Energy Resources, Economics and Environment
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Lecture 5 P1
Energy Economics

Today we are going to talk about energy economics.

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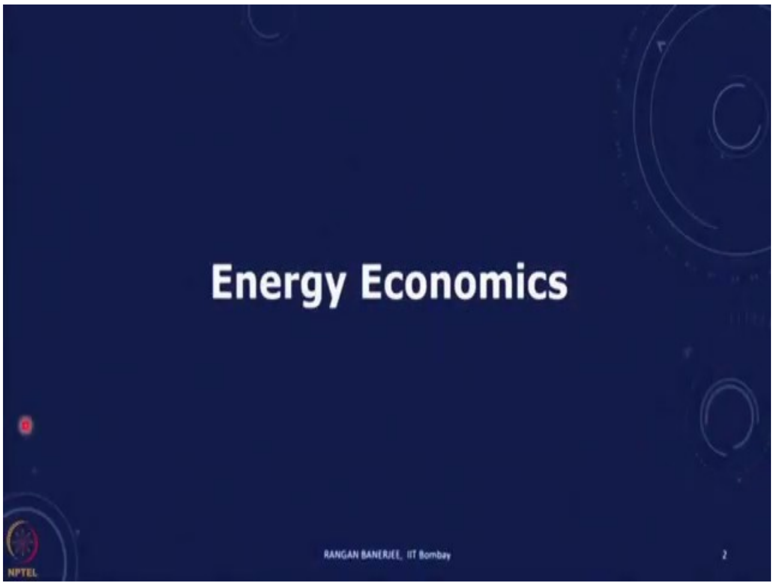

We are going to talk in terms of looking at a viability of an energy efficiency or a renewable project. And the subject that we are covering is also going to be amenable for any project, any project whether it deals with energy or not, the principles will remain the same, but we are going to focus basically on energy related projects.

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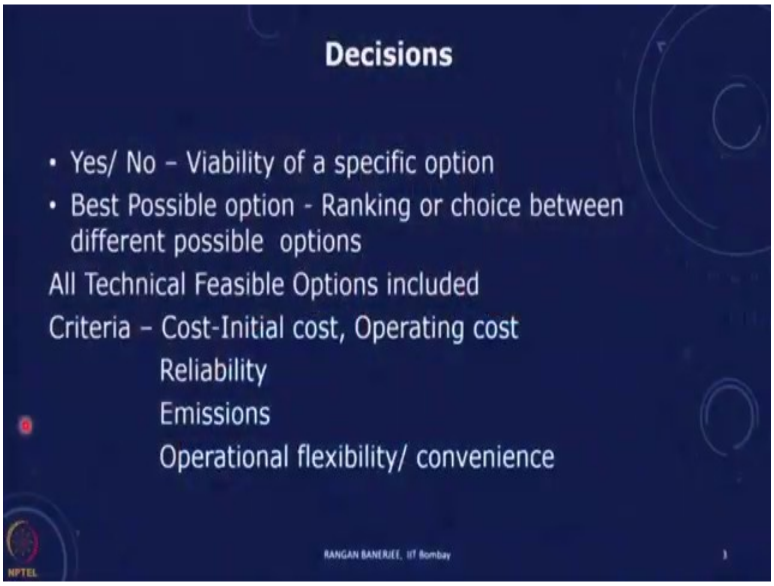

So, what are the types of decisions that one takes? If you are in an industry or you are in a company, we want to decide there are two types of decisions. One is, you can think in terms of a Yes, No kind of decision. So, for instance, there is a boiler or a furnace in an industry and from the exhaust gases which are going out, they are going out at some temperature. So, we may decide, should we have a waste heat recovery system where we recover the energy from that boiler.

We have a pump where we are looking at pumping water, should we have a controller or a variable speed drive. So, it is a yes no kind of decision, a particular option whether we should go for it or not go for it. There could also be another type of decision for instance, you are looking at a remote village or you are looking at an island and you want to electrify that island you are looking at let us say Elephanta Island you can, you have an option where you can connect from the mainland you can have a pipe electricity supply going under the water and then you have a grid based supply coming from the mainland.

You could also think in terms of a diesel engine, or a solar photovoltaic, or a biomass gasifier engine. And so there are a whole host of options and we may want to look at out of all these options, which is the best possible option. So, we want to rank or choose between the different possible options. So, whether it's a yes no decision or a decision where we are choosing between a number of options, the basis and the economic calculations are the same.

In this lecture, we will assume that all technical feasible options have been included and they are all equivalent in terms of their performance. So, whenever we look at different options, there are multiple criteria on which we can be compared. One is there could be the cost criteria, which could be the initial cost or the operating costs. We can think in terms of the reliability, we can think in terms of emissions, in terms of the operational flexibility or the convenience.

So, usually whenever we take decisions, it is a combination of a variety of things, but for this lecture, we will presume that there are many different options which are being considered all these options have equivalent performance and we are only making the comparison based on the economics.

