Energy Resources, Economics, and Sustainability

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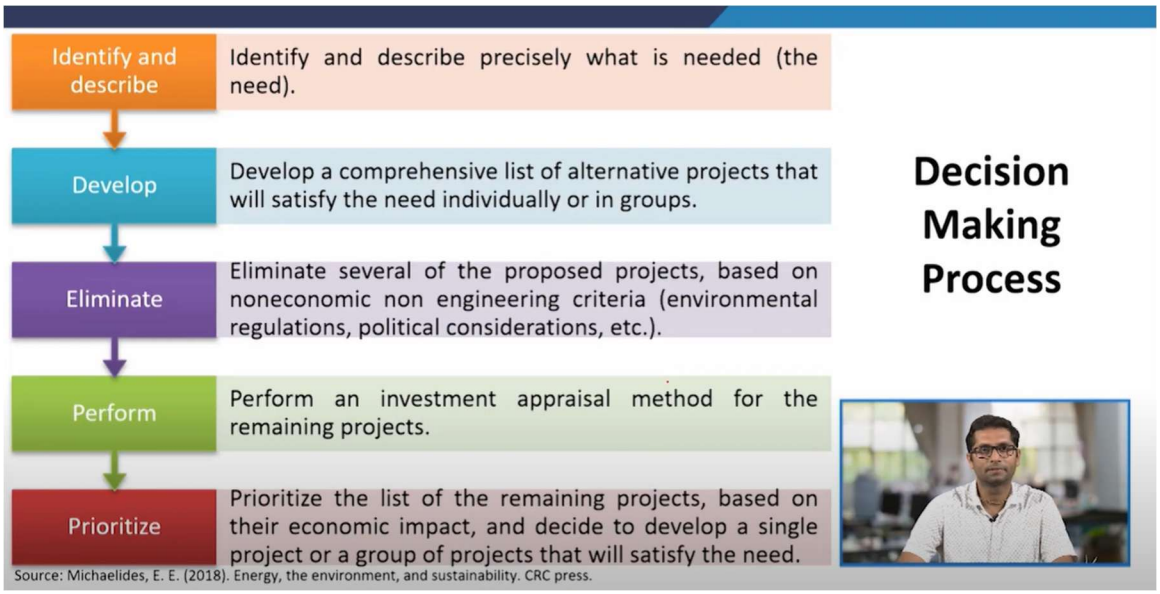
Week – 03

Lecture – 03

Lecture 13 - Energy Economics-III

Hello everyone, welcome back to the lecture of the course energy economics, energy resources, economics and sustainability. For the past two classes, we have been discussing the basics of energy economics. We have tried to understand the different basic terms, what it means and we also tried to understand some of the applications with a few simple questions. So when we are talking about energy economics, one thing that comes to our mind is the decision making. So normally when we are dealing with energy scenarios, it comes into being we have a lot of options which could be made or which could be used for achieving a particular goal, how to evaluate those purposes and one of the basic methodology that is adopted is evaluate them on the basis of economics. So in this class, we will try to understand how can different methodologies be used for evaluating the different purposes. But first let us try to focus on the decision making process itself. So decision making process, any decision making process for that matter would have these five steps. The first thing is we would want to identify and describe the problem.



It needs to be described as precisely as possible. One particular problem would be like the city of Roorkee would need 100 megawatt of more electricity in the future. Then you develop a list of comprehensive alternatives that could be used to fulfill that need. It could be you can come up with a new 100 megawatt coal fired power plant. You could look for an alternative location for a hydel power plant, maybe 100 megawatt of solar PV plant or it could also go as like why not we go for reducing the consumption of the city so that there is no need for extra power.

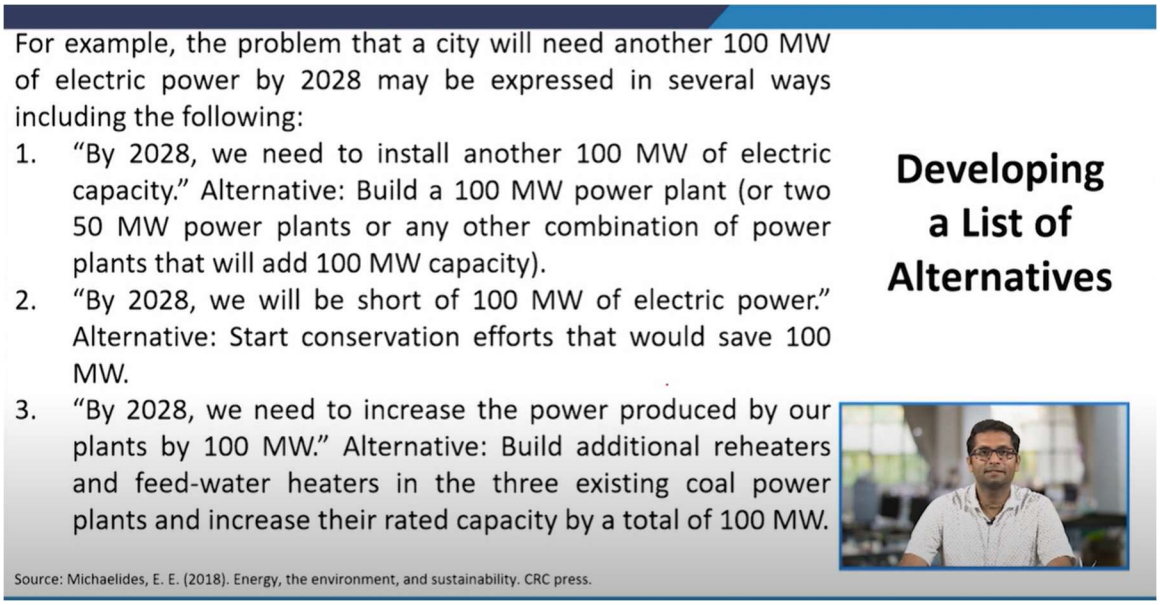
Then as we move further, we would want to eliminate some of the choices. This elimination could be on the basis of different kinds of like different decisions. Environmental could be one. We don't want a nuclear power plant to be set up. There is an advocacy group who is not in favor of setting up a nuclear power plant.

So that plant is ruled out. There might be environmental regulations like there are many migratory birds that come in the city of Roorkee and they might possible wind power plant would cause harm to those birds. So in that case, a wind power plant is also ruled out. There might be other advocacy groups who would not want the expansion of a hydro based system. There could be other political considerations that come into being.

So the third step is basically eliminating the options which might have hurdles as we move further and this is normally based on the previous experience with similar plants. Then you need to perform an investment appraisal method. This is where you would have the different economic tools coming into being. So once you know like these are the possible alternates that could be used or that could be there to meet a particular goal, you would want to evaluate them purely on the terms of economics. You don't pay any heed to the environmental regulations or other kinds of barriers as of now. That was done in the previous step.

