

HYBRID ELECTRIC VEHICLES



NEED FOR HYBRID ELECTRIC VEHICLES (HEV)

- ❖ To be a useful vehicle, a car must meet some minimum requirements
 - ◆ It must drive at least 400-500 kilometres before re-fuelling.
 - ◆ It must be refuelled quickly and easily (3-5 minutes).
- ❖ A pure electric car, however, cannot meet all of these requirements.
 - ◆ Current standard EVs can only go 100-200 km between charges
 - ◆ They need a long time to recharge their battery
- ❖ A hybrid EV is a compromise between an IC engine car and an electric car.



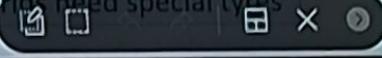
HYBRID ELECTRIC VEHICLES (HEV)

- ❖ A hybrid vehicle combines two power (energy) sources.
 - ❖ Typically, one energy source is a standard fuel and the other is a storage.
 - ❖ Possible types: diesel + electric, petrol + flywheel, fuel cell + battery.
 - ❖ The two power sources can support either one or two separate drive systems.
-
- ❖ The two power sources may be arranged in:
 - ★ Series: an engine driven generator charges the batteries, which in turn powers the electric motor that propel the car.
 - ★ Parallel: the vehicle is driven simultaneously by its engine and motor.