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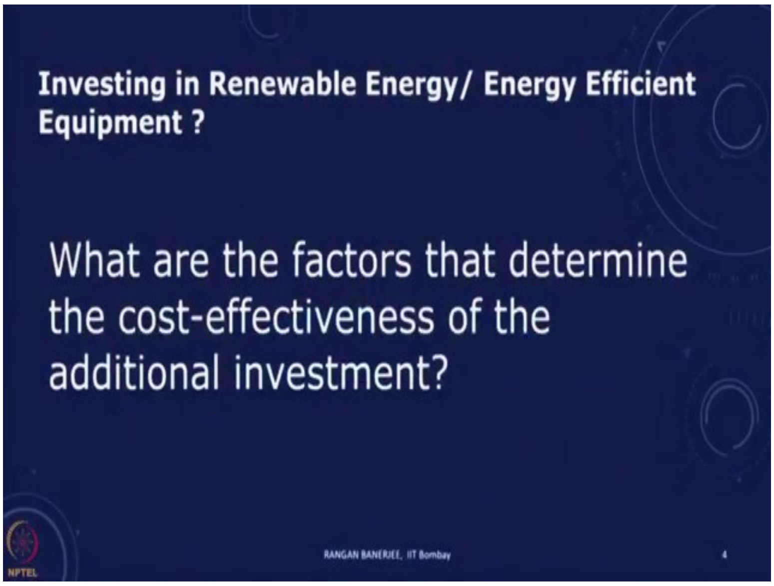

So, let us look at the factors which determine the cost effectiveness of an additional investment we are looking at something where we are putting in a waste heat recovery boiler or a variable speed drive and energy efficient equipment on what basis should we decide whether it is cost effective. So, there are many different parameters which we will consider.

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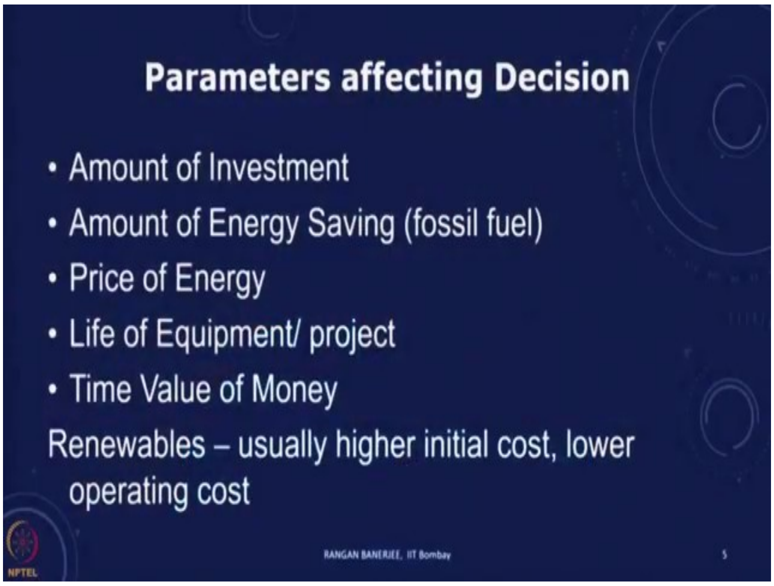

One of the parameters which affects the decision is what is the amount of investment so, if we have to invest more, then we would expect that we, we may need to look at what kind of savings are obtained. The other parameter is the amount of energy saving and most of the cases we are looking at fossil fuels being replaced by renewable or fossil fuels being saved. So, how much is the amount of energy saving?

What is the price of the energy? So, that the amount of energy saving into the price of energy will give you the annual savings and then you compare the investment with the savings, there is also in these, the life of the equipment or the project will be involved. And then the time value of money. The time value of money is a concept that we need to understand and based on that concept, everything else in this lecture we can then calculate the parameters. So, we will first start with the kind of different indices. So, we said, the amount of investment, the amount of energy saving, the price of energy, life of equipment, all of these affect the decision and then there is the time value of money.

Typically, when we think in terms of renewables, usually they are higher initial costs, and they have lower operating costs. So, of course, now the costs are coming down, but in general as compared to fossil, fossil will have an operating costs renewables almost as a zero operating costs, but they have an higher initial cost and we usually make this kind of trade off.

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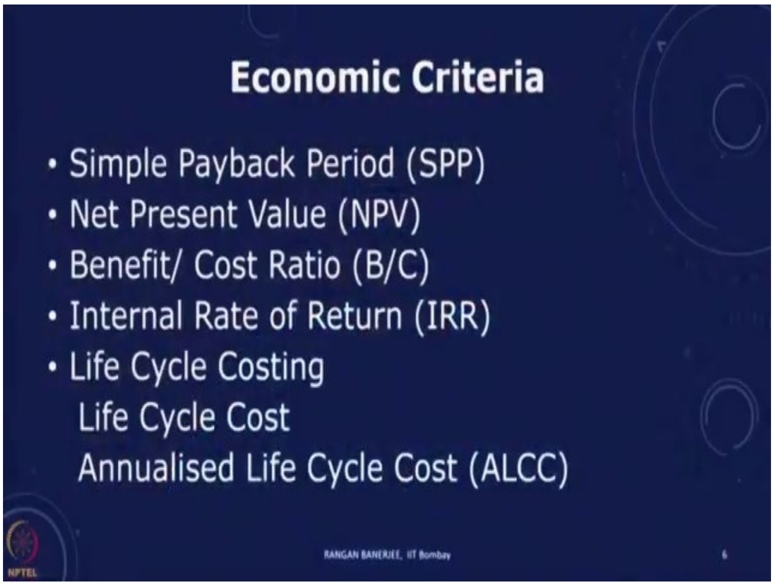

So, we have different indicators that we compute when we calculate the economic criteria. Some of the indicators are mentioned here. The indicators that you see the simple payback period, the we will define that this is the one which is the pay back simple payback period, very commonly used, and based on its simplicity, ease of calculation, then we have these three indicators the net present value, the benefit by cost ratio and the internal rate of return.

