Energy Conservation and Waste Heat Recovery
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Lecture - 65
Energy Economics – IV

Good morning welcome back to Energy Conservation and Waste Heat Recovery. Today we are going to continue our discussion on energy economics and last class we got introduced to the concept of LCOE which is levelized cost of energy. We were looking at the definition of from the UK government which said that it is the net present value of the total installation and operating costs of a generic plant over the net present value of the electricity generated over its operating cycle or over its operating life. So, today what we will do is we are going to look at some of the definitions of or how do we write LCOE.

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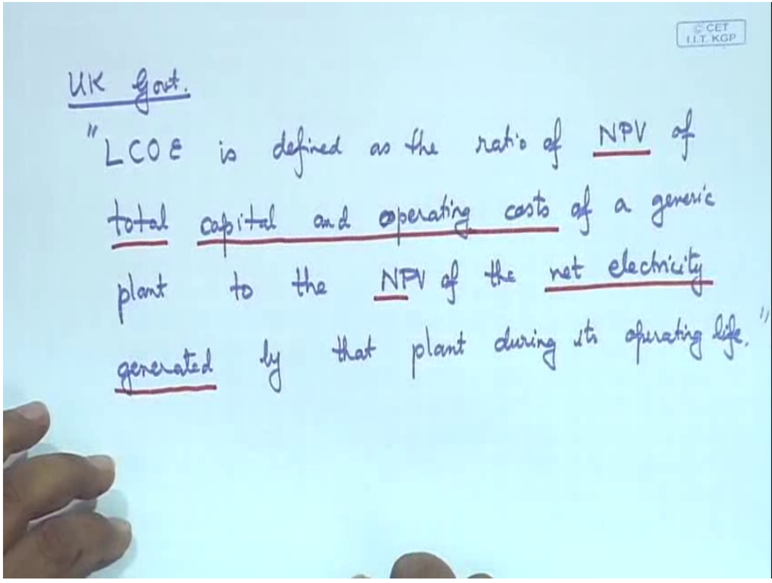

So, LCOE can in very simple terms I can write LCOE in this manner.

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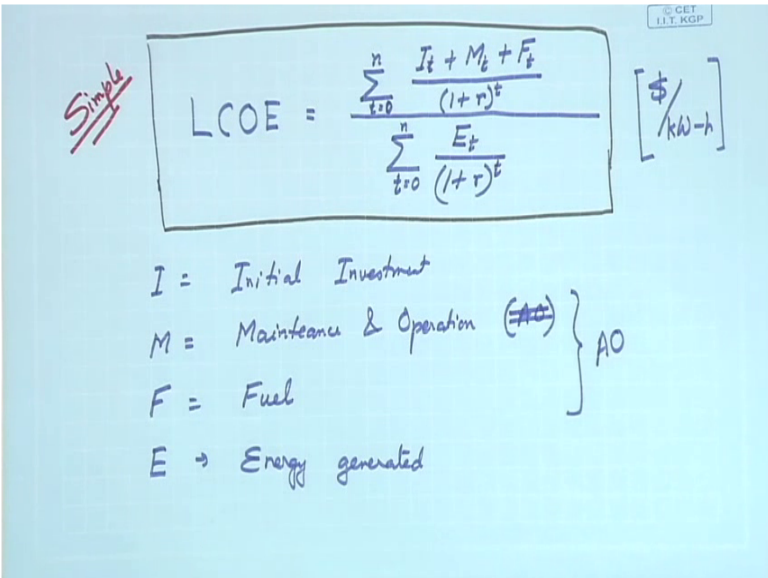

It is a ratio it is the cost of generating 1 kilowatt hour of electricity. So, in the numerator we have to write down the costs and let us say the life cycle goes from 1 to n years, n is its useful life. So, I would write it as the initial installation cost. So, I would write it as I t I would rather write it I from 0 to 1, 0 to n plus M t plus fuel F t, I will come to that what each of these means divided by 1 plus r to the power t recall from our discussion of net present value r is the discount rate. And in the denominator I will write the net present value of the total electricity that is generated and this is also going from 0 to n I would write E t divided by 1 plus r to the power t. So, this is a very simple expression for LCOE.

