Non-conventional Energy Resources
Prof. Prathap Haridoss
Department of Metallurgical and Materials Engineering
Indian Institute of Technology, Madras

Lecture - 05
Energy Consumption

In this class we will look at energy consumption. Very key to our entire discussion on non conventional energy resources, is to have a good feel for where is this energy consumption occurring and what are various factors associated with it.

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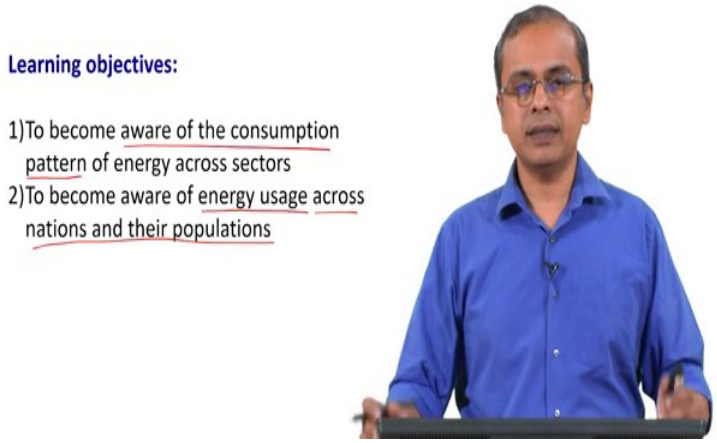

So, for this class our learning objectives are as follows: we should become aware of the consumption pattern of energy across sectors. So, consumption pattern; first of all what are those major sectors where energy is being used, and some sense of you know what is the consumption pattern across those energy sectors; whereas more energy being consumed, where maybe we should pay more attention and perhaps we are not paying as much attention to some sectors, and as supposed to some other sectors and so on.

So, that is something that we would like to look at in this class. And so, we would like to become aware of consumption pattern across various sectors. In addition it is also of interest to become aware of energy usage across nations, and their populations okay. So, energy usage across nations and their populations is again something that is of interest to be to become aware of. This actually gives us a some more holistic view of what is this

energy spectrum that we are talking about that is getting consumed, because as I have said through out and I continue emphasizing this through this course.

This big picture is very critical for us to have in the back of our minds; when we look at individual technologies and that will also give us sense of you know, what is the likely impact of that technology where is that technology likely to be employed, and which of those technologies should be pursued. If somebody gives you a new technology that they you know encourage you to look at, then what are factors that you should you know consider.

Before you make some decisions saying this is something that we should pursue. So, therefore, it is good to have these things in the background you know what is the energy being consumed for across which sectors it's being consumed for, and how is it being across nations and their populations. So, these are learning objectives for this class and as we as proceed through the class, I will highlight the points associated with this learning objectives ok.

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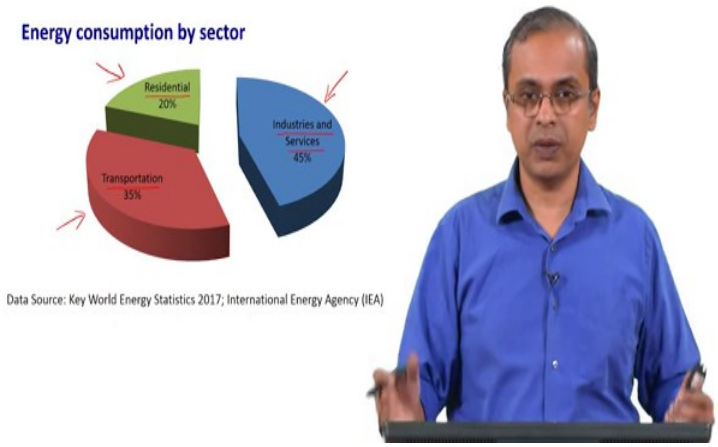

Okay so if you look at energy consumption across sectors, the three major sectors across which the energy is being consumed. And the first is this industries and services sector that you see here, the other is transportation sector and third is a residential sector.

So, these are three sectors across which energy seems to be consumed. So, if you just look at the numbers we have about 45 percent being consumed by the industries about 35 percent by transportation. So, between the two of them about 80 percent, and the remaining 20 percent is being consumed by residential sector. So, this itself I think is data that we should think about for a moment and consider it, and see what implications it has see what bounce our ideas on you know energy, energy usage, energy conservation clean energy etcetera with as against this data that you see on your screen.

So, the first point is you know when you look at energy and clean energy in common popular literature. So, you read articles in the newspaper you read articles in magazines you visit websites that talk about clean energy, most of the time you hear it in the context of transportation. So, we hear it significantly in the context of you know you know electric vehicles. So, this is I think the image that sticks to our mind, when we say clean energy electric vehicles is something that sticks to our mind.

So, there is a significant emphasis on transportation in the common discussion of energy, and you know how you can improve the ways in which we use energy in terms of the cleanliness of the associated energy, what are the technologies that are employed; always in all these things we tend to talk of transportation; we talk of you know electric vehicles, electric cars, electric buses, and this is the context in which we look at it we even look at pollution from aircraft and so on. But I think if you look at this data, one thing that really strikes out I mean strikes you as being very prominent, which we don't see in common discussion, is the fact that the industry and services sector is actually consuming 45 percent of the energy.

So, somehow in common literature we don't see this emphasis on the aspect associated with industrial use of energy. But it stands out there as you know in fact, the largest fraction of energy being consumed across all nations in the industrial sector, it's in the 45 percent that you see there almost you know approaching half the energy that we consume in the world is being consumed by the industrial sector.

And. In fact, I will draw your attention to those the data that I kept pointing out earlier that you know GDP is linked to energy usage, I keep pointing that out and that is you know some kind of a representation of how well a nation is doing, how well it is you

know progressing people keep drawing your attention to GDP, and GDP is linked to energy usage.