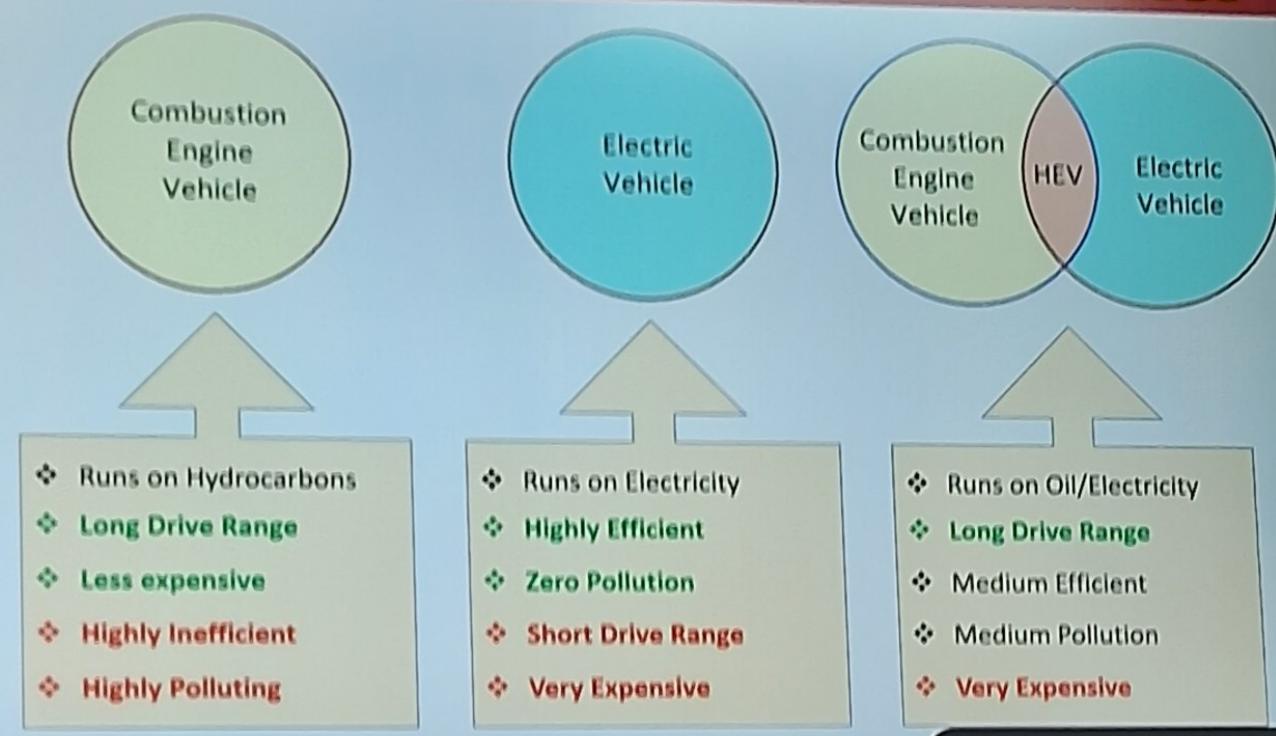


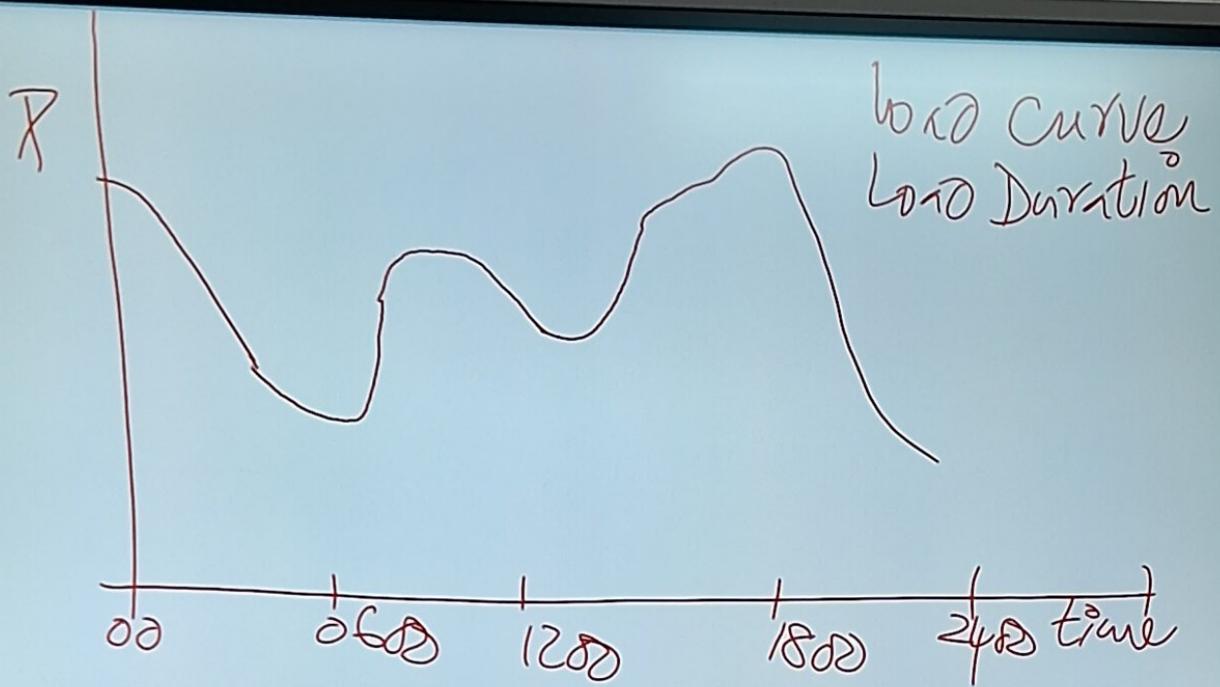
PROS AND CONS OF HYBRID VEHICLES

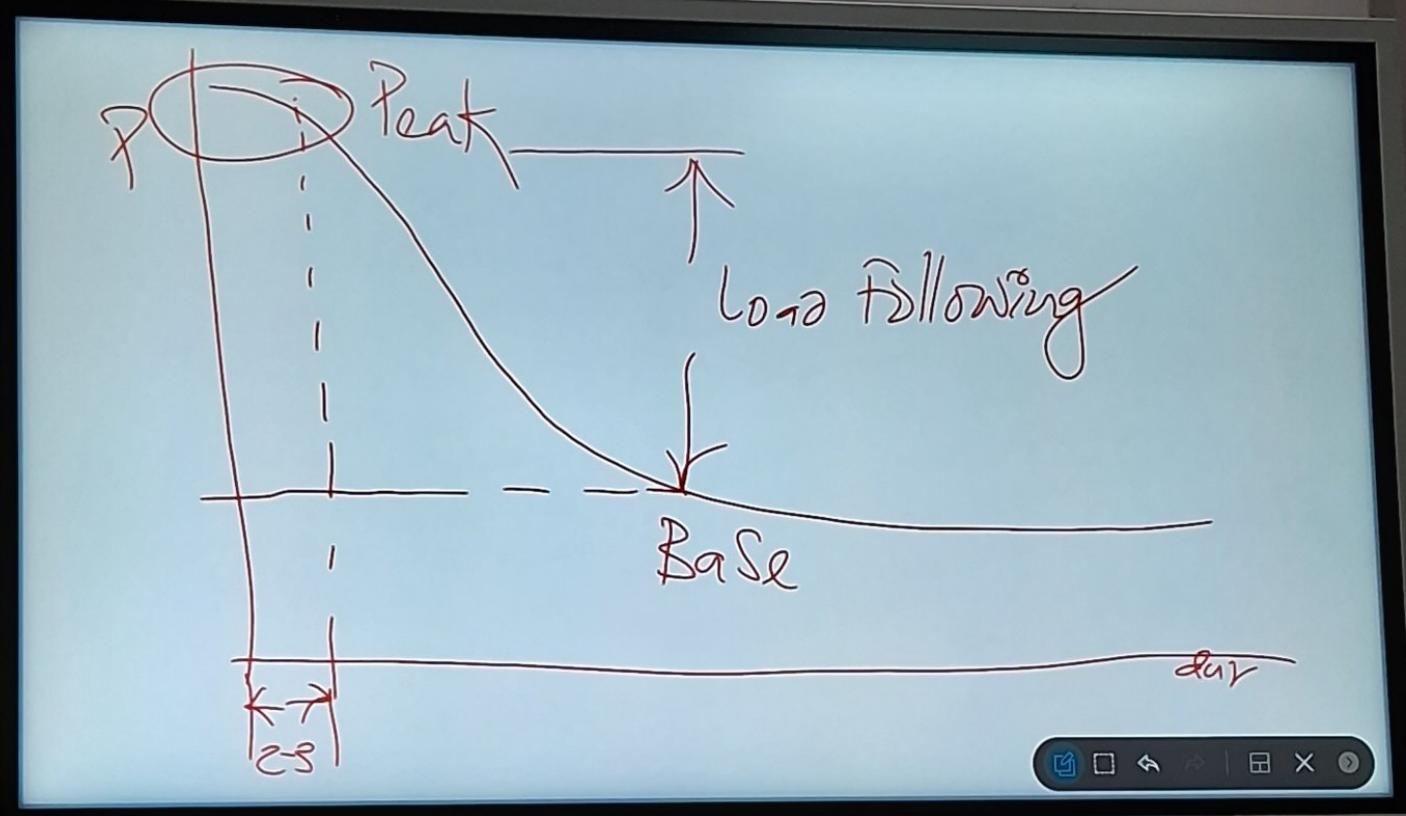
Advantages	Disadvantages
<ul style="list-style-type: none">❖ Long travel ranges than battery EVs❖ Uses smaller engines than IC engine vehicles❖ Uses Regenerative Braking❖ Better overall mileage❖ Reduced petrol consumption❖ Much lesser tailpipe emissions than ICE❖ Engine can be shutoff during idling❖ Easy cold start due to larger battery & motor❖ Improved acceleration (most of the time)	<ul style="list-style-type: none">❖ High initial cost❖ Not fully emission-free, only reduced emission❖ Needs more complex controls❖ More expensive than ICE/BEVs❖ Little highway mileage increase❖ Higher maintenance costs❖ Extra maintenance items❖ Some hybrids need special tyres



