Fundamentals of Electric Vehicles
Technology and Economics
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Lecture 24
Li-Ion Battery Cells

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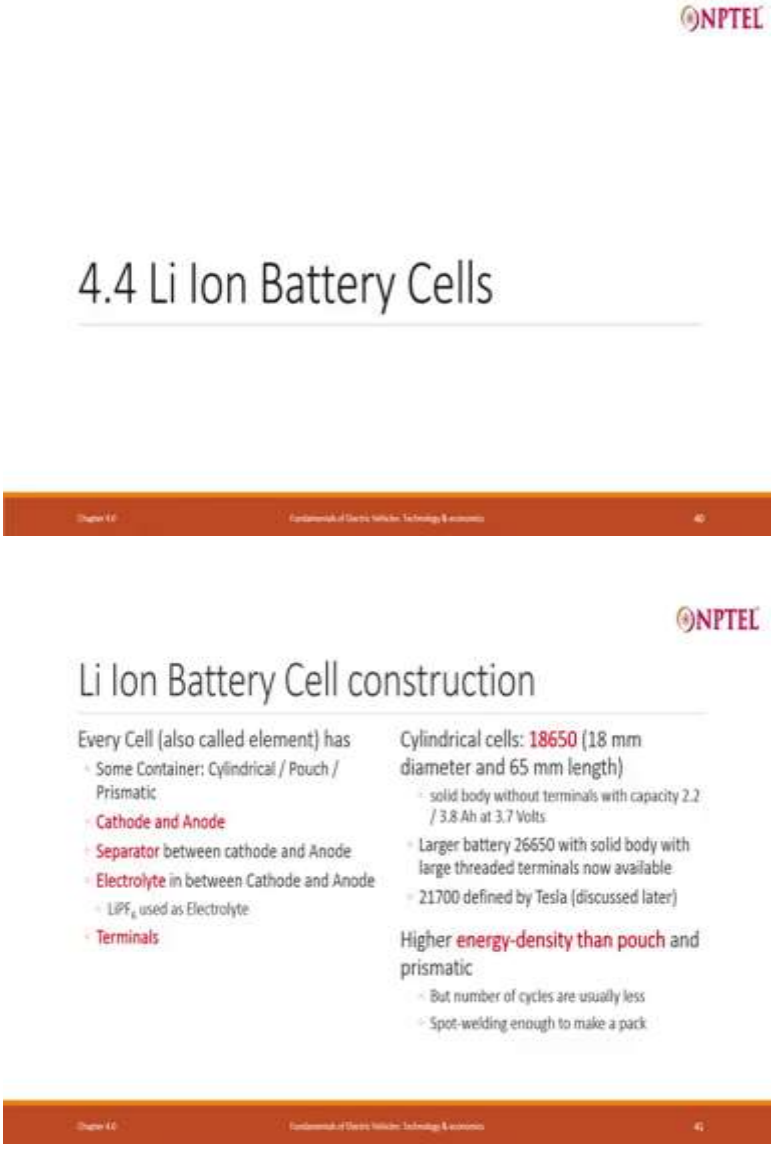

Now I am going to go into I have talked about the future batteries I have talked about alternate various kind of lithium ion battery let me get into the cells or lithium ion battery cells. And what does it consist of, I have talked about every cell has some container, the

container of 3 kinds; cylindrical, pouch, and prismatic. The 3 kinds of container it is either a cylindrical cells, I think I should have picture somewhere.

I will get into the picture in a short while. Cylindrical; like a pencil cylindrical, pouch and prismatic we will get into that, that is a container, it always has cathode and anode. So, anode typically tends to be graphite or graphite with silica. Cathode is the one which is NMC or NCA there is the separator between cathode and anode and there is a electrolyte in between cathode and anode.

And the one that is used is lithium phosphorus fluoride that is the most commonly used. There are a few other alternatives, but nothing as (())(01:28) as well. Then there are terminals, which will and the terminals has to be very well designed, because they will take in the current or take out the current.

Cylindrical cells; the most common cylindrical cells which are used is called 18650, 18650. Basically, because it is 18 millimeter in diameter and 65 millimeter in length 6.5 centimeter it is like your pencil torch cells, solid battery body without terminals with a capacity of, it started with 2.2 ampere hour and it has gone to 3.4 and 3.8 ampere hour today.