And the link comes because of this fact that industries are using, literally close to half of the energy, that is being consumed by those countries and that is the reason why you see this linkage and that emphasis. So, when you talk of energy when you talk of alternate forms of energy, and alternate forms of generating energy and supplying energy etcetera. If you find a way in which this can become applicable to the industrial sector, it makes a huge difference and surprisingly most of the time we are not talking about it much; we are mostly talking about transportation sector.

There is a there are two reasons for this. So, the first reason is that transportation is something that almost all of us see personally on a day to day basis. So, we have it in our homes I mean we have vehicles in our homes may be two wheelers maybe four wheelers different types of vehicles, we have we have available at our disposal in our homes, in our street, on the roads, we sometimes use public transport.

So, almost every day all of us are using some form of transportation. So, I think when somebody talks something relative to transportation, it really sticks in our mind okay. Not at the same time that is a very large fraction of industries that around in the world. However not each one of us is not necessarily working in a petrochemical industry we are not, which one of us is not working in a steel industry and so on. So, what we don't necessarily work directly in those industrial setups.

So, we are doing all sorts of different jobs. So, very wide fraction of a population, may be may be involved in completely different you know activities, which may not be directly linked to an industry in the conventional sense of what we think of as an industry; you know where you have this huge machines generating different kinds of products, producing different kinds of products, assembling them etcetera and they are giving out different you know emissions from the plant and so on.

Many of us are not directly associated with those industries, we are doing different kinds of you know livelihoods we are living, likely we are pursuing likelihoods which are of different kinds not necessarily linked with industry, but all of us almost all of us are going to use transportation in some form or the other on a day to day basis, and that is why whenever the discussion centers around transportation when the tell you there is an

alternate vehicle out there, that send a new vehicle has been released pretty soon, you see it on the road I mean those of us who are curious about transport and different kinds of you know cars and motorcycles and two wheelers around.

Possibly have an eye out see, oh you see that new car on the road or that's an electric vehicle that's a different kind of vehicle things like that. So, it you know relates to us and we relate to it much more closely, then we relate to an industry. So, supposing someone were to say there is a new power plant that has been set up in some place said 300 kilometers from your home, it is unlikely that most of us will make the trip of 300 kilometers and go and see the plant. And even if you do go and see the plant, chances are you will not be allowed inside the plant because they will they have security restrictions lot of other safety issues and so on.

So, they are not going to let you in. So so, therefore, it's sort of stays out of the public psyche, but if you look at this plot, 45 percent of the energy is being used by them. So, in the grand scheme of things when you look at alternate technologies non conventional sources of energy, you have to bear in mind that you will make a significant impact; if you have a way in which that alternate source of energy can be adopted by the industries ok.

So, that is something you have to keep in mind. So, as we look at you know even in our following class, we will look a little bit more closely at the industrial sector and what they do where do they need the energy and so on. And you will feel you will find that the it has its own peculiarities, it is not as easily addressed as perhaps you can address it the transportation sector. So, it has its own peculiarities and for instance one peculiarity I can point out is the fact that, industrial set ups typically need huge infrastructural investments.

So, if you see a industry that has been set up a typically they have put in a massive amount of infrastructure you know cost have been borne by in during the set up of that, industry and the expectation is that it will last for you know 50 years 100 years may be you know 150 years till it becomes obsolete at in some fundamental sense right. So, that is the way it is going to be.

So, if you go and see an industry today, chances are that plant was 30 years ago it was set up 50 years ago etcetera, when much of the technology that we are currently talking

about didn't even exist. Of course, as those plans you know go through their lifetime, the people who work in those plants, people who are in charge of those plants are continuously modernizing those industries. It is not that they are sitting with you know really old outdated equipment, they are modernizing those equipment as time goes by, but that takes its own time, it has its own process it takes its own time and there maybe some critical parameters, critical machinery associated with the industry which they may not be able to that easily change.

Simply because it is so central to the plant, you basically have to you know dismantle the plant and reassemble it if you are going to change that part of the industry. And they may even do it, if it makes economic sense and if there is some compelling reason to do so. But, generally speaking they have to balance various factors, while making a decision on how much of a change they want to make into that plant. And therefore, it is likely that the plant is not necessarily running at its most efficient best, it is also likely that it is not running in the most environmentally friendly possible manner that it can it can ever be run.

So, they will move in the direction, they does definitely a push in the direction, but how far they go will depend on various circumstances. So, that is something peculiar to the industrial setup, we will explore it in much greater detail in one of or immediately succeeding classes. So, we will see that, but just at the moment its interesting to know that this is the issue with the industrial sector. Then we see the transportation sector, as I mentioned this is something that is very visible to us. We see it every day, we see it all around us and we have wide range of vehicles.

Now, again transportation sector has lot of interesting issues associated with it. So, for example, if you take a vehicle let's say you take a car and a typical automobile car that is there in many households let's say, it is very interesting to do some analysis on you know what is the fuel consumed by the car being used to do, right. So, you say gave 20 you know whatever you know say 15 kilometers per liter something like that it gave right 15 kilometers of travel per liter and so that's the efficiency and then you think of a new car, which is you know 17 kilometers per liter, 20 kilometers per liter 25 kilometers per liter. So, that's the way we keep pushing the car's boundary, we try to you know feel go that it has done something good.

You will also hear in many you know international settings that, they are trying to encourage people to do something called car pooling which means more than one person is travelling in the car. So, the point that you have to remember when you talk of an automobile is that when you compare a two wheeler, two a car, two a bus etcetera you have to keep in mind what is the weight of the person and the vehicle versus the weight of the vehicle. And so, in one of later classes we will do a little more detailed analysis of it, but just to give you an idea typical car is about 1000 kgs.

So, 1000 kgs is roughly the weight of a typical car I mean. In fact, I would say that is a small sized car some of the bigger cars are even more heavy, but you can assume it's about 1000 kgs is the weight of car that is a reasonable number to work with, and the typical person who is sit who is sitting in that car is going to be less than 100 kgs ok.

