Energy Economics and Policy
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Week - 4
Energy Supply - Part I
Lecture - 2
Energy Investment

Welcome to the 2nd lecture of the 4th week and we are going to discuss the investment in energy projects.

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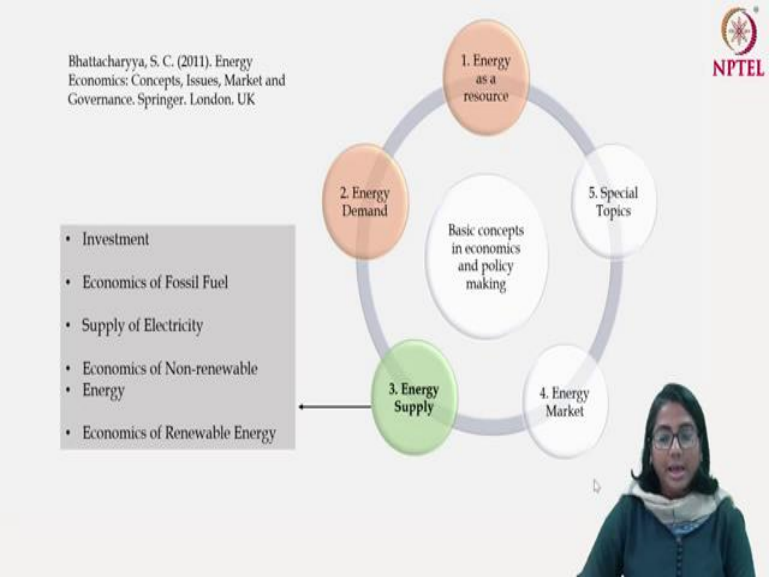

As mentioned in the previous lecture we are going to cover five topics or subtopics under the module energy supply during week 4 and week 5. And given is the book that you can refer to for further details. Investment actually refers to the investment in energy resources and in this lecture, we are going to cover the same.

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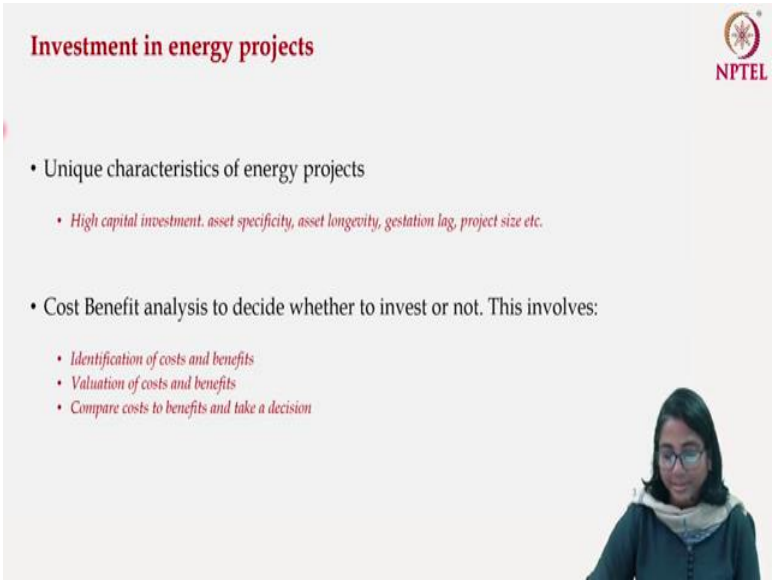

When we talk about investment in energy projects, it is very different from investment in other projects. Even if we compare with heavy manufacturing, investment in power plants and other energy projects bear some very distinguished characteristics. We are going to discuss these unique characteristics of the energy projects with regard to the power plant and also try to understand how the cost benefit analysis can be carried out in order to take the decision in favor of or against the investment in the energy projects.

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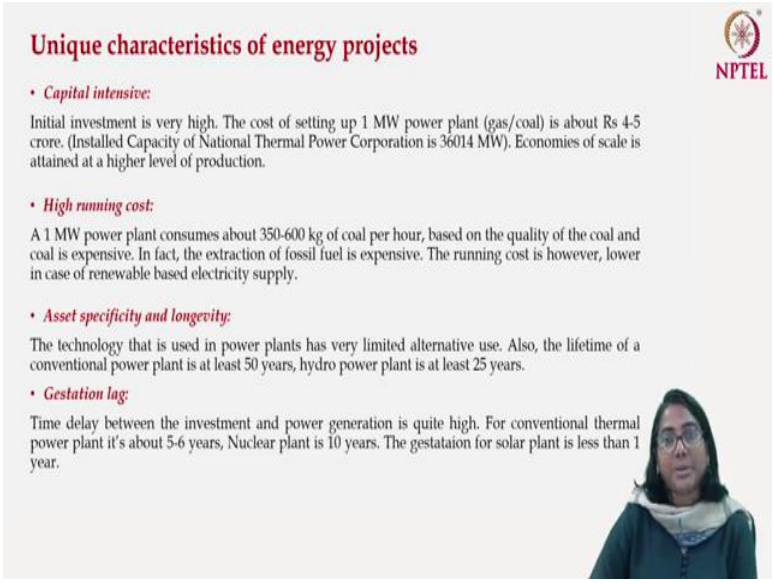

What are the unique characteristics of the energy projects? All energy projects are extremely capital intensive in nature; which means that the initial investment of the energy projects is very high. In the previous lecture, we discussed that there are two types of inputs of production, one is a fixed input and the other is a variable input. If you think about energy production, the fixed input which is the capital that is required is very high.

For example, in India to set up a one MegaWatt power plant which can be gas fired or coal fired; it takes approximately 4 to 5 crores of rupees. As for the size of the power plant, if you think about the National Thermal Power Corporation (NTPC), the size of the power plant that they have all together is 36041 Mega Watt. This provides a fairly good idea of the volume of investment that is needed in order to set up a power plant. This is one of the distinguished characteristics of investment in any power project.

Second important factor in this regard is that the economies of scale are attained at a higher level of production. If you have less amount of money and want to invest in a power project or energy project, you can think that you will be able to set up a smaller power plant but that is not possible because in case of power plant you get reap the economies of scale and variable inputs become efficient only at a higher level of production.

Recall the shape of the average cost curves, the shape of the productivity curves, it increases upto a certain point of time. The producer wants the productivity of variable input to go upto the point from where it starts declining. Therefore, you need to produce a certain minimum amount of power in order to take advantage of the huge investment that has been carried out at the beginning.

