Electric Vehicles

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Vehicle

- A vehicle is a machine designed for transporting people or cargo, generally self-propelled.
- It encompasses a wide range of devices, including cars, trucks, motorcycles, trains, ships, aircraft, and even spacecraft.

What is Electric Vehicle (EV)?

- Electrical energy is used to generate motion
- Energy from generators/power grid is stored in a battery (chemical energy)
- Battery discharged electrical energy is the input to an electrical motor
- Motor converts electrical to mechanical energy
- This is also called electrical engine.

Internal Combustion Engine

- A combustion engine, also known as a heat engine, is a device that generates mechanical power by burning fuel within a combustion chamber.
- This process releases energy that drives pistons or turbines, converting chemical energy into mechanical energy.
- They involve a four-step process: intake (fuel and air mixture enters), compression (mixture is compressed), combustion (mixture is ignited and burned), and exhaust (combustion products are expelled).
- Examples include gasoline engines, diesel engines, and gas turbine engines.

Internal Combustion Engine

- The entire engine requires hundreds of precisely crafted moving parts. That makes the engine heavy and expensive.
- Since all the heat and explosions cause a lot of wear and tear, you need a lot of maintenance, and even then it wears down pretty quickly.
- The heat engine also wastes a lot of energy.

Internal Combustion Engine

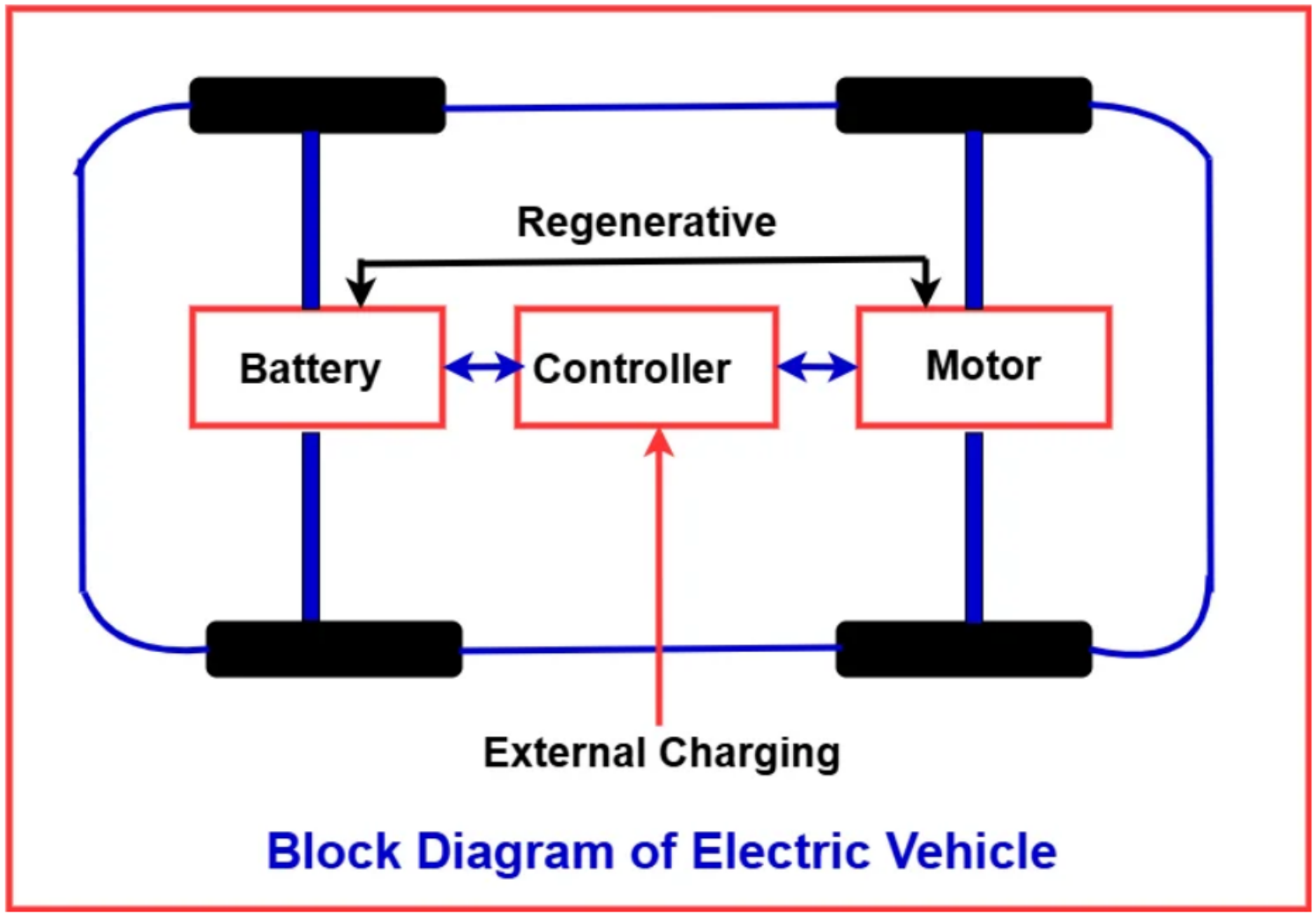
- In practice, even though we've been improving the internal combustion engine for more than 150 years now, a regular car wastes more than 75% of the energy it consumes as heat.
- And a sports car like the Bugatti Veyron wastes more than 95% of energy if you drive it in regular city traffic.
- For health and climate change, the biggest problem is the exhaust fumes.
- These fumes are unhealthy, burning 1 liter of gasoline produces 2.3 kilogram of carbon dioxide gas

