Solar Energy Technology

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Lecture - 37
Life Cycle Savings: The P 1, P 2 Method

Last time we were discussing about the economic analysis, the ultimate objective has been after evaluating the performance of solar energy systems on long term basis, we couple it with the economic analysis.

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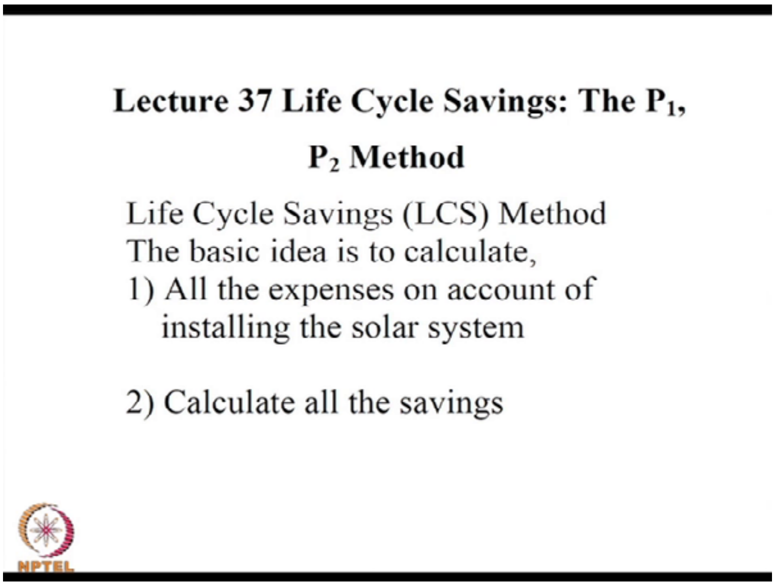

A simple issue is about this life save savings method or the payback period which we have indicated by the simplest possible thing whatever is the fuel cost saved in the first year to the investment it may require a few years to recover the investment, though it is a simplistic calculation. Now, we shall go a little detailed about the so called life cycle savings method - the p 1, p 2 method. That means the life cycle savings or calculated based upon two parameters; p 1 and p 2. In general the basic idea of the method is all the expanses on account of installing the solar system has to be taken into the account, and calculate all the saving.

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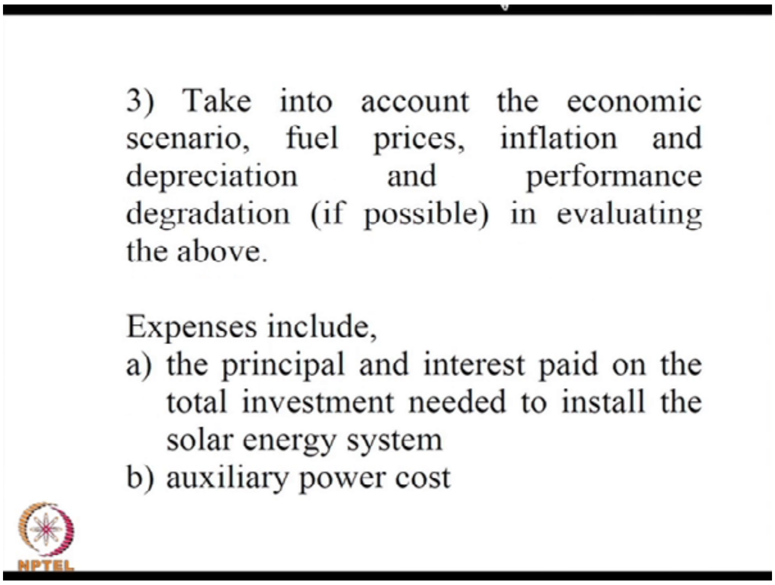

Take into the account economic scenario, fuel prices, inflation and deprecations and performance degradation if possible in evaluating the above.

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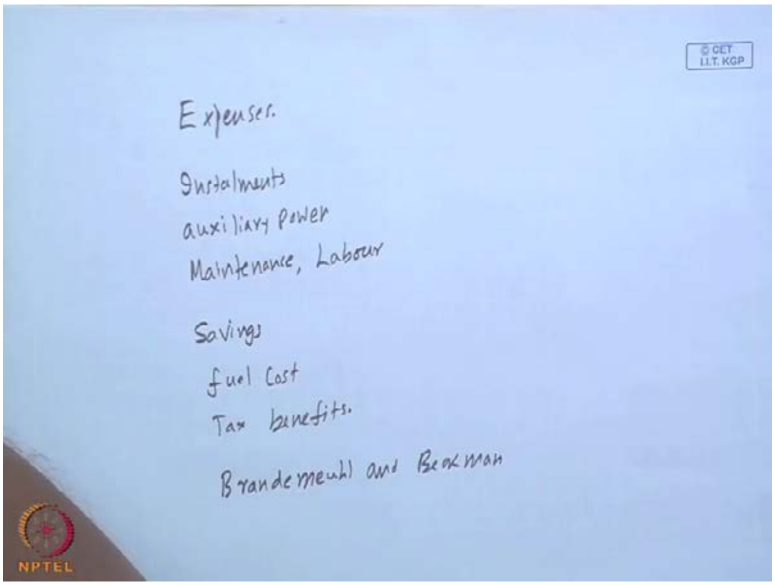

Similarly, when you have installed the solar energy system, there will be certain expenses which may involve the principle and interest paid on the total investment needed to install the solar energy system, and the auxiliary power cost. So, let us say installments and the auxiliary power.

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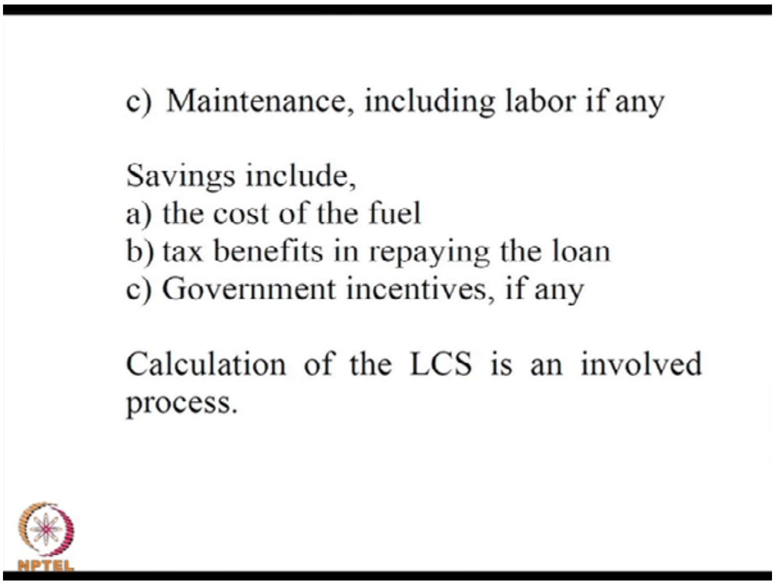

In addition there will be certain maintenance cost even cleaning the solar collectors, and that may include the labor also, and mainly the savings come from fuel cost. What is the fuel it saved? And there could be tax benefits, because this is a green investment, there are tax benefits given by the government in various countries, and then government incentives if any in other words there may be the subsidy in that, and there may be additional benefits by the government by installing if you install a solar energy system, and do not use the conventional fuel. So, in general the life cycle savings as we have explained the amount of money that the system is going to save to the earner during the life time of the solar energy system, we will call it the life cycle savings.

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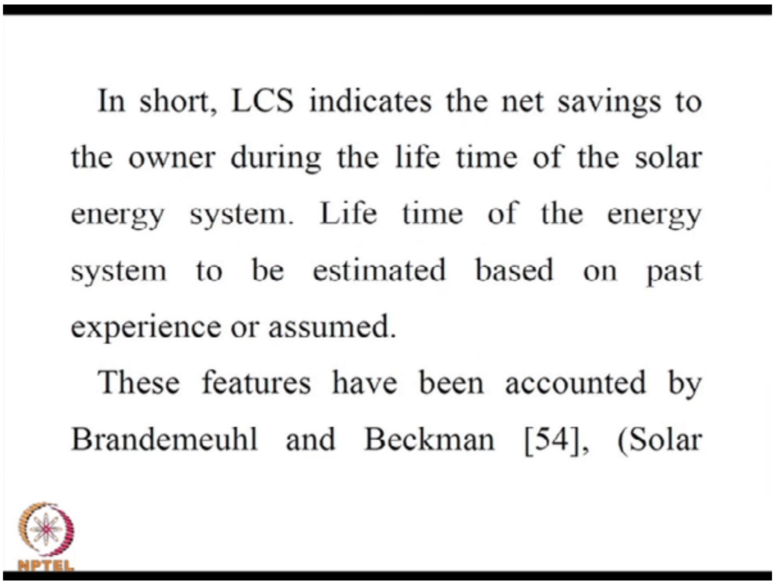

So, the calculation of this is air involved process, because the fuel prices do not remain constant the interest rates may not remain constant, auxiliary power rate may not remain constant. So, all this features have to be take in to a account, of course assuming a certain scenario, and these feature have been accounted by Brandemuhl and Beckman; the reference will be given is available in your companion notes.

