**Energy Resources, Economics, and Sustainability**

**Prof. Pratham Arora**

**Hydro and Renewable Energy Department**

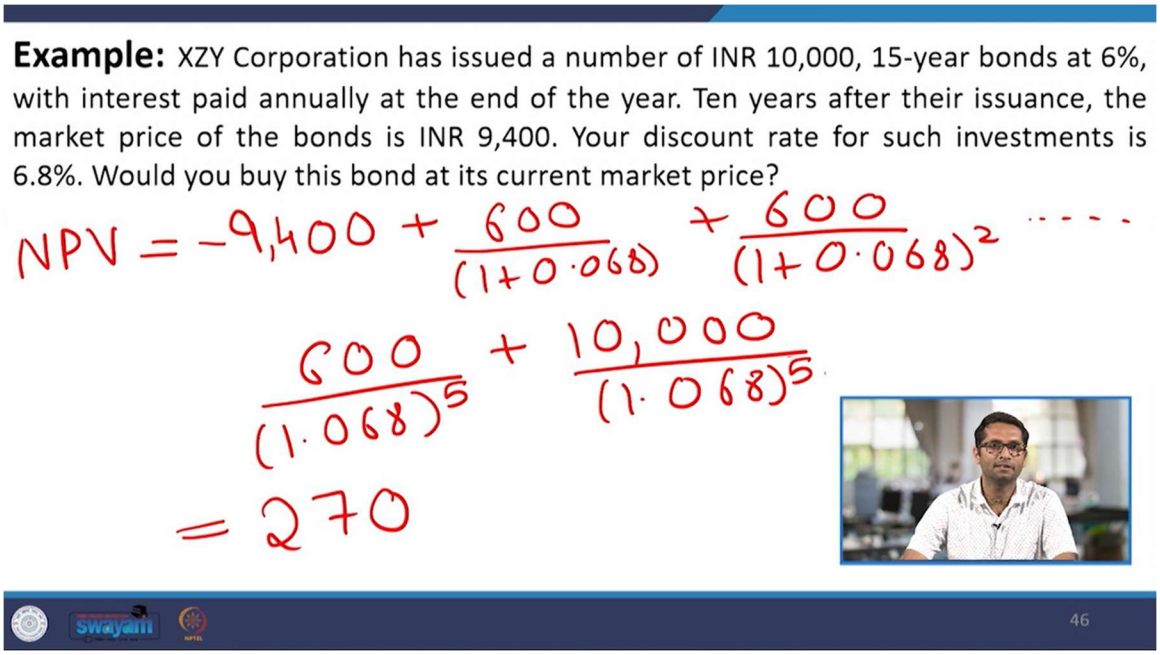
**Indian Institute of Technology Roorkee, Roorkee, India**

**Week – 03**

**Lecture – 04**

## Lecture 14 - Energy Economics-IV

Welcome back to the course Energy Resources, Economics and Sustainability. In the last class we have been discussing some of the methods for investment appraisal and we will continue the same discussion in the same class. In the last class we have been discussing some of the basics of the net present value method. Basic of the method is that we would want all the future cash flows to be discounted to the present value and then add them up together. If they come up to be positive and the project is found to be profitable and might be applied in the future and this same methodology could also be used for evaluating different energy efficiency options. In that case we would want to select an option which has the least NPV.

