Energy Resources, Economics, and Sustainability

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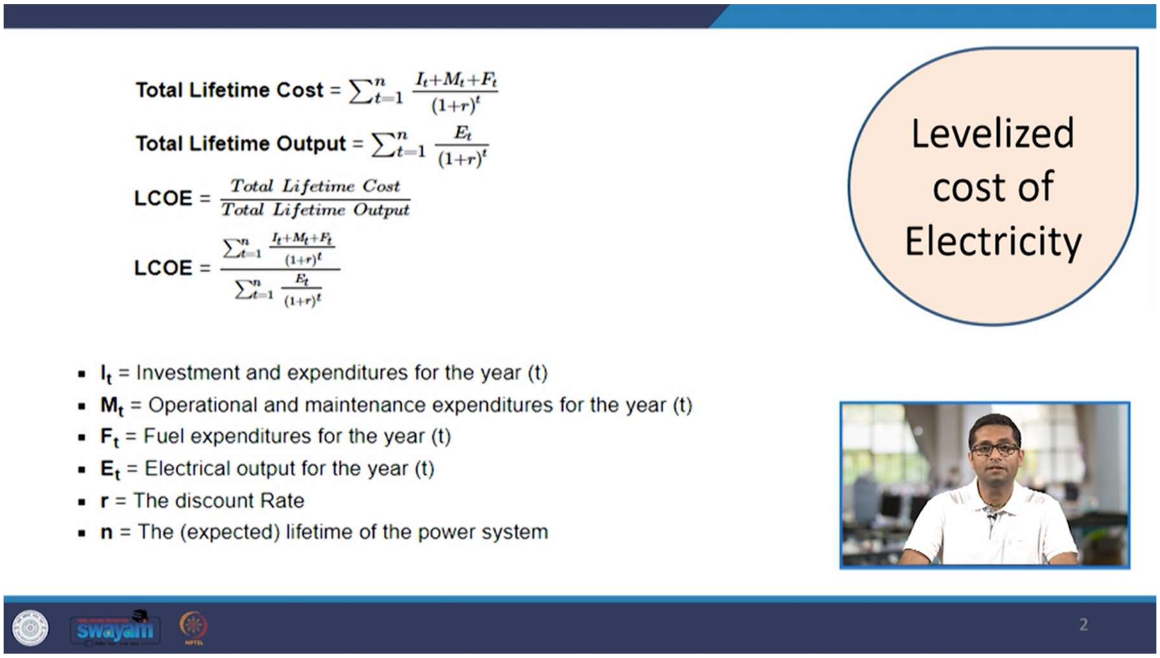
Week – 04

Lecture – 02

Lecture 18 - Economic Decision Making and Project Financing

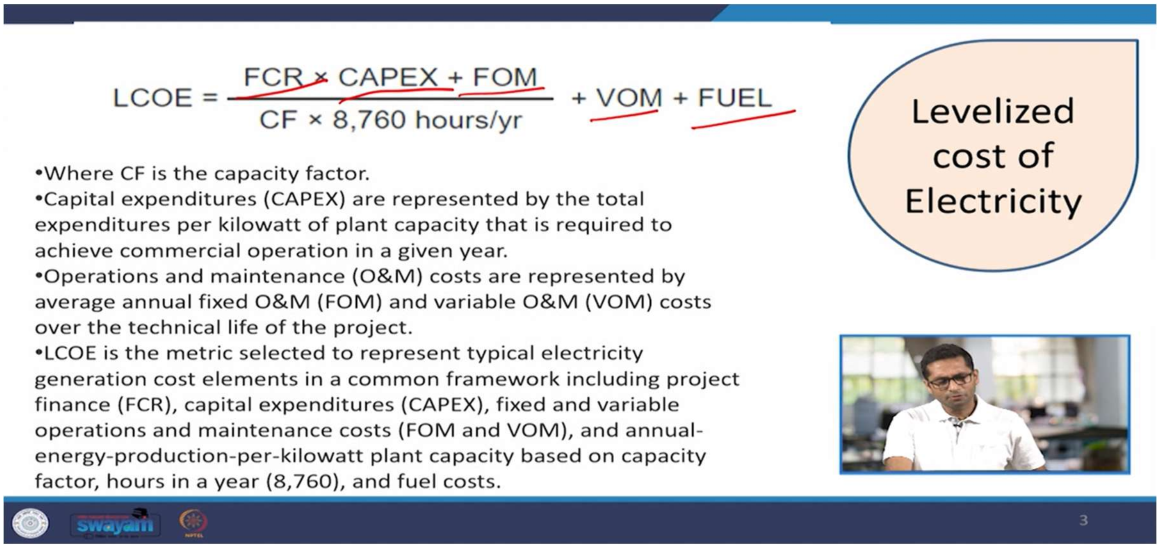
Hello everyone. Welcome back to the course Energy Resources, Economics and Sustainability. In the past few classes, we have been discussing the applications of different financial appraisal techniques and trying to see their applications in different projects which are all related to energy related instances. We have discussed the importance of NPV, how that could be applied for a financial model to a wind farm, how the same concept of NPV would come out to be very handy when we are doing a project appraisal which was based on energy efficiency or mortgages with respect to solar PV installations. So these were some of the applications of different kinds of tools which could help us analyse which project was profitable and which project might not be so good to be carried out. Further, there might be a question in your mind like is there a methodology wherein we can estimate the price of the product that was produced from an energy related entity.

Up till now, the methods like NPV, IRR, annual worth or similar methods will give you certain characteristics which would help you estimate if the project is expected to be profitable or not given the time value of money taken into account and the total life of the project also taken into account. But none of the projects as such give us the value at which one of the products or the major product that is produced would be sold. In a majority of cases for energy related firms, this product would be electricity production. It could also be heat. It could also be motive power. So let us try to understand another matrix that is commonly used in energy related projects and that is called levelised cost of electricity.



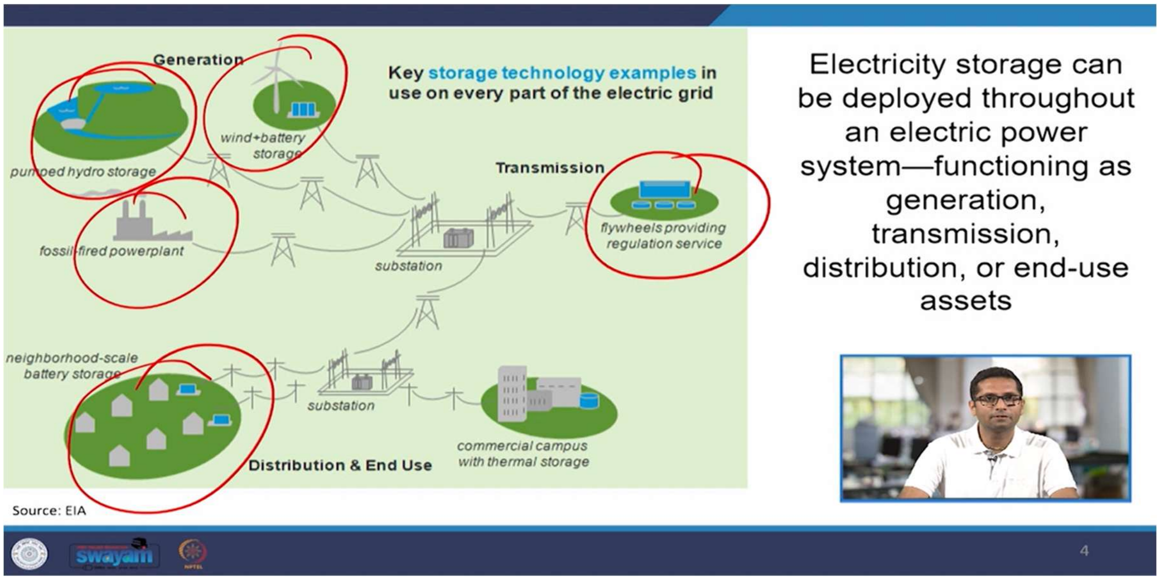
Levelised cost of electricity or LCOE as it is commonly known is basically a methodology that helps give us an average cost of electrical electricity produced by a particular route throughout the life cycle of a project. This is very similar to the NPV method where we discount all the future cost to the present date but in this case we are also discounting the energy that would be produced so as to give you an approximate price at which electricity or any other product in this which could be even hydrogen or which could be even storage that is available throughout the lifespan of a project which can vary from maybe 10 years to all 40 to 50 years. So that is one of the matrices that has been readily used by different kinds of agencies that deal with energy also by the major think tanks.

Some of the major reports that come and try to bring in the future projections of the energy market commonly use a term LCOE but there is no one particular formula for LCOE. Different kinds of organisations have their own custom made formulas. So the one that you see in front of you is the most basic formula that you would find in most of the reports and this was like predicted by the BEIS of the UK which wanted to predict the average electricity cost from the energy projects and it is a very simple formula wherein you have all the future cash flows discounted and so is the future energy output. You divide the two and you get the LCOE. On similar terms people have also now come up with terms like LCOH which basically stands for levelised cost of hydrogen and something also called LCOS which says levelised cost of storage.



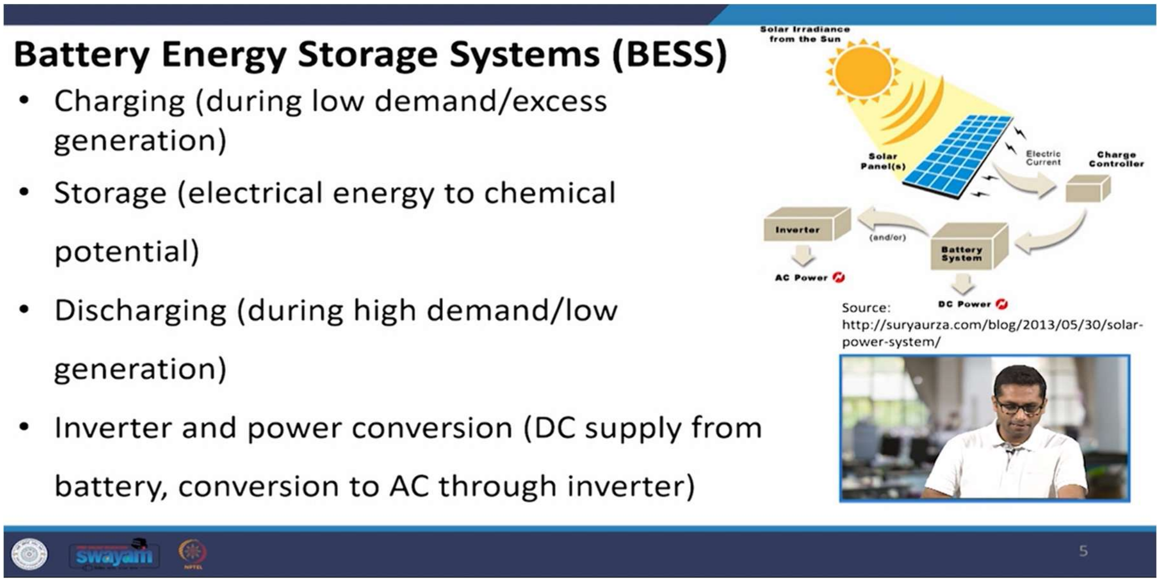
Ultimately there is another formula for LCOE which is proposed by the NREL which is the National Renewable Energy Labs of the US and in this formula what you see is you would have the CAPEX coming in and that is multiplied recovery factor. So basically the CAPEX is divided throughout the lifespan of a project and that is then added to the variable operating cost, the fuel cost and the fixed operating cost is also a part of it. You would divide that with the capacity factor and the number of hours for which the plant is operating in a year. So basically the earlier formula was putting all the values of the future cash flows to the present year and then dividing that with the energy production to the present year whereas this formula takes in its form of annuity which we have discussed before and then adding that with the CAPEX multiplied with the capital recovery factor. Overall these two formulas can be used interchangeably but the formulas can also give you different results in certain circumstances.

