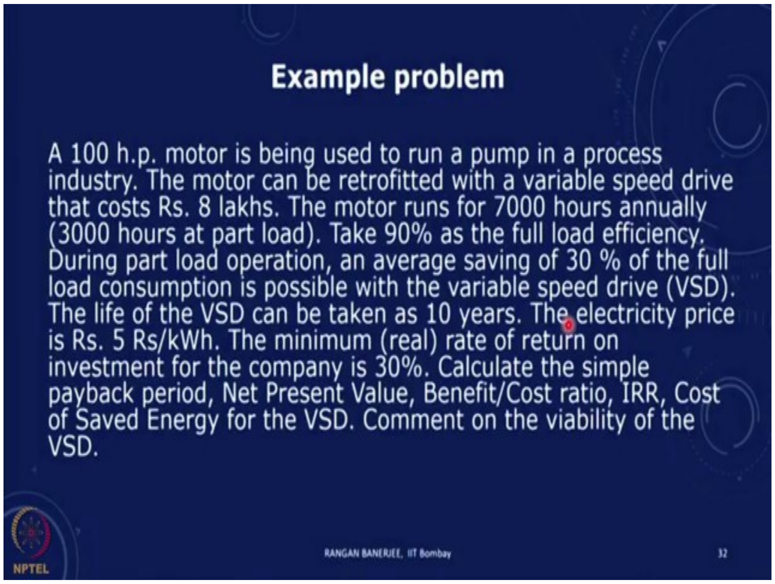
**Energy Resources, Economics and Environment**
**Professor Rangan Banerjee**
**Department of Energy Science and Engineering**
**Indian Institute of Technology, Bombay**
**Lecture 6 P1**
**Energy Economics – Part 3**

(Refer Slide Time: 0:26)

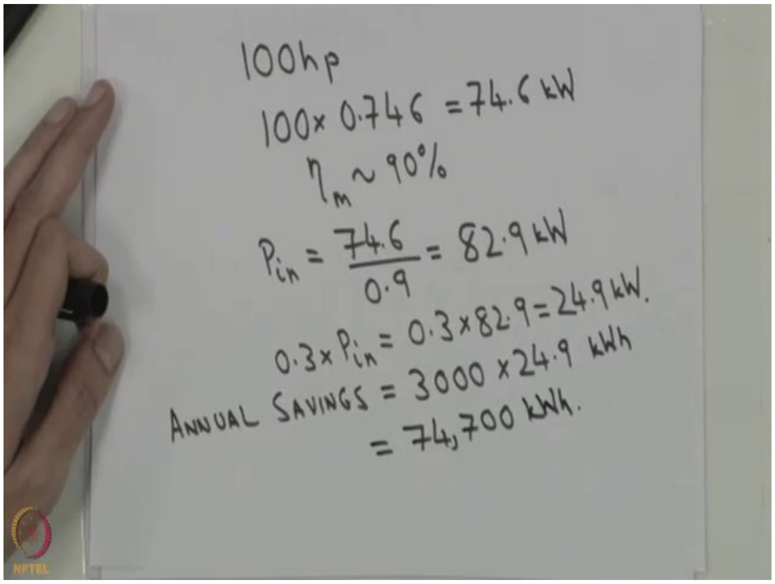



So, now let me do one thing, let me, let us take an example problem, where we do the calculations for all the concepts that we have learnt so far. So, let us look at this problem, this problem is from the tutorial sheet that we have, we are talking of a motor in an industry and that motor is a 100 horsepower motor it is being used to run a pump in a process and this motor can be retrofitted with a variable speed drive that cost 8 lakhs, the motor runs for 7000 hours annually of which 3000 hours it transit part load.

Now, what happens in the case of the variable speed drive is when we are running it at part load it is running inefficiently, if you have a variable speed drive instead of throttling the pump we will run the motor at a different speed and we get savings. Now, we told that the full load efficiency is 90 % and during part load operation if we put a variable speed drive we get an average saving of 30 % of the full load consumption.

And the life of the VSD is given the electricity price is ₹ 5 per kwh, the discount rate is given to you as 30% we want to calculate the simple payback period, net present value, benefit by cost ratio, and internal rate of return.

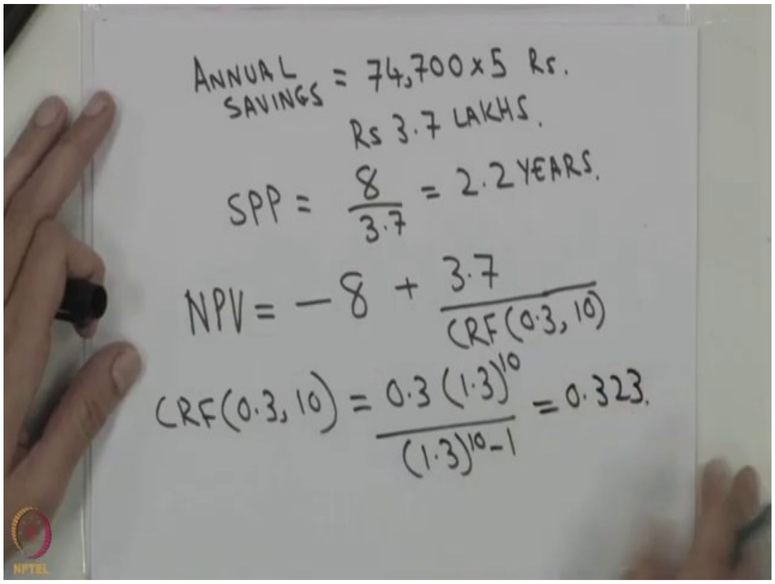
(Refer Slide Time: 1:53)




So, let us start by looking at if you are talking of 100 horsepower that will be 100 you can is 0.746 that is 74.6 kW is the full load rating of the motor, the efficiency of the motor is 90%. So, the input power that is required at full load is 74.6 by 0.9 which comes out to be, this is you can calculate this as 82.9 kW.

