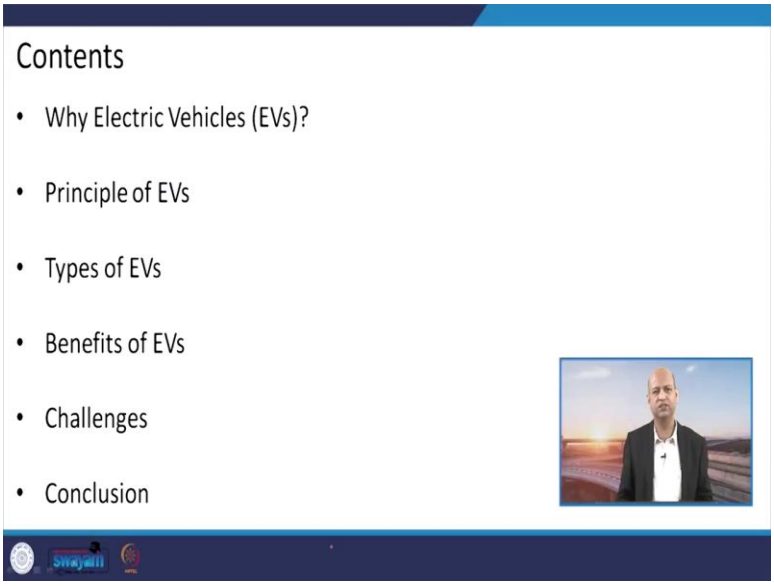
Sustainable Transportation Systems
Professor Bhola Ram Gurjar
Department of Civil Engineering
Indian Institute of Technology, Roorkee
Lecture 48
Electric Vehicles and Sustainability

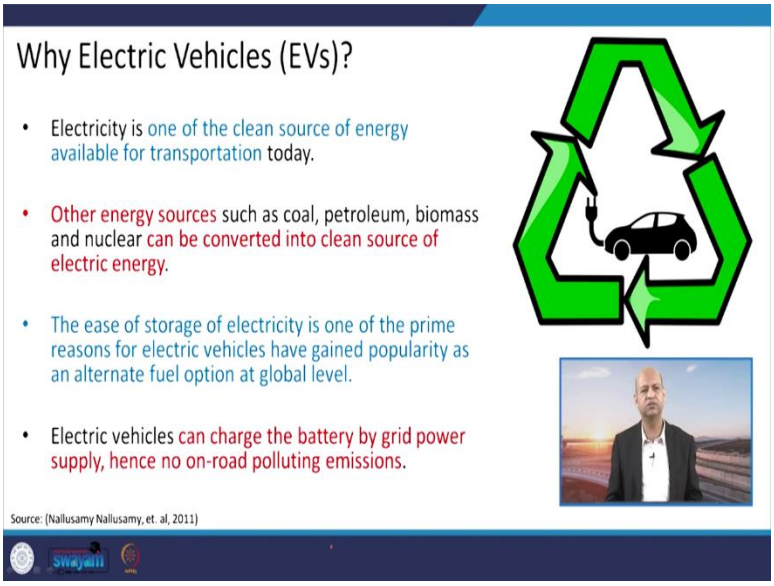
Hello friends, before this lecture we discussed about alternate fuels, and within that alternate fuels' electricity was also considered as one alternate fuel, you can say. So, today we will discuss about electric vehicles and the relationship with the sustainability, or you can say from the environmental sustainability, why electric vehicles are so important, what is their technology and how they are taking place or space in the, this whole transportation gimmick, you can say.

(Refer Slide Time: 00:52)



So, today's lecture will comprise of these things like why electric vehicles are needed, or why should we go for that and what are the principles which are responsible for EVs to run on the ground, and the different types or kinds of electric vehicles, and what are different benefits which we reap out of electric vehicles, and then there are certain challenges or limitations which we need to overcome if we want to propagate the electric vehicles in a large number, and then we will conclude this lecture.

(Refer Slide Time: 01:36)



So, when we talk about why electric vehicles are so important, or why they are needed, and why this is kind of incoming thing, then we need to know that because this is one of the cleanest source in the sense when we run the vehicle or the mobile or any kind of transportation medium or mode, when we run it with the help of electricity, that is, the battery basically, and electricity runs like, in gasoline or diesel, the power is, the source of the power is gasoline based IC engine, and the diesel based IC engine, those kinds of things.

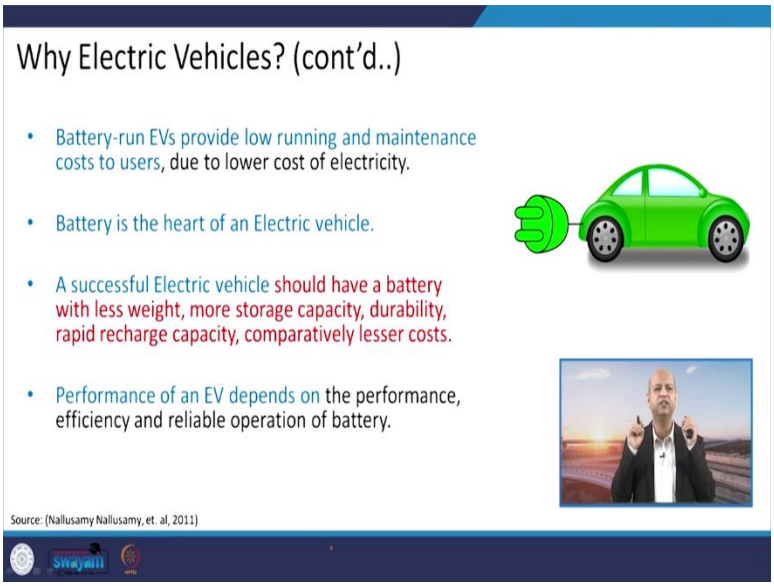
So, here this is the motor, which is driven by electricity. And electricity can be drawn from like fuel cell or from battery those kinds of things. So, they do not emit any kind of emissions, like greenhouse gas emissions or air pollutants. Although like, in a hydrogen fuel cell, for example, emissions are water vapor. So, that is greenhouse gas. We need to be careful about this. We cannot just make a sweeping statement that there is no emissions. There are emissions in certain cases. But as such, when better driven vehicles are there, there are no emissions or tailpipe emissions, if we talk about, like, oxides of nitrogen, particulate matter and sulfur dioxide, those kinds of things are not there.

Although there will be some emissions like resuspension, dust from wheels, and some other non-exhaust emissions kind of things may be there, but in comparison to the normal cars, normal automobiles, those emissions will be very less. So, if we compare with the energy sources of like coal, petroleum biomass, et cetera that can also be converted into electricity because you can produce steam and then through steam you can run the turbine, through turbine you can produce

the electricity, and you can use that electricity to charge the batteries and then batteries can run the automobile.

So, those kind of cycle of energy transformation from one stage or one form to another can be taken care of in certain system. And it is very easy to store. If we have good battery life and a nice efficient battery then it can be very good alternate option for running the vehicles. And also like charging the battery from the grid power supply, and you can then use that battery for the vehicles. So, there may be different modes basically, which we will see in next slides.

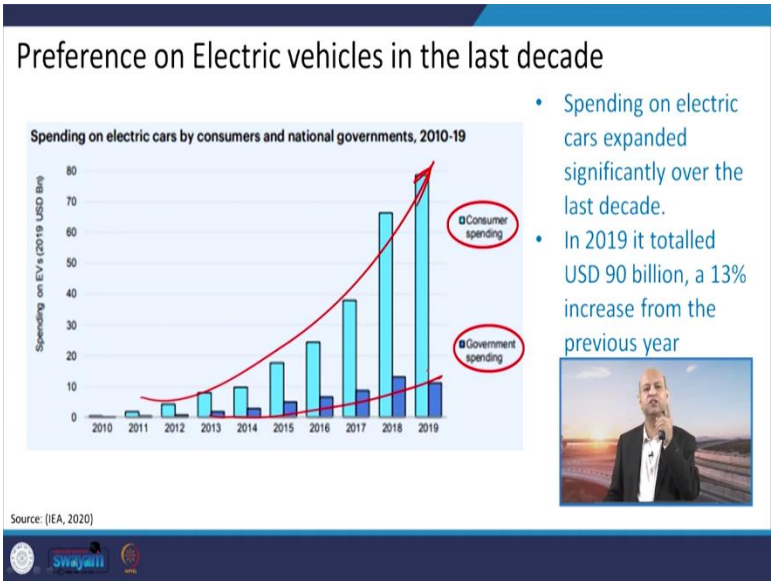
(Refer Slide Time: 04:36)



So, again, when we talk about battery run electric vehicles that provide like very less maintenance cost and very less operation cost in comparison to the gasoline or diesel driven vehicles. So, the battery is the core thing. It is the heart of electric vehicles, basically. So, if we can develop very good batteries in terms of capacity, in terms of their life, in terms of very low maintenance and all those things, then we can really go for this battery driven electric vehicles in large scale.

So, less weight, more storage capacity, more durable, and rapid recharging capacity, and then comparatively at lesser cost if we can make or manufacture the batteries, then this can really support the electric vehicle in a revolutionary way, you can say. So, many experiments are going on. Several kinds of batteries are being produced from left to commercial level and scenario is very good when you will see certain data in due course of time. And the performance basically, efficiency and reliability of the operation of battery, that drive the performance of electric vehicle.

(Refer Slide Time: 05:52)

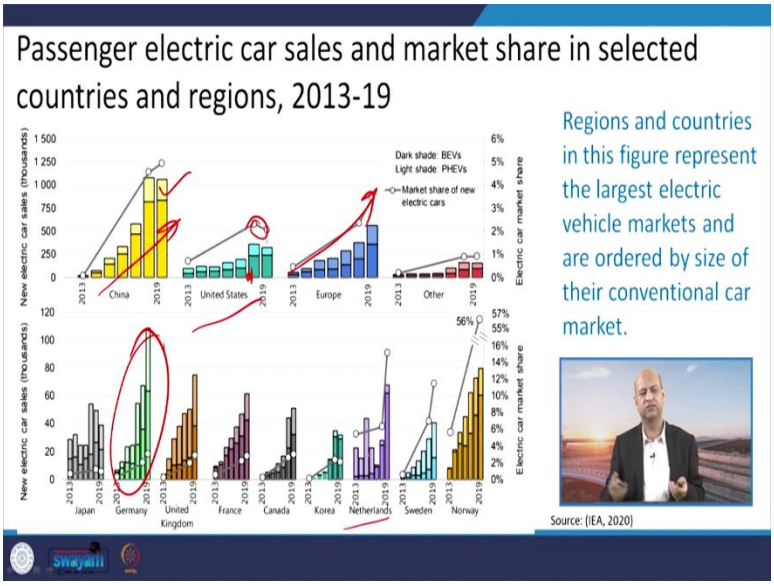


When we see, like preference on electric vehicles in the last decade then, for example, this consumer spending, if we compare the consumer spending on electric vehicles, so it is rapidly increasing, you can see, like this. So, that means consumers are preferring it, they are going for green kind of technology.

And the government spending is also increasing day by day. But it is not increasing as fast as consumers' choice. So, that means if the policies of the government to invest more money through subsidies or other kind of taxation system related free kind of modalities, then this scenario can further change, means it can be viable.

Otherwise at present, if you compare the cost then it is costly in comparison to the normal traditional vehicle technology. But if subsidies are given to these electric vehicles related parts, battery research and development, and production, other, some more kind of facilities or promoting kind of policies can be implemented, and if you can have environmental tax on those vehicles, which produce, which emit lot of emissions, then this will be really competitive technology. So, you can see the trend is good.

(Refer Slide Time: 07:20)

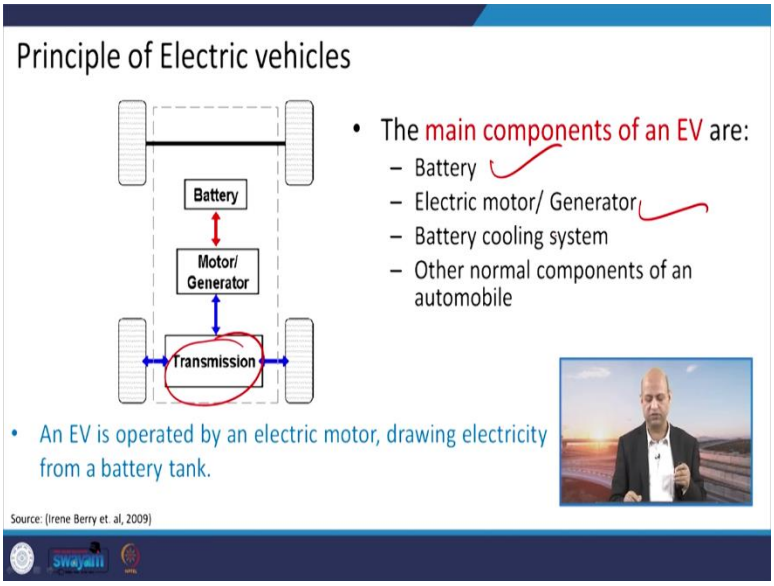


Well, when we again compare like, passenger electric car sales from 2013 to 2019, in different countries like China, and this dark color is related to battery operated electric vehicles, and the light color is related to plug-in hybrid electric vehicles. So, you can see, these batteries driven electric vehicles, this trend is more. So, the number of passenger electric car sales is increasing.

So, again, this indicates that the choice of the people towards this green technology in the transportation sector is really welcoming. In the United States of course, it is increasing but after certain time, because of certain regions it is decreasing, means maybe from 2018 to 2019. There may be some regions, but in Europe it is quite increasing. And then in other countries also overall increment is there.

When we talk about these electric car markets here, in other countries like Japan, Germany, so you can see that Germany, the growth is very high. And Netherlands also. So, there is quantum jump kind of things in certain countries. So, but overall, we can say that the sale is increasing. That means people are welcoming this electric vehicle market.

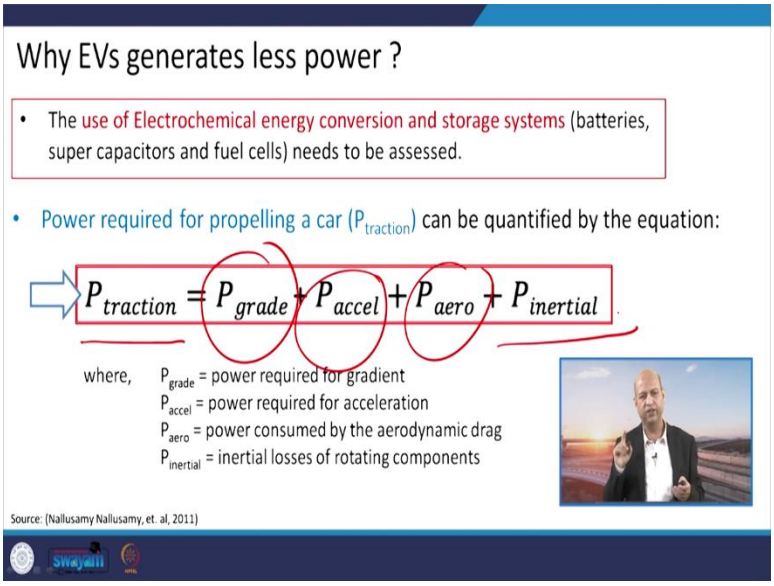
(Refer Slide Time: 08:45)



Well, what is the principle of electric vehicle? It is very simple. Like IC engine may be a little bit complicated, but in this, the battery basically, this charges the generator and the motor is driven by the generator. And then this torque is there and the transmission of the power is there. So, it is a very simple system. There is no much wear and tear or maintenance, like, you have to go for periodically maintenance of these engine, gasoline or diesel-based cars. But in this case parts are very simple and the operation is also very simple.

So, main components are basically, battery and the electric motor and generator, and the battery cooling system. Of course, when electricity related, the flow is there, so heating occurs and there are losses also, energy, because of heating. So, cooling system is required. And then other normal components which every automobile has, like wheels and brakes and other things.

(Refer Slide Time: 09:50)

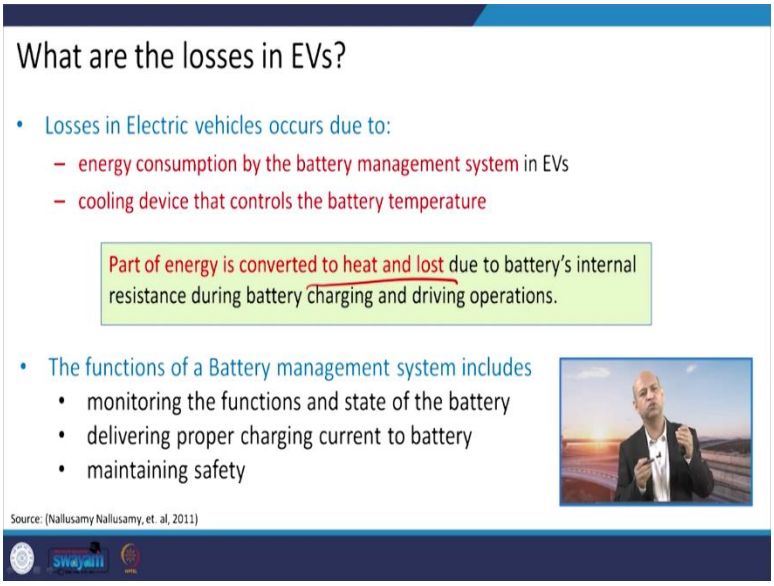


Well, so why it generates less power? There is one question that when we use this electrochemical energy conversion and the storage system. So, there are various steps where the loss of the energy is there. So, you can see, this equation basically

$$P_{traction} = P_{traction} + P_{accel} + P_{aero} + P_{inertial}$$

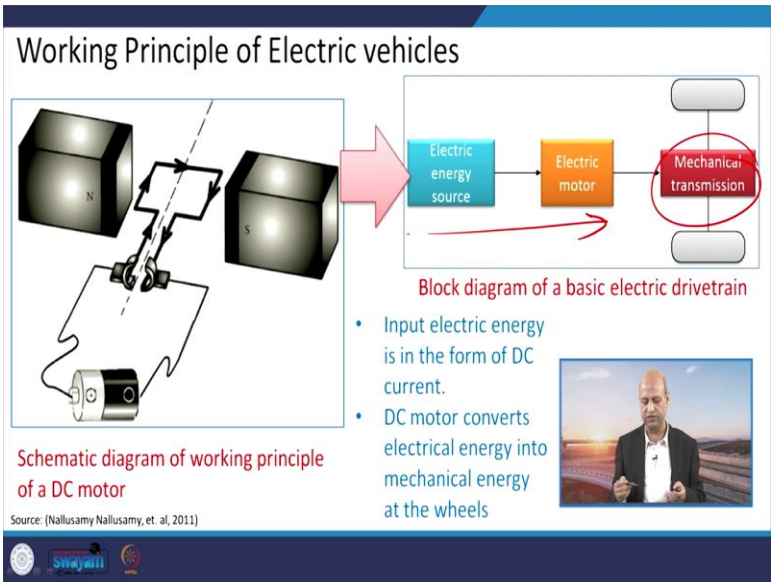
the traction related energy available is required, for like, the gradient related power, and then the this acceleration related power, and aerodynamics, some friction is there, and then inertial related the losses or rotating components, those inertia and those kinds of things are there. So, all these need for the power is there. So, that traction, which is required from the battery must fulfill this particular need of the power.

(Refer Slide Time: 10:40)



So, what are the different losses? If we talk about the losses, so basically you have different kind of parts, like, when you go for, this heat loss is there. So, battery's internal resistance is there and that creates the heat. So, for that charging and the driving operations in the, in terms of heat loss, lot of losses is there. So, those kinds of losses you have to configure when you talk about the total efficiency of the electric vehicles from the battery.

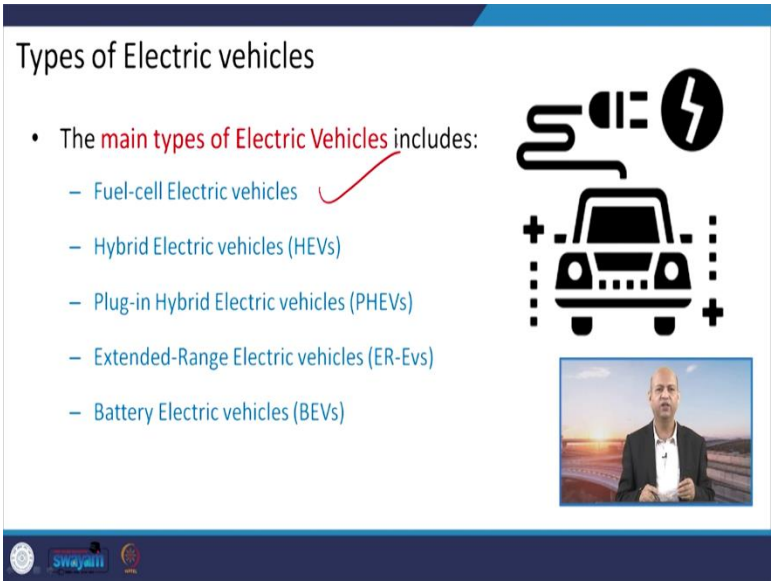
(Refer Slide Time: 11:13)



The, working principle is shown in a simple schematic diagram, you can see, the DC motor. So, this power is going and then here this DC is produced and that drives the motor and then

mechanical transmission is driven by the motor. So, that we will revolving rated motion is there and it drives the, the shaft and then wheels are driven. So, basically DC current is there.

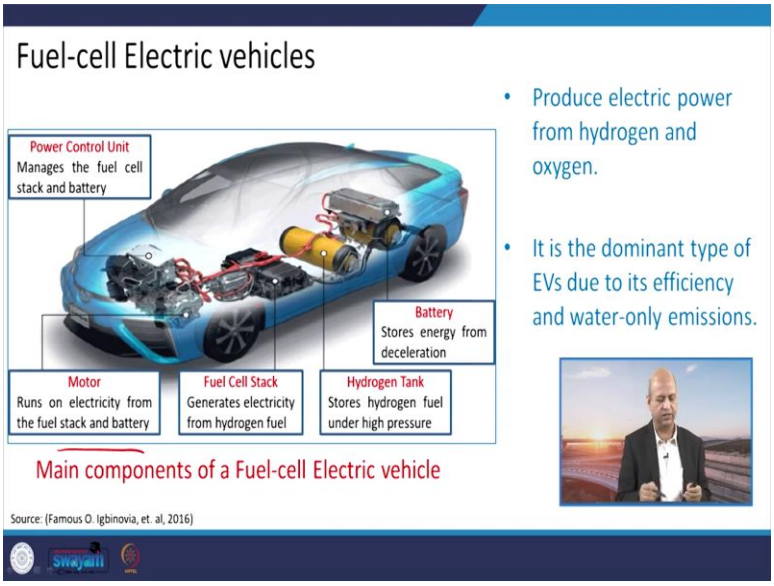
(Refer Slide Time: 11:45)



And if you talk about different kinds of electric vehicles which are available nowadays in the market, so on the basis of their source of energy, like fuel cell electric vehicles are there, then there may be some hybrid electric vehicles where you have some gasoline related arrangement, that IC engine, and also this electric generator, that kind of battery related charging arrangement. Plug-in hybrid electric vehicles maybe they are, where source of electric energy from outside, from the grid you can charge the battery, whereas in the hybrid this is not the case.

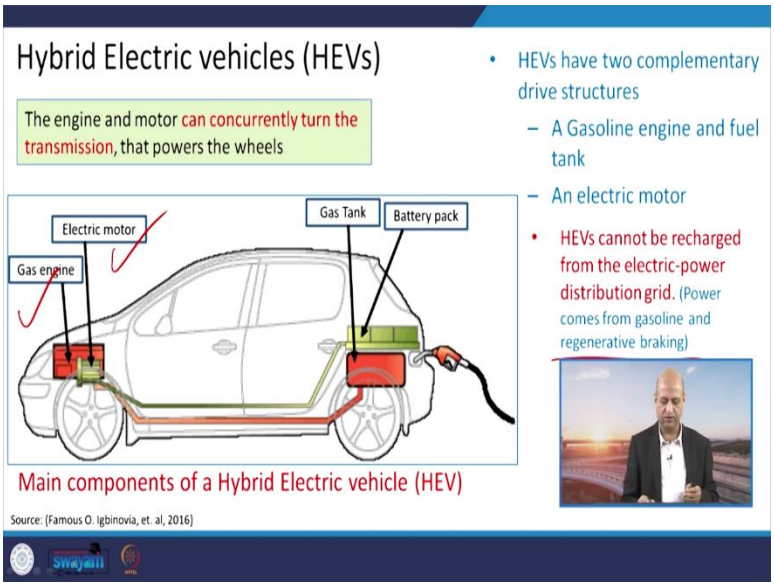
Extended range electric vehicles can be there, where again you have some sort of a generator, based on gasoline or some fossil fuel. So, when batteries down then you can use that particular generator to charge the battery. So, those kinds of arrangements will be there. And there may be completely fully battery driven electric vehicles also. No gasoline used in any form, and you just charge it from the grid power, external grid power. So, that is one BEV, that is the Battery Electric Vehicles.

(Refer Slide Time: 13:00)



If you see this diagram, again, from the fuel cell electric vehicles, you can see different kinds of parts. So, the hydrogen tank is there, then fuel cell stack must be there, which create the electron transfer and the electricity circulation. Motor is there for running from the electricity. And the fuel stack and battery charges, it takes the energy from, and then battery storage is there. So, this kind of arrangements can be there in the fuel cell electric driven vehicles.

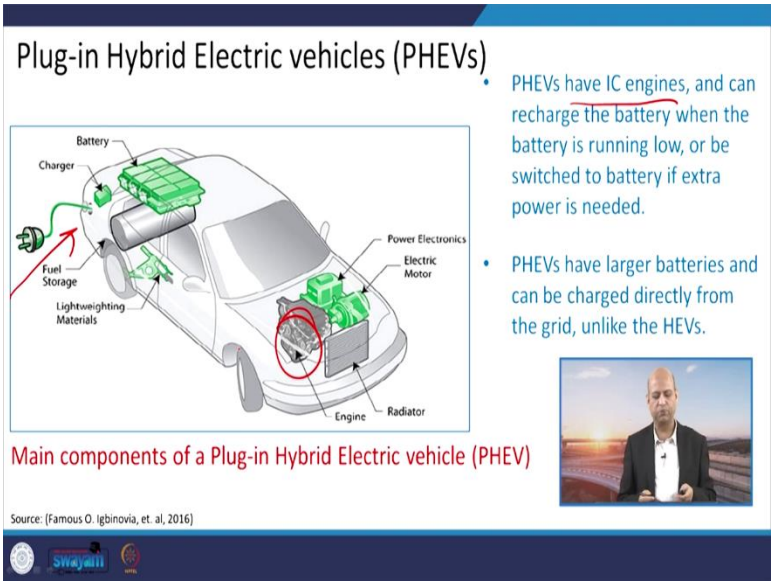
(Refer Slide Time: 13:35)



In hybrid, as I said, the booth power sources are there. Gasoline engine is there, electric motors is there. So, electric motor is basically charged by these braking related regenerative, regenerative

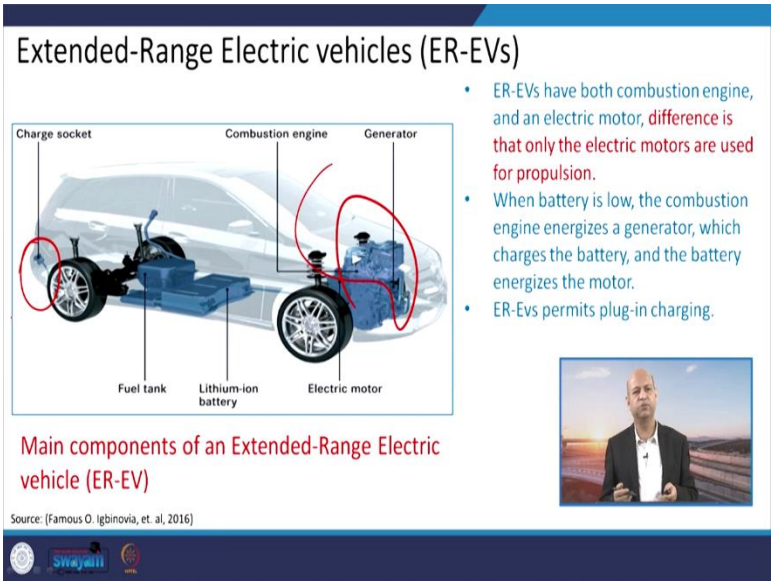
braking kinds of motions, which transfers the energy and charges the battery. And then gas tank is there. So, whenever it is needed, both powers can be complemented or supplemented concurrently.

(Refer Slide Time: 14:06)



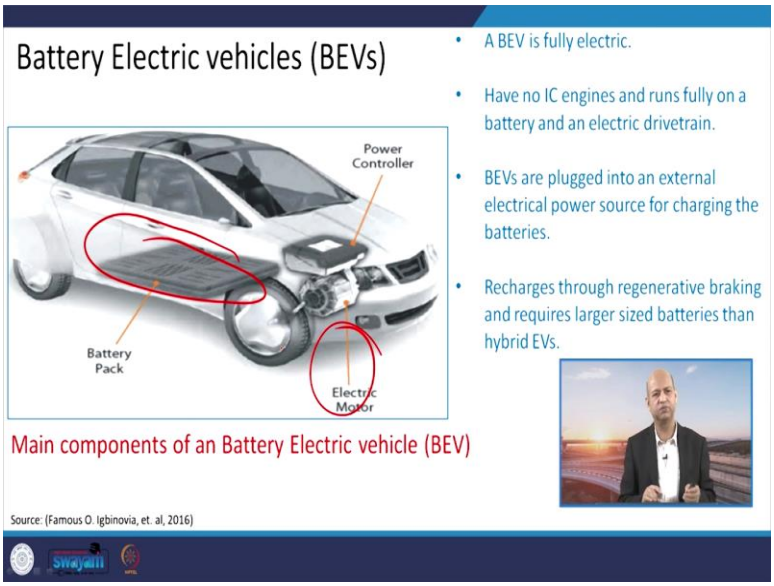
And then if you talk about plug-in hybrid electric vehicles, where the external charger is there. In this case, hybrid, there is no external charger. Only the charge happens by these breaks and those kind of motions. In case of plug-in hybrid, the electric vehicles basically you have external this plug-in, from the grid power you can charge the battery. Also, you have fuel storage and this IC engine is there. So, basically whenever you can turn the switch on and off depending upon which kind of power is needed. So, that is why it is called plug in hybrid electric vehicle.

(Refer Slide Time: 14:50)



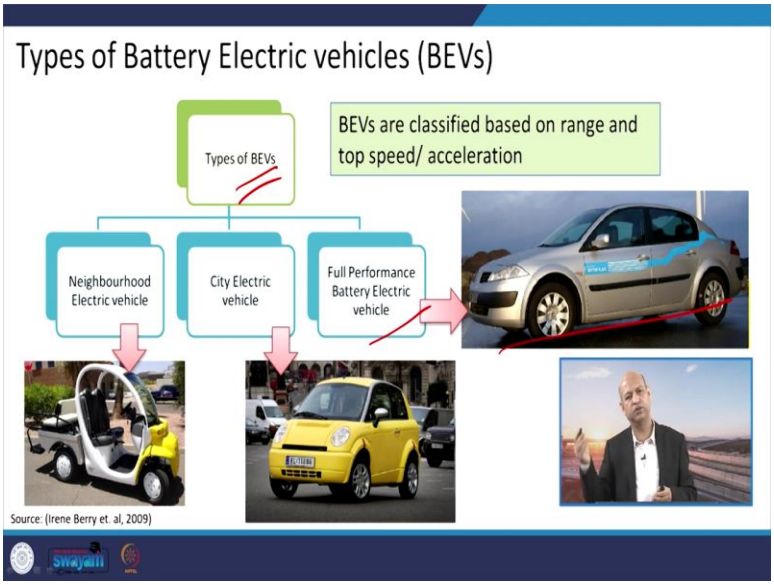
Then extended range electric vehicles are basically, you have this combustion engine, but this is not used for directly powering the vehicle. But when battery is down then battery charged by this. So, in emergency case kind of thing, otherwise battery is there and the charge socket is there, you are charging the battery. But in case of emergency when battery is low then this can be used for that. So, extended range electric vehicle it is known as.

(Refer Slide Time: 15:18)



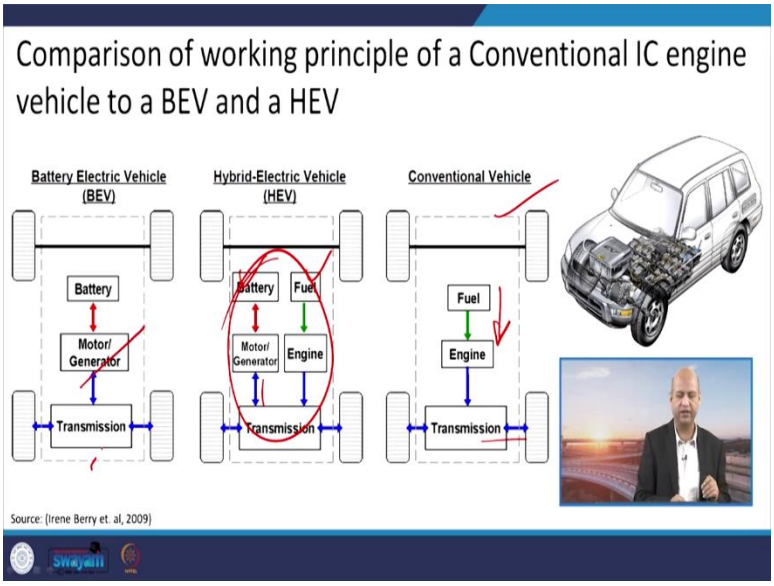
And the completely battery driven electric vehicle, it is purely, the battery pack is there in the, at the bottom surface. And then this power controller mechanism and electric motor. So, very simple mechanism is there otherwise the whole design can be of simple car.

(Refer Slide Time: 15:38)



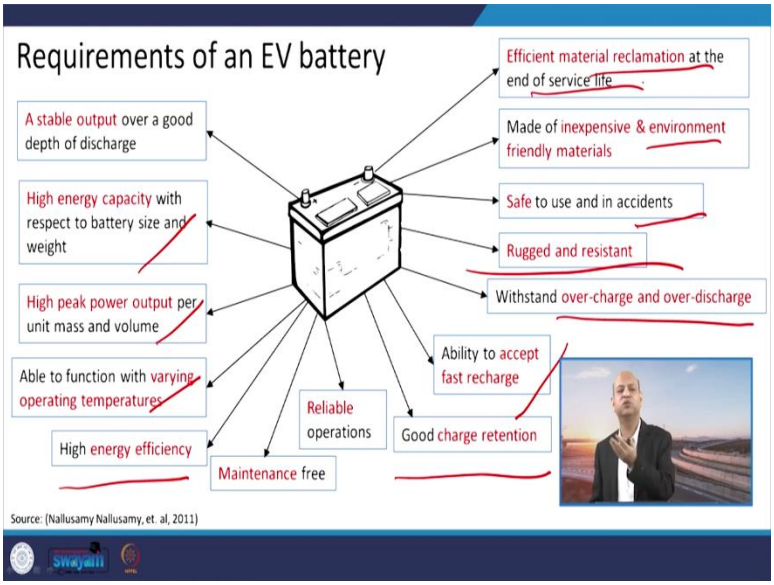
When we talk about different batteries, because they have different capacities. So like the neighborhood electric vehicles, which are of less charge, and, so these BEV's, and city electric vehicles, which can move around the cities also. And the full performance battery electric vehicles, which can run like 200, 300, 400 kilometer depending upon the battery capacity and those kinds of things, in one single charge. So, then again you have to charge. So, the charging facility must be there.

(Refer Slide Time: 16:05)



When we compare the working principle of these conventional IC engines and the BEV or Battery Electric Vehicles, or hybrid electric vehicles, you can see, so in conventional vehicles basically fuel runs the engine and then engine gives transmission related motions to the wheels. In hybrid fuel engine, and then battery and motor generator, these two arrangements are there in parallel, and battery operated, only battery, battery, motor generator and transmission. So, those kinds of things comparison, you can see.

(Refer Slide Time: 16:45)



When we talk about electric vehicle batteries, so there are certain requirements which should meet otherwise our purpose of drawing good power at, every time when vehicle is running, that will be refuted. So, those characteristics are like, it should be able to give a stable output, it should not fluctuate otherwise you will not be able to run the vehicle at certain speed, with certain power. So, the flow of the electricity, the output from the battery must be stable. That is very, very important.

And this should not drop like when battery capacity is going down, then power is going less. No, no, no. That kind of thing will not go for the good vehicle technology. Whether it is discharging or charging, the, the stability of the power should not change. Then high energy capacity, means in one go of charging it should, the energy density must be very high. In one charge, you should be able to run the vehicle for several hundreds of kilometers.

High peak power output per unit of mass or per unit of volume. So, again the density of the power must be good. That kind of material, and the technology should be used. It should be able to function with varying operating temperatures, whether low temperature, high altitude places, or if you are running the vehicle in the desert, very high temperature. So, that should not affect the performance of the battery. So, that is also one important thing.

High energy efficiency. As we have said, that the energy efficiency means to give the power with, per unit of energy must be very high. Maintenance free, should be the battery, otherwise if it requires a lot of maintenance then it will discourage the users. Reliable operations. At any, as we have discussed, temperature, or any other situations, the reliability should not go, means it should give you power at any time or at any location. Those kinds of things.

Then the good charge retention, means once it is charged it should not discharge very quickly. Slowly, it should discharge and it should keep its capacity. And the ability to accept the fast recharge, otherwise at present the slow recharging technology is there. But development and innovations are going on and the fast charging capacity batteries are coming in the market. So, it should be able to get, accept the fast charging instruments or facilities.

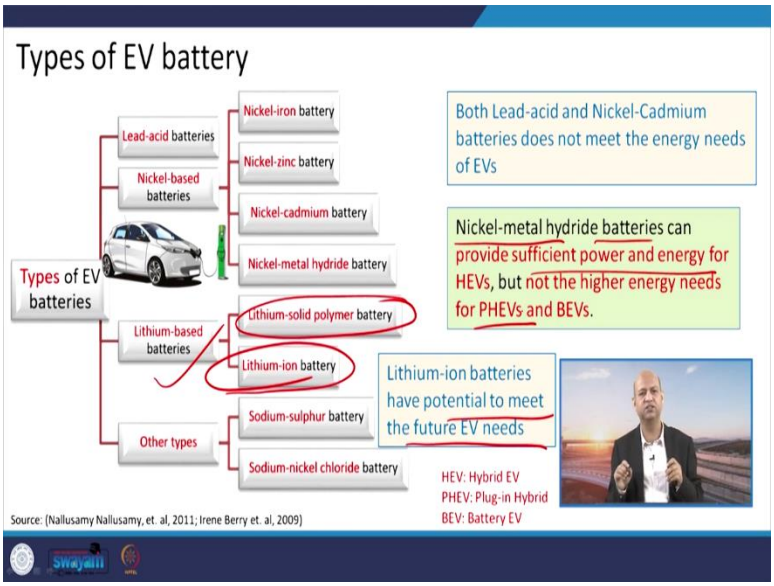
It should also withstand overcharge and over discharge. It should not that once it is discharged then it will go off completely. No. Even if it is over discharged because of some emergency, it should be capable to get again charged quickly. So, that kind of technology must be there. Otherwise, it will be very difficult for you to recharge once it is gone zero.

Then it should be like rugged, robust and resistant to any kind of hard situations, so harsh climate and harsh typography. It should be safe to use. And in accidents it should not explode or it should not add to the accident. So, safety is prime thing in that way.

It should be inexpensive, and environment friendly materials should be used. So, it should not be using those kinds of materials which once a battery is discarded, it will harm the environment. No, that material should not be used. So, the environment friendly material and inexpensive, very cheap material can be used.

So, those are the good quality requirements or parameters which makes the good battery for BEVs. And the efficient material reclamation at the end of the service life. So, whatever material is there, whatever waste is generated out of the battery that should be kind of a resource for some other activity. So, one can reclaim after, that life is over, of that battery, so the different components, different materials should be reused in some other way. So, that kind of thing we should keep in mind when we are designing and developing the electric vehicle batteries.

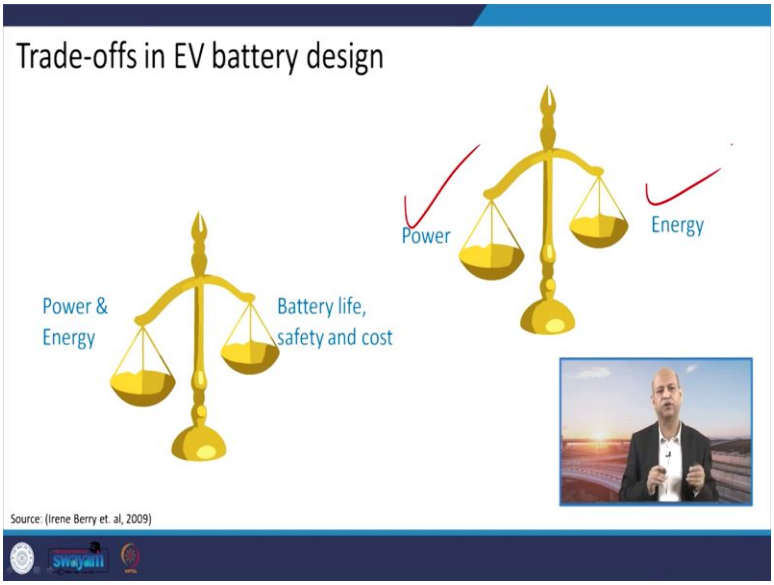
(Refer Slide Time: 21:03)



Well, based on the technology, based on the development, research kind of thing, these are the types of EV batteries which are at present, present in the market. Like, lead acid batteries, or these nickel-based batteries, lithium-based batteries, or other types. And you can see these lithium solid polymer batteries is also there. So, their length is also showing their kind of technology.

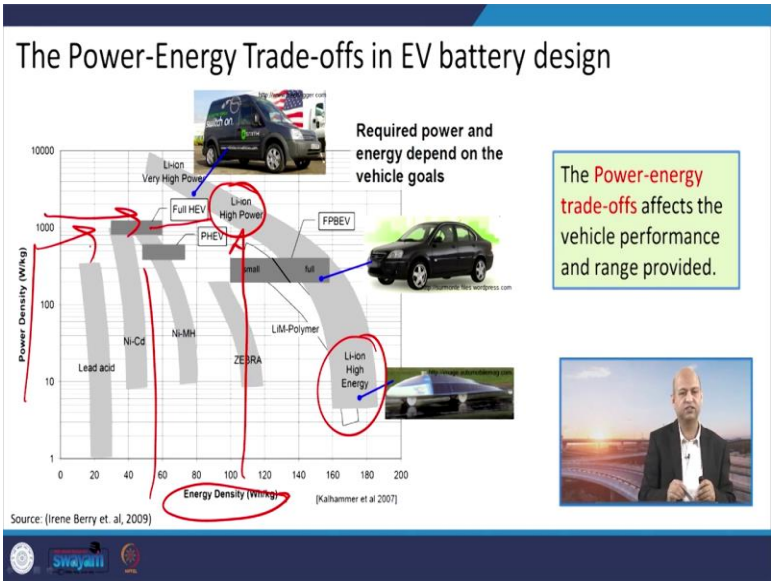
And lithium ion battery, this is one which is having very good future because it has potential to meet all the requirements which we have discussed. So, for like, low energy needs, these lead acid or nickel kind of batteries, cadmium batteries, maybe they are offer low quality kind of things, otherwise they do not meet the real requirement of the electric vehicles. And for low quality, and low power kind of thing, these nickel metal hybrid batteries can also be used for like plug-in hybrid electric vehicles etc. But the lithium ion battery have been seen that it is good for the long distances and high power related vehicle technology.

(Refer Slide Time: 22:25)



When we talk about like, means, there is like, we need good power, we need good energy, efficiency, and also we need good battery life and the safety, so there is this power and energy related trade-off is there. When something goes on higher side other thing goes down. So, the, one balance is required. So, according to the technology we need to strike a balance.

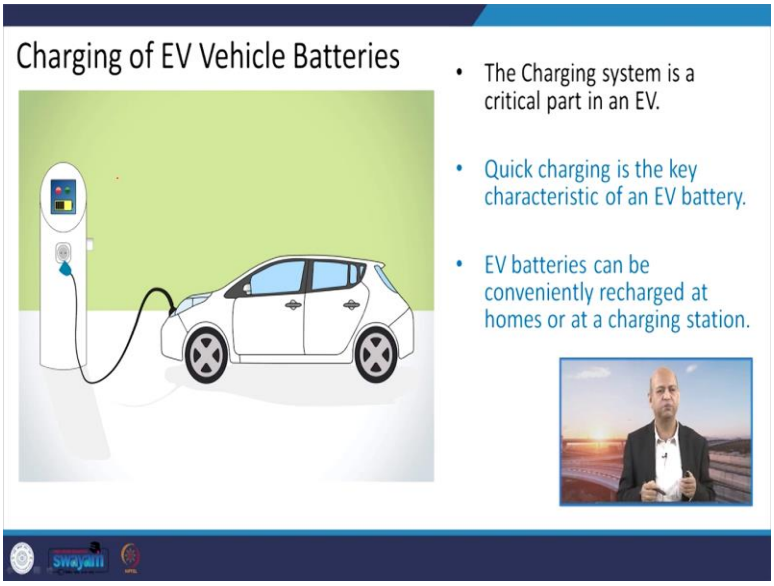
(Refer Slide Time: 22:52)



Well, when we see the energy density, watt-hour, per kg and the power density watt per kg, if we compare them, different technologies give different scenarios. Like full hybrid electric vehicles, they are having this kind of situation where good power density, but middle or low energy density.

When high energy density is, there like these lithium ions high energy capacity, then the power density is less basically, but these high powers related, can be there with the same technology at the middle kind of ground then high-power density can be achieved. So, this kind of balance we need to go for. That how much power density must be there and how much energy density must be there. So, do not go for very high energy density, you go for the middle or moderate, and then you can achieve a good power. So, those kinds of vehicles can be easily designed.

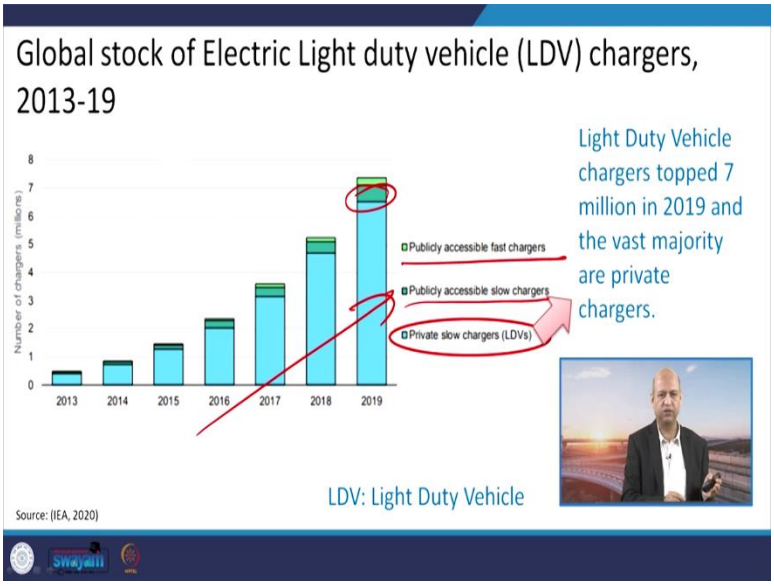
(Refer Slide Time: 23:50)



Well, when we charge EV vehicles from the grid power, so the quick charging is the key thing. The power charging infrastructure should be such that within a few hours, or if possible half an hour or a few minutes, you can give a very good charge so that you can go. And whatever like 10 to 15 minutes if you are spending at the petrol pump, gasoline pump, or the those traditional pumps., if in that kind of time period if you can give a good charge for next ride, then you can say that that would be the very good characteristic of electric vehicles. So, the technology is coming.

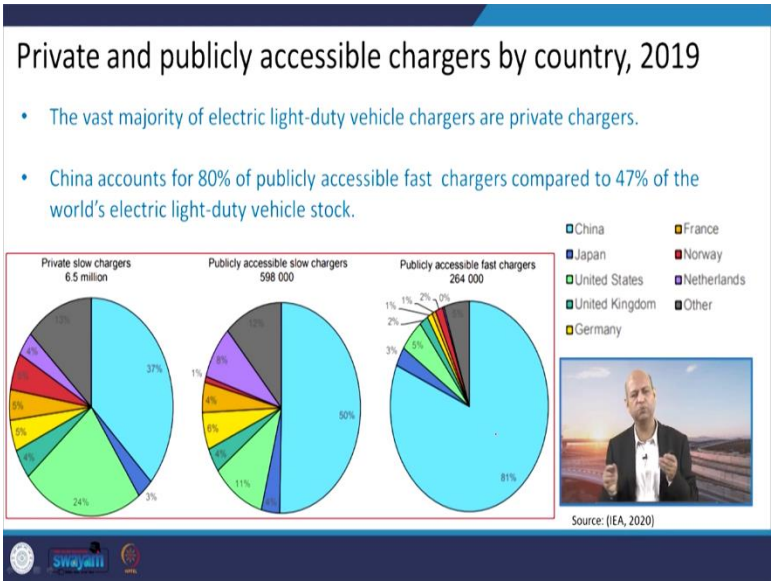
Right now, when we are charging from domestic kind of electric power supplies then it takes a lot of time. But once, in place is there technology which has good charging apparatus and equipments which can give quick charge, then this will further boost the popularity of electric vehicles.

(Refer Slide Time: 24:55)



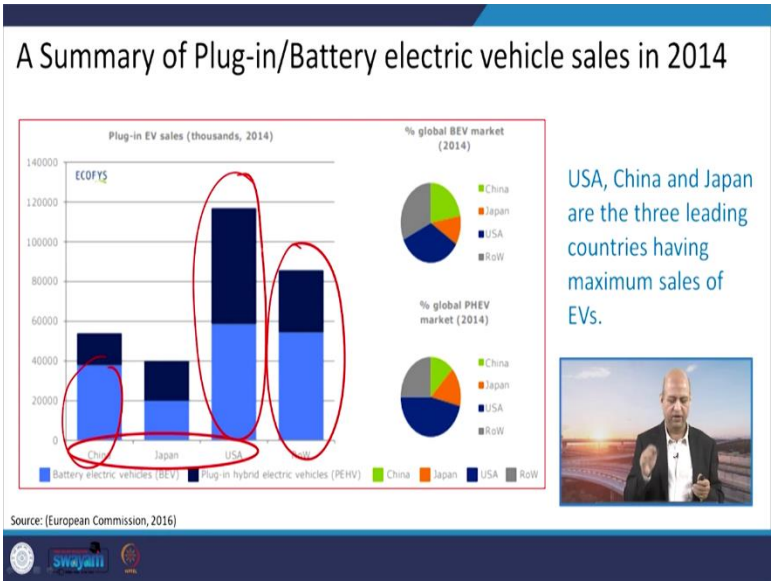
Well, when we talk about their share, like globally stock of electric light duty Vehicles chargers, 2013 to 2019, so you can see, like private slow chargers are increasing in a large number. Then, publicly accessible slow charges are also increasing. But publicly accessible fast chargers now picking up, means there were no technology, but now technology is coming up. So, slowly, I mean to say, maybe in further 5 to 6 years or so you will see lot of fast charging equipments in the market, and that will really change the scenario.

(Refer Slide Time: 25:36)



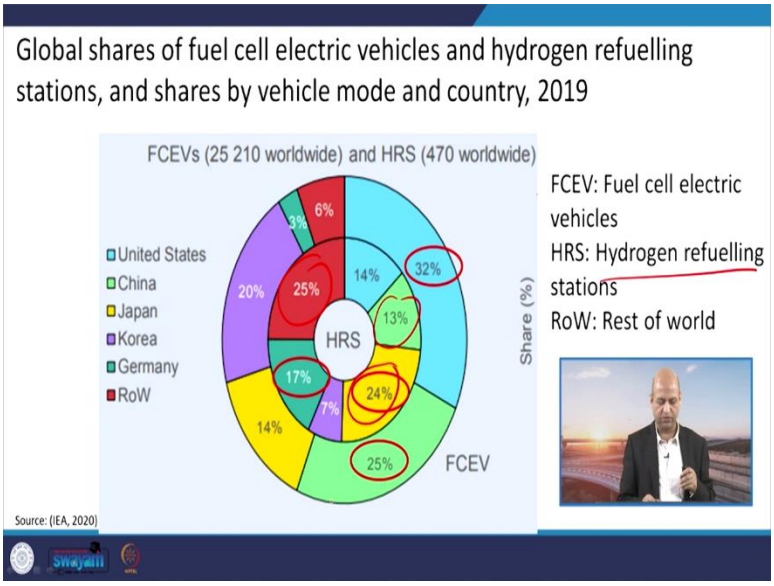
When we compare the private and publicly accessible charges by, country-wise of the 2019 data, then you can see like this China is dominating in that numbers basically, and then Japan, United State or United Kingdom, Germany, France, so Europe and USA and China, they are really giving great boost to this kind of technology in terms of chargers or accessibility.

(Refer Slide Time: 26:05)



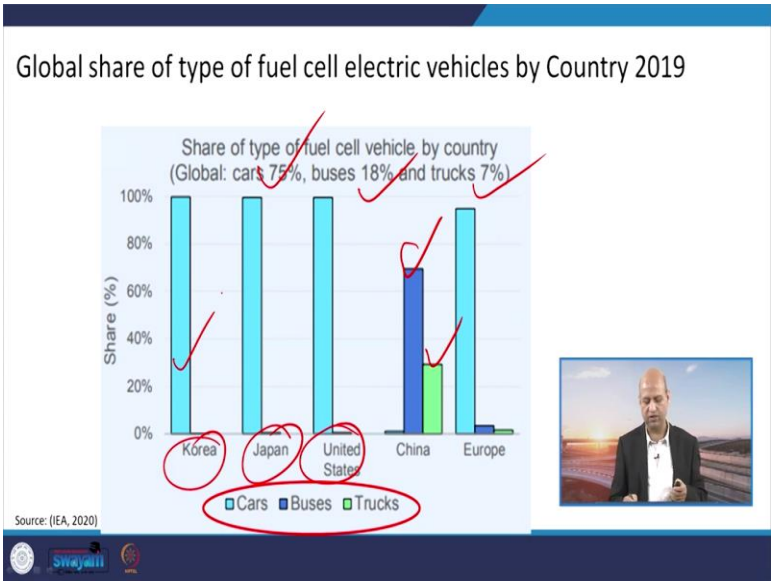
Plus, if we compare the summary of plug-in and battery electric vehicle sale figures of 2014, so again, you can see, like China had good number, but USA has highest number in that sense. So, comparison can also give that the, these developed countries and those highly focused countries like China and the rest of the world also, means other countries are also picking up but Japan, Europe and USA and China, they are the leading countries in this particular technology.

(Refer Slide Time: 26:40)



And battery scenario is also, can be seen in this like hydrogen refueling stations. If you see the number, so that 24 % basically, in Japan, 25 % in a rest of the world, and 13 % in China, those numbers of the stations. But if you want to see the fuel cell electric vehicles, so the number is big. 32 % in like United States and 25 % in this, China. So, those kinds of numbers, you can see.

(Refer Slide Time: 27:15)

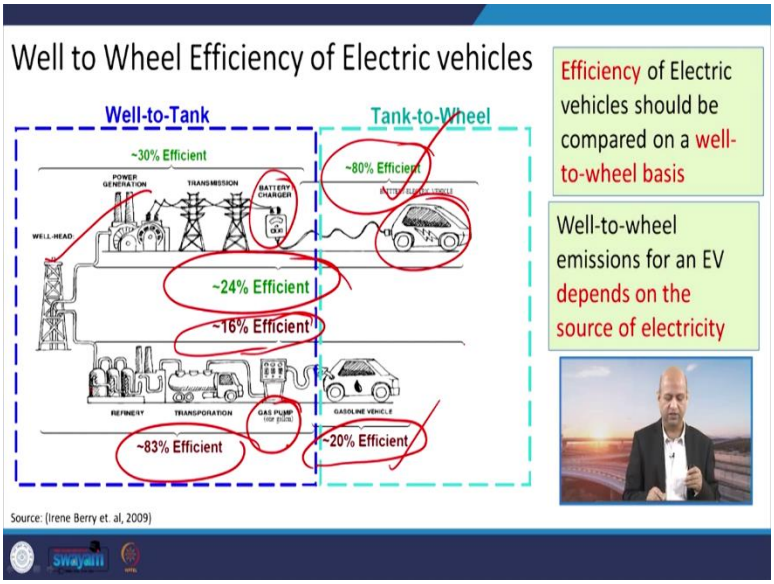


Well when we see the global share of types of fuel cell electric vehicles, so automobile related vehicles, popularity is in Korea, Japan and the United States, means cars related kind of sale, 75

%. And buses 18 %, and trucks 7 percent. So, that is the distribution of these fuel cell related electric vehicles at the global level. So, cars are 75 %, buses 18 % and trucks 7 %.

And you can see that in China, basically, these are buses and trucks, so the China is making lots of investment in these kinds of goods vehicles or public transportation systems. So, that is a good sign when we talk about like environment friendly ways. But the pub privately owned vehicles or cars they are doing good sale in United States, Japan and Korea, South Korea and Europe also.

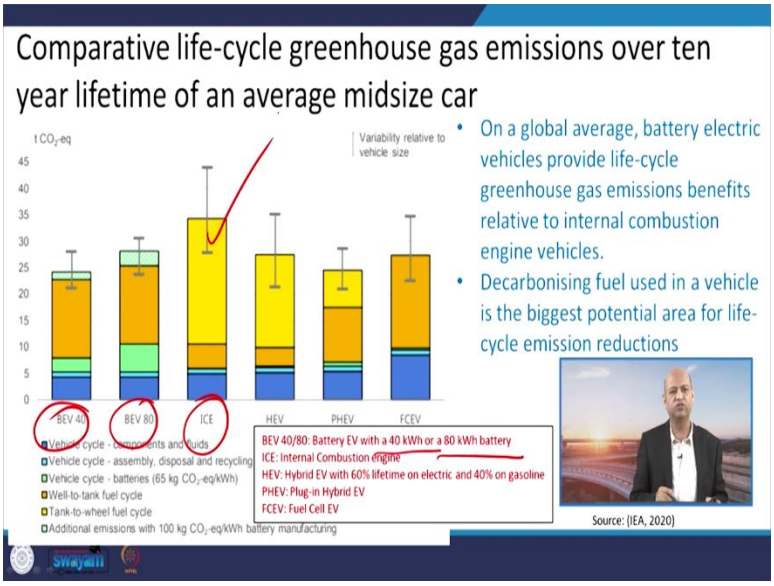
(Refer Slide Time: 28:15)



When we talk about like well to wheel efficiency of electric vehicles then, like 30 % efficiency is there when we generate the power from this fossil fuel and transmit to the battery chargers, around 30 %. From battery chargers to the transmission of the motor and vehicle speed, the 80 % efficiency, we achieve. So, the overall 24 % efficiency is there in case of electric vehicles.

Whereas in case of gasoline or these fossil fuel-based vehicles, you can see overall efficiency is less, like, 16 %. And how does we achieve this? Like 83 % efficiency from the fuel to this gas pump, from gas pump to drive, you take the power and drive the car, then only 20 %. So, it is highly efficient, you can say, in competition to that kind of 80 % and 20 % like comparison. And the overall is 16 %.

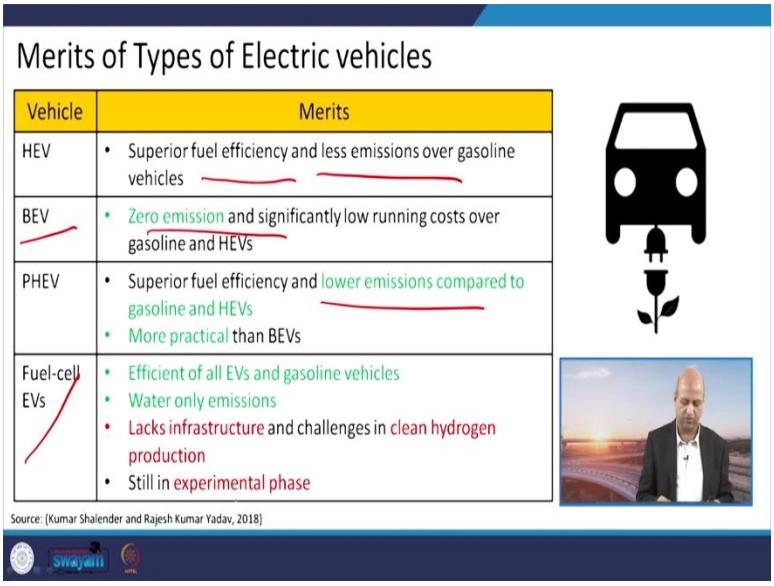
(Refer Slide Time: 29:35)



So, from an efficiency point of view from the well to wheel, also the electric vehicles are making better sense. So, when we compare lifecycle greenhouse gas emissions over 10-year lifetime of an average mid size car, which is driven by like IC engine, means gasoline or diesel, et cetera, and then battery electric vehicles of different capacity like 40-kilowatt hour, or 80-kilowatt hour battery, those kinds of batteries, so the emissions are less.

It is very simple, means complete lifecycle, means manufacturing of the car, driving some material from the mines, producing battery, charging them, all infrastructure related complete lifecycle assessment, even then you will find that a lot of saving is there, means very less emissions in comparison to these fossil fuel driven technology. So, that is again because we are going towards less emissions of the greenhouse gases even if you compare complete lifecycle assessment. So, even then we are on advantageous side.

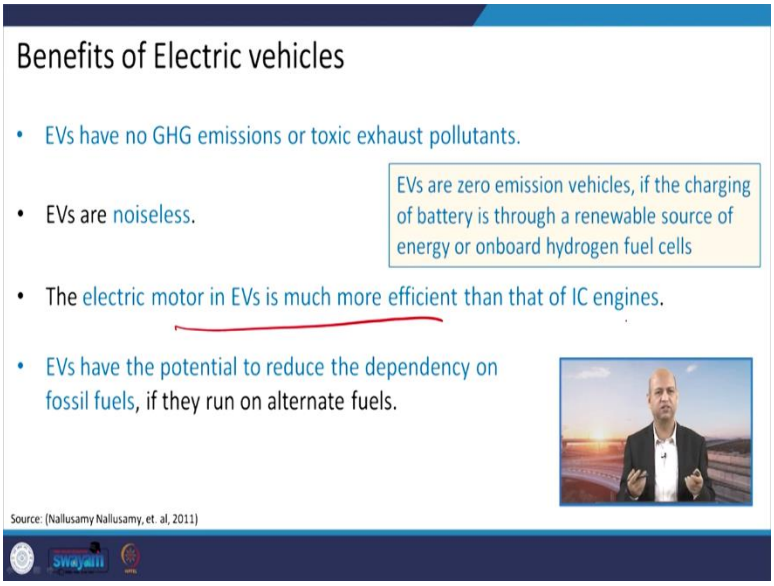
(Refer Slide Time: 30:15)



There are several merits of different types of electric vehicles. Like hybrid electric vehicle, it has superior fuel efficiency, basically, if you compare different kinds of electric vehicles, less emissions over gasoline vehicles, that is true, battery driven electric vehicles, zero emissions, basically. In hybrid there is little emissions from the gasoline because it is using that gasoline also. But in BEV, that is battery operated electric vehicles, zero emission is there. Exhaust emission, I am talking about.

Then plug-in hybrid electric vehicles, again, lower emissions compared to the fully gasoline driven vehicles. And it is more practical because sometimes you need, when battery is low, and you can shift from one way to another. Fuel cell is very good, it is very efficient, basically, in comparison to the gasoline vehicles. And the emission is only the water vapor. So, no air pollutants but greenhouse gas. Water vapor is a greenhouse gas, we should remember this. And it also can add to the humidity, complete city is driven on the basis of that technology. But there are challenges like, infrastructure is lacking, and the clean hydrogen production is also a big challenge. And it is still in the experimental phase. It is not a natural technology, basically.

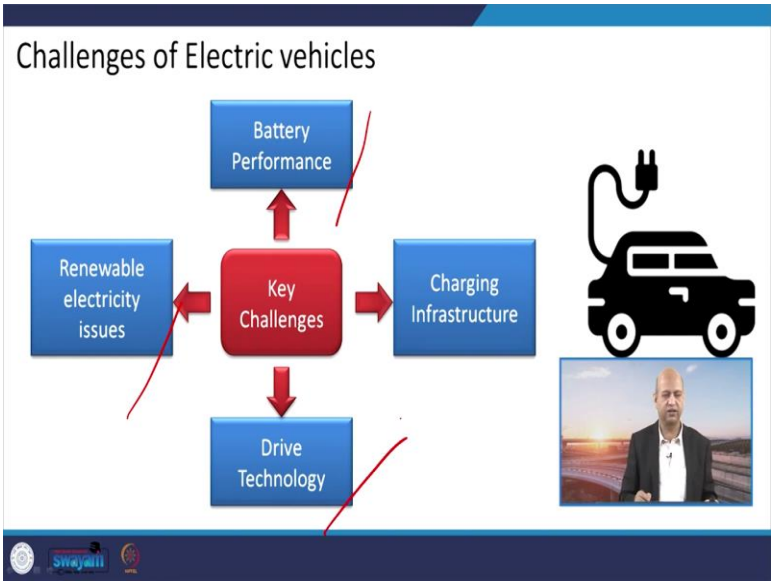
(Refer Slide Time: 31:50)



Then, we talk about different benefits, like no greenhouse gases, no toxic exhaust pollutants in comparison to the fossil fuel driven vehicles, and it is noiseless, also zero emissions in case of like battery driven vehicles, as just we discussed, electric motor, this is very efficient in terms of power transfer, transfer, in comparison to the IC engines. Very efficient.

And then it has potential to reduce the dependency on fossil fuel. That is a big advantage, because most of the countries are dependent on other countries to get fossil fuels, and that way they also spend a lot of foreign currency. In that we also one advantage is there. If you can produce electricity from renewable energy resources, then it is a great way of doing mobility or meeting the requirement of the mobility.

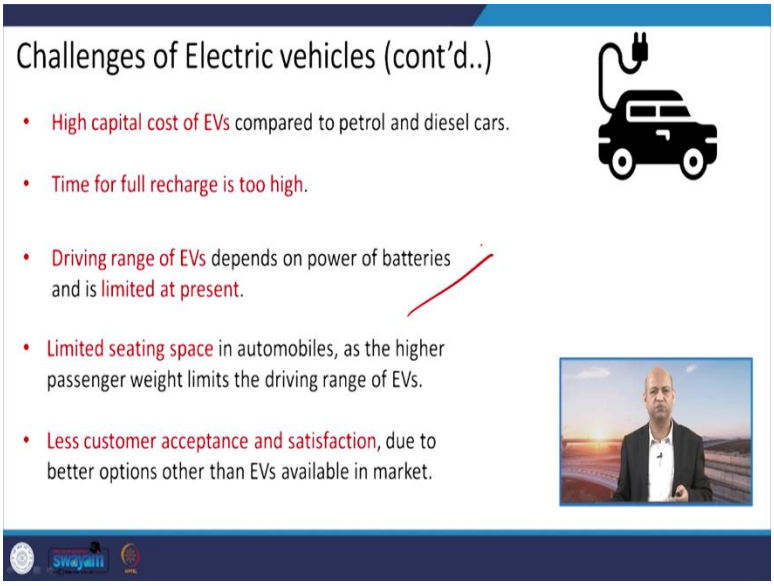
(Refer Slide Time: 32:40)



But there are challenges. Of course, challenges are there because battery performance related challenges are there. Still research is going on how to make the battery more and more efficient, and the charging infrastructure is not as other infrastructure is there for fossil fuel based cars. It will take time, means when users will multiply, numbers, the requirements or the need will be there, demand will be there so, and private players are allowed to go for infrastructure development, then things will change. That is, quite hopeful scenario is there.

Renewable electricity issues are there, means the share is still from the coal based power plants or gas based power plants. So, of course, those power plants emit lot of emissions, air pollutant emissions, greenhouse gas emissions. So, if you can really switch over to solar, wind or other renewable sources of electricity, then it really helps to go for this BEV, battery electric vehicles. And then the drive technology is also sometimes challenge because of these infrastructure related issues.

(Refer Slide Time: 34:02)

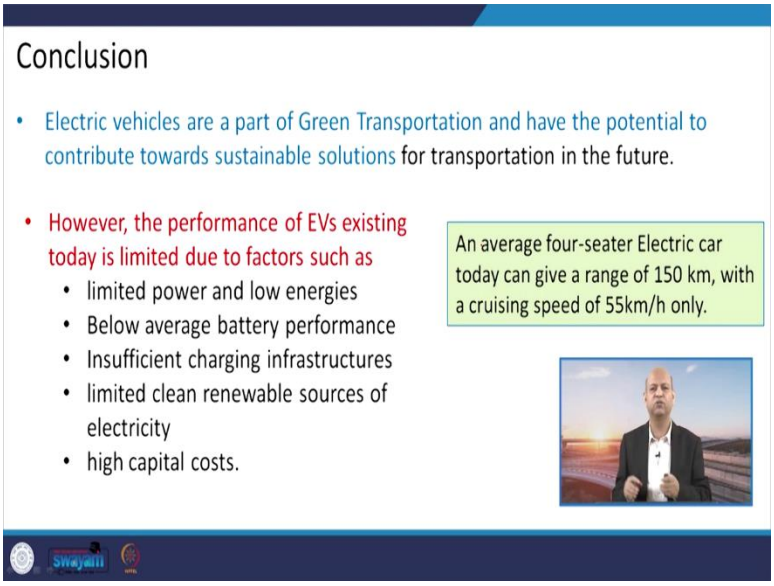


And in addition to that, like high capital cost at present, because only less number of vehicles are being produced, technology is new, and the buyers are less in number, so that way, break even point, reaching it will take little bit time. Then the recharging is also, at present, very slow in comparison to, like you go for the petrol pump, you have the gasoline, you drive your car. But here you have to wait for charging it. So, at, at present full recharge, it takes a lot of time but if fast charging stations, we can develop, then this problem will be taken care of.

Driving range also depend upon the battery' limitations, and the battery size et cetera. So, different kinds of vehicles are being generated. Two wheelers of low capacity which is used for local moments, et cetera. But if you want to go for long distances, then of course, you need very high capacity related batteries. The seating space related challenges are there because as you increase the weight of the automobile, then more energy is taken from the battery, and quickly discharge of the battery may be there.

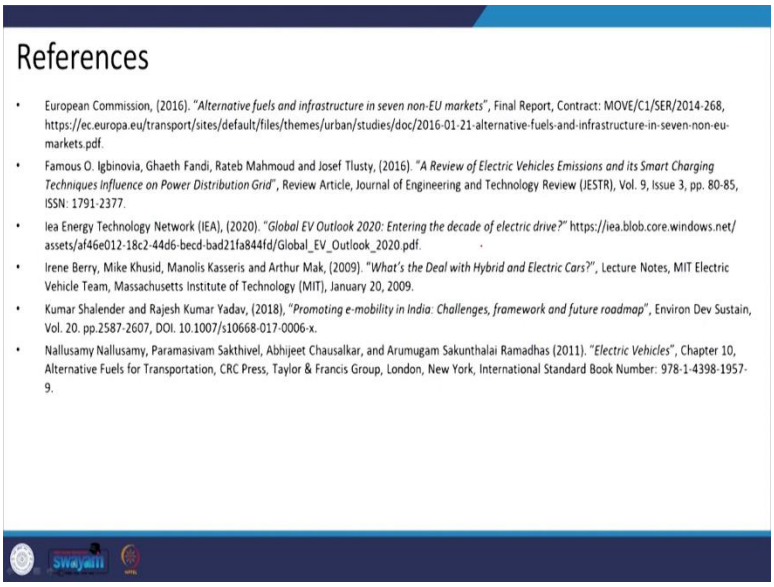
And less customer acceptance because of the challenges because smooth infrastructure is not there in place at present, but as infrastructure will grow, grow and people will be more aware about the environmental damages which is caused by fossil fuel driven vehicles then the acceptability will also increase for the electric vehicles.

(Refer Slide Time: 35:27)



Well, in conclusion, we can say that green transportation to popularize, we should popularize the electric vehicles, battery operated vehicles, and it is a requirement or the need of the hour. We should go for zero emission related vehicles. And if we can really harness the power from these resources which are renewable, then, and we can also meet the challenges of good infrastructure of fast charging et cetera, then we can really boost this market of the electric driven vehicles or battery-operated vehicles in a large way. And that will be real green technology in the mobility sector, in the transportation sector, and we will have a sustainable transportation mode.

(Refer Slide Time: 36:31)



So, this is all for today, in this particular lecture. These are the references, which you can go through for additional information. And you can learn what are the latest technology in battery driven vehicles, and the fast charging related infrastructure, two-wheeler, three wheeler, even trucks are coming, operated by batteries. So, a lot of technologies are coming. It is very exciting area. So, please go through these references and learn more about it. Thank you for your attention. And we will carry on sustainable related issues in future lectures also. Thank you.