If the like the number of years in which the CAPEX is taking place is confined to one, there are no major replacements taking place in between, both the formulas are expected to give a similar results but these are not the cases in energy related projects where the construction or the CAPEX utilisation can span for a few years. So one might have to be careful when using a formula like this but the overall aim for calculating the levelized cost of electricity is to come up with an average price of electricity production so as one can make an informed choice or one can even make business plans for the future given that this much electricity would be produced and this would be an average price. Let me take you through a case study which we undertook recently and try to estimate the levelized cost of storage for different options.



So as we can see we are moving towards more and more towards renewable energy and many parts of the renewable energy or many ways for the production of renewable energy are flexible in nature which means they are available during certain parts of the day and not very readily available in other parts of the day. Solar for instance is during the daytime when they have its own span and it also calls for the storage of electricity when it is available in excess and the same electricity could be used when the different sources are not operating as per their rated capacities.

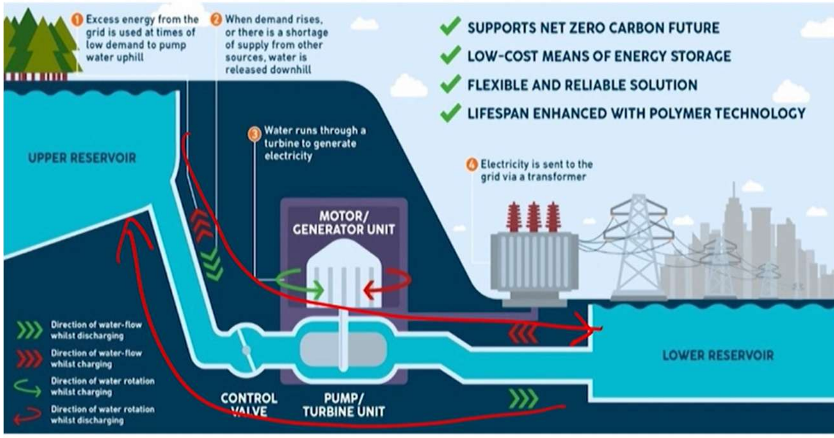
So there are different kinds of storage that have been proposed. What you can see in front of you is a typical functioning of the grid where you would have electricity being coming from wind, from fossil fuel power plants, from other renewables and then there could be certain kind of storage like the pumped hydro storage or there could be battery storage that is coming in and even flywheel. So what we undertook was let us try some of these methodologies which have learnt to come up with a cost of storage and let us compare those things. So what we did we tried to estimate the levelized cost of storage for the 5 prominent technologies and then try to see how do they compare among themselves. So this is just to give you an understanding of how these methodologies can be applied in real life for a meaningful comparison.



So the technologies that we compared, first one of course the batteries you would have been reading in the popular literature a lot of thrust is going into the batteries. There are 3 major industries which are putting their money into batteries. One is the automobile industries, we have the IT industry and we have the energy industry. They are seeing a lot of future in the batteries. We have a lot of gigafactories of 4 batteries coming up in different parts of the world.

The principle remains the same. You have an electrochemical mode of storage which would store extra electricity in the form of DC current when it is available at a large, in an excess and when you do not have the electricity being coming in through the different renewable or the variable sources of energy you might want to use these batteries to make up for the power requirements. Among the batteries also we have different types and in this particular study we tried to compare 2 prominent types of batteries which were the lithium ion batteries which is supposed to be the most prominent one existing today and then we also considered a sort of futuristic technology which is called the flow batteries or the vanadium flow batteries. Then another technology that we wanted to compare was pumped hydro. Pumped hydro is one of the storage technology that is gaining a lot of focus from the government's perspective.

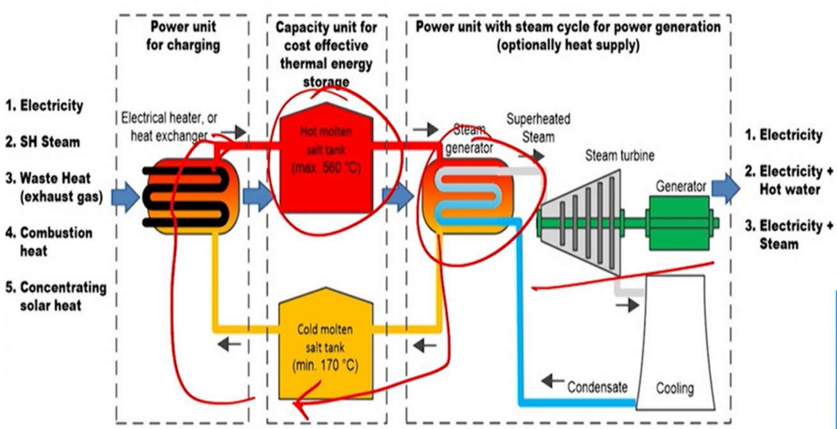
Pumped Hydropower Storage



Source: https://blog.belzona.com/how-to-improve-pumped-hydro-storage-efficiency/

So for this particular type of storage one needs 2 reservoirs at an elevation difference. So when you have excess electricity you would have a pump pumping the water to a greater height. It gets stored there and having potential energy. Whenever you need the excess power to be taken in you would use the same pathway in the form of a turbine and convert this potential energy of this resource into running of the alternators and production of electricity. Then another methodology for the production of or for the storage application could be the molten salt energy storage.

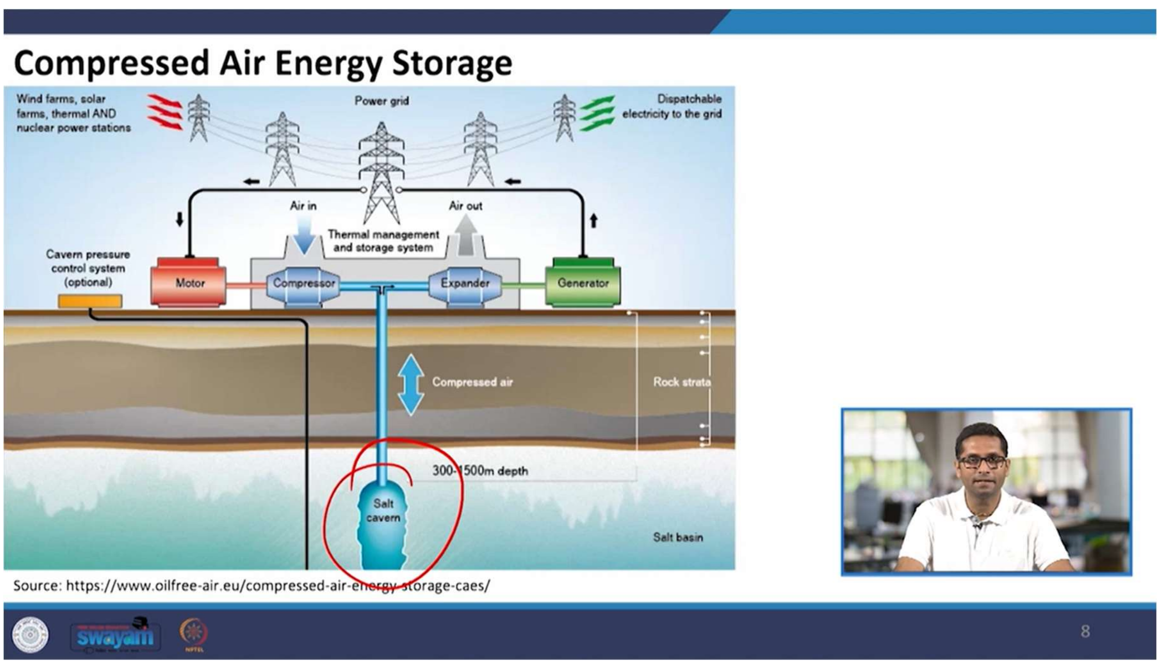
Molten Salt Energy Storage (CSP)



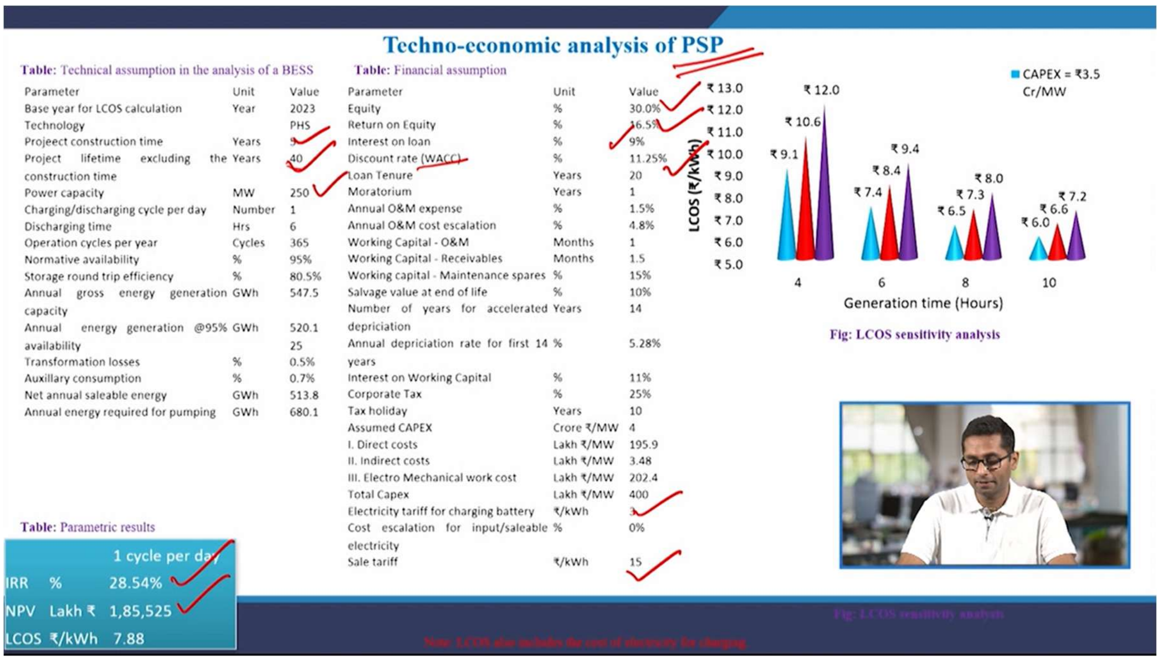
Source: German Aerospace Centre (DLR)

So there is this type of storage slightly difference in the form that it would not be taking an excess electricity which might be produced from solar or wind. It what it would be doing is it would be taking or making use of concentrated solar. So whenever in the places where we have excess solar available we can use that to heat molten salts up to a certain temperature and this molten salts can stay at this temperatures for quite some time and whenever we are in need this hot temperature could be used for raising steam and this steam could be using conventional steam turbines and which are coupled to a generator and producing electricity. On being cooled down this molten salts can again be heated during the daytime completing this cycle. Although these kinds of system could also be run on electricity where electricity is used for raising the temperature but the efficiency of these systems from electric power to power basis is not expected to be very high.

So that is why one of the application of the system is you raise excess heat whenever the sun is available and use this heat in the night time when you do not have much power coming from the renewables. Another alternate would be compressed energy storage or CAES.



You do not find much of it in India. It is basically a phenomenon that is found more in the developed world. The basic principle is you would use a compressor when you have excess electricity, compress the air which is a free resource as such and store the air in a salt cavern or it could either be an abandoned mine and the air gets stored there at an elevated pressure and whenever you are in need of excess electricity you would pump this air back through an expander coupled with a generator and produce excess electricity. So the concept remains similar. Whenever you have excess electricity you would compress air and when you are in need of excess power you would want to expand the same air and produce excess electricity. The air as such could be recycled. Then we try to formulate the business models which had a lot of parameters.