So, we will keep an upper limit of 100 kgs, let's say him and whatever he or she who is in the car plus they are some luggage. So, let's say it's 100 kilos. So, if you approximate the calculation you see that you know about 90 percent. So, when that vehicle is on the road and its moving, 90 percent of the weight of that vehicle roughly 90 percent of the weight of that entire you know vehicle plus occupant plus that occupant's baggage. If you look at that combination 90 percent of the weight of that combination is the vehicle itself. Only 10 percent of that weight of that combination happens to be the occupant and his or her baggage right. So, whatever fuel you spend travelling from let's say your residence to your office or residence to some other place to your relatives place or your friends place, whatever wherever you are traveling.

If a travelling from residence to your office, whatever fuel you spend in the process 90 percent of that fuel was spent transporting your vehicle from your place of residence to your office. Only 10 percent of the fuel that was consumed was spent on transporting you and your baggage from your place of residence to the office. So, this is something that doesn't really strike us most of the time, but really that is the reality. So, transportation has all these you know interesting parameters hidden inside it that sometimes you are not aware of.

Can you imagine that I mean 90 percent of the energy has been spent transporting your vehicle; only 10 percent of the energy was spent transporting you. So, that is a I mean that is a phenomenal piece of information for you to bear in mind, it represents potential

for energy savings right I mean you are not talking for 5 percent saving, 10 percent saving, 90 percent is available there for you to say to do something about. So, right now that's a massive amount of room there for you to improve. So, transportation sector actually has a lot of room for improvement.

Supposing you make the same automobile half as heavy right now suddenly your I know you instead of 90 percent only 80 percent is going to be spent on transporting the vehicle right. So, you are the percentage over which you can say significant. So, when typically you are looking at 1 percent 2 percent improvement in efficiency, here you have 90 percent room for improvement, so much room that you can make differences in right.

So, transportation is interesting in that perspective. First of all its very visible, secondly is there a lot of room for improvement and the third thing is in one fundamental sense it differs from the industrial sector, and that is transportation is distributed right. So, it is all over the country. So, if you draw the map of a country any any nation you just draw the map of a nation, draw the map of your state or your city at any given instant, now if you just look at the map and you just I know put dots representing vehicles present all over that city.

You will find that the vehicle is I mean vehicles are spread out across the entire city right. So, I mean all roads, parking spots lot of places the vehicles are just parked, I mean vehicles are present and many most of them are possibly running. So, these vehicles are all over the place therefore, the pollution associated with the transportation sector is also distributed right. So, it is distributed all over the city. So, all whatever pollution they are doing they are doing all over the city.

So, you see that also in a very visible sense right. So, you see the smog that develops due to all the pollution that is present all over the city because transportation is present all over the city right. So, that's another reason why its a very visible sector. You see it first of all it is all over the place the pollution associated with it is all over the place and we personally use it. So, these are the reasons why its a very prominent sector and it sticks in our mind as something that, we need to associate do something about.

The industrial sector on the other hand is often far away from the city okay. So, typically I mean may be some cities have grown and reached the industry, but generally speaking the industry is set up significantly away from the city and therefore, again it doesn't stick

in our mind. So, you may know that there is a company which is there 300 kilometers from your place of residence, but it doesn't stick in your, you don't see it every day. So, it doesn't stick in your mind.

So, any improvement they may do may does not necessarily register in your mind whereas, suppose suddenly all the vehicles were clean, you would know the difference you would know immediately you would know the difference you would smell the difference on the road as you walk, you won't smell those fumes coming off of those vehicles. Whereas, write now in populated you know densly populated cities you walk, you will you can smell the diesel fumes of vehicles which are just you know passing by near you, and you will struggle to breath that's how bad the pollution is in some several cities.

So, this is one major difference between the transportation sector and the industrial sector. So, again these are sectors that we will look at quite a bit more carefully as we you know look at this data from these sectors in greater detail little later, but for now I think these two points these few points this few aspects that I highlighted are interesting to keep in mind. The last is the residential sector; again this is all our homes. So, if you look at our homes there is scope for you know lot of we do use a lot of energy, 20 percent of the energy used around the world internationally is for residential use, and theres lot of room for improvement and it is going on continuously.

So, if you look at a televisions, previously we had CRT based cathode ray tube based televisions, we had cathode ray tube based you know personal computers at our homes. So, mostly those seem to have been changed by LED or you know LCD type of displays which are very low power low in power consumption relative to those CRTs. So, that is one way things have improved, the lighting has also changed from you know incandescent bulbs to you know CFLs what we call tubelights inside in the Indian context to LED based lighting, so significant drop in power usage.

So, actually lot of lot of things are happening in the residential sector, that we are you know not necessarily completely aware of or at least we are not we may be aware of, but maybe we don't realize the significance of it. There's a lot of changes that are happening in the residential sector, which help us you know run things much more efficiently. Of course, our expectation of comfort, our expectation of convenience has always been

going up. So, whereas, previously we expected a fan and you know some nice windows to get a ourselves good cross breeze, with the pollution and you know increasing heat levels in several cities, we no longer feel comfortable with that.

We want you know completely sealed houses sufficiently you know insulated houses with good air conditioning. So, we have moved in that direction and so our power consumption goes up. So, but again they are looking at ways of you know making that more efficient, making that more targeted so that you have air conditioning where you wont and so on. So, lot of technology is being looked at which try to improve the energy usage pattern in the residential sector. So, in some this is the sort of the major sectors that we are looking at.

The industrial sector, the transportation sector and the residential sector, and I tried to highlight some of the important features associated with these sectors. And we will look at these sectors in greater detail at a later date.