The next is the high running cost. It's not only the capital cost for the power projects that are high, the variable costs are also high. Other than labour or material, one of the major inputs of the production of energy is fuel. This can be coal, gas, uranium and so on or if you think about renewable resources, it can be solar or wind energy.

However, if we just keep aside renewable for a while and think about the gas fired or coal fired power plants; then again to give you another example, a one MegaWatt power plant will consume approximately 350 to 600 kg of coal per hour that is, to produce one MegaWatt power for one hour requires 350 to 600 kg of coal. You can imagine the huge expenditure that has to be incurred in order to produce energy so not only the fixed cost but the running cost of energy projects is also very high.

However, for renewable energy the running cost is not so high. The running cost may be minimum for solar power as it is neither labour intensive nor requires any raw material or fuel, so it can wane.

The third important point is the asset specificity and the longevity of the capital investment made. The capital investment has gone up to set up a power plant, certain kinds of machinery or assets. These assets are very specific to energy production so if I decide tomorrow that I do not want to continue with the production of energy, I cannot suddenly convert the power plant into some other manufacturing unit.

The asset that is required for the production of power in the energy projects is very specific to that particular project and also there is the matter of longevity. Once the project or the plant is set up it is not going to go away within a couple of years' times. So one cannot divert investment within 2-4 years because once a power plant is set up it stays for at least 40-50 years, for example the conventional coal fired or gas fired power plants. Even for renewables, the hydro power projects are going to stay for at least 25 years, so the longevity is huge. If you invest some x amount of money today; firstly, this x is going to be very high and secondly you cannot divert this x amount. The asset that is purchased out of this x amount of money is for a long period of time and it creates a lot of uncertainty. You are actually going to block your investment or going to block your money in a particular project for a number of years.

Again, think about the developing countries where the investment has competing demands. If you are investing in one particular project where the investment is going to stay for 25 to 50 years; one has to be really careful to understand what is the outcome of that particular project, what are the private benefits that are going to be generated, not only that, what are the social benefits that are going to be generated out of the investment.

The final point that we are going to discuss here is the gestation lag. For an investor it is very important to understand the revenue flow. If I am investing money today, I know tomorrow I am going to get my money back but one needs to understand what is the difference between or what is the distance between quote-unquote today and quote-unquote tomorrow. In the case of a power plant if I invest today, I can't expect an outcome within a month or a year.

The gestation lag that is the lag between the investment and the generation of revenue is quite long in case of power projects. For example, for the conventional thermal power plants, the gestation lag is about 5-6 years. If you start building the power plant today, you have to wait

for at least 5-6 years to produce power in order to sell it in the market and therefore to generate the revenue stream. However, if you think about solar power, the gestation lag is quite less, it is less than one year.

All these features of energy projects show us that a lot of investment is needed at one point of time where the money will be blocked for a reasonable period of time and after that the return is going to be generated. Now the question is, once this kind of investment has been made, what is the outcome? If I consider that the outcome is the production of electricity, what are we going to do with that electricity? This electricity is going to support activities in the manufacturing sector, transport sector, the railway system and also support a lot of household activities.

The output that is being generated not only generates an income stream for the investor and the laborer working in the plant but it also generates a certain stream of social benefit. Since there is a social benefit which is generated out of the output that is being produced in the market and requires a lot of investment so the private investors may not be interested to come and invest in this project. In this kind of a situation the government plays a role.

As for the investment in the power sector in India, most of the investments in the early days were coming from the government. Even today, for the National Thermal Power Corporation, (NTPC) the money for investment comes from the government.

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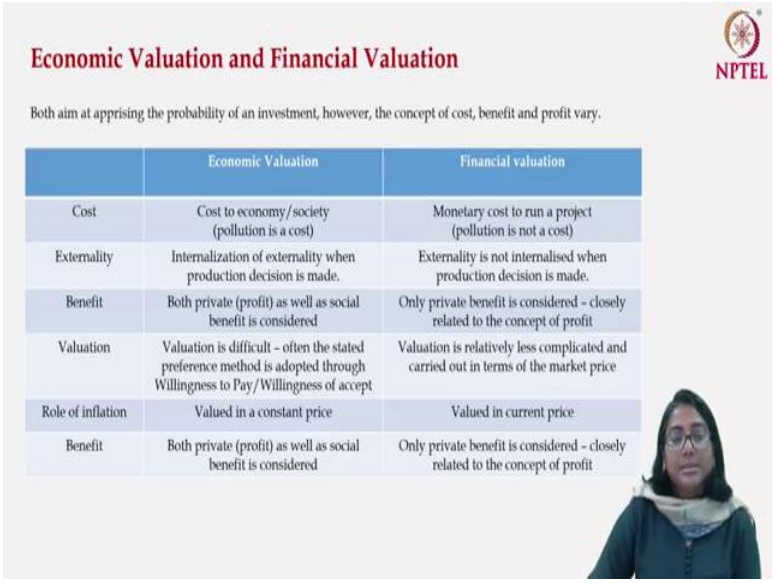

Next, we will discuss different criteria to analyze the cost and benefit that is being generated out of the energy projects. When we do this kind of valuation that is when we try to understand what is the cost of setting up or running a particular project viz a viz what are the benefits that are going to be derived. Here, we should be able to distinguish between two concepts; the economic valuation and the financial valuation.

Let us have a quick look to understand, what is the difference between the concepts of economic valuation and financial valuation? Both the concepts try to apprise the probability of an investment. Both the criteria, the economic valuation as well as the financial valuation try to judge whether it's worth investing in a particular project or not.

We are going to compare the economic valuation and financial valuation in terms of six criteria. One is the cost, the second is the externality, the third is the benefit, fourth is the valuation, fifth is the role of inflation and finally, the benefit.

What is the cost? When we think about the cost in terms of economic analysis, we take into account the social cost. It is not only the private cost of investment or private cost of running the energy project but we also take into consideration the social cost. However, when we are doing the financial valuation, we are only talking about the monetary cost.

How much money do I need today in order to invest in an energy project? How much money do I need to run the project? This is in monetary terms and if you think about coal fired thermal power plants, it causes a lot of pollution if proper pollution abatement measures are not adopted in the plant. The pollution is a component of economic cost and not financial cost because pollution is going to reduce the air quality which will lead to health hazards which in turn will lead to cost on the part of private individuals.

