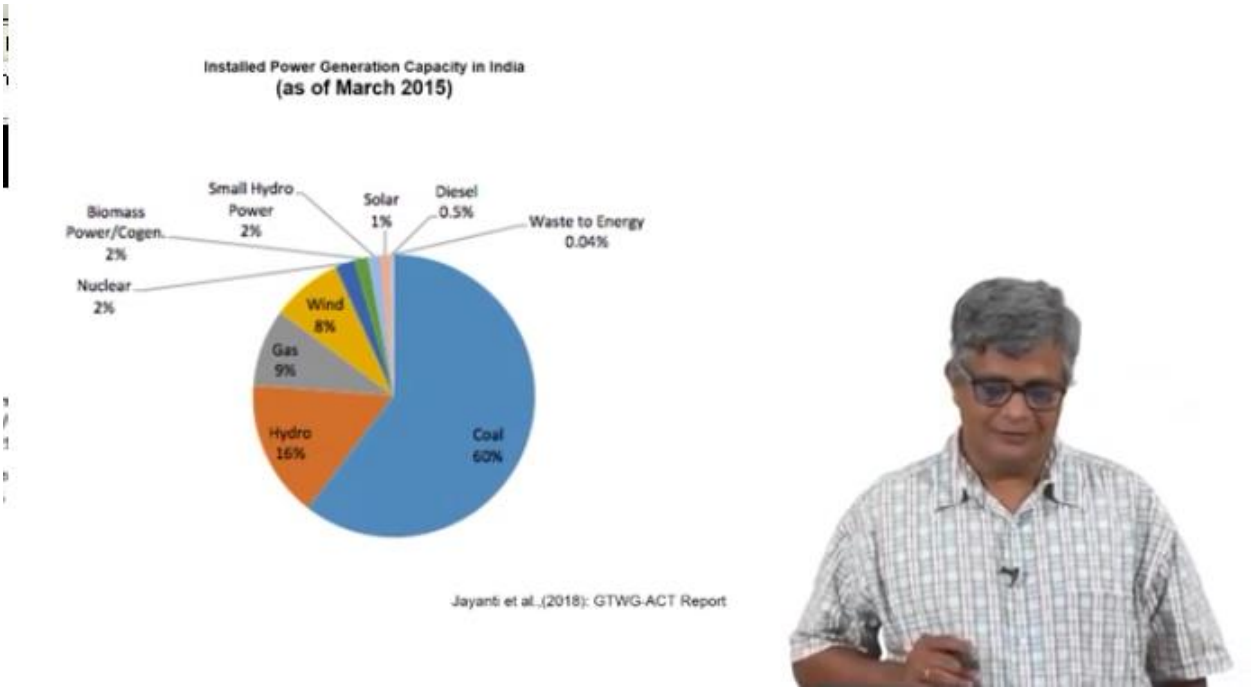
So, and this is where the importance of what the energy is needed in the modern society, and then what has been the trend, and what will be the future needs all this comes here. And you can see here in this particular slide, we have demand for primary energy by country over the period between 1970 all the way to 2010, 2015, which is the current times and projected demands up to 2040. So, this is taken from energy outlook by British petroleum which produce an annual report which gives the energy outlook stretching for the next 20 years or so. And so this has been a continuing exercise, and we can see certain trends here, and these are important for us in terms of what we need in future and how we are going to get that thing and why we also need.

Here we have OECD countries these are economically developed countries, and then we have distinguished here is China, India, other Asian countries than India and China, we have Africa, and all others Middle-East, Latin America and all those. So, you can see here through the 1970's and 1980's, 1990's even 2000, the economically well-developed countries, the OECD countries had increasing amount of energy. But since then it has been leveled off, and it is expected that the energy demand from this economically developed countries will be will not increase significantly in the next 20 30 years, and it may even decrease. There are a number of reasons for it, and we will not go into that particular thing. But what is important and what is also interesting here is the energy consumption and the projected energy consumption by China. In 1970s India and China were consuming about the same amount of energy here, but there is been a rapid industrialization by China for the past 3-4 decades, with sustained double-digit increase in terms of GDP for 20-30 years. Now it has leveled off to some extent, but still, it is rapidly growing economy. And rapidly growing economy needs lot of energy because of the linkage between GDP and energy consumption. And we can see that trend here, 1980s a small amount, 70s and