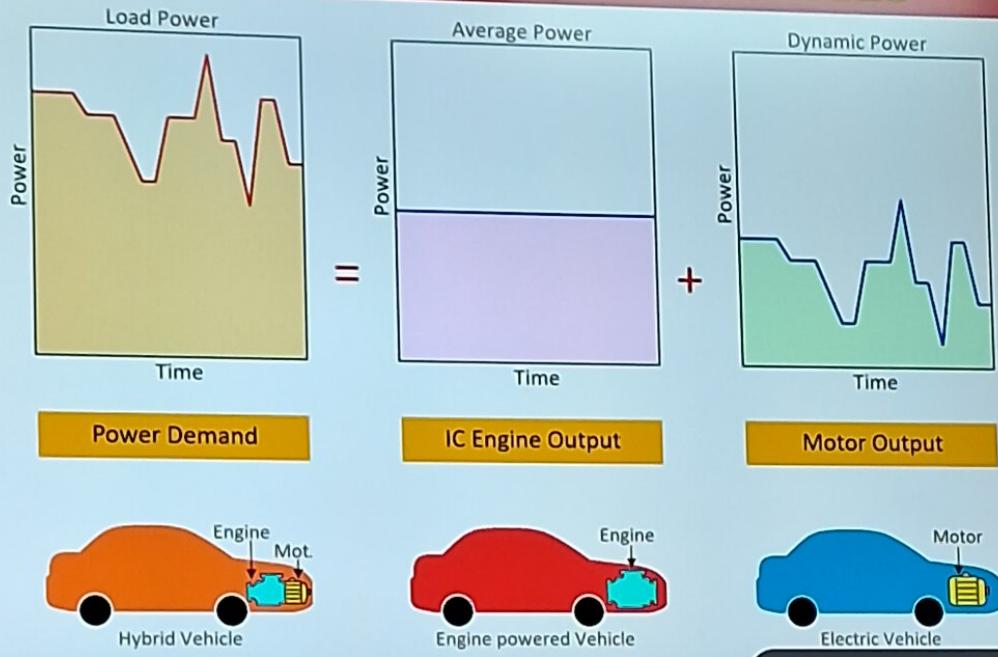
ADVANTAGES OF HYBRID ELECTRIC VEHICLES



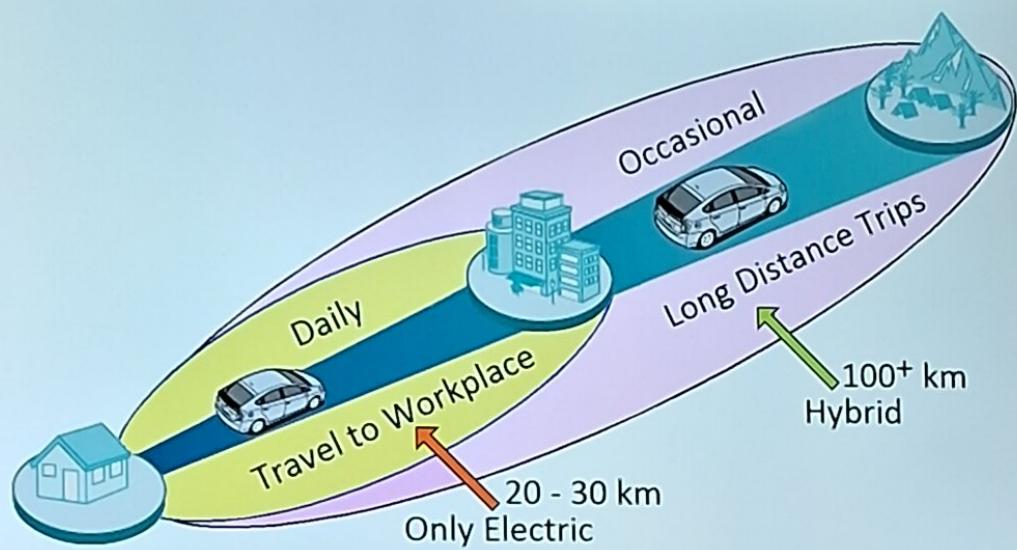




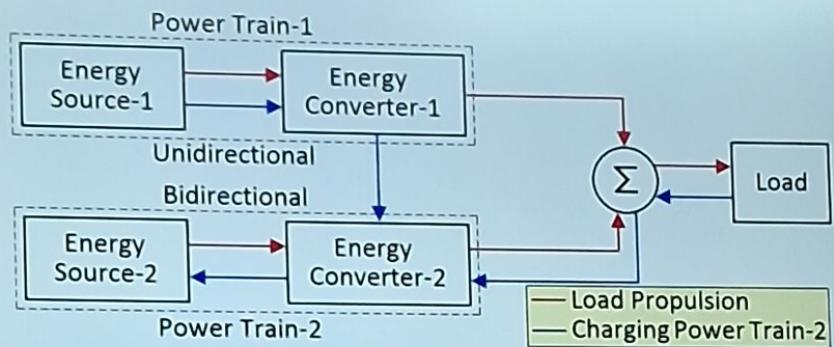
ADVANTAGE OF HYBRID VEHICLES



RANGE OF ELECTRIC & HYBRID VEHICLES



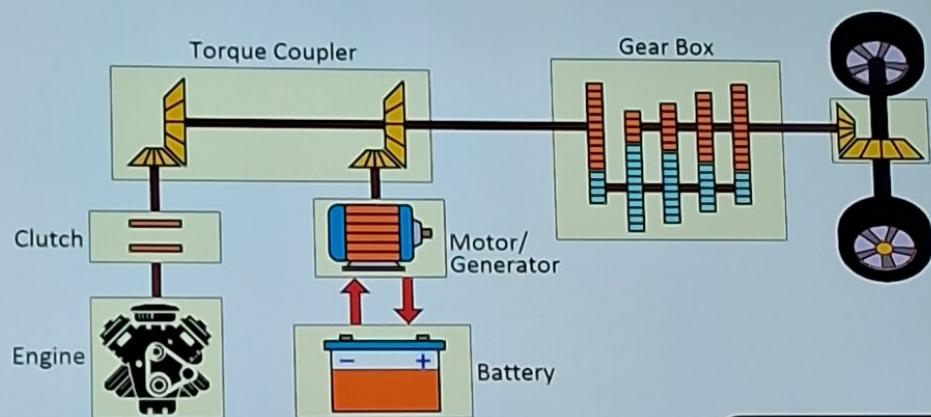
POWER FLOW PATHS IN HYBRID VEHICLES



- ❖ Power train-1 is typically the conventional ICE system in which power flow is only unidirectional: from engine to wheels.

ARRANGEMENT OF HYBRID DRIVETRAIN

- ❖ A normal vehicle has a mechanical drivetrain driven by an engine.
- ❖ A hybrid vehicle uses two or more different types of power, such as IC engine plus electric motor.

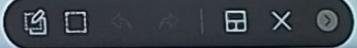


TOYOTA PRIUS: THE FIRST HYBRID VEHICLE



Plug-in Hybrid
(Year of Introduction: 1997)

- ❖ Being a plug-in hybrid electric vehicle (PHEV), Toyota Prius can be:
 - ◆ plugged into an electric outlet for charging its battery
 - ◆ fueled at a petrol station



TOYOTA PRIUS: THE FIRST HYBRID VEHICLE

Engine System	Electrical Systems
<ul style="list-style-type: none">◆ Front-engine, front/4-wheel-drive◆ Engine: 2.0 L, 4 Cylinder◆ Atkinson cycle, petrol◆ Engine efficiency: 40%◆ Curb weight: 1,570–1,620 kg◆ Petrol range: 12.5 to 13.2 km/litre	<ul style="list-style-type: none">◆ AC: 650 V (for traction motor)◆ DC: 222 V (Li-ion battery)◆ Battery Capacity: 13.6 kWh◆ Motor Power: 83 kW◆ Energy Consumption: 174 Wh/km◆ Only Electric range: 40-70 km



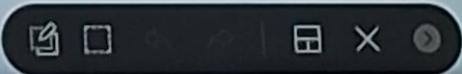
TOYOTA PRIUS: THE FIRST HYBRID VEHICLE

- ❖ Being a plugin hybrid electric vehicle (PHEV), Toyota Prius can be:
 - ◆ plugged into an electric outlet for charging its battery
 - ◆ fueled at a petrol station
- ❖ Prius uses a series-parallel hybrid drive system.
- ❖ It can drive the wheels using both electric motors and/or its petrol engine.
- ❖ If the battery energy is sufficient, Prius runs on the electric motors only.
- ❖ Rooftop PV panels are added to charge the battery when the car is parked (prime model).



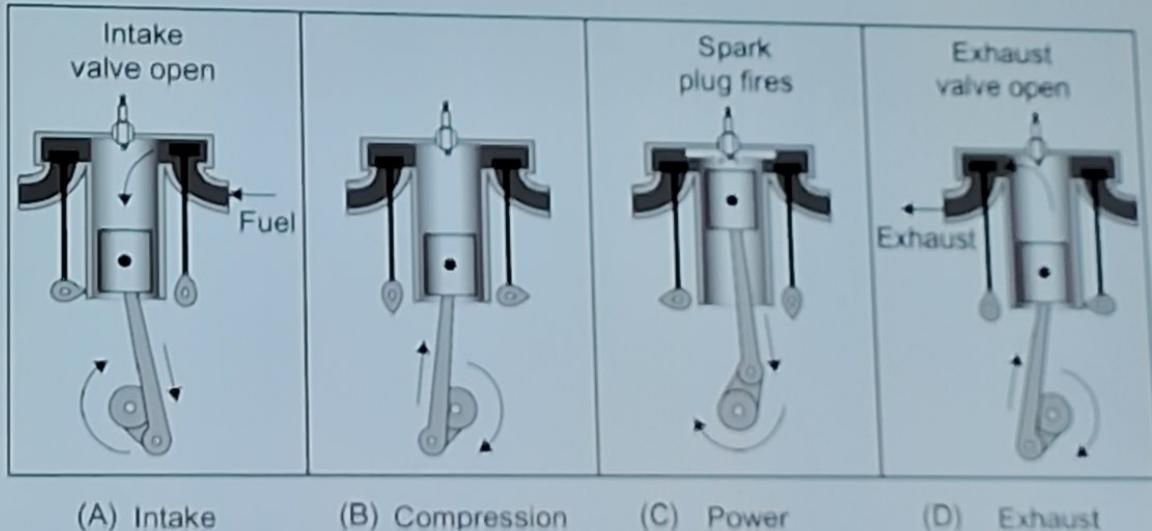
OTTO CYCLE

- ❖ The Otto cycle, invented by Nicolaus Otto in 1876, uses a spark ignition piston engine.
- ❖ It is the thermodynamic cycle most commonly found in petrol engines.



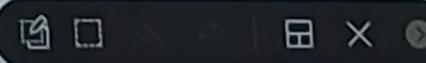
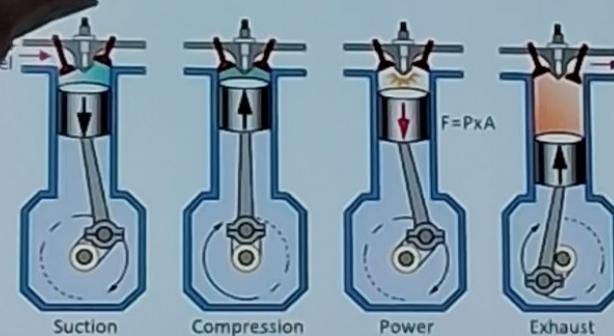
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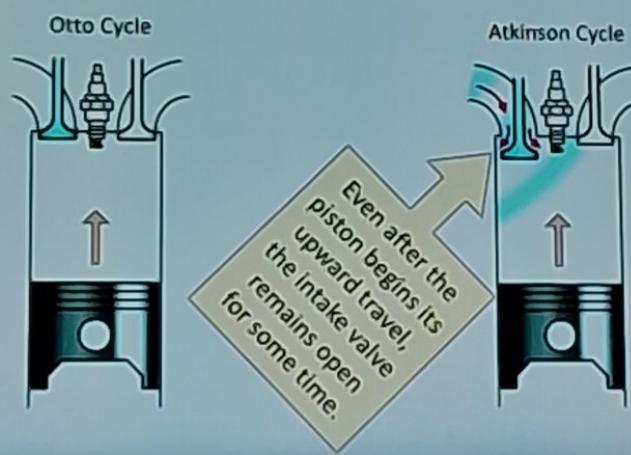
ATKINSON CYCLE

- ❖ Invented by Dr. James Atkinson (1882), works almost like the Otto cycle.
- ❖ Holds the intake valve open even during some % of compression stroke.
- ❖ This allows some of the Air/Fuel mixture to escape back into the intake manifold.



