Energy Conservation and Waste Heat Recovery
Prof. Anandaroop Bhattacharya
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur

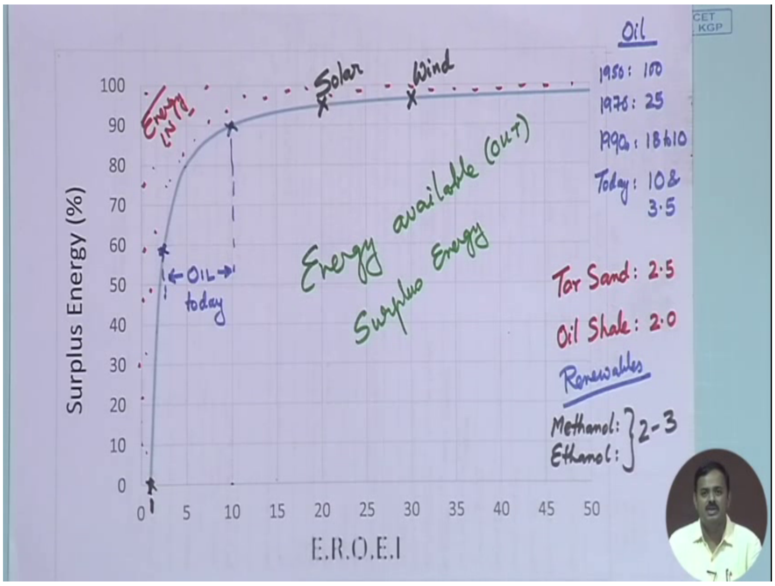
Lecture – 63
Energy Economics – II

Good morning and welcome back to the next lecture of Energy Conservation and Waste Heat Recovery. What we will do today is we will continue our discussion on energy economics.

So, in the last class if you recall we were looking at the metric called EROEI, energy returned on energy invested which is a ratio or which gives or which denotes the surplus energy that we have which is available to us for use. And the reason why this is important is as we said part of the energy that we generated is used up for generating that energy itself.

So, EROEI is a ratio of the energy that we have to spend sorry that the energy that is available to us over the energy that we have to spend to get that energy out, to get that available energy out.

(Refer Slide Time: 01:18)



So, this is what we are talking about the net energy and we looked at this curve and what we said was this curve denoted ERUI or EROEI and on the x axis and surplus energy on the y axis. And we say that the oil if we look historically in 1950s we could get one barrel we compared to spend 1 barrel of oil to get 100 barrels of oil.

So, the surplus energy that was available to us was 99 percent if 100 barrels of oil was available to us then only one barrel out of that was spent to get that 100 barrel out. But today what happened was oil wells have become we have to go deep we have to dig deep the oil fields a larger and we have to use much more sophisticated and huge enormous machineries in order as or enormous test rigs to drill that oil out and so today the ratio or lies between 10 and 3.5 depending on the location and so on

So, that is that is the story of oil what about some of the other things all right. So, we talked about tar sand tar sand, let us talk about oil shale. So, tar sand is around 2.5 oil shale is around also 2, lower than this, 2 would be somewhere here we are all now an energy cliff for both of these, all right.

So, why is this because we have to spend a lot more energy to get these sources of energy out of let us say these shale oil out of the shales or the rocks. What about renewable? For renewables let me write down some of these numbers let us talk about methanol, ethanol. So, these are all in the range of 2 to 3. If we talk about wind or solar they are high, this is for example, this is where wind is around 30, solar again depends it is a range, but if I have to these are again ballpark numbers if I have to point solar I would again point it around here.

So, the cost of getting this energy this is how where it stands nuclear I think the jury is still out it is not easy to put a put a point on this curve because especially because nuclear if you have to I mean at the end of the light the decommissioning costs of a nuclear plant is huge. So, how much will it all turn out to be if we add that cost as part of energy in then the jury is still out. So, we do not know that. So, this is where we are all right.