Now, when we are operating with the VSD variables speed drive at part load we get a saving of 30 % to a saving is 0.3 into this input power which is 0.3 into 82.9 which is 24.9 kW. We are operating the pump annually at 3000 hours with separating at part load, we are getting savings only during those 3,000 hours. So, annual savings is going to be, annual savings is 3000 into 24.9 and the units are kwh. So, this turns out to be 74,700 kwh. Now, we have told that electricity price is rupees 5 per kWh.

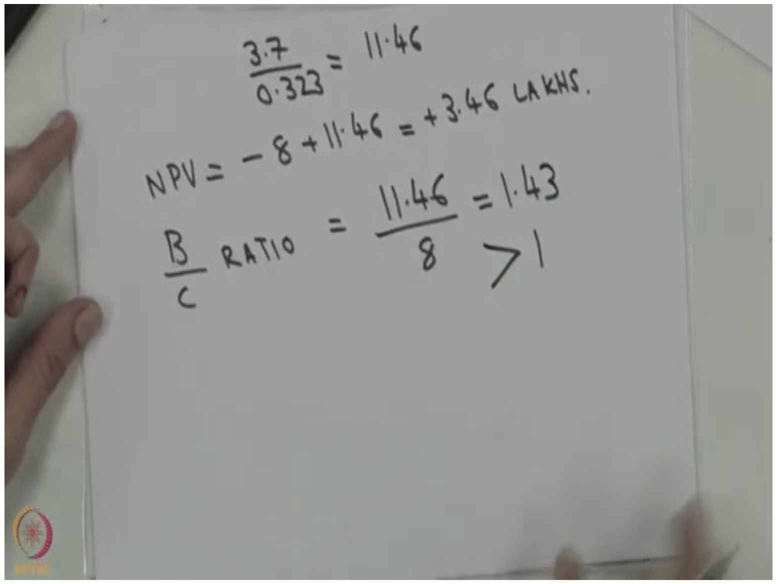
(Refer Slide Time: 4:06)




So, the annual savings, annual savings, annual savings are just multiply the total that we have which is 74,700 into 5 rupees and this turns out to be you can do this, you will get 3.7 lakhs, we were told that the investment is 8 lakhs. So, the simple payback period is nothing but 8 by 3.7 which comes to about 2.2 years that was a first thing that we have to calculate.

Now, let us calculate the net present value, so the when we talk about the net present value we will like to calculate the this is going to be NPV is let us do this in lakhs. So, this is minus 8 lakhs plus 3.7 divided by capital recovery factor, discount rate is 30 % point 0.3 and the life is given to you as 10 years. So, CRF 0.3, 10 let us calculate that is 0.3 1.3 raise to 10, 1.3 raise to 10 minus 1, it comes out to be 0.323.

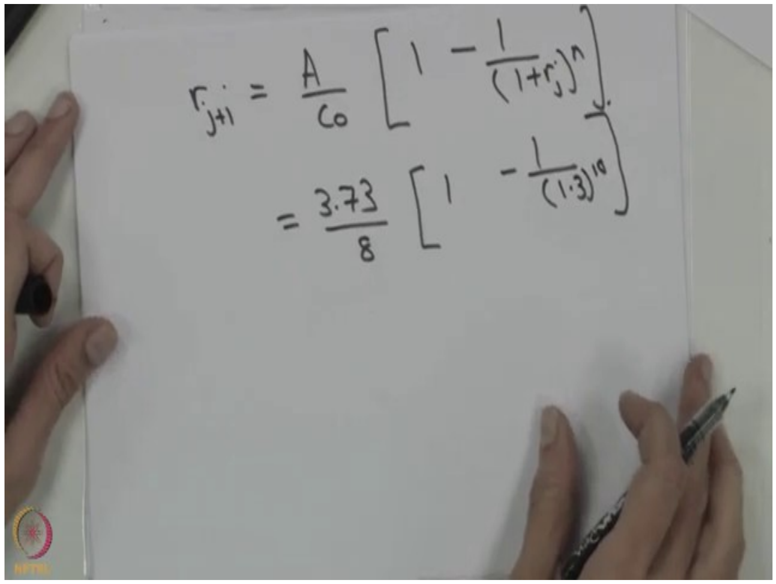
(Refer Slide Time: 6:04)




So, then this becomes NPV the benefits stream is now going to be 3.7 by 0.323 which is 11.46 lakhs. So, the net present value is minus 8 plus 11.46 is plus 3.46 lakhs, net present value is positive. So, the company should go for this, if you look at the benefit by cost ratio this is going to be 11.46 divided by 8 which comes out to be 1.43 B by C greater than 1. So, we can go for it.

Now, let us look at calculating the internal rate of return, what do you expect the internal rate of return to be, is it going to be less than 30 %, or more than 30 %. So, it is obvious that with a discount rate of 30 %, we got in net present value to be positive. So, the rate of return is going to be more than 30 %.