The health hazard due to pollution is a component of economic cost however, it is difficult to get a monetary value of this cost and therefore cannot be included as part of the financial cost. Hence, pollution is a cost which is an economic cost in terms of economic analysis and is not considered as a part of financial valuation.

Next, comes the concept of externality. Externality is an act which affects other's behavior, that is if I do something and that causes the behavioral decision of some other entity, then I am causing externality to the other person. Externality can be both positive or negative. Positive externality is a situation where my activity is influencing the productivity of somebody else in

a positive manner and the negative externality is the other way around. If you think about the emission of the power plants, this is causing a negative externality in the locality. People will suffer from respiratory problems not for something that they have done but something that has been done by the power plant. The power plant is actually causing a negative externality in the locality.

In case of economic valuation, since the concept of social cost is accounted for therefore, this kind of externality needs to be internalized. However, in case of financial valuation, because we are not taking into account the social cost but only the monetary value therefore there is no need to internalize the externality.

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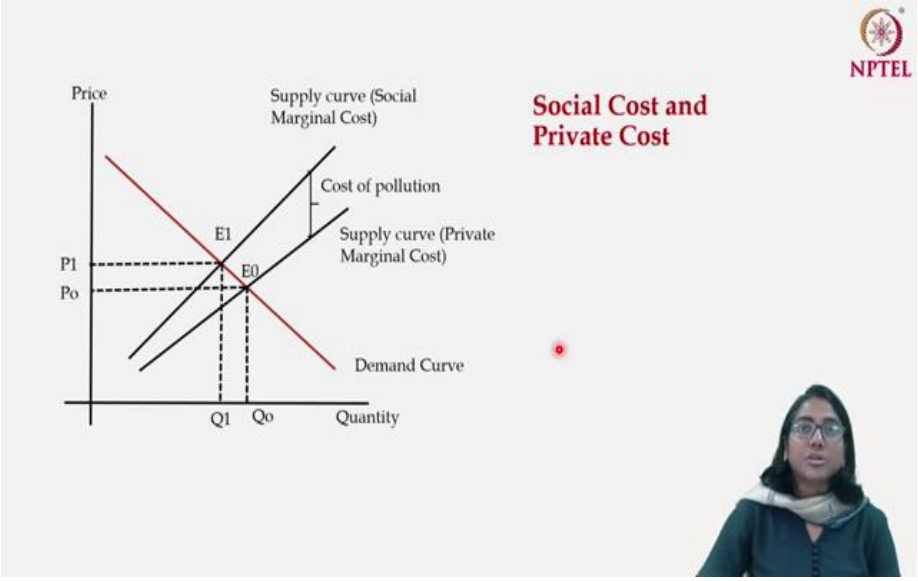

We will just quickly have a look at the diagram in order to understand, what is the implication of internalization of externality in the context of big projects?

Let us start with this kind of a framework where we have price and quantity and this downward falling curve is the demand curve. Let us take the example of the demand curve for electricity generated by the coal fired power plants. This is the demand curve for electricity and we are assuming that the electricity is coming from coal fired power plants. And there is a supply curve of the firm. Now that we know the concept of the supply curve, we know that the positively sloped curve represents the upward rising part of the marginal cost curve over and above the average variable cost. The supply curve shows the decision taken by a plant based

on its own individual cost or taking into account the financial cost. The private marginal cost curve comes out of the financial cost accounting.

With the given supply and demand curve the market determined equilibrium is at E_0. Q_0 is the amount of electricity being produced by this coal fired power plant and this is being sold at the price P_0. This is the market equilibrium with private marginal cost or the private supply curve. The problem is that it does not take into account the cost of pollution.

Suppose the government mandates that each of the power plants have to use some kind of pollution abatement mechanism so that the emission is reduced. If that is the case, then the firm has to incorporate some additional cost. This is what is called internalization of externality. The externality that this power plant was creating is now being internalized in terms of additional cost.

The moment the government forces power plants to use emission control measures, the cost goes up, this is the same as internalization of the externality. What does the supply curve look like? We have a new supply curve which incorporates the additional cost that the plant has to incur if it has to reduce the pollution. This new supply curve can also be called the social marginal cost curve, where the externality has been internalized.

However, if we take into account the cost of pollution, you will see that the equilibrium of the market changes. The new equilibrium now emerges at the point E_1 where the price charged for per unit of electricity is P_1 which is higher than the previous price P_0 that was emerging out of the private marginal cost. And you will also see that at this new equilibrium, the quantity supplied in the electricity market is less than the quantity that was supplied under the private marginal cost. The price has gone up and the quantity supplied has been reduced or the market equilibrium quantity has been reduced.

As the cost of pollution is taken into account, the quantity of electricity produced has declined and the price has gone up. When P_0 was determined as the price it did not include the cost of pollution. When you go for the social marginal cost curve, it includes the cost of pollution, as a result the price of the output goes up and the production that is supplied in the market reduces giving rise to a new market equilibrium. This is the concept of internalization of externalities.

Coming to the third point, we have talked about the cost, now the question is how do we come to the understanding about the benefit? In case of economic valuation, both private benefit

which can be calculated in terms of profit as well as the social benefit has to be considered. What is the difference between a private benefit and a social benefit? Suppose you are investing in a particular power energy project; it will not only lead to profit which will accrue to the entrepreneur but will also provide employment to people. This generation of employment is a social benefit whereas the wage that these individuals are earning is more of a private benefit that will be accounted for in the financial valuation. The wage and the investment will be accounted for in the financial valuation; however, the positive externality that will be created through the increase in employment will not be accounted for in financial valuation but that will be accounted for in economic valuation.

Understanding these two different types of benefits becomes very important when we discuss renewable and non-renewable energy. This can be also explained in terms of cost and externality. If we compare the non-renewable resources that is the fossil fuel-based power generation with the renewable based power generation in terms of profit and the production of electricity, they are quite comparable. However, there is a negative cost in terms of emission of greenhouse gases for use of non-renewable resources.

However, if you think about the renewable resources, there is an economic or social benefit that is accruing in terms of reduction or mitigation of greenhouse gas emission. This is a particular form of benefit and if we can come up with the value of the mitigated emission, that will be a part of economic valuation. However, in the absence of a market, if carbon credits are not sold then that will not be included as a part of financial valuation.