Again let me write down what is I, I is initial cost initial investment which typically is at the 0 is here M is maintenance and operation, operation and maintenance also I would say it can be written as AO, sorry operation and maintenance let us say, and F is fuel and these two together is annual operating cost AO. And what is E? E is the energy generated and here also we have to put a discounting to get net present value of the energy that is going to be generated let us say 5 years later. So, today if I have to do this, this is how I am going to calculate LCOE, clear.

So, this is I would say rather a simple definition, which does take into account several of these metrics. So, for example, now if you look at this let us talk about a natural gas or a natural gas plant I would need fuel. So, this F is going to be a significant amount in subsequent years initial investment cost will be there, but when compared to a solar plant this eye is going to be very high, but F is going to be low right.

Remember this I have put it as it which is investment that we are making every year, but every year this is going to be not valid, most likely it is not going to be that valid unless you keep on adding features to your plant over the over its life or at least for the first few years of its life. But typically I will have a significant value at t equal to 0 and probably nothing significant after that only exception is as I said if you want to keep adding features or scaling up your plant over the years then of course, I will have some value in year 1 2 3 4 5 and so on clear.

So, this is one way. So, what is the unit here? If I look at the unit, the upper one is cost. So, this is going to be dollars or rupees or whatever and the lower one denominated is going to be kilowatt hour. This is the unit of LCOE it is dollars per kilowatt hour or dollars per megawatt hour or depends on the on the location it can be pounds per kilowatt hour it can be rupees per kilowatt hour and so on. We can look at a more complex definition of LCOE as well, and that is also there let me first write it down and then try to explain each of this.

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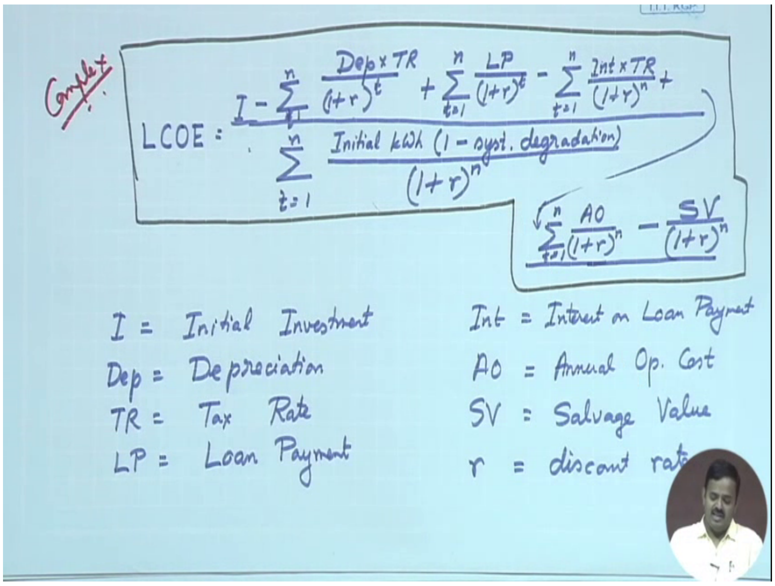

So, I would first right the numerator and I would say I minus sigma again r not r sorry t 1 to n depreciation divided by 1 plus r to the power t times tax rate, I will come to what each of these mean plus sigma again t 1 to n LP 1 plus r to the power t minus sigma 1 to n Int or interest times TR 1 plus r to the power n plus, I am sorry I am running out of space I will write the I will continue the numerator over here the bottom. I am sorry this is going to come here plus sigma again t one to n annual operating cost one plus r to the power n and then minus salvage value 1 plus r to the power n. And what is going to the denominator? Against t 1 to n initial kilowatt hour times 1 minus system degradation divided by 1 plus r to the power n.