What you do now is basically do an economic analysis and see which is the particular pathway that is going to give you the most benefit or the most profit based on the assumptions that you are considering. And then finally you prioritize like if there are different kinds of plants which are competing, there might be mutually exclusive options or there might be complementary options and you prioritize based upon the capital that is available and the manpower that is available. If you have enough capital, you would want

to go for more than one option being together. And then there might be some kinds of bottlenecks in terms of the expertise that is available for the running and the operation of a plant. This could be both in terms of the manpower available or the resources that are needed. One particular example that we can see in the past is like India spent a lot of money in the setting up of gas power plants. But as time proceeded, there was a big mismatch between the supply of gas and the running capacity of those plants. And as a result, we have a lot of gas power plants which are not stranded assets, which are just standing there in the search of gas that might come in the future and they might be able to run. So we would have to prioritize in a nice way.

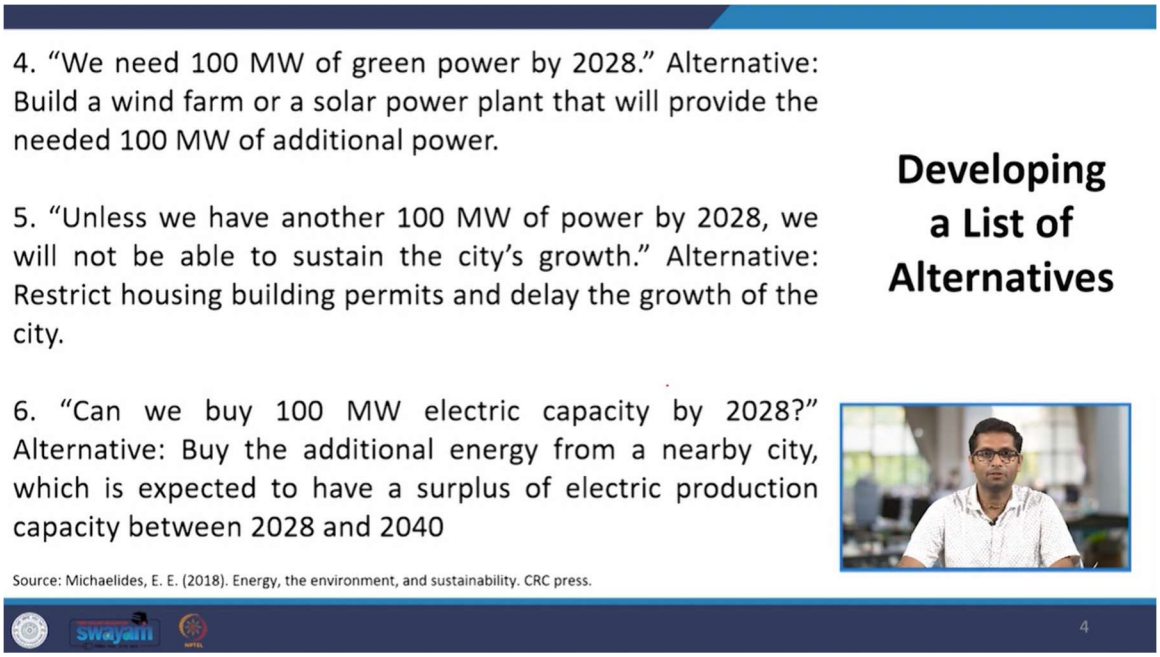


So let's try to understand this in a much more detail. The first thing that you would normally do is come up with a list of alternates. So suppose the problem or the loosely defined problem would be that by the year 2028, the city of Roorkee or any city for general might need 100 megawatt of additional electric power. So one way of looking at this is like we would need an additional 100 megawatt of electric power. So let's go with a conventional power plant which could be coal based.

So the option here could be that we can go for one plant of 100 megawatt capacity or maybe two plants of 50 megawatt capacities. The 100 megawatt plant would give us advantage in terms of economies of scale, but it might be easier to operate 50 megawatt plant if we want to ramp down the consumption, then it might be easier in that case.

Another alternate method of looking at the same problem could be maybe we can redefine the problem as like by the year 2028, we might be short of 100 megawatt of electric power. So why don't we start over with conservation efforts? Why don't we use like BE 5 star rated appliances that brings down our consumption? Or why don't we use LEDs in place of incandescent bulbs that can help save a lot of electricity in that sense and there might be a pathway that could be laid down for saving a total of 100 megawatt till the year 2028. So that changes the premise altogether.

Then there could be another alternate. We could also look at this problem in a way that by the year 2028, we need to increase the power production of the plants by 100 megawatt. So this doesn't necessarily mean that we have to install a new power plant which might be based on conventional technologies like coal or it could be based on new technologies like wind or solar. We need an additional 100 megawatt. Can the plants that are already there be refurbished to supply an extra 100 megawatt? We can look into the options like can there be an additional reheaters or feed water heaters that could be applied to maybe the three existing plants that are nearby and their capacity could be increased by 100 megawatt. In that case, we just need to adjust or we just need to update the ongoing capacity and we don't need to build in totally new plants.



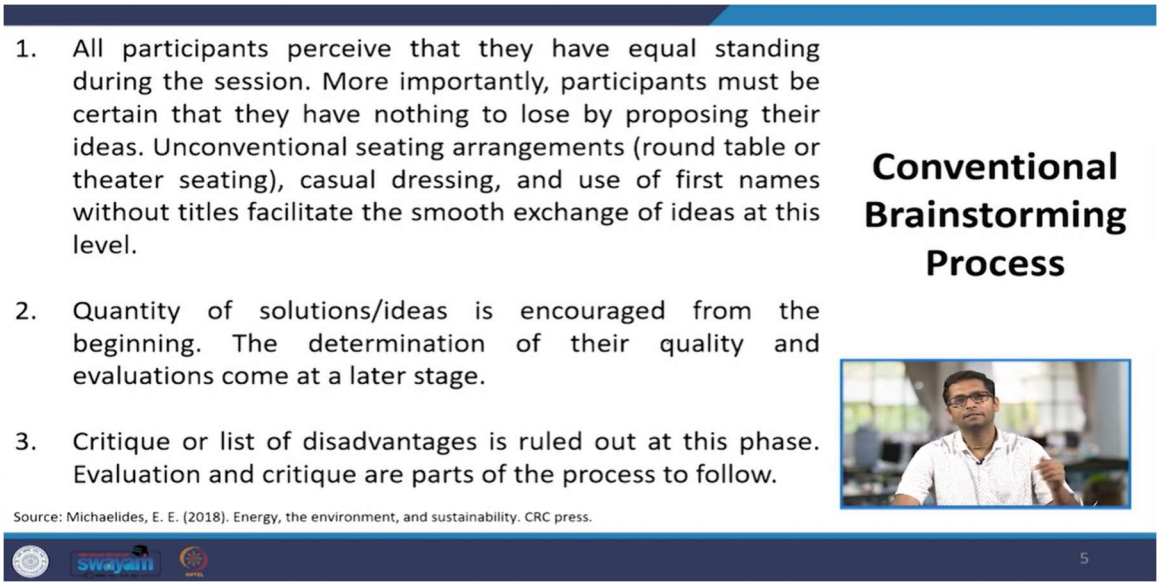
Another way of looking at the same problem would be like now India has announced its net zero targets say 2070. If a coal power plant was to come up, its life is going to be at least 30 to 40 years. We should not go into a power plant that again causes a lot of emissions. So let's update our problem statement to be like we need 100 megawatt of clean or green power by 2028.

