



**NPTEL**

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Video Course on

**Electric Vehicles Part 1**

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## Lecture # 2

# Intro EV Benefits of Using EVs

### Introduction to EV

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- Historical Background
- **Benefits of Using EVs**
- Overview of types of EVs and its Challenges
- Motor Drive Technologies
- Energy Source Technologies
- Battery Charging Technologies
- Vehicle to Grid
- EV Systems and Configurations
- HEVs Systems and Configurations



Hello everyone. So we have already covered the historical background related to EV development in our previous interaction. Let us begin the discussion on the next topic under introduction to EV which is benefits of using EV compared to other modes of transport.

## Benefits of Using EVs

### Why EV ?

- Global Population, with current trend, may increase from 6 Billions to 10 Billions by 2050.
  - Vehicles in use may increase from 700 millions in 2000 to 2.5 Billions by 2050. ✓
  - If all the Vehicles are ICEVs, then all cities may be covered with permanent smog with extreme air pollution.
- ARB report (2011), around 9000 people die/year due to fine particle matters in California.
- Sustainable Transport
  - Low or Zero Emission Vehicles.
  - Promotion of Public Transport.
  - Renewable energy sources (less dependence on fossil fuels)



So the big question is why Evs. It seems that the global population which is 6 billion currently if it increases with the current trend may become 10 billion by 2050. So what that means? It means the vehicles in use may increase from 700 million which was there in 2000 to 2.5 billion by 2050. and if all these vehicles are IC engine based vehicles then most likely all the cities will be covered with permanent smoke with extreme air pollution. And this is very drastic in terms of health. According to one of the reports of ARB which is Air Research Board, which came in 2011, around 9000 people die every year in California due to fine particle matter. So this numbers are alarming and there is a necessity to think ahead.

So what is the way out? One of the promising solutions is sustainable transport. So what is sustainable transport? It means use of low or zero emission vehicles, promotion of public transport so that very less vehicles will be on the road. Use of more and more renewable energy sources for charging this zero emission vehicles. It also means we will be less dependent on fossil fuels which is the large source of air pollution. So to better understand the advantages and shortcomings of EV let us compare the EVs with other modes of transport.

## Benefits of Using EVs

1. Energy Sources ✓
2. Pollution ✓
3. Energy Diversification ✓
4. Efficiencies ✓
5. Capital / operating cost ✓
6. Performance. ✓



The comparison can be done on following parameters. Energy sources. Pollution. Energy diversification. Efficiencies. Capital and operating cost and performance. Now let us compare the different types of energy sources used in different types of vehicles.

## Introduction to EV

### Benefits of Using EVs

Comparison of Energy Sources (Storage) used for Transport

- Gasoline (Petrol) } *Liquid fuels*
- Diesel } *Liquid fuels*
- Compressed Natural Gas (CNG) } *Gaseous fuels*
- Hydrogen } *Gaseous fuels*
- Batteries ✓
- Ultra-Capacitors
- Ultra-Flywheel



We all know gasoline which is petrol, diesel, compressed natural gas, CNG, hydrogen, batteries, and the upcoming ultra-capacitors, and ultra-flywheels. So petrol and diesel are liquid fuels. While CNG and hydrogen are gaseous fuels. Battery stores the energy in chemical form and provides energy in electrical form. Ultra-capacitors stores the energy in electro-statics form while ultra-flywheel stores the energy in mechanical form. Both petrol and diesel have similar energy content per unit mass which means they have same specific energy.

But since diesel is more denser compared to petrol it has higher energy content per unit volume. The energy per unit volume is also known as energy density. By having higher energy density the diesel is more fuel economical compared to petrol. The CNG has higher specific energy compared to liquid fuels but it has very low energy density.

On the other hand hydrogen requires storage at a very high compressed state by using high pressure and therefore it requires lot of ancillaries around its fuel tank but on the positive side it has very high energy density compared to petrol, diesel and CNG. Therefore, there is a serious effort to make hydrogen based fuel cells electric vehicles a commercial viability. Batteries if you take recent battery example, let's say lithium ion battery, the lithium ion battery has specific energy and energy density very low around 75 times low and 25 times low compared to petrol which means that for the same energy content the mass of lithium ion battery will be 75 times more compared to a petrol and it requires 25 times more volume compared to volume. This is a serious limitation of batteries compared to liquid fuels. Ultra capacitors provides very high specific power. But it can store very limited energy. As we know ultra-flywheel stores energy in mechanical form at very high speed but it has drawbacks such as it is less reliable and there is a safety concern around it when it is used inside the electric vehicle.