Next is the method of valuation. It is easy to do a valuation from a financial perspective because everything will be judged in terms of the market price so whatever component we include under cost or benefit, that component will be analyzed in terms of its market price. It is not very difficult to come out with the financial valuation although it has its own complexities. However, things become very challenging when we talk about economic valuation.

When we are talking about generation of employment or when we are talking about reduction of pollution in the local vicinity, it does not have any value. The reduction in pollution so bad which has been curtailed it doesn't have any market, it doesn't provoke any kind of market price. In that case if you don't have any understanding of the price, how do you value something? How do you say, what is the value of the emission mitigated or what is the value of the pollution that has been reduced?

In that case we take a different approach called the Stated Preference approach; here people are asked about their willingness to pay and willingness to accept. For example, we can go and ask them if the power plant reduces the pollution, how much money are you willing to pay because you are getting some fresh air. Suppose if you want to set up a wind turbine then people are going to face some challenges. What is the compensation that those affected would like to have, what is their willingness to accept? These are some indirect methods of Stated Preference how one can go for economic valuation.

The next one is called the role of inflation. What is inflation? Inflation basically changes or decreases the value of money. 10 rupees today is not equivalent to the value of 10 rupees 10 years back, inflation reduces the value of money. Therefore, when we are talking about the economic valuation, everything is valued at a constant price.

If I am thinking about100 rupees today and 100 rupees 10 years down the line then these 200 rupees will not actually be added up because 10 years down the line, the value of 100 rupees will change. Hence, everything is valued at the constant price. Inflation this way plays a role in the context of economic valuation; however, in case of financial valuation everything is calculated at current price. In fact, in case of financial valuation inflation is a kind of contingency that will be kept when financial valuation is pursued.

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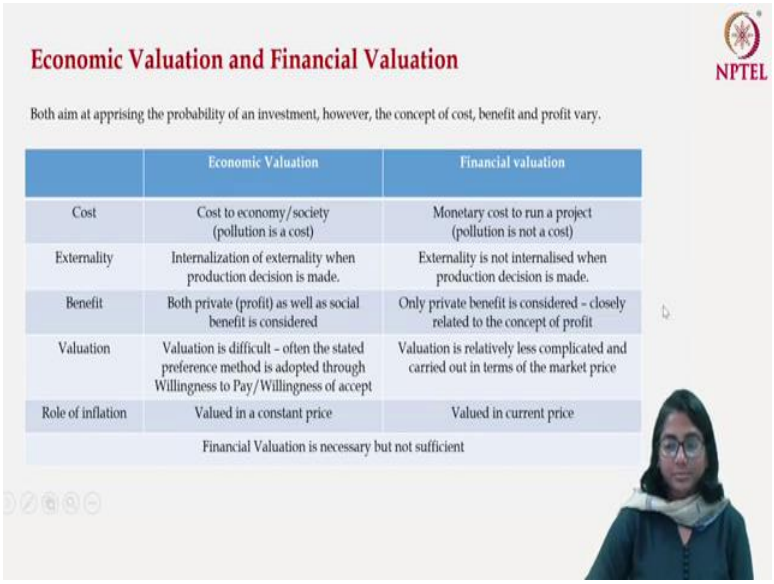

Finally, we are saying that financial valuation is necessary but not a sufficient condition for the project appraisal. We also think about externality, social cost, etcetera while taking a decision

about the investment because there are certain investments which may not generate a huge private benefit but there may be huge social benefit, one such example is setting up of schools.

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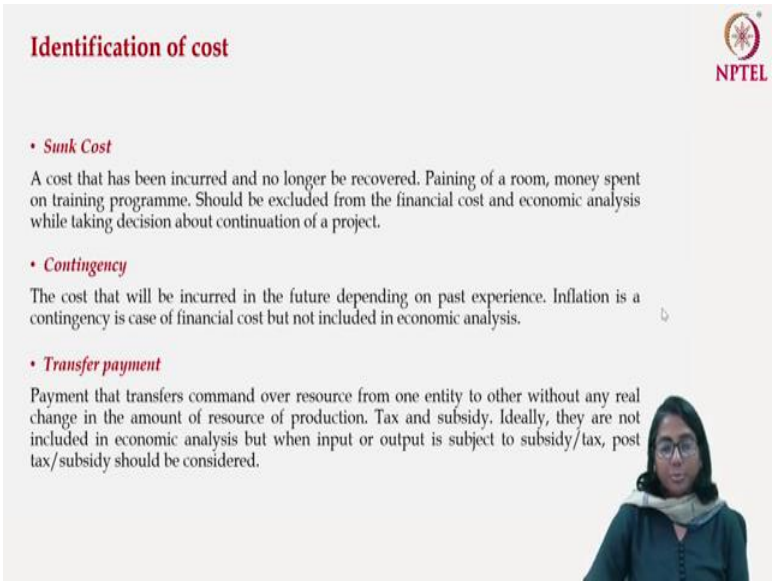

Once we understand the difference between economic analysis and financial analysis, the next important task is to identify cost components and benefits. Let us first begin with the different cost components that one has to be careful about when thinking about taking a decision about investment.

The first example is a sunk cost. A sunk cost is a cost that has already been incurred and can no longer be recovered. A very good example of sunk cost is that, suppose you have an office and you have rented one particular room and got it painted. When you are leaving that office, you can't take the paint away. The investment that you have made is going to stay there and there is no way that you can recover it. The money spent on painting the room and other such costs are called the sunk cost. This kind of cost should be excluded from the financial cost and economic analysis as well while taking any decision about the continuation of a project.

The second one is the contingency. This is the cost which will be incurred in the future, depending on the past experience. Inflation is a contingency when calculating the financial cost. However, it is not included in the economic analysis because you are already valuing everything at constant price, assuming the role of inflation away.

The next important component is the transfer payment. This is the kind of payment that transfers the command over resources from one entity to the other without any real change in the amount of resource or on the amount of production, nothing changes other than the change in ownership. If I give somebody 10 rupees that is just a change of ownership of that 10 rupees however, at the background there is no production or consumption activity that has changed. This kind of payment is called transfer payment. One very good example of transfer is tax and subsidy. When we are giving tax to the government or getting subsidy from the government, the underlying production structure doesn't change, only the money is transferred to or from the government. However, when you are doing an economic analysis, it's important to consider the post-tax or post-subsidy price of both input as well as output. Although you do not take into consideration the transfer payment as a component of your cost, it will be when you are talking about post-tax or post-subsidy inputs and outputs.