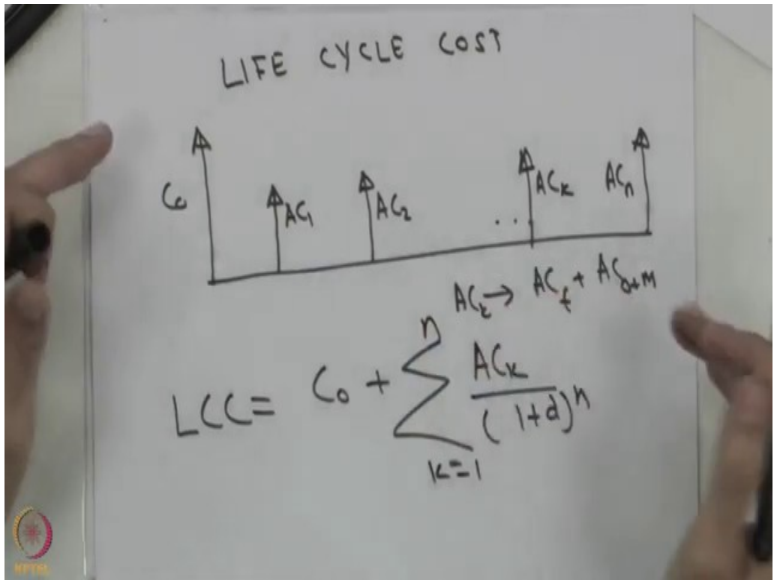
(Refer Slide Time: 7:26)




So, we can use this formula which says, which we derived that is rj plus 1 is A by C0 1 minus 1 by rj raise to n and if you do that you will find that if we look at this formula this will come to 3.73 by 8, 1 minus in this case if we take 1.3 raise to 10 and then calculate and you will find that you, we get in two or three iterations it will quickly convert and you get the value which is I think something like 43.43, 43 % rate of return.

So, we have seen how to calculate the simple payback period, net present value, benefit by cost ratio and internal rate of return, and as we saw all of these give essentially the similar kinds, similar result. So, let us move forward and now let us look at the next concept which is the concept of the life cycle cost.

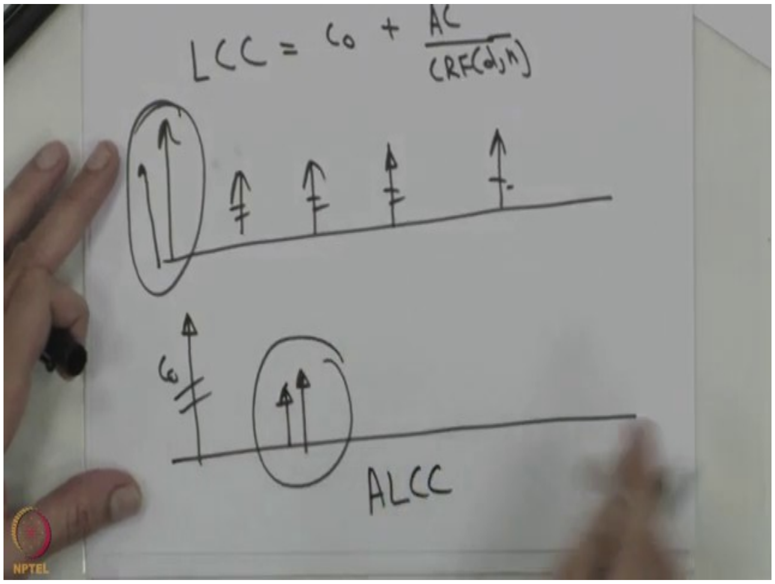
(Refer Slide Time: 8:48)




In the case of life cycle cost, we are looking at what is the way in which we can get the life cycle cost is we are taking here the upfront cost C0 and then every year, we have associated with it an annual cost. So, there will be an annual cost AC1, AC2, and ACk, ACn this cost the ACk in the kth will have the annual fuel cost, annual operation and maintenance cost, and any other labor and other cost, which can be also taken in, so each of these will in each of these cases.

So, what we can do is we can take the total sum of all the cost, the life cycle cost will be C0 plus sigma ACk 1 plus d raise to n, k is equal to 1 to n, and that gives us the life cycle cost, the cost of owning and operating that equipment over its life time and you can then look at the relative magnitudes of different things.

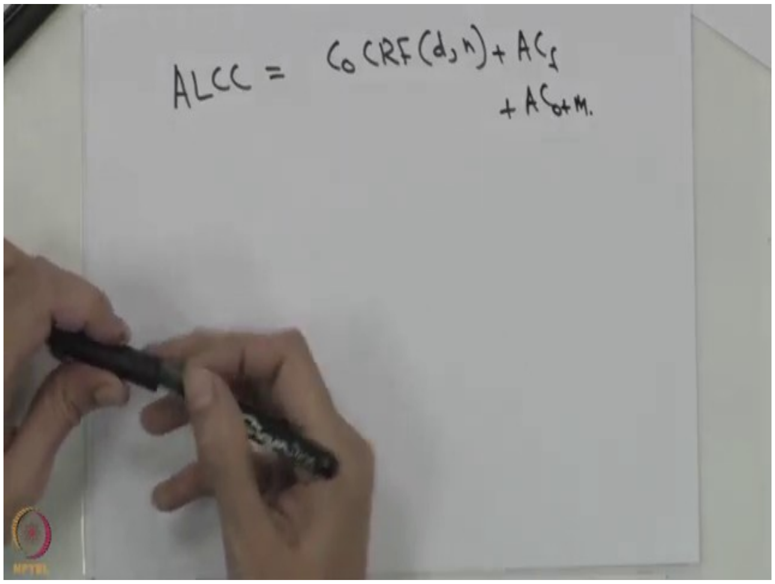
(Refer Slide Time: 10:26)




If the annual, if the annual cost are constant then this can be simplified to C0 plus AC by CRF, d, n. Now, there is a situation, when you if you are annual cost which are constant and if we are looking at we can instead of taking the life cycle cost, where we took the what we did was we to this and we took all of these annual cost and we replace all of these by an equivalent upfront cost and we added these two, instead of doing that we could do the situation where we took an annual cost which is constant take the C0 and replace it by an equivalent annual cost.

So, then this case we are now doing this as this is called the annualized life cycle cost. So, either we take the annual cost which are there and bring them upfront to an upfront life cycle cost, or we take the initial cost annualize it added to the annual cost, and that becomes the annualize life cycle cost. This is convenient way often in the case of annualized life cycle cost specially why, because it helps you to tackle equipment and projects with different kinds of lives.

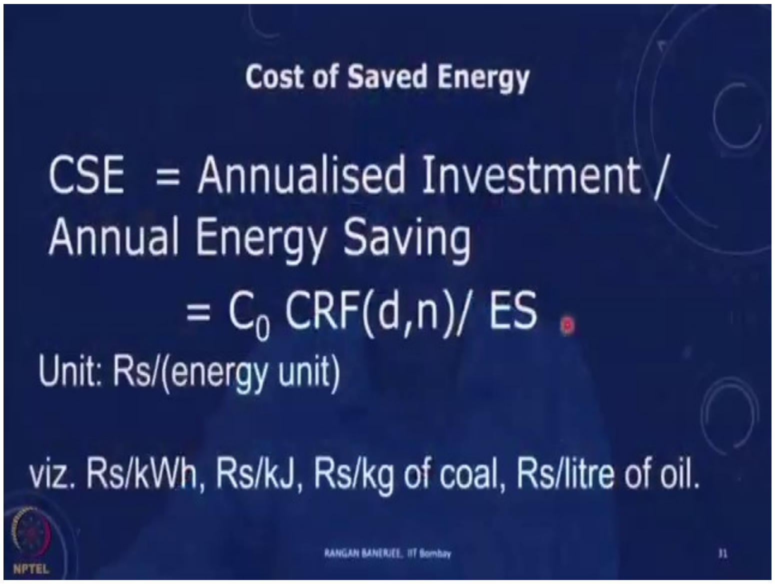
(Refer Slide Time: 12:02)




So, the ALCC typically would then mean that you just take this will be for this you will take C0 and annualize it plus then the annual cost of fuel, annual cost of O & M and so on. So, this annual lives life cycle cost is the annual cost of owning and operating the equipment.

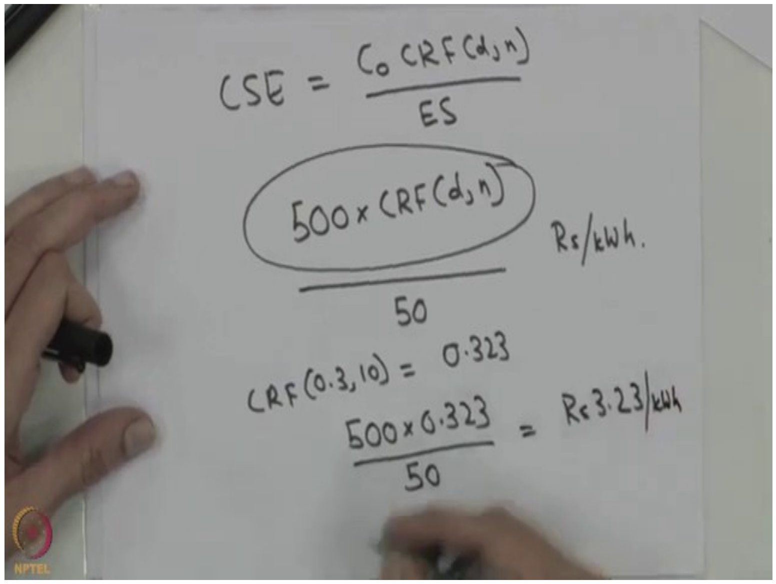
This is very convenient because for instance if you look at a power plant or you will looking at let say a solar photovoltaic plant where you have photovoltaic modules which have a certain life and then you have the battery which has a different life you can take all of these, annualize it get the annual cost, get the annual generation and we can then convert it into a ₹ per kWh. So, this is that is one of the ways in which we can look at this.

(Refer Slide Time: 13:03)




So, let us there is this other concept where we talk about the cost of saved energy which is very similar to this concept, the cost of saved energy is a concept where we take the annualized investment divide it by the annual energy saving. So, many cases what happens is that when we talk of a new generating plant, we talk of ₹ per kWh and when we talk about savings we want to compare it with generation. So, the cost of saved energy can and calculated for an energy efficiency option by taking an investment, annualizing it, dividing it by the annual energy saving and this will mean that.

(Refer Slide Time: 13:44)



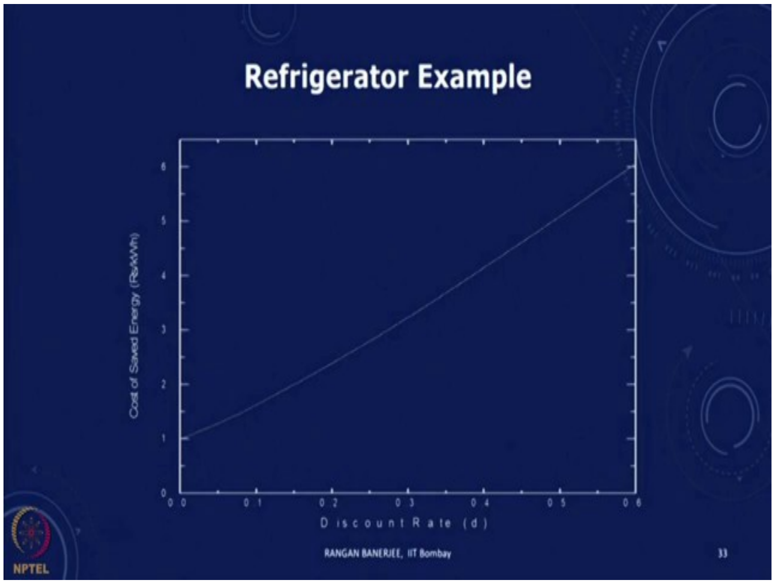

This annual cost of saved energy will be C0 into CRF dn divided by the amount of energy saving and the units then will be in terms of rupees per the energy unit, rupees per kwh, rupees per kilojoule, rupees per kg of coal, rupees per liter of oil, you can then compare it with the price at which you are getting the electricity, or the fuel, and if it is low, this price is lower than the price at which you have purchasing then it will make sense for us to go ahead.

So, just to give you an example let us take an example where we take other cost of a standard refrigerator is 10000 rupees and the expected electricity consumption per year is 450 kilowatt hour, cost of an energy efficient refrigerator of the same capacity is 10,500 rupees for the same load annual electricity consumption is expected to be 400 kilowatt hour. So, what is the cost of the saved energy?

Now, this cost of the saved energy will be depend on the discount rate and typically what happens here is that your incremental investment is ₹500. So, 500 into the capital recovery factor, this is the annual amount in terms of rupees that we are paying, in terms of the annualized investment, this divided by the saving which is 50 kilowatt hour will give you the rupees per kilowatt hour.

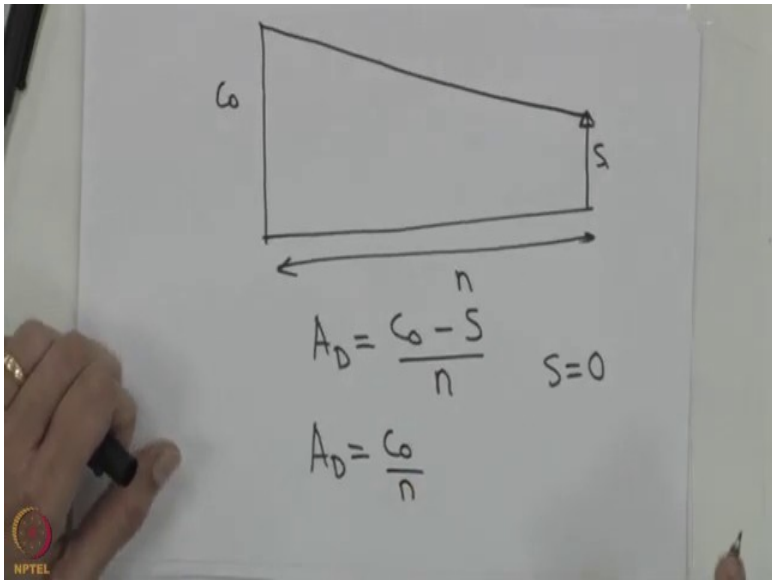
Now, if we took a discount rate of 0.3 and this is all we said CRF 0.3, 10 then this will be 0.323 we had calculated it earlier. So, you get 500 into 0.323 by 50 and then this the cost of saved energy turns out to be rupees 3.23 per kilowatt hour, if your discount rate is lower than this cost of saved energy would be lower. So, we can see this I have shown you this plot.

(Refer Slide Time: 16:17)




So, this gives the example which shows you how as the discount rate increases the cost of saved energy would then increase because the effectively that initial investment that we are making is now equivalent in terms of higher annualized investment. This one concept, additional concept that we need to understand which often gets confused in the process whenever we are doing this calculations is about depreciation. So, we must understand the depreciation is an accounting concept, it is concept wear if you look at an asset, we adjust the value of the asset and we depreciate it over its lifetime.

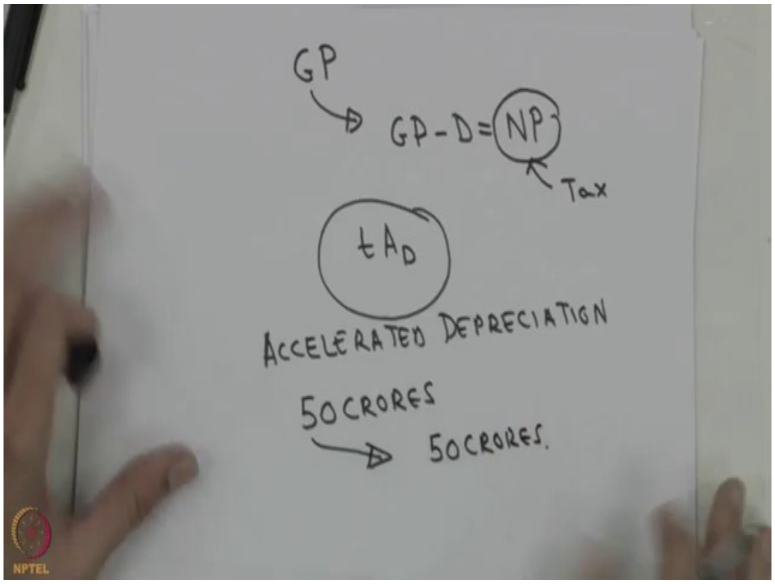
(Refer Slide Time: 17:26)




So, typically what happens is that we considered an annual depreciation and one of the ways in which you do that is we take a straight line depreciation, we say that if you have the C0 and at the end of its life if you have a salvage value S, the book value of this asset is adjusted. So, that every year we reduce this by a straight line depreciation, which is C0 minus S where S is the salvage value at the end of the life. There are situations where if you take S is equal to 0 then the depreciation is taken as every year C0 by n.

Now, in general since we have already taken this C0 as an upfront cost and we are using that in the calculations it would not make, it does not make sense to again add up the depreciation then will be double counting the cost.

(Refer Slide Time: 18:56)



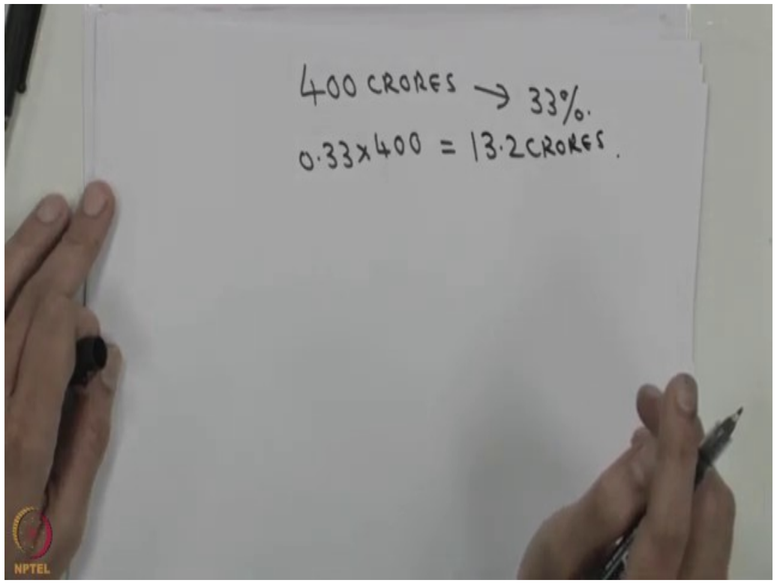

However, there is a benefit that we get from the depreciation in the sense that if there is a company which is a profit making company, then the company after we will have a set of gross profits. And from the gross profits we are allowed to subtract the depreciation to get the net profits and the company is tax based on the net profit.

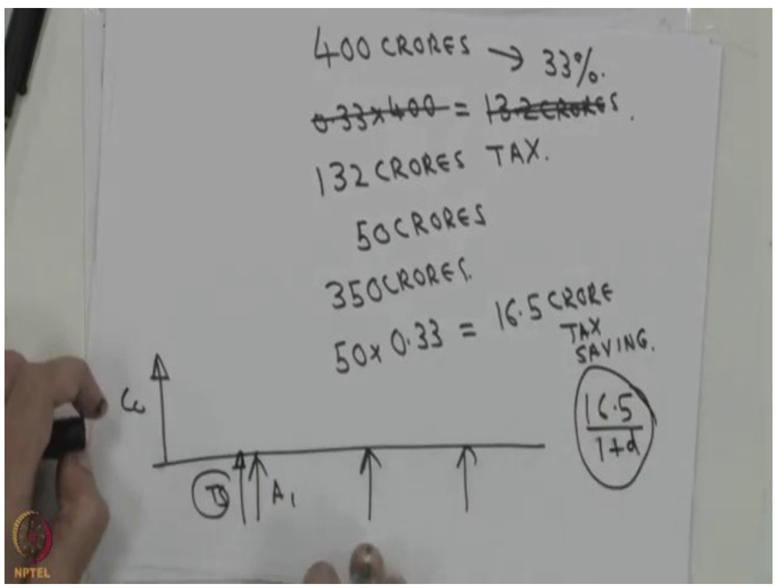
So, essentially if you look at a company today the tax rate maybe of the order of 30 % or 33 % the saving each year is T into AD, the tax rate into the AD. Now, in a sense will not make too much of a difference and we can neglect the effect of the tax on the depreciation because the value of the book, value of the asset get depreciated.

However, there are situations for instance in the case of renewable where the government provides a policy of accelerated depreciation, accelerated depreciation for instance, for instance for till sometime back we had 100 % depreciation for some of the energy, renewable energy equipment like wind farms.

So, for instance if a company has made an investment of 50 crores in an wind farm, in the first year itself it was allowed to depreciate this 50 crores.