Today 3.5 ampere hour is common 3.8 is also available, the battery voltage nominal battery voltage or usage is 3.7 volts. So 3.7 volts multiplied by 3.5 ampere hour that is the capacity, it is a 10 watt hour approximately, 10-11 watt hour is not a very large capacity each cell is 11 watt hour. See, if I want (1000) 1 kilowatt hour I need a close to 800-900 cells. If I want 100 kilowatt hour, I need 100 thousand individual cells.

And remember, I will again talk about, a cell fails battery significantly get impacted we will come to the failure later on. There is another called 26650, which is 26 millimeter in diameter and 650 millimeter in length, is that correct? Sorry 65 millimeter in length, but 26 millimeter in diameter, solid body last 3 terminals at the end. This was for short time, for tools etcetera it was used, hand tools.

And then Tesla came at 21700 it is a 21 mm diameter, this is maybe I do not know 70 is the really the length but approximately that, this will be discussed later again. Cylindrical cells have higher energy density than pouch and prismatic, when it is introduced. So as the first 300 watt hour per kg cells will always be cylindrical cells, but soon pouch and prismatic will pick up. But number of cycles are less. All you need is a spot welding to make a pack. So very easy to make a pack.

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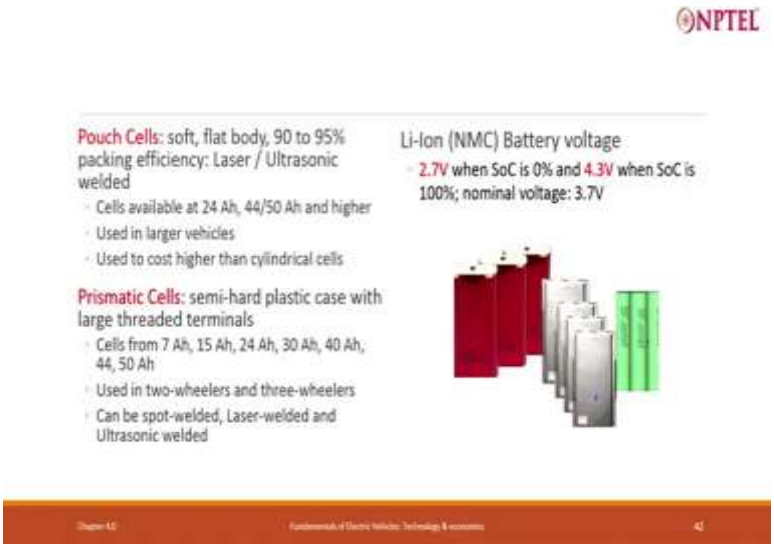

So, this is what the pictures are, this is the cylindrical cell, this is a pouch cell and this is prismatic cells. The pouch cell is soft, flat body soft. You will in fact, twist it if you want ofcourse it will destroy the battery. It has a very high packing efficiency.

Even this density is less in the pack you can make it much-much better, 90 to 95 percent it is one out the top of another, all that you then do have to do is conductors which you put it on the site. So, the conductors or bus bars and then ofcourse cooling you worry about because the heat is also dissipated from the side you have to worry about the coding.

You have 24 Ah, 44 Ah, 50 Ah and nowadays even 60 Ah or 70 Ah. Normally you do not change the size of the remains the same and you keep on increasing the energy density because as the energy so, the Ah capacity increases. I have seen now 60 Ah and 65 Ah

and 70 Ah you will soon see. It used to cost higher than cylindrical cells but not necessarily. In larger vehicles you invariably use pouch cells.

Then there is a prismatic cells, this is a semi-hard plastic case with large threaded terminals. Cells are 7 Ah, (14) 15 Ah, 24Ah, 30, 40, 44, 50 and let the new ones are 60, 65. A lot of them are using 2-wheelers and 3-wheelers can be spot welded, laser welded or ultrasonic welded, even pouch cells has to be laser welded or ultrasonic welded. Spot welding somewhat difficult, so this is the three kinds of cells that are available.

There are pluses and minuses, it depends on the manufacturer, do not cannot say that this is what you should use always. Lithium ion battery, the NMC battery that we will talk about is 2.7 volts, when it is 0 percent SoC and 4.3 volts when SoC is 100 percent and typically you operate between 3.1, 3.2 volt sometimes 3.3 volt to 4.15 volt and the nominal voltage is taken as 3.7. This is the battery cell capacity sorry, this is a cell voltage. So, this is the voltage multiplied by Ah will give you the capacity in terms of watt hour.

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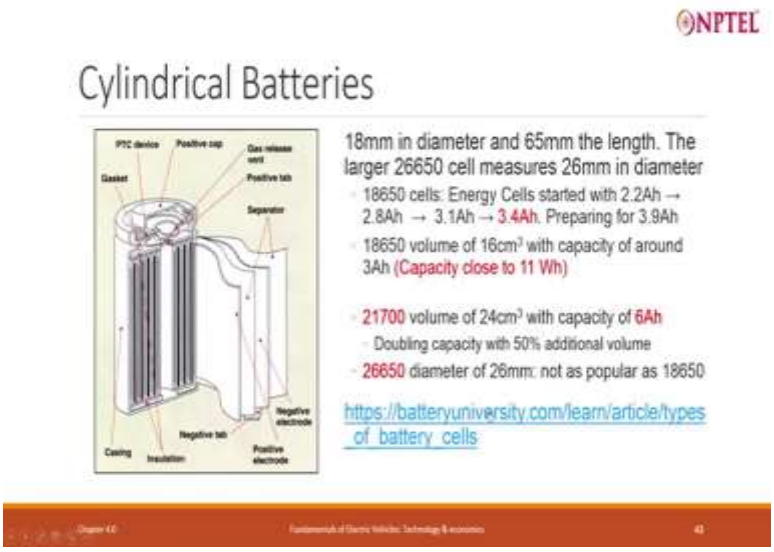

So let us look at the cell. So, the cells are designed by taking material and rolling it, rolling one layer after another. So, typically, you have this positive electrode, negative electrode. You have this negative tab.

You have the separator in between the positive tab is sitting here there is a gasoline vent because there is a gas filled in something goes wrong gas is released. There is a positive cap, PTC device, gasket, casing, insulation etcetera. 18650 as I told you the most common one is 3.4 Ah though 3.9 Ah is also likely to come 18650. So, 18650 volume of 16 centimeter cube with a capacity of around 11 watt hour.

So, you can just imagine this is what it is. 21700 has higher 24 centimeter cube volume with a capacity of 6 Ah This is going to 6 Ah, so it is doubling the capacity with 50 percent and additional value that is the one which has given at edge, 21700 it doubles the capacity with only 50 percent additional volume.

So, capacity 6 Ah instead of 3 Ah the size is only doubles 24 centimeter cube as opposed to 16 meter were size only one and a half times Okay, this is the attraction, okay, 26650 is 26 mm diameter not as popular as 18650. Again you can get more details in this battery university.

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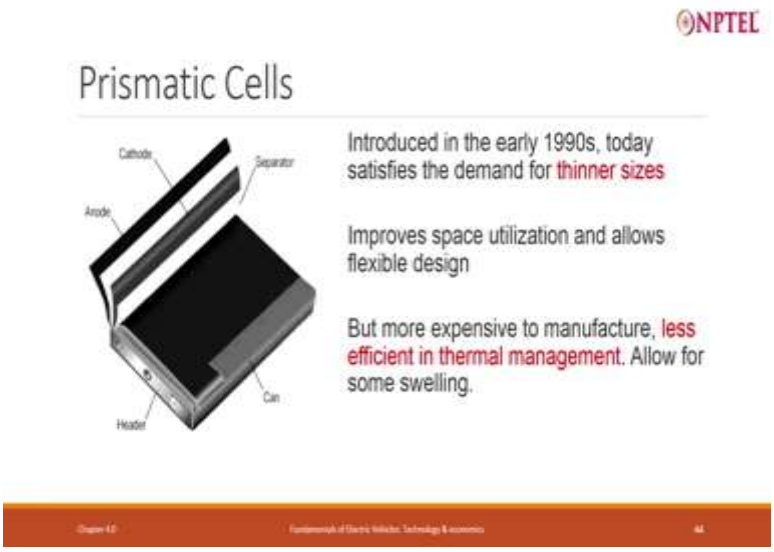

Prismatic cell; this was introduced in 1990s. And prismatic this is the one which is very thin. How thin? Much thinner than a cellphone about a third, no way half, almost half as much. So and since it is stacked on top of each other, it improves the cell utilization,

space utilization so volume can be low of the pack. Whereas if you look at cylindrical cells between cylindrical there will always be gaps, cannot do much.

But it is far more expensive to manufacture, you cannot just keep rolling and creating cells, you have to keep on folding one after another keep folding and thermal management is less efficient because while the heat is generated all over you can take out heat only from the sides, because it is going to touch the next one and next one, one on top of it.

The other problem in this prismatic cell that as you charge fast particularly it tend to swell and the swelling can be very problematic. If it swells beyond a certain point that life cycle gets horrible, finished, so you have to compress it, it has a swelling tendency inside you have to compress it. You put extra pressure life cycle is gone straight away, you put less pressure it will swell in a life cycle goes out, gets bad.

So you have to really design it with the right pressure, really right pressure. Sorry, that is that is either I am mixing up cylindrical cell and pouch cell.

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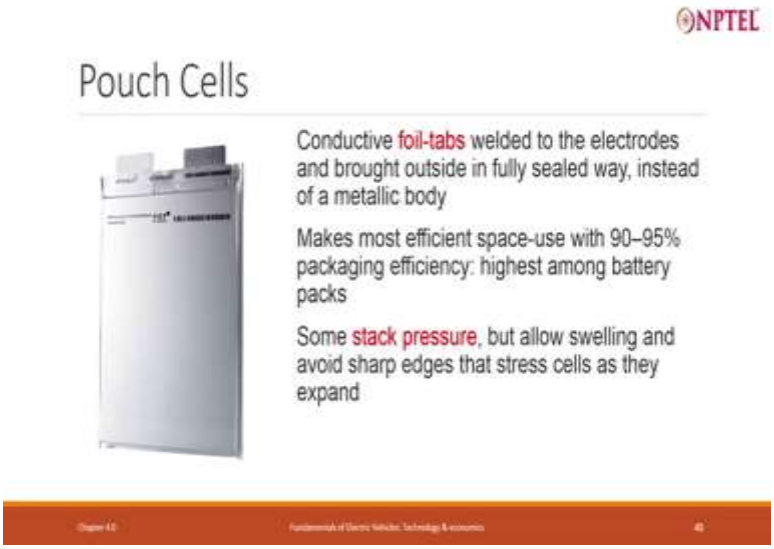

The pouch cell has similar issues, conductive foil-tabs welded to the electrodes and brought outside in a fully sealed manner makes most efficient even more efficient than prismatic cells. This is the one where pressure is very important (not) the other one is

aluminium k, so the pressure is not that important. Yeah, but still yeah plastic also not as important, the pressure is not as important somewhat important, but more important in power cells.

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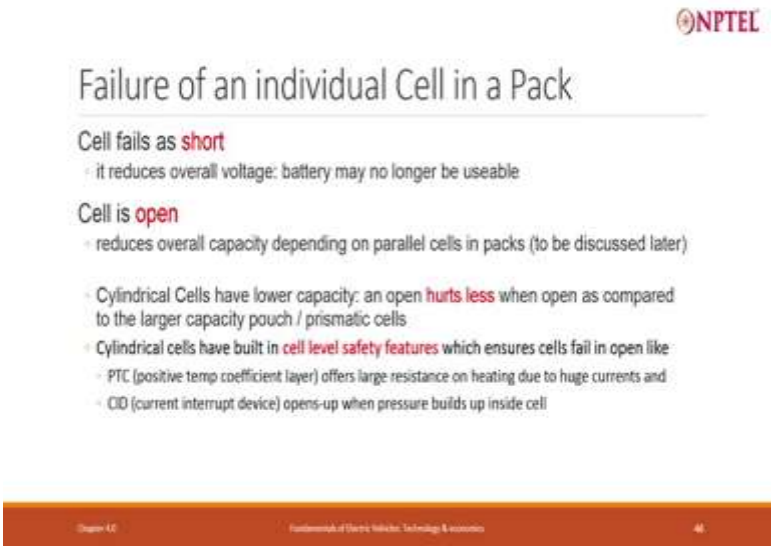

Let me come to some very interesting work, which will not find it anywhere. You have a battery pack and cell for whatever reason has shorted. For the pack, if a cell has shorted and cells are connected in series, the voltage reduce and if I have to drive a motor which demands a certain voltage, my voltage has gone down cells pack is no longer usable. So pack is no longer individually usable if one cell gets shorted, that is a big-big problem.

So you do not go on cellphone failure as shortage. What if the cell is open it reduces the overall capacity and this will be discussed in detail later on. It depends on the way number of parallel cells are there, that one string will go and cells is open. Cylindrical cells have lower capacity and open hurts less than open as compared to the larger capacity pouch and prismatic cells.

Since a lowers capacity, or open if it is short your problem but it is open it reduces capacity, since it has a lower capacity that much capacity only goes down. So if it is a let us say 310 A watt hour capacity. So or 3 Ah into whatever the voltage is that 3 Ah will go down it has many parallel cells.

The other advantage cylindrical cells have built in cell safety feature which ensures a cell fails in open, it does not fail very often in short, there is something called positive temperature coefficient layer offers large resistance on heating due to huge current so normally if it is getting heated because something is going wrong.

So, it kind of prevents it and there is a current interrupt device which will open up at that time when there is a when pressure builds up inside the cell. So, there is a this makes it better.

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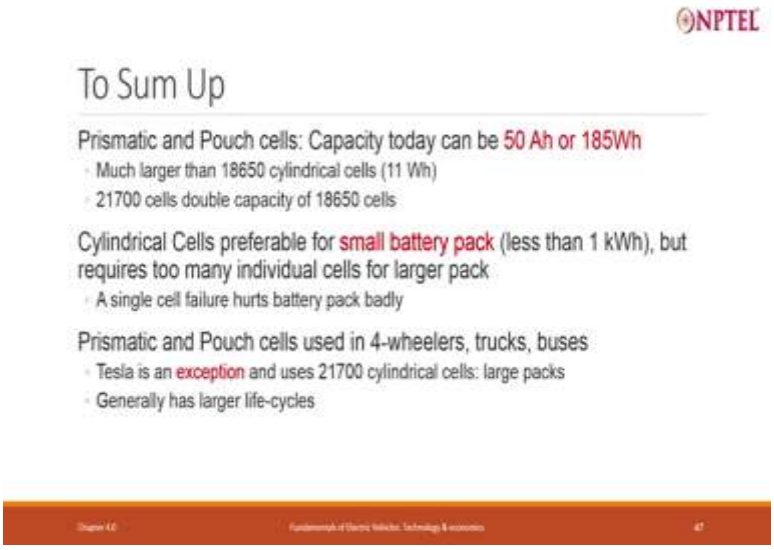

To sum up prismatic and pouch cells, capacity cells are can be 50 Ah or 185 watt hour or even more, I will say 200 watt hour, much larger than 18650 if it is 11 hour watt hour. 21700 will double the capacity 22 watt hour, but still 22 watt hour versus 200 watt hour.

So, if you want to make a large pack, go for pouch cell a prismatic small pack, you can look at cylindrical cells for smaller battery pack and for large pack it is 4-wheelers, truck, buses used the prismatic pouch, but remember, Tesla has defined this and it has gone for 21722 watt hour cell and it has made very large pack. So, they all this should be taken up as a qualified statement.

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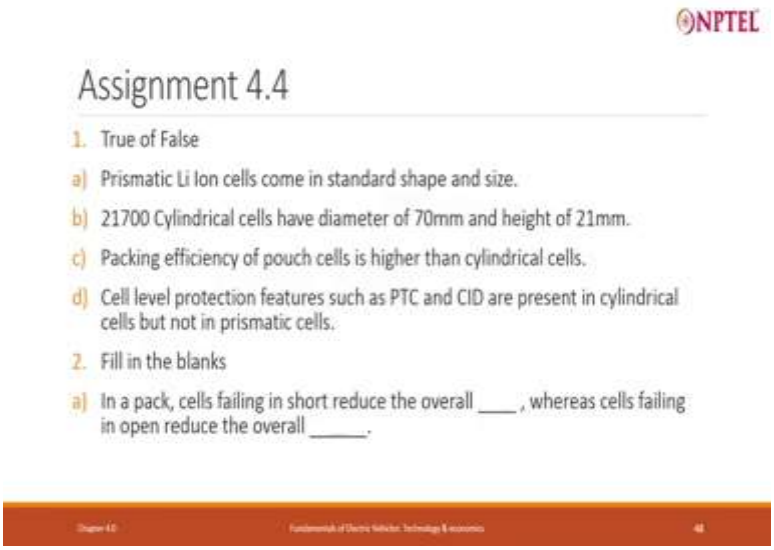

I have given another assignment again simple true and false. Prismatic lithium ion cells come in standard shape and size. Does it come in standard same shape and size? Not always. Cylindrical ones come in standard, 21700 cell has 70 mm diameter, height of 20. That is right. Prismatic ones can come different. So there are also some fill in blanks I am giving you have to do this homework.

I think I will end today and tomorrow get into something that Nanda knows better than I do state of health, state of charge estimation and self-discharge. Okay, we will do this tomorrow.

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What makes a Battery Pack?

Number of cells assembled to form a battery-pack for required voltage and capacity
- Safety Issues
- Cell Balancing
- Careful electrical design so that every cells get equally charged / discharged

Cells: Chemistry evolves continuously bringing costs down

Materials: depends on chemistry
- Quantity used depends on Wh/kg
- Cost of material and Availability

Battery Pack: 35% Value
- Thermal Design
- Mechanical Design
- Battery Management System

Cells: 25% value add
- Chemistry changes every two years
- Highly Controlled Process
- Wh/kg, Costs per kWh and life-cycles critical

Materials: 40% Value
- Li, Mn, Co, Ni and Graphite
- Material prices sky-rocketing

Battery Pack Design: Electrical

Battery-pack required certain Voltage and Capacity (in Ah and Wh terms)
- Voltage chosen based on requirement of drive-train components and total battery Capacity
  - High Currents implies large ohmic losses (thick cables): normally limited to <200 Amps
  - Therefore depending upon energy (kWh) of storage, certain voltage preferred
- 48V or 72V for small batteries for 2W /3W and small 4W
  - 100 Wh to 15 kWh: 1 kWh requires 21 Ah cells – possible with prismatic and cylindrical
- 350V for medium sized batteries for larger cars and pick-ups
  - 20 kWh to 70 kWh batteries; 1 kWh battery requires < 3 Ah – possible only with cylindrical
- 750V for motors for buses and trucks
  - Battery size of 60 kWh to 300 kWh: too many cells if cylindrical used

Then we will come what makes a battery pack in fact I am getting things ready for Kaushal battery pack design electrical building up serial parallel, electrical design failures in battery pack.

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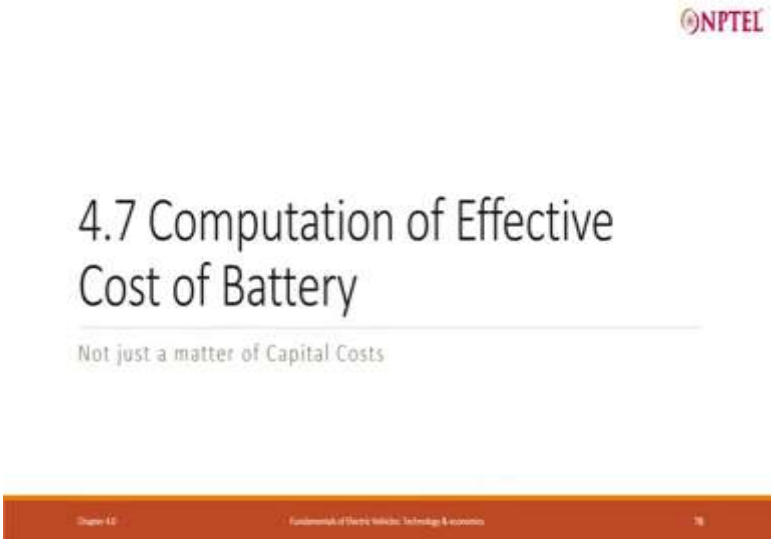

And then I will come to computation of effective cost of battery. This is important, very interesting, this is what you can compare things and somewhat involved for operational cost and after having done that, and seeing the impact of this very important something that I will say I am the author of this work and then what does it take what kind of

charging to do pretty much I look at the charging and that is it chapter on battery will be over thank you.