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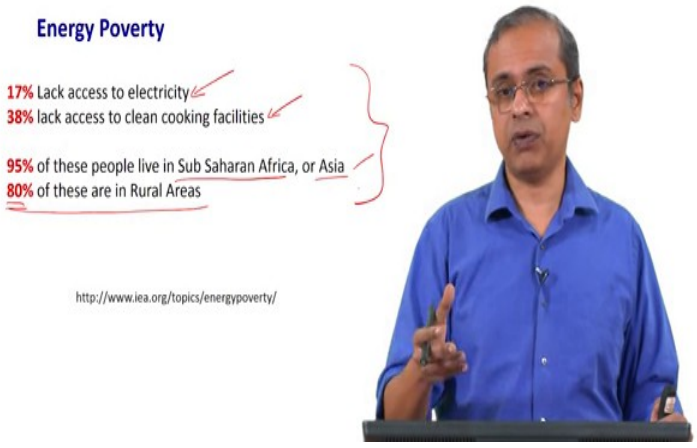

While on the topic of energy usage, I think it is very interesting and very informative to look at this idea of energy poverty okay. So, we talk of poverty in mostly we look at it in economic terms we look at you know. Some, we have some line which we define as the poverty line, often there is a lot of controversy on what you define as the poverty line, but at the end of the day there is some definition of a poverty line and we declare the so many people are below the poverty line. And so, it implies that you know we have so

many people who have a serious issue with their means of livelihood, they are really struggling for livelihood and therefore, necessarily something has to be done to assistant them.

But that is one aspect of poverty, in the context of energy there is also this term called energy poverty, you can go look it up there is a lot of you know definitions for it and so on, but the basic idea is this that you know it represents a set of people who are not getting sufficient access to energy, and maybe due to economic reasons. May be due to economic reasons, may be due to the location they are present in etcetera, but they are not getting sufficient access to energy.

So, for example, it is very interesting to see that you know we are approaching the year 2020, we are approaching that year 17 percent of the world's population lacks access to electricity. So, in 17 percent of the homes in the world there is no electricity, you cannot just go and you know flick a switch and get a light to turn on. So, once it is you know past 6 pm if it becomes dark they are past 6 pm, it is dark the house is dark, you have to go to bed you have to do something else maybe you light a small candle or something and you read using the candle light that is it otherwise fundamentally it is dark.

So, in 17 percent of the homes around the world this is the case whereas, in modern cities you know especially in homes that are you know you know at least say let's for example, what would be described as middle class homes, I mean lighting is never an issue with just in most of us just take lighting for granted, we don't even think twice about it, it's an expected and assumed feature in any household, we don't even think that there is a possibility that it won't be there. In developing countries such as India we often have at least from time to time we have power cuts, and that is the only time we realize that you know we did have some lighting and at the moment it is not there.

So, and then we grumble about it till you know the half an hour goes by or whatever till we get the power back. Of course, those situations have been improving, but the point is most of us take it for granted, and yet there is 17 percent the population who has no little or no access to electricity right. There is significant. 38 percent this is 40 percent close to 40 percent, that is an amazingly large number of the population 40 percent is amazingly large amount of the population. 40 percent nearly 40 percent of the people around the

world lack access to clean cooking facilities okay. So, this is energy poverty when we say lack access to clean cooking facility, it means they don't have piped gas of any form.

They don't have electricity in any form to run and you know say let's say they don't have electricity to run an induction stove, they don't have piped gas to run their regular stove, they don't have a gas cylinder to run their regular stove right. So, they lack again these facilities that most of us take for granted in any modern city in any you know in certainly in any modern country, we assume that the these things are there okay.

So, there is of nearly 40 percent of the population who don't have access to this. They are out there you know sometimes often in the streets using just old style cooking, where they basically have some fire wood that they have collected and they are using the fire wood to run a small open stove and on that stove there running their cooking. So, that's 40 percent of the population that's huge, that's not a small number at all by any stretch of imagination. In addition you find that this is not uniformly distributed. You find that for example, 95 percent of this people live in Sub Saharan Africa or Asia.

95 percent; so, this a very large number of people both in Asia and Africa who are in this condition, were they not getting enough electricity they not getting sufficient you know facilities to do their cooking in what we would consider the current style of doing the whole cooking process. And 80 percent of these people are in rural areas; which is again to be expected, because I mean city is generally tend to be reasonably well equipped, even and cities there is a there is a depending on the city you go to you will find a wide range of economic people with a wide range of economic backgrounds, you find you know ultra rich people, you find rich, you find middle class, you find say lower middle class in terms of you know just the availability of facilities at their disposal and then you find really poor people.

So, those poor people really don't have even though they are sitting in a city, they don't often have they may see all the facilities that you and I have, but they don't have access they don't personally have access to those facilities. And so, they lack those facilities but still. But still so, that's probably 20 percent of them 20 percent of these people who are lacking the facilities are sitting in the cities, but 80 percent of these people who are lacking the facilities of this no access of facilities are actually living in rural areas. So,

these features that you see, know in terms of the kind of percentage of people and what we are looking at in terms of access to some facilities.

If you take this together, this is what is you know broadly defined as energy poverty. So, energy poverty is a real thing that's my point in this information that I am sharing with you. Energy poverty is a real thing, many of us are not aware of it we tend to again you know just like we talk of transportation sector, we talk of economic poverty we don't think in terms of what other implications it has. An economic poverty possibly directly is linked to energy poverty, but regardless there is energy poverty and that is something that we should be aware of.