EVs

- In an electric motor, it all works completely different.
- We will dive into all the types of electric engines later, but fundamentally they all work by using magnetic fields.
- The advantages of the electric motor are numerous.
- It only has one moving part, we call that the rotor.
- Therefore, it can be relatively light, compact and inexpensive.
- And since magnetic fields are very *gentle*, an electric motor can last essentially forever without any maintenance.

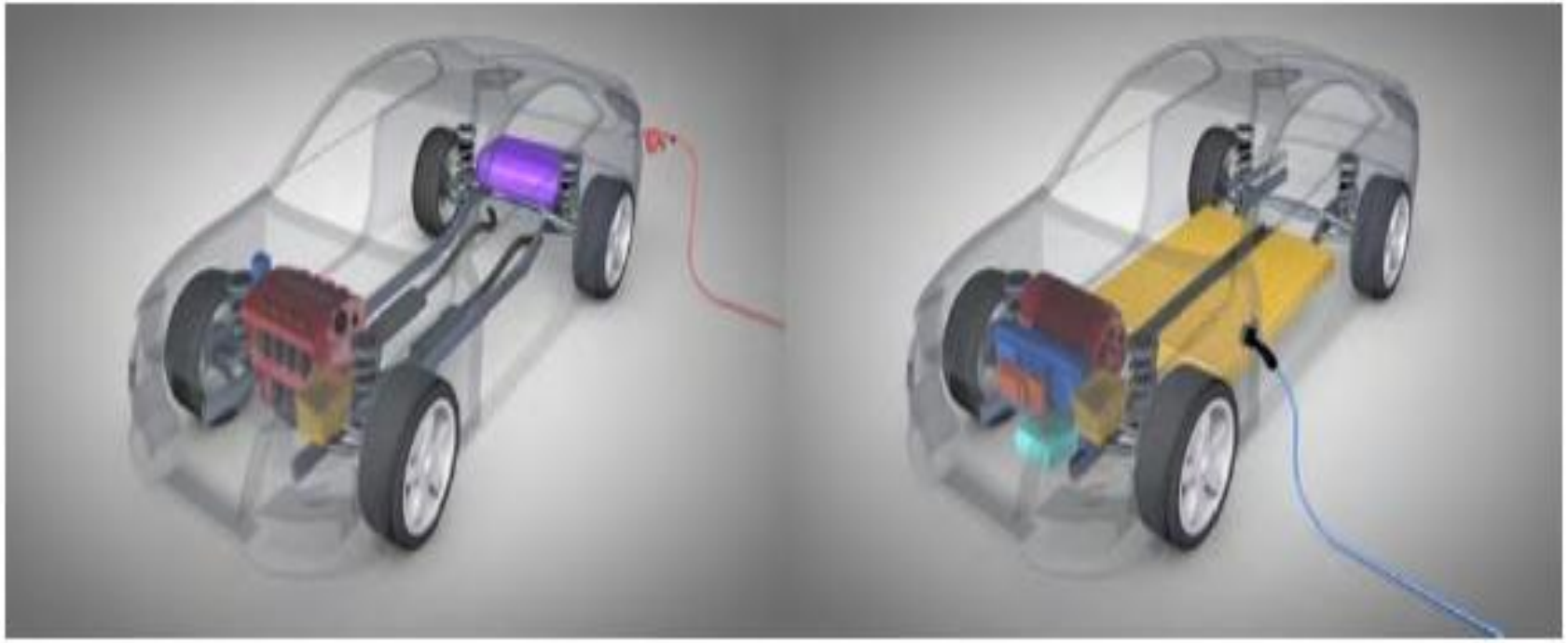
EVs

- The energy efficiency of the motor can be close to 100% and you can win back energy when braking.
- Because of this, the average electric car is four times more efficient than the average conventional car.
- And if you compare sports cars the electric car is up to twenty times more efficient.
- So oversizing an electric engine does not materially reduce efficiency and the engines are cheap and light.
- For health and climate, the biggest advantage is clear: it can run on renewable energy and the motor itself has zero emissions.