So in that case, our options are limited. Maybe we would want to go for wind farm. We would want to go for a solar power plant or a hydel power plant which has 100 megawatt of additional power capacity. Then another alternate for looking at the same issue could be like unless we have another 100 megawatt of power, we will not be able to sustain the city's growth. Any city in India would be growing at an exponential rate.

This is true for all the metropolitan. We have a huge flux of people who are moving from rural areas to urban areas in the search of better lifestyle. This nevertheless entails that our energy consumption is increasing at a good rate. This is one of the reasons why we need extra power capacity specifically in the cities. A purview in which we can look at this problem could be like why don't we stop the growth of the city altogether.

So that's slightly on a negative side but again that's an option that could work. We discourage more people from coming and settling in the city so that the power requirement remains more or less the same. We don't allow the city to grow beyond certain limits. In that case, there might not be a need for 100 megawatt of additional power by 2028. So that is another solution that might exist.

And finally there could be another way of looking at the same problem is can we buy 100 megawatt of additional power by 2028 by some additional power plant that might be located in the vicinity, maybe in a different state. So in India we have different states producing electricity by different methodologies or different technologies. What if some state maybe Himachal has a good amount of extra electricity and can we buy some additional electricity from a neighboring state which basically states that we don't need to build our own infrastructure. So again that is an option and that might be looked into. So again when we are looking at a need for growth in energy capacity, it needs to be looked from the different point of views.



There could be different alternates and there could be different pathways for achieving a similar goal. So we need to rephrase the problem and look at it from the different perspectives. And these kinds of alternates are normally developed in what is called a conventional brainstorming process. So when we have a decision making process for such kind of plants, so it is basically two types of brainstorming that is happening, so two types of meetings. So one is the conventional brainstorming and this is followed by a nominal discussion. So what a normally is done is a group is formed of around 10 to 15 people who are all subject matter experts who have a known knowledge in this domain for the previous and a team is created by the decision makers and they are brought into a room to make the discuss. The underlying principle for these kinds of meeting would be like the quantity of ideas and brainstorming would produce a good quality output. So that is the underlying method like you discuss the different quantities of ideas and no matter it is good or bad, you discuss and come up with the pros and cons and this discussion would lead to a few quality ideas which could be taken later on. So in this case which is a conventional brainstorming process which is the initiating process, people are brought together who are subject matter experts. They are made to do a brainstorming process.

So normally this is a casual discussion with the people normally casually dressed and addressing each other by their first names and they are encouraged to come up with ideas no matter how weird they are but just come up with different ideas that are feasible and normally they are not critiqued and the disadvantages are ruled out at this phase.

4. Improvement of contributed solutions and combination of solutions is actively encouraged.

5. All solutions/ideas are succinctly recorded in a way that all the participants can see and, if appropriate, propose corrections, modifications, and combinations with other solutions.

Conventional Brainstorming Process

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

So what is of interest is they would want to bring in as many ideas as possible and the discussion is mainly targeted towards improving the idea that might be coming from and also on like combining one or two different ideas if they can provide a better solution. And at the end of this process all the solutions are recorded and they are like they are coupled with the different kinds of corrections, modification and combination that are possible within the group. So once this recording is done then normally there would be an exercise in which the ideas which are not feasible because of certain environmental issues, policy regulations are thrown out of the bucket and they are not considered to be feasible.

1. All participants are expected to present and discuss their ideas in an orderly fashion. Formal presentations are given. Questions, comments, and critique of the ideas are allowed at this stage of the nominal group session.

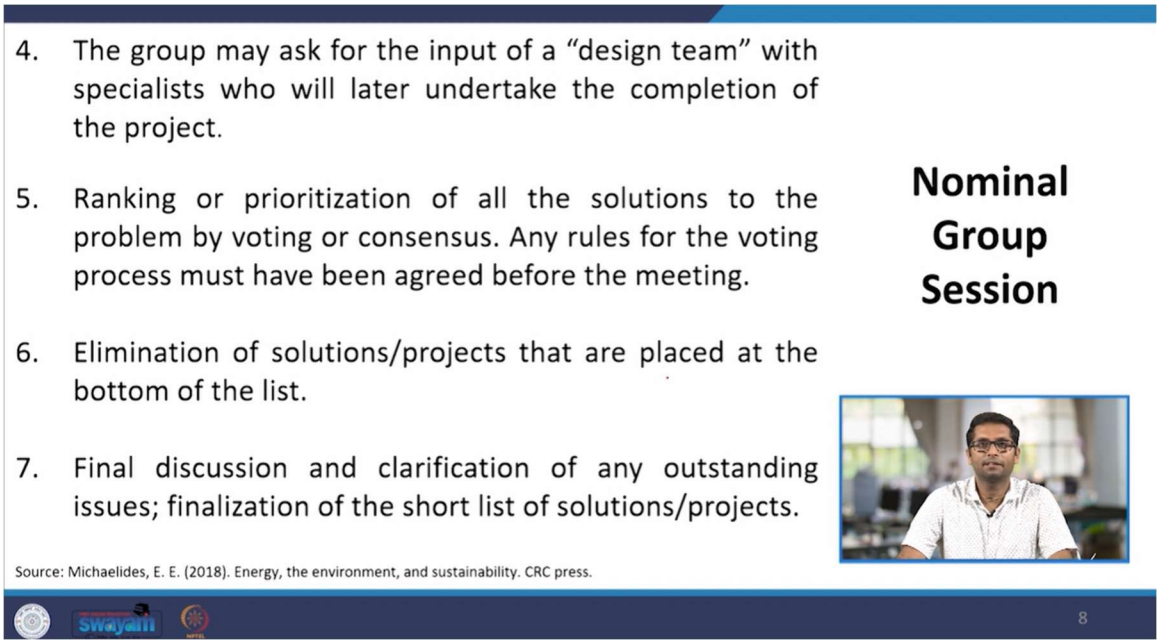
2. Clarification, further study, and modification by the proposer follows, based on the comments, criticisms, and suggestions from part 1. The expectation at this stage is that a better, more optimal solution will be formulated.