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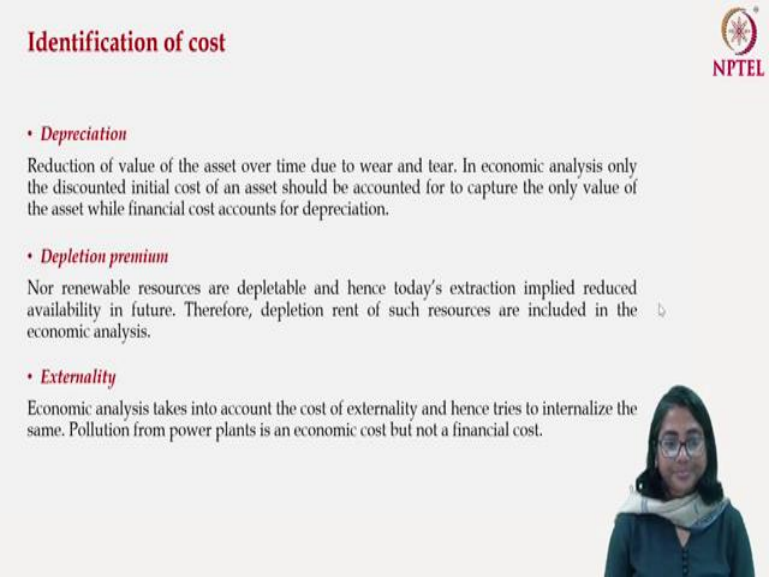

The next one is depreciation. What is depreciation? Suppose, a power plant has been set up and an investment of one crore of rupees has been made to buy a particular machinery which can run for 10 years. After 10 years there will be some wear and tear and decay in the machine and the machine will stop working.

As an entrepreneur I calculate the value of wear and tear every year and set aside a particular amount of money so that at the end of the 10^{th} year there is enough money to replace the non-functional machinery. The amount of money that is being set aside as a compensation for the

wear and tear of the machinery, is called the depreciation. When we talk about depreciation this is of course a cost that is being incurred by the energy producers or any other producers per se.

Depreciation is more like a financial cost that is being set aside and is not a part of the economic cost because through depreciation you are actually building up reserves to replenish some amount of money at the end of the 10 years. Depreciation is not a part of the economic analysis but it is taken into account in case of financial analysis.

The fifth one is called the depletion premium. If you think about the non-renewable resources, these resources are depleted overtime. There is depletion after some point of time and the resources will no longer be available to be extracted and will no longer be available to use. Because we are depriving the future from the use of these resources as we are using it today, there is a depletion premium. And this depletion premium or depletion rent of this kind of resources are included in the economic analysis. Depletion premium is like a time value.

The final one is the externality; economic analysis takes into account the cost of externality and hence tries to internalize the same. However, in case of the financial cost we do not take into consideration the cost of externality.

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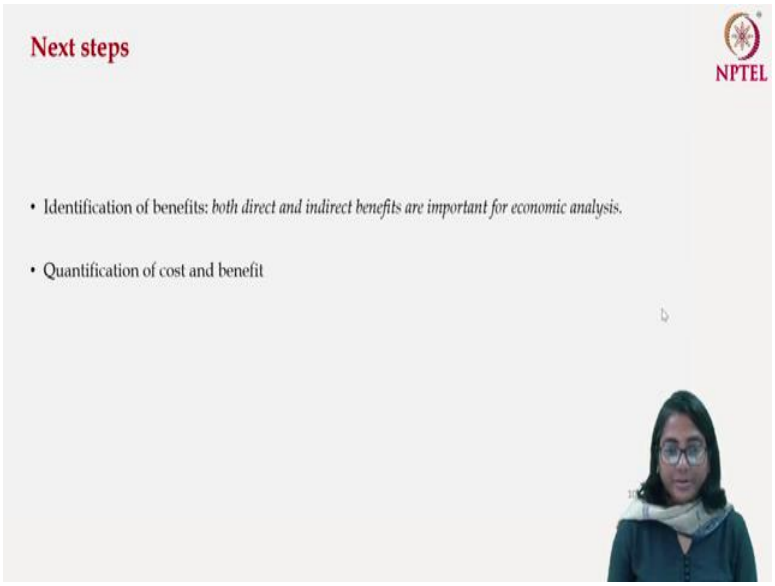

The next step after you identify the costs, is to identify the benefits. The benefits can be of two types; one is the direct benefit and the other is the indirect benefit. For example, what is the

direct benefit from setting up of, may be hydropower projects. One of the benefits is definitely of producing electricity. Electricity has a particular price and therefore, electricity is being bought and sold in the market and it is generating some revenue.

The second benefit is of course, the revenue that is being generated through the payment made to laborers, purchase of the raw material, maintenance of machinery and the profit earned by entrepreneurs. For example, these are the direct benefits that are generated by the production of energy.

There are certain indirect benefits as well. For example, if there is a dam, it will attract a lot of tourists. Another example could be coming up with hospitals and schools when a locality is built up. There are diverse benefits which are being generated from this particular project which is not directly linked with that project but has some other social benefits. When we are doing economic analysis, it is important to identify both, the private benefit or the financial benefit as well as social benefit.

Once the benefit and costs are identified it is important to quantify the cost and benefit. What is the value that you are going to attach to the cost and what is the value that you are going to attach to the benefit? This is relatively easy, if you have a full functional competitive market in place. There are different methods for the quantification of both cost and benefit for different kinds of inputs.

We are not going to go into the details of quantification of cost and benefit but what we will do is that briefly we are going to discuss four methods which come really handy when you try to do the cost benefit comparison with respect to any energy related project. These are fairly general mechanisms so it’s not only applicable or uniquely applicable in the context of energy projects but this is generally applicable for any project appraisal or any project evaluation.

