Energy Economics and Policy
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Week - 01
Energy as an Economic Resource
Lecture - 03
Measurement of Energy

Welcome everybody. In the previous session, we had discussed the classification of energy resources and today we are going to discuss the Measurement of Energy Resources.

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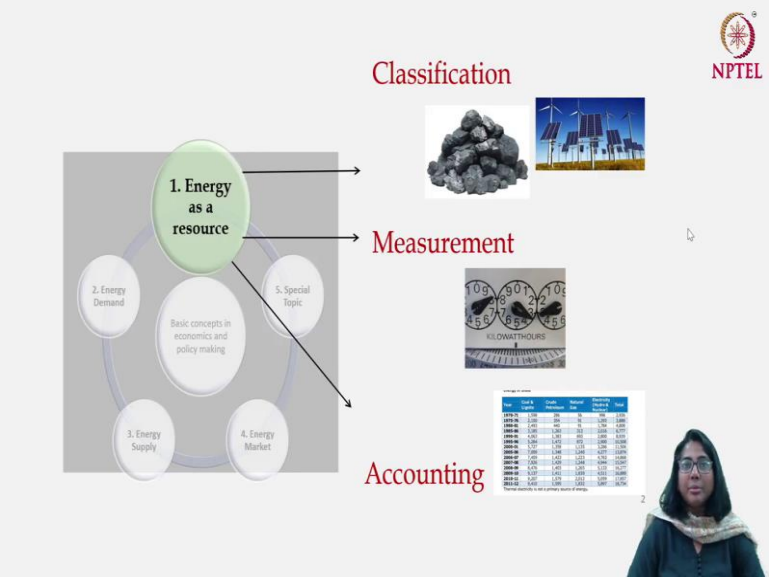

We are going to explore how different forms of energy are measured in various parts of the world. So, both the type of energy as well as the geographical location matter. Before I go into the part of measurement of energy resources, let me start with the following question.

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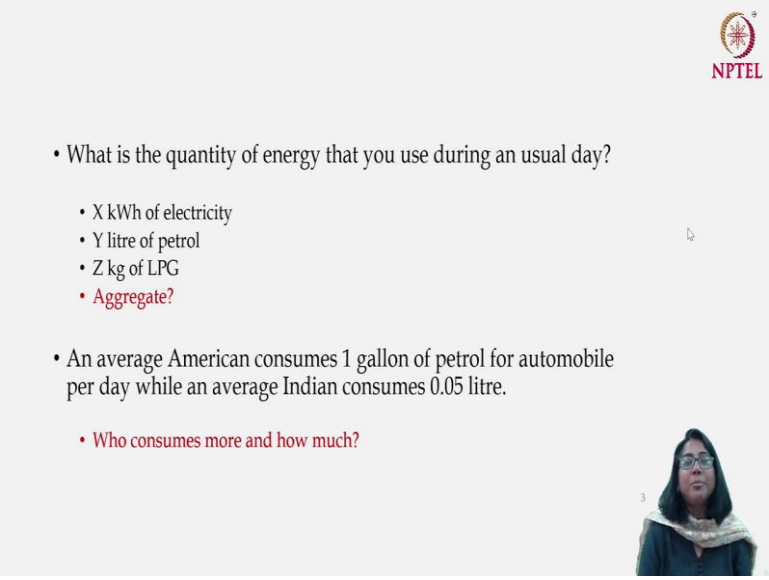

What is the quantity of different types of energy that you use during an usual day? I would like you to pause the video for a while, take 2 minutes and write down all kinds of energy that you actually use during a day, and the quantity. If you have written them down, probably your answer looks like this. You have used X kiloWatt hour of electricity, Y litre of petrol for your mobility (to drive the car) and probably Z kg of LPG for the purpose of cooking.

Now the question that we begin with is: now that you have different types of energy measured in different units. If I ask you what is the total amount of energy that you have used over a day, you will probably not be able to add this X, Y and Z. So, this is one of our objectives: to understand how you can aggregate different types of energy measured in different units. Coming to the second question, an average American consumes 1 gallon of petrol for automobile service per day whereas an average Indian consumes 0.05 litre. And let me ask you the question: who do you think consumes more and how much?

So, from your general knowledge probably you will be able to say that the average American is actually consuming more petrol as compared to an Indian. But if you don't know what is the conversion factor between 1 gallon and 1 litre of petrol, you will not be able to tell me how big the difference between these two units is. So, towards the end of this session, once we discuss the measurement of energy resources, you should be able to understand and you should be able to answer these two questions. That is the objective of this particular session. So, comparability is important!

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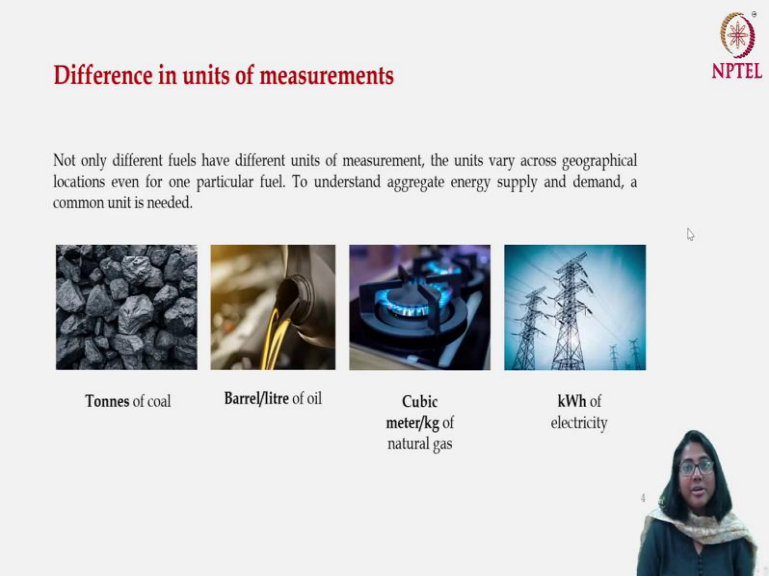

As I have already mentioned that these are the examples of different types of fuel being measured in different units at different parts of the world. So, if you look here, we have ‘tonnes of coal’; this is measured in tonnes. You have ‘barrels of oil’ or in some other places, it’s measured as ‘litres of oil’. You have ‘cubic meters of natural gas’ or you often say, ‘kg of natural gas’ and electricity is measured in terms of ‘kiloWatt hour’. So, we are going to see how one unit can be converted to the other unit to come up with the measure of aggregation.

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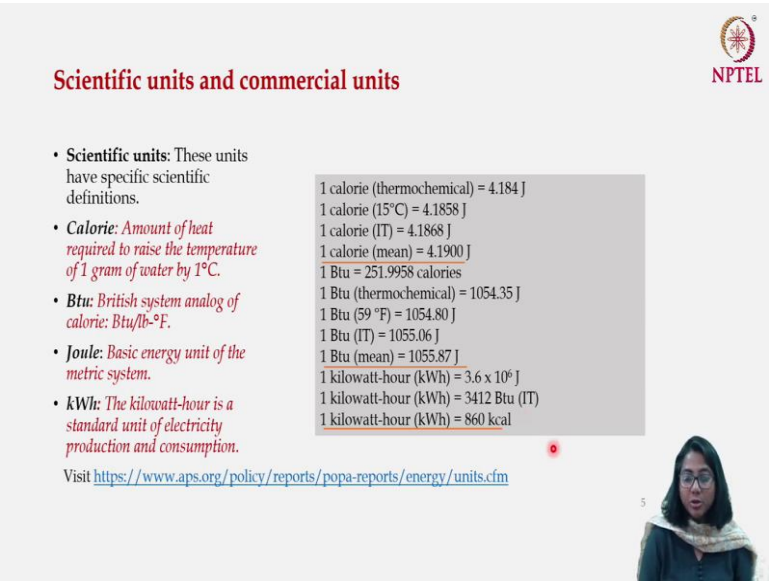

Basically, energy can be measured using two different types of units; one is called a scientific unit and the other is called a commercial unit. Let us begin with the concept of the scientific unit. Each scientific unit actually has a very specific scientific definition. So, what are the different scientific units that we use to measure energy? They are as follows: calorie, Btu (British thermal unit) Joule and kiloWatt hour. Let us begin with 'calorie'.

You probably all know from your basic science understanding that calorie is that amount of heat which is required to raise the temperature of water, 1 gram of water, by 1 degree centigrade. So, often it is said, to raise the temperature from 14.5 centigrade to 15.5 degree centigrade. So, I repeat again: this is the heat that is required to raise the temperature of 1 gram of water by 1 degree centigrade from 14.5 to 15.5. Btu, the British thermal unit; this is the exact analogy of 'calorie' that is used in the British system. So, this is the heat that is required to increase the temperature of 1 pound of water by 1 degree of Fahrenheit. So, you see that both calorie and Btu, they have a specific scientific meaning. So, when I say that the energy consumption is 1 calorie, it has a specific scientific meaning, irrespective of the type of energy that you are using. Similarly Joule also has a specific meaning, the kiloWatt hour also has a specific meaning. These are the four different types of scientific units that we use.

Now the problem that you have is that coal will be measured in terms of calorie, electricity will be measured in terms of kiloWatt hour. So, what is important? It's important to understand, 1 calorie is equal to how much Joule or 1 calorie is equal to how many kiloWatt hour or 1 Joule equal to how many kiloWatt hour. So, these kinds of conversion factors are important to understand. So, this is a chart that tells you the basic conversions. This you can keep with you and this is very helpful to do any kind of calculation when you are, you know, kind of doing a comparison between the different types of energy or at different parts of the world.

So, coming up with a few very important things; first is 1 calorie. So, calorie again is measured in a little bit different way with different definition, but if you talk about the average, on an average, 1 calorie implies 4.19 Joule. This is one of the most important things to remember. The second one is 1 Btu. So, 1 British thermal unit on an average means that there is 1055.87 Joule. And the final one, this is often used in the measurement very frequently: 1 kiloWatt hour is equivalent to 860 kilo calorie.

So, if you know the kiloWatt hour of energy which is being used, you can convert them to kilocalories simply by multiplying it by 860. So, this is one important chart that you have to

take a note of. If you want to know more about the scientific units, you can visit this website. This website is from American Physical Society and this gives you a lot of information about the measurement of energy.

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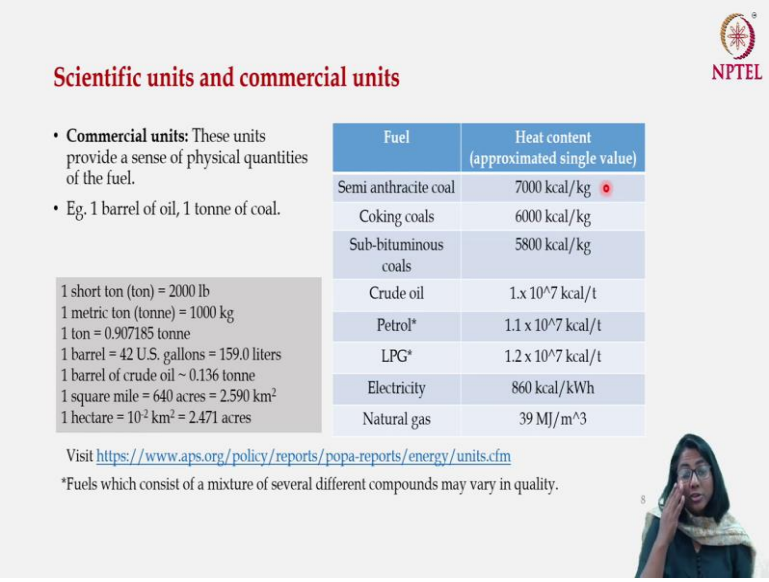

Next we come to the commercial units of measurement. Here we actually don't talk about the heat content of the energy, but essentially what we talk about is the amount of fuel that we are buying or we are selling and that is why this is called a commercial unit. So, when you are buying or selling a fuel, it is a commercial unit that is taken care of. This is the physical quantity; the unit that specifies the physical quantity; for example, we say 1 barrel of oil or 1 tonne of coal and so on.

The next task that comes is to understand if we have several commercial units, how do we actually convert one commercial unit to the other. For example, what is the oil equivalence of 1 tonne of coal. So, this is the kind of question we would like to answer. So, suppose if we have already gone through the energy balance. If somebody asks what is the total production of primary energy in India? So, probably you have to add 1 tonne of oil with 1 tonne of coal and so on. So, how do we do that kind of a conversion? This is another conversion table and this is again very helpful to do some kind of a measurement.

Here you will see that although we talk about tonne, tonnes are measured in two different ways. In the British unit, the short tonne which is often written as 'ton' is 2000 pounds, whereas, if you talk about the metric tonne, which is the American system then it's written as, 'tonne'

(with the double n). So, this is ‘tonne’, which refers to 1000 kg. So when we talk about the tonne, we usually talk about the metric tonne which is, which is equal to 1000 kg, unless otherwise mentioned.

And there is a conversion between the short tonne and metric tonne and you have a conversion rate between the barrel and gallon; between the barrel of crude oil and tonne and etc. etc. So, these are again very important conversion factors that are used to convert one commercial unit to the other. It is again the same website that you can refer to, to know more about it.

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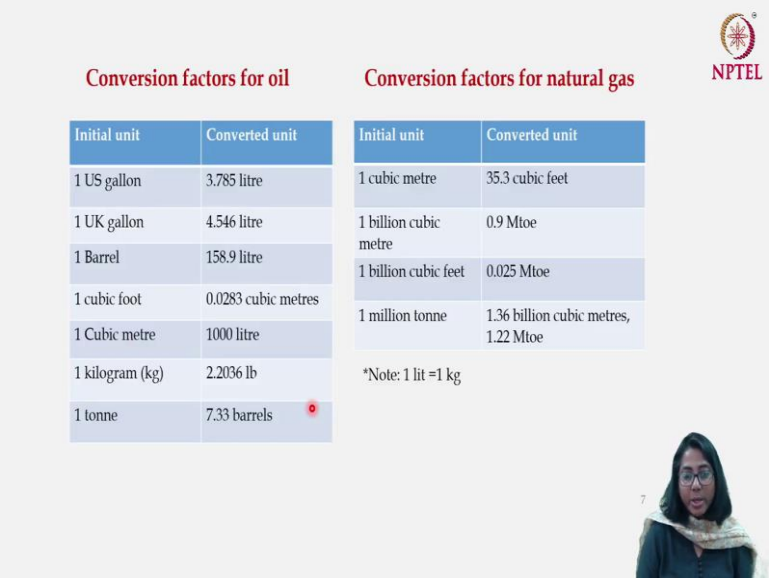

Before we go into the conversion between the scientific units and commercial units, let me just quickly show you what are the most used conversion factors for oil and natural gas. So, here you can see that even if you are talking about gallon, gallon is measured in two different ways, in two different parts of the world. So, in the US 1 gallon is equal to 3.785 litre whereas in the UK, 1 gallon will imply 4.546 litre. So, if you see that the information is given in gallon, you have to enquire whether the source of information is the US or the UK and thereby you have different other conversion factors.

Similarly, for natural gas, these are the most importantly used conversion factors in the context of commercial units. One quick information that probably all of you are aware of is this; so, one litre is being converted to 1 kg. So, this is the, there is a 1 is to 1 conversion rate between

the kg and litre[1]. Coming back to the commercial units and scientific units, let us now have a quick look at how the scientific units can be converted to commercial units, what are the rates of conversion for different fuels.

Now you can understand that if you have everything measured in tonne, 1 tonne of coal will produce some different amount of energy or different heat value as compared to 1 tonne of coal. So, the heat produced by 1 tonne of coal and the heat produced by1 tonne of oil, these two are going to be different or though, by physical quantity they are the same. So, let us have a quick look at what are the conversion factors. So, this goes on fuel-wise. So, this is different for different fuel. If you take semi-anthracite coal, then the heat content of semi-anthracite coal is 7000 kilo calorie per kg.

Now you have to be careful to understand that there is no one single heat content because the quality of the coal may vary, therefore ideally you should get a range. However, we take some average value, which is in between. So, all the values that are reported here are sort of an average value for each fuel. The second one is the coking fuel, and for coking coal the heat content is little less than the semi-anthracite coal which is 6000 kilo-calorie per kg. Similarly, you can get the heat content of other fuel as well.

If you look at petrol, the heat content of petrol per tonne is 1.1 multiplied by 10^7 kilo calorie and for LPG, it's more or less the same because both of them- they are have sort of by-products of oil. So, this is 1.2 multiplied by 10^7 kilo calorie per tonne and the conversion rate for electricity, we have already discussed. This is approximately 860 kilocalorie per kiloWatt hour. These stars (*) are put here because, see, petrol is not one particular form of fuel. It is a mixture of several different compounds and therefore, depending on how the mixture has been created, this heat content may vary. But this is again, as I said, as the, for the, for any back of the, you know, the envelope calculation, you can use these values.

[1] Note this is not exactly the case for all liquid.

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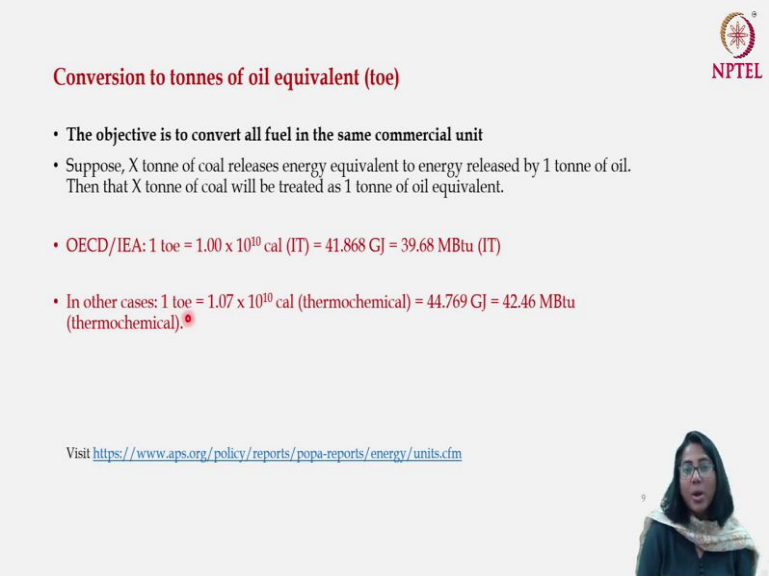

Coming to the last part of the conversion, which is again very very important. We often use a unit which is called the ‘tonnes of oil equivalent’ or ‘toe’. Now, what is meant by ‘tonnes of oil’ equivalent? Here, our objective is to convert all the fuel in the same commercial unit and this is one of the very important commercial units that is used. If you again go back to your energy balance table in many of the countries, you will see that figures are given in terms of tonnes of oil equivalent. In fact, when we were going through the energy balance table for India, we saw that all the energy, they were measured in terms of tonnes of oil equivalent.

So, what is the ‘tonnes of oil equivalent’? Suppose X tonne of coal releases energy, which is equivalent to the energy released by 1 tonne of oil. So, X tonne of coal needs to be burned to produce energy that is equivalent to the energy released by 1 tonne of oil. So, this X will be referred to as 1 tonne of oil equivalent. So, X tonne of coal is equivalent to 1 tonne of oil. So, this is the oil equivalence formula.

Now, there is a little catch when you talk about the tonnes of oil equivalent because there are two ways how things are usually measured. One is the OECD or IEA- International Energy Agency literature; there you will find that the conversion rate is as follows. So, there they are equating 1 tonne of oil equivalent to 1*(10^10) calorie. However, if you look at any other literature, there is a little difference in that. There 1 tonne is considered to be 1.07*(10^10) calorie. So, if you look at it in terms of energy produced, in the first case, 1 tonne of oil equivalent is actually 41.868 GigaJoule of energy whereas in the other cases, 1 tonne of oil

equivalent is equivalent to 44.769 Giga Joule of energy. So, there is a little bit of difference of the magnitude of almost, you can see 3 GigaJoule, if you are talking about 1 tonne of oil equivalent.

So, again when you are doing measurement or when you are doing some empirical work, be a little bit careful about the source of your data. So, these are the small things that you have to know or keep in mind if you are doing some kind of empirical research. Depending on that you have to convert and in most of the cases if you look at the reports or at the data sets, they usually mention what the conversion factors are. So, keep your eyes open to understand what are the exact conversion factors that are being used.

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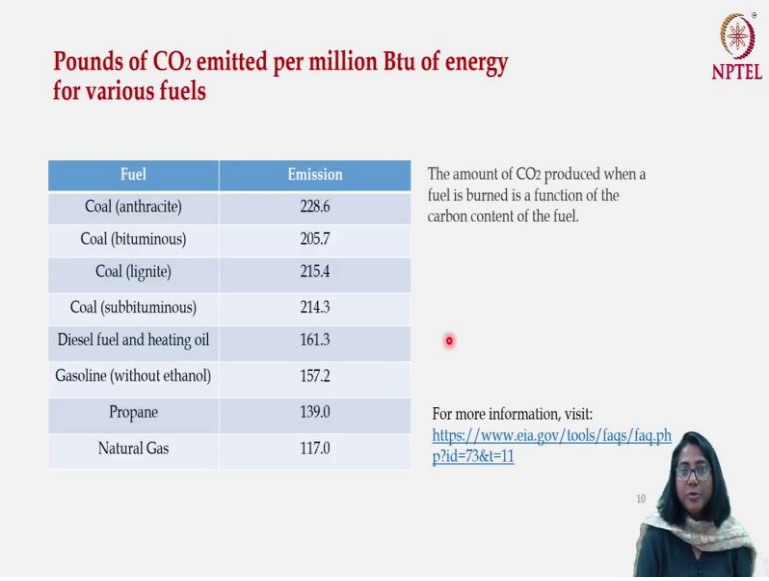

Let us now move on to the last bit of it, which is very very important and what we are doing here, we are trying to understand how many pounds of CO_2 is being emitted if you burn a particular form of fuel. This is very important if you want to understand the implications for climate change of burning a particular type of fuel because it depends on the carbon content of that particular fuel, how much CO_2 is being emitted. So, if you look here; if you burn one pound, if you burn, so, see this is the pound of CO_2 emitted. So, this is 228.6 pounds of CO2 being emitted per million Btu of energy. So, if you burn coal which is equivalent to 1 million British thermal unit, then the emission of CO_2 will be 228.6 pounds. Similarly if you burn gasoline without ethanol; if you burn gasoline which is equivalent to 1 million British thermal

unit that will emit carbon dioxide which is equivalent to 157.2 pounds. So, here you see the units of measurement are basically the British units of measurement.

You can convert this now and to do the conversion, you can actually convert it to you know, kg or tonnes of CO2 emitted per million Btu or you can say per GigaJoule of energy used from various fuels. So, this is one of the very important pieces of information that we often used when we try to understand what is the emission from the fuel used in a particular country? So, you take these emission factors and calculate what is the total of, the total amount of energy being used therefore, what is the total amount of CO_2 being produced?

So, we are going to stop here and I hope now you are in a position to answer properly what is the total energy used, what is your total energy used on a particular day or now you can also tell us what is the exact difference between 1 barrel of petrol and 0.05 litre of petrol. In the next session, we are going to come back with some exercise and practical examples where we will discuss this in further detail.

So, thank you for being with us; we see you in the next class.