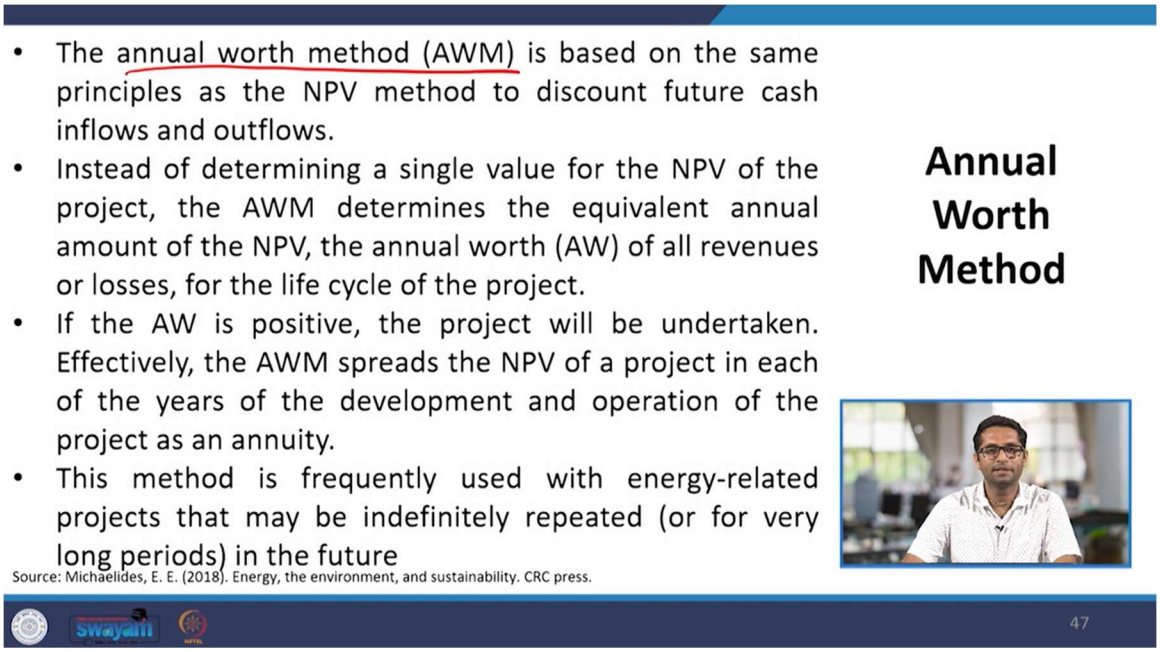


Let us also try to do a simple question with respect to NPV before we move to other kinds of investment appraisal methods. So let us take an example of any corporation which has issued a number of 10,000 rupees 15 years bond at the rate of 6%. So what happens in the form of bond is that the company would issue a bond say a 10,000 rupees for the individuals or the corporates to take, the length of the bond is defined. So the company will give the exact amount of the bond at the end of 15 years in addition to that it will be giving an interest that is paid annually at the rate that is defined.

So in this case it is 6%. So the company will borrow around 10,000 rupees from you and it will return the exact 10,000 at the end of the 15 years. In addition to that as an interest it will be giving 6% interest on the borrowed sum every year for the issue of the bonds. Now suppose like there was a person who bought the bond at the onset but now the condition is that it has been 10 years since the bond has been issued and the person is in the need of money and he or she would want to sell the bond for rupees 9,400 and now you would have to decide whether it is profitable for you to buy this bond or not. Your discount rate for these kinds of investment could be 6.8% and let us try to make a do a simple calculation wherein we will try to estimate if we should go for buying this bond or not. So if we would want to calculate the NPV the first thing we would have to make a payment of around 9,400 today for buying the bonds. Then I would be getting an interest of 6% which would be 600 rupees on an yearly basis. So that starts from the next year. So it would be 600 and I divide that with 1.068 which is my discount rate for these kinds of investments. Then I would get a similar kind of interest that is returned to me the year after that and I would be getting such kind of returns for the next 5 years. So I have just written the total amount raised to power 5 and also at the end of 5 years I would also get the bond value returned which is 10,000 rupees and that again needs to be discounted by the same factor. So let me add all these values and try to see if it comes out to be positive or negative and let me repeat it again. So at present I am making an investment or buying the bond from another entity which is selling me at around 9,400.

For the next 5 years also I will be getting the interest back which will be 600 rupees per year and I would want to discount that with my factor which is 6.8% and at the end of 5 years I will also be getting the 10,000 rupees back which is the bond value. So if I do this calculation add them up together this would come out to be roughly around 270 rupees

which comes out to be positive and that it also reflects that it would be safe for me to invest in this bond because finally I would be making some kind of profit out of it and it is advisable to buy this bond. So these are some of the applications of the NPV method that could be applied for a variety of scenarios that could range from setting up of an energy plant to evaluating of different energy efficiency options and even to your personal lifestyles where you would want to see if a certain investment by you makes sense or not. So this is one of the most widely used investment appraisal methods but apart from this there are many other methods as well and let us go through them.




Another method that is used for the energy projects is the annual worth method. So this method again is very similar to the NPV method and the difference here lies in that in the NPV method I am discounting all the future cash flows to the present year whereas in the annual worth method I am taking the yearly value. So what I am saying is the total value of the project or the total cash flows are seen as a form of annuity. What would be the payment or the profit or the loss that is happening every year and that is a simple value. So apart from instead of seeing the total worth in the present year or seeing the future value which is normally the case in the NPV method this method basically sees the annual total cost or revenue for the project in a particular year. Basically converting the net present value into an annuity and to see if that makes sense or not. In effect this is very similar to the NPV method and this has again been widely applied in a similar way.

**Example:** A transmission corporation is considering updating its medium-range transformers every 5 years to ensure low transformation losses. A new transformer costs INR 2,50,000 and may be sold in 6 years for INR 50,000. The increase in revenue, due to the higher transformer efficiency, is INR 80,000 per year. If the discount rate for the corporation is 20%, calculate the AW of the project.

$$A = PV\left[\frac{r(1+r)^N}{(1+r)^N - 1}\right]$$

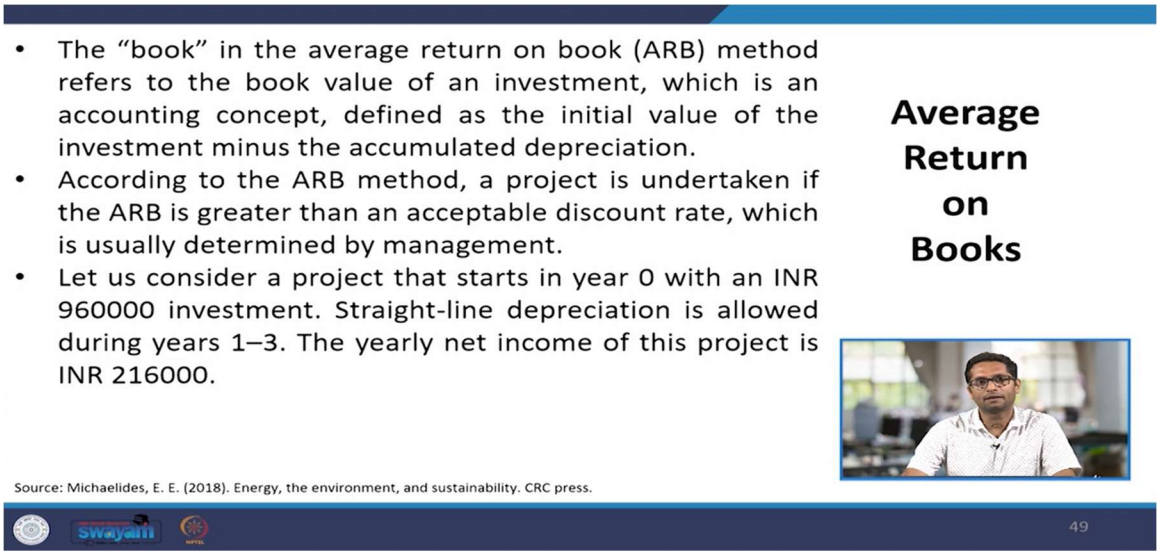
$= -83594$
$+ 80000$
$+ 6719$
$= 3125$



So if I go let us try to understand this with the help of an example. Say a transmission corporation is considering updating one of the transformers every 5 years and it wants to ensure that it is a profitable investment. So the aim here is to update the transformer every 5 years. A new transformer costs around 2.5 lakh rupees and may be sold in 6 years at around 50,000 rupees as scrap and an increase in revenue that happens due to this higher transformer efficiency can be attributed to around 80,000 rupees per year. The discount rate for the cooperation for such kind of investment is 20% and we would want to calculate the annual worth of this project. So the formula that we would be using for converting the annual worth based on the present value would be if I am talking about the annuity or the annual worth it would be the present value multiplied by the discount rate. Again the function discount raised to the period n 1 plus r minus 1.

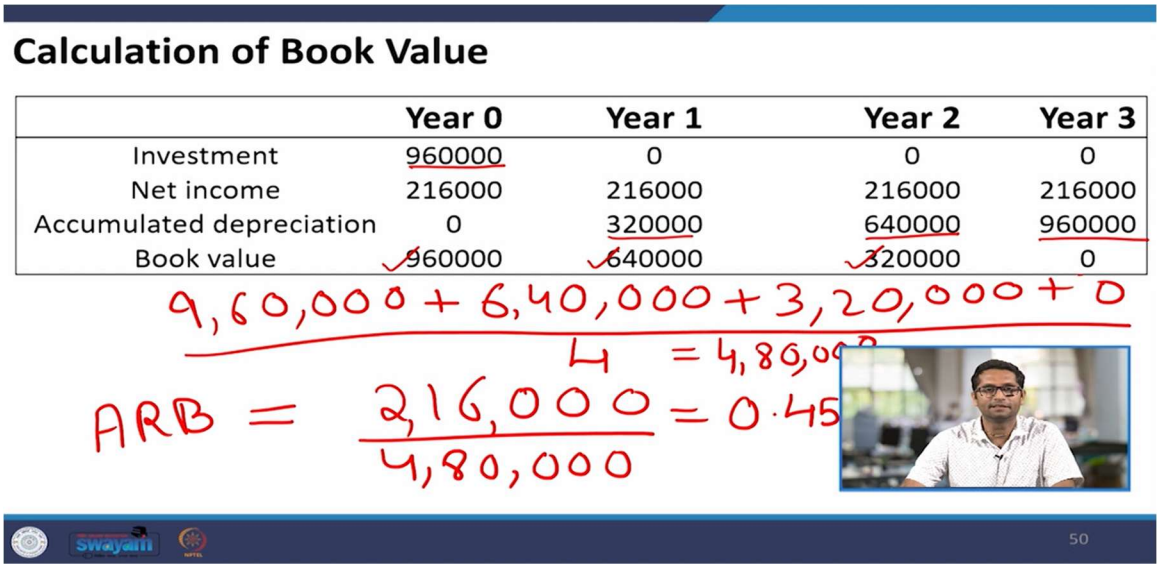
We had derived a similar equation in the previous classes as well but there was a slight modification based upon whether when the cash flows are taking place. So even if you study the different formula that are available in the literature the equation is going to look something similar but there might be slight modification based upon whether the cash flows are starting from the year 0 or year 1. So this is one of the normal equation that you use but you might come with a slight variation or you can also derive it we have done the derivation in the previous classes and the equation could look very similar or it could be a slight modification based upon when do you consider the cash to be flowing in if it is from the year 0 or from the year 1. Again there are two kinds of annuities that are considered one is the annuity due and the other is the annuity payable and depends upon when are you paying the annuity is it at the start of the financial year or the end of the

financial year. So coming back to the example so if I consider the annuity or for the annual worth of 2.5 lakh rupees of investment and I put that in the formula the value would come around to be roughly 83,594 which would be negative because I have an investment to make my profit that happens is around 80,000 per year so I add that further I also make a gain because of the selling of the transformer at the end of 6 years so even that needs to be equally divided among the 6 years and I can use the same formula and I will get the value of around 6719 so I would want you to do the calculations at your end. So again let me repeat so the first thing is I would want to divide a 2.5 lakh rupees throughout the lifespan of 6 years and this is what the value looks like my yearly gain from this transformation updation would be 80,000 rupees and again I make a gain by the selling of the scrap of the transformer at the end of 6 year which is 50,000 and even that needs to be equally divided among the 6 years and discounted as per the discount rate which is 20% I add these three values together and the final value that I get is around 3125 rupees per year and it comes out to be positive and I can go for this project if this was to be negative I would have not been in favour of this project. One of the advantages of the annual worth method is that if the price of the different commodities or the price flows are increasing in a similar fashion I can keep on using this method perpetually I don't need to be dependent upon the project life of 20 years or 30 years. So in this case like the transformer would be replaced every 5th year or so I can use the same methodology and I am pretty sure that it will be making profit for me because it is based on an annual basis rather than a project basis.



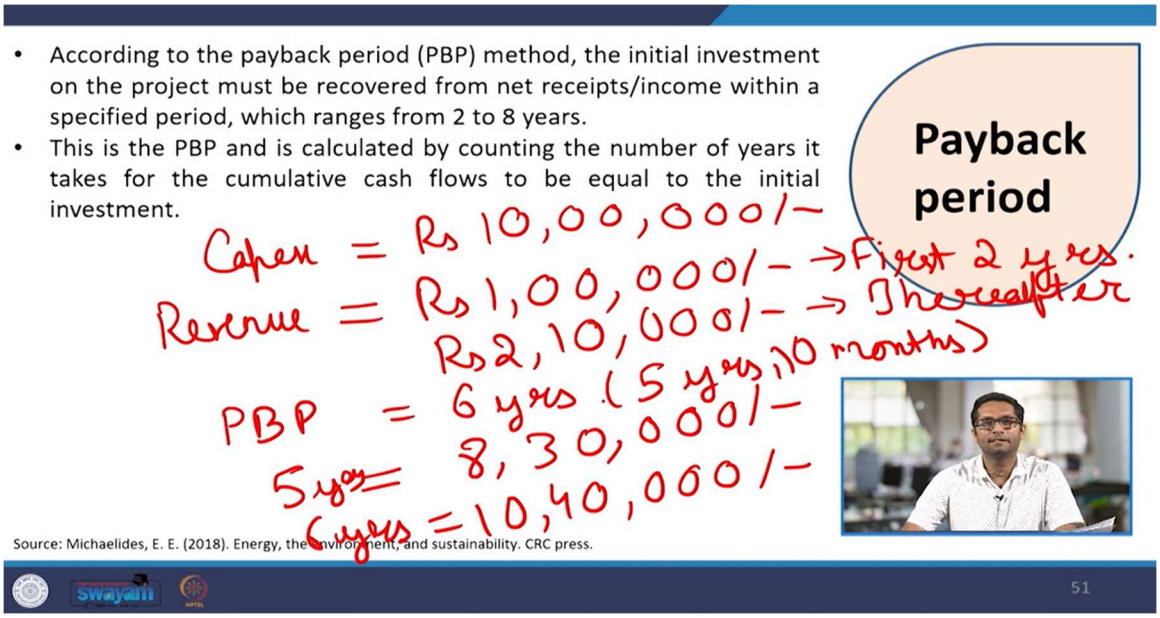

So that is one of the advantages of this particular method. Further there could be another method which is called the average return on books. So the book in this definition of average return on book is basically the book value which is an accounting concept which is basically the capex of that you have put in minus the depreciation that would be

happening and it depends on the depreciation schedule that you would be following for the capital asset. And this kind of methodology is basically coming from accounts background where you would want to see the book value and what you would do is you would divide the revenues by the average book value of a particular project and if that comes out to be more than what your minimum acceptable return is you would go for this project. So again let us consider a simple project in which you would make an investment of around 9,60,000 rupees and then this investment you are expecting would depreciate using a straight line method. So straight line method basically entails that the investment is linearly decreasing in its value and that happens for the first 3 years and from this project you also have like revenue that is generated and that revenue generation happens to be around 2,16,000 per year.




So basically this is what the table for the annual average return on books would look like. So you would have an initial investment of 9,60,000 that is occurring in the year 0 and there is no other capex for the following 3 years and this capex would be losing its value linearly. So in the first year it will be losing one third of the value which is 3,20,000 another 3,20,000 in the second year so the total depreciation comes out to be 6,40,000 and finally all of it would depreciate in the year 3. If I consider the book value, the book value would be the total 9,60,000 in the year 1. I subtract the depreciation for the year 1 and this would come out to be 6,40,000 at the end of year 1 and then at the year 2 I subtract 6,40,000 from it which brings me to 3,20,000 and finally the book value would

be 0 at the end of 3 years because all the value has depreciated. If I talk about the income, income would be constant for the total 4 years which would be 2,16,000 or so. So if I would have to evaluate the average return on book, so first thing is I would take in the average value for the 4 years which is 9,60,000 plus 6,40,000 plus 3,20,000 plus 0 which is at the end of 4 years and divide that with 4. So this is basically the average book value that I have and for the average return on book value I would just subtract the revenue, the average revenue which is 2,16,000 and the value of this particular case would be around 4,80,000, this is the previous calculation and so I divide this by 4,80,000 and the value would come around to be around 0.45. So if this book value is more than the minimum acceptable value based upon my experience in the past I would go with this particular methodology if it is less I would discard this particular plant. Again as you would have understand there are a few disadvantages of this particular methodology, one is that it does not take into account the time value of money. So an income in the year 0 is equivalent to the income in the year 3. So there is no time equivalence of the different payments that is taking place. Further this also depends upon the experience of the accounting firm with the different kinds of investments.So the ARB method cannot be uniformly adopted by the different kinds of organizations. So again this is one of the type of investment appraisal methods. Further in this investment if another investment was occurring after 3 years or 4 years it will be difficult to account for that so that is another disadvantage.



Then another kind of investment appraisal methodology that is used by different types of industries would be at the payback period. So payback period is basically the number of years that I would need to recover my initial investment.

So this is basically the initial investment divided by the future cash flows and whenever the total cash flows are equivalent or more than the initial investment that I made that is basically said to be the payback period and it normally varies from 2 to 8 years. Let us try to understand with the help of a simple example. Say if I am setting up a plant with an initial capex of 10 lakh rupees that is initial capex and the revenue that I am generating is 0.5 lakh rupees. Say I am just taking arbitrary case it is rupees 1 lakh rupees per year for the maybe the first 2 years and then the revenue increases to around 2,10,000 rupees maybe thereafter.

So for this kind of investment if I am trying to look at the payback period this would come around to be around 6 years. Because by the end of 5 years the total revenue that I would have generated is 1 lakh for the first 2 years that brings up to be 2 lakhs and then 2 lakh 10,000 for the next 2 years so it is next 3 years I would say and this would be around 8 lakhs 30,000. So if I talk about 5 years the total revenue that I have made would be around 8 lakh 30,000 which is less than my initial investment of 10 lakh rupees whereas at the end of 6 years I would have made almost around 10 lakh 40,000 of revenues which is again greater than 10 lakhs. So I would assume 6 years to be my payback period some institutions or like some kind of entities would want the exact payback period and you can do that as well so in this calculation it will come around to be 5 years, 10 months if you want the exact payback period. Again this is one of the methodologies but again not widely used and accepted because as we can see the thing that is absent here is the time equivalence we are not taking into account the discount rates.

The other thing is if the investment entails that there is a major capital expenditure that is occurring maybe down the line 5 years or 6 years it does not take into account for that investment. We can also try to understand some of like the difference with the help of few hypothetical cases. So here in we have 4 different projects and we will try to compare the payback period and the net present value of these 4 hypothetical cases. So in these we have the cash flow that is occurring in the 4 years starting from year 0, year 1,

year 2 and then year 3. So the initial cash flow or the initial investment is the same for all the 4 cases which is 1,60,000 and I am taking a negative figure and then their revenues could be somewhat different.

## PBP and NPV for Three Hypothetical Projects

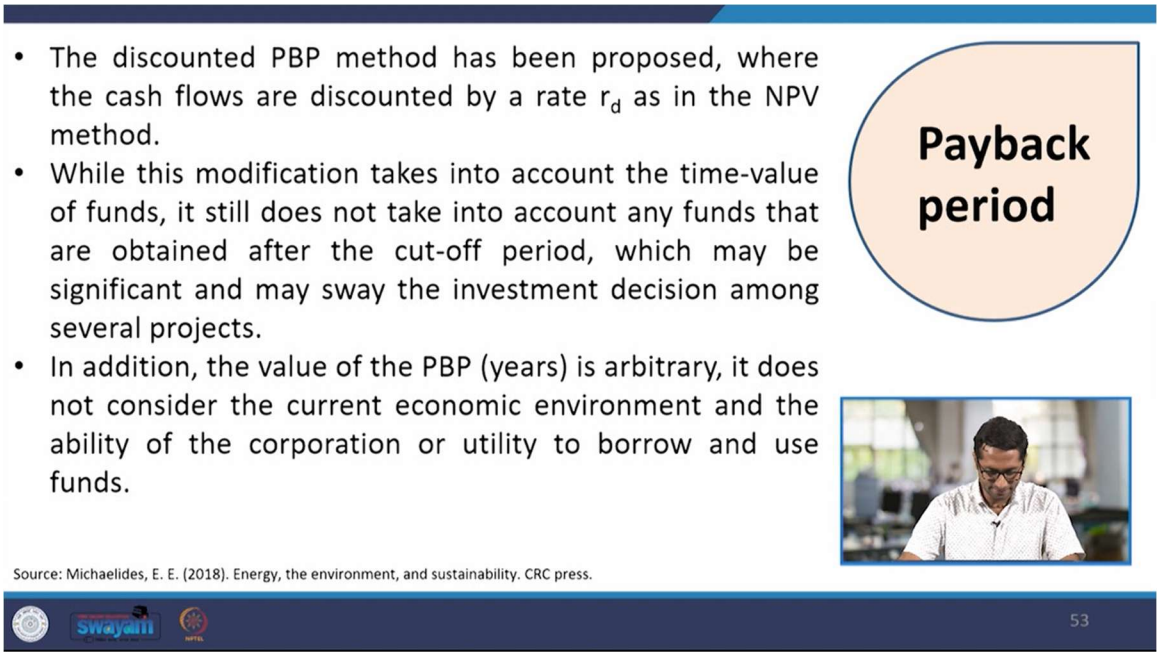
| Project | $CF_0$ | $CF_1$ | $CF_2$ | $CF_3$ | PBP, Years | NPV |
|---|---|---|---|---|---|---|
| A | -160,000 | 80,000 | 80,000 | 400,000 | 2 | 279,360 |
| B | -160,000 | 0 | 160,000 | 400,000 | 2 | 272,720 |
| C | -160,000 | 80,000 | 80,000 | 8,000,000 | 2 | 5,988,560 |
| D | -160,000 | 0 | 160,800 | 0 | 2 | -27,120 |



So in the first case I am having a revenue of 80,000 for the next 2 years and then a revenue of 4,00,000 rupees. For the second case I have a revenue of 1,60,000 in the second year and there is no revenue in the first year and finally in the third year I have a revenue of 4,00,000 rupees. In the third case the revenue jumps in the third year almost to around 80,00,000 and finally in the case of D we have a revenue that is just coming at the end of second year. So you can see if I use the simple payback method and the payback value of all the 4 different projects or investment would be the same that is 2 years. I am able to recover my Capex in the first 2 years.

So in all the 4 cases the addition of cash flow 1 and cash flow 2, CF1 and CF2 is either equal to or more than that of CF0. So the payback period is 2 years for all the cases whereas if I look at the NPV there could be highly different. So we can see for the project C because of for a jump in the cash flow that is happening in the year 3 which is beyond the payback period so it is not able to account and the net present value is way more as compared in the previous 2 options. So this is again a major disadvantage of this methodology which is unable to look at the cash flows that are occurring beyond the

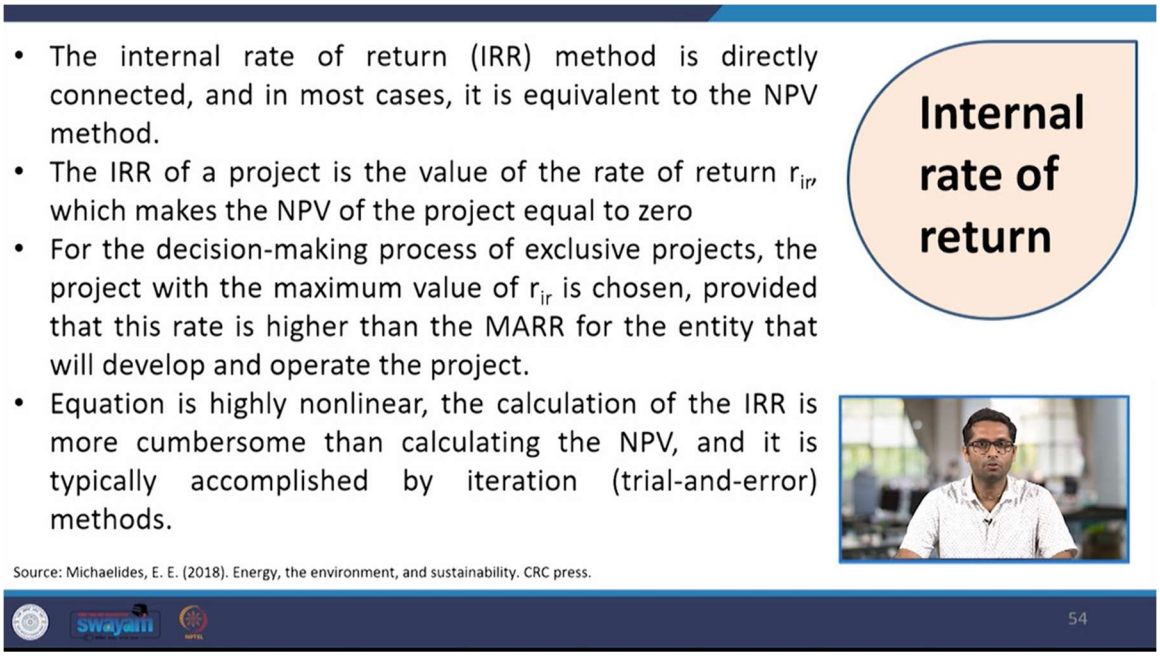
payback period. Further it also says that like a payback period to be quite small for an investment that is expected not to be profitable at all. So if we look at this investment it is not having a positive net present value and not expected to be profit making strategy for the future but still because this particular methodology is not taking into account the time value or the time equivalence of money it has that disadvantage.




And to overcome this disadvantage people have proposed that the cash flows might be discounted by a discount rate of the entity while this brings up or a better methodology in terms of payback period but still the inherent inability of the methodology to account for any cash flows that occur beyond the payback stays there and that does not go away. So if there is a major revenue jump that is happening beyond the payback period or a major investment that occurs or a major replacement cost that might occur beyond the payback period for a particular project it might not be taken into account and might not give you the right decision making power with the help of this tool. So these are some of the advantage and disadvantage with respect to the payback method. Beyond this we also have a methodology which is called the internal rate of return.

So again internal rate of return is something that is equivalent to the net present value. Internal rate of return basically gives you the discount rate at which the net present value of a particular project accounting for all the cash flow through its lifespan is would be 0.