Block Diagram of Electric Vehicle

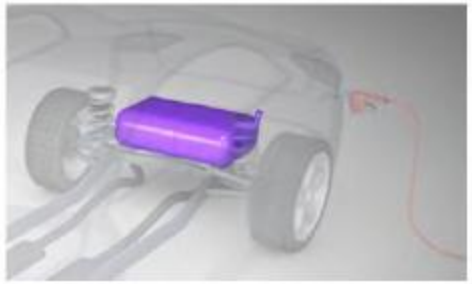
EV and ICEV

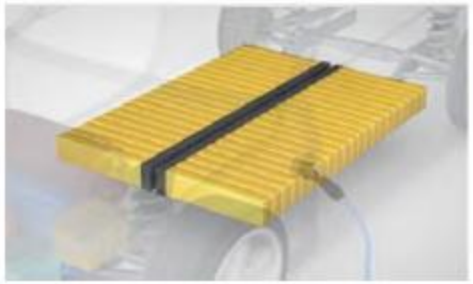


EV vs ICEV

- It is clear the electric motor is superior in every way.
- So why did we end up with the gasoline engine until know?
- To answer that question we must turn to the question of energy storage.
- When you look at motors, the electric engine has the upper hand.
- But if you look at energy storage, the heat engine has the upper hand: fuel is a really marvelous way to store energy. And batteries compare very poorly to that.

Fuel storage vs battery storage





- A lead-acid battery from 1900 stored only around 0.01 kWh per kg: that's more than 1000 times worse
- No wonder the gasoline engine won!
- A lead-acid battery at the end of the last millennium was better at 0.035 kWh per kg but that's still about 350x worse.
- A nickel-metal hydrate available at the turn of the new millennium stores 0.08 kWh. This is still 150 times less.