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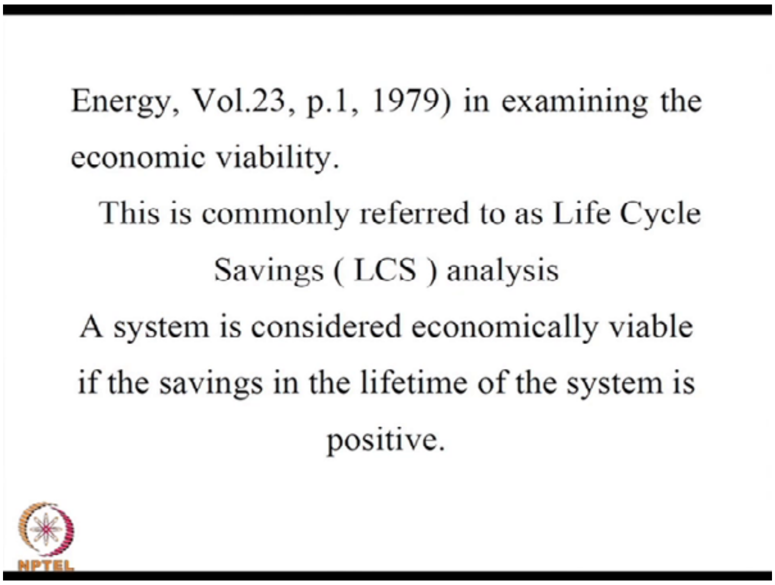

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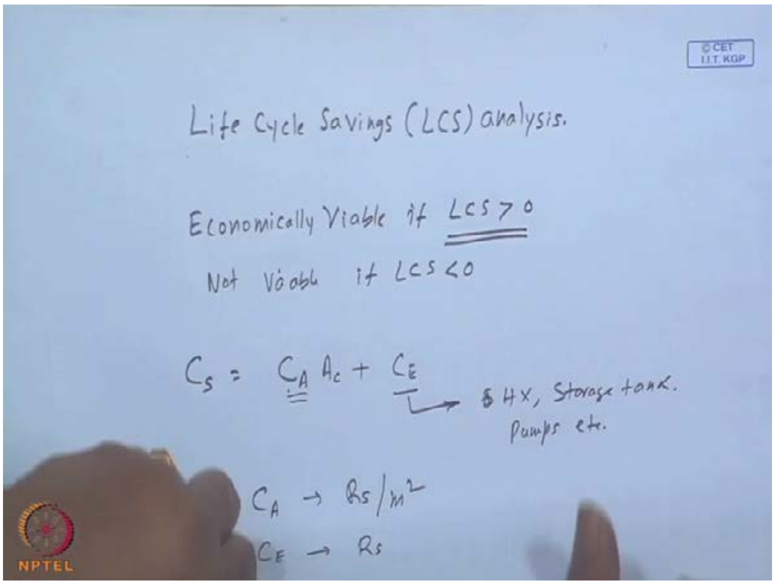

So, this is commonly known as the life cycle savings analysis; short form LCS analysis. And of course, as we had pointed out earlier, a system is considered economically viable, if LCS is positive, and not viable if LCS is negative. So, if you maximize the life cycle savings in the sense when it is positive, it will lead to some sort of a optimum configuration for the system under consideration.

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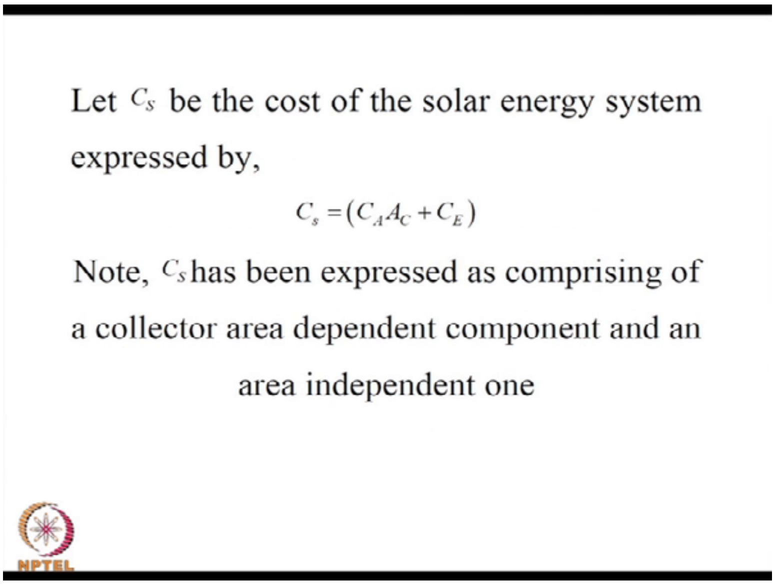

So, now we split the total cost of the system C s as comprising of an area depended cost C A times A c plus an area independent cost, in other words if collector area is taken into the account if 100 square meters are there it should be 100 multiplied by something and f it is 200 it will be 200 multiplied by something. So for each collector you may also associated a certain amount of piping, certain amount of platform, certain amount of stands or whatever are necessary. So, you can put all those things in this factor C A which depend upon the area of the collector, and in addition this C E may be coming from heat exchanger and may be to some extent storage tank though that is also proportional to the collector size and then pumps, etcetera.

So, unless the size drastically changes, the pump and the heat exchanger and this storage tank do not change directly in proportional to the coast of the area of the collector. So, C s is a m x plus c type of equation, where C A is the coast per unit area of the collector involved and C is a fixed cost which is independent of the area. So, this C A could be R s per meter square, and C E is simply rupees.

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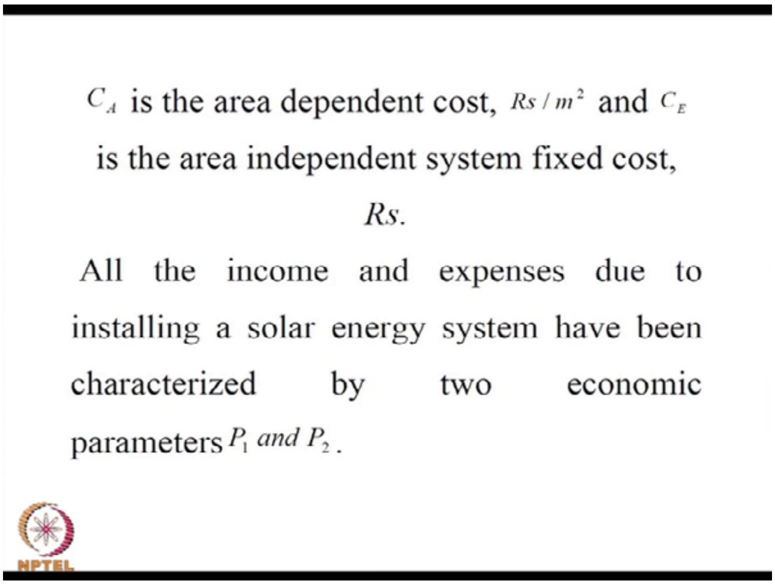

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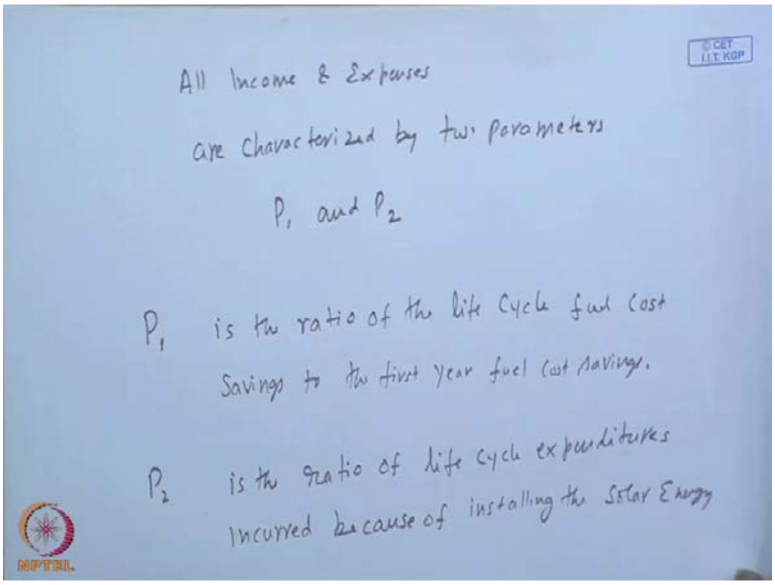

So, Brandemeuhl and Beckman they said all income and expenses which are necessary to evaluate the economic viability of the system or characterized by two parameters - p 1 and p 2.

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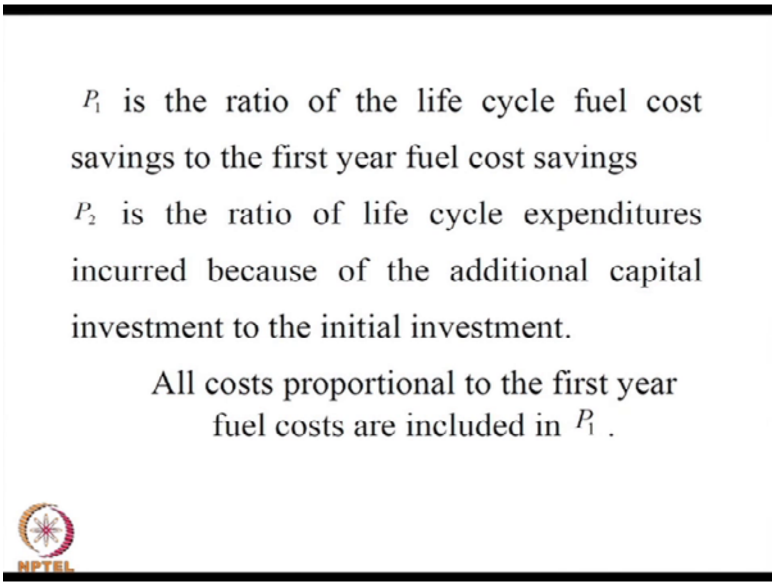

So, p 1 if you want to have an idea before we try to calculate that is the ratio of the life cycle fuel cost savings to the first year fuel cost savings. So, in other words this p 1 will take into account how the fuel prices are going to change over the life cycle of the solar energy system. And p 2 similarly sort of a indicated expenses is the ratio of life cycle expenditure incurred, because of installing the solar energy system.

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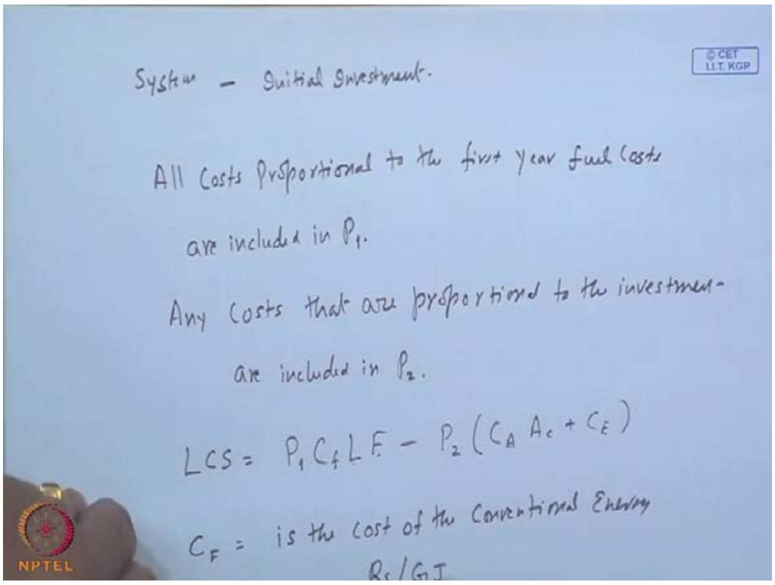

So, is the ratio of life cycle expenditure incurred, because of the addition capital investment to the initial investment. So, you may make a down payment 100 percent or 80 percent or 10 percent, and there will be several things like deprecation of the system inflation etcetera, etcetera. So, all cost proportional the first year fuel cost are included in p 1, all cost proportional to the first year fuel cost, this is just to make you appreciate before you go for a formula to calculate the p 1 and p 2's; basically p 1 is going to indicate, how much you are going to save. So, all that should be proportional to the first year fuel cost according to the economic scenario

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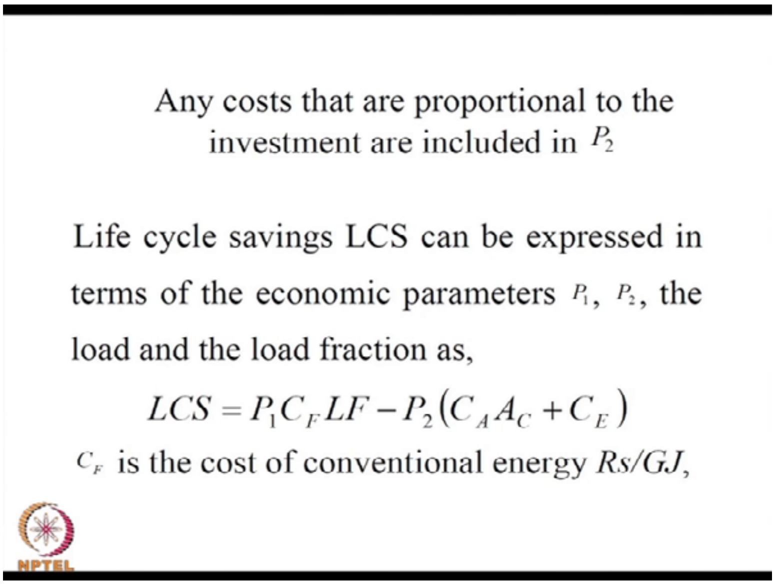

Then any cost that are proportional to the investment are included in p 2 to the investment are included. So, you may make a down payment of ten percent if the investment is larger the 10 percent will be larger, if the depreciation is more the final value will be less if the inflation of the system is higher, my final value will be higher; they are all included in p 2. So, life cycle savings is simply given by the parameter P 1 C f times load, and the load fraction F minus P 2 times C A A c plus C E. So, basically if you forget about P 1 and P 2, it is almost like that simplistic payback period calculation, life cycle savings will be the cost of the fuel in the first year multiplied by the load fraction to the solar load fraction, a load into the load fraction that will give you the energy level. So, this the amount of fuel money saved in the first year minus the cost of the system. And C F is the cost of the conventional energy, which could be R s bar giga joules.

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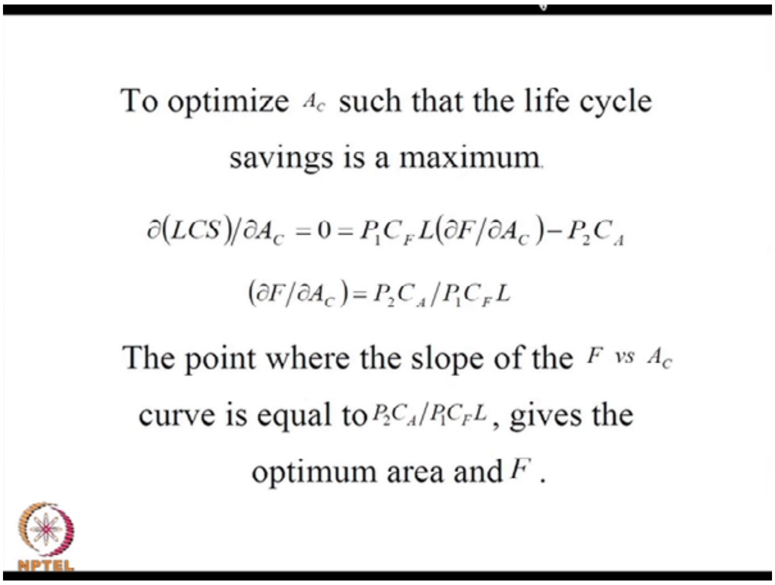

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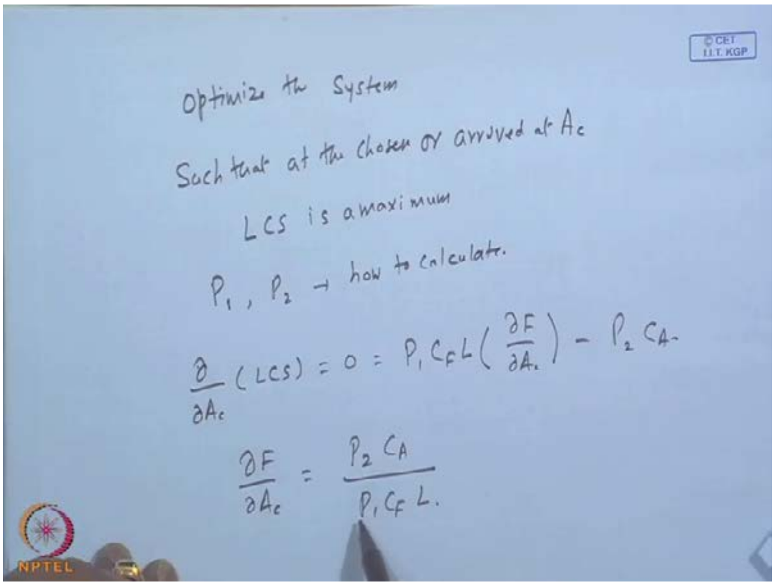

So, how do we optimize A c or system such that at the chosen or arrived at AC LCS is a maximum, you recall so far we have not said how to calculate p 1 and p 2. However sufficient indication is given that life cycle savings can be written in terms of p 1 and the cost of the fuel in the first year multiplied by the energy delivered in the first year minus the cost of the system multiplied by an appropriate factor right. So, this will be optimum will be delta by delta A c of LCS should be equal to 0 which will be P 1 C F L times d F by d A c minus P 2 C A right, because that is a A c that differentiate with respective to the area that goes of and the fix coast does not give anything. So, from this you can find out d F by d A c will be P 2 C A upon P 1 C F L. So, if the, slope of the solar load fraction with respect to area equal to P 2 C A upon P 1 C F L that point will represent either a maximum or minimum in the present context it will be maximum, one can easily verify that if you divide this rather, second differentiate it will be negative or just equal to 0.

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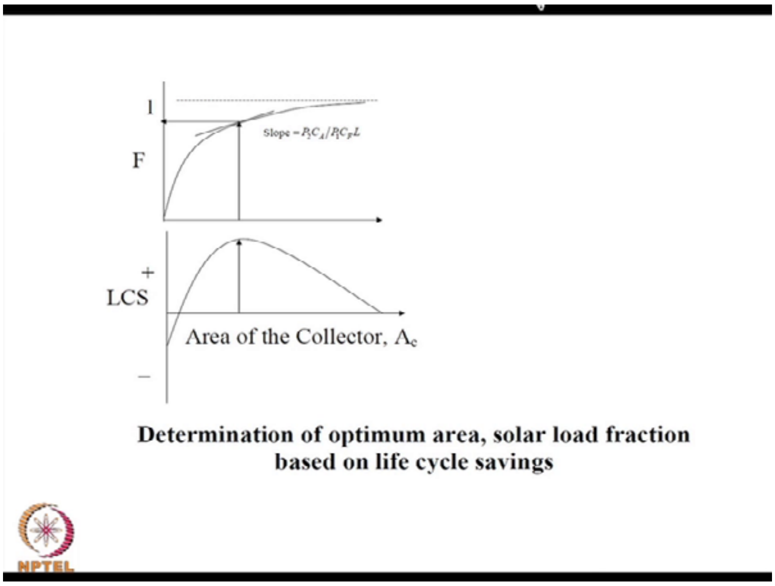

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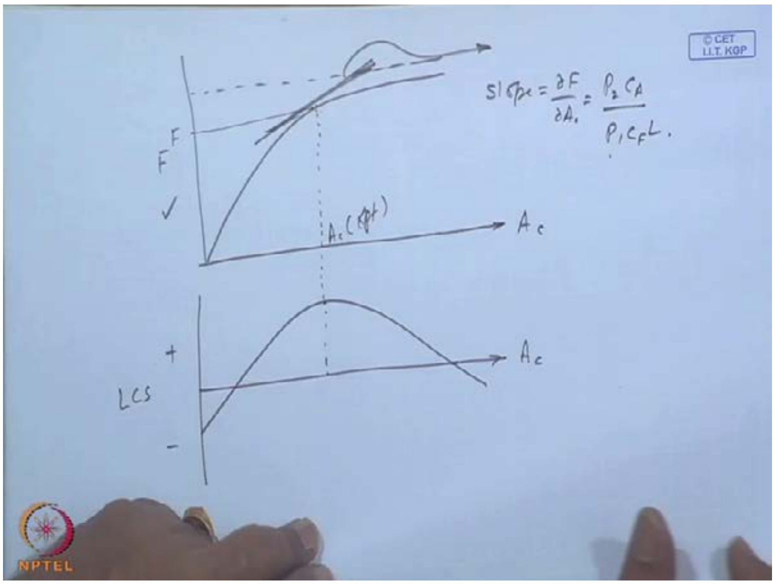

So, now we have briefly indicated about the life cycle savings curve, this is the area A c and this is LCS positive and negative, and this is area verses F, curve this should be a optimum that is where you have your LCS maximum. So, if you draw a line with slope equal to of course d F by d A C is P 2 C A by P 1 C F L. So, you know this number having calculated P 1 and P 2, C A is known, C F is known, L is known. So, you will find out this number and draw a line with the slope being equal to this number and where ever it cuts, of course I have drawn a little clearway just to be clear.

So, that is where my optimum F and A c lied. So, the area of analysis is that you find out that the life cycle saving is a maximum where your load fraction deliver need not be 100 percent, but the returns per rupee investment is the maximum. So, that is how now you understand the importance of the solar load fraction versus the area curve for the long term performance, that we have strangled through a large number of equation and methods to find out F versus A c curve That combined with the life cycle savings will yield what should be the optimum for the particular system or application under consideration.

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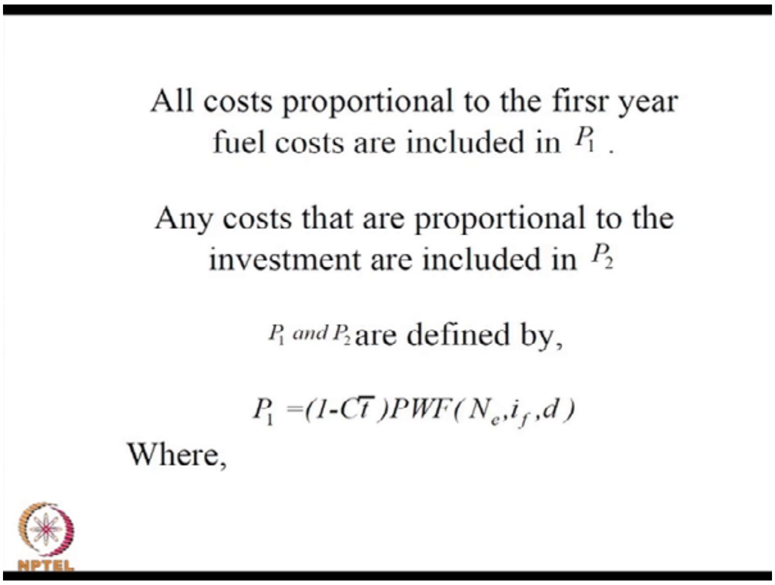

Now, let us try to have an idea of how to calculate this P 1 and P 2. So, this is a bit of economics and you just listen carefully and then you can go through these slides in detail, and then work out for yourself.

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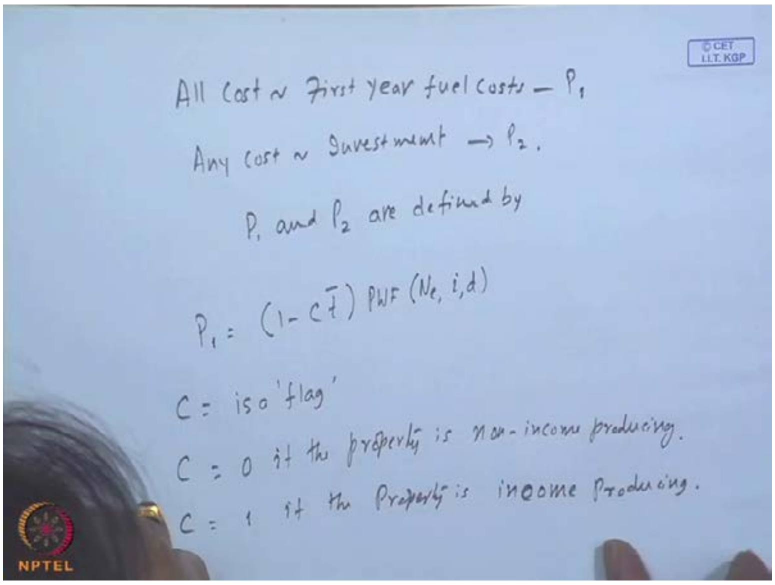

So, all cost proportional to the first year fuel cost are in P 1, and similarly any cost proportional to the investment is in P 2, and P 1 and P 2 are defined by P 1 is equal to one minus C t bar times PWF N e i d. Let me explain where C is a flag, C equal to 0; if the property is non income producing. In other words where distinguishing, even if it is solar energy hot water system, if it is used for domestically for bathing or cleaning dishes, its non income producing, but if it is used for degreasing or any automobile industry or any other industry. It will be considered as income producing, and C should be equal to one; if the property is income producing. In other words simply if C is equal to 0, it present worth factor of N e i d is nothing but P 1.

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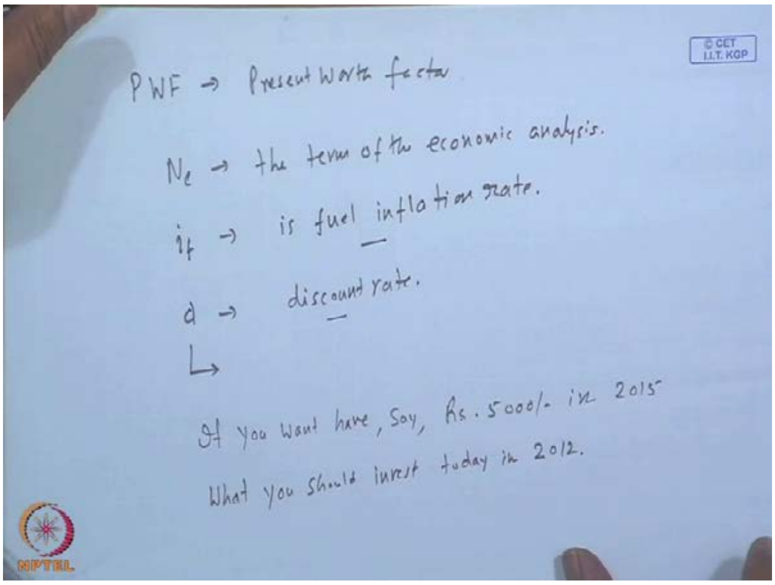

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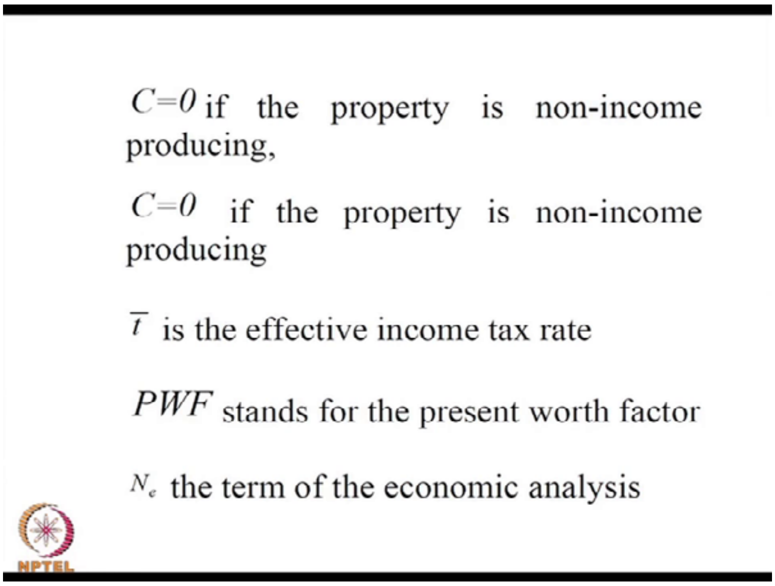

So, and of course PWF is a present worth factor which will depend upon N e the term of economical analysis, it may be 10 years, it may be 20 years, it may be 15 years or 5 years like that. It could be ideally the life of the solar energy system, but in case you are not sure you would like to see whether the life cycle savings are positive or not and when positive what is the minimum N e that could be required i f is the fuel inflation rate.

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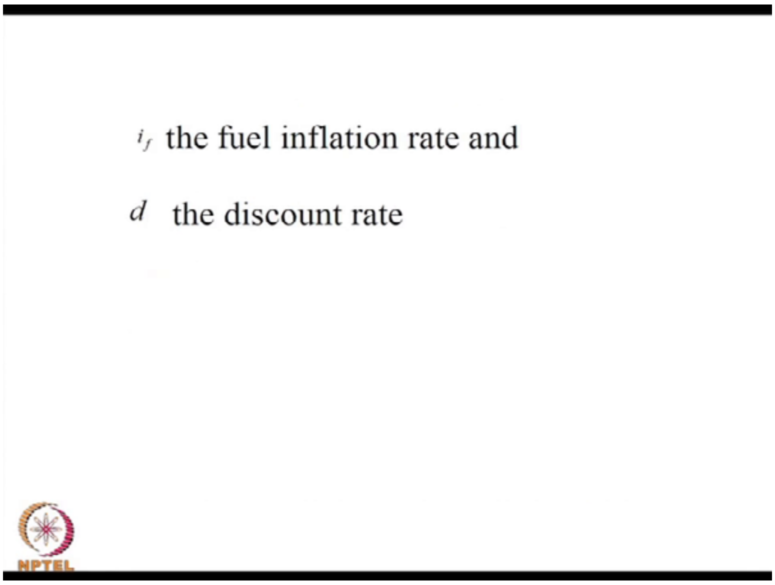

So, the fuel prices may be going up at the rate of 10 percent, 10.5 percent or whatever. So, you definitely the compare it to the first year fuel savings to the total fuel savings will depend up on what is i f? And d is the discount rate, this is a delicate thing to understand and one would think that i f equal to d, but i f in the context represent analysis is the fuel inflation rate; it is the inflation rate of the fuel only, not the overall inflation rate. This discount rate d is if you want to have say R s 5000 in two 2015 what you should invest in a bank or any where today, in let us say2012. So, you want to have 5000 rupees 3 years later from today.

So, there is 5000 rupees is discounted, and it become 3832 whenever is the number in 2012 terms of money. So, if there is a good chance that the inflation rate and the discount rate are equal, and in general it should be the same if you are talking about overall discount rate overall inflation rate, but since you are talking only about the fuel inflation and the discount rate in general. So, these things will differ in calculating your P 1 and P 2.

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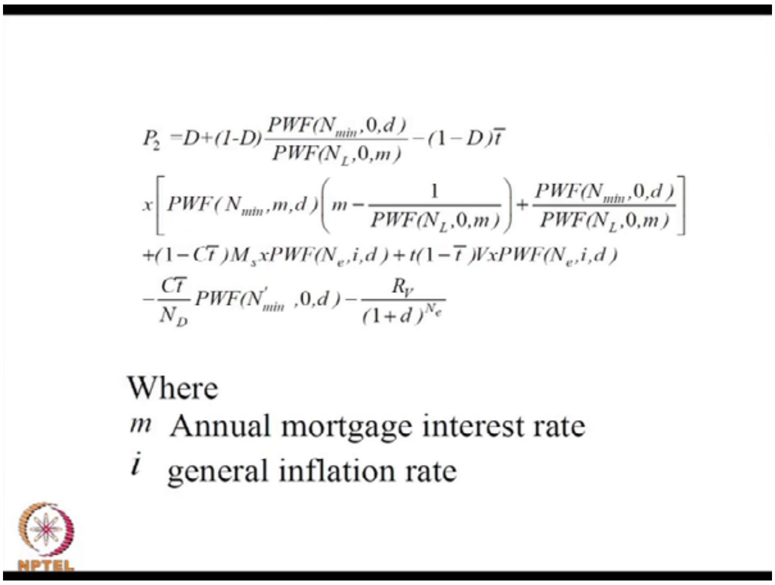

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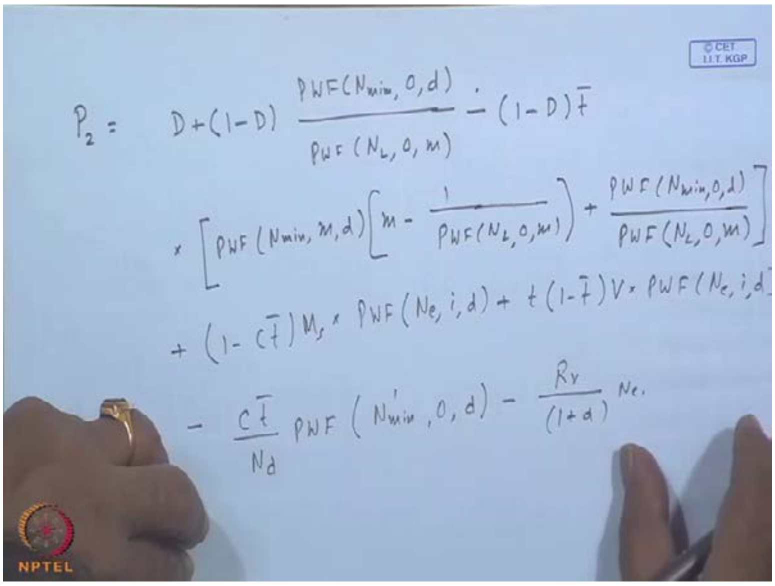

Now, P 2 you have a long expression. So, I think this should be focused a little longer D plus 1 minus D, and present work of N minimum 0 d upon present work of N L 0 m times, I am sorry minus 1 minus D into t bar, and this multiplied by present work of N minimum m d times m minus 1 by PWF of N L 0 m, you do not have to be scared about this long expression, because only thing that is dangerous is that present worth factor. Fortunately there are websites given that n minimum or whatever the next number, and the D it will calculate and tell you the present worth factor straight away.

So, of course I will give the formula too, but this looks like an enigma, because you do not know the economic term the present worth factor which simply means I mean if 1000 rupees are to be spent after 10 years what is the present worth of that plus 1 minus C t bar times M s into present worth factor of N e i d plus t not t bar 1 minus t bar times V into present worth factor of N e i common t minus C t bar. This I am writing I suppose you will able to see it from your screens while I am writing or the typed version N min dash or you can refer to Branbdmeuhl and Backman original paper which I have given the reference or the text book by Duffy and Backmen.

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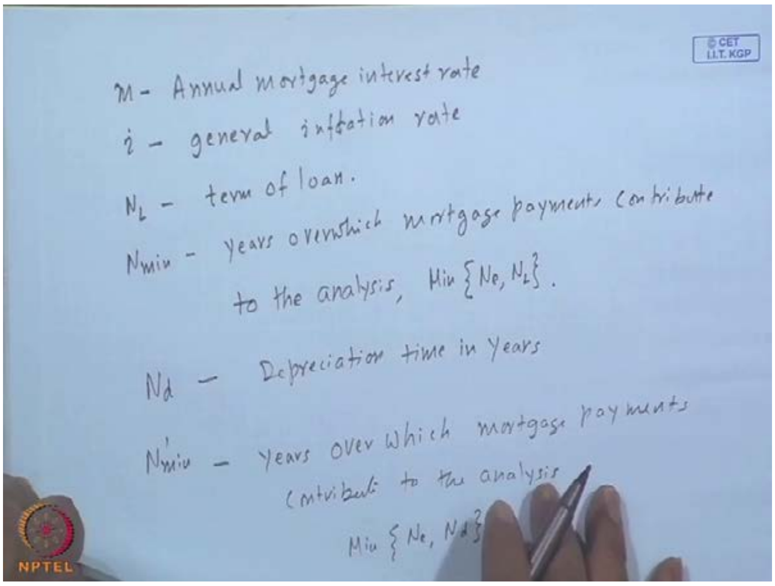

So, this is available and you make sure that the expression that you are using is correct, I am writing is correct. So, this is a lengthy expression and this symbol got a meaning has got a explanation m annual mortgage interest rate, these terms those who are not similar with lot of economics may sound unfamiliar, but you can easily go to Wikipedia and then try to have a understanding, because I my whole objective here is to say that that there are rational methods to evaluate the economic viability or rather than a hand waving approach two years.