3. Group modification and clarification of each idea follows. The ideas/solutions to the original need are formulated as projects.

Nominal Group Session

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

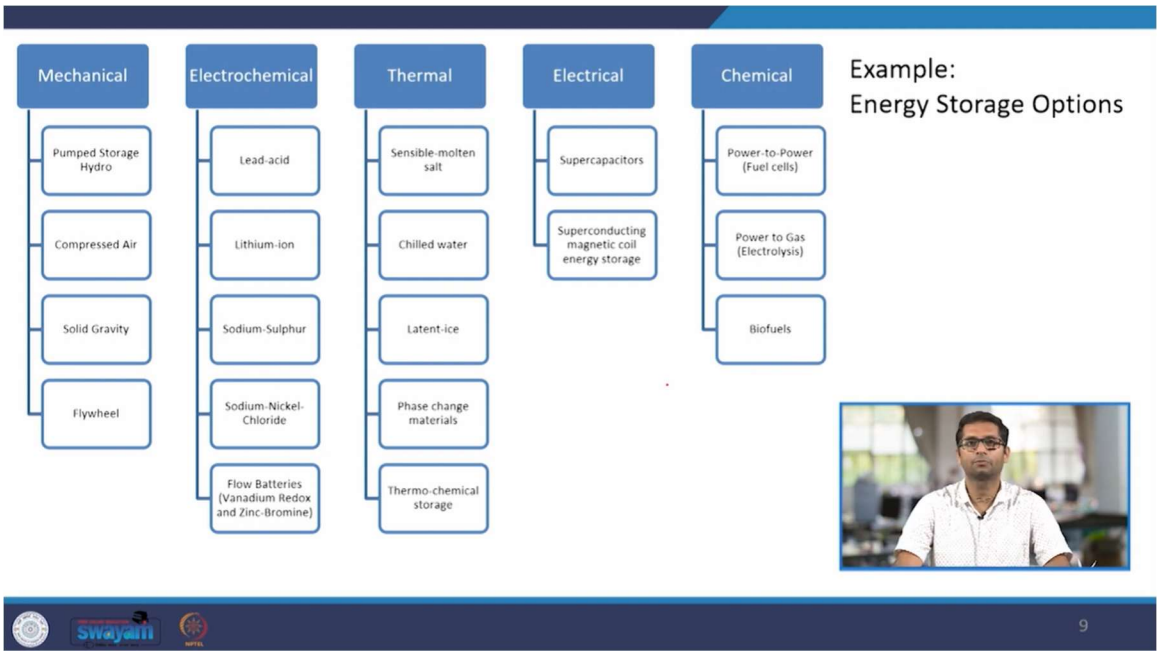
And what follows after this is a nominal grouped session in which we have a more focused group again containing of the experts and in this session the experts are expected to present and discuss their ideas in a more orderly fashion. There are proper presentations in which the ideas are commented upon, they are critiqued upon and like they are taken through a rigorous cycle in which the whole committee decides like which is a better solution which is not. Then the clarifications and modifications are sought and normally like at this point like most of the ideas which might face regulations because of environmental issues, advocacy groups or political fronts are ruled out.



Then at this time like the group might also take inputs from the different teams of engineers or the design teams who would be responsible for designing this project and also for the operation of the project to see the application of a project in a particular scenario. And then of course we need to rank, normally voting or consensus is the method and again as I mentioned earlier the elimination of solutions are placed like we eliminate the solutions as much as possible and normally a very small group of solutions are then proposed and sent to the economic analysis team who will do the economic analysis of the whole process. So, all the like removal of projects that are based upon the policy fronts or like or the other issues or based upon the proposition of different advocacy groups are removed at this particular stage so that the only decision that is left

for the further or the final team or the management is selecting the best option and that is purely on the economic basis.

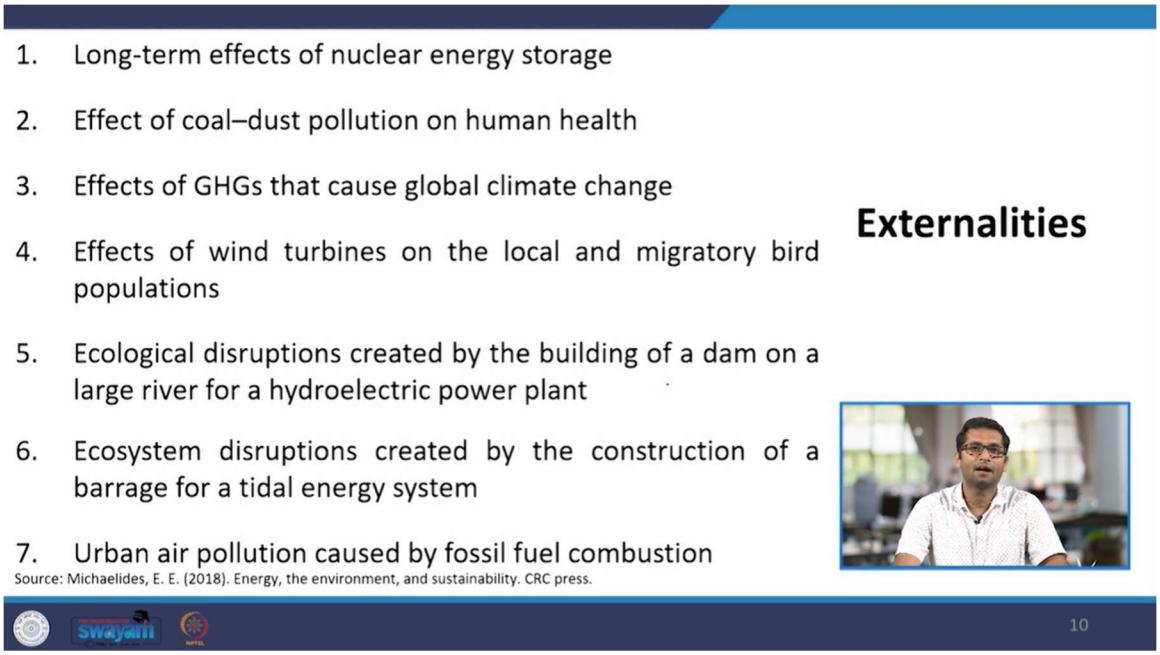
So, what happens is after that there is the management that sits together, prepares an detailed economic analysis or financial model for the proposed technologies and whichever comes out to be the most economical or profit making is then selected and the procedure is followed for the setting up of that plant. So at after this level there is no more looking back into the environmental issues or other issues that might patch up and the final decision is made up purely on the financial basis and normally you would go for a project that would be profit making for the coming few years because if you select a project that might like help you meet the needs of the government but is not profitable that might not be able to sustain the organisation for long.



