Energy Resources, Economics, and Sustainability

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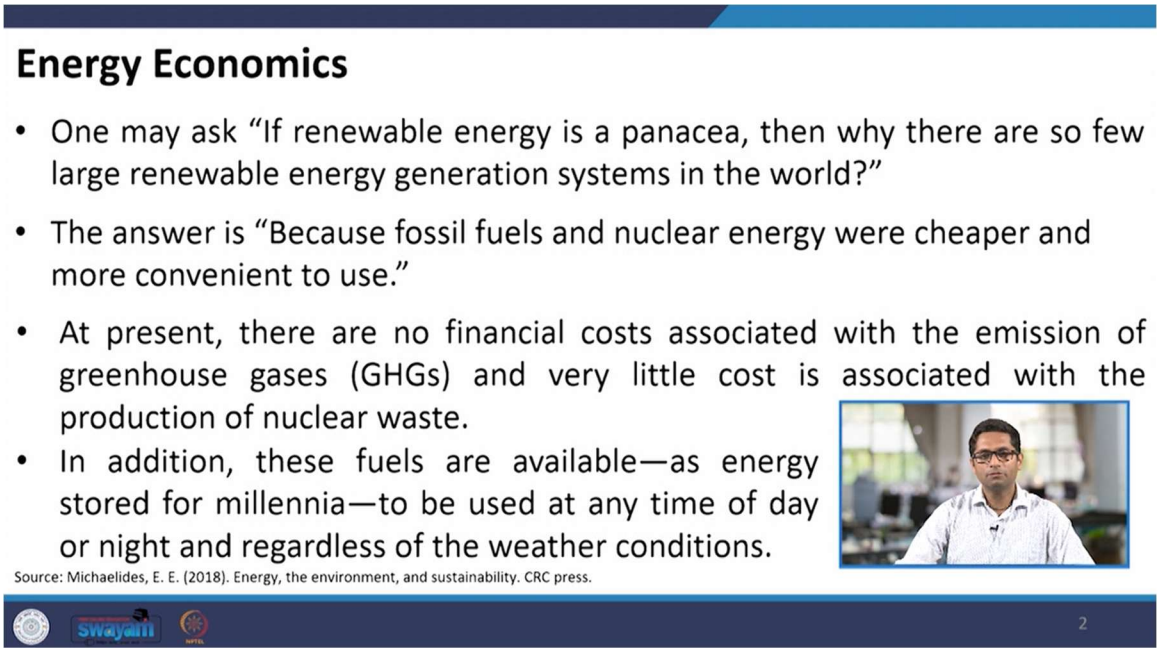
Week – 03

Lecture – 01

Lecture 11 - Energy Economics-I

Hello everyone, welcome back to the course Energy Resources, Economics and Economics and Sustainability. So, from this week onward we will be trying to understand some of the basics of energy economics. In the earlier weeks we have tried to understand the energy scenarios throughout the world, what, how the energy is produced, how the energy is consumed, how it differs in different parts of the world and we studied the basics aspects of both renewable and non-renewable sources of energy. So, going further it might come to your mind that everyone talks about renewable energy like everyone is saying we should go for renewable energy but if we go out we hardly see any renewable energy in action.



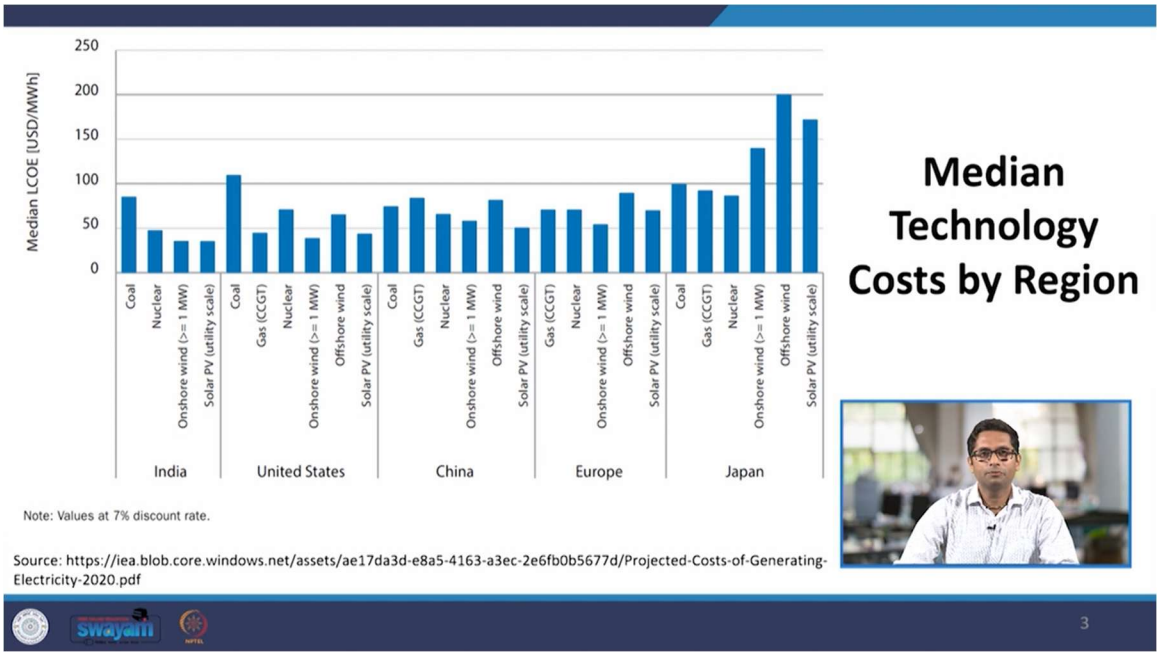
Of course, you would see a few solar rooftops here and there, a few EVs on the roads but exactly how much renewable energy do we see and that like all of us are puzzled by this question like everyone talks about maybe green hydrogen, green technology, this is the era of sustainability or ESG but why is renewable energy not seen so often in the world around us. And the simple answer that I would say would be that because fossil fuels and nuclear and the allied energies have been there for almost many decades they have been a convenient source of energy to be able to be used very easily and above all they are still cheaper as compared to most of the renewable sources of energy.