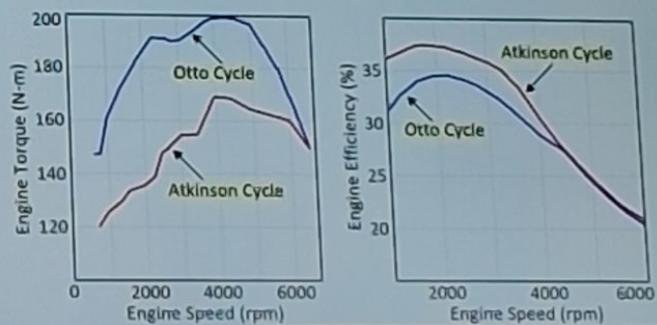
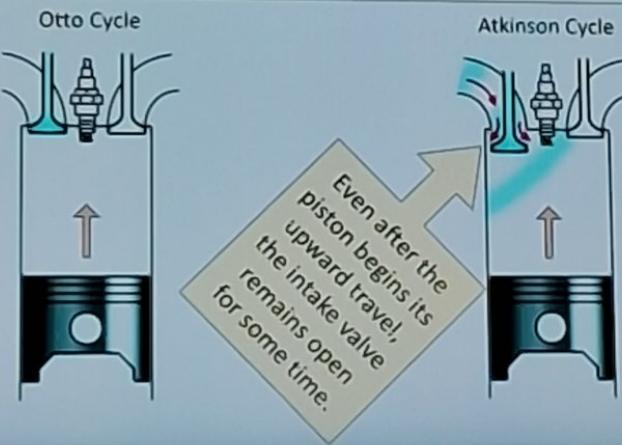
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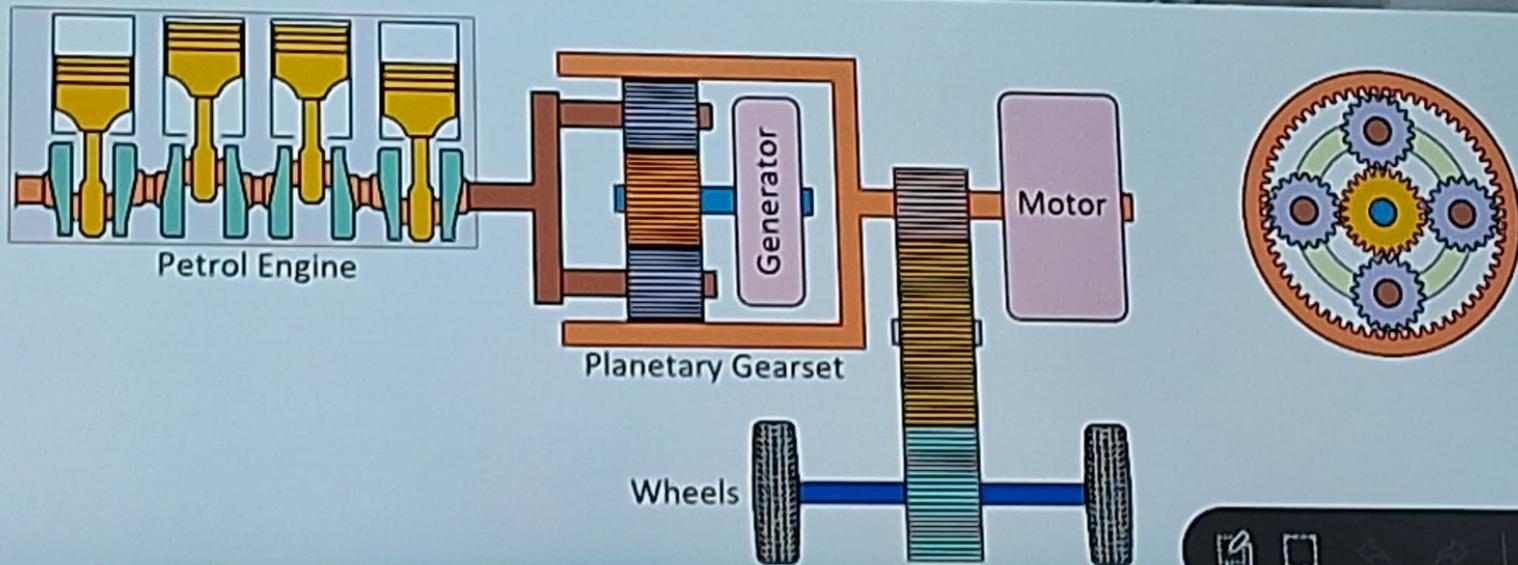
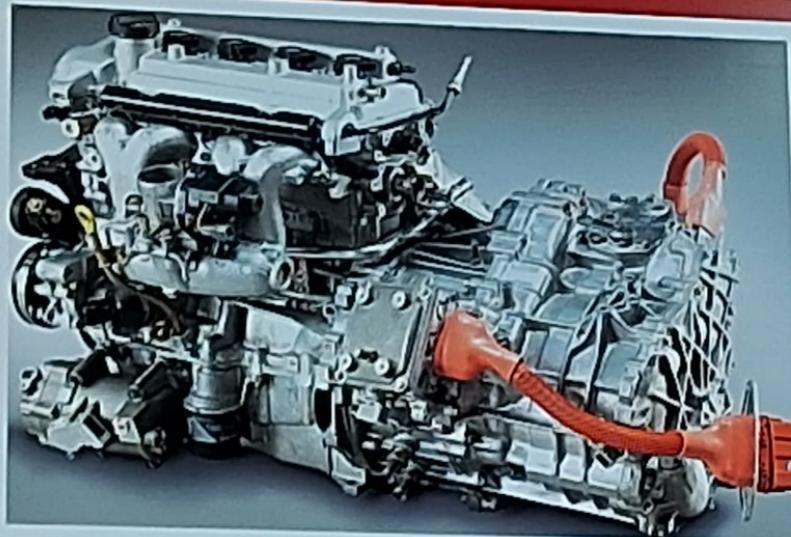


ATKINSON CYCLE

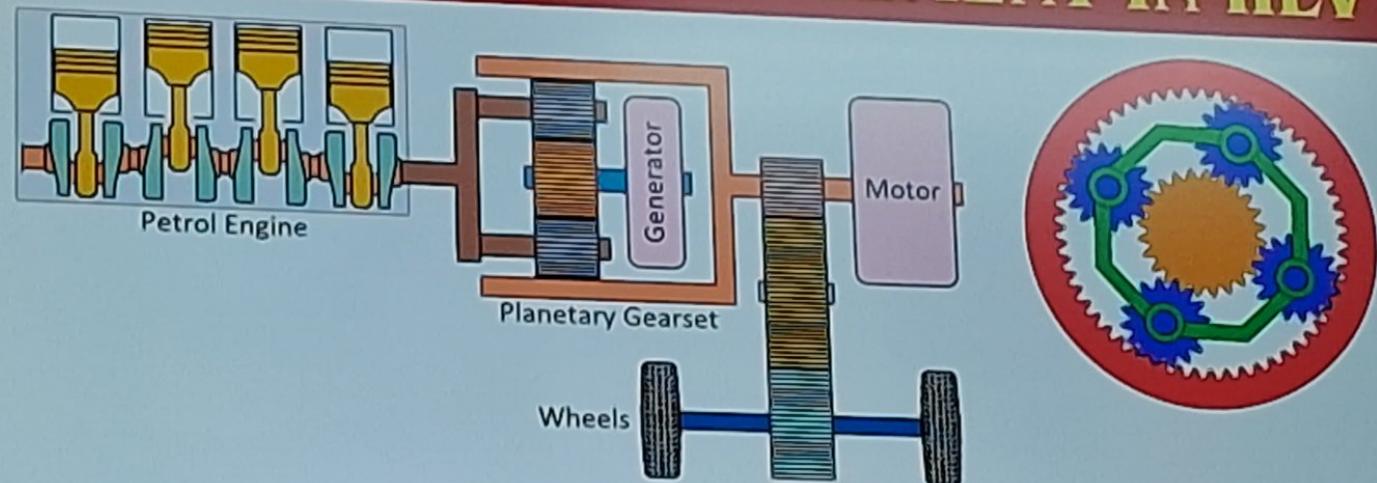
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- ❖ Holds the intake valve open even during some % of compression stroke.
- ❖ This allows some of the Air/Fuel mixture to escape back into the intake manifold.
- ❖ Result: Reduced engine displacement, compression ratio, and fuel consumption.
- ❖ Increased efficiency at lower speeds (but reduced torque).