All these three indicators use the time value of money. Most companies use one or more of these measures the NPV, the B by C ratio or the internal rate of return. So we will first talk about the simple payback period, then we will introduce the concept of the time value of money and the discount rate. And then we will define these three indices, the NPV, the B by C ratio, and internal rate of return.

After doing that, for many large projects, societal projects and government projects, we also look at life cycle costing, and where we will look at life cycle cost, or the annualized life cycle costs. So, these are all the different criteria and we will see how we derive these criteria, we will then take some examples and calculate these criteria and use it to make our decisions.

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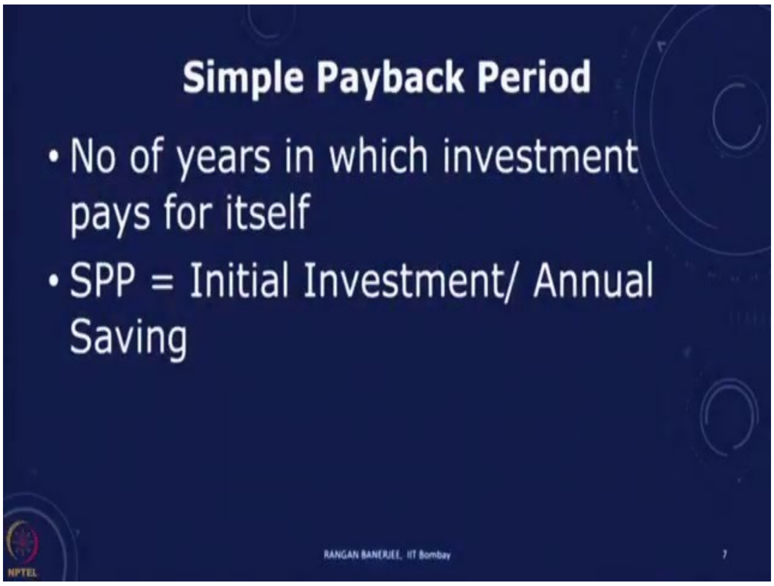

So, let us start with the first index, which I am sure most of you are already familiar with. This is the simple payback period. The simple payback period, as the name suggests, is an index which just reflects the number of years in which the investment will pay back for itself. So, in terms of a definition, it will be the initial investment by the annual savings. So, very straight forward calculation, we just look at whatever is the initial investment divided by the annual savings and we will get the payback period.

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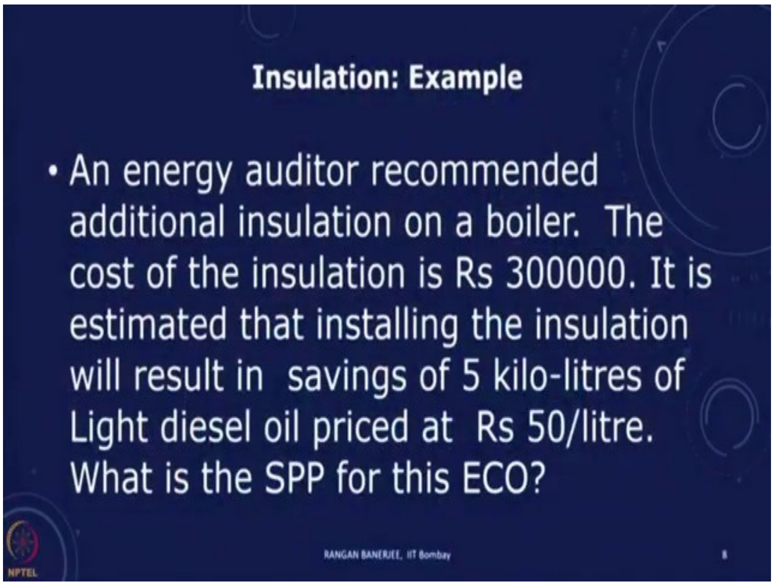

So let us take an example, let us consider an example when an energy auditor has done an audit of a boiler, and that auditor has found that there is some insulation which can be improved and by doing this insulation you are, on an annual basis based on the way the boiler operates, we get a saving of five kilo litres or 5000 litres of light diesel oil. The price of light diesel oil is 50 rupees per litre. So, we want to calculate what is the simple payback period for this energy conservation opportunity. You can do this, this is very straight forward.

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$$SPP = \frac{C_o}{AS}$$

$$\frac{300,000}{5 \times 1000 \times 50}$$

$$1.2\,YEARS\,(1\,YEAR\,3\,MONTHS)$$

$$SPP < SPP_{acceptable}$$

We can just take simple payback period is the initial investment by the annual saving, initial investment here is 3 lakhs and the annual saving is we have 5 kilo litres, five into 1000 one kilo litre is thousand litres and we are paying 50 rupees per litre. So, we get an annual savings is 2.5 lakhs. And simple payback period is simply 3 lakhs divided by 2.5 which is nothing but 1.2 years or roughly 1 year 3 months.