So, I am sorry this is a little complicated, but let me again write it down or let me again spell out each of these terms, so that you can follow. The first term is I and I will we know that that is initial investment your installation cost the second one I would write it down Dep is called, Dep is called depreciation. So, now, every asset in this case this plant the equipments etcetera they are going to depreciate with time the value of what I what it is today is not going to be the same of course, an old product sells for less than a new product we know that because there is a depreciation. So, what happens is the business can claim a tax rebate due to this depreciation that tax rules, tax laws allow for that.

So, therefore, if I show that my equipment has depreciated by this value I can claim a tax rebate on that. So, that has to be subtracted because that is a cash inflow. So, TR stands for tax rate. Let us say for building this plant for building this installation I have taken a loan which I am repaying it is a debt or a loan. So, it is a loan payment LP is loan payment which I have to I have to pay the monthly installments to the bank or the yearly installments to the bank clear.

Now, out of this loan payment I will get some tax rebate because of the interest that I pay as part of my loan payment clear. So, for example, as individuals we get you know a tax rebate because of interest that we pay on our housing loan. So, similarly here also the businesses are allowed to claim a tax rebate because of the interest they play on loan payments. AO we know is operating cost annual operating cost. SV salvage value this is what I am going to get is an inflow at the end of any else and R is the discount rate.

If you look at the denominator what I have written is initial kilowatt hours. So, this is the rating of the plant, but the plant is not is going to degrade with time. So, today if my plant let us say gives x gigawatt hour over a period of 1 year after 5 years it is going to be maybe only 80 percent of that because the system has degraded equipments do degrade. So, therefore, the production that I am getting after 5 years or after any number of years is going to be less because of system degradation so that has been taken into account. So, when you add up the energy that is generated and again remember I do not have this data I am trying to calculate an LCOE today to make sure what is going to be the cost of energy for the plant that I am proposing to build. So, I do not have this data I have got to assume something and then calculate it in this manner clear.

So, LCOE come, LCOE calculation can take into account a variety of stuff like this. So, this is I would say a little complex in the sense that it kind of encompasses a lot more elements right, compare that with a very simple one that we wrote clear both of these are valid. So, what I said try that I am trying to say by showing you these two different definitions of LCOE the point that I am trying to drive home is yes LCOE is a very good metric it is a level playing field to compare different energy installations energy installations you know using different sources of energy of course, all that is given and valid. But before comparing LCOE it is very very important also to keep in mind to know that how was the LCOE calculated, what are the factors that went into the LCOE calculation.

If somebody comes and says and takes into account all this the depreciation the interest all these and it will show that my cost is actually less it does not take into account system degradation. So, that is one way. The other guy may come and say and he just uses a simple formula he does not take into account his depreciation, he does not take the tax rebate due to interest on loan payment, he just show he just shows the loan payment and he says that you know the cost is going to be high he also says that you know my system is going to degrade with time. So, he is being very honest he is going to being very fair and he is considering all this.

Now, is it fair to compare these two LCOEs that have been calculated completely in different terms in using different factors; no. So, the point that I am trying to drive over here is it is important to know that how the LCOE has been calculated.