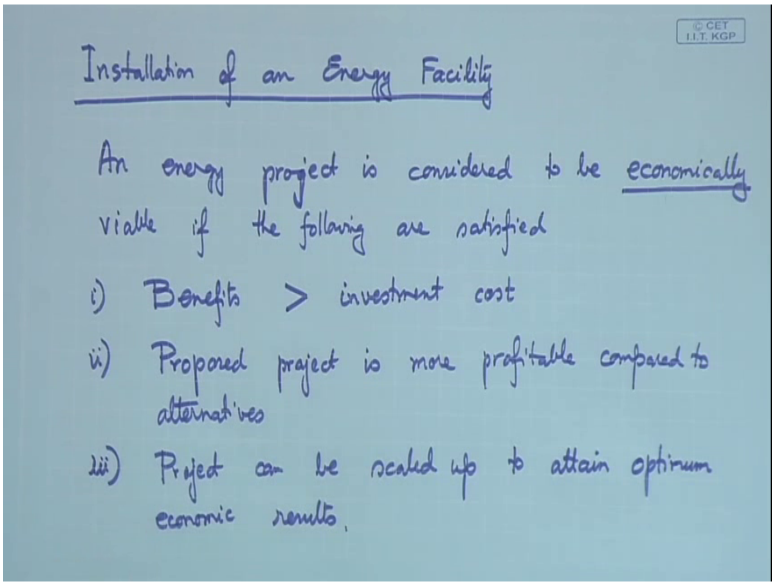
So, again what I am trying to say is the point I am trying to make from here is the fact that the surplus energy is what the matters is the surplus energy the amount that is available below this curve which is going to drive the growth of an economy, growth of the economy of a nation all right. By the way on this curve if you ask me where is hydrogen remember we studied hydrogen economy in the last and before studying energy economics. Hydrogen does not even form here its 0, why because there is no source of hydrogen all right.

So, hydrogen definitely 0 and the rest of it as I have shown here, oil we are towards energy cliff solar and wind they are good propositions as part of renewables, but if we talk about bio methanol, ethanol etcetera they are also not very attractive definitely more than 1, but not attractive we are still in the energy cliff all right.

So, that kind of wraps up our discussion on the energy economics and how energy and economic, energy drives economic growth all right. So, the socio economic growth of a nation if you look at it energy plays a vital role in that all right. So, if that is the case let us move on and talk about some energy economics and some other parameters. So, remember we talked about EROEI as one of the metrics of energy economics. What we will go next is if you think about installation of an energy plant what is it that we are going to talk about.

When are when is it that we are going to say that the energy installation is viable, let us look at that.

(Refer Slide Time: 06:45)



So, I would say installation of an energy facility. So, what is it that I am going to talk about? So, I would say an energy project sorry is considered to be economically viable. So, here now we are talking about economics of an energy installation this is no longer about how energy impacts economy, but it is about economics of an energy installation. This is how we made that transition from through EROEI which are talked about how surplus energy drives the nation, but which also talks about if a source of energy and uninstall, if you look at a source of energy while largely whether it is makes economic sense whether it is economically viable. So, from that we now come into economic viability of an energy project.

So, this is going to be economically viable if the following are satisfied and what are those? The first I would says benefits is larger than investment cost, this has to be and this is kind of we already saw that as when we talked about net energy, energy out over energy in.

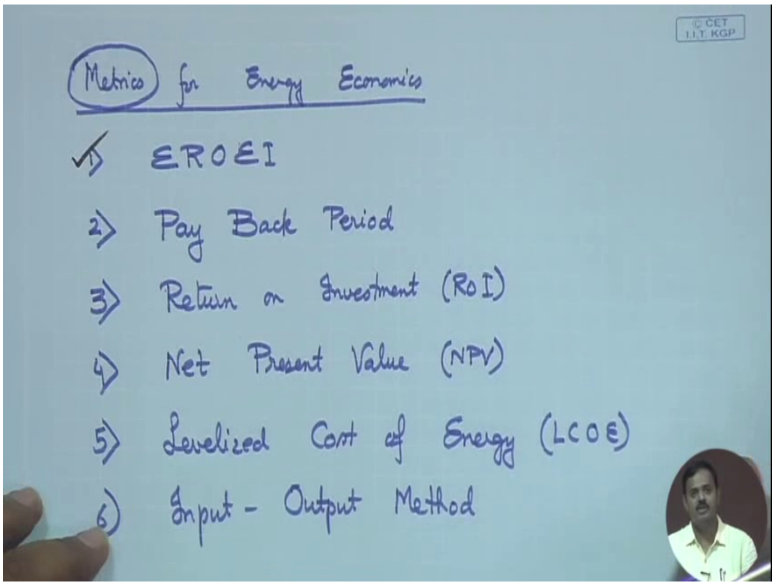
Now, but what we talked about benefits is also something it is not just about the energy which is definitely the major portion major part, but there are other metrics also which we are going to talk about all right.

Second what? Proposed project is more profitable compared to alternatives, this is true for any business proposition not just energy. If because let us say I am going to start a business or an start a business on energy and I have to go and get funding I have to convince my investor that what I am proposing will turn out to be more profitable and profitable is not just about money or it, but it may be about benefits also which you know kind of indirectly does have a monetary value attached to it. So, it is more profitable compared to alternatives has to be right, we have to pick the best alternative. If somebody is, but if some other alternative is better we better we should invest in that and not something which is inferior.

Number 3, project can be scaled up to attain optimum economic results all right. So, for example, what I am trying to say here is if I talk about any energy installation, I will first set up what we call pilot plants which are small scale plants just to show that you know this is actually possible this is this is technologically feasible this is economically feasible and we actually generate energy out of the source that we are talking about.

But finally, I also have to come up with a proposition where we say that yes I am going to show you a proof of concept let us say for 100 kilo watts plant, but what I am doing can be scaled up to give me several megawatts right. So, for example, if I set up an oversea based plant for waste heat recovery and my pilot may be a 20 kilo watt plant and that that may run wonderfully well, but finally 20 kilo watts is what? It is a very small amount of energy that is available, small amount of power that is available. That technology that I am trying to show to be viable through this pilot plant should be scalable if successful I should be able to scale it up to give me at least 10 times that amount of power then it becomes attractive, then I can say you can you know you can run this small factory using just the waste heat recovery. So, that is what I mean that the project should be able to be to scale up the project so that the optimum economic results are attainable, all right.

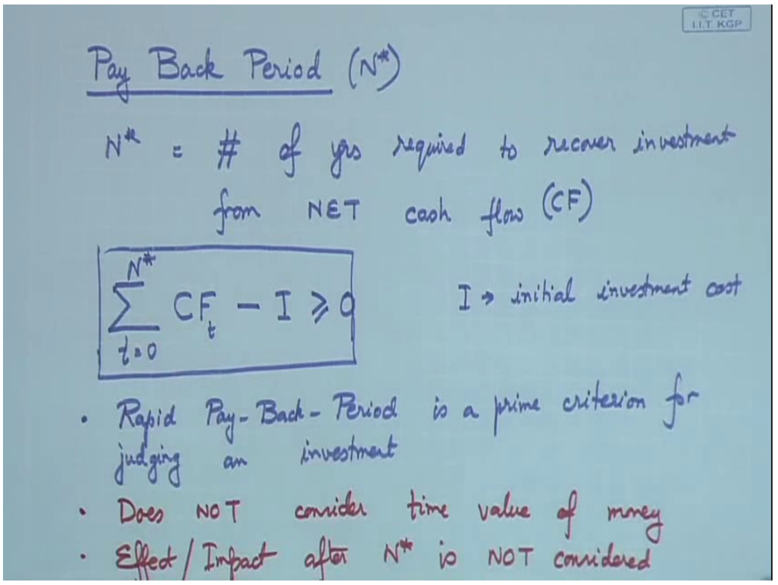
(Refer Slide Time: 12:20)



So, now we are going to talk about a few metrics. So, let us talk about metrics for energy economics. Let me first list them one by one. So, the first one was we have already EROEI and I am not going to talk about that this is already done. Let me write down a few more things and then we will talk about it, we will talk about payback period, we are going to talk about return on investment or ROI, we are talking about something called net present value or NPV, we are going to talk about something called levelized cost of energy or LCOE and finally, we are going to talk about something called input output method.

So, these are some of the metrics that we are going to talk about. So, EROEI is something that we have already spoken about let us talk about payback period we will take we will keep coming back to this list and take each of them one by one. So, payback period is the first one and let us see what that is.

(Refer Slide Time: 14:15)



So, payback period that is denoted by N star, what is it? I would say N star is the number of years typically it is expressed in terms of years for small installations I mean in terms of energy installation it will be it will typically be in years. But again remember these are all generic economic terms also. So, sometimes payback is also given in terms of months and so on all right.

So, number of years required to recover investment from net cash flow and cash flow means cash inflow. What do I mean by this? Once my plant is up and running and let us I am producing electricity, I am going to stay sell that electricity to the state electricity board or wherever and at a certain cost and that is how I am generating revenue right.

Now, in order to set up this plant maybe I have spent money, maybe I spent 100 crores of rupees indian rupees. Now every year I generate so many gigawatt hour of electricity and I sell it to the electricity board and I probably make money let us say 5 crores every year or maybe 10 crores every year. But however, I also have to keep that plant running in order to run that plant I have to maintain the equipment, I have to employ people and pay their salaries, I have to pay taxes on the earnings that I am getting and lot of other things. So, once I remove all these expenses which are regular expenses that incurred and you will operating for operation and maintenance and taxes what I am left with is the net cash flow right.

Again it is like savings I get a salary, I pay part of it as tax, then I pay part of it to you know to pay my bills to pay my fees for my children and for my food for my living and all these family expenses and so on and then at the end of the month what I mean what I am left with if any is my savings. So, that my net cash flow that I have.

So, that is the net cash flow over here which is the total revenue that I generate minus the operating expenses and that net cash flow will be some amount let us say out of 10 crores what I am left with is about 7 crores and I have invested 100 crores to set up the plant. So, therefore, it is going to take me 7 7 7 7; I keep on doing that and finally, it is going to take me a little more than 14 years to recover the 100 crores that I had invested to set up the plant. So, that is like what do we call the payback period.

So, therefore, I can write this way that sigma t equals to 0 to N star and I would say CF and this I would write it as CF of t minus initial investment must be greater than equal to 0, where I is initial investment cost clear. So, this is one way of defining payback period N star, right.

So, now if you think about it if I am an investor if I put money in a business and I am getting share I would write to have a rapid payback period, I would like N star to be as small as possible. So, rapid payback period is one of the trying criteria for judging an investment. So, let me write down rapid payback period is a prime criterion for judging an investment.

So, the example that we gave that 100 crores and 10 crores of total cash inflow every year minus expenses etcetera and the net cash flow, net payback the payback period we calculated was 15 years a little more than 14 years. 15 years may not be very attractive to an investor he said oh I have to wait for 15 years from today to get back that money oh I am not very attractive. However, if you say its 5 years then it will. So, that is a good amount that is a good way I put in money and get it back in 5 years and after 5 years whatever I get is my profit. I have already covered my cost in 5 years. So, it is important and you know an impatient investor would like to have a very rapid payback period.

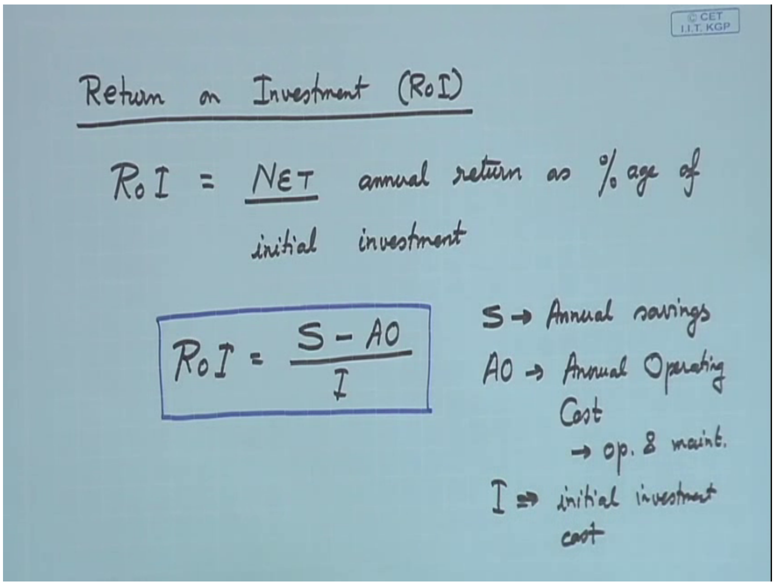
Now, what are the drawbacks of payback period? One of the drawbacks of payback period the way we have calculated is it does not consider time value of money and also I would say effect impact after N star is not considered.

So, payback period only deals with cash flow till the payback period after that what happens, it does not it is not considered it is payback period is defined that way, but more importantly does not consider the time value of money. So, again the 10 crore that I get in the first year versus 10 crore that I get after ten years is not of the same value, 10 crores after 10 years is worth much less today.