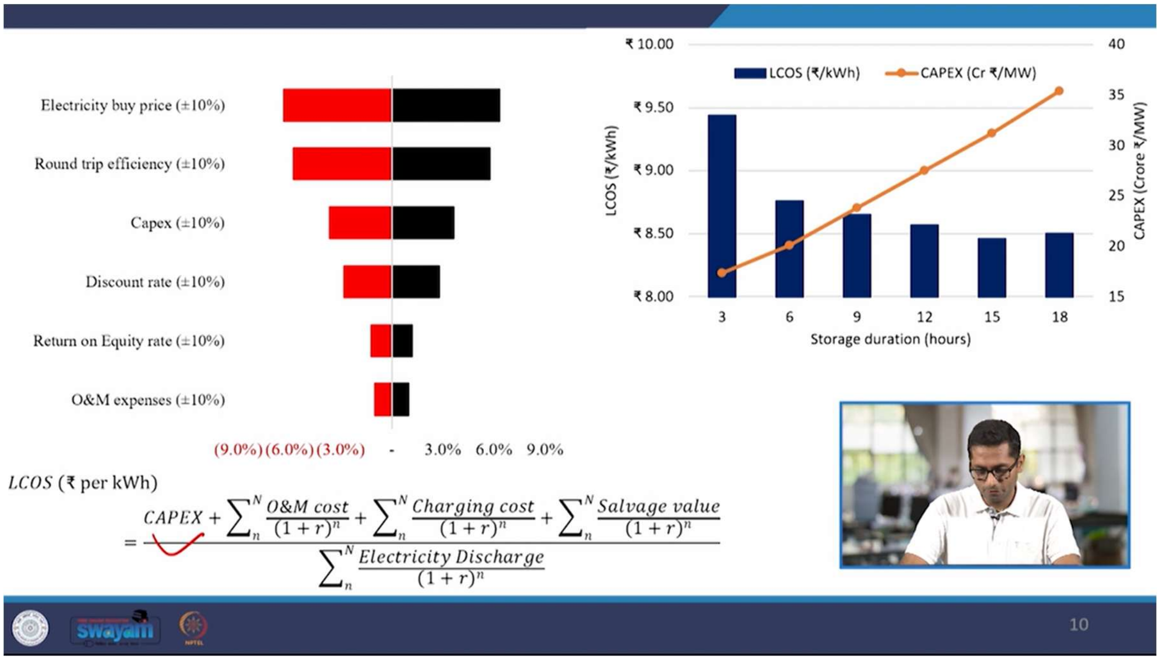
Some of those parameters are shown in front of you like it would consider the construction time like these parameters are shown for a pump storage plant which is one of the most prospective technologies that is expected to come up in India.

So you would have a construction time that normally varies to around 5 years, lifetime of 40 years which is huge. The capacity in this case has been assumed to be 250 megawatt which is quite small but with respect to the normal capacities of hydropower plants which vary between 1000 and 2000 megawatts. Then we are assuming that the charging, discharging will happen one cycle a day. Discharging time will be 6 hours, 365 days of operation, availability of 95% and I won't go through all of the assumptions but like these are some of the parameters that go into it. So this particular example I am showing you to give you a glimpse of how these calculations are done in detail.

Some of the basics of these calculations we have already covered in the last classes. Again when you are making a plant like this you would not want to put all of your own money. So in this equity is assumed to be 30% and then debt from the market will be the remaining 70%. The return on equity is basically the profit I would want on my equity and that I have assumed to be 16.5% and this is based on the CERC guidelines which is the Central Electricity Regulatory Commission.

You would also have to pay an interest on the loan. In this case I have assumed to be 9%. Then comes the discount rate. So in discount rate we normally choose a weighted average of cost of capital which is WACC which is basically the average of the two discount rates which is the return on equity as well as the interest on loan and based upon and divided by the percentage of equity and debt and that would come around to be 11.2% in this case. Then we have many other assumptions. The breakdown of the CAPEX in this case I have assumed that the electricity that is used for charging is coming at around 3 rupees and the cell tariff is assumed to be 15 rupees. So this is a hypothetical scenario and based upon this I have calculated three different results which is the internal rate of return, the net present value in lakh rupees as well as the LCOS which is 7.88 rupees which includes the charging rate of electricity. We can also see from the graph on the top right that the LCOS which will be the level as cost of storage would be a function of the generation time as well as the CAPEX. So the CAPEX of this kind of plant would be based upon where this plant is expected to come based upon the terrain, the raw material supply, the availability of water and the basic CAPEX varies from somewhere between 3.5 CR per MW to 6.5 CR per MW. So here in you can see the CAPEX have been changing. So it is 3.5 stands for blue, the red is 4.5 and then 5.5 is for the purple colour. What you see on the x axis is the generation time. So you could use the same reservoir based on depending on the water capacity for generating electricity for 4 hours, 6 hours, 8 hours.

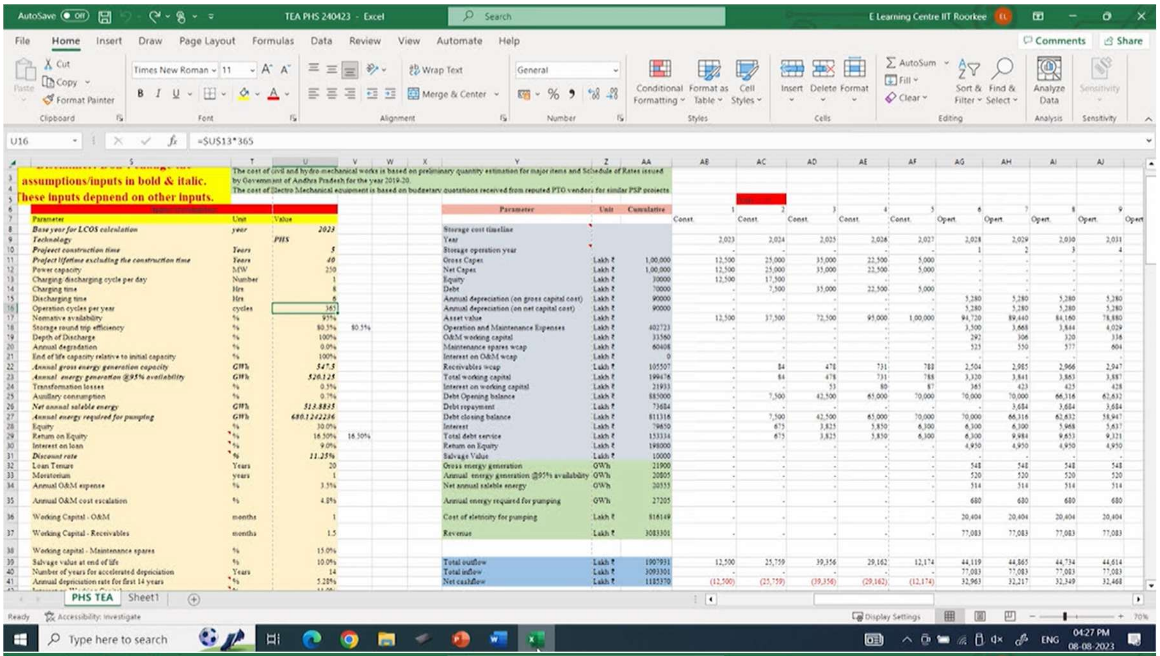
So the more you use it for generation of electricity the lower goes the LCOS because you are making the use of the same resources for a greater amount of electricity generation. So let me take you to the formula of the LCOS. So the LCOS formula is something you can see on the bottom left. It will be the CAPEX added with the operation and maintenance cost which is now discounted as per the years.

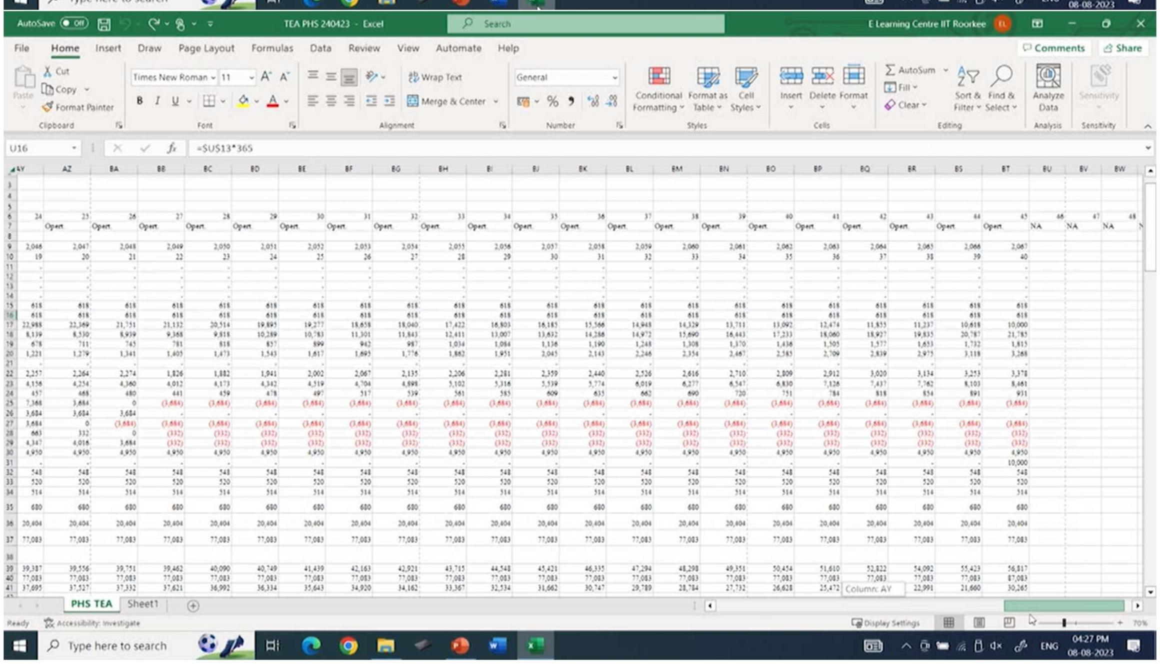


The charging cost which is the cost of the charging electricity, the salvage value at the end of the plant it might be sold at certain price and finally on the denominator we have the electricity discharge which is again discounted.

So this is a formula that is very similar to the BEIS formula for LCOE and this is the formula that we have used for our calculations and normally you could also have a sensitivity analysis done where you can see what are the parameters that have the most effect on the final LCOS. So what you see on the graph on the left hand type is the LCOS and you can see the electricity discharge which is 3 rupees per unit which we have taken as the maximum effect on the final LCOE price. Then we also have the efficiency. In this case we have taken a pretty efficient system of more than 80% efficiency but again that affects the overall levelized cost of storage. The CAPEX, the discounted that we assume, the return on equity, own and expenses.

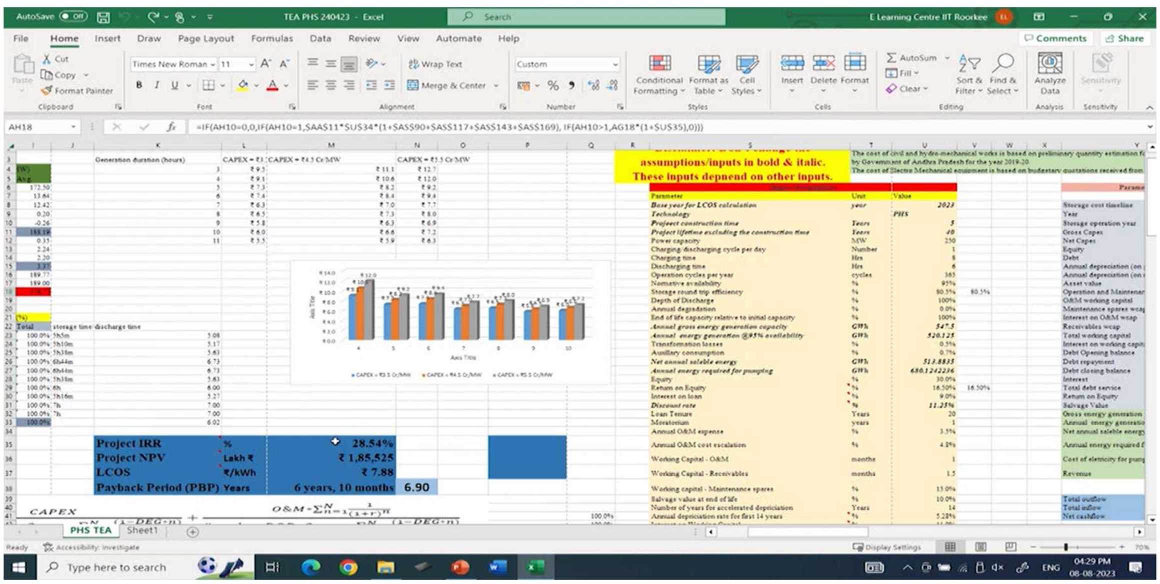
So normally you would want to understand these parameters to make out like which are the factors which would drastically affect the LCOS. Something similar you can do with other storage capacities as well. So let me also show you like how these kinds of Excel sheets look in reality. So let us go to the Excel sheet. So let us try to understand how a typical Excel sheet for a project like this looks in reality.