So let me repeat it again like internal rate of return is basically giving you the discount rate at which the net present value of a particular project taking into account all the future cash flows including capex, opex and revenues would add up to be 0. So as you would have understood like and this is basically solving a non-linear equation so it has a computational cost to it but further like if the internal rate of return that you get as an answer is more than the minimum acceptable rate of return for your entity or for the corporation you would go for this project and if it is lesser than that value you would basically discard this process. How do you solve it? So normally the solution is achieved by different iterations there are different kinds of like methodologies and most of them rely on the trial and error methodology.




Let us try to understand this with the help of again an example. Let us consider three different projects that would be there and we have the total cash flows of these projects as well. So we can have the cash flow 0 which is basically an investment and then the cash flow for the next 5 years or so and the cash flows are shown in front of you and what you see in the last two columns is basically the IRR in terms of the percentage as well as the NPV for the projects. So what we see for the first two cases is that the IRR for the first project that is project A comes to be way more than the project B. So the project B has an IRR of 20% whereas the project 1 has an IRR of 33.4%. So if I go with an IRR methodology I am expected to go by project A whereas if I look at the NPV this is the

opposite. The project B has a higher NPV than a project A. So if these two methodologies are basically following a similar kind of analysis why are the results different? The difference lies in the IRR basically gives us the how fast money is coming back to us. So in the case of project A what you see is that the investment is given back to you at a pretty fast rate. So all the investment is coming back in the first 3 years and if you add them up together you are not gaining much whereas in the case of B all the investment is coming back to you slowly the total amount of money that comes back in the next 5 years is somewhat larger.

## IRR and NPV for Three Mutually Exclusive Projects

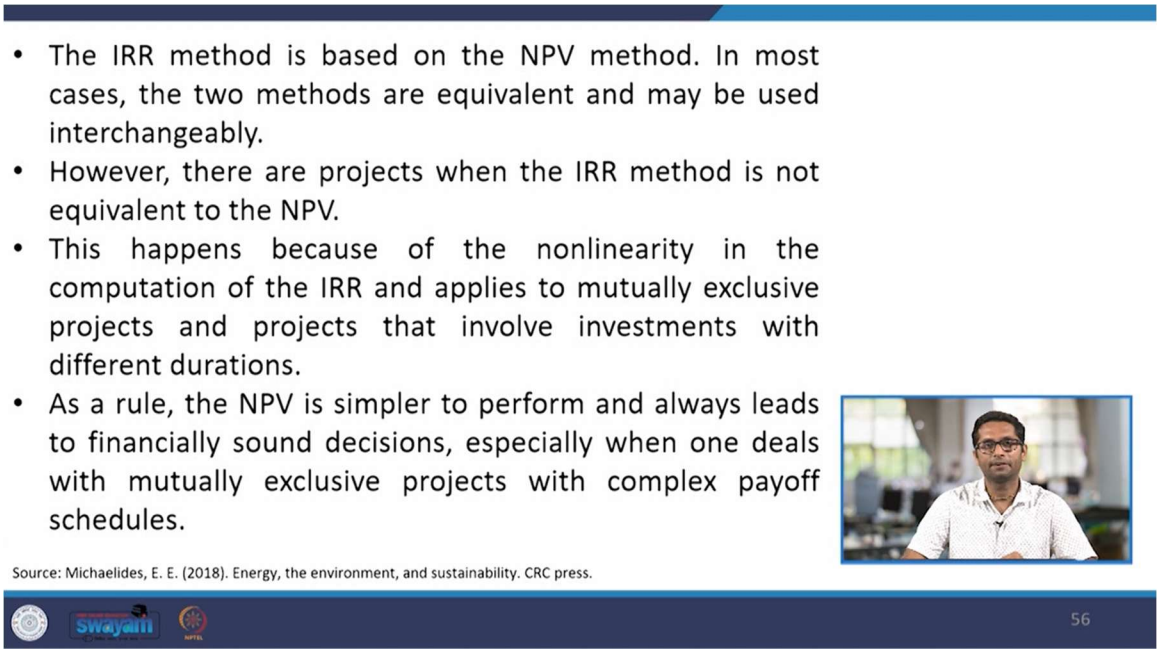
| Project | $CF_0$ | $CF_1$ | $CF_2$ | $CF_3$ | $CF_4$ | $CF_5$ | $CF_6$-$CF_\infty$ | IRR, % | NPV |
|---|---|---|---|---|---|---|---|---|---|
| A | -720,000 | 480,000 | 400,000 | 320,000 | 0 | 0 | 0 | 33.4 | 287,360 |
| B | -720,000 | 144,000 | 144,000 | 144,000 | 144,000 | 144,000 | 880,000 | 20.2 | 322,640 |
| C | 0 | -480,000 | 96,000 | 96,000 | 96,000 | 96,000 | 583,200 | 20.2 | 169,520 |



So an IRR methodology is used by corporates where they would want to see how fast the money is recovered because an investment in a risky business also entails that you would want to recover the money as fast as possible. You might want to lose some money rather than losing all the money so you would want to recover as fast as possible. Again the two methodologies are expected to give you a similar result if I would have adopted a higher discount rate for the NPV methodology. So in this case the discounted that was chosen for this calculation was around 10%.