(Refer Slide Time: 20:44)



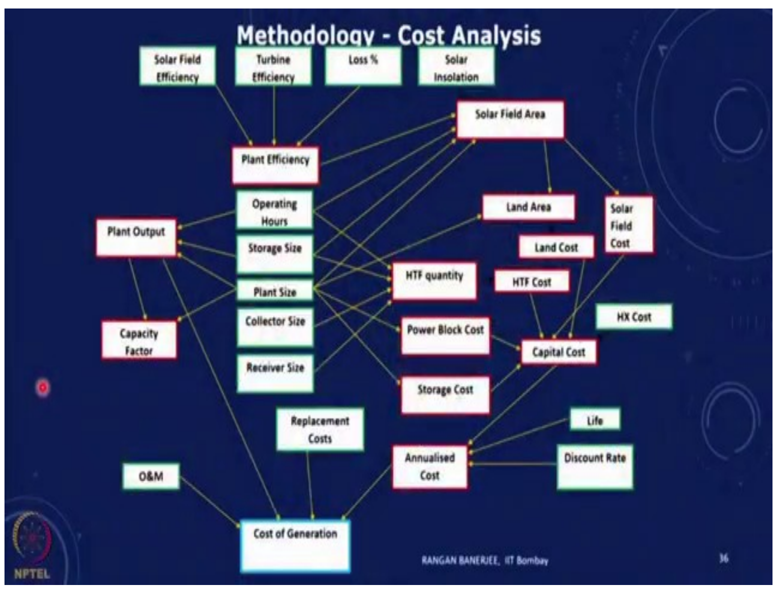

So, that suppose the company had a profit of let us say 400 crores and the tax rate is say 33 %. So, it would have been paying 0.33 into 400 as the tax, which is 13.2 crores would have been the tax that is paid, sorry. So, this is, this would be 132 crores would have been the tax.

So, in the case of suppose we have made an investment of 50 crores in a wind farm and there is a 100 % depreciation, it will mean that that company is now going to be taxed only on 350 crores. So, the net saving is 50 into the tax rate 0.33 is 16.5 crore tax saving at the end of 1 year.

So, in terms of the benefits stream that we have after wind farm, where we have C0 and you have these annual cash flow streams we are getting at the end of 1 year an additional tax saving stream which will be 16.5 divided by 1 plus D with the result that all the indicators that we talk of the net present value, benefit by cost ratio, the internal rate of return, all of these would improve with this.

In any situation when we do the economic calculations there are when we look at a project there are a large number of parameters which are outside our control, there a number of variables and assumptions that we make and it will be worthwhile in all these cases to try and show some of these parameters.

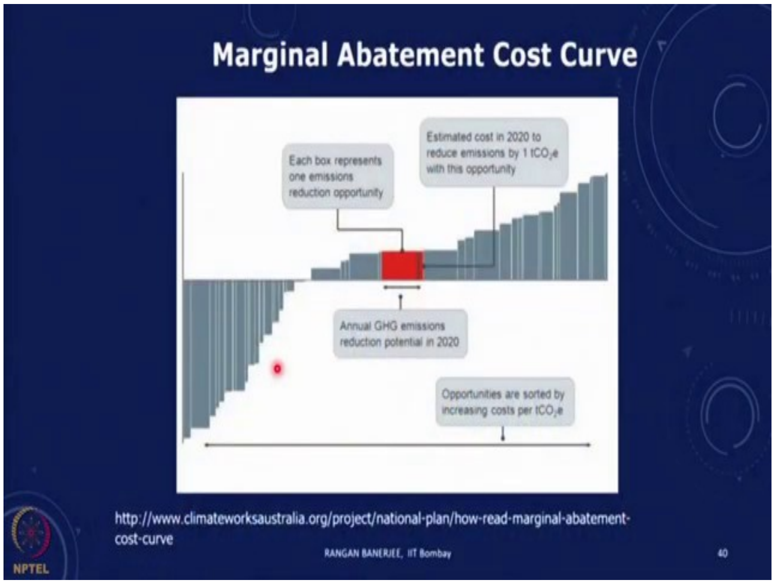
(Refer Slide Time: 23:17)




For instance, this is the cost of generation from a solar thermal power plant and you can see that when you look at it we are talking about the field, the efficiency, technical parameters, the plant output which will depend on the insulation solar field cause, capital cost, storage cost, annualized cost, replacement cost, discount rate.

So, all these parameters and we can see in many of these cases if there are ranges of values we can do a sensitivity and do the calculation for this.

(Refer Slide Time: 24:00)



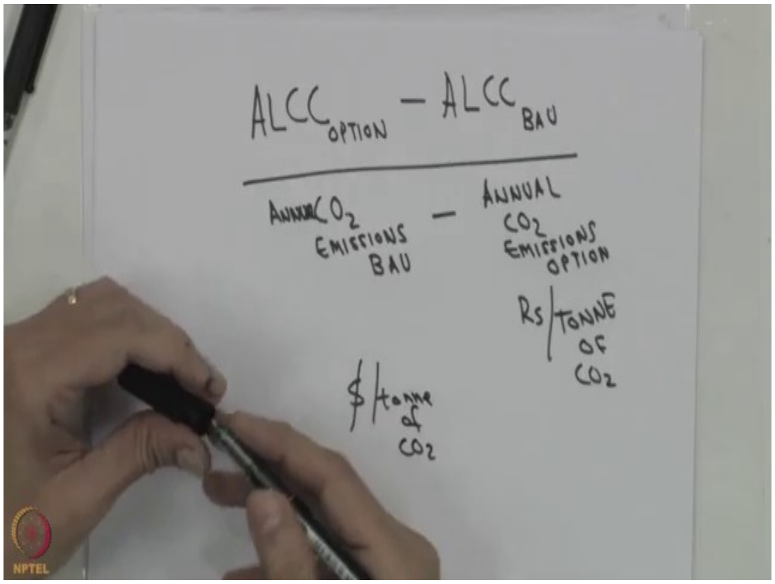

We would like to just, I would like to just talk to you about using the concepts that we have learnt so far to calculate for the marginal abatement cost curve. So, when we talk in terms of we introduce this concept of energy and environment and the issue of climate change and when we look at climate change, we are looking at for different options we see what is the impact in terms of the greenhouse gas emissions, or this $CO_2$ emissions.