80s, 90s, 2000, 2010 these are all actual data, 20 it is still going up, 30 it is still going up and 40 going up. China alone is going to consume as much energy as most of the OECD countries put together. China currently is the largest energy consuming country in the world, followed by US. And so the rapid industrialization sustained over 2-3 decades has actually meant that China needed a lot of energy and India is in the same phase of development these days. And you can see that India's energy needs have been increasing and it is expected to increase much more much more. And India too is going to take up large area of energy here, and this is only over the next 20 years or so. And this is followed by other Asian conditions who are also in the same wave of development, era of development or decade of development as us in terms of Malaysia maybe the Koreas and Vietnam and these kind of countries. Africa will be lagging behind, but even its energy needs are going to grow up. And other countries their energy needs are growing up slightly but not best that much. But what we see is that world energy need, demand is going to increase. And it has been increasing like these and the increasing tendency, demand is not coming from OECD counties, developed countries, it is going to come from India, China and other developing countries, okay.



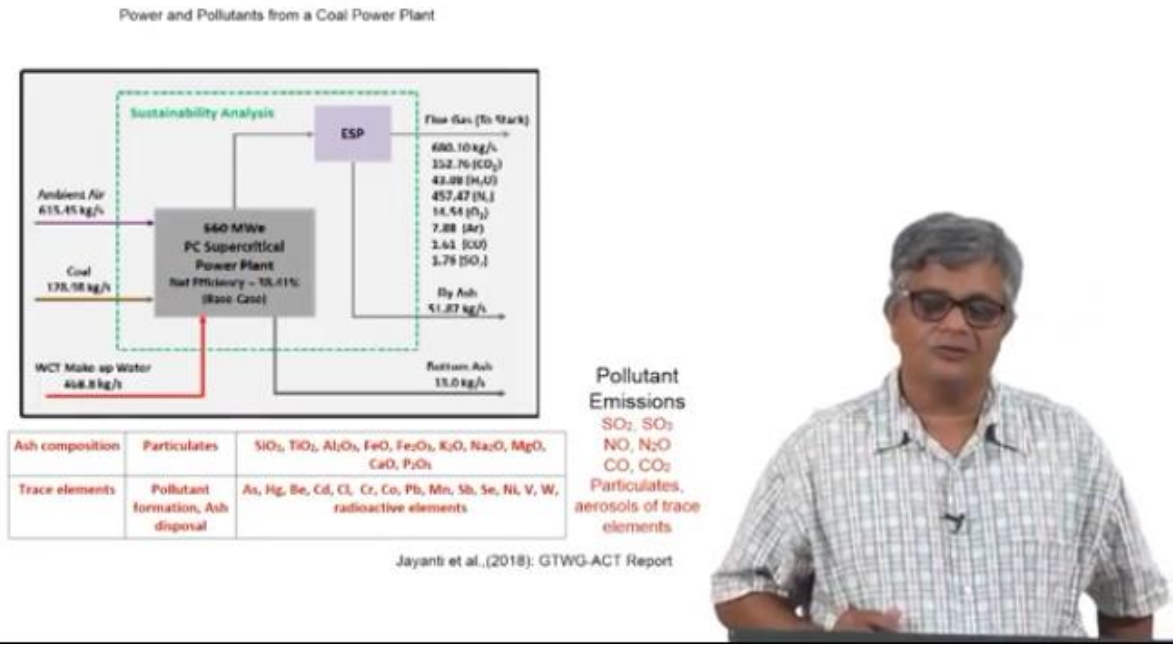
So, these countries are have been consuming small amount of energy per capita, and they are going to demand more and more, and this is driving the hunger for energy, and this is going to be a continuing trend, okay. So, we will come back to these things later on.