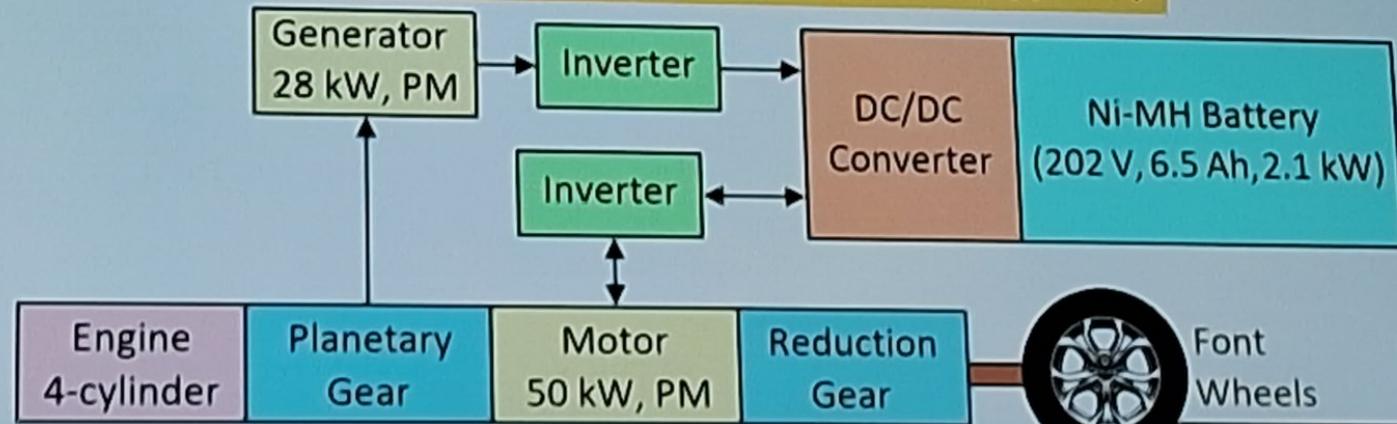
TOYOTA PRIUS HYBRID CAR DRIVE TRAIN



ENGINE-MOTOR ARRANGEMENT IN HEV



Toyota Prius Drivetrain Layout (typical)



DEFINITION OF HYBRIDNESS

- ❖ Hybridness (or Hybridisation), H , is defined as:

$$H = \frac{\sum P_{EM}}{\sum P_{EM} + P_{Engine}} = \frac{\text{Sum of Power of all Electric Motors}}{\text{Sum of Power of Electric Motors + Engine Power}}$$

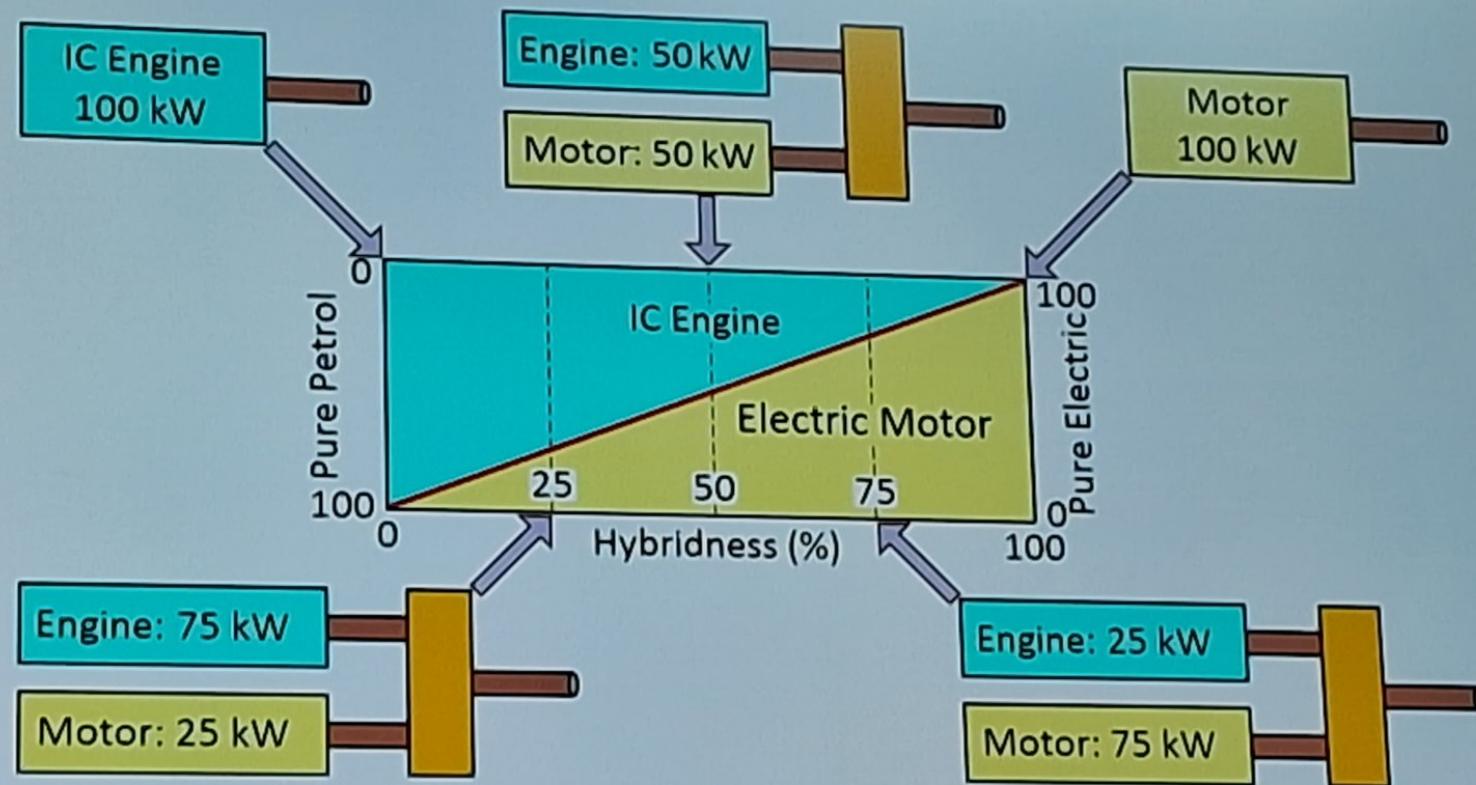
- ❖ Few hybrids (e.g. motor-in-the wheel) have more than one motor besides the engine.
- ❖ An example of hybridness:
 - ◆ Consider a light van with Diesel engine: 110 kW & Electric motor: 23 kW.
$$H = \frac{23}{23 + 110} = 17.3\%$$
 - ◆ This is a mild hybrid system.