So, one of the curves which has been introduced and this was introduced by McKinsey is called McKinsey cost curve on the X axis is the amount of annuals $CO_2$ savings from a particular method, annual GHG reduction potential. So, what happens is we start with a base year and we see what is the kind of emissions in that base year.

If we take the base year and continue with the same kind of growth in the future we will have a business as usual scenario, till a future year let say 2020 if we wanted to have more investments in renewables that would involve a certain cost that cost is expressed in terms of the rupees, or dollars, or euros per ton of $CO_2$ saved on the Y axis and on the X axis we have the annual $CO_2$ savings. So, with this, this is a marginal abatement curve and with this kind of curve we can then compare all these options. So, that we go for the ones which are cheaper.

Now, you will find that there are some which are negative, some options which are negative in terms of cost and that is because even if you do not consider the $CO_2$ savings they are cost effectives. So, these are energy efficiency options mostly and so the idea is that in overall if we want to have a fixed amount of $CO_2$ saving that we target, we should go in this order and look at all these options. So, we can take and we will do an example where we will see how to calculate.

(Refer Slide Time: 26:16)

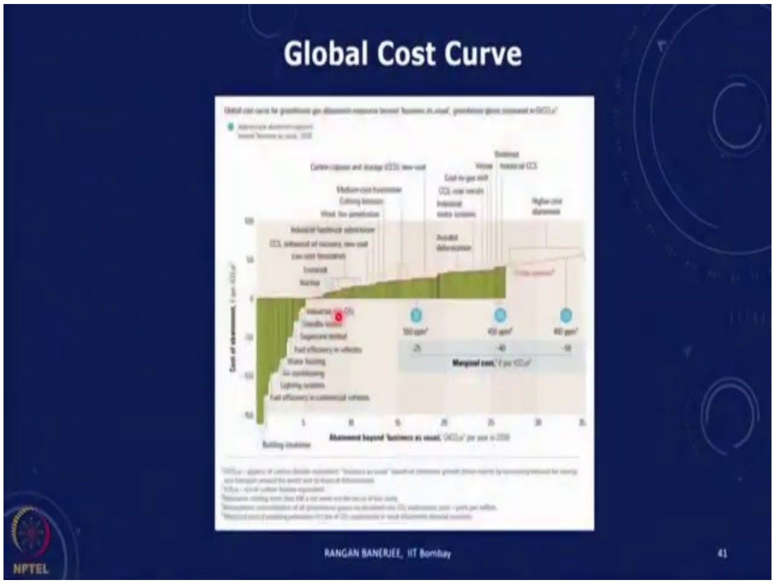



So, essentially what happens is if we look at a, we can look at the ALCC for the option that we have minus the ALCC for the base case, or the business as usual case and then we can have the $CO_2$, annual $CO_2$ emissions, annual $CO_2$ emissions with the option that we have. So, you get a $CO_2$ savings, annual $CO_2$ savings, we have the annualized and then we can get this incomes of rupees per ton of $CO_2$ saved.

You can find these curves in terms of you will see dollars per ton of $CO_2$ and then they can be compared and then we can see which of these options does a wind firm, is a wind firm cheaper than energy efficiency option, is it cheaper than a biomass option, is it cheaper than doing carbon capture and storage, and we can do some of these calculation.

So, will do an example where we can take this, so, we have seen how to do the annualized life cycle cost, we have also seen in a previous lecture how we can calculate what are the $CO_2$ emissions from first principles and then we can take this and get the marginal abatement curve.

(Refer Slide Time: 27:59)




So, similar fashion this is showing you the McKinsey curve for the world and you can see that there are many these options mostly the energy efficiency options, and then depending on where we want to stabilize we are already today at more than 400 parts per million in terms of this $CO_2$ emissions. If you want to stabilize at 450 PPM or 500 PPM the more the stabilization then will go for all the costlier options.

(Refer Slide Time: 28:33)

So, today we have looked at the economic criteria which are used as a basis for decisions, we looked at the simple payback period and we said the simple payback period is a good index to use for projects which are relatively low cost but we are not taking in that the effect of the time value of money with the time value of money, we looked at net present value, benefit by cost ratio, and internal rate of return, all three come from the same equation but there is a slight differences in how it can be calculated.

We then look at also what is the concept of inflation and how it affects the decisions in terms of we said we can always look at we do not need to adjust for inflation though everything in terms of constant money terms and look at the real discount rate, or if you have inflation and the nominal values, we can take the nominal discount rate, discount rate is the critical concept that we need to understand which reflects the scarcity of capital and typically if companies are more capitals scares they would rather prefer options which have lower investments initially.

We then talked about the concept of life cycle costing and annualized life cycle costing and briefly introduced the marginal cost of carbon save all of this we saw the effect of taxes and depreciation, and the taxes government policies all of this can affect the viability of a technology, or a system when we are doing a calculation and we have multiple sets of parameters, we can also look at the sensitivity and look at the impact of variables on this. With this, we will conclude this session on energy economics. We will take up one or two examples in detail, where we can illustrate some of these concepts in a later class.