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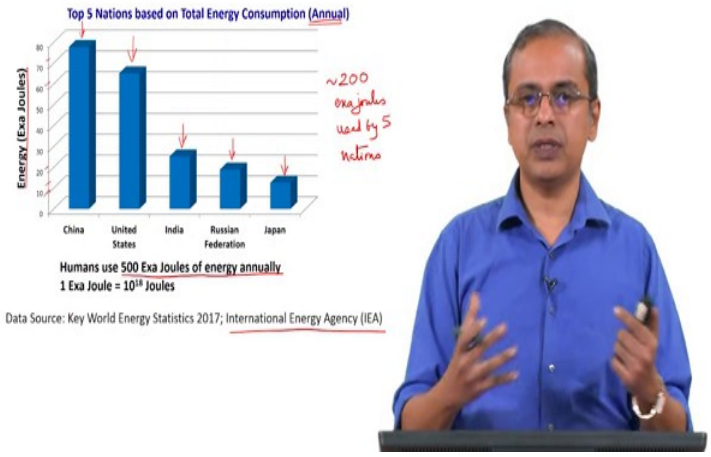

Right so, now let's take a look at how energy is used across nations, and you can see here the top five nations based on total energy consumption, and this is annual energy consumption top five nations. For a long time the United States was the highest consumer of energy and in fact, you were they were the single largest consumer of energy in the world. In the recent years China has caught up and is now the number one consumer of energy internationally. And so, they have overtaken the United States and then we have India. So, if you look at the top five nations, we are in the third position India is in the third position in terms of the amount of energy that is being consumed annually and after that we have the Russian federation and we have Japan.

So, these are the top five nations in terms of energy consumption. Now just to you know put things in perspective, I mentioned this number 500 exa joules of energy being consumed annually by all of mankind across the planet right. So, across the planet all of the mankind is consuming 500 exa joules of energy. So, if you look here this is energy in exa joules. So, by the way, so this energy data is from the international energy agency. So, some of the data they have lot of data available on their site, plus there are other sites also which have plenty of data on energy usage across various sectors and various you know nations, in various different formats they have put this data together.

So, fair amount of the data I am showing you in is has been picked up from various of this publications and for example, some of this data is from the international energy agency publications. So, I have taken it from there and re plotted it here in you know picked up the data that is of interest for our discussion, and then re plotted it here to show it and share it here; so if you here. So, I saw. So, often the units they use that is very different. So, often there are using units of million tons of oil equivalent. So, that is that is seems to be the unit that many of those publications used, but that is not necessarily the you know the scientific technical unit that we are comfortable with in the in the you know sort of the scientific parlance of doing things.

So, I would rather use joules. So, I have converted most of this into joules and in our case since we are talking of energy consumption at a international level across the world, exa joules seems to be the you know number to go with a 10 power 18 joules. And so, I have tried to scale things in that context.

So, you see here on your y axis energy in exa joules and the total is 500, you can already see here that you know if you take China for example, that is already somewhere in the 75 mark 75 exa joules. The United States is over 60, India is over 20 and the Russian federation is somewhere here maybe about 15 and Japan is about 10. So, if a look at it 10, this is 25. So, let's that is 50 and, this is 115 of that order and about 190. So, if you total all this up, if you total the energy used by all of these five countries we are looking at close to 200 exa joules; so approximately 200 exa joules.

So, this is 75. So, you add 65 this 140. So, 165 there, 15 would get you about 180 190. So, close to about 200 exa joules this is an approximate number that I am doing. So, 40

percent of the energy that is being used out of the 500 exa joules, 40 percent of the energy that is being used is actually just being used by five countries.

So, five nations use 40 percent of the energy. So, that's that should put this energy usage in some sense of you know put some perspective on this energy usage, but I will I mean on the one hand that may seem like a very skewed way of using energy, it's all in one direction, that just five countries are using all of this energy, but the other aspect of it you should keep in mind is that it this 5, you have the two of the world's most populous nations are present in this 5.

So, between China and India we have about 2.6 billion people in the of the planet parked here between China and India. And so, that's a very significant fraction of the population that's almost one third the population of the world. So, we are looking at something of that nature. So, therefore, and then, once you add all this other nations populations, we are actually looking at about you know 40 percent or more of the population of the planet. So, in some sense it is not a terribly alarming number by itself taken by itself that you know about 40 percent of the energy is being used roughly by 40 percent of the population.

So, that that sense it's not a very alarming number, but if you step aside and say how many nations it's just 5. 5 out of you know very large number of nations that are out there. So, that sense, in that sense it is skewed in you know in the in the control of five people, five nations which are using this energy. However, this is one part of the picture this as I said you know this is I wanted to you to get some perspective of how nations use energy and how their populations use energy.

So, how are their populations using energy that is something that comes out in a big way, when you look at this energy total energy consumed annually on a per capita basis. So, that is you divide this energy by the number of people in that nation. So, by the population of that nation, then you get the amount of energy that is being used by an individual in each of these nations right. So, you take the total energy consumed by the nation divided using the number of the people in the nation or the population of the nation, that gives you the total amount of energy consumed per individual in that nation annually.

So, that is per capita energy consumption per year right. So, that's what I am going to show, you in the next slide, you will find that that slide shows you the data in a drastically different context.

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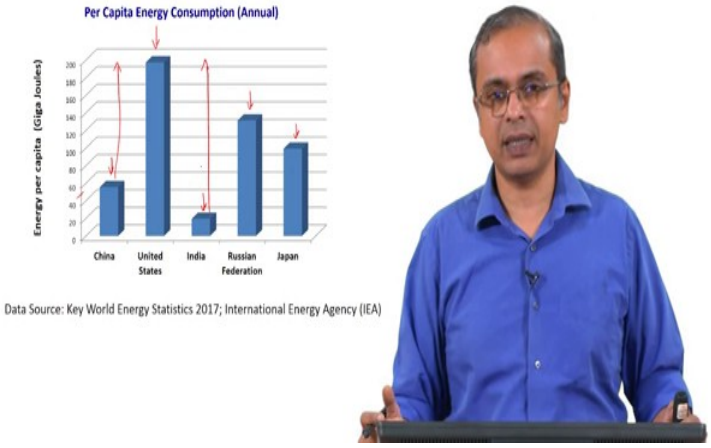

We will come to this in a moment, but this is this is the per capita energy consumption annually, you can see here this is a huge difference, right now and for a long time United States has been the highest consumer of energy on our per capita basis right. And then comes China then comes India, Russian federation is bit on the high side Japan is on the high side okay. So, per capita consumption is very different right per capita consumption is very very different if you keep this in mind.