CLASSIFICATION OF HYBRID EVs

- ◆ Depending on the Share of Electric Motor to the traction power:
 - ❖ Micro Hybrid (start-stop systems) (μ HEV)
 - ❖ Mild Hybrid (MHEV)
 - ❖ Full Hybrid (FHEV)
- ◆ Based on the Drive Train arrangement (i.e. engine and motor connection):
 - ❖ Series Hybrid (SEV)
 - ❖ Parallel Hybrid (PEV)
 - ❖ Combined (series-parallel) Hybrid (CEV)
- ◆ Based on the Energy Source
 - ❖ Battery EV (BEV)
 - ❖ Hybrid EV (HEV)
 - ❖ Plug-In Hybrid EV (PHEV)
 - ❖ Fuel Cell EV (FCEV)

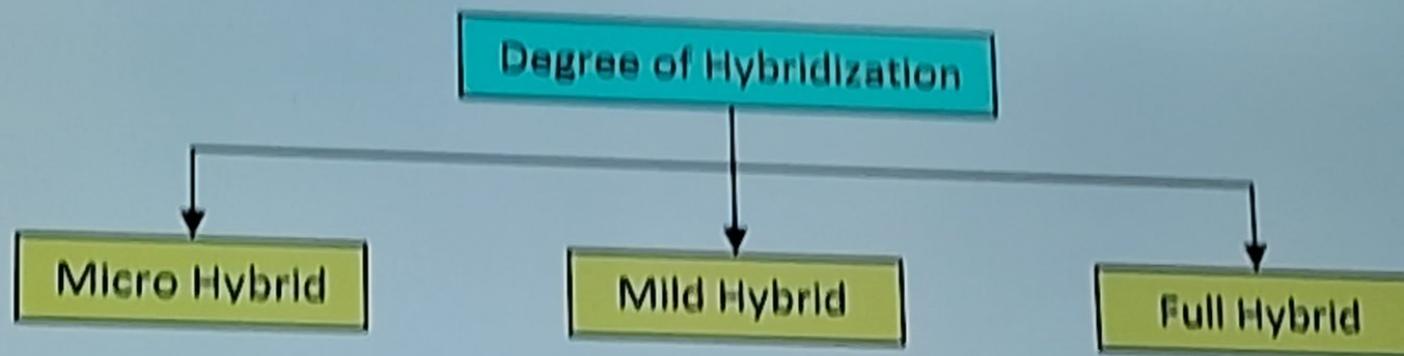


VARIATIONS IN HYBRIDNESS



CLASSIFICATION BASED ON HYBRIDISATION

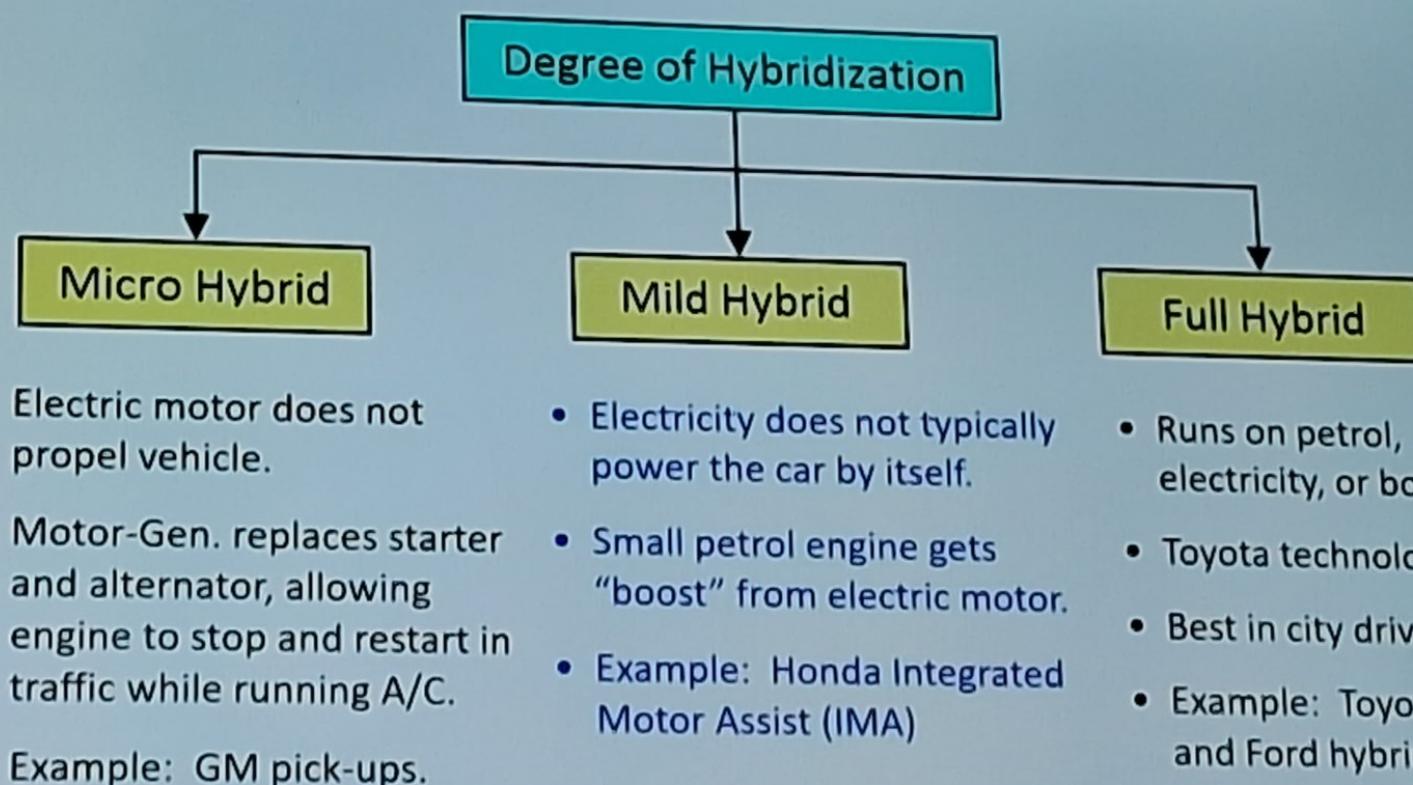
- ❖ Hybrids can provide performance while improving fuel economy ratings.



- Electric motor does not propel vehicle.
- Motor-Gen. replaces starter and alternator, allowing engine to stop and restart in traffic while running A/C.
- Example: GM pick-ups.