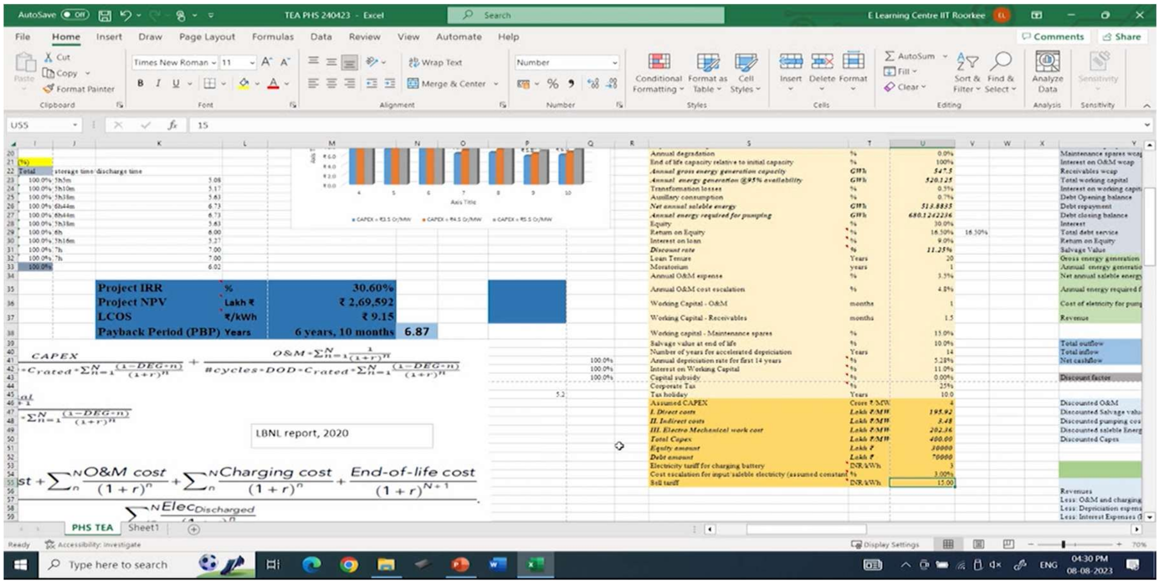


Of course this is a hypothetical scenario but just to give you a glimpse of like what sheets or Excel sheet or models like this look like. So you would normally have an Excel sheet like this which would have a lot of parameters going in. You would have the construction period, the different kinds of efficiencies that are involved, the CAPEX and the different financial parameters and then you would have the cash flows that could range for the number of years. So in this case the plant is having 5 years of construction period and then it goes for almost 40 years of operation. So that is why you can see it is going to 45 years or so.

Then you have the different cash flows coming in front of you and most of these cash flows will be automated like the formulas you can see in the formula bar are quite large and it takes into account a lot of factors that are involved. So I would not go into each one of them but this was just to give you a glimpse. And so the exercise that was carried out for this hypothetical scenario aimed at calculation of 3 basic parameters which was the project IRR in terms of percentage, project NPV and the liveliness cost of storage as well as the payback period.

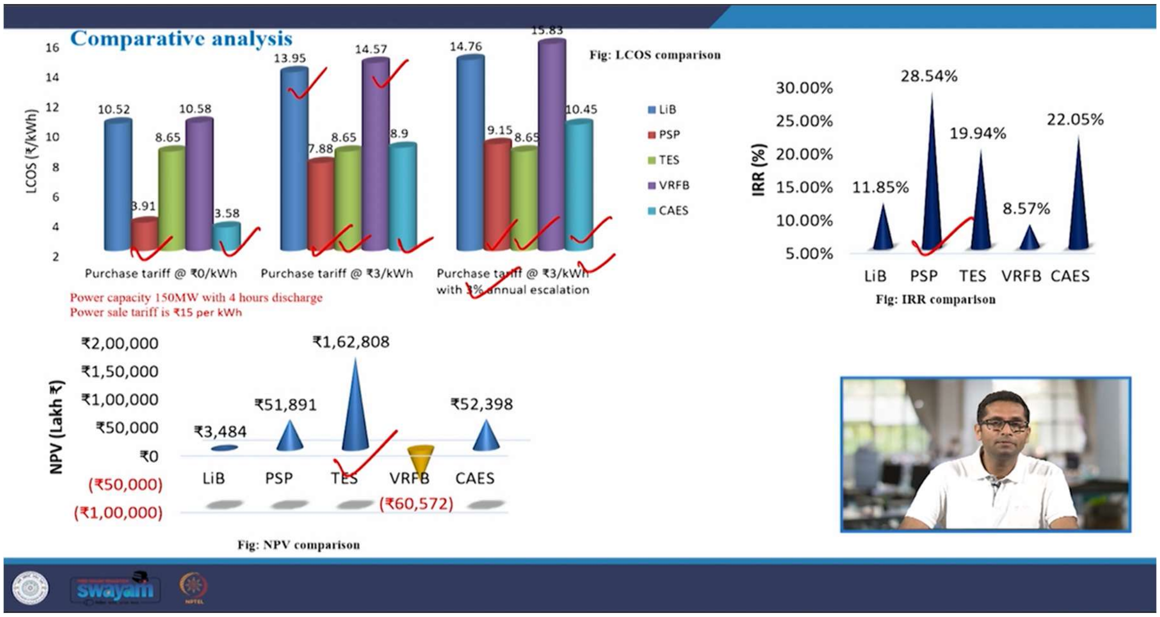


So normally you would see people comparing the different parameters because no one parameter is expected to bring out all the information. IRR basically gives you the profitability sorry IRR and NPV both give you the profitability but IRR also gives you the fast how fast the money is returning to you. LCUS basically gives you the levelized cost or the average cost at which electricity would be sold or which would be produced. And then payback period also gives you like the estimated amount of time in which you would be able to recover the capital and the different firms might have different types of minimum or maximum values attributed to each of these 4 factors. So in this simple scenario what we have is we have the electricity being coming in at Rs. 3 a unit then it would be stored and when the excess electricity is required from the storage it turns out to be around 7.88 Rs. So this is on the basis of 3 Rs. of the charging price. One major assumption that is being taken in this particular analysis is that like the electricity price remains constant throughout. There is no escalation so if it is available at Rs. 3 today it is going to available at Rs. 3, 40 years down the line as well.



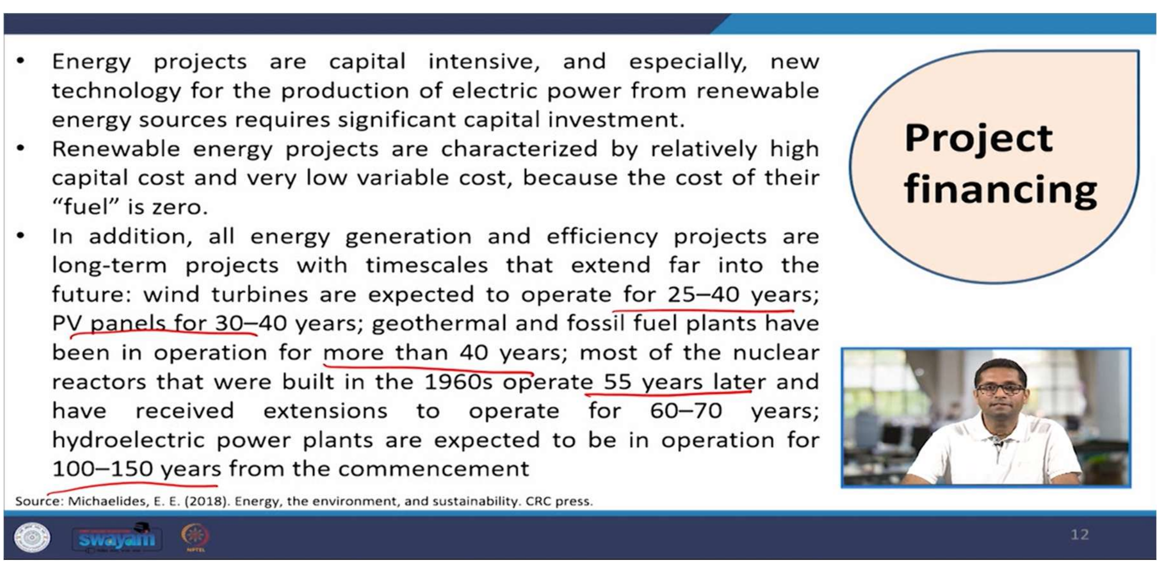
This might not be the case in the real scenario you might want to have an escalation to that and if that is the case I just put in a parameter here so it gives us the percentage of escalation and if I put a 3% escalation which is nominal I can see that on running out the sheet the LCUS changes from 7.88 to 9%. The project IRR also becomes a bit higher and the NPV also increases and the payback period almost remains the same. We can also see the effect of the IRR NPV on the selling so this gives us like how the electricity would be sold and also like if the electricity selling price which I assumed to be 15 Rs.

I bring that to around 10 Rs. in this case we can see how the IRR comes down the NPV comes down and the payback period increases. So these are the kinds of analysis that the management of the company would be doing to understand like what could be the different ranges in which the electricity could be sold. So the LCUS basically gives you the levelized cost of production of electricity whereas it does not include the taxation and the other financial parameters which come into being when you do an IRR and NPV calculations. So this was just to give an understanding how this different kinds of parameters will be used together to give us some meaningful results. So coming back to the slides let us try to understand how this results for the 5 different types of storage compared among themselves.



So the comparison for the levelized cost of storage can be seen on the upper left hand side where you can see the blue basically reflects the lithium ion batteries then the red is pumped storage. The green refers to thermal energy storage, the purple refers to the vanadium flow batteries which is another kind of batteries and the light blue color basically refers to the compressed air storage. So if I am neglecting the electricity by price and I am just assuming the price of storage where I am not including the price of the what electricity we can see that the cheapest options would be either the pump storage as well as the compressed air. And both of them this is just the basically the operating and the capital expenses being normalized over the lifespan and this is the average rate at which electricity would be available. Again mind you this does not include the charging of electricity with 3 rupees.