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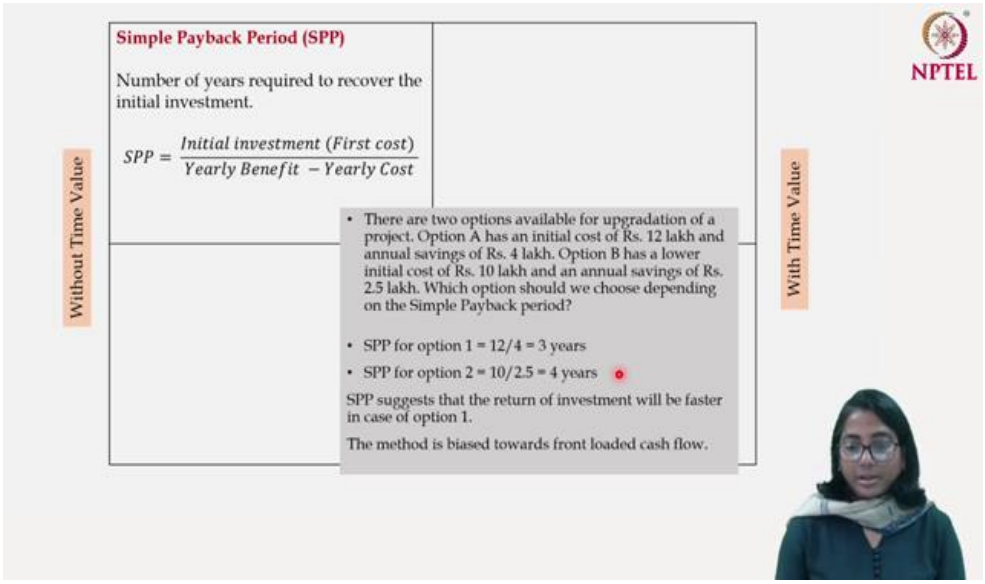

When we think about the cost and benefit, there are two ways how one can perceive the concept of cost as well as the concept of benefit. One is without the time value that we have here. We will plot these two here and the other is with the time value. The difference between without time value and with time value is that if we are analyzing something without a time value, we essentially assume that money doesn't grow over time.

Whereas if we are taking the time value into account, we assume that money yields value over time. In another word one can say, under the context of without time value it says that the money has no opportunity cost whereas, with time value we say that money has an opportunity cost. For example, if I have 100 rupees today than without the time value that is without the inflation, tomorrow also I will have 100 rupees in my pocket and one year down the line also I will have 100 rupees with me. However, if the value of time is taken into account and the amount that I have is 100 rupees and if there is a 5 percent rate of interest in the banks then I can invest this money and after one year these 100 rupees will become 105 rupees. This is the difference between the concept of the time value.

We start with a very simple concept, it doesn't take into account the time value but is an initial crude measure and a quick way to assess how long it will take to get money back from an investment, called the Simple Payback Period (SPP). This gives the number of years required to recover the initial investment.

We take the initial investment also called the first cost and then you divide it by the yearly benefit minus yearly cost. If you have different net benefits in different years, you may also take an average. For example, you have two options. The option A has an initial cost of 12 lakh rupees and an annual saving which is yearly benefit minus yearly cost of rupees 4 lakh. The second option has an initial investment of 10 lakhs and annual saving is 2.5 lakh. Now the question is, which option should you choose in order to select one particular form of investment based on the indicator of simple payback period.

For option one, the simple payback period is given by $\frac{12\ lakh}{4\ lakh/year}$ that is 3 years. The interesting part is that it is written as $\frac{12}{4}$, so the rupee units cancel out and we are left with the unit of year. SPP is represented in terms of the number of years that is crudely you need 3 years to recover your initial investment.

For the second one, the simple payback period is $\frac{10}{2.5}$=4 year. Although the initial investment is less in case of the second option, the payback period is smaller in case of the first option and if you are guided by this particular criterion, then probably it is better to go for option one. There are various advantages of using the simple payback period but only as a starting point, the final decision is never taken on the basis of a simple payback period.

For example, if you calculate the SPP and find out that a simple payback period is something like 70-80 years then of course, you don't go for that project. However, if you find that in one case you have the simple payback period is 3 years and for the other it is 4 year, you do not take the decision immediately about which project to choose but all that you can say that both the projects are viable. This criterion is used more for rejection and not for the final acceptance.

One problem with a simple payback period is that it is biased towards the front-loaded cash flow, it is only talking about the number of years within which you are going to recover your cost. It might be the case that in this particular project yearly net savings is 2.5 but that is for 4 years. It may be possible that beyond 4 years net saving can increase which cannot be captured within the concept of the simple payback period.

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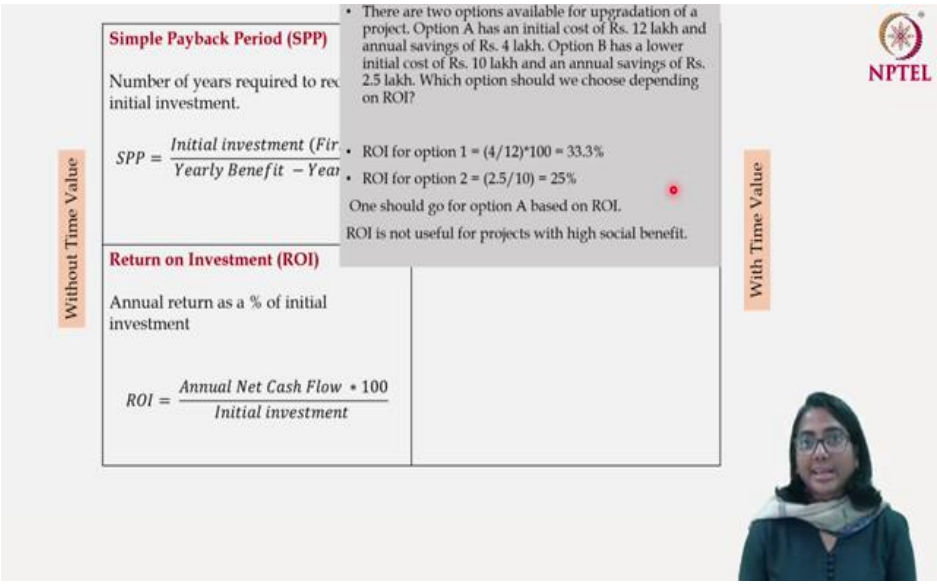

Next is called the return on investment or the ROI, this is also without the time value. Here also we assume that if I keep 100 rupees in my pocket today, one year down the line it will stay as 100 rupees, so I am not going to put it in any investment to yield more money out of it. What percentage of initial investment are you getting every year as the net cash flow? We are going to elaborate the concept of ROI with the help of the same example as in case of the simple payback period. One option is with rupees 12 lakh of initial investment and net annual cash flow of rupees 4 lakh and the other investment which is rupees 10 lakh as the initial investment and 2.5 lakh of rupees as annual net cash flow.