If the discount rate was beyond 15.8% or 16% or more both the methodologies would have given you a similar answer. Further we can see two methodologies or two projects which have the same IRR in the case of project B and C both happen to have an IRR

which is almost similar in terms of 20.2% would have a very different NPV as well. So in this case it becomes difficult to which particular methodology you would want to go for. So again IRR is a good methodology that has again all the three features of a good investment appraisal methodology. It takes into account the entire span considers the cash flow over the entire span of the investment and also takes the time equivalents into account but when it comes to solving these equations it could be computationally intensive and further it might not always give you the best answer. For the best answer you might would want to use the IRR methodology in conjugation with NPV or some other methodology. So like in this case the two investments are coming to be similar in terms of IRR but it would need you to do a net present value analysis as well to understand which project would generate more profit over the lifespan.




So as we have discussed as a rule of thumb NPV is one of the simplest methodologies and one of the most widely adopted appraisal methodology that you would find very often in all the popular literature as well as different reports which would want to compare the different kinds of methodologies and beyond that we also have a methodology that is the external rate of return. So what happens in the external rate of return is that we would want to compare the different kinds of investment on a similar lines as the IRR but in this case all the investment or the cash flows that are negative or that are outflows would be discounted to the year 0.

- The external rate of return (ERR) method, also known as the modified internal rate of return, is a variance of the previous method.
- According to the ERR, all the cash outflows of a project are discounted to the present, year 0, at a discount rate equal to an external reinvestment rate $i_{er}$, which is defined by the management.
- All the cash inflows of the project are discounted to the last year of the project, year N, using the same rate $i_{er}$.
- The ERR is the interest rate $i_{err}$ that makes the two sums of discounted cash inflows and cash outflows to be equivalent. A project is accepted to be developed if $i_{err}$ is greater than the MARR.

**External rate of return**

Source: Michaelides, E. E. (2018). Energy, the environment, and sustainability. CRC press.



Whereas all the inflows or the profit that you would be making are discounted to the final year and it uses a rate of return which is called the external reinvestment rate IER that is again defined by the management of a particular company and then it would involve coming at another interest rate which is called the IERR which would be used to equate the present value of all the outflows equal to the future value of all the inflows. So you would want to generate or come up with the interest rate that would equate all the future outflows taken in the present values and all the inflows taken at the future value and see if the interest rate that you come up for equating these two values is more than the minimum acceptable rate of return. Further this kind of methodology would entail that you are wanting to determine three different interest rates which is the external reinvestment rate, the interest rate IERR and the minimum acceptable rate of interest and this also brings in the element of uncertainty because these are a few values which are specific to a management of a corporation and that is one of the reasons again not many people would want to use a methodology like this. Finally we would come to another methodology which is called the profitability index. So in the profitability index it is also called as the benefit to cost ratio.

- The profitability index (PI) is sometimes referred to as benefit/cost ratio. It is defined as the sum of all discounted future positive cash flows divided by the initial investment.
- The PI method has several common features with the NPV method: The time-value of funds is inherent in both methods; the present value of all positive cash flows is used in the PI method, and both methods may use the same discount rate.
- However, when the investment occurs over a period of several years and when the investment and revenue streams follow a complex pattern and are mixed during several years, as it often occurs in the early stages of an energy project, the PI method becomes more cumbersome to use and may lead to erroneous decisions, especially when complex and mutually exclusive projects are considered.

**Profitability Index**

Source: Michaelides, E. E. (2018). Energy, the environment, and sustainability. CRC press.



It is basically dividing all the revenues that are being generated through the lifespan of a project and divide that with the initial investment. So I am taking the discounted cash flows that are happening in the future and I divide that with the initial investment.

$$PI = \frac{\left[\frac{CF_1}{1+r} + \frac{CF_2}{(1+r)^2} \cdots\cdots \frac{CF_N}{(1+r)^N}\right]}{I}$$

$$PI = \frac{1}{I}\sum_{n=1}^{N} \frac{CF_i}{(1+r)^i}$$



So for defining a profitability index so if you have different cash flows occurring at different time spans so I would define the profitability index as the cash flows and that starts from year one when you are having a revenue generation and that would normally

be divided by a discount rate. A cash flow maybe for the second year for the discounting it and goes in till the year end which is again discounted and I divide that with the initial investment that I am making in the year zero. So if I have to define this, this is profitability index it is one by i and the summation of n going from one till the year n and this would be C of i divided by one plus r raised to power i.

So this is a normal notation for this. Again this methodology takes into account the cash flows throughout the lifespan of the project and further it also considers the time equivalence. But if in case the investment is spread to more than one year maybe two to five years which is the normal case for energy related project this is a shortcoming of this project on further if the investment beyond or in the middle of the project which again is something usual for energy related project this methodology might not be able to accommodate that quite well. So with this we have tried to understand the different kinds of investment appraisal methodologies and that could be applied for evaluating different kinds of energy related projects. We have tried to understand the basics of net present value, the annual worth method, the payback period, the internal rate of return, the profitability index, the average return on books. So these are some of the methodologies that you might come across when you are studying different kinds of investments in the energy related domain and now you understand how these calculations are being done.

The most common and the easiest and the most widely acceptable method is NPV which you will find in most of the cases and in the future we will also try to understand these concepts with the help of more concrete examples. Thank you.