Now, we have calculated the index the simple payback period, how do we use this for making a decision? The first thing is the simple payback period must be less than the life of the equipment of the project. So, in this case, the installation is going to last for 10 years or 20 years. The second thing is the company which is making that investment will decide what is the maximum acceptable simple payback period.

So, for instance, if the company says any project, which has a payback of less than two years, it is willing to accept then we compare this 1.2 with two and we find that the simple, the payback period is less than the minimum or the maximum acceptable payback hence, we can go ahead and invest. So, this SPP must be less than SPP acceptable. And the company who is making the investment will decide what is an acceptable payback.

So for instance, if you have a project where there is a payback of three years, and the company wants paybacks only less than two years the company will not go for it even if the project will give benefits for more than 10 years. So, we have to, the decision will be taken by the company which is making the investment. So, this is what we look at in terms of the simple payback period.

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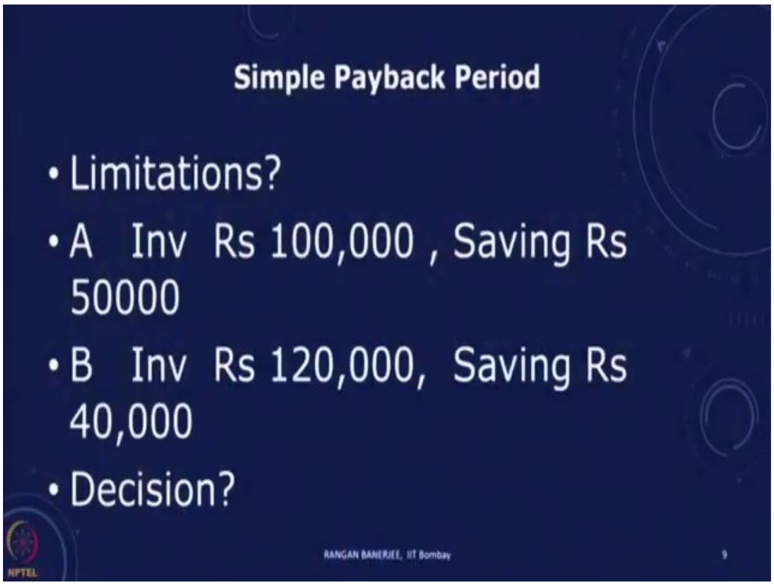

Now, let us talk about what are the limitations of this simple payback period. For doing this, let us take a simple example. We have these two options, Option A and option B for the same application in the case of A, there is an investment of one lakh and the saving of 50,000. So, if we look at this if we just divide one lakh by 50,000 we will get a simple payback period of two years for A. So, SPP A is two years and in the case of B investment is higher which is 1.2 lakhs and the saving is lower which is 40,000.

So, the simple payback period for B is three years.

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		LIFE
$SPP_A = 2\,YEARS$		3 YEARS
$SPP_B = 3\,YEARS$		8 YEARS

So, if you write this we will see that SPP_A is 2 years and SPP_B is 3 years. And if the company has any project which is less than equal to three years it is willing to go, when you compare these two it looks like the project with the lower simple payback period is the one that we should opt for. So, we should opt for A but if we are told that for instance the life of A is 3 years and the life of B is 8 years, then immediately you will see that the decision changes.

And it is more rational to go for B because we are getting payback for a long, we are getting the savings for a longer period of time. So, one of the limitations of the simple payback period is that is does not cash consider the cash flows after the payback is achieved. The second limitation is it considers all cash flows as equivalent. So, that means, whether the return cash flow is in this year or it is in the next year all of them are considered equivalent. There is no concept of time value of money.

Despite these limitations, the simple payback period is an index that is widely used because of its simplicity and specially if it is, for any project which has relatively low investments, and it has the, it has quick paybacks. So, if you are calculating something where you are getting a payback of six months or a year, simple payback period may be sufficient for you to make the decision.

However, if you are looking at a large power project, which has significant investments, and you are talking of payback periods of 4 years or more, you we need to look at the time value of money and other issues and then some other criteria would be more suitable. So, as I told you earlier, the main concept that we need to understand is the time value of money and to look at the concept of the time value of money we have to understand that individuals, companies, industries, we all prefer money today compared to money in the future.

What is the reason for that? The reason for that is mainly because anything associated with the future is uncertain. There is a risk associated with the future. And because of that, all individuals prefer to have the money today compared to money in the future. This preference that individuals and companies have for money today as compared to money in the future, is something that we would like to understand and incorporate in our calculations.

In order to do that, we introduce a concept called the discount rate.

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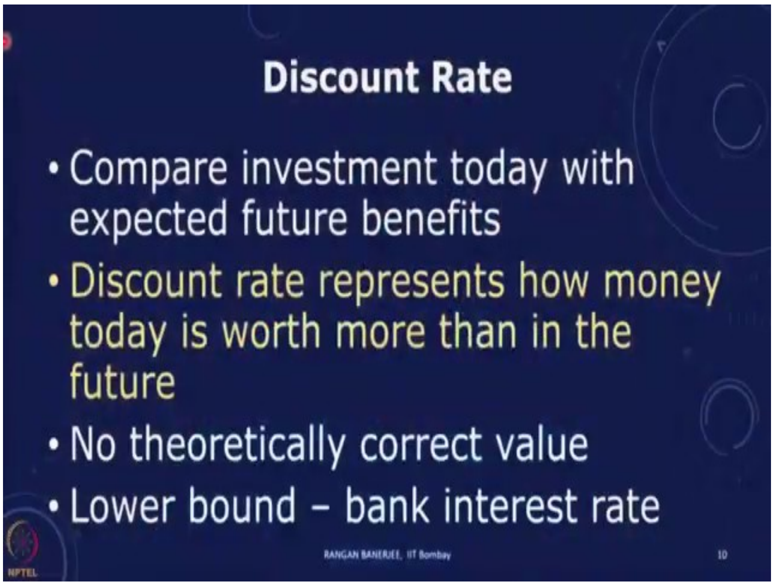

And the discount rate is a basis by which we compare investments today with the expected future benefits let me just show you.