So, therefore, that time value of money that the many money d values over time that is not considered in this definition of payback period it just sums up the total net cash flows over the years and the moment it equals or exceeds the first time it equals or exceeds the initial investment cost we said that is the payback period. So, that is the drawback. But nevertheless it is a very quick way of it is of it is a very quick criterion and probably a very important criterion when we judge an energy investment or any business proposition for that matter.

So, therefore, that brings me to the next thing. Next metric what did we talk about? So, payback period now we have discussed return on investment clear, so this is what we are going to talk about now.

(Refer Slide Time: 22:45)



So, return on investment or ROI for a banking I ROI may also mean rate of interest, but here ROI is return on investment we are not really talking about banking here we are talking about energy projects where we are putting in money, so that is the investment and what I get out of that of the production of that energy plant or energy installation is the return.

So, ROI is again the net annual return as a percent or fraction of initial investment. So, again I would define it first as ROI I would write it as S minus AO over I and I will tell you what all these means. So, what is S? S is annual savings, if you are talking about energy its annual savings in terms of let us say fuel, I was producing some energy and consuming some amount of fuel and by this new method I am consuming producing the same amount of energy consuming much lesser fuel. So, that is my annual savings.

What is AO? I would say that is the annual operating cost and this will include operation and maintenance O and M, it may include taxes that you pay and so on. And what is I? This we have already said is initial investment cost clear. So, this is ROI right.

So, now if I look at this and try to relate the payback period. So, what happens? When s minus a o over a period N over a period N becomes equal to I or just greater than I that N is or N star that N star is my payback period. So, payback period and ROI are actually related, clear. It is just another way of looking at it, right.

So, let us take an example again from real life I am trying to show what is ROI and what is payback period completely different from energy. Let us say we stain an apartment complex and which is guarded by a certain number of security personnel all right. And I say that I am going to for added security and safety I will install CCTV cameras everywhere or let us even think about roads the roads in the city today where we are installing CCTV cameras and the CCTV cameras does help in tracking traffic violations, in tracking accidents and so on right

But to install the CCTV cameras everywhere I would have certain amount of investment that I have to the certain amount of money that I have to put. So, that is my initial cost. But then I say that you know if you put these see this cameras then in my apartment complex for example, I can reduce the number of security guards by two right or in case of a city I can really reduce the number of traffic police men who are you know stationed at different corners and trying to catch people give them these fines etcetera, I can reduce those number I can put them to good use elsewhere. And have the CCTV cameras record those violations take pictures of the number place and then we send someone’s to those people based on the records that we recovered from the number of plates.

So, of course, there is an initial investment cost in terms of installing these cameras in terms of wiring, in terms of the recording device, in terms of someone to operate that, but the savings is in terms of lesser number of personnel that I have to deploy. So, then you can say that for example, the apartment complex it cost me 20 lakhs to puts a CCTV cameras everywhere, but that would let me allow me to reduce 3 security guards and the combined salary of both any of the 3 of them annually is let us say 4 lakhs.

So, then I can say that you know my return on investment right away is 4 lakhs and my payback period therefore, is 5 years because I have spent as my initial investment I had spent 20 lakhs. So, therefore, my return on investment is 5 years. Again keep in mind that I am just talking about the salary that I am saving, but of course, there is some additional cost in maintenance of these cameras, in servicing of this cameras and so on. So, which I am saying that I am saving 4 lakhs every year after deducting those from the I mean that is my net savings or 4 lakhs. So, the secured salary of the security guards minus the operating cost is 4 lakhs.

So, that is an example from real life for energy installation also is the same. For example, in a village where there is no electricity today. So, we are using diesel generator sets. So, diesel gen sets the cost of producing that electricity is very high almost three times the amount that we pay from the that that we pay for our electricity bills that we get from the grid.

So, therefore, now if I bring electricity to that village what is happening? Of course, bring that electricity there will be a huge capital expenditure involved, initial investment is high and somebody has to pay for it. But then I am not going to use diesel anymore, but instead I am going to generate that electricity in a captive power plant which is going to light up that village and therefore, that diesel cost is gone I am going to produce electricity at probably half or one third the cost and, over a period of time I am going to recover that initial investment and after that whatever is the cost differential will be my savings right.

So, with that we will come to the end of this lecture. So, today what we did was we wrapped up our discussion on energy recovery on energy invested EROEI and then we talked about two other metrics one is the payback period and the second one is return on investment. In the next class we will start our discussion on a third metric which is called or rather a fourth metric which is called the net present value.

Thank you very much.