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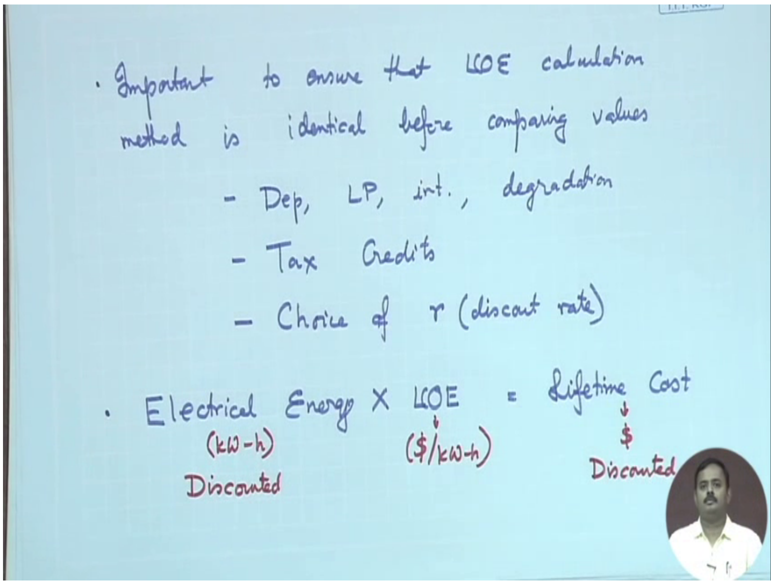

So, important to ensure that LCOE calculation method is identical before comparing values and example as I said was you know thinking of factors for example, depreciation loan payment interest degradation all these are there. One can also say that I am going to put in tax credits now for renewable energy for solar for wind some governments gives you tax credits, tax credit it is not a discount or that you get because you are paying interest it is just that the fact that you are putting up us.

So, people who put up a solar panel let us say in California they get a rebate on their electricity bill. What else? The choice of r right discount rate this can be arbitrary this can be subjective and can play a huge role in altering the value of your LCOE. So, all these need to be kept into account right. So, now, if I write electricity or sorry electrical energy times LCOE is equal to lifetime cost right. So, what is this going to be? This is going to be in kilowatt hour per megawatt hour, this is going to be dollars per kilowatt hour and this is going to be dollar right. Again keep in mind this is discounted, this is also discounted clear all right.

So, if you look at this and I say that this is a power plant that I own today and we generating electricity which I am selling to customers how much am I going to charge? So, LCOE can also be thought about as the minimum cost of electricity that I can charge to my customer to make this plant economically viable, to make this plant I would save in profitable to make this plant non loss making or not a losing proposition right.

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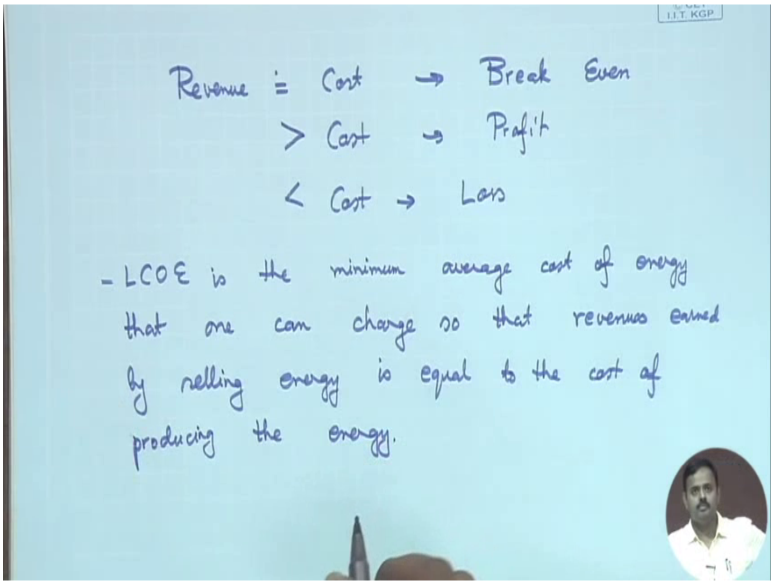

So, if I look at this, this is my revenue if revenue is equal to cost then I am break even greater than cost profit less than cost is loss. So, therefore, as I said LCOE you can also think of it as LCOE is the minimum average cost of energy of course, that one can charge so that revenues earned by selling energy is equal to the cost of producing or generating the energy right.

We looked at various factors we looked at initial cost right. What all did we look at? We look at if you look at revenues and versus costs.

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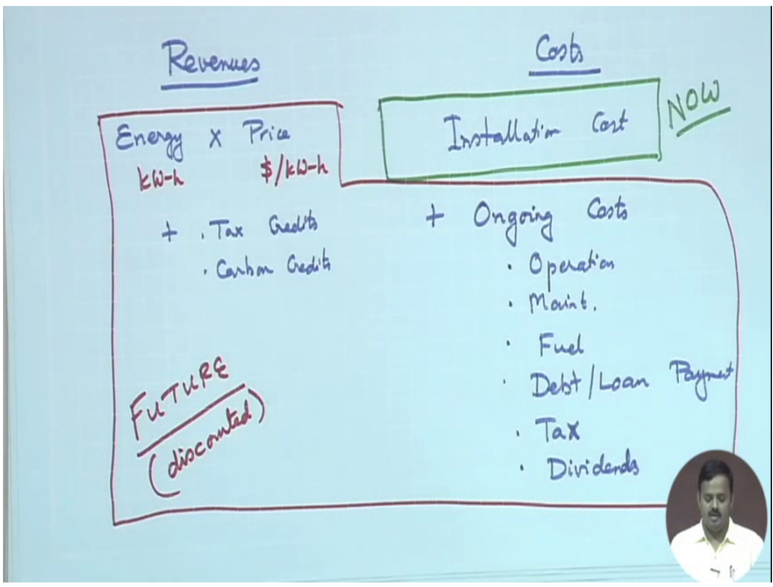

So, here I would write installation cost which also includes equipment labor everything plus ongoing costs which is operation, maintenance, fuel, debt or loan payment, tax, etcetera etcetera a lot of things, dividends that you have to pay your shareholder all that stuff if you are a company.

What is the revenue? Revenue is your energy times price this is kilowatt hour and this is dollars per kilowatt hour and there can be other revenues also plus let us say tax credit, carbon credits etcetera etcetera.

Now look at this, all this is for the future and if you look at this, this is now for present this is now this is future. So, if this is future this has to be discounted right the net present value method you have to find the net present value by using the discount rate right. So, the way I am showing this is here is again to drive home the point that all these can be can become part of your LCOE calculations. So, when we are comparing two installations we have to make sure that the factors that have been incorporated while calculating LCOE must be the same for two LCOEs to be compared for the two installations all right.

So, that kind of brings us to an end of LCOE and which kind of what we have done is we have finished another metric of energy economics. The last one that I am going to talk about today is something called Input-Output analysis.

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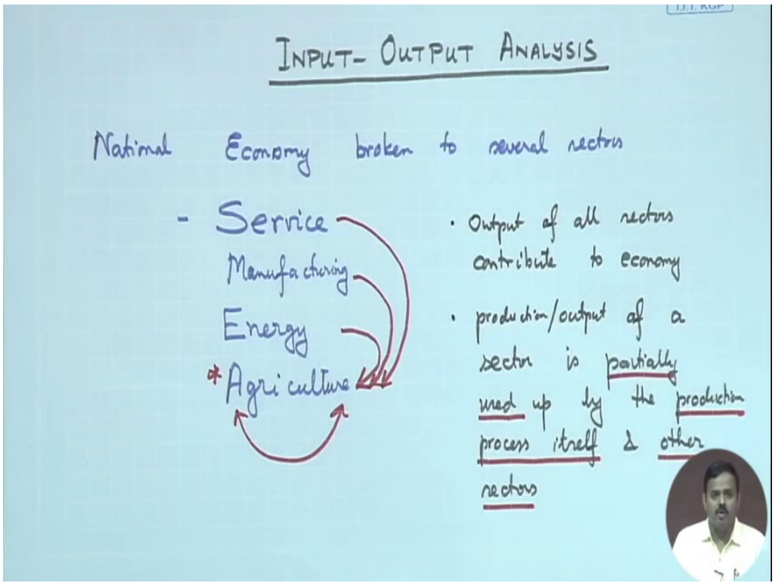

We probably would not go we would not be able to finish it, but we will just introduce this is a very very classical method. This is not really a metric in the sense that it is not a term like LCOE like it does not have a definition it is not like a mathematical expression it mathematical exercise is an analytic analysis.

So, before we start it is input output method is a very classical method in the field of economics it was first proposed by a Nobel Laureate economist his name is Wassily Leontief, Wassily Leontief proposed this is 1950s and it was I would say that it is one of the first successful implementations of a mathematical model in microeconomics. And as we will see as we go through this the beauty of this method lies in its simplicity. It is very powerful, but it is very simple and that is where the beauty lies.

So, let us talk about it if we think about a nation take a step back think about a nation even in India for example, a nation a national economy is typically broken up into several sectors. So, India for example, I think has hundred to one thirty sectors. So, what can be these sectors be? Sectors can be a agriculture, transport, energy, banking, manufacturing lot of things, even energy can be broken down into you know electricity into coal and so on, information technology so on and so forth all right.

So, if you think about these economic sectors and let us say I would write down national economy broken to several sectors and let us talk about only one of those. Now let us take just a few of them let us taken let us say India for example, and I would say I will take four such sector service manufacturing, energy because that is what we are talking about here and since its India will take agriculture. Four major sectors when we talk about service, we will talk about any service in this like banking post office so on alright.

If you look at this all these sectors have outputs, but what is more important is sector of output of all the sectors each if you take any sector the output of that sector goes as input to other sectors. For example, let us take agriculture. So, let me write down here what I just said that first of all output of all sectors contribute to economy, but more importantly what I would like to say is the production or output of a sector of any sector is partially used up by the production process itself and other sectors. Let me underline this, for some of the partially used up production process itself and other sectors.

So, let us take into account agriculture. So, agriculture for example, the output of this plays a major role in Indian economy we know that, but now if you look at it what goes into agriculture. First thing that is the output of energy goes into agriculture yes because we need the agricultural machinery, we need the harvesters, we need the tractors etcetera and once the crop is harvested we need to transport it to the market finally, to the end user. So, agriculture industry does need input from energy. And when we started our discussion energy economics we rather say that almost output of any sector or anything production of anything requires energy. So, we will see that energy actually plays an input output is an input to almost all sectors.

Does manufacturing form an input to agriculture? Of course, because all these tools the harvesters the machines agricultural machinery are all produced by the manufacturing industry. What about service? Yeah because the farmer may have to take up loan you have to may have to borrow money for crops for seeds. So, the service industry like banking does play a role and this forms an input to the agriculture sector. And what about agriculture, itself yeah of course, because part of the agricultural harvest or part of the agricultural output forms the seeds all right. So, this is important.

So, you can see that all this side output of all the other sectors form input to the agricultural sector and there are various other examples. Steel and automobiles are two different sectors, but steel output of steel forms an input to automobile right. For example, what else electricity goes to all sectors also industries, but to the power plant itself. So, that is an example of electricity that is generated in a power plant is used in the power plant itself as well as to the end user and to all other plants also that is energy again all right.

So, this kind of tries to tell us that you know if we look at the economy and look at the different sectors of economy the output of any sector is used up by all by some or all of the other sectors as well as by the sector itself and then whatever is left after that is available for use by the consumers to meet their demands and also let us say for export. So, for example, agriculture industry the crops or the harvest that we produce first has to feed the population only after that can we think of exporting it. The energy that is produced has to first run the existing infrastructure pro and then it comes to the end user and then finally, we can think of selling energy to outside the country all right.

So, therefore, this is where we will stop today we talked about the different sectors of an economy and how they are interdependent on each other. In the next class we will talk in more details and we will take up a specific example to show what is the input output analysis that was proposed by Wassily Leontief.

Thank you very much, have a great day.