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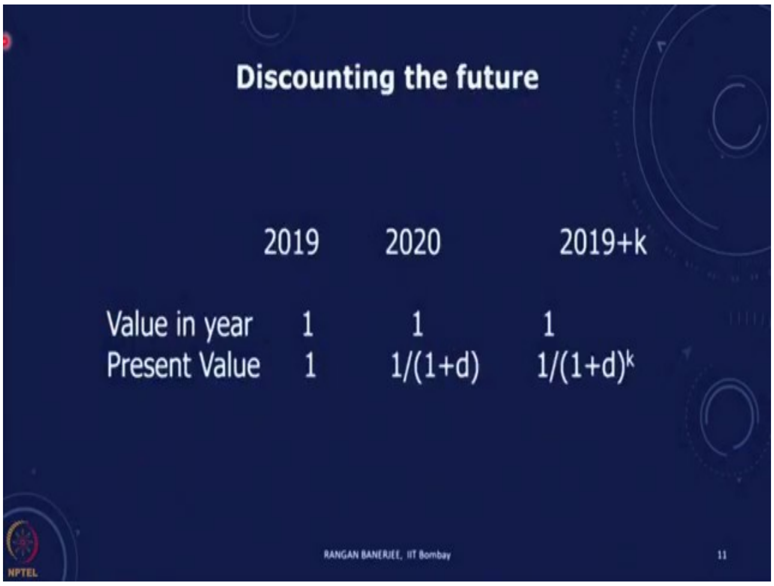

So, for instance, what we will do is that if you have in different years.

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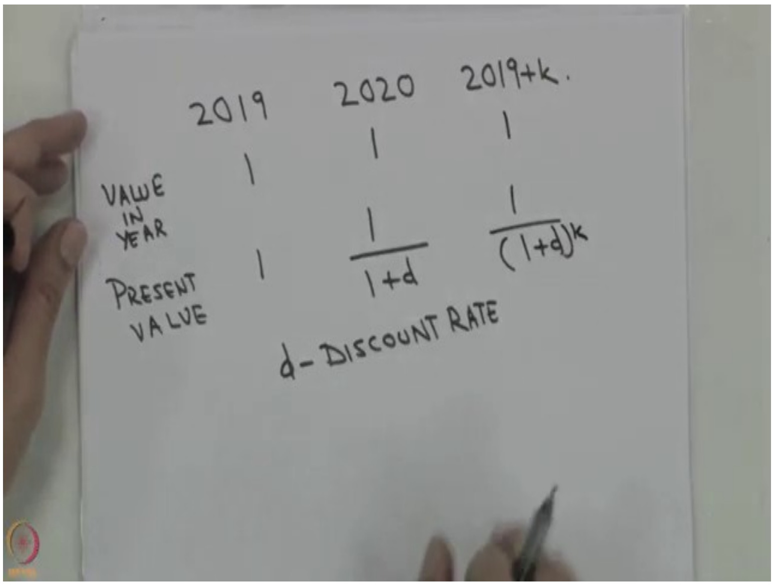

We are talking of 2019, 2020, 2019 plus k, if we had the value in the year and the present value. So, if we have one unit, one rupee, 1000 rupees, one lakh that in 2019 that is the same unit in 2019. If we talk about one unit one rupee in 2020 that has less value for us today. So, that would be reduced by a factor which is one by one plus d, where d is the discount rate.

It is a positive number discount rate and you can, we can put it as a percentage also or as a fraction. And so, this is we are discounting the future we are reducing any future cash flow to bring it into equivalent value with equivalent present value. So, suppose we had it in the kth here, then this will be one by one plus d raise to k, okay, so, this just means that we take any future cash flow and we bring it into its equivalent present value by dividing by this one plus d we are discounting it or reducing it to bring it into the present value.

Now, we can look at this as let us try to understand what does this value of discount rate mean?

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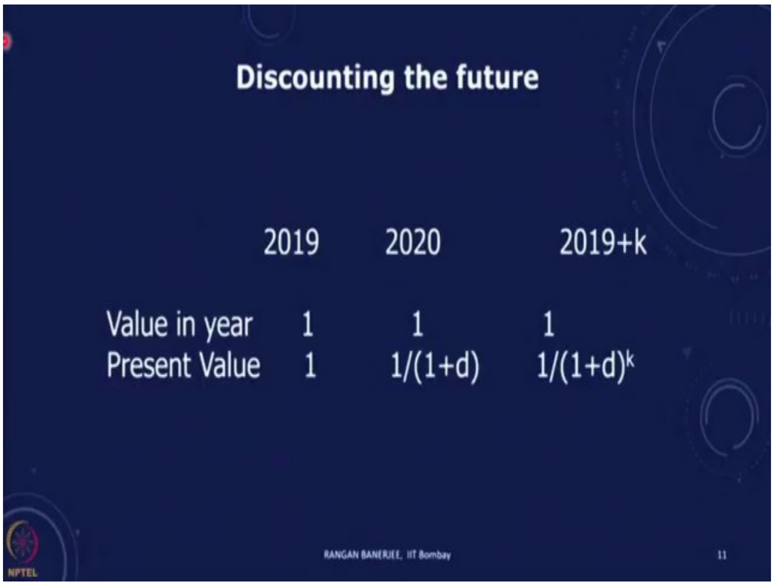