- But then people woke up, primarily because they needed lighter batteries for cell phones and laptops.
- By 2015, a lithium battery as produced by the *Tesla Gigafactory* has about 0.25 kWh/kg, still 50 times worse

Extra Weight of Batteries

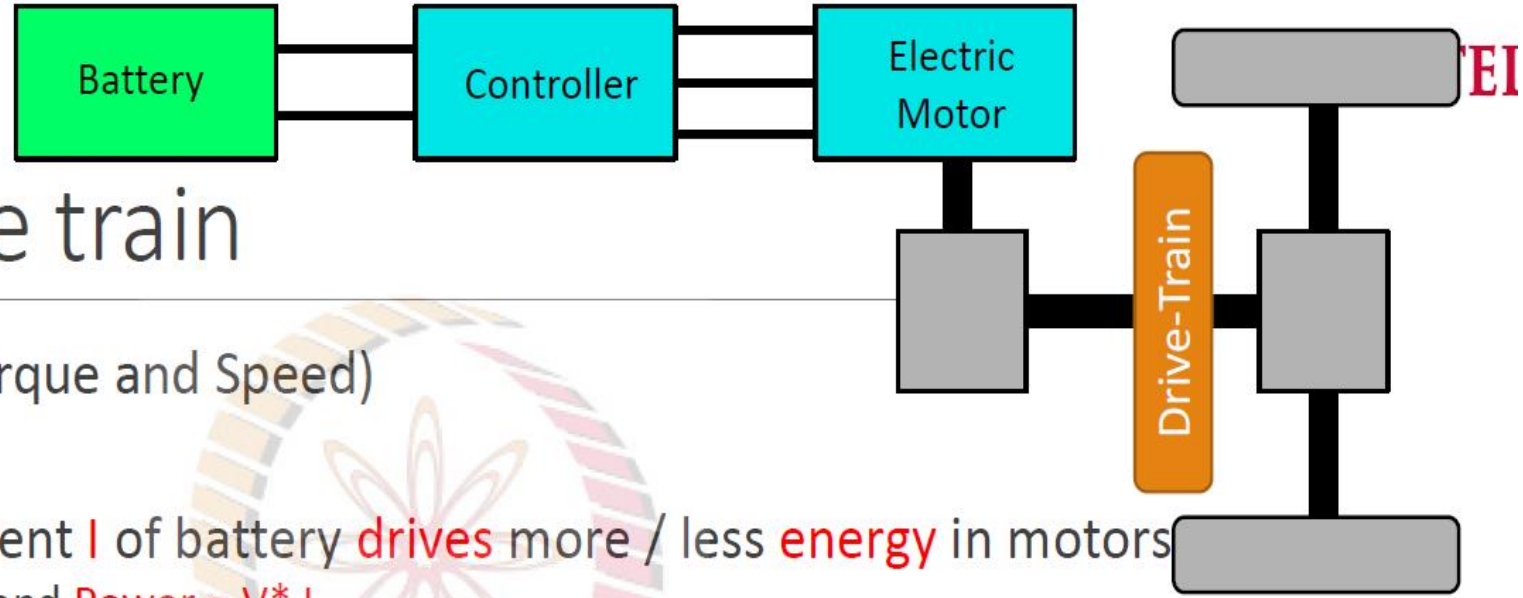
The extra weight of batteries (Lithium-air maximum energy content is theoretical)

Energy source	Year	Energy (Whr/kg)	Compared to gasoline
Gasoline	1900-20??	12 000	-
Lead-acid	1900	10	1200x worse
Lead-acid	2000	35	350 worse
NiMh	2000	80	150x worse
Lithium	2015	250	50x worse
Lithium	2025	400	30x worse
Lithium-air	????	12 000*	same

- How bad is that in reality, if we want to be able to drive a distance of 500 kilometres?
- In 1900 we would have needed to take 10000 kg with us: a very big elephant.
- At the end of the last century, it was still a rhinoceros of 3000 kilos.
- The nickel-metal hydrate battery turned it into an 800 kg bison.
- But with the advent of the lithium battery, the 10000 kg elephant has turned into a 400 kg gorilla by 2015.

Energy source	Year	Extra kg for 500 km	Equals
Lead-acid	1900	10 000	Elephant
Lead-acid	2000	3 000	Rhinoceros
NiMh	2000	800	Bison
Lithium	2015	400	Gorilla
Lithium	2025	200	Pig*

- if you take the weight of the drivetrain into account, the electric drivetrain is so much lighter than the entire electric vehicle will actually be lighter overall in 2025!
- So the idea that batteries make electric cars heavy will soon be something of the past.