If we calculate the ROI, for the first option the return on investment is 33.3 percent which is derived by $\frac{4}{12} * 100$. In the second case of option B, the return on investment is 25 percent. In the first case not only is the simple payback period smaller, that is, not only you are getting the money back quickly but the return on investment is also higher.

Here also one should go for the first option by the criterion of return on investment. Return on investment is usually the second step after the simple payback period but it fails to justify a project which has high social benefit. So, if you think about schools or hospitals the rate of the return on investment may be low, but it has high social benefits.

However, it generates a huge social benefit or economic benefit which is not being taken care of while calculating the ROI. This is not really useful when you are evaluating a project with high social benefit.

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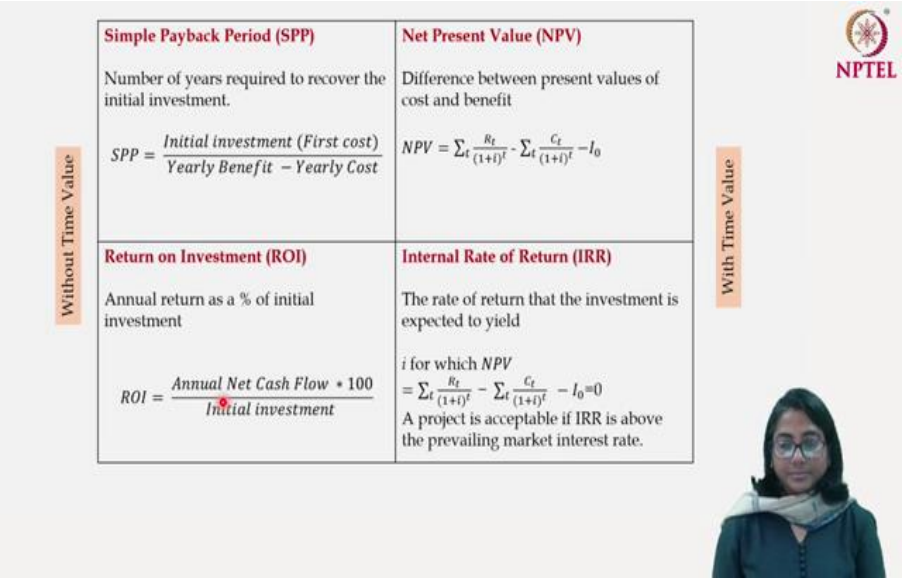

Both these criteria; the simple payback period as well as the return on investment do not take into account the time value of money. We move on to something bit sophisticated which is called the net present value. This is perhaps the most used indicator in order to appraise the projects and this takes care of the time value of money.

Net present value is the difference between the present values of cost and benefit. If you look at the formula,

$$NPV = \sum_{t=0}^{n} \frac{R_t}{(1+i)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+i)^t} - I_0 .$$

R_t is the return from the project generated at time period t, i is the rate of interest that is prevailing in the market, C_t is the running cost that you have to incur at time period t in order to run the project. I_0 is the initial investment in the project (the assumption is that this investment is being made today, that is I_0 means $t = 0$).

Now, you can also write it as: $\sum_{t=0}^{n} \frac{R_t - C_t}{(1+i)^t} - I_0$

In that case $R_t - C_t$ will give you the net benefit at the time point t.

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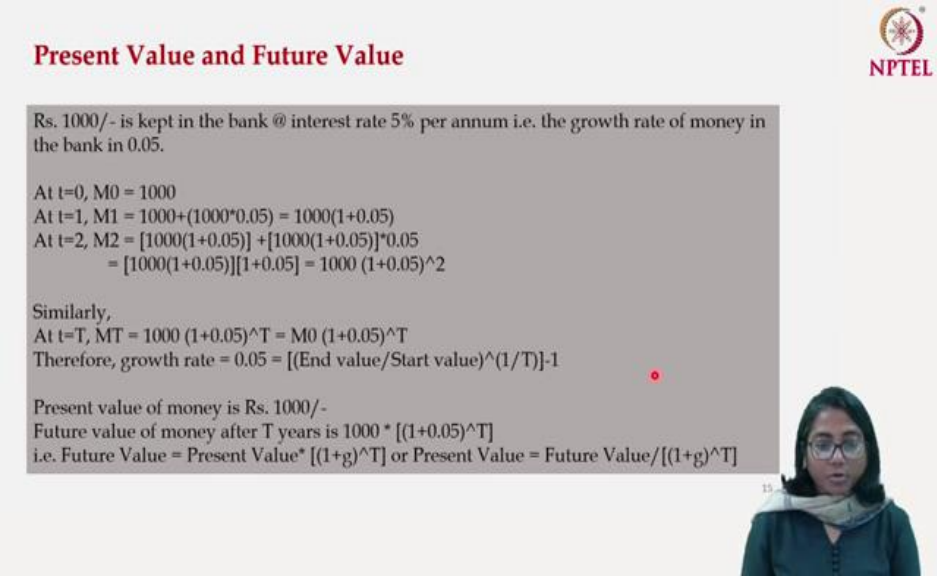

Let us have a quick discussion on the concept of present value and the future value with the help of an example which has already been discussed.

Suppose, Rs. 1000/-has been kept in the bank at a per annum interest rate of 5 percent and the money is growing in the bank. At time point , the money that I have is the previous Rs. 1000/- plus a 5% of Rs. 1000/-, i.e.,$1000 * (1 + 0.05)$. And similarly, at the end of time period $t = T$, the money that I have is $M_0 = 1000 * (1 + 0.05)^T$. The growth rate is 0.05 percent.

There we said that the $(\frac{End\ value}{Start\ value})^{\frac{1}{t}} - 1$ is the growth rate (g). But here we are actually interested in the end value and the start value and we are giving them two different names viz present value and future value. The present value of the money is 1000 rupees.

The future value of the money after T years down the line is going to be $1000 * (1 + 0.05)^T$. This entire expression $1000 * (1 + 0.05)^T$, is the future value of this 1000 rupees. Therefore, we see that the $Future\ value = Present\ value * (1 + g)^T$or we can write $Present\ value = Future\ value/(1 + g)^T$.

Now, if you see that the $Present\ value = Future\ value/(1 + g)^T$ you can connect it to the concept of end value and the start value, the start value is the present value and the end value is the future value.