So, typically what happens is that suppose consider a company which has many different projects, which it can invest in and each of these projects has a rate of return on the project and it has an investment which is there. So, suppose we have these different investments and we arrange these projects in terms of, from the highest rate of return to the lowest rate of return.

So, that means there is a project which is giving us the highest rate of return, we would like to go for it first and for that we would have to.

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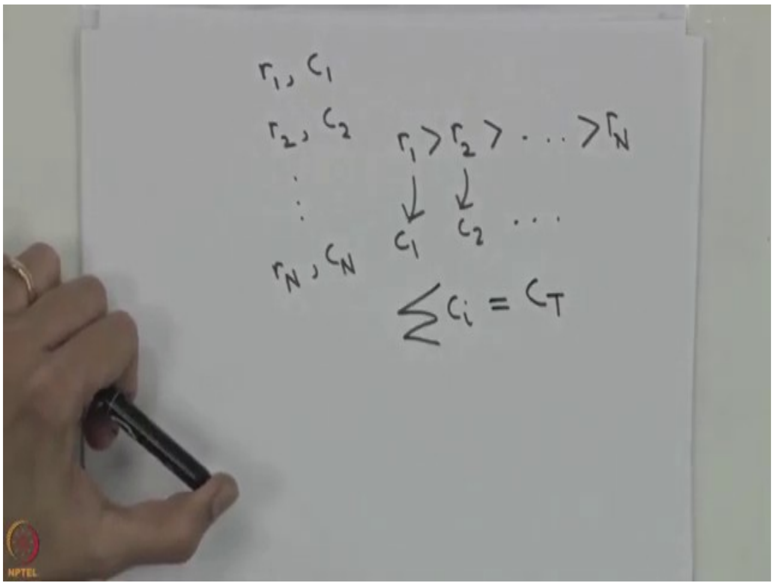

So, let us make it so that r_1 c_1, r_2, c_2 and so on to r_n , c_n we arrange it so that r_1 greater than r_2 greater than and so on to r_n. So, the idea is that we arrange these projects in terms of the amount of return that we are getting. So, we will first invest in the project which gives the highest rate of return in that process we will use up c_1 then we will use up c_2 we can keep on doing this till our entire budget gets used up.

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So, suppose we have this rate of return here. This one is r_1 and we have put c_1, then r_2 c_2, r_3 , c_3 and so on. Till the time that the total amount that we are investing sigma c_i will be equal to the C total or the total amount of money that I have to invest. So, that means this value of rate of return any project which has a rate of return greater than or equal to this is what I am going to invest in. So, this value then becomes my discount rate.

So, that this will mean that suppose the company had half that amount of money instead of C_T which we have here, if it had half the amount of money what will happen is, this point will shift here and your discount rate will be higher. If it had more money, then the discount rate would be low. So, the discount rate really reflects the scarcity of capital. In another sense, if we look at it, suppose you were thinking in terms of investing hundred rupees in a bank or an institution that you have faith in what is the minimum amount of annual return that you expect before you make that investment.

So, if you think about it, you can put down a value and you will see that, that value suppose you say that value is 20 rupees, that means that you will make an investment of hundred rupees if and only if you are getting 20 rupees or more every year, your principal is gone, but every year you get a fixed amount of return. That value 20 is actually your discount rate.

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So, typically what happens is, if we go back the discount rate represents how money today is worth more than money in the future, there is no theoretically correct value it reflects the scarcity value of capital it also reflects how people what kind of, how do you treat future risks and what is the key, what is your risk aversion, the lower bound will of course be the bank interest rates so you will expect at least a minimum which will be the bank interest rate that you get. But in societies where capital is scarce in developing countries you usually have higher discount rate.

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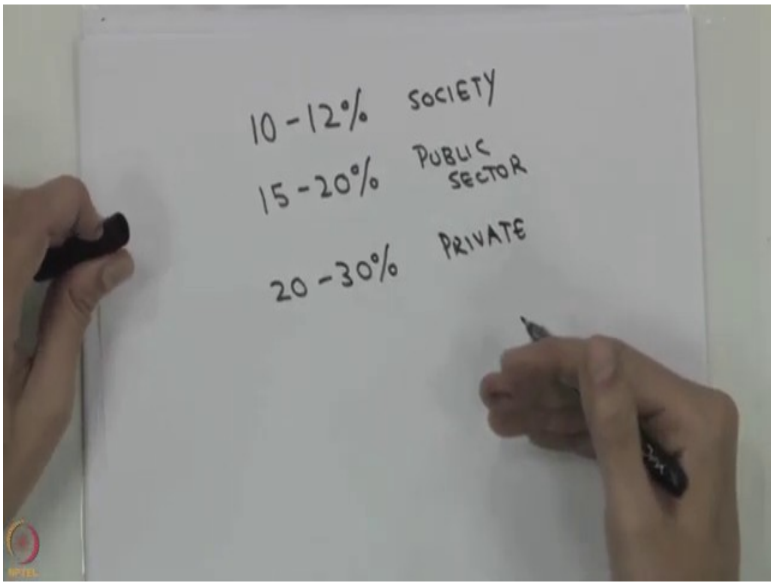