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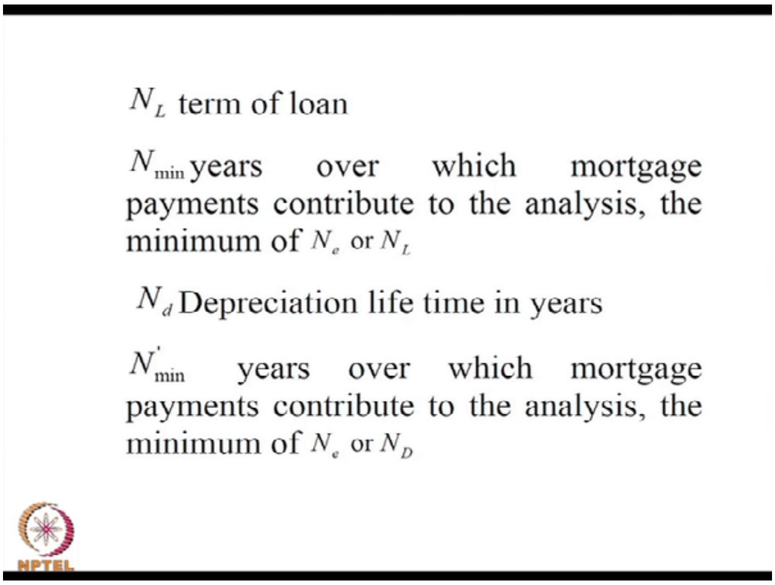

It is fine right instead of that you can actually calculate depending upon the economics scenario of the country the location depending upon the application. So, N L is the term of loan, N minimum years over which mortgage payments contribute to the analysis actually, it will give the minimum of N e N i right which we have already defined. N d is the depreciation time in years, then you also have a N min dash t right, yes that is the less, but one term in the previous expression years over which mortgage payments contribute to the analysis, this is minimum of N e or N d. So, it is N minimum and N minimum dash are the same in one expression use the minimum of N E or N L and in other expression minimum of N e or N d either deprecation or the economical depreciation or the term of flow; they all in principle can be different. So, if any terms should be the minimum N minimum will be equal to N minimum dash.

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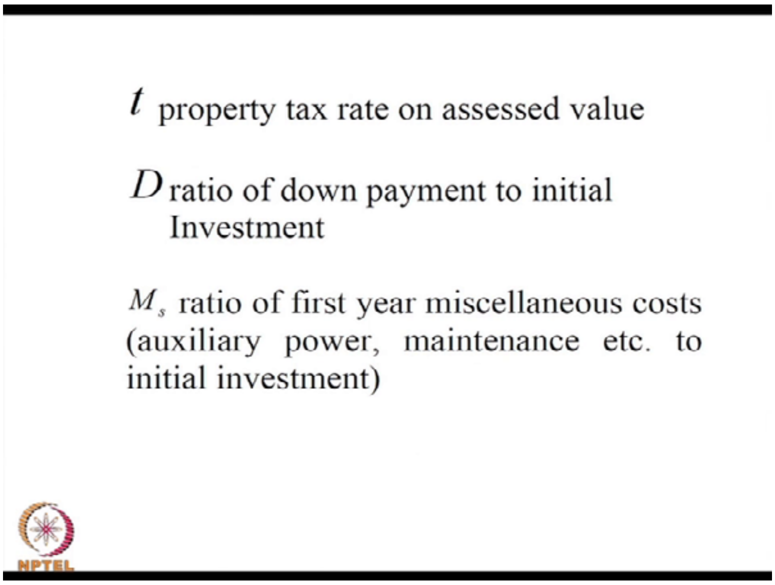

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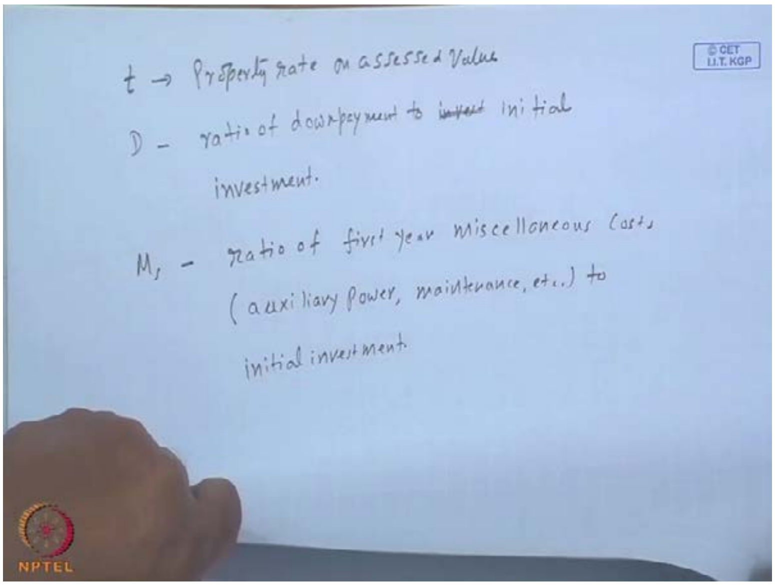

t is the property rate on assessed value, and D is the ratio of down payment initial investment So, somewhere this terms looks unfamiliar, because as students or as youngsters you may not be dealing, and some of them are even unfamiliar to me too until I tried to find out or suppose a house is going to cost about 32 lacks in India right. And then you may be paying through equalized monthly installments to the bank or to the whoever has given you the loan, but then there may be 10 percent on payment. So, you may pay 3.2 lakhs initially, and then the rest in terms of installments.

So, D is the ratio of down payment to the initial investment whether you have not whether or not you have really actually put in that money. So, in other words the commitment for the investment is so much out of which you paid certain percentage as the down payment; that is called the down payment. And M s is the ratio of first year miscellaneous cost, this could include auxiliary power, maintenance, etcetera to initial investment. So, this in a way is going to tell you out of 32 lacks or 40 lacks whatever you have invested on this solar energy system or in general anything, you need the ratio of the first year miscellaneous cost to initial investments. In other words if it is large property probably your first year cost will be also higher, and if it is a small property it will be less.

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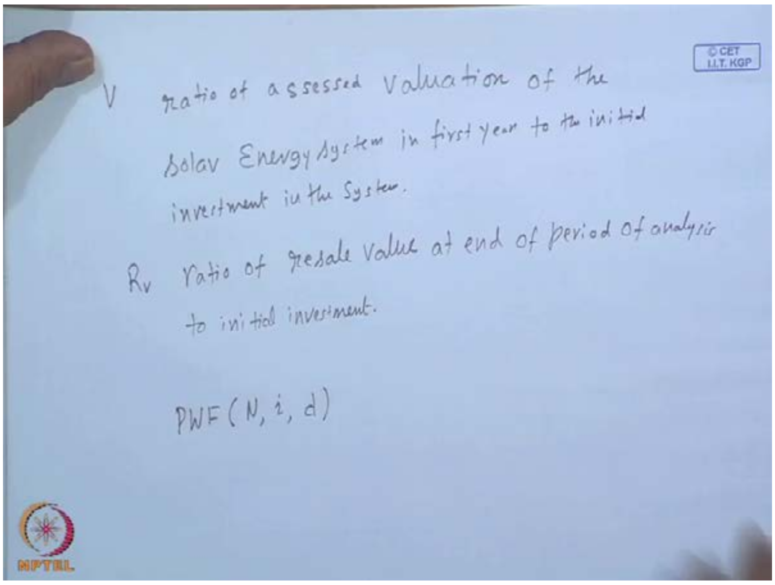

And the V is the ratio of assessed valuation of the solar energy system in first year to the initial investment in the system. So, assessed value (( )) solar energy system in first year to the initial investment in the system, you may not pay all the amount. So, there is the particular ratio. So, because that is going to the decide how many installment you will pay, how much you will pay or how many years and consequently your present worth factor etcetera, etcetera.

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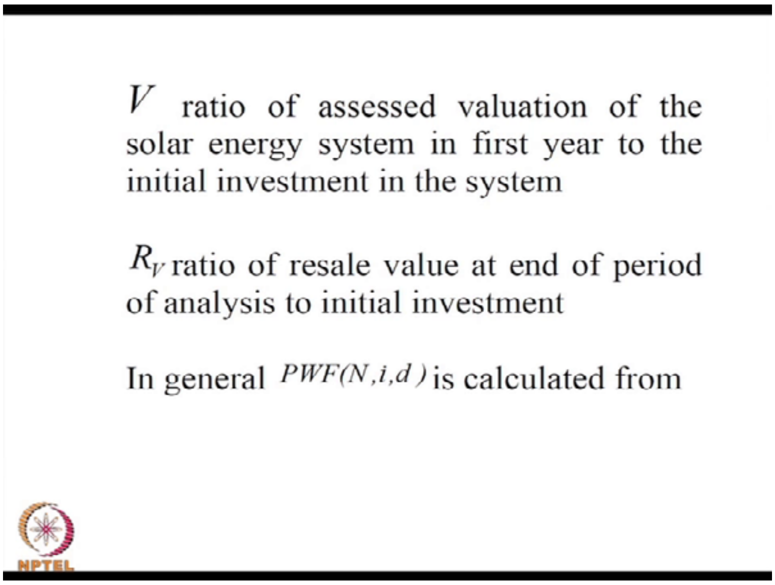

R v is the ratio of the resale value at end of period of analysis to initial investment. So, this could be a factor one less than one or even more than one its inflation is high. So, one has to find out, if the R v is higher it is a better system, in general the economic viability will become better and better.