So, I will come to this I will emphasize some ideas associated with this in just a moment, if you take our total energy consumption you look at per capita consumption and you also look at this idea of energy poverty; where I said you know various places in sub Saharan Africa are and some places in Asia are consuming a lot less of power, and I am actually in conditions that we would consider as energy poverty. If you keep that in mind total energy consumed by country is per capita consumption etcetera.

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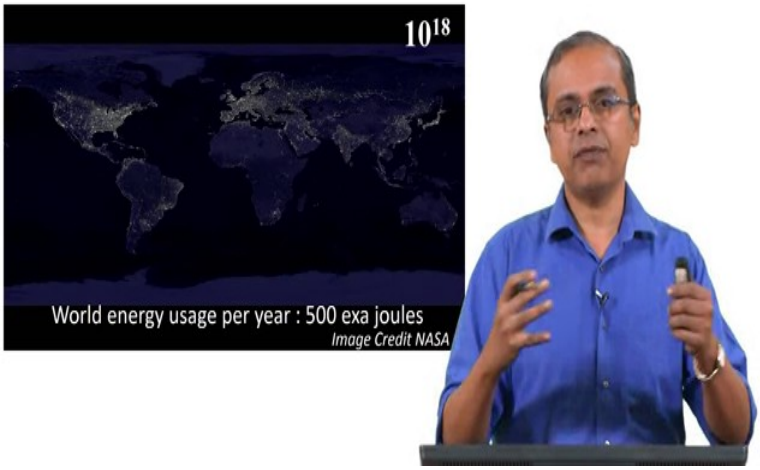

Now, if you relook at this image, you see that all that information comes together right. So, first thing you see is this is somewhere up here is the Sahara. And so, this much of this is sub Saharan Africa much of Africa that you see down here if sub Saharan Africa.

You see that it is dark basically it is dark, very little to no energy consumption there in a relative sense in this picture. So, that is very consistent with this idea that you know there is a lot of energy poverty in this region and it is not really being consumed very uniformly. In Asia its a bit more distributed. So, it's maybe difficult to pin point those regions where there is lot less energy consumption, but you can see up here and all here is a lot less relativity lot less energy consumption out here. You can see here the five major nations you will see here Russian feeder first of all his China which is the up down here which is here, then you have the United States.

So, this area and you know. So, that's the United States that shows up, there is India there is the Russian federation. So, that is somewhere in that region and this of course, Japan. So, you can see here that you know these are the I mean the regions so two regions which are poor. So this is, these are all the high energy consuming regions relatively speaking. So, high energy consumption is happening here and then you have relatively poor regions which are the other two regions that are marked on your sheet on this slide.

So, you can see really you know this image captures this information nicely, and it is very consistent with all the other data that we have discussed. Now I will also point out

that generally speaking everybody wants a better lifestyle. Now the term better is used in a at least from the perspective of you know common acceptance of the idea of better. So, everybody wants a nice home, everybody wants a comfortable means of transportation, everybody wants a comfortable office to work in, good environment inside their homes and so on. And that is natural it is to be expected and it is completely reasonable that most people would expect this its highly inappropriate to adopt a position that only a few should have access to it.

So, if you look now if you keep that idea in mind, and you look at the fact that you know the energy usage is so, I mean a non uniform across the world, the only conclusion you can draw is that all the people who don't have access to energy or are not living lifestyles consistent with the better energy usage or higher energy usage, I would not say better energy usage higher energy usage, will aspire to lifestyles which have higher energy usage.

And assuming things work for them, assuming there is good economic development various places in the world they will start increasing their level of energy usage. So, when you talk of 500 exa joules of energy, it is very clear that you can only expect that this will go up. I mean every, likelihood is that as we go forward it will only go up. So, total amount of energy we consume it can only go up, because there are so many people waiting to consume more energy. Because that is their path, that is a integral step to getting themselves better lifestyles.

So, with that amount of people waiting to improve their lifestyles and aspiring to improve their lifestyles, trying their best to improve their lifestyle they will only increase the total amount of energy that is being used. And so when you go to this per capita energy consumption and you see this distribution, where let's say the United States consume so much more let's say it is not consuming almost 200 you know giga joules per person annually per annually and China is consuming 50 giga joules per person annually.

So, every on average the Chinese population would like to increase their consumption, so that they can live life styles very similar to the American lifestyle. Indians would like to like to raise their consumption. So, they can also live lifestyle a similar to that of an American lifestyle.

So, right there you can see that you know China could climb up to 200; India can climb up to 200. And so, Indian contribution to the energy consumption would can go up by a factor of 10, and Chinese contribution to energy consumption can go up by a factor to 5 if all of us try to live the American lifestyle. So, this is what happening around the world; the nations compete with each other at a political level to try and you know place their case forward as you know saying that this is what our situation is this is what we want to do.

And we are I mean we have justification for it, and in many ways you have to step back and look at the justification, and you have to understand at a person human being level those justifications are valid. So, we have to as a community, as a human community look at this picture in a greater you know broader sense, to understand what needs to be done with non conventional energy sources, cleaner energy sources such that you can meet these aspirations of people trying to increase the amount of energy they are consuming, in order to get themselves better lifestyles.

But to do so in a manner, that is also very you know comfortable for the environment. To do so in a manner particularly it is important to remember that we need to do this in a manner that is not self destructive right. So, that is very critical. If we just as we did not in the calculation in a one of our earlier classes, even in the current usage current you know state of usage which is 500 exa joules per year, it is just a broad approximations that we did which where all reasonable approximations in my opinion.