So, in the, in typically if you see, we will look at a discount rate of 10 to 12% which will be like a society discount rate. And if you look at 15 to 20% are the discount rate for the public sector companies. Also, the companies which are investing in the infrastructure sector have this kind of and 20 to 30% of the private companies, private industry, these are the kind of discount rate. These are typically the discount rates for in Indian context.

If you look at households and you look at low income households you may find that the discount rates are quite high 40%, 50% 60%. So, now that we have looked at this concept of the discount rate, let us see how we can use this to look at the decision where you are making an investment today and you are getting the benefits in the future.

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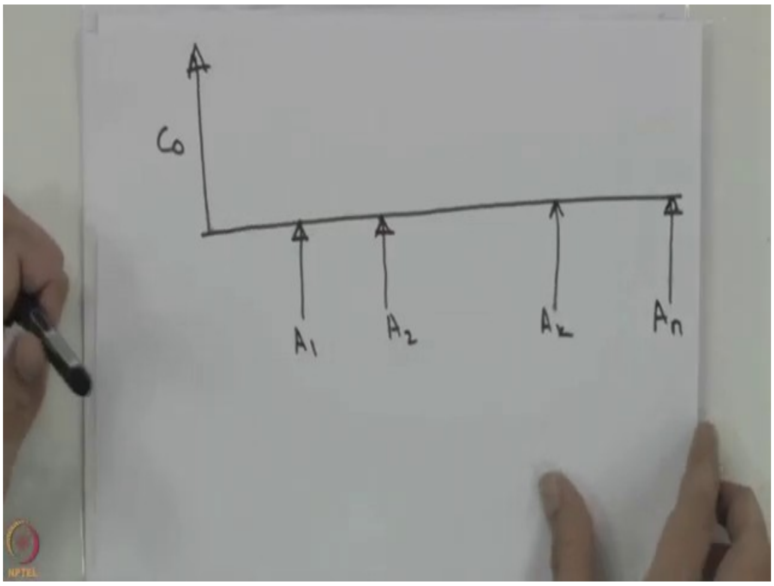

So, we would like to now look at a situation where we are looking at, you are making an upfront investment Co and we are getting benefits over the life of 30 equipment in different years A_1, A_2, A_k to A_n where n is the life of the equipment or the project. Now, the question is how do we put this all together? So, let us look at a way in which we can take all of these cash flows and bring them up into a present value, equivalent present value.

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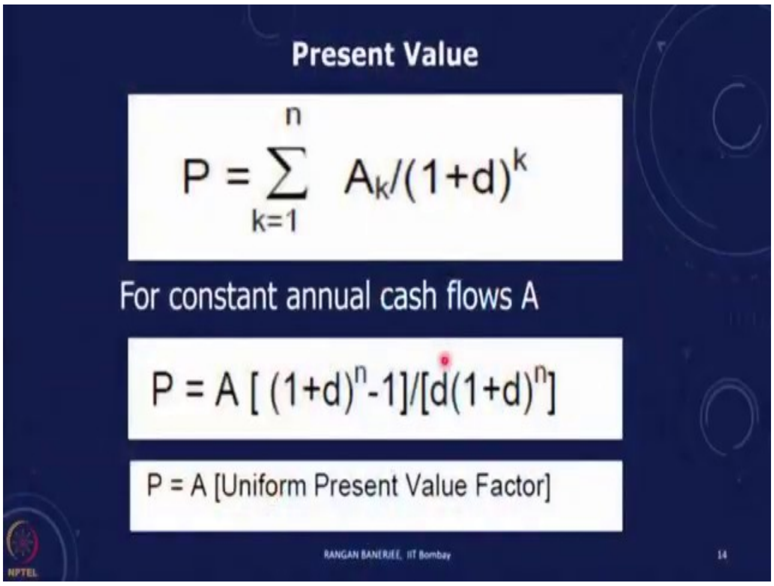

So, when we would like to do that, let us take this and we will derive that we have a present value we want to replace all of these A_1, A_2, A_n. So we will try to, we will see that.

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$$P=\sum_{k=1}^{n} \frac{A_k}{(1+d)^k}$$

$$\text{¿} \frac{A_1}{1+d}+\frac{A_2}{(1+d)^2}+\ldots\frac{A_k}{(1+d)^k}+\ldots\frac{A_n}{(1+d)^n}$$

$$A_k=constant=A$$

Now, there can be a special case in many situations where we have Ak is equal to constant. Constant in terms of this is the constant cash flows, which is A and this is often the case because what we are doing is we are making a calculation today about the future, we are looking at a project where you are going to get a same amount of electricity generated or a same amount of energy generated, if we do all the calculation based on today's prices, then you could have constant annual cash flows.