If you look at power generation in India, power generation, electricity consumption is is very important in a modern society, and electricity is a premium form of energy, it is used by industry for GDP, it is used by people for most of their daily lives. And energy spent on power generation is an important part of the whole debate on energy and environment, nowadays. So, as of March 2015, these are data taken from the ministry resources of India, so these are in a way official here. And we see that 60% of energy, electricity generation as of March 2015 in terms of capacity to generate has come from coal for India, and hydro is 16%, gas is 9%, wind is a renewable energy, most friendly form of renewable energy is 8%, and then nuclear is only 2%, it is increasing slightly but not by very much, biomass power and cogeneration for electricity production is also a very small element.

Small hydro, there is so much talk about it, but that is also a small component, solar, this is 2015, but even now it has not really gone up that much. And so waste to energy we have at city level we are usually concerned about this waste to energy but in terms of actual electricity generation that constitutes a very small component.

And what we see here is that significant part of this India's energy, electricity is being generated by fossil fuels, and this has been, this is one of the problem areas for us in terms of justifying this particular thing.



So, what is the problem with power generation using fossil fuels? Here we have a schematic diagram of what actually comes out of a coal power plant. We have about 130 kilograms per second of coal is being used to produce 660 Megawatt electric power, 660 Megawatt of power is maybe one of three power plants supporting the needs of power for a big city like Chennai, and its surroundings and industry. So, it is not a big amount but it is not a small amount, and so when we burn this much of coal and we have said that coal is a primary supplier of electricity in India, it has 60% of capacity, electricity generation capacities is fed by coal, and more than 70% of electricity generation is also from coal, okay. So, this produces the useful power that we have, that we want which is the electrical power, but it also requires water, it also produces ash, as bottom ash, and then it also has comes out as fly ash. This bottom ash comes out in large lumps, fly ash comes out in micron size particles, both are a problem for us from a disposal point of view.

In addition to that, we are also generating lot of gases, out of which we have carbon-dioxide, we have carbon-monoxide, sulfur-dioxide, what is not indicated here is also nitrogen oxides. In addition to all these things which are in large quantities, coal in its raw form, as mineral form also contains trace elements, minuet quantities of number of these other elements including mercury, arsenic, cadmium, chromium and even radioactive materials, okay, these are very minor things. But if we keep on burning coal, some of these go along with the bottom ash, some of this go along with the flue gas, and then one goes directly into the soil, the other goes directly into the atmosphere, and people will be affected in both ways from it, so this is a cause of environmental problem.

So, in the quest for electrical power which is needed for our GDP generation and economic prosperity, by depending on coal we are producing large quantities of pollutants including Sox's, sulfur-dioxide and related compounds, nitrogen oxides, carbon monoxide, carbon dioxide, particulates, aerosols of trace elements, okay. So these are very important pollutants, and so this

is also one of the banes of the earlier cities of Europe, and current cities of China and India where a lot of coal is being consumed for power generation.

We hear of so many ill effects in terms of the environment and the breathing problems, the visibility problems and all those things coming because of the pollutants that are emitted by this coal guzzling power plants. We also have some of these pollutants coming from gas-fired and oil-fired things, so when we use fossil fuels there is a possibility of formation of these and other pollutants, and this is where the nexus, the linkage between energy and environment comes. When we want to generate power, we are also generating pollutants, pollutants which are polluting the air around us, polluting the water bodies around us, polluting the soil around us. And on top of that, there are demands for water, there demands for resources and all these things. So, there is a very strong linkage between energy and environment, and this is something that we should be aware of when we look at the demands of the society, demands of society and other people for economic prosperity, and also quality of life gauged by the environmental condition, and the quality of water and air and other services. So, there is a strong linkage between these two. And so, we, but the question of, we cannot forsake energy because there is going to be an environmental problem.

At the same time, we cannot pursue economic prosperity relentlessly forsaking the consequent effect on environment, and none of these issues is very simple. So, we are going to look at in the next few lectures, we are going to take one by one, and look at what is the bigger picture, and final picture, and what is a texture of each of these things. And then we are going to look at what kind of solutions can we have, in terms of making the two conflicting requirements of energy versus environment into energy and environment. So, we will meet again in lecture two.

Thank you.