You find that in less than less than 100 years in 86 years we will double the amount of CO_2 in the atmosphere that is just using current estimates. Now if China increases its energy usage fivefold, India increases its energy in usage 10 fold, we are not talking of 86 years we may be talking of 10 years, we may be talking of 5 years as the amount of time that is required to double the amount of CO_2 in the atmosphere.

So, we may make vastly more drastic changes in our environment, if we don’t change the manner in which we produce the energy and simply increase the consumption of energy right. So, I don’t see any issue with the increase in consumption of energy, I mean that is a natural direction in which we will go, maybe we will have you know more efficient technologies and therefore, we may have a more comfortable house and a more

comfortable automobile, without increasing the amount of energy consumed in the processes, so that may happen.

But independent of that, it is only natural the people may consume more energy. It is more critical for us to look at this supply side of the energy, and figure out if you can provide this existing 500 exa joules or even one more than 500 exa joules in a clean manner. Think that is really the main responsibility of you know the scientists and engineers and technologists who work in this area. To try and get these kinds of technology is out there fast enough, that you know energy can be consumed, but that does not happen in a self destructive way.

When you start you know doubling CO_2 every 4 years and so on 5 or 10 years time, then you are doing this in a very self destructive way. You are going to have situations where you know cities and nations cannot withstand the consequence of this kind of an increase in CO_2 in the atmosphere, which is not really being addressed as seriously as perhaps it should be okay. So, that's some of the points that I wanted to make with respect to this plot.

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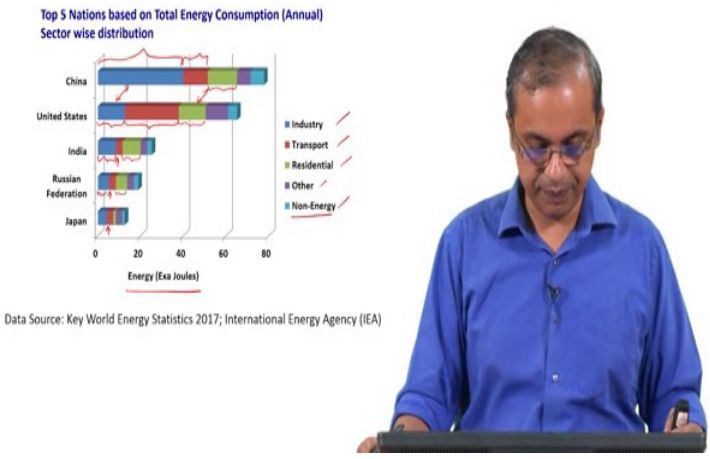

I would also like to take a look at you know we saw the overall energy consumption of the five nations, I also wanted to show you this split up of energy across various sectors in these nations.

So, for example, if you take you see here there are specific sectors that I am pointing out industry, transportation, residential. So, these are the three major sectors that you see, you also have some other sector which may be we are not defining well enough, and then there is a sector that is marked as non energy.

So, maybe I will take a moment I explain what we mean by non energy. And that is basically you know things like end uses where the fuel that is being used its not necessarily being burnt, but it is still being consumed. So, that is for example, perhaps its a good example of that would be lubrication okay. So, lubrication is an aspect that is being used in industries around the world again all are automobiles it is being used, we all put you know engine oil in our automobiles at a different points in time.

Oil change is a very critical thing for the lifetime of an engine. So, but there we are not necessarily burning the oil right it does degrade and then we eventually dispose it and we put fresh oil etcetera. So, that constitutes energy I mean we will put it its packaged into this calculation of energy, but it is on a sort of non energy use, it is not really being converted to energy.

So, still you have major sectors here, you can see that is that there are differences between nations. So, for example, if you take China versus the Unites States, you find that in the Chinese current usage pattern a very significant part of the energy is used in the industrial sector okay. So, that many industries are coming up there in China and that's how this industrial sector is you know existing China. So, they have put in a lot of effort to build those industries in that country. Much less is being used in the transportation sector.

So, transportation sector is much less in the relatively speaking in the Chinese context. The United States it's the bit the other way, you do have some consumption of energy in the industrial sector, but you do see a much larger fraction of people, I mean much larger consumption of energy in the United States happening in the transportation sector.

So, this also brings out a cultural difference between the nations. In the United States people just love their automobiles, may be around the world they love their automobiles may be that may be generally true, but in the United States it's a, its a very integral part of their society as many people as possible own automobiles and they have multiple automobiles and so on.

And that really reflects in the consumption of energy in that nation. And also if you hear you know lot of talk in the political sector about jobs being lost industrial jobs being lost, that many American industry jobs have been lost to other developing nations and particularly often the complaint is that American jobs have been lost to Chinese industries, you can see that difference here you can see that showing up here. You see a very small industrial sector here; you see much larger industrial sector in China.

So, I think that conveys to you very nicely what's happening in the political scenario relative to what shows up in the data right. So in fact, if you go to the United States and you go to a typical shop know typical you know retail shop and you would look for something made in the United States, you will find it very difficult to find. Invariably the items that are sitting there are made in China. So, that is the reality as of today it may change today that is as you approach the year 2020 that's the reality on the ground.

And I think what you see here in terms of energy usage. So, how much of industrial production is there in China, how much of industrial production is there in the United States, and at least as it shows up in terms of energy consumed by those sectors, you can see the stark difference between the two nations right. And if you look at India for example, we are sort of uniformly distributed in energy usage between the industrial sector and the residential sector.

The residential sector is roughly the same maybe the Chinese residential sector uses a bit more than the Indian residential sector, and it is similar to the amount of energy being used by the American residential sector. But you can see here you know this is American population is about one fourth the population of China. So, even the residential typical American house is effectively using 4 times as much energy as a typical Chinese house right.

And similarly with respect to India it is may be using 5 times as much energy or 6 times as much energy as typical house in India. So, you can see these differences showing up very nicely in this pattern of you know usage across these various nations, then you have the Russian federation again uniformly distributed between housing and I mean sorry industry and transportation industry and housing, and smaller sectors are transportation. You can see here the transportation that is happening here, happening here and

happening here is all relatively small it is not a very significant fraction of the overall energy usage, it is there I mean it's very much visible there.