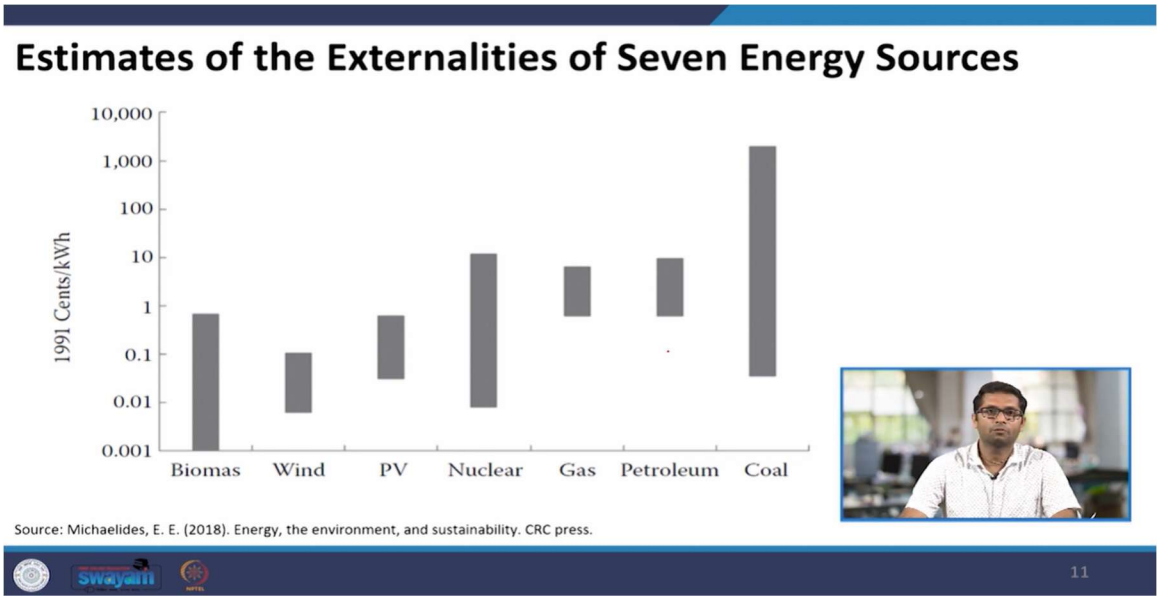
So, this is for an example, so this is one of the exercise that we experienced lately like India as we are going towards the different kinds of renewable power sources and most of the power sources that would help us achieve the net zero target are flexible in nature which means they are available in certain times of the day and certain times of the year. So, for the times which are not in the or in which the energy is not available we might not want to go for certain storage options and when we look at the storage option there are many of them there could be mechanical storage, electrochemical storage, thermal

storage, electrical storage, chemical storage and here in the slide in front of you can see there are a lot of storage options that are being explored. When you look at the popular literature possibly you would only come across batteries and in some cases pumped hydro as well but if you see like there are a lot of storage options that are being explored in the different parts of the world and the different kinds of nodal agencies in India are also looking towards this like what could be the different possible storage options.

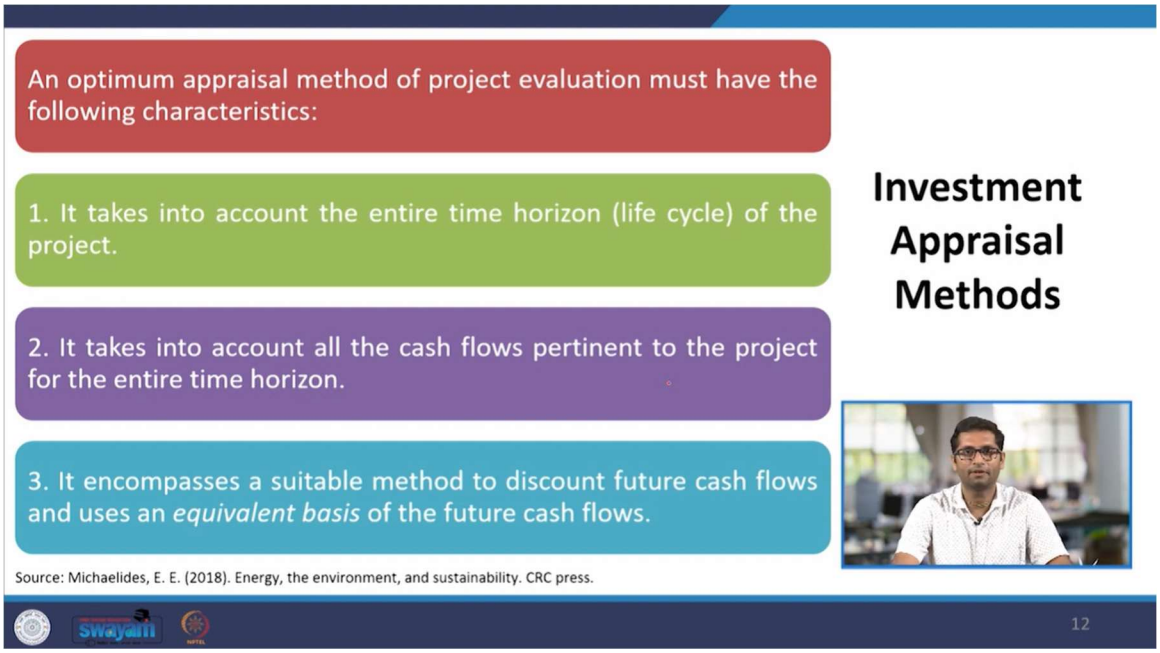
So, based upon like there were discussions held on what are the possible storage options which are which of them have more advantages which of them have more disadvantages then what is the scale of operations, how does the supply chain act like do we have like certain materials that might be needed for some of these storage options, are there critical elements, are there some regulatory issues. So, all this have to be listed on and once that is listed on the team formalize like maybe India should focus as of now on pumped hydro, lithium ion batteries, vanadium flow batteries, compressed air and thermal storage. So, these were the five technologies that were listed on and then business models were prepared and then discussed among the different nodal agencies. So, this is just an example how things are carried out. Now when it comes to selecting of the best options one thing that is often left out is externalities.