Electric drive train

Motor and controller (Torque and Speed)
- Power = Torque * Speed

Battery + electricity: current I of battery drives more / less energy in motors
- voltage V nearly constant, and Power = V* I

DC-DC converter(s) convert the Battery voltage to desired voltage to drive auxiliary including power-brakes, electricity, air-conditioning and others
- including all electronics, communications, sensors and lights

Regeneration during deceleration and climbing down: Mechanical power converted to electricity to charge battery

Battery Charger to fill electricity (charge) in battery

Gears multiplies Torque but

A IC engine or a EV motor may give less torque than a vehicle requires

- A **gear** is used to multiply torque by n
  - Vehicle Torque = n * engine /Motor torque
- At the expense of rpm: Vehicle rpm is reduced by n
  - Vehicle rpm = engine / motor rpm / n

Vehicle power is same as engine / motor power

- Thus Engine / *Motor Torque may be multiplied at the expense of Motor rpm*
  - *A must for IC engine / an option for EV motor*

Do we use multi-gear or Changeable Gear?

Multi-gear or changeable gear can change gear-ratio to different values

- Gears changed using a clutch which temporarily disengage gear from motor
- Common in all ICE vehicles

But EV motors are usually designed to work efficiently with a large range of speeds and torques

- It normally uses a single FIXED gear
- That would be the preference, as long as one can meet all vehicle requirement with the motor and a fixed gear

Power does not change with gear-ratio

World’s first Solar Train

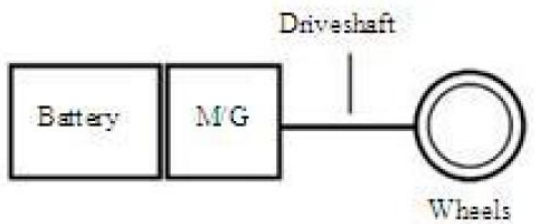
- https://youtu.be/jCe-MpUB-vs?si=4Zy898YnoYhYROoc

ICEV

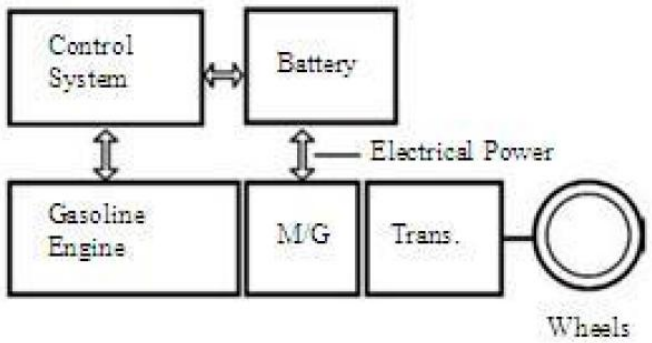
- Chemical to mechanical energy
- How to start combustion?
- How to give auxiliary electrical power?

Hybrid Vehicle

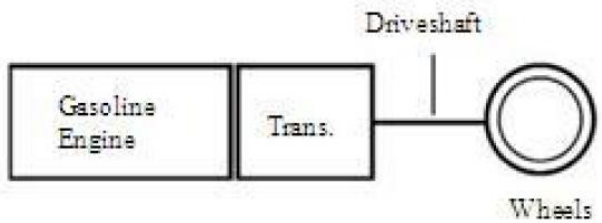
Pure Electrical



Hybrid



Pure Gasoline



Plug-in Hybrid vehicle

- Hybrid with an option to charge the battery
- Less pollution

References

- NPTEL Course: **Fundamentals of Electric vehicles: Technology & Economics, IIT Madras**

- TU Delft - Electric Cars: Technology -DelftX eCARS2x

- NPTEL Course: **Introduction to Hybrid and Electric Vehicles, IIT Guwahati**