We have discussed that today's 1000 rupees is one year down the line becomes more than 1000 rupees. In the similar manner if I am promised to get 1000 rupees after one year, today's valuation of that 1000 rupees which I am going to get after one year is less than 1000 rupees meaning 1000 rupees after one year is less than 1000 rupees today because if I put less than 1000 rupees in bank which gives me a certain rate of interest, I will be able to get 1000 rupees tomorrow. If there is a positive rate of growth, the present value is less than the future value. If there is a rate of decline then the present value is greater than the future value.

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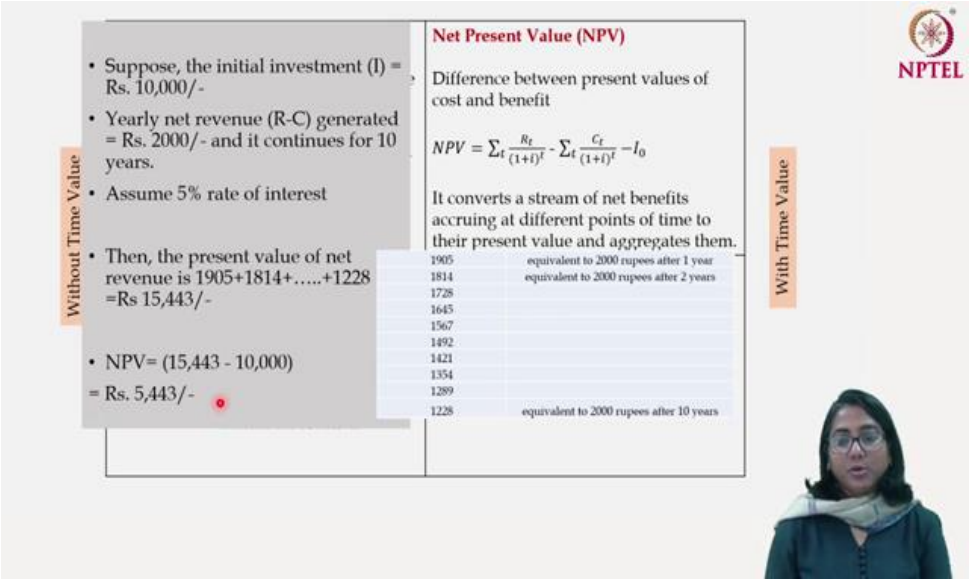

Here we come with the concept of net present value again. When we are saying that this is $\sum_t^{\blacksquare} \blacksquare R_t$. This is the revenue stream generated from a particular project.

If I am going to get the amount R_t, 1 year down the line, what is the present value of that R_t? If I am going to get a different R_t, 2 years down the line then what is the present value? And what is the present value of the revenue that I am going to get 3 years down the line? Similar is the concept for cost (i.e. variable cost) that is if I am going to incur a cost C_1 one year down the line then what is the equivalence of that money today that is what is the present value of that money? If I am going to incur a cost C_2 two years down the line, then what is the amount of money that is today's equivalent. I_0 is the investment that I am incurring today; this is anyway the present value.

What NPV actually does is that, it converts a stream of net benefits that is $R_t - C_t$ accruing at different points of time to their present values and then aggregates them. Let us take an example

which will make things clear. Suppose, the initial investment that a project requires is 10000 rupees, this is I_0. The net revenue that is $R_t - C_t$ generated by this project is rupees 2000 and it continues for 10 years. An assumption that we are making here is that, $R_t - C_t$ doesn't change over time so you are getting 2000 rupees every year as net revenue and this revenue stream continues for next 10 years. Assume there prevails a 5 percent rate of interest. The question is if you are getting 2000 rupees after 10 years then what is the present value of the 2000 rupees?

The calculation is like this, the 2000 rupees that you are going to get after one year, the present value of that 2000 rupees is 1905. In other words, what we can say is that, if I keep 1905 rupees in the bank today with a 5 percent rate of interest; one year down the line I am going to get 2000 rupees. In other words, if the future value is 2000 rupees one year down the line with an interest rate of 5, then the present value is 1905 rupees.

Similarly, if I am going to get this 2000 rupees, 2 years down the line, then the present value of that 2000 rupees is 1814 rupees which means, if I keep 1814 rupees in bank with an average annual rate of growth of 5 percent, then 2 year down the line I will get 2000 rupees. Similarly, if I am going to get 2000 rupees 10 year down the line, then the present value of that 2000 rupees is 1228 rupees which means, if I keep 1228 rupees in the bank at 5 percent average annual rate of growth, then after 10 years this will become 2000 rupees. This is the present value of 2000 rupees that I am going to get every year. And then for the net present value, add all these net present values together. If I add $1905 + 1824 + 1728 + \ldots\ldots + 1228 = 15443$. This is the present value of the net revenue derived from the project.

Adding up all these present values, we get a gross present value which is rupees 15443. This is the gross present value; however, today you are making an investment of 10000 rupees. The net present value is $15443 - 10000 = 5443$, the net present value is positive. The project which has a positive net present value is worth considering.

Net present value as a criterion is used not only to understand whether to consider a project or not, it is also used for the ranking of the projects that is to rank different options or different projects based on net present value. Higher the net present value of a project, the more lucrative that project will be, it's more reliable to invest in that particular project.

The final concept that we are going to discuss is called the Internal Rate of Return or IRR. What is the Internal Rate of Return? This is actually related to the concept of net present value.

IRR is that rate of return at which the NPV is equal to 0. It is that rate of return for which the net present value is equal to 0.

The present value of your net revenue is the Internal Rate of Return. In the calculation of Internal Rate of Return there are certain complexities. One problem is if you want to solve this particular equation, NPV equal to 0 it will give multiple solutions for I. The second problem is sometimes it is difficult to take IRR as a deciding factor because oftentimes you don't know what you want to compare with. However, oftentimes people do compare Internal Rate of Return with the market rate of interest. If the Internal Rate of Return is above the prevailing market rate of interest the project is accepted. A project is acceptable if Internal Rate of Return is above the prevailing market rate of interest.

These are four most used criteria for project evaluation and they become really handy when an investor is trying to understand whether to invest or not to invest in an energy project. Because let us recall again that investment in energy projects is very high, has a huge gestation period and moreover once you invest the money gets blocked because you cannot transfer your assets to some other project and there are lots of risks involved in the context of energy projects.

We stop our discussion on investment in energy projects here. This is a very broad discussion as most of the things are not very specific to energy projects but these are actually specific to the evaluation of any big projects. In the third lecture we will discuss some interesting issues on energy supply.

Thank you, see you again.