It is not you know it cannot be dismissed, it cannot be overlooked it is very much there and any improvement you make in that sector is definitely going to impact the total energy that is being consumed by that nation. But in a relative sense its a smaller fraction as supposed to what you see in the United States.

So, I think this conveys to you some variation across these nations; again this is again in exa joules as I said I have converted all the data so, that it is all consistent with respect to the unit of joules. And so we can see this data here.

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Right having looked at all that, it is also of interest to see the total energy production. Top 10 nations based on total energy production annually, and see how this relates to all that data that we spoke about with respect to the consumption of energy.

So, we saw the consumption we saw you know how the 500 exa joules you know 40 percent of it is come basically being used by five nations, and with respect to that if you look at the energy production you find actually in fact, some of those nations are there even in the energy production picture.

So, you do have China number 1, you have United States you have the Russian federation, you have India. So, four of those nations show up here, Japan is very small it

consumes considerable amount of energy doesn't really produce that much, it is not really in this in this picture that you are seeing on your screen. So, four of those five nations show up here; you also have the other major producer of energy who is not such a large consumer of energy and that is Saudi Arabia.

So, you see those countries from the Middle East Saudi Arabia arriving visible here, you also see Iran visible here. So, these are two countries from the Middle East which produce a lot of energy within the top 10 energy produces. So, they are actually exporting a lot of energy, they are not consuming as much energy they are exporting lot of energy. And therefore, from you know a geopolitical kind of situation, they have a lot of say they have a lot of influence based on the fact that they produce and supply energy to various sectors various other nations in the world.

So, they are able to exert influence because of this, and there again you know when you look at non conventional sources of energy, it impacts all of these as well. It impacts the amount of influence at any given nations has on another nation, it influences the amount of independence each of the nation has each of the nations have when they develop their own sources of energy.

You have other nations here Canada; you have Indonesia Australia and Brazil. So, they are not certainly not in the top five energy consumers, but they are also consuming fair bit of energy and they show up energy production scenario. So, I think you can see again here that you know this all of this is relatively consistent information that we have seen, few nations consuming a lot of energy and significant variations in a per capita consumption.

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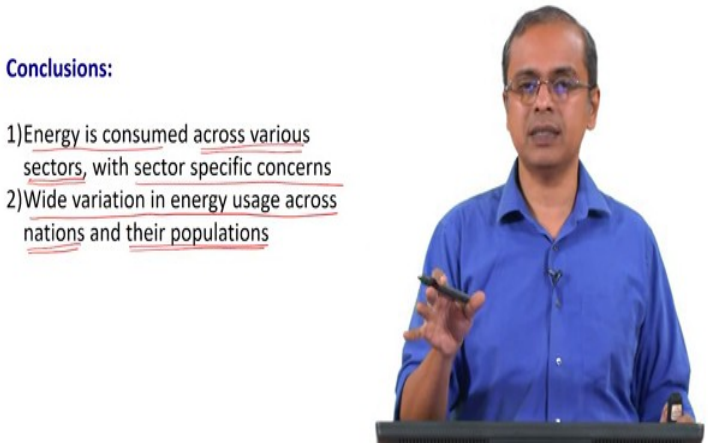

So, we will conclude this class by highlighting some of the parameters that we have discussed through this class. First is that energy is consumed as you may have guessed across various sectors and there I particularly highlighted the fact that we often don't pay attention in the in the common you know popular parlance, in the popular discussion that is there common discussion that you hear in newspapers, magazines, debates etcetera we don't discuss as much about the industrial sector and that consume 45 percent of our energy.

So, that is a point that I wanted to highlight; energy is consumed across various sectors and not all sectors we are aware of particularly the industrial sector we seem to be little bit blind sided towards the industrial sector, and each of these sectors has some sector specific concerns. You know be it the lifetime of that sector, industry, lifetime of the vehicle whether it is localized because it is industry, whether it is distributed because it is automotive sector things like that.

So, you have all these concerns which are sector specific and these are some of the points that I highlighted as we went through this class. And the other point that we wanted to highlight was that there is wide variation in energy usage across nations; very wide variation in the usage of energy across nations and especially with respect to their populations ok.

So, if you look at any you know statistic on how much is energy is being used across nations, you see vast differences between nations and sometimes particularly once you look inside their population and see how uniform it is within their population, often the non uniformity is really what stands out. So, even if you take India and China, and you look at the amount of energy that is being consumed by these two nations you will find a small fraction of the population actually consumes most of this energy, and they possibly consume the same amount of energy as people in the United States do on a per capita basis.

A large fraction of the population actually consumes significantly lower amount of energy and that keeps the overall per capita average of these two nations slow. So, there is significant disparity of usage of energy in the usage of energy across populations, across the world. So, even nation wise there is significant variation, because as I said several places in Sub Sahara and Africa and many places in Asia, large sections of people are living in under conditions that we would describe as being in the on the with the term of energy poverty.

So, large fractions of the population fall on under that category, but there are very rich people as well and over consuming a lot of energy. So, across nations you have various nations which consume lot of energy, nations that are energy poor. Even within the nation you find wide variation in you know ability to access the energy and utilize energy, and that shows up you know with a lot of disparity in the population. So, there is wide variation of energy usage across nations and their populations.

So, those are the two points that I wanted to highlight. And with all the discussion that we have had in this class: looking at the energy usage, across sectors, across nations and across their populations.

Thank you.

KEYWORDS:

Energy Consumption; Industries and services sector; Transportation sector; Residential sector; Energy Poverty; Non Energy

LECTURE:

This lecture dissects statistically the usage of energy across nations, across sectors and across populations. The statistical insight gives clarity on energy usage, energy production and energy shortage.