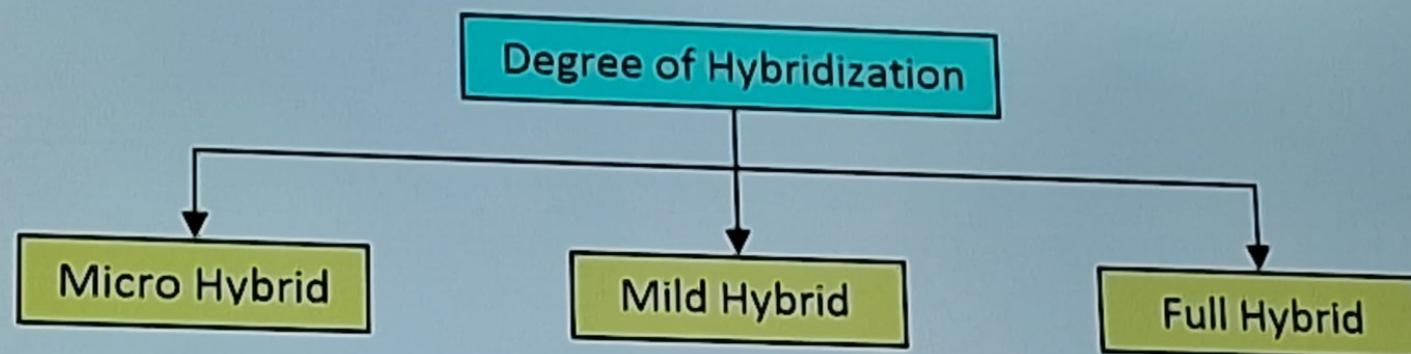
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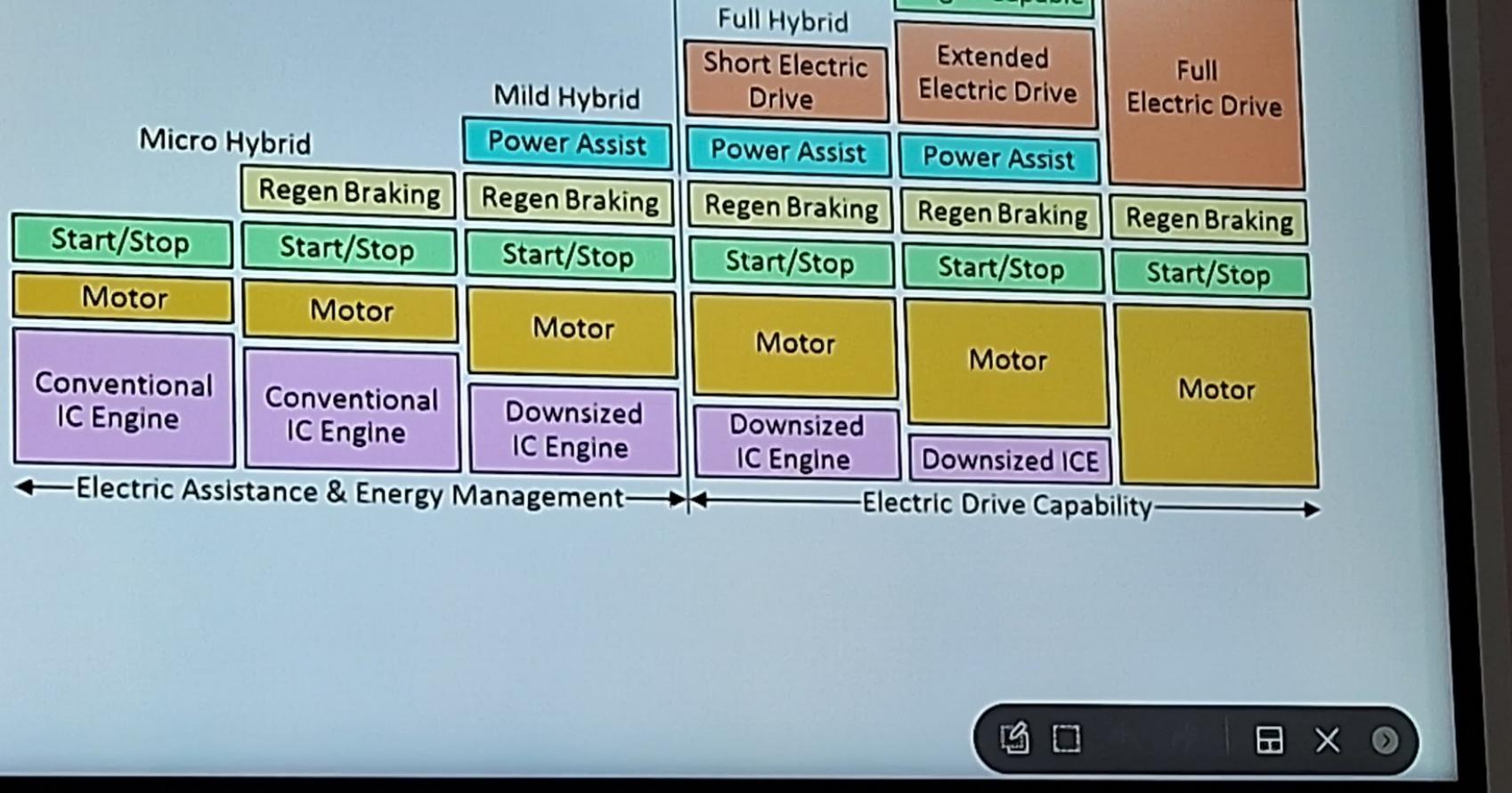
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 - Motor-Gen. replaces starter and alternator, allowing engine to stop and restart in traffic while running A/C.
 - Example: GM pick-ups.
- Electricity does not typically power the car by itself.
 - Small petrol engine gets “boost” from electric motor.
 - Example: Honda Integrated Motor Assist (IMA)
- Runs on petrol, electricity, or both.
 - Toyota technology
 - Best in city driving.
 - Example: Toyota Prius and Ford hybrids.

BATTERY CAPACITY FOR HYBRID VEHICLES

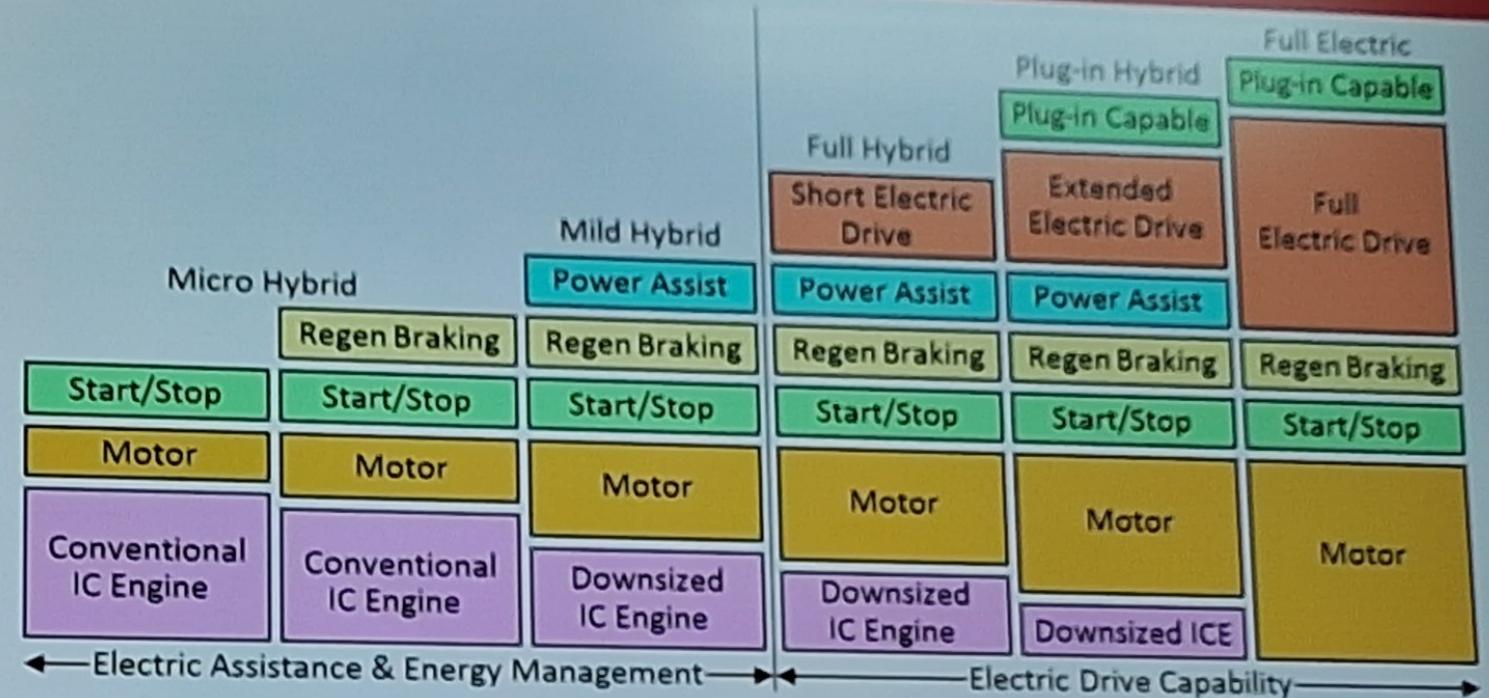
- ❖ Hybrid electric vehicles (HEV) generally use very low capacity batteries in comparison to battery electric vehicles (BEV).