Introduction to EV

## Benefits of Using EVs

Pollutants and Greenhouse Gases

- Particulate Matter ( $PM_x$ ) ✓  $PM_{10}$  ,  $PM_{2.5}$
- CO, CO<sub>2</sub> ✓
- CH<sub>4</sub> ✓
- NO<sub>x</sub> [N<sub>2</sub>O, NO and NO<sub>2</sub>] ✓
- Volatile Organic Compound (VOC) ✓
- Total Hydrocarbon ✓
- SO<sub>x</sub> [SO<sub>2</sub>] Etc. ✓

*Green house Gases*



There are various types of pollutants and green house gases which are released as emission from vehicles and they are the reasons for smoke, and air pollution. So some of them are particulate

matter which is known as PM<sub>x</sub>. Carbon Monoxide and carbon dioxide, CH<sub>4</sub> which is Methane. NO<sub>x</sub> gases which is N<sub>2</sub>O, NO and NO<sub>2</sub>. VOC which is volatile organic compounds. Total hydrocarbons and SO<sub>x</sub> gases which is Sulfur dioxide .

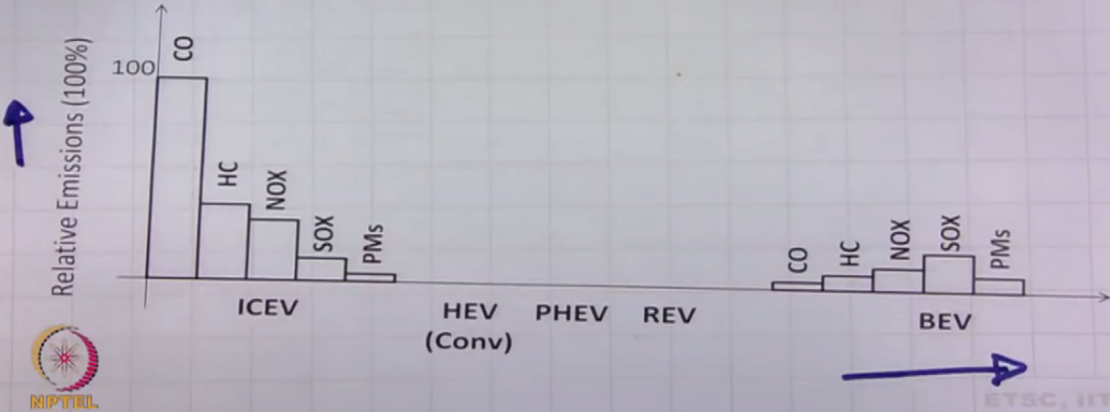
Particulate matter are particles released as a part of combustion cycle. These particles are extremely small in the range of micrometers. Therefore, they cannot be filtered by human throat and nose and therefore, it enters the body and affects heart, lungs and brain. These particulate matters are cancerous in nature and one of the major reasons for causing cancer due to air pollution. Diesel engine releases more PM compared to petrol. PM particles less than 10 micrometers which are PM<sub>10</sub> are very dangerous and if inhaled can cause severe damage. So these are clubbed and referred to as PM<sub>2.5</sub>. These three gases are known as greenhouse gases. Due to the presence of these gases, infrared radiations are trapped in the atmosphere. Due to the presence of these gases, the infrared radiations will be trapped in the atmosphere and cause the greenhouse effect such as climate change and global warming. Carbon Monoxide is a colorless, odorless gas which is very dangerous for human health. It is poisonous. Large amounts of CO<sub>2</sub> are released by IC engine based vehicles which adds to the already present CO<sub>2</sub> in the atmosphere and thus contributes to the greenhouse effect.

NO<sub>x</sub> gases, VOC and total hydrocarbons are responsible for building the ground level ozone layer. So the ozone layer if it's present at the ground level is very dangerous for humans. It can create lining in the lungs, and cause major respiratory illness such as asthma and lung inflammation. So diesel engines are the main source of NO<sub>x</sub> gases. So these gases can be filtered using catalytic converters but these devices are costly. So NO<sub>x</sub> gases can be minimized by use of urea filters.

So SO<sub>x</sub> gases which are dominantly SO<sub>2</sub> sulfur dioxide gas is released by coal based thermal power plants. So we can say that if electricity is used in EVs they are creating more SO<sub>x</sub> gases in the atmosphere. So the sulfur dioxide gas reacts with oxygen and water present in the atmosphere and creates sulfuric acid in the atmosphere. So these are the major reasons for acidic rains. The solution is low sulfur coal should be used for power generation which is costly of course. So let us have a quick look at the graph of relative emissions caused by various pollutants with respect to type of EVs.

# Benefits of Using EVs

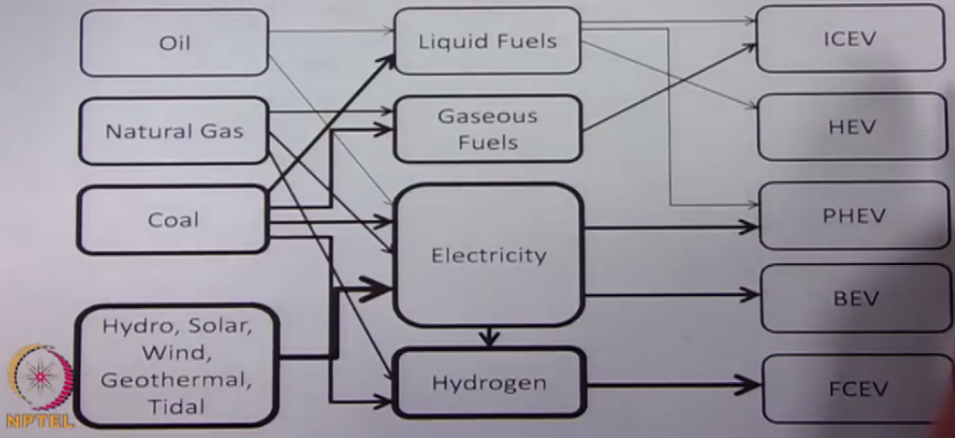
Comparison of Pollutants and Greenhouse Gases



So it can be clearly seen that the harmonic emissions by the use of battery electric vehicle is comparatively very small as generated by IC engine based vehicles. The emissions by hybrid vehicles lies somewhere in between these two streams. So the global countries are pushing for hard regulations. We all know about EURO regulations in Europe. And Bharat Stage regulation in India which is enabling vehicle manufacturers to do research such that the emission of this pollutants can be minimized.

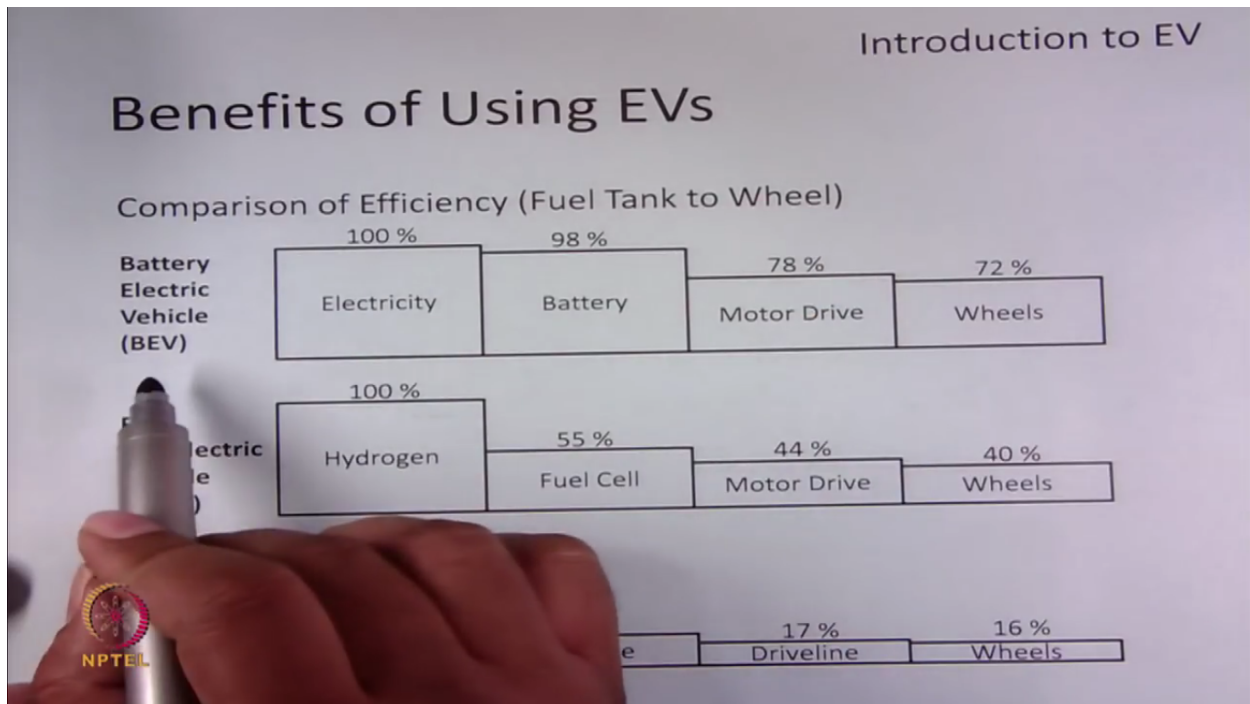
# Benefits of Using EVs

Comparison on Energy Diversification



So it is interesting to compare energy diversification of different types of vehicles. ICEV engines typically use liquid fuels and gaseous fuels. Which are coming from either oil or natural gas. While pure electric vehicle such as battery electric vehicle and fuel cell electric vehicle use either electricity or hydrogen as energy carriers. So if we see the types of fuels and the sources which are required to generate these fuels we can clearly see that electricity can be generated by almost all the energy sources. Therefore, EVs have a definite advantage compared to IC engine which requires oil and natural gas as its fuel.

So among different types of vehicles PHEV you can say most energy diversified because it can run on both liquid fuels, and electricity. And these two fuel sources have an already excellent infrastructure support present now. The use of EV also provides higher energy efficiency.

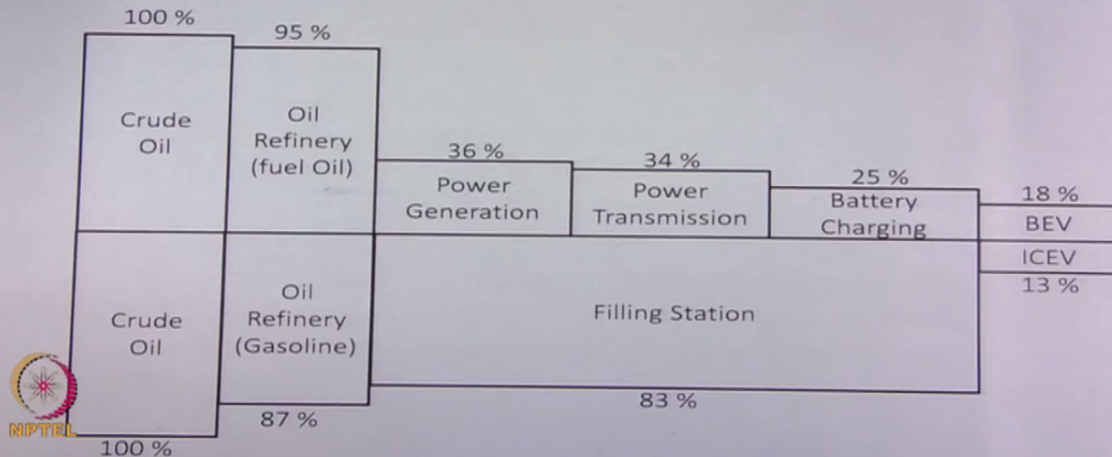


So if we compare fuel tank to vehicle efficiency the battery electric vehicles provides 72% efficiency at the wheels and the fuel cell in the IC engine vehicles provide 40% and 16% efficiency at the wheels if you take the starting source as 100%. A more fair comparison can be done if we start from the source of energy which is let's say crude oil.



# Benefits of Using EVs

## Comparison of Efficiency (Well to Wheel)



So if we start with 100% crude oil for both battery electric vehicle and IC engine vehicle we can see that the efficiency on the wheels is 18% for battery electric vehicle and 13% for the IC engine based vehicles. The major loss in calculation of battery electric vehicle efficiency happens in power generation. It is only 36% for a typical thermal power plant. While the major loss component in the efficiency of IC engine based vehicle is very inefficient engine efficiency only 20%.

So the overall efficiencies of battery electric vehicle and IC engine based vehicles are comparable. But battery electric vehicle have few advantages such that energy can be recovered during breaking as generative power. Secondly it can be charged using renewal power which is pollutant free. So let's compare EVs with ICEV in terms of capital cost and performance.

## Benefits of Using EVs

### Comparison of Capital/Operation Cost and Performance

- The BEV has advantage of higher fuel economy than the ICEV.
- The BEV is much more expensive than the ICEV.
  - Due to initial Battery Cost.
  - Replacement of Battery after few years.
- BEV requires less maintenance and is more reliable.
- BEV can recover energy during braking. It is also less noisy
- BEV allows high performance, and smooth control.
- BEV requires charging, and has limited range per charge.
- BEV can be charged by renewable sources such as solar.
- For the same energy requirement, BEV requires more space and heavy.



So battery electric vehicle have higher fuel economy compared to IC engine based vehicles but they are more expensive because of higher initial battery cost, and the requirement of battery replacement after few years. The BEV requires less maintenance. It's more reliable. As we mentioned it can recovery energy during breaking. It is also less noisy. Batter electric vehicle also allows high performance control. On the negative side, BEV requires continuous charging and they have a limited range per charge. So this is cause of concern. It causes range anxiety among customers. BEV can be charged using renewable energy sources such as solar. Also for the same energy requirement BEV requires more space and is more heavy.

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So we will begin our next topic of discussion which is overview of different types of EVs and their challenges in the next interaction.

Thank you.