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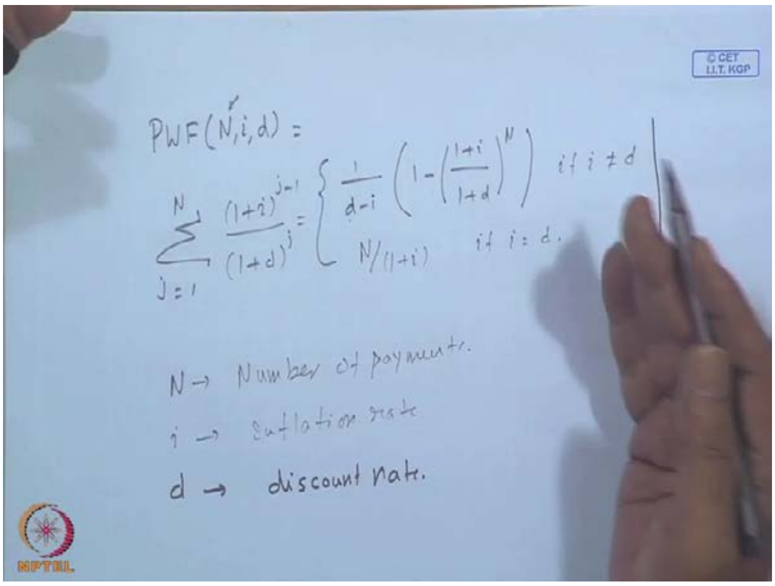

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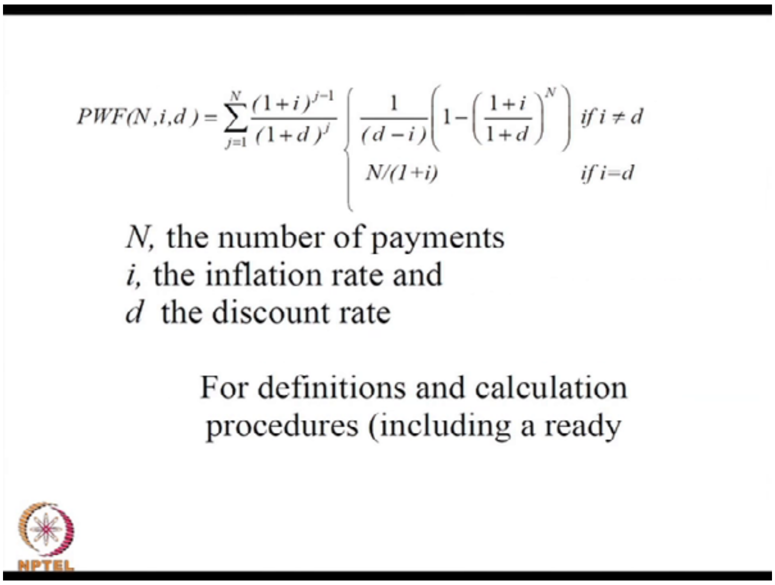

Now, in general present worth factor over a period, N which inflation rate i and a depreciation rate d right, it depends upon three parameters is calculated from sigma j is equal to 1 to N that is the total number of events 1 plus i to the power j minus 1 by 1 plus d to the power j times one by d minus i 1 minus 1 plus i by 1 plus d to the power N, if i is not equal to d. So, this should be equal to and simply N by 1 plus i if i is equal to d right.

So, if i equal to d, this will be d, this will be d j minus 1 by j it would be 1 by 1 plus d summed over 1 to N will be n by 1 plus i or 1 plus d. So, 1 by d minus i into 1 minus 1 plus i by 1 plus d to the power n that is the same thing which we are written in terms of n, and this is summed up over this period. N is the number of payments which may be your number of years of analysis, and i is the inflation rate and d the discount rate. So, as I was pointing out the inflation rate and discount rate could be similar similar order of magnitude at least that is bore not by the fact, that this present worth factor is given if i is equal to d is i is not equal to d. Now, I am sure still this terms will be little unfamiliar to you. So, you go through them a good number of times.

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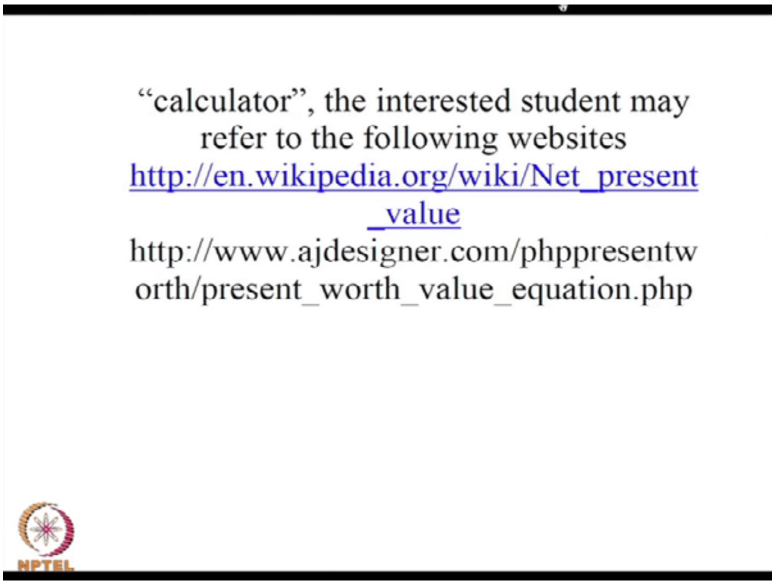

And you can see a very good references even in Wikipedia and another website ajdesigner dot com and where you have even the, so called calculators. Just you give i d n it will tell you your present worth factor or the quantity that you are looking for and then you make sure your calculation is correct.

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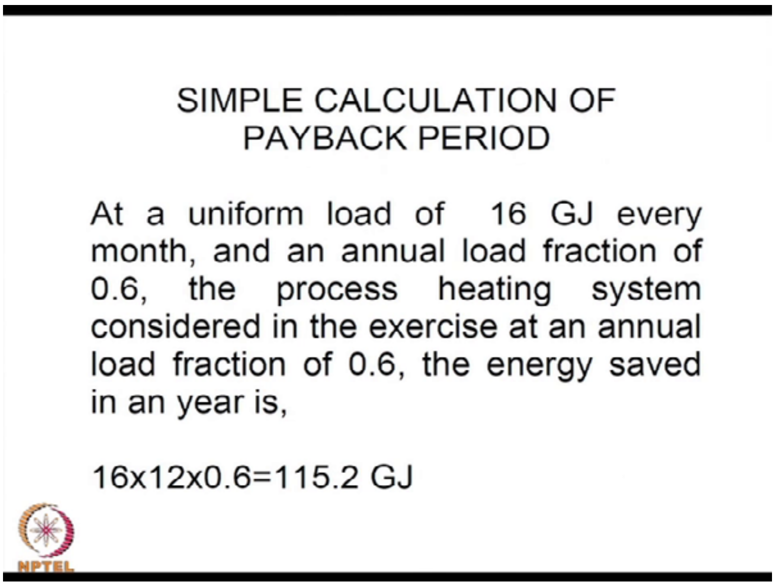

So, we made that simple payback period calculation in the last class, and however I was not very happy with that coal having a payback period some 37 years are so, and then I realize that the prices at the pit head of the coal mine as per the website of the coal India.

So, consequently considerable transportation cost is a is involved, and I enquired locally and the rate change a quite a bit. So, I thought let me compare the coal LPG and the electricity relatively by the simplest method of this one.

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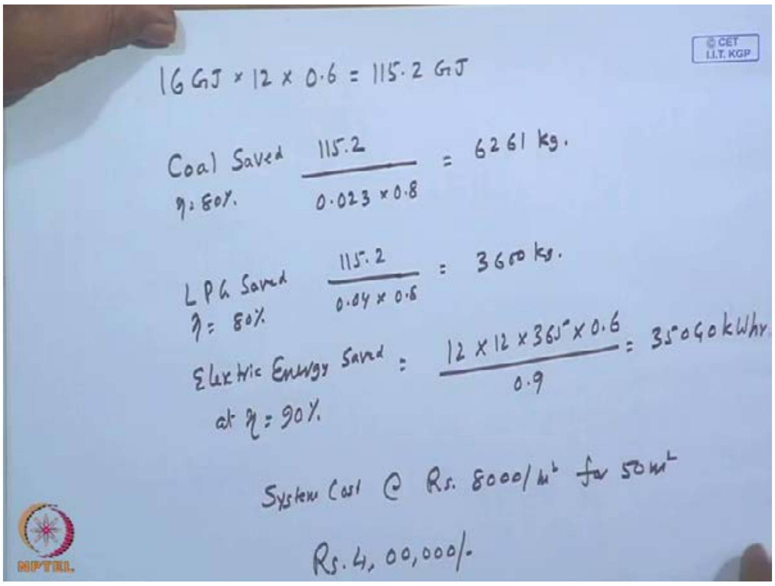

So, the first year savings at the rate of 16 giga joules per month for 12 months at a solar load fraction of 0.6 will turn out to be 115.2 giga joules; these are consistent numbers. So, only thing is I am doing it only for one year. So, that my payback period is the total upon one year cost or savings.

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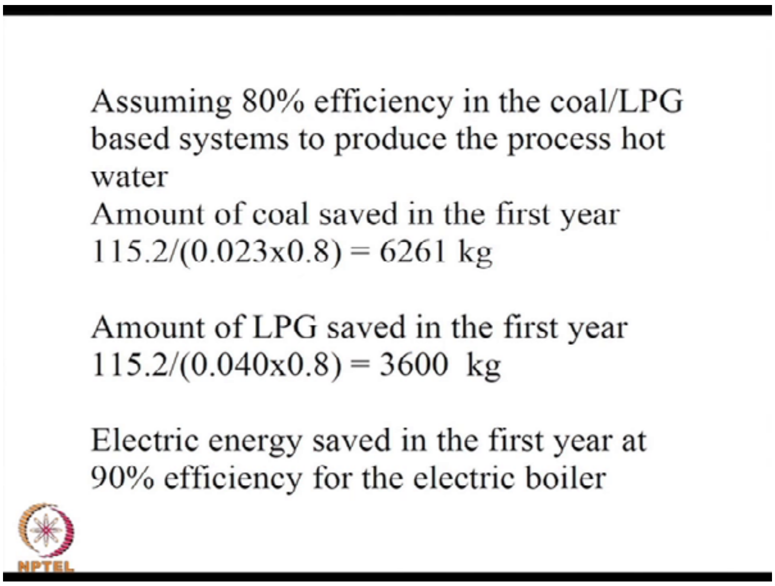

And if your assume a 80 percent efficiencies for both LPGH and coal based system; coal saved 115.2 by the calarific value in giga joules 0.023 into the efficiency which is 80 percent; that will be 6261 kilo grams. And LPG saved will be 115.2 upon 0.04 giga joules; that is the calarific value multiplied by 0.8, the efficiency will be 3600 kilo grams.

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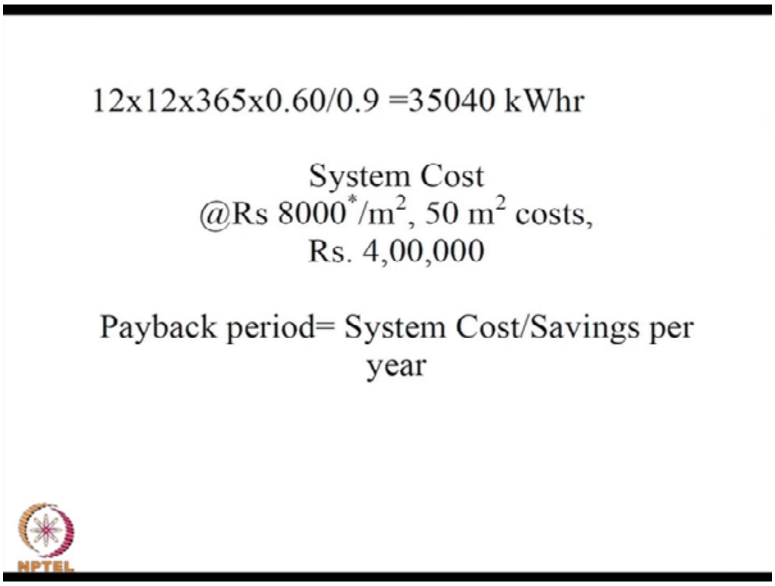

Electric energy is saved, so if equal to 80 percent in those two cases at this should be little higher which should be equal to it is 12 kilo watts for 12 hours a day multiplied by 365 multiplied by the solar worth fraction 0.6 by efficiency 0.9 this will be equal to 35040 kilo watt hours. And we already estimated system cost at R s 8000 per meter square for 50 square meters will be Rs 4 lakhs.

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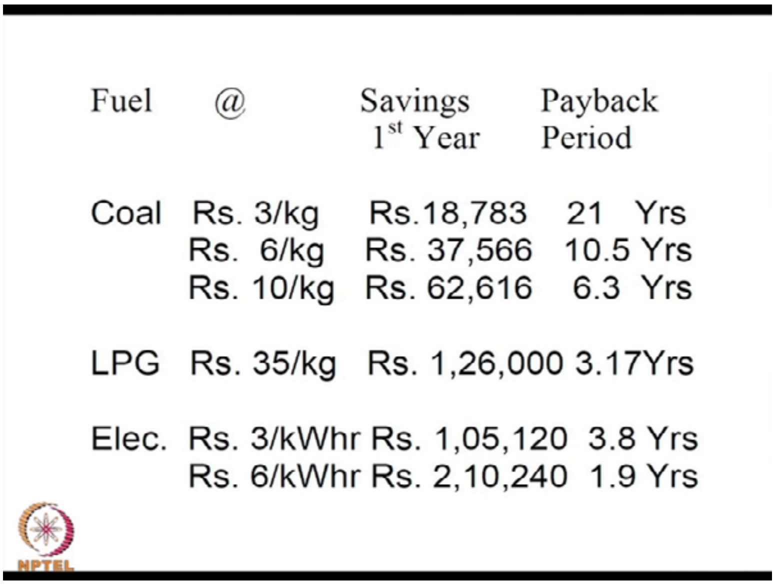

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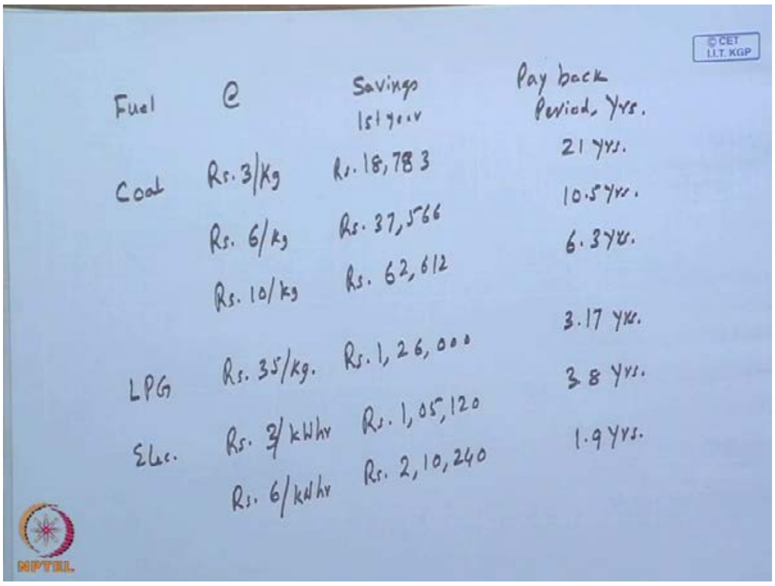

So, in a simple form of table, I have shown here all the fuel and at the rate of saving first year and payback period in years. So, first one is coal at 1.1 rupees 70 paisa is too lower value 3 per k g, this comes to about R s 18783 leading to 21 years, and at R s 6 per k g this comes to double 37566 this becomes half 10.5 years, and R s 10 a kg which will be R s 62616 leading to 6.3 years. These are not cooked up numbers and I have locally verified that the coal just house hold coal is sold at about rupees 10 per k g. So, 6.3 years still it is a large time, if you compare with a coal this is about 450 rupees, of course there is recent hike for first 600 and the next seventh and onwards I do not know whether it will be the sixth one or the subsequent one. So, I took 35 rupees a k g and this will come to R s 1 lakh 22 thousand 0 0 0, and this comes to 3.17 years quite reasonable. Electricity this is where we had little bit of confusion, so if you take at the lowest spectrum rupees three per kilo watt hour this comes to R s 105, 120; that comes to 3.8 years and if you take in the domestic bills I have verified it varies from 2.752 rupees 75 paisa to 7 rupees also depending upon the block.

And if somebody is using a electric geyser we will definitely be in that higher range, this comes to 1.9 years; the numbers I do not say they are unimportant, but what we are trying to essentially imply is that the viability of the solar energy system will depended upon with what source of energy you are comparing. Right and if you go to wood charcoal or the wood picked up by in India the poor people who sale it may be at rupee k g or even less then if you compare that heating or with any solar or electrical that will be highly looks uneconomical, but this seems to be, and these are definitely with respect to electricity should be somewhere in between even LPG three years.

So, again I am assuming inflation and depreciation this cost may cancel each other and this is a fairly indicative of the actual accrued savings or the payback period. So, we shall consider the other important things having done this economic analysis in our curriculum we have got the passes system, that is what we shall doing next lecture.

Thank you.