If I were to include the charging of electricity as well the result would be a bit different. We would have the pump storage coming out to be lowest at 7.88 rupees and then the thermal energy storage and the compressed air the batteries being on a higher side somewhere around 13 and 14 rupees and these are comparable to the normal market figures as well. What you see here that the cost of thermal energy storage would not change because that kind of storage is not being charged from electricity. It is basically the extra thermal energy that we are able to generate at a site and we would be able to use. So you will see in all the 3 scenarios the green or the thermal energy storage remains constant. So if I have the electricity coming at 3 rupees a kilowatt hour probably I would go with solar sorry pump storage type of storage. But again that might not be a realistic case as well. Although companies can sign in a long term power purchase agreements but there might be some escalation as well. So if I consider the escalation of electricity as well like 3 rupees at the base price and 3% as an annual escalation we can see the results would again differ. We would have the cheapest option would be thermal energy storage then comes in the pump storage and then comes the compressed air. The batteries being again on a higher side. Here in we can see based on the different assumptions we could have different types of energy storage giving us the best result. If I do not consider the any electricity charging price or escalation compressed air comes out to be the best but given that it is not as efficient as pump storage it loses when I go towards the inclusion of electricity as well. So these are some results that one could derive and also you can see a comparison between the IRR and NPV of these types of storage. So we can in the IRR we can see that the pump storage would have the maximum IRR but the thermal energy would have the maximum NPV given an electricity sale price of 15 rupees and the power capacity in this case has been assumed to be 150 megawatt for 4 hours. So almost 600 megawatt hours of total electricity. Again this was just to give an understanding like these kinds of decision making can be a bit complex. It could have many parameters coming into being and the interplay of parameters is something that needs to be understood. Now coming to these kinds of project one would be interested to know like who would normally finance these kinds of projects.

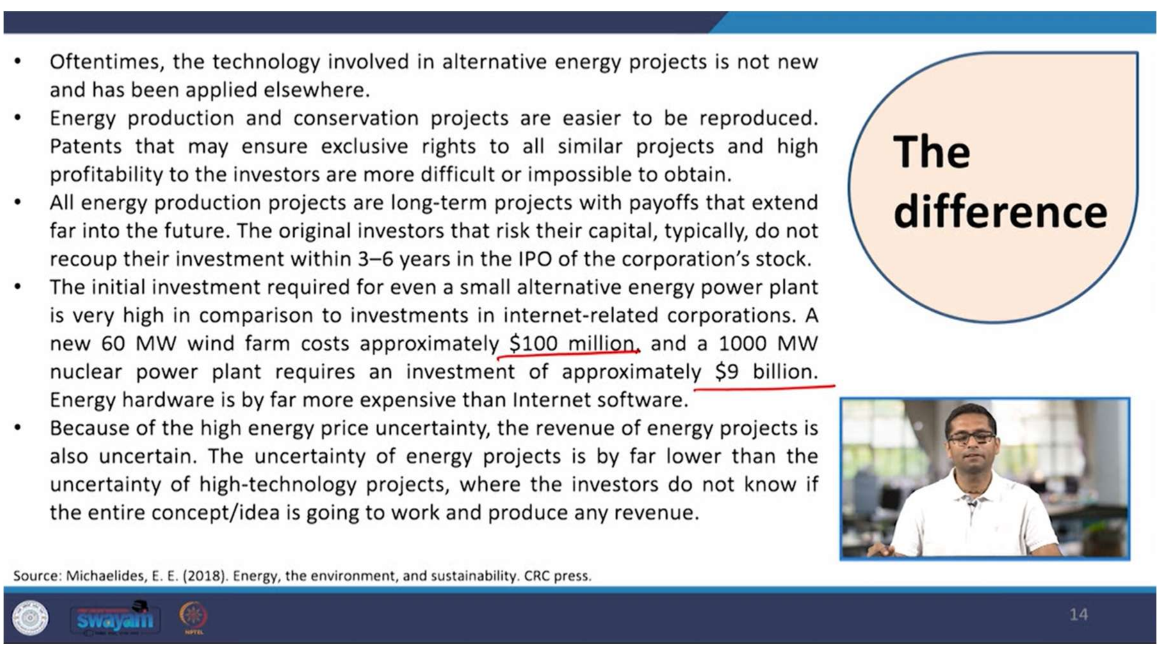


So these kinds of projects are very capital intensive where you have many 100 crores of investment going into it. Some of them can be relatively risky as well because of the changing policy scenarios. And another instance that brings in the aspect of uncertainty is the long life of these projects. So the typical PV panels are expected to last for around 30 years or so, something same for the wind energy farms 25 to 40 years. Fossil fuel plants we have seen in our country have been upgraded so that their life has been extended.

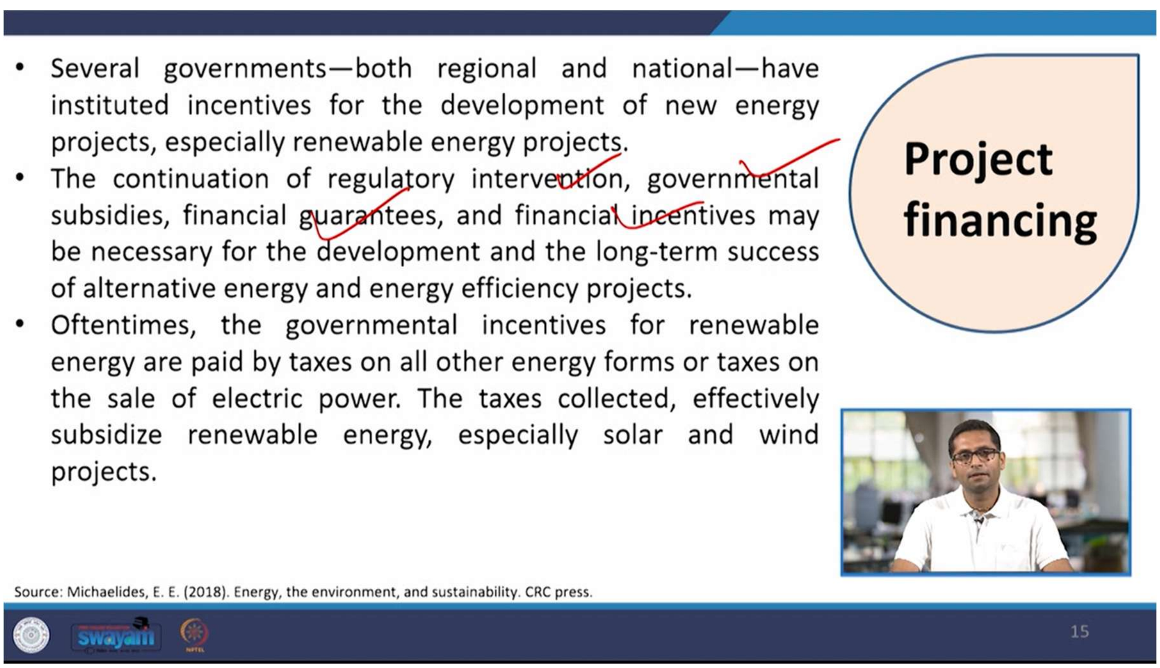
So there have been plants that have been operating more than 40 years. Nuclear power plants in the developed world we can see have been running for around 50 years or more. And then hydel power plants we all understand can have much more life which can span from around 100 to 150 years. So all these aspects make like the decision making or project financing in the avenues of energy related projects a bit complicated. If we try to compare that with the past two decades where we have been seeing an economic revolution, we have seen a lot of startups coming in becoming unicorns, raising a lot of capital, having a good amount of market valuation.

But we need to differ ourselves like do these things also apply to the energy domain. The answer precisely would be that it would not be very similar. If you see at most of the startups that came up in the last two to three decades and became a joint corporates like Google, Apple, Amazon, Weeboo or Yahoo, not Yahoo and they were based upon some basic tools which had a wide application but they were built on simple computer programs. They had a very nice idea but the input or the startup money that was required was pretty small. So what normally happened was there are investors called as the angel investors which would probably give you a few thousand dollars based upon your idea where you can start up your concept, come up with innovative computer programs, website applications which could have a wide acceptance among the audience.

When the idea gains a good traction, you would have the venture capitalists coming to the scene which don't mind putting in a few million dollars for your startup so that you can hire a lot of people, you can do a lot of advertisements to reach the markets and try to establish the product. And what normally happened with a lot of these products would fail but even among the products that don't fail, the return that the capitalist or the venture capitalist would come up would normally be of the rate of around 10 to 1000 times of the capital that they would have invested. So normally the returns are quite fast to be realized. So normally what would happen is the startups that go well normally would have an initial public offering or the IPO coming in 3 to 6 years where they would be trying to raise money from the market and if the company is successful, the venture capitalists would be able to recover a good amount of the money that they have invested with a good return as well. Not all of these startups are expected to be successful but even among the few that become successful are good enough for the venture capitalists to make up for the gain that they are expecting.

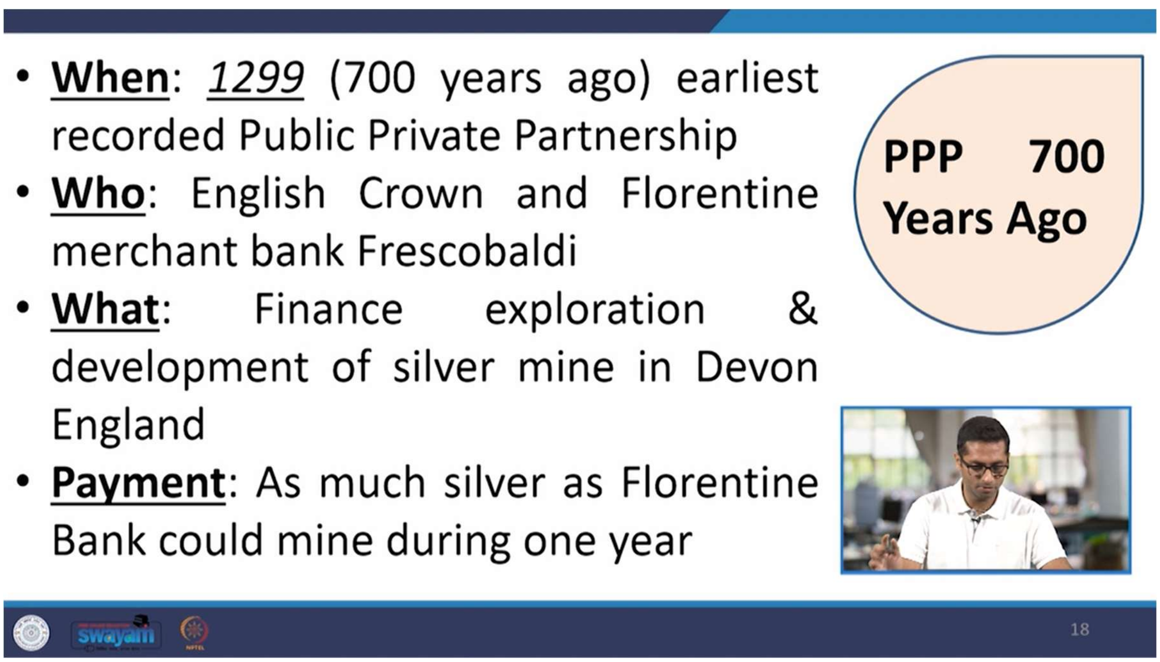


Now coming to the scenarios for the energy projects, the energy projects normally would not have a good amount of innovation involved because the technologies being in the form of different renewable energy technology as well are pretty established ones. So this would not call for a very innovative idea. Further the capex that is involved as we have discussed will be very huge. Normally a normal wind farm would have a capex somewhere around 100 million dollars and it could extend to around 9 billion dollars for a nuclear power plant. Further as compared to the earlier case where you can see that most of these companies would come up with an IPO or realize the capital in 3 to 6 years, this is quite difficult for a renewable energy based project because the typical life would span from 30 to 40 years or even more. There is also a huge price uncertainty in the market given on the geopolitics that occurs, the different kinds of scenarios that are being created because one country going to war with another can spoil the whole business model that you would have envisioned for the future few years. And this brings in a lot of uncertainty which the people are a bit reluctant to invest in. So that is why you don't see many startups coming in the energy field. So one might want to understand like who would then really invest in a project like this.