Vehicle Type	Battery Capacity (kWh)
Micro Hybrid	-
Mild Hybrid	< 1
Full Hybrid	1.5 – 2.0
Plug-in Hybrid	10 – 12
Battery Electric	20 – 110 ⁺

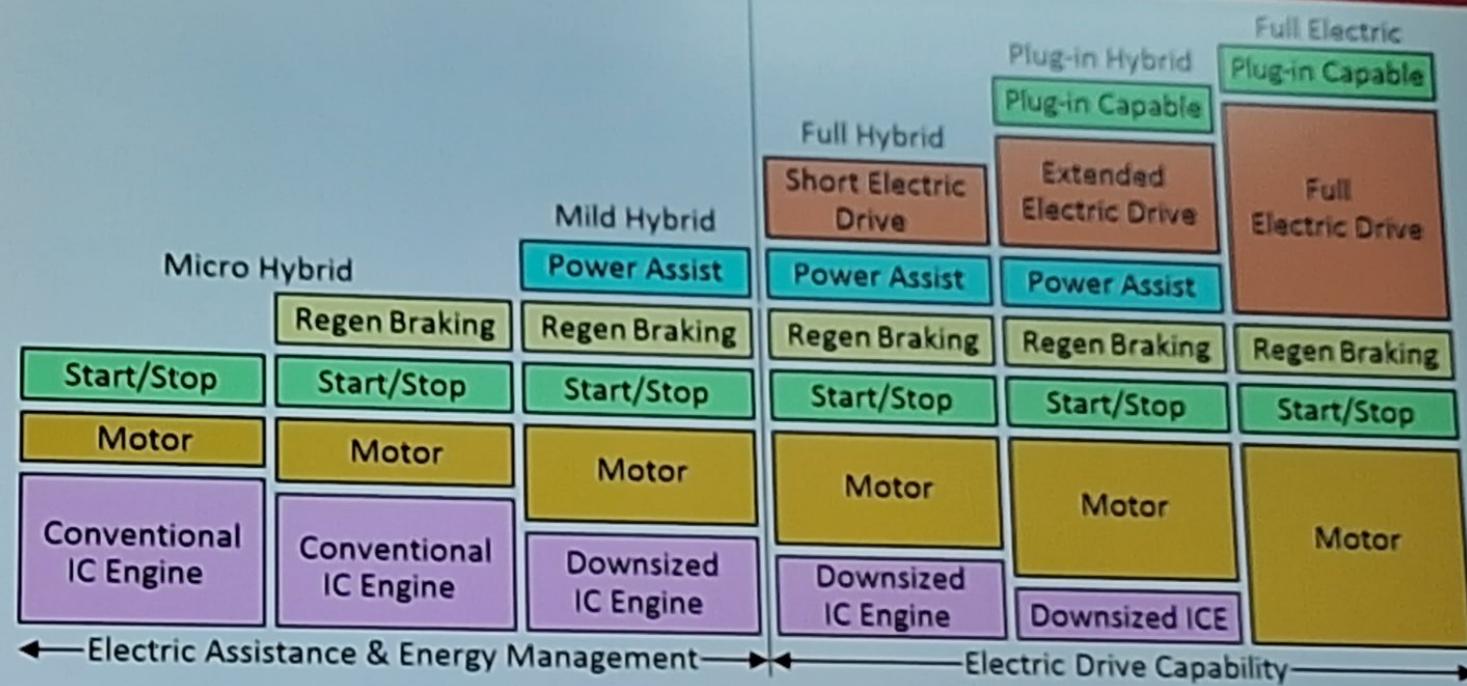




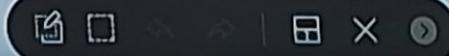
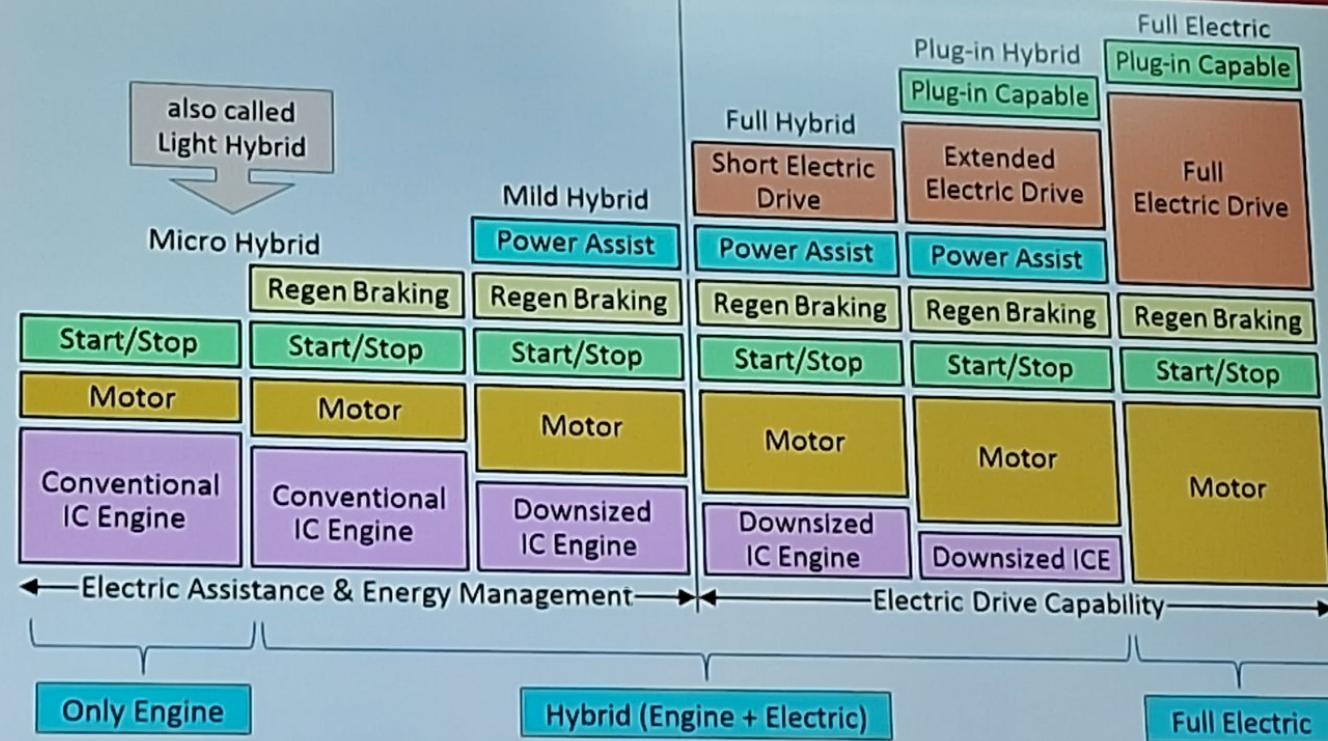
CLASSIFICATION OF HYBRID VEHICLES



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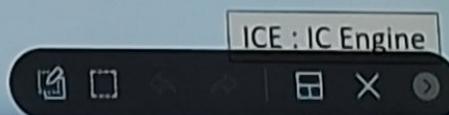
CLASSIFICATION OF HYBRID VEHICLES



LIGHT (MICRO) HYBRID

- ❖ Does not have a traction motor
- ❖ A small motor is used only for starting the engine
- ❖ Vehicle is never driven by a traction motor
- ❖ ICE starting motor runs as a generator while the vehicle is in motion
- ❖ Utilizes a low voltage battery
- ❖ Lead acid batteries
- ❖ Batteries recharged by
 - ◆ ICE motor (generator mode)
 - ◆ Regenerative braking

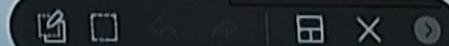
ICE : IC Engine



MILD HYBRID

- ❖ A small traction motor assists IC engine when extra torque is needed
- ❖ Vehicle is never independently driven by an electric motor
- ❖ ICE starting motor runs as a generator while the vehicle is in motion
- ❖ Utilizes a high voltage battery > 144 V
- ❖ Nickel metal hydride batteries
- ❖ Batteries recharged by
 - ◆ ICE motor (generator mode)
 - ◆ Regenerative braking

ICE : IC Engine



FULL HYBRID

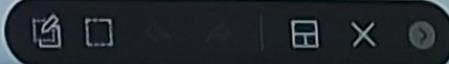
- ❖ Full hybrid EVs use relatively high-power traction motors
- ❖ Vehicle can be driven solely on electric traction motor – for short distances
- ❖ IC engine runs when more torque is required: uphill, overtaking, or battery soc is low
- ❖ Utilