Energy Resources, Economics and Environment
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Lecture -1 P1
Energy Flow Diagram

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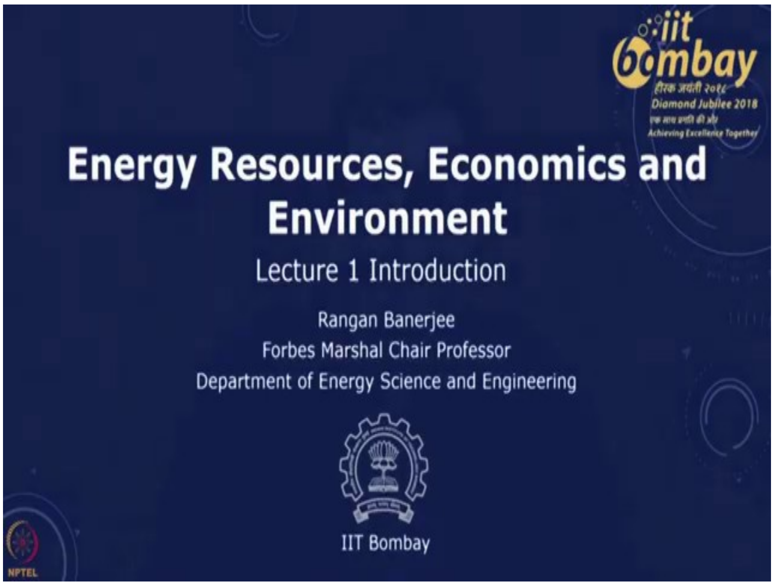

Welcome to the semester long course on Energy Resources, Economics and Environment. My name is Rangan Banerjee and today we will start with looking at the basics of the energy flow diagram. So, let us start with an energy flow diagram.

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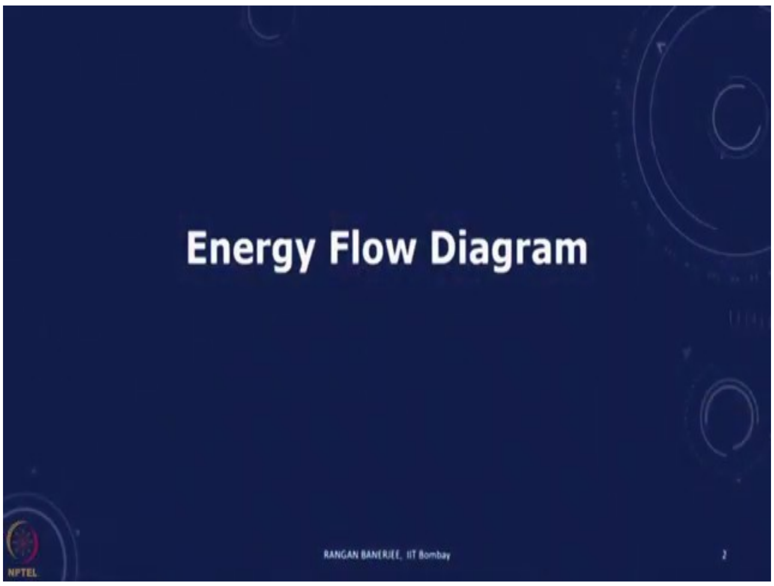

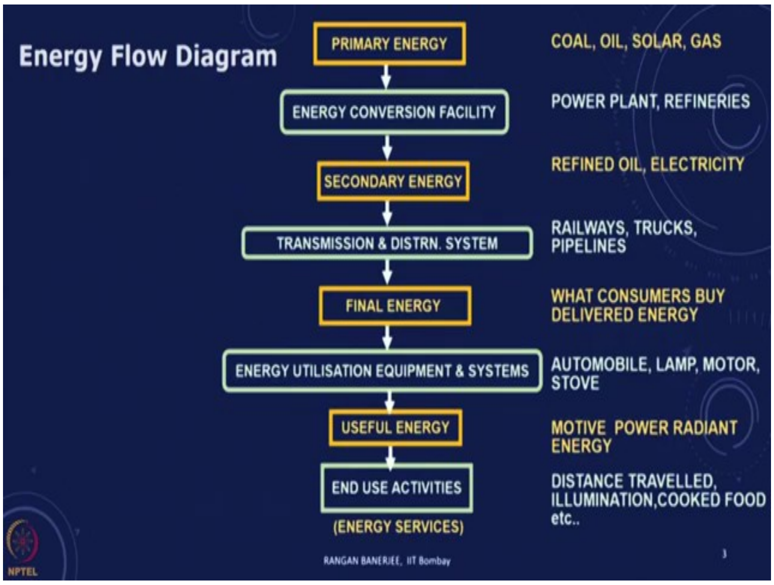

What is an energy flow diagram? When we think in terms of any human activity, any human activity needs energy. So, if you are looking at the screen that you see, the screen has to be illuminated, if you are looking at the comfort conditions when we think in terms of air conditioning or the cooling that also needs energy.

So, that energy comes through a whole sequence of steps. We have at the energy that is available in nature is primary energy. This is the energy source is like coal, oil, solar, natural gas, wind. The energy that is available in nature is not directly something that we can use. We take that energy; we convert it in an energy conversion facility.

So, we first take the coal, convert it, we mine it, we wash it, we transfer it to a power plant and then we get the secondary energy. So, secondary energy is the electricity that we get from the power plant which is burning coal. That secondary energy itself goes through a whole network, a transmission and distribution system.

And then it reaches your house or it reaches the campus, the final energy that we buy from the distribution company and that is then use that electricity then goes and it is used in your air conditioners, in the fans, in the lights to give you useful energy or the end-use activities. So, whenever we think in terms of different energy systems we need to look at all these terms: primary energy, secondary energy, final energy, useful energy.

We are interested in the energy services, in order to provide those energy services we need to have primary energy extracted, that primary energy needs to be converted in a conversion facility to give secondary energy. That secondary energy is distributed till it reaches the final end user which is and that is the energy that we buy the electricity, the oil, natural gas that is used in the equipment to give the useful energy.

So, when you talk about each of these conversion steps, each conversion step needs a certain amount of energy for the conversion and so when if you need 1 unit of energy useful energy, we would probably need 2 units or 3 units of primary energy. So, whenever we do a comparison and when we do a calculation, we can think about whether we are talking of primary energy, secondary energy, final energy or useful energy.

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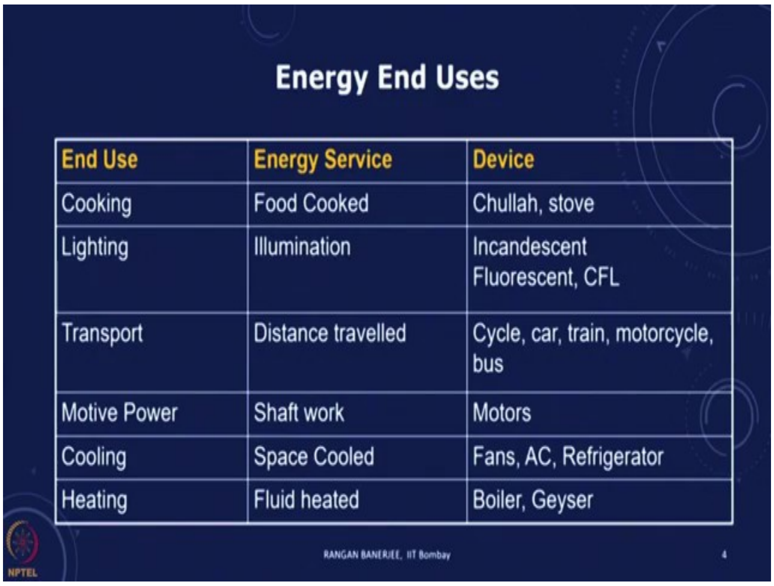

So, let us move on. When we talk about all the end users that we need, so we think of all the things that you do in your daily life. When we look at cooking the energy service is the food cooked. So, you have the Chullah or you have the stove or the microwave oven that is where energy is being used to give you the processed food.

If you talk of lighting the energy service is illumination, you have different kinds of bulbs, you have the traditional incandescent bulbs, then we have the fluorescent, then you have this compact fluorescent, and now you have the LED. When we talk about transport we are looking at travelling, distance travelling.

So, passengers being transported or goods being transported and then you have a whole host of cycle, cars, train, motorcycle, bus, aircraft and each one of them is an energy system and has a conversion and an efficiency. In the factories we have a large numbers of motors which are being used to create some shaft work and the devices the motors. Cooling we are looking at space cooling, we have fans, ceiling fans and we have air conditioners, we have refrigerators.

In the industrial processes we have heating that is provided that is fluid is being heated so the devices are boilers or geysers and in each of these cases we can look at what is the energy input, what is the output, what is the energy service and do this kind of analysis.

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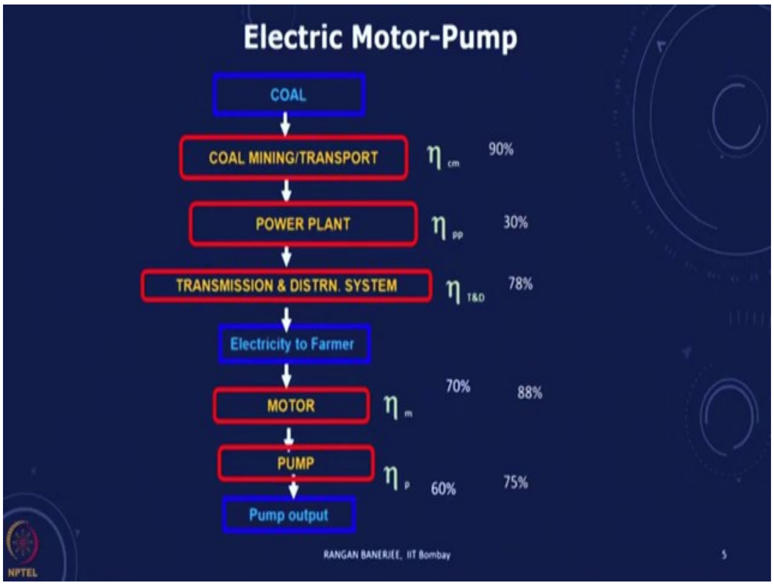

So, just to give you an example let us look at a situation where we are using an agricultural pump, a farmer is using a pump to pump water, the pump output is the useful energy, the useful service energy service that is required. The pump is providing the energy in from the motor drives the pump and the pump is transferring the energy into the water which is then allowing it go to the storage or to the filed directly.

Each of these has certain efficiency. The farmer buys electricity from the distribution company. That electricity is coming through a transmission and distribution system. That electricity is being generated in a power plant which is using coal. That coal is being mined and transported and then you have primary energy.

So, if you look at typical efficiencies of all of these the numbers that we have put, the mining efficiency may be of the order of 90%, power plant has an efficiency of about 30%, transmission and distribution about 78% efficiency and the motor pump depending on actual operating may be of the order motor may be of the order of 70% pump of the order of 60% the best efficiency is may be 88%, 75%.

So, if you multiply all of these you will see that the overall efficiency that we get from the coal to the final pumping that efficiency is actually relatively low and that gives us an incentive to try and see can we reduce some of these steps. So, whenever we look at different kinds of energy systems it is always useful to try and look at it draw, the energy flow diagram and look at it from the context of primary energy to the final energy service.

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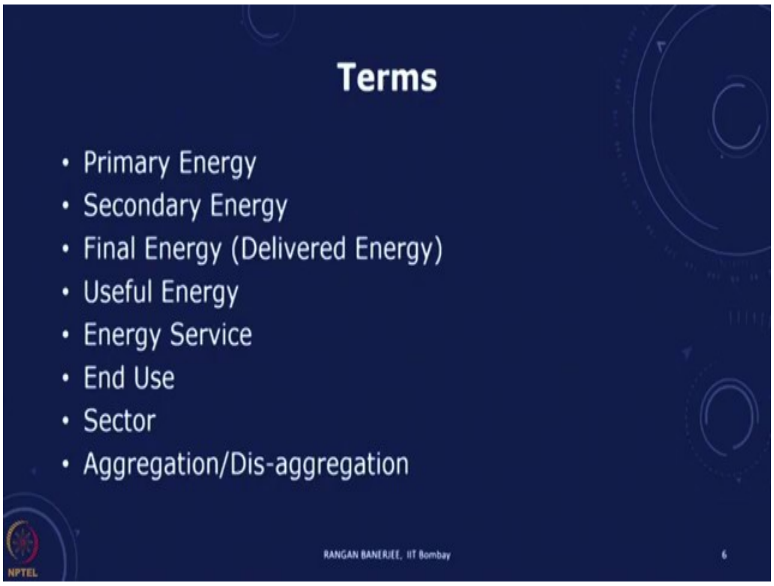

So, let us look at what are the terms that we have study? We studied the terms primary energy, secondary energy, final energy or the delivered energy, useful energy, energy service. And then we can also classify it into different kinds of end uses. So, end uses will be like, one end use is lighting, end use of heating, end use of cooling, end use of cooking, end use of transport and then the sector.

When we talk about sector, we are talking of residential, industrial, commercial. Whenever we talk in terms of a, we want to get an idea of an energy system we have to decide what is the level of aggregation and dis-aggregation. What is aggregation and dis-aggregation? When I put things together that is aggregation when I separate them out that are dis-aggregation.

So, we may want to calculate for the city of Mumbai what is the overall energy used, or for the state of Maharashtra what is the overall energy used, for the country for India what is the overall energy used, for the world what is the overall? So, that is an aggregate calculation. We want to dis-aggregate it by in each house hold by each end use how much is the energy used, so that is the dis-aggregated. So, in any of these cases we can always calculate and do an energy balance and try to see how the energy is being used and what is the quantification.

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When we move forward with this in order to do this is quantification we have different kinds of units. So, traditionally we used to use calorie and the British thermal unit and the Quad, now in the SI system we use joules and we use kilo watt hours. We also need to differentiate between energy and power.

When we are talking of power if you are talking of watt or kilo watt or megawatt that is the rate at which the energy is being supplied and that power aggregated over a period of time will give you the energy. So, watt and horsepower these are units of power. When you take 1 watt and you run it for an hour you get 1 watt hour, or the kilo watt hour is 1 kilo watt running continuously for an hour.

So, we need to be able to convert between different units and for this you can look at any source on the web or you can look at the energy basics in the global energy assessment which I will put at the end of the references. We also have different prefixes like Kilo 10^3, Mega 10^6, Giga 10^9, Tera 10^{12} , Peta 10^{15} , Exa 10^{18} and depending on the kind of calculation we are doing.

So, if you are doing the calculation for the world, you will be talking in terms of Exa joules, if you are talking of a country may be Exa joule or Peta joules if you are looking at a smaller thing it may be kilo joules or mega joules or Giga joules. There is also these are all in terms of energy units, earlier we could also calculate in physical units.

So, we can talk in terms of million tons of coal, million tons of oil. So, there is an energy unit where all if you talk of coal, oil, natural gas, we convert them all into equivalent oil. So, million tons of oil equivalent and you will see if you look at the BP side or you look at many of this sides the energy balance is are given in terms of Mtoe.

Which is million tons of oil equivalent, the coal is also converted into oil equivalent and million tons of coal equivalent kilo tons of coal equivalent. So, these you should be familiar with the units and you should be able to make conversions between the units and some in some of the tutorials that we provide you will have some examples where you can do this.

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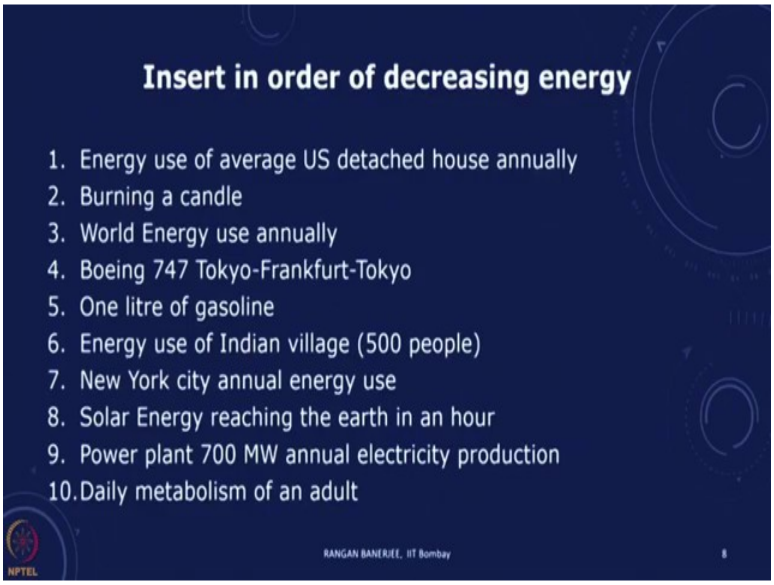

So, here is this exercise which will give you an order of magnitude of the different kinds of units and the idea is that you see for different kinds of activities, I want you to think about it and insert in order of decreasing energy with the highest energy being on top and then the lowest.

So, the different items that we have put energy use of an average US detached house, burning a candle, the world energy use annually, the Boeing 747 going from Tokyo to Frankfurt and back to Tokyo, 1 litre of gasoline or petrol, energy use of an Indian village typically of 500 people, New York City annual energy is used, solar energy reaching the earth in an hour, a power plant of 700 megawatt annual electricity production and the daily metabolism of an adult.

So, take a minute and just put down your sequence the highest energy to the lowest energy, and if you see compare this sequence with the results that we have here.

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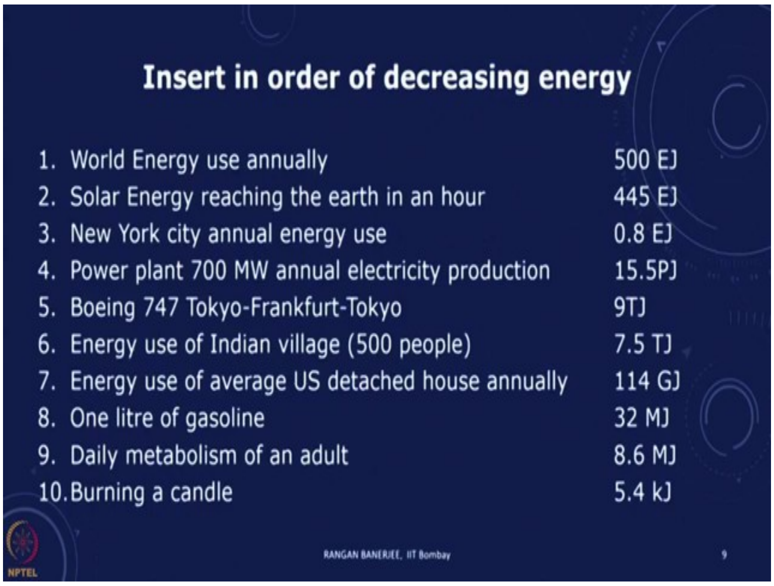

The world energy use annually is about 500 EJ, solar energy reaching the earth is an hour is about 445 EJ. So, that means we have abundance solar energy right, in 1 hour we have enough which is equal to the amount which the world is using annually. New York City annual energy use 0.8 EJ, Power plant 15.5 PJ and 747 Tokyo Frankfurt to 9 TJ a lowest is the burning the candle daily metabolism of an adult is somewhere in between and this just gives you a sense of the relative magnitudes of things.

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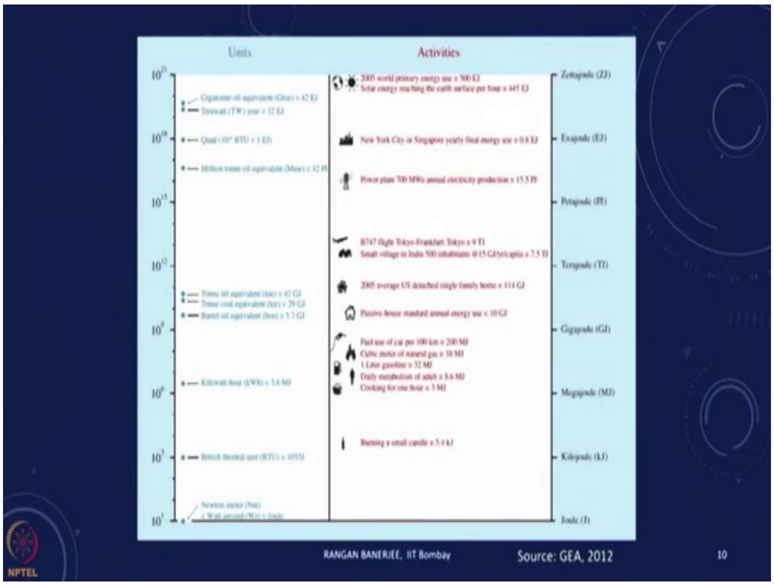

So, you can look at this on this axis this is from the global energy assessment you can see this, this axis talks about different activities and in different units and you have a scale which goes from 10 raise to 1 to 10 raise to 23 and you can see the in terms of the starting from joule to ZT and going up to EJ and you can see the relative magnitudes of some of this you know this gives you an idea of the relative magnitudes of the energy use. So, this is very similar to the exercise at we just now did.