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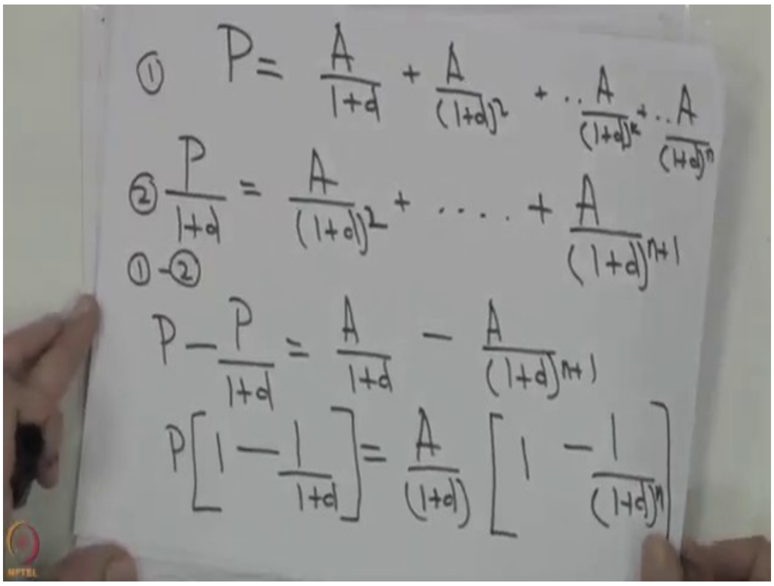

So, when we have constant annual cash flows, this will reduce we can see this, this becomes a geometric progression, this becomes P is equal to A by 1 plus d plus A by 1 plus d square k plus A by 1 plus d raise to n. So, we can take this and we can divide this by 1 plus d and we'll get a by 1 plus d squared plus and so on a by 1 plus d raise to n plus 1.

So, you can now subtract 1 and 2, if we just subtract 1 minus 2 we get p minus p by 1 plus d is equal to A by 1 plus d minus A by 1 plus d raise to n plus 1. So, you get this you can simplify it 1 minus 1 plus d take A by 1 plus d common here and you get 1 minus 1 plus d raise to n we took 1 plus d common.

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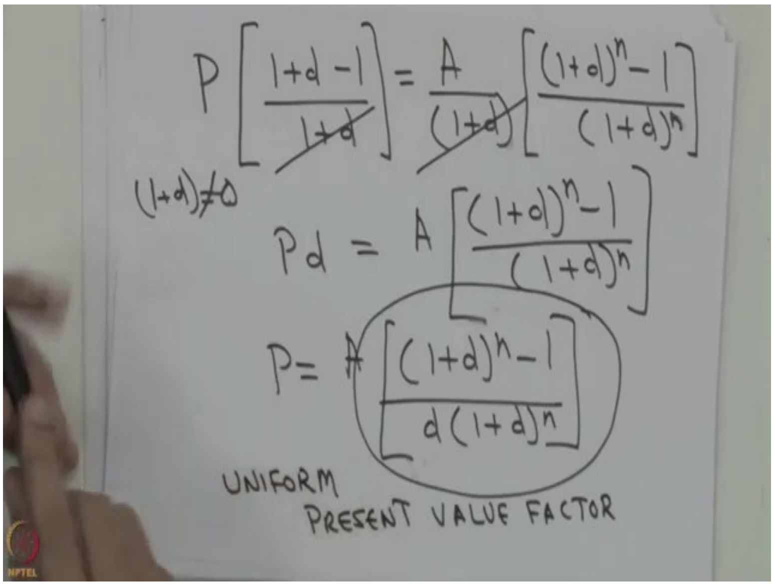

So, when we simplify this further, we can write this as P into 1 plus d minus 1 by 1 plus d equal to A by 1 plus d and I can take 1 plus d raise to n common, this becomes 1 plus d raise to n minus 1. Now, 1 plus d is not equal to 0. So, I can cancel out these two terms, and then I get P into d is A into 1 plus d raise to n minus 1 and 1 plus d raise to n, so P is equal to A into 1 plus d raise to n minus 1 divided by d into 1 plus d raise to n. This factor which we have is called the uniform present value factor.

This factor is what we multiply the annual cash flow stream to get it into the equivalent upfront present value. This is called the uniform present value factor, and we will use the inverse of this the uniform present value factor.

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$$UNIFORM\ PV\ FACTOR = \frac{P}{A}$$

$$\text{CAPITAL RECOVERY FACTOR (CRF)} = \frac{A}{P} = \frac{d(1+d)^n}{(1+d)^n - 1}$$

CRF(d, n)

So, uniform present value factor as we said in uniform present value factor is uniform PV factor is equal to P by A. And the inverse of this is the capital recovery factor, then that is the factor that we will be using in most of our calculations. Capital recovery factor also known as CRF in a short form is A by P, which is d 1 plus d raise to n by one plus d raise to n minus 1.

And so, this is a factor of two variables, discount rate and life and if you see this, this is what we are talking of d into 1 plus d raise to n by 1 plus d raise to n minus 1.

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$$UNIFORM\ PV\ FACTOR = \frac{P}{A}$$

$$\text{CAPITAL RECOVERY FACTOR (CRF)} = \frac{A}{P} = \frac{d(1+d)^n}{(1+d)^n - 1}$$

CRF(d, n)

And this gives us the way to calculate the annualized investment corresponding to a particular investment. So, if you have an initial investment, we can convert that into what does it mean in terms of an annualized investment. Let us take an example.

[Continued in next lecture]