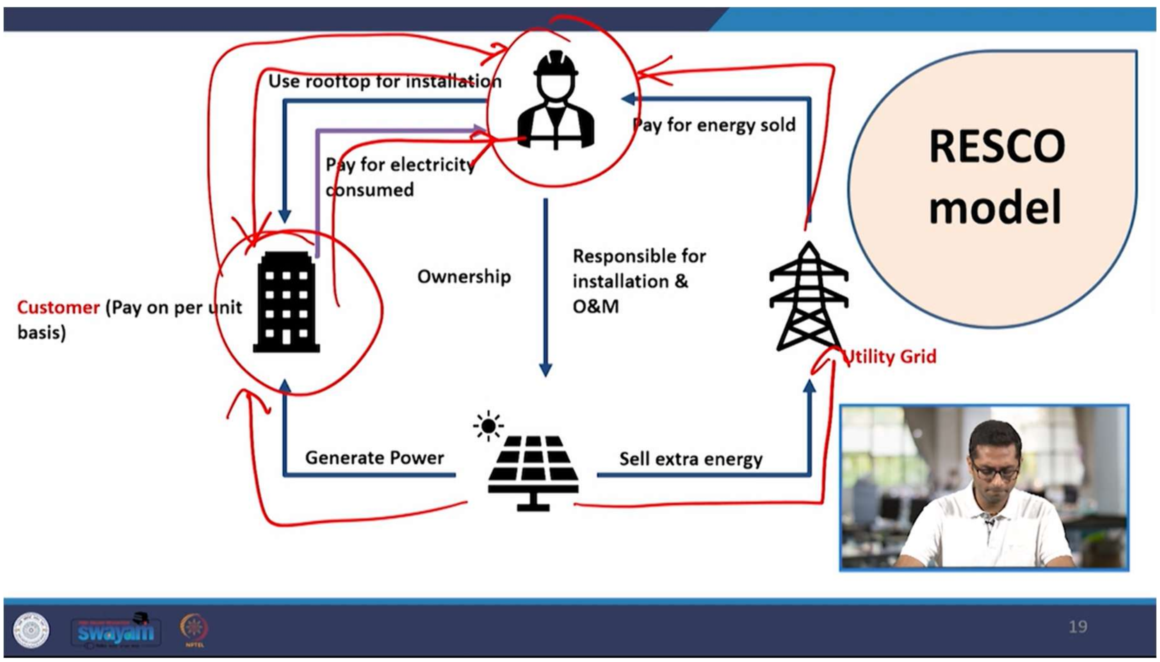


The answer would be it comes from the governments like many of the governments, the regional and the national governments see these projects as the projects for national importance and would want to fund these projects because these projects basically would guarantee the energy independence of the population and the projects that the population undertakes.

So the government would come up with the different kinds of regulatory interventions, some of them were like the tax credits or the tax incentives or the government subsidies, the financial guarantees or the financial incentives that might be necessary for the development of long term success. So we see a majority of the renewable energy projects, the government incentives are there and they could be in the form of the different kinds of policies, the tax rebates and this is what makes the projects very successful in the long run. Also there have been other kinds of models which would involve the public and the private financing of the renewable energy projects. So one such is the RESCO model but before discussing the RESCO model let us first go into the history of project financing. So project financing basically started almost 700 years back and the earliest record of project financing was like the one between the English Crown and the Florentine Bank at Frescobaldi.

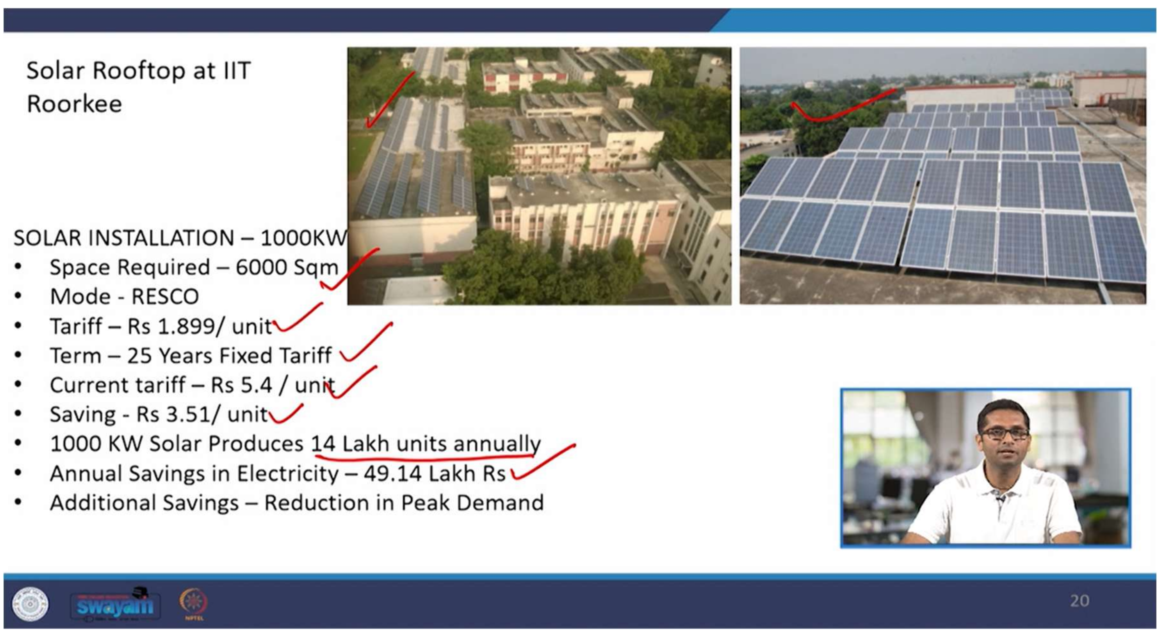


So what happened was like the English Crown in the UK wanted to explore a silver mine in Devon, so it needed finance for exploring the silver mine. So what it did was it approached the Florentine merchant bank which was called Frescobaldi 700 years back and asked it to make up for the like put the money in the mine so that the mine could be extracted and in return of the payment what the Florentine Bank can do it can extract as much silver as it can in the first year. So the agreement was such that the Florentine Bank will put in the money for the mining for the development of the mine and as a return for putting in the capital the Florentine Bank was free to dug as much as silver as it could in one year. Beyond that all the silver that remained in the mine belong to the English Crown and they can extract it later. So this is how public private financing has developed 700 years ago and it still is being carried out and some of the instances could also be seen in the renewable energy market.



One such instance in the renewable energy market could be the Resco model which is the renewable energy service company. What you have in here is you would have a company that would put up a plant say in this case it could be a solar PV plant. So the plant is owned by this company and it is also liable for the operation and maintenance of the plant. Where does it put up a plant? It puts the plant in the house or a building of the customer which provides the land the required land for putting of the plant and what does the customer get in return for the land? It is getting the clean power that is generated and the customer is also paying for the electricity that is generated at a known tariff. So normally this tariff that is the customer has to pay is cheaper than the market rate and the customer also gives the rooftop for the installation.

So all the things the investment from the customer is that he will give the land that is requirement and further it also enters into a long term agreement with the supplier that it will be buying at the electricity and so and so price. What does the company get in return? Well it gets to sell the extra electricity to the grid and make money out of it. Further it also gets the payment from the customer at the agreed price and the price of the electricity is such that the company makes the profit in the long run. Further the company is also making profit from the different kinds of subsidies that the government has for the renewable energy projects. So these kinds of projects have been running in the country and one such project is there in IIT Roorkee where we have almost 1 megawatt of solar installed on the rooftops of different departments and buildings.

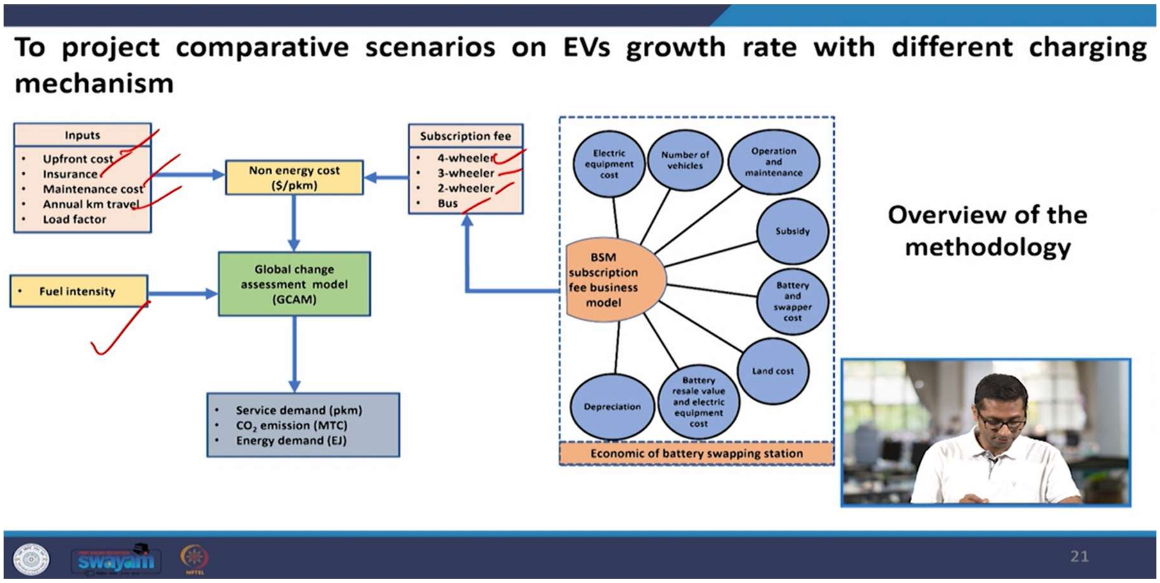


So you have some of the rooftops you can see in here. So these rooftops were installed in the Resco mode. So the space required which was around 6000 square meter was given by IIT Roorkee to this firms. The tariff which was selected was around 1.899 rupees or 1.9 rupees and this was applicable for a term of 25 years. So for the term of 25 years IIT Roorkee will be buying the electricity that was being generated from the solar PV panels at the rate of 1.9 rupees a unit or 1.9 rupees a kilowatt hour which is significantly less than the market tariff of around 4.5 rupees.

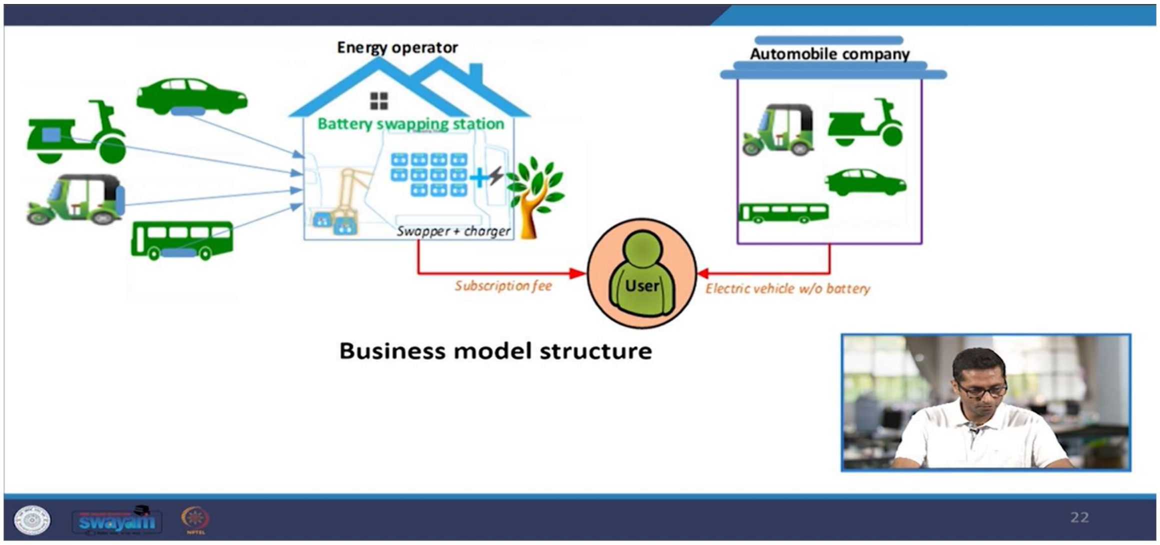
And so the savings in terms of electricity that came to IIT Roorkee was around 3.51 rupees that could be huge. The only thing IIT Roorkee had to give was the land in that form of the rooftops that were available in the different buildings. And overall the total plant produced around 14 lakh units annually and for IIT Roorkee the total savings come to the tune of around 50 lakh rupees and that could be huge a year. Further it also helps the institute go towards sustainability because it is having a reduction in the peak demand. Further the electricity that is being generated from a plant like this comes under the larger domain of renewable energy or green power that helps in the progress of the sustainability of the institute as a whole.

So this is an example with respect to the application of RESCO model and these kinds of application can be found in different parts of the country as well. Further to the previous example of the RESCO mode there could be other kind of innovative models that can come up for different kinds of energy related technologies inception into the market. One such methodology could be through innovative business models and we have taken care in this case through the battery swapping mechanism. So just to give you an understanding normally it is expected that EVs would come up at a good rate in the future and one of the key things that holds the EVs back is the charging time that it was required and the charging infrastructure. So one particular solution to that has been proposed by the different think tanks is the use of battery swapping mechanism.

So what happens in a battery swapping mechanism is that you would go to a charging station where you replace your discharge battery and pick up a battery that has been charged just replace the battery in a span of few minutes and the vehicle should be good to go. Compared to a normal charging mechanism which could be fast charging or other kind or wireless charging can span from around half an hour to a few hours. So this kind of mechanism could have considerable time savings but further the technical aspects of these kinds of charging mechanism are still not widely agreed upon. There is no single charging infrastructure, the size of the batteries or type of the swapper that has been accepted by the different kinds of industries or the different automobile industry players. But let us try to explore that if in the future the EVs were available for you to buy without the batteries and to add the batteries almost make up from 30 to 50% of the total price of an electric vehicle.



This brings down the price of the EV quite drastically and in return possibly you can rent in an EV using a tariff which could be the subscription free from a BSM player which could be the battery swapping mechanism cooperation. So we did try to make a business model like this where we would have a business player that would set up a plant which would have the capacity of charging around 100 batteries for 100 plus EVs in a day or so. And this kind of mechanism is expected to make things more lucrative for the EV buyer and given if these kinds of mechanism was in place in the market and given the cost economics we would want it to understand how the propagation of EVs would be expected to grow in the future. So what we try to do is we try to come up with different business models with respect to battery swapping mechanism and given the battery swapping mechanism subscription fee model which the user would have to pay what could be the change in the EV adoption in the future in the Indian market. So we made a business model and we tried to do this for all the kinds of EVs which included the 4 wheelers, 3 wheelers, 2 wheelers and the buses. And we also took into account the upfront cost, the insurance, the maintenance cost, the kilometers that was travelled, the fuel intensity and we try to understand the effect of overall thing using an integrated assessment model which was GCAM on the service demand, the CO2 emissions and allied things.

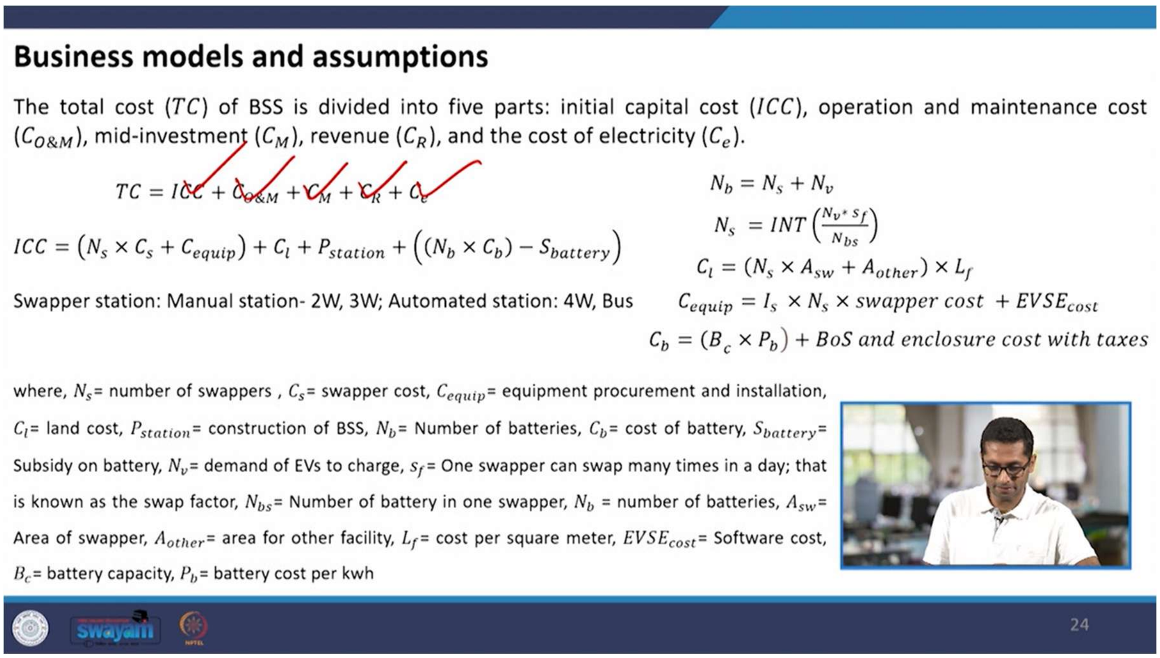


So for the business model to explain you better it is something very similar to the gas cylinder that you would rent in your home. So you do not own these cylinders perpetually but you rent it for subscription fees. Something similar could be in the case of the battery swapping mechanism where you are renting in a battery and you change the discharge battery with the charge battery and you pay a monthly subscription fees. And the subscription fees could be different for the cars, 2 wheelers, autos, buses as well as the commercial vehicles as the private vehicles based upon the usage frequency.

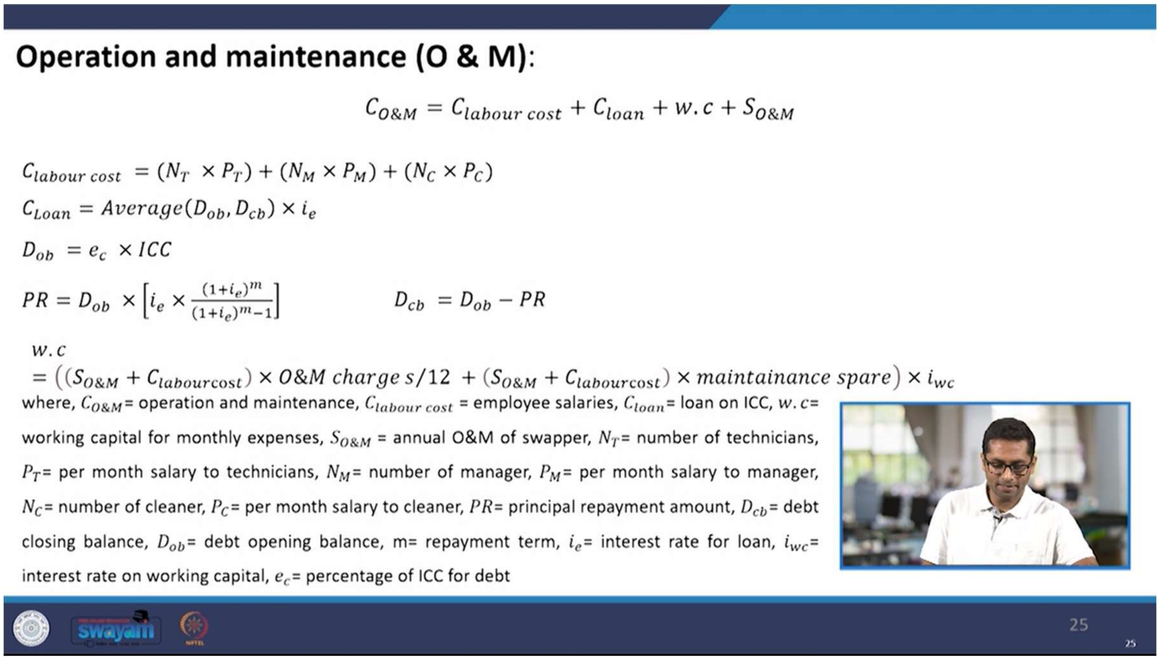
Proposed scenarios of the study

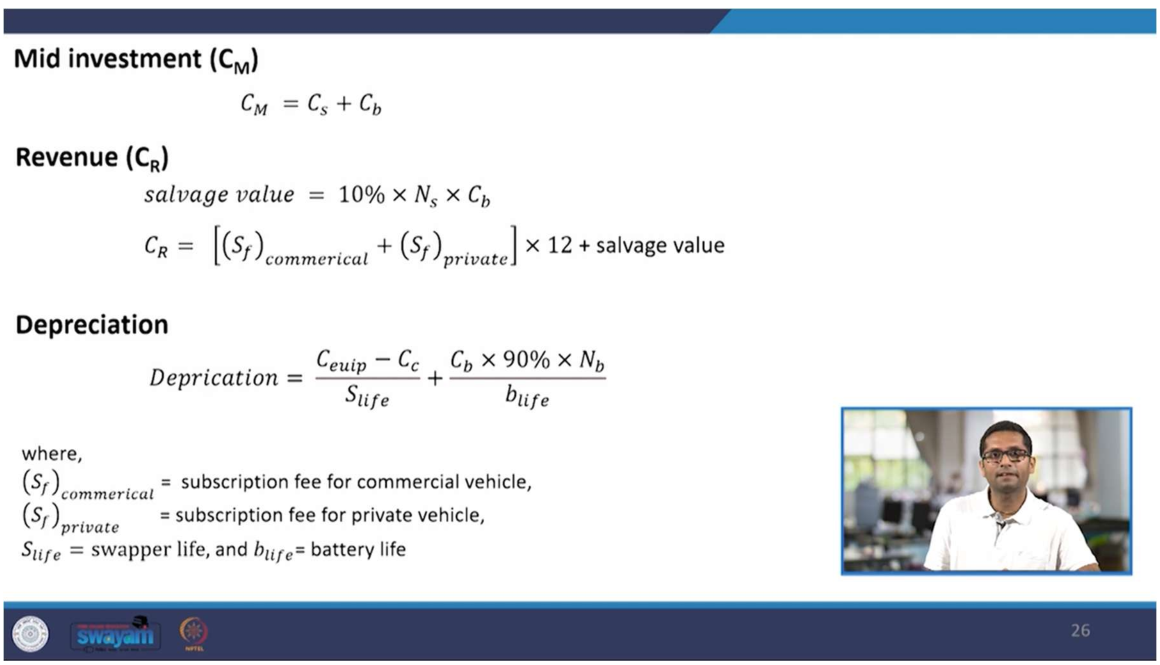
Scenario: 1	Scenario: 2	Scenario: 3	
EV_PC	EV_BS	Scenario 3.1: EV_BS_50%	Scenario 3.2: EV_BS_100%
• Point charging (pay as use) • Buy EV with battery • 100% vehicle charged from PC	• Battery swapping (subscription fee) • Buy EV without battery 100% vehicle charged from BS	• 50% subsidy that is currently being provided for EV_PC	• 100% subsidy that is currently being provided for EV_PC
*Passenger sector: 2W, 4W, 3W, Buses			

So a model was created and we wanted to compare that with conventional first fast charges and also try to understand the effect of different kind of subsidies that the government can bring in. So the subsidies we have chosen was like 50% of the current subsidy on EVs with point charging and 100% of the subsidy that is equivalent to the current market. So currently there is no subsidy in battery swapping mechanism. So this is how the business model looked like.



The total cost included the initial cost, the operation and maintenance cost and the cost of mid-investment, the revenue that is generated from the subscription fees and the cost of electricity. The initial investment would include the batteries, the buying of the station or leasing the land for that, the buying of the swapper which is the mechanism that would change and the discharge battery with the charge batteries. So I would not go into details of each and every component but this is just to give you an understanding. The operation and maintenance cost would include the labour cost, the loan that you would have taken, the working capital and other O&M costs. Then there could be a changing of the batteries and the swapper in the mid. So the life of 28 years has been assumed and the battery life is assumed to change to be of around 5 years or so.





The swapper would be changed in another 14 years or so. Then we can also have revenue from the salvage of the used batteries that happen after 12 years. Further we have taken simple depreciation, a straight line depreciation in the case like this and we have used the simple formulas for NPV as we have discussed before. And this is how the business model looked like for the different modes like the 4-wheelers, 3-wheelers, 2-wheelers, buses.

NPV calculation

$$NPV = \sum_{t=0}^{n}(R - E)(1 + i_d)^{-t}$$

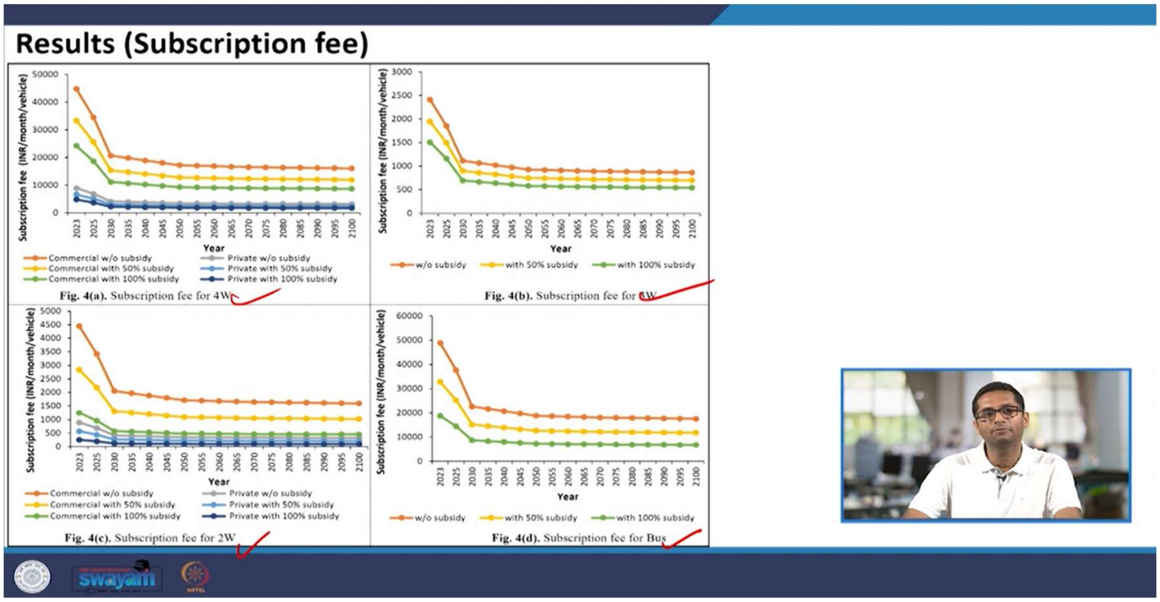
$$\text{Outflow } (E_t) = \begin{cases} ICC, t = 0 \\ EBITDA + IT + MI + C_{Loan} + w.c, t = 1,2,3 \ldots \ldots (n-1) \\ EBITDA + IT + w.c, t = n \end{cases}$$

$$\text{Inflow } (R_t) = \begin{cases} S_{battery,} \; t = 0 \\ C_R + Salvage\ value, t = 1,2,3 \ldots \ldots (n-1) \\ C_R + Salvage\ value, t = n \end{cases}$$

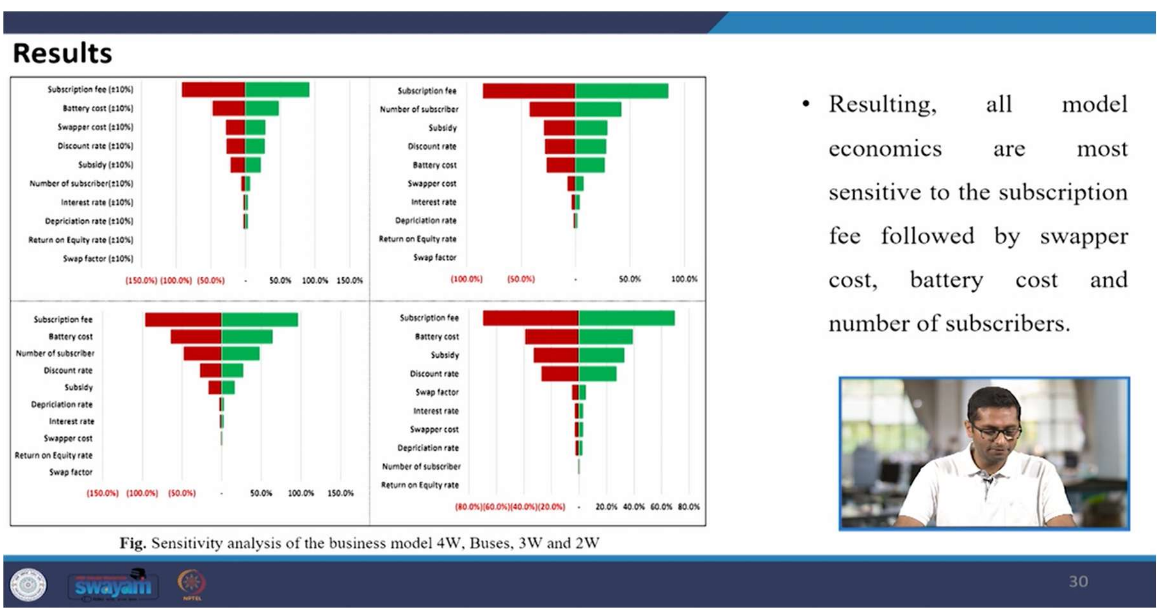
Business models and assumptions

Parameters	Unit	4W	3W	2W	Buses	References
Station capacity	number of vehicles/days	100	100	100	100	
Station service life	year	28	28	28	28	[1], [2]
Initial investment	10^6×INR	101.85	7.5	9.0	87.51	
Floor space	m^2	132	47	47	430	[1], [2],[3]
Battery capacity	kW	30.00	5.00	2.50	160.00	
Battery life	year	7	7	7	7	[4] [5]
Swap factor	times	1.30	1.60	1.50	3.00	[7]
Result	without subsidy					
NPV	10^7×INR	3.7	0.3	0.6	8.3	
Subscription fee (S_f)	INR/per month/ vehicle (Year 2025)	•34478.46 * 6,889	•1855.19	•3419.67 * 683.93	•37,619	
Result	with subsidy (50% subsidy that is being provided to EV_PC)					
NPV	10^7×INR	2.2	0.2	0.4	4.3	
Subscription fee (S_f)	INR/per month/ vehicle (Year 2025)	• 25,672 * 5,134	•1496.94	•2181.49 * 436.30	•25,164	
Result	with subsidy (100% subsidy that is being provided to EV_PC)					
NPV	10^7×INR	0.7	0.01	0.1	0.9	
Subscription fee (S_f)	INR/per month/ vehicle (Year 2025)	•18653.42 *3730.68	•1158.16	•959.66 *191.93	•14432.00	
*Private vehicle, •Commercial vehicle						

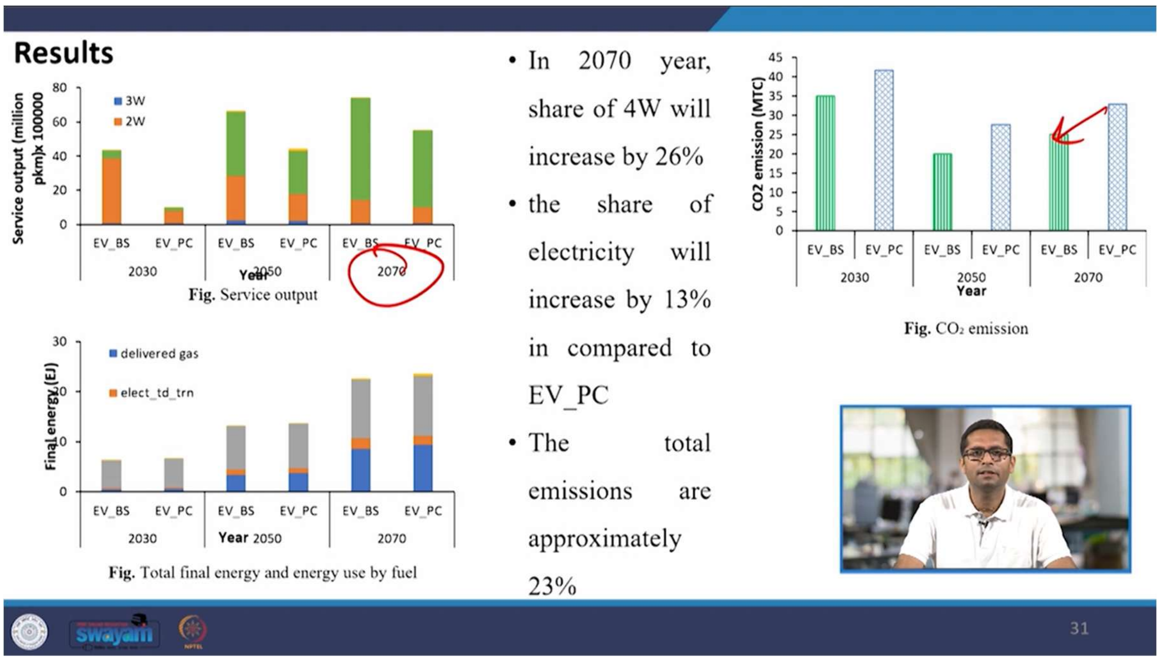
It was assumed that it would have around 100 vehicles per day. It is lasting for 28 years. We know the flow space, the capacities of the battery was around 30 kilowatt and then we also had the NPV calculated for the different modes based upon the subscription fees. So we could calculate the subscription fees both for the private and the commercial ones. So both of these are applicable to 2-wheelers and 4-wheelers. 3-wheelers anywhere are commercial and the same has been assumed for buses as well. So you would see for a private one, the subscription fees was around 7000. For a commercial it was come out to 37000 or so. Something similar for 2-wheelers and both private and the commercial ones.



And based upon that we can also see how the subscription fees are going to change in the future. So these are the results for 4-wheelers, 3-wheelers, 2-wheelers and buses respectively. We are expecting that there is going to be a drastic reduction in the price of batteries in the future and the subscription fees is linked to the battery price because this is where the investment is happening and that is why you can see after 2030 the subscription fees would be changing.



So the subscription fees that we have come up is very dynamic in nature and normally we would also calculate sensitivity and we can see like subscription fee which is the major source of revenue would be the most sensitive parameter for the all 4 modes. Further we would have the battery cost and the swapper cost which is the capex changing the business models. The subsidy from the government can also have a drastic effect in this case on the business model.



If you go towards the result we put in this input into the GCAM model which is a integrated assessment model and we found that on a 1 year basis of capex we can see that the battery swapping can help us in increasing the intake of EVs by a good extent. The reason being like for the upfront cost if it takes us 1 year as a cost and the battery swapping appears to be cheaper and people might want to adopt it based upon the standard methodologies and further this can also help in increasing the EV penetration till the year 2070 which is the net zero target for India and given that the EV penetration is increasing you could also have somewhat of a CO2 reduction going further.

But again this is based on the assumption that people would value their time more than this and don't mind paying a subscription fees throughout the life. So this is based upon that underlying assumption. But just to give you an example that there could be different kinds of innovative business models that could be coming up which could be related to the energy industry and this is one such option. So with that we would like to end today's lecture. In today's lecture we have tried to understand another matrix for the financial appraisal of a project which was the life cycle cost of electricity.

We have also discussed the different kinds of project funding mechanisms but could be the innovation how they are different from the conventional funding of startups and with that we would like to end today's lecture. Thank you.