So, in today's world like if you have to adopt a technology or go for a technology economics still make the choice of like which technology is to be adopted and to be used. So, it has so happened that like the sources of energy specifically fossil fuels and nuclear and the allied technologies with all the shortcomings and their effects on the environment have continued to be the most cheapest and the easiest source that could be used for the application of different sources of energy. And also there have been no significant effects or that have been put on the GHG emissions that result from the use of this resources. So, there is no penalty that has been put on the countries who would be using excess of the GHG gases or who would be producing a lot of nuclear waste.

So, there have been no legislation or no fruitful legislation I would say on this front. Further the sources of energy have been available at any time that we want. Now the demand of energy is not uniform throughout the day. It would increase and decrease through the different time spans and it is also not constant through the different seasons. Depending upon which part of the world you are in and as you are studying the earlier part of the course as well some countries would have a greater heating needs while others would have a greater need for the cooling needs.

And this all entails that we should have a source of energy that we can increase or decrease as per our demand. And this has not been the case with many of the renewable sources of energy. For an example solar and wind are available only during certain aspects of the day. What if I need to use the energy during the night time or what if I need to use the energy when the wind speeds are below the cut-in speeds. So, in that case it becomes difficult for us to make appropriate use of the energy and storage is still

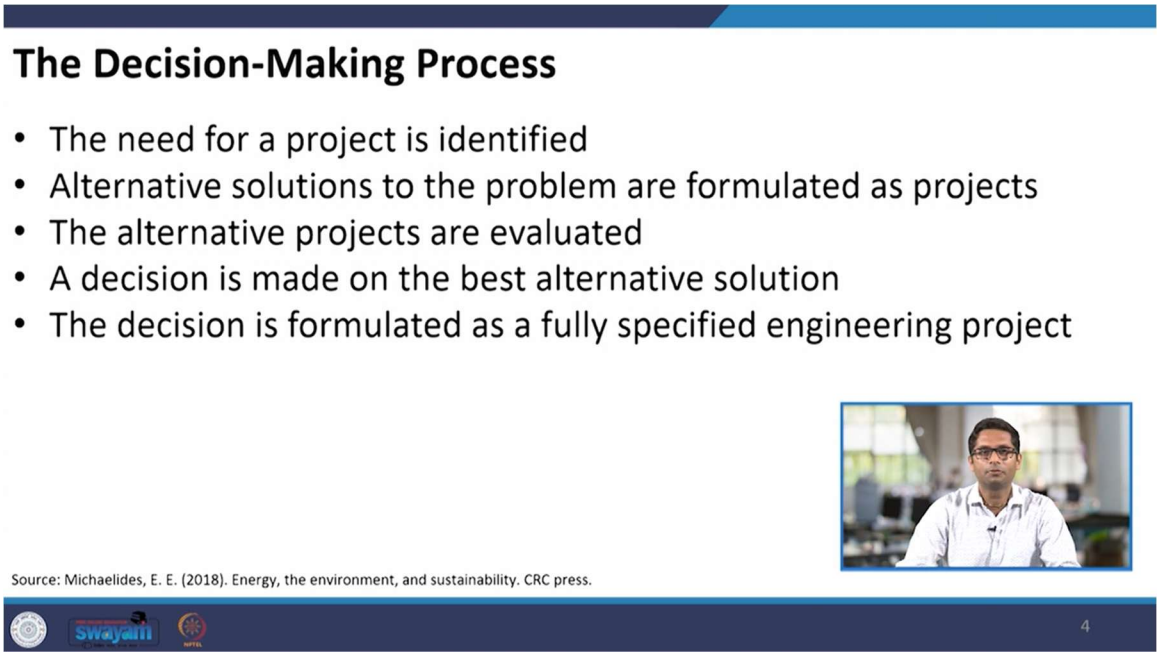
presently not a very economical option for the energy use. And that has been one of the major reasons for the world to still stick to these resources that are cheaply available.



If you see the cost of some of the technologies in different parts of the world and this is a fairly recent data we can see that solar and other sources of energy are coming close or even lesser than what is the cost of electricity production from a conventional resource like coal. So, what you see here is the median LCOE when you say the term LCOE it is the levelized cost of electricity production and this is given in terms of US dollars per megawatt hour. And on the x axis you see the different types of fuels that might be utilized for the production of electricity. So, we have the case for five major economies of the world you can see India on the far left side and we can see because of the gaining technologies and the condition in India like solar or onshore wind has become comparable even lesser than as compared to coal.

But this is not the case exactly for other countries say if you consider the case of Japan coal or gas or nuclear steel continue to be the cheapest source. It had been a bit different for China as well. So, different countries would have different types of economies and based upon what is most profitable for the different industries they will keep on using that resource. But this scenario has changed quite late on and you can see significant effects or significant changes that would be happening in the future. So, in the future I

would suggest like we would be seeing more of the renewable energy in action because it has now become like economical to use it in day to day life.



Now, how would one decide like whether we have to go for a renewable source of energy or a clean source of energy and that is a difficult choice to make. So, some of the major steps that are involved in a practice like this are shown in front of you. The first thing that is the need for the project is to be identified. Say we are currently situated in a town called Roorkee and in Roorkee say there is a need for future electricity demand say 100 megawatt to come up. So, that is the need of the project.

Second we would want to analyze the different kind of alternates that are available. Now, the easiest way could be I could build a coal power plant as there have been in the past. An alternate could be I can go slightly into the Himalayas and build a dam there which could be providing me the extra electricity of 100 megawatt. I can also go for a solar farm. I can also try to see the possibility of a wind farm in the nearby areas or there is another technology that is upcoming is that is the use of hydrokinetic technology wherein I can put in small turbines in the flowing rivers that might be able to extract some energy.

So, once the alternatives that are possible are listed down I would like to evaluate the alternatives and this evaluation could be done on different aspects. Say there has been a movement of people that say we do not want any more dams to be built in the Himalayas.

So, that issue is ruled out at the very onset. Further there might be certain environmentalists who would say that this area is home to a lot of like migratory birds that come in a particular season and the location of a wind farm in so and so area might be harmful for these birds which might have a collision with their wind farms and might not have a good future in that sense. So, in that case some of the alternates might be ruled out.

Further there could be another lobby who would be against the use of a nuclear power plant which would say that we had an experience of a Fukushima in Japan quite a decade back and they would not want to experience something similar in India in the future. Then once the decision is made there is an economic evaluation among a few options like whatever is coming out maybe a solar plant or a coal based power plant and there would be a team of people who would be trying to understand which would be the most economical. They would also try to understand like a plant not from the present perspective but from a perspective of the future demand increase as well. So, the demand is not going to be constant for maybe for the 10 years or so it is going to be either increasing or decreasing and based upon the projection that have been made people would want or the decision makers would want to have the flexibility what if the demand rises. Will the plant be flexible enough to provide more electricity in the future? And once the decision is made the project is finally awarded to an engineering firm which will do a step by step design of the whole process.

So, they would want to say put in like what will be a time frame when the project would be built. So, a typical project for an energy related project can take somewhere between 2 to 5 years for the complete building and then what will be the operation years? Well it is going to be operational for 15 years, 20 years for a hydropower plant it could go as high as 60 to 70 years. And it would also try to be like which aspects of the plant would be built first which would be built after how the operation changes over time. So, this is the normal trajectory that would be taking place for an energy plant that is projected to be in the future. A major aspect that would also dictate the price at this front would be the price of the variable cost.

A variable cost is basically the cost over which we have little control and one variable cost that would eventually come in is the price of the fuel that would be using. So, of course you can go for greener fuels but for the construction or the transportation of the raw materials you would anyway be using some kind of liquid fuel like petrol or diesel. And any fluctuation in the price of this can affect the decision of the plant because such kind of activity normally ranges from 2 to 5 years. What if there is a drastic increase in the price of the fuel? The price of construction of the plant would have a very drastic effect in that sense. So, we will try to understand these things as we move further.

Fundamental Concepts of Economics

- **Average Cost:** The total of all fixed and variable costs of a product calculated over a period, usually 1 year, divided by the total number of units produced, e.g., the average cost of electricity is INR 4/kWh, the average cost of production of the battery the XYZ factory produces is INR 2,00,000/- per battery
- **Average Revenue:** The total revenue of the product units sold over a period, usually 1 year, divided by the total number of units sold, e.g., the average revenue of electricity is INR 5/kWh; the average revenue of the battery the XYZ factory produces is INR 3,00,000/- per battery.
- **Average Profit:** The difference between average revenue and average cost. Using the two examples earlier, the average profit of electricity is Re 1/kWh and that of the drill bits is Rs 1,00,000/- per battery.

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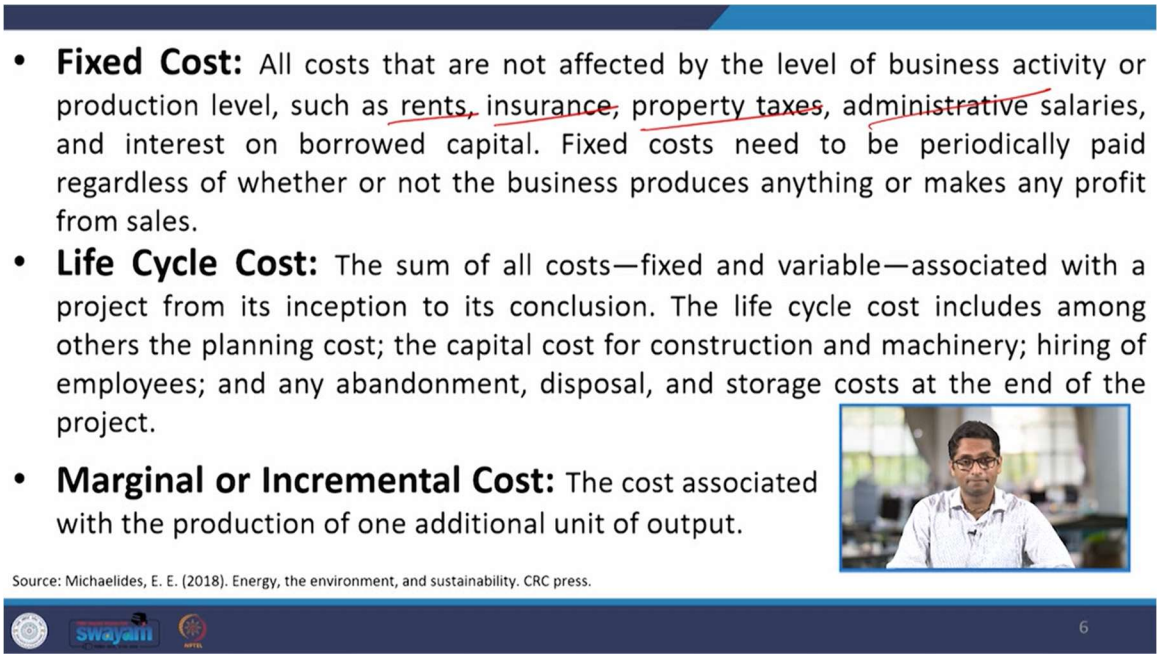
So, let me try to introduce you to some of the basic concepts of economics. Some of you might be also aware of them but for the benefit of everyone let us go through them one by one. First thing is the average cost. So, average cost is basically the total of all the fixed and variable costs. And this is typically calculated over a year.

So, an example could be like the electricity that we get in our homes has an average cost of 4 rupees per kilowatt hour which is also referred to a unit or one of the batteries that might be used in some of the industries might cost 2 lakh rupees for a battery. Another term that we would like to understand is the average revenue. Now when you say average revenue it is like the revenue that would be generated over selling of a particular period and this also would typically be one year and it would be divided by the total number of

products sold. So, another typical example could be like a discom selling electricity at say rupees 5 rupees a kilowatt or a manufacturer of a battery selling a battery for 3 lakh rupees per battery. Now whatever is the difference between the revenue and the cost comes out to be the profit. So, this is the premium that the or the profit that the firm will be generating and if the firm is spending 4 rupees for generating 1 kilowatt of electricity, 1 kilowatt hour of electricity and charging the customers 5 rupees per kilowatt hour, 1 rupees becomes its profit. And in a similar way the profit for batteries would be 1 lakh rupees per battery.

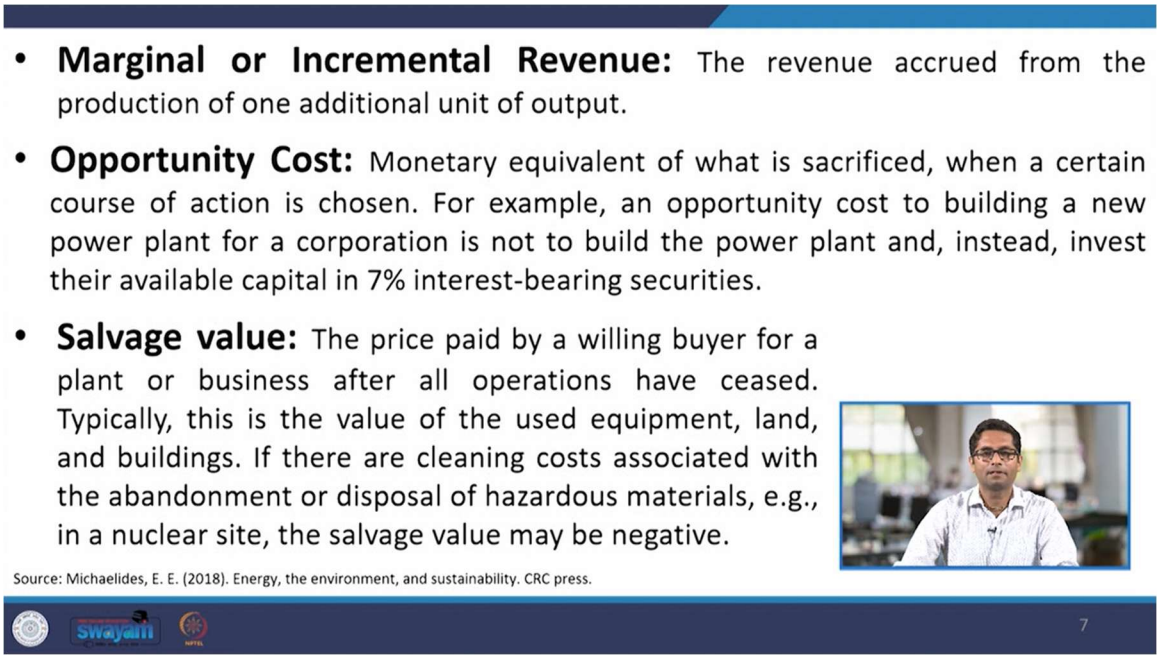
similar



Then there would be some costs that would be incurred by the industry or the energy industry that will be the fixed cost. Now fixed cost is something that you would be paying irrespective of whether the plant is operating or not or operating in the full capacity or the not. These kind of costs includes like costs like the rents of the property or if you are renting something the insurance premium that stays constant, the property taxes that you would be paying, the administrative staff like the managers or the salaries that you would pay you would be paying them you would not be firing some staff if the plant is not operating for a month or two.

And also if you are borrowing certain capital from the different kinds of banking institutions you would have to pay the interest. Whether the plant is operating or not operating is not none of their concern they would want their payment to be delivered on time. And fixed costs like are periodically paid whether the business produces any profit or not. Then there is also the lifecycle cost. Lifecycle cost basically means taking into account all the costs over the life cycle of the project.

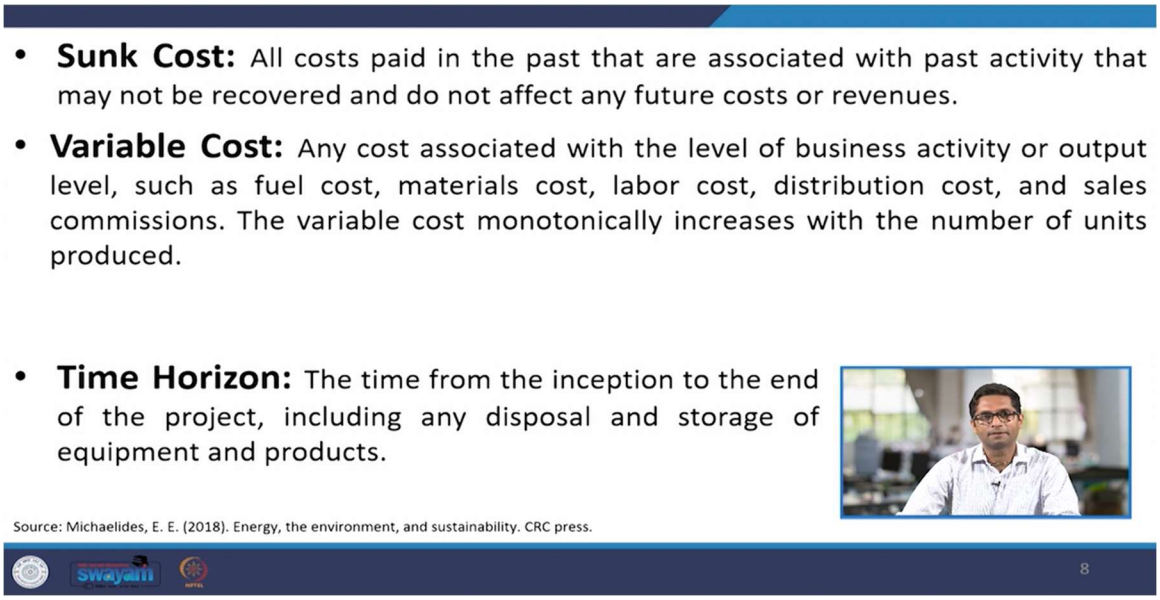
This means the construction cost, the cost during the operations and also the final disposal or abandonment cost or any storage cost that would be required at the end of the plant. Like in the case of a nuclear power plant you would have to incur some cost for removing any contamination of the soils that might be resulting. Or in the case of a coal power plant you might want to sell off the disregarded equipment and that might fetch you some profit at the end of the plant. Further there could be a marginal or an incremental cost. This is basically the cost that would be associated with the production of one additional unit of output. Say a plant is designed for producing 100 megawatt of electricity. What would be the incremental cost in terms of both operations and the modification that I would have to put in if I was to produce 101 megawatt of electricity.



In the similar way there is an incremental revenue. Say suppose a plant has been designed for 100 megawatt of electricity production. If I go for 101 megawatt of electricity

production will there be an additional revenue that I will be generating and is that justifiable. Then there is also the opportunity cost. Opportunity cost is basically equivalent to that if I am taking in, if I am choosing a certain path and what would be the cost associated with the path that I have not chosen. Say we can have an example say I am building in a new power plant and opportunity cost for that new power plant would be that suppose I would not gone for that plant I have invested that money that for building the power plant in a bank deposit and that bank deposit was giving me 7% interest. So based upon I can compare which path was a better path. Then finally we have the salvage value.

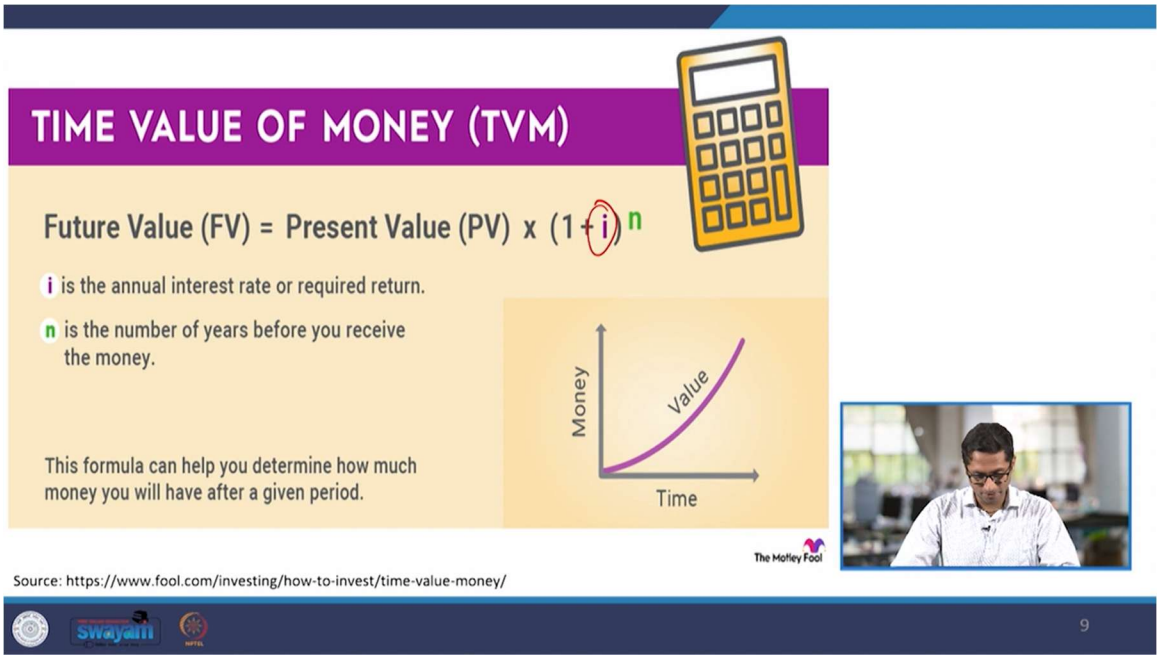
Salvage value is basically the amount that you can own or that you can gain by selling of the equipment, land or the buildings after the useful life of a plant is over. So this can be both positive and negative as I have told earlier as well like for typical plant like a coal based power plant this value could be positive because you would have equipment made up of steel and other metals which could fetch you some price. On the other extreme there could be a nuclear power plant where you would want to clean up the contamination that would have been produced by the plant through its lifestyle.



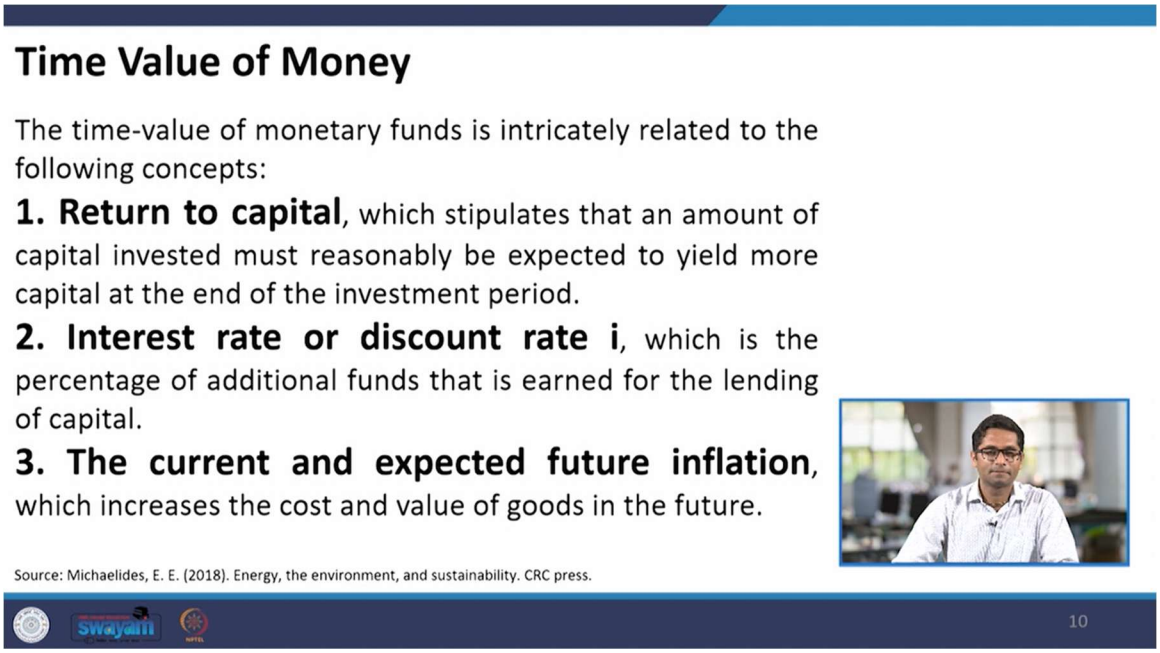
Further there could be a sunk cost. Sunk cost is basically the cost that you have incurred but it is no longer recoverable or useful. There might be like you would have put in some investment on a new building up a new infrastructure but that infrastructure could not be

used because of some reasons. One example in the Indian aspect could be like there was a lot of investment that went into natural gas based power plants and most of it is now a sunk cost because there has been hardly any use of natural gas based power plants because coal happens to be cheaper and natural gas was not readily available. Then there of course would be a variable cost. Now variable cost would be something related to the operations of the plant. So this basically turns out to be the fuel cost.

This would increase with the generation capacity of the plant more the generation more will the fuel cost or the labour cost that is associated with the day to day operation, the distribution cost, the transportation cost. So all these cost would increase or decrease along with the operations of the plant. If the plant is operating at a full capacity or the rated capacity and this would be optimum if they are going for a lower capacity. So this cost might be increasing might not be a linear approach but would be decreasing with a decrease in the operational capacity of the plant. And then we also need to understand the time horizon like this the types of projects that we normally deal for an energy related field would vary somewhere between 10 to 50 or 60 years which is a very long time horizon and so investment that are made in this aspect can be quite risky. Further it also needs to be taken into account like any disposal or the storage of the projects that happen in the between. So the time horizon is an equally important aspect.

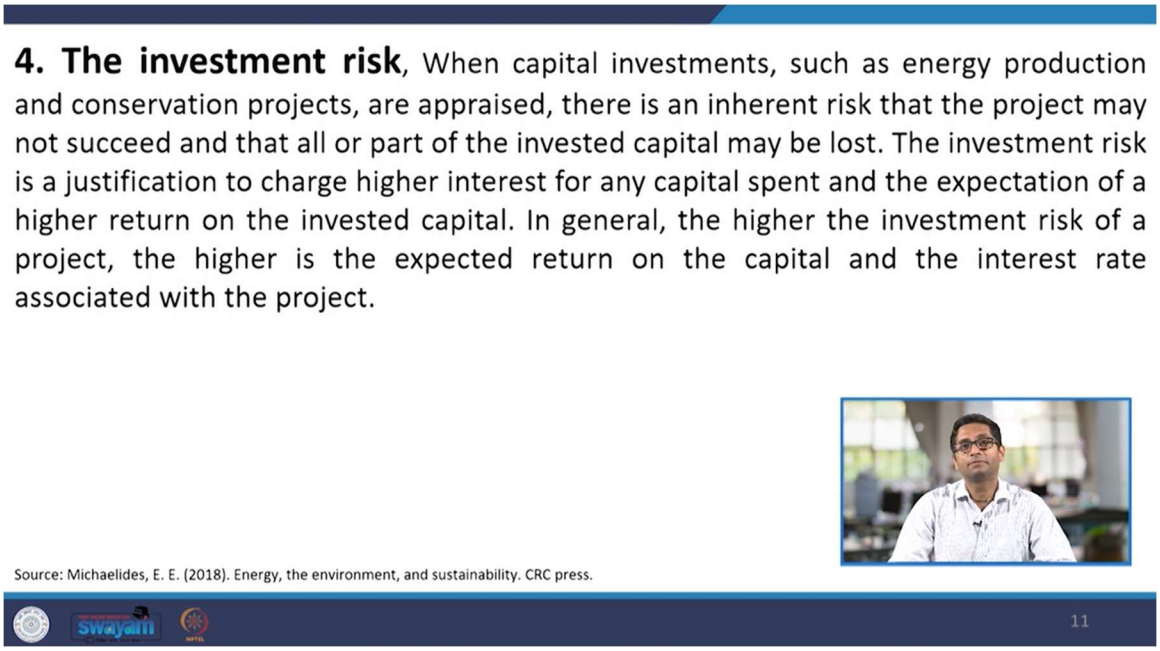


So from time we also need to understand the time value of money. So by time value of money I would say that if I have 100 rupees in my pocket today it would be not be equivalent to having any 100 rupees one year down the line. What I mean to say that if I would have to put in an equivalence in the future I would want to have more than 100 rupees in my pocket.



So this goes by the simple formula that if I have 100 rupees today this would have certain amount of appreciation with time which could be by the interest rate I and depending upon what this interest rate is the future value of 100 rupees that I have today would be 110, 120. So if I have 100 rupees today this would be equivalent to maybe 120 rupees two years down the line where I can also say if I have 120 rupees two years down the line this is equivalent to 100 rupees today. So this means there is an appreciation in the value of money with time and this could be seen with a simple graph. Now a few of you might be and want to know like why this appreciation really takes place like why can't the value of money could be assumed to be constant over. So there are many explanations for this one of it says that if I was to invest the money that I have in a bank account this would naturally fetch me some interest and I am not just going to keep it in a locker I will put in a bank account that will give me some interest and if I am using it for some kind of investment I naturally would want a gain that is greater than that and this is where the time value of money comes in and it is basically dictated by either the interest rate or the

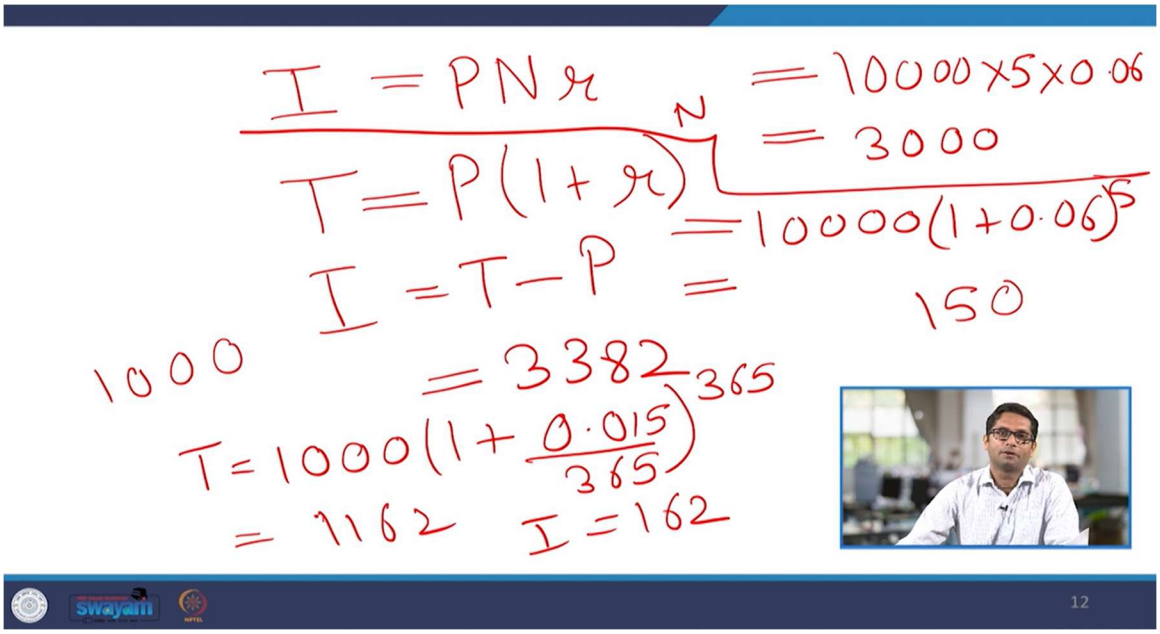
discount rate which is basically the rate at which the value of the money would be growing in the future. Further we also are aware of the concept of inflation wherein the price of commodities would not stay stagnant but would be steadily rising in the future to account for that we also need the value of money to rise and then there is also an important aspect of the investment risk.



Now a particular energy project would have a great degree of risk that is involved there are two reasons for that one is the technology is constantly changing there is a push for newer and newer technologies so if I set up a coal plant today I am not aware that maybe 10 years down the line there is a policy which forbids the operation of coal plants at all. Further the technologies or the new technologies that are coming in are being applied at a scale that they have not been used before so there could be some issues with the operation of like maybe acres of solar fields which I am not aware of but that might happen. So there is a lot amount of investment risk that is involved and the investors or the bankers who would normally fund these kinds of project would want to make sure that they have made enough profit before they tend to enter any risk. So they would want to offer the capital or the loans at a higher rate and this is again where the value of money comes into it. Energy projects as such have a greater investment risk there are two primary reasons for it one is the scenario for the energy market is in a flux there is a lot of like and there's a lot of lobbying going on for renewable or clean sources of energy. Further the life of

these kinds of plants spans from 15, 20, 30 or 40 years and it is very difficult to commit or explore how the things or the policy or the policies are going to be there for the next 10 years, 15 years, 30 years. There will be a lot of geopolitical factors, political factors that would be coming in and people are afraid to put in their money. Then we can also understand the simple aspects of simple and compound interest. So this is something that we would have studied in our school days as well.

So when I say a simple interest I would say that the interest that is generated for a loan that I have taken would be a function of the principle multiplied by the time period and then multiplied by the rate of interest. And this is a very simple calculation. Further if I would want to go for a compound interest the total that I would have to return after the period would be T it will be a function of the principle then the rate of return 1 plus rate of return raised to power n which is the time period and the interest would basically be the total minus the principal amount. So just to take an example if I was to take a principle of 10,000 rupees the interest if I want to charge for that for 5 years at a 6% interest rate this would be 10,000 into 5 years into 0.06 and this value would roughly come around to be 3000 rupees.



Similarly if I would have taken a compound interest, so the compound interest maybe I can use in here and this kind of calculation would be principle remains at 10,000. So I am talking about a total one and this will be 1.06 raised to power 5. The total that I would be

generating would be 13,382 and the total minus principle would come around to be 3382. So for a similar kind of factors that you would take in a compound interest is expected to give you a higher return and this is also the case with the credit cards.

So if you have ever analyzed the different kinds of credit cards that you would be buying or using some of them would charge you an interest on the daily rate. So what they would say is like we are charging a 15% interest rate that is compounded on a daily basis. So let us try to understand the calculation say suppose you are spending 1000 rupees using a credit card and the credit card will be charging a 15% interest rate but it is compounded daily. So what it is essentially doing is it is the total would be 1000 into 1 plus 0.015 which is the interest rate divided by 365 and compounded on a daily basis.

So whereas if it was compounded just once a year it would be have like 15% interest rate would mean 150 rupees. If you do this calculation this would come out to be around 1162 or the interest that would be charged would be 162. So what is happening here is just because it is compounding daily it is having an extra interest revenue of the of 12 rupees over 1000 rupees. So you might say this is a fairly small amount but depending on the quantum of revenue or the quantum of sales that they make on using the credit cards even the small amounts can add up to a very big value. Let us also try to understand this concepts with the help of another simple example.

Say a contractor is building a new housing and he or she has two different options. One thing is like it can take a loan of 40 lakh rupees for 5 years at a simple interest of 7% or a compound interest at 6.5% and it is assumed that all interest and the final capital will be taken at or will be paid at the end of the loan period. So which type of interest would you choose? So we can again do the simple calculation suppose the house is worth 40 lakh rupees and for the simple interest the calculation goes as it is for 5 years and 0.07. So the total amount that would be payable or the total interest that would be payable at the end would be 14 lakh or the total principal plus interest that I would be paying would be almost 5 lakh 40 thousand at the end of 5 years. Now if I would have to go for a compound interest this would mean that the total would be the principal of 40 lakhs and 1 plus 0.065 which is a lesser interest rate and it is for again 5 years. If you do this calculation the total amount that you would be paying would be roughly 54,80,347.

Question: A contractor is building a new housing development and is given the option to take an INR 40,00,000 loan for 5 years at a simple interest of 7.0% or at a compound interest of 6.5%. All interest and capital will be paid at the end of the loan period. Which type of interest should the contractor choose?

$40,00,000 \times 5 \times 0.07 = 14,00,000$

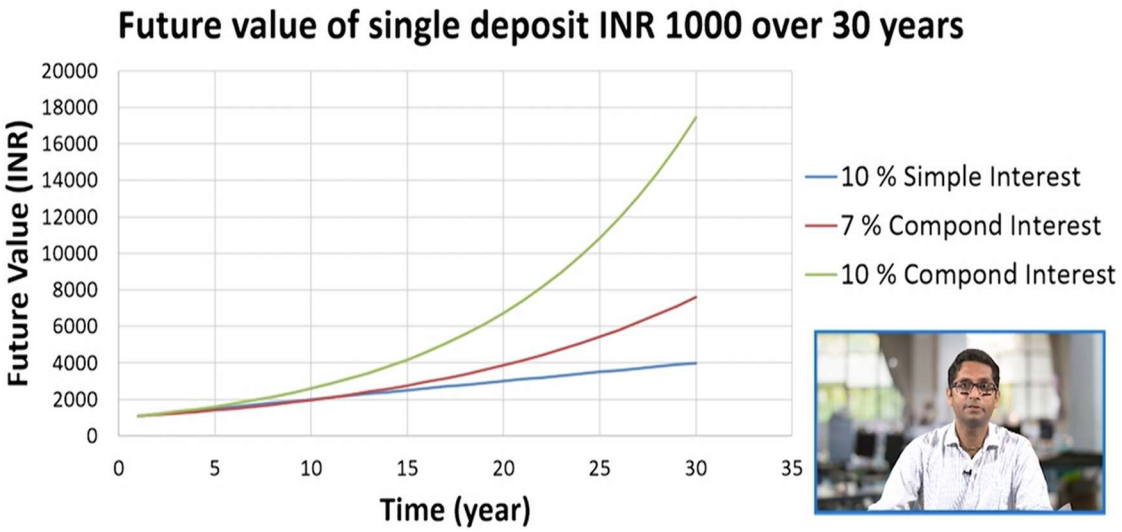
$P + I = 54,00,000$

$T = 40,000(1 + 0.065)^5$

$= 54,80,347$

Yeah. So yeah in the earlier case this is for 54 lakhs and in this case 54 lakhs exact and this in this case this is 54,80,347. So even for a lesser interest rate a compound interest is expected to generate more revenue or is going to be like if you are taking a loan it is going to be much more dearer to you. So it is always better for the companies to give you interest on a compound interest because in that case they can always charge interest on the interest that is generated. So this is these are some of the basics with respect to simple and compound interest.

Why Compound Interest?



So the same calculation could be seen here. So the fund that I wanted to make is like it makes a lot of difference whether you are using a simple interest or a compound interest. Herein you can see how the value of the money would be changing if there was a simple interest at 10%, a compound interest at 7% and a compound interest at 10% and how the value of 1000 rupees would appreciate for the next 30 years or so. So if you see there is a linear rise for 1000 rupees and it might end up being 4000 in 30 years for a 10% simple interest and if I take compound interest at 7% this might turn out to be more than 7000 and in case of 10% compound interest it would be more than 17000 or so. So there could be a huge difference that could be made by just the discount rate or the percent at which the compounding is taking place. So this is an important aspect and we will be trying to understand the influence of these factors on the economics of a built power plant in the future. So with this we end today's class. Thank you.