So, by externalities I mean there are effects of certain plants or there would be economic effects that are not taken into account like the effects on the environment, the effects on the lifestyle of the people. There might be certain diseases that might be caused because of some of the affluence that are created by any plant and they could have economic penalties on the people that live besides the plant and most of these are coming under the heading of externalities and not many times are they accounted for when the business models or the financial models or the economic models are created. Just for the sake of example there could be long term effects from a nuclear power plant storage which is storing radioactive material. There could be human health effects that come from the coal dust that originates from a coal based power plant. Of course we are aware of the greenhouse gas emissions that come from the different power plants maybe coal based, natural gas based. The wind turbines have negative effect on the migratory birds that travel. There are a lot of bird hits that happen. Then there could be ecological disruptions because of building of large scale dams. We have experienced things like this in our country as well. Construction of a barrage for a tidal energy system again causes ecosystem disruption which is not good for the aquatic life and we all are experiencing the urban air pollution in all the metro cities that we have. So all these come into the form of externalities and there have been attempts to give it an economic value. But again it is very difficult to come to a consensus among the different agencies and different organizations of the economic values that might be attributed to these technologies.



Just for the sake of example like this is one study the sources given that we have referred to like which have tried to quantify the externalities cost for seven different energy options. So what you have on the y axis is the cost in terms of 1991 US cents per kilowatt hour of electricity and what you have on the x axis are the different energy production technologies. So we can see there are different costs attributed and of course the cost on the y axis are on the log scale. So the increase you might want to understand is not linear but it is an exponential increase. So the most cost are of course attributed to a source of energy like coal which have serious consequences both in terms of the CO2 emissions as well as like the emissions in terms of the particulate. Then it might be better slightly better in terms of gas or petroleum. Nuclear again it is widespread it depends upon like how the history has been but again there could be some implications of disaster like Fukushima. Then again like a system which is based on PV or wind does also have certain externalities cost which might be caused by the different kinds of emissions during the building of these plants and something similar for the biomass. But again let me repeat the same point it has been very difficult to come to consensus where upon the economic value has been like justified and it has been and there has been a solid ground to adjust the numbers and that is one of the reasons why they have not been taken into account so far.

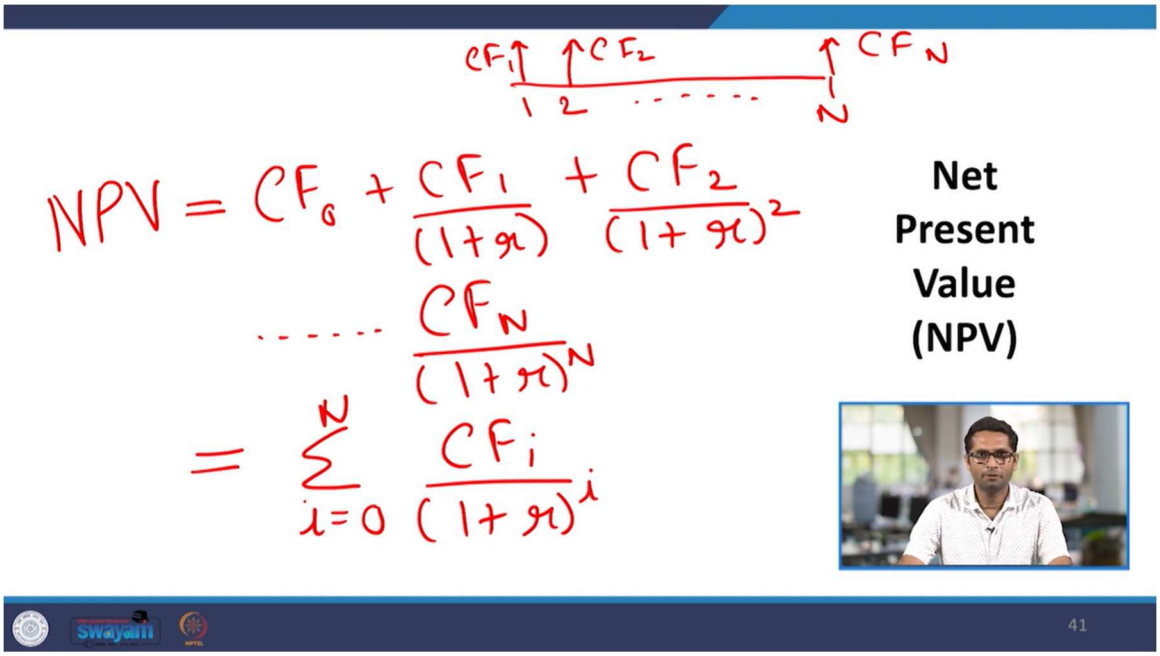


So coming back to the economic analysis now let us try to understand the different types of investment appraisal methods that would be taken into account once the nominal discussion group have came up with the final solutions. So normally it would be a 2 to 5 solution that this group would come up and it is basically the duty of the management team or the economic analysis or the financial analysis team to select the best options. So for any the best option or the best methodology the methodology should have these three major characteristics. So these three major characteristics is like it the methodology should take into account the entire time horizon of the project which means it should take into account the capital cost that is involved during the build up of the plant that might again take 3 to 5 years.

Then the operating cost and the dismantling of the plant at the end. It should also take into account all the cash flows pertinent to the project over the entire time span. It should not happen that the cash flows are only taken till the breakeven cost is reached or they are not concerned about the cash flows that are made for the replacement of a certain equipment. So the cash flows need to be taken into account throughout the entire life span. And finally the methodology should be able to account for the time value of money.

So it should be able to discount the future cash flows and bring up with the present value or the other way round. So as the equivalence basis for the cash flows is maintained. It should not happen we are just considering money on the absolute basis because as we have understood in the previous classes 100 rupees that you have now is not equivalent to 100 rupees one year down the line. So there is a change in the value of money that happens over time. So any good investment appraisal method should have these three features which I would want to repeat it for you.

\It should be taking into account the entire life span of the plant or the project. It should be able to account for all the cash flows over the life span and finally it should be able to account for time value of money. Now let us go through some of few major investment appraisal methods. The first one is called the net present value. So what happens in the net present value is that I discount all the future flows to the present day and add them up together to see the present values of the future flows.



So suppose I am making all the investments over the lifespan that is happening in the different years. So say year 1, year 2 the investment we have cash flow 1, cash flow 2 comes the year n we would have another cash flow that is occurring they might be positive or negative depending upon whether it is the CapEx or the revenue that you are generating but you would have different times of cash flows that would be occurring throughout the lifespan of a project. So what the NPV method does in a sense is adds all the cash flows that could begin from the year 0 so that is when the investment would occur. So cash flow 0 that occurs in the year 0 that is present and then we have the cash flow 1 and then I discount that with the discount rate which I have assumed to be R in this case. The second cash flow would be discounted by 1 plus R square of the whole comes the nth cash flow CFn and this is 1 plus R raised to power n.

So if I would have to write this with a single equation this would be a summation with i varying from 0 till n the cash flow i divided by 1 plus R raised to power i. So this is how you would define the net present value in which you would be discounting all the future cash flows depending on the discount rate and this discount rate as you can see has a good role to play it is one of the major factors that needs to be determined and often there is a lot of discussion on like what is the discounted that you should be choosing. So we have discussed this particular aspect like in the previous class where we have discussed

the different factors that would dictate this discount rate. So different organizations would have their own discount rates and there could be a huge variations. Even among the different countries that you might deal with the discount rate could have very different variation. So in the sense this is one of the simplest methods and one of the most widespread methods for investment appraisal and if you see it does take into account all the three factors that we have discussed in the last slide. It covers the whole life span of the project, it covers all the cash flows throughout the life span of the project and finally it is able to discount or bring in the time equivalent of the different cash flows with the help of discount factors. So again if you have a different alternates which are available which could be complementary to each other or which could be mutually exclusive you would want to choose either one or more than one of them and finally you would give the priority to a project which would have the highest net present value.

If the alternative revenue-producing projects are exclusive—that is, only one must be selected—the alternative project with the highest positive NPV is selected to be developed.

If the projects are not exclusive, they are ranked in order of decreasing NPV, with the first few projects having the priority for further development. When several nonexclusive projects are feasible, the decision of how many projects to pursue is dictated by the availability of critical resources, such as

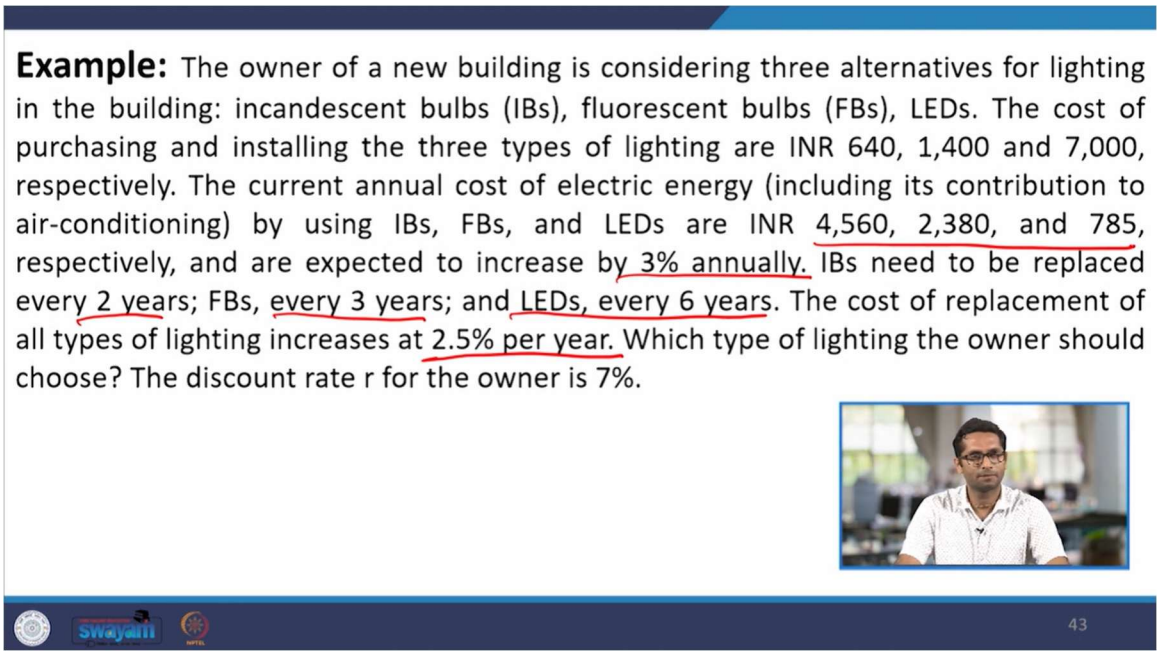
1. The availability of capital (do we have enough funds available for all the investments needed?).
2. The capacity of the entity to simultaneously pursue these projects (can the engineering department undertake the design of all the projects? Do we have enough engineers and managers to supervise all the projects?).

Net Present Value (NPV)

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

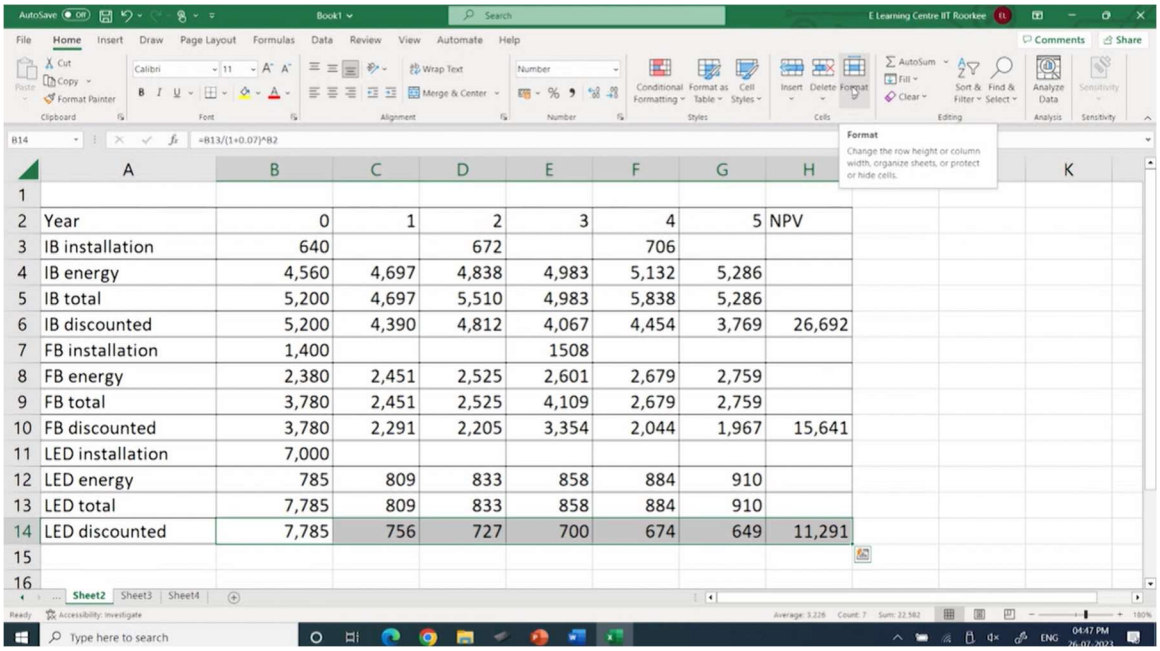
So the project if you are comparing a variation of different projects the project would within a net present value or the highest net present value would normally be given the most preference because that is the one that is expected to generate the maximum amount of profit and you would normally want to go with it. If you have more than one project that are available the choice might be based upon the availability of capital.

Does the organization who would want to set up these kinds of plant have the necessary capital and in that case it might want to give priority to one of them and further it might want to also want to account for the manpower that is available because there needs to be like operation that needs to be done and do we have enough engineers and managers to supervise and manage the project altogether. So these are some of the factors that would dictate net present value. Again the net present value could be used for another point of view when we are comparing the different kind of energy efficiency projects. So in that case the choice would be dictated by the project which would have the least cost or the least NPV in that case. So that is quite opposite. So for comparing the different kind of energy production plants you would go for a plant which has the maximum profit or the maximum NPV whereas if you are trying to go for a case in which you would want to minimize the energy or bring up with the most efficient system you would want to go with a system which has a maximum cost involved in it. So to understand this let us try to go through a simple example.



Now this example is that like a future building is considering changing the electricity profiles and has three different options. The conventional incandescent bulbs which we have been using in the house here for decades. Then there could be the fluorescent bulbs dictated by the term FB and finally LEDs.

Now the cost of all the three technologies is incremental. It has been proposed that the cost varies from Rs 640 to 1400 to 7000. So there is a huge jump if we go from fluorescent bulbs to LEDs and it has also been found that based upon the efficiency the electricity consumption over the year by this technology could be hugely variable. So as we understand that incandescent bulbs are of course cheap but they also consume a lot of electricity they are not found to be very efficient. If you go towards fluorescent bulbs they are significantly efficient and if you go towards LED lamps they are much more efficient. And it is also expected that the cost of these of like the annual cost would have an increment by 3% annually that might be dictated by the increase in the electricity price. Here the cost of these bulbs which might be dictated by the raw material cost also increases at a rate and that rate could be 2.5% per year. Further these different technology bulbs would have a different life span. For the case of an incandescent bulb the typical life span would be 2 years. It would be increased to 3 years for a CFL and for the LEDs it can go as high as 6 years. So given these constraints and we also know that for the owner of the building the discount rate that he or she has chosen for himself or herself is around 7%. Let us try to evaluate which is the most beneficial option. So what we will go we will use a simple excel based spreadsheet to come up with a solution. So let us go to excel and try to evaluate the three different options.



	A	B	C	D	E	F	G	H
1								
2	Year	0	1	2	3	4	5	NPV
3	IB installation	640		672		706		
4	IB energy	4,560	4,697	4,838	4,983	5,132	5,286	
5	IB total	5,200	4,697	5,510	4,983	5,838	5,286	
6	IB discounted	5,200	4,390	4,812	4,067	4,454	3,769	26,692
7	FB installation	1,400			1508			
8	FB energy	2,380	2,451	2,525	2,601	2,679	2,759	
9	FB total	3,780	2,451	2,525	4,109	2,679	2,759	
10	FB discounted	3,780	2,291	2,205	3,354	2,044	1,967	15,641
11	LED installation	7,000						
12	LED energy	785	809	833	858	884	910	
13	LED total	7,785	809	833	858	884	910	
14	LED discounted	7,785	756	727	700	674	649	11,291
15								
16								

So I am hoping everyone can see the excel sheet. So here we have done put in the primary numbers. So what you see on the left hand side is the cost of installation of the incandescent bulbs, then the energy used by incandescent bulbs, the total of these two the CAPEX and the OPEX which is basically the installation cost and the energy cost and finally I would want to discount that for the future and the discounting is happening by using a discount factor of 7%. So in the first case since it is the year 0 there would not be any discounting occurring. Also the installation cost is increasing at 2.5% yearly so the cost of 640 would increase to around 672 in the second year and then 706 rupees in the fourth year.

Further we are taking the total lifespan of 6 years so as to compare the different options given that all the three have different lifespan. So whereas like an incandescent bulb would have lifespan of 2 years, it would be 3 years for a fluorescent bulb and 6 years for an LED installation. So we have chosen 6 as a matrix or the number of years to compare to have a fruitful comparison between the three. So if I talk about the energy consumption this would be increasing at a rate of 3%.

So let me put it so first year and then I multiply that with 1.03 and let me increase that for the next 5 years or so. The total of course would be an addition of these two factors so I am just putting in and this is the total amount that I should be getting and finally I would want to discount it with the number of years and taking 7% as the discounted which you can see in here. And if I discount that this is the total cost would be on an yearly basis. So what I would want to do is I would want to add all the yearly cost and this gives me the NPV of this particular technology.

So it costs around 26,692 rupees. Now let us go towards the second option which would have an initial cost of 1400 for the installation and this needs to be replaced after 3 years and given an increment of 2.5% on yearly basis. For the third year the cost would be around 1508. Again the energy cost is somewhat lower in this case which would again be increasing at the rate of 1.03. So let me put this factor and this is how the energy consumption would be increasing for the next 5 years. Further we would have an increase in the total cost as well and finally we would want to discount that with the same factor. So again the cost remains same for the year 0 whereas that would change in the future

years. So we would have the cash flows that look like this for the next 5 years and what I can do here I can do an auto sum and I can see there is a significant reduction that happens in the net present value for the cost that are occurring. A similar exercise can be done for the LED installation as well where you can see there is a one time cost which is almost 10 times higher to that of an incandescent bulb.

Then we also have the energy cost which is again an order of magnitude lower and this would again increase at the rate of 3%. Let me increase it for the next 5 years or so. The total would also increase and finally I would want to look at the discounted flows as well which are again discounted at rate of 7% or so. And if I total that I get the total cost which is coming out to be 11,291 rupees or so. So what we understand from this example is that it might be wrong to just go by the simple CAPEX or by the simple operating cost.

So as we see in this example that incandescent bulbs seem to have a very small upfront cost but if you take all the cost throughout the lifespan and taking 6 years with 3 replacements it comes out to be more than double to that of an LED bulb. Whereas for the LED bulb we can see that the installation cost is more than 10 times of what you would get for an incandescent bulb but because of the energy savings that happen for the next 6 years or so the overall lifespan cost comes out to be very small. For the fluorescent bulbs it is somewhere in the between and this example helps us understand the 3 factors that are important that taking all the cost throughout the lifespan considering the whole lifespan of a particular technology and taking the time equivalence also into the picture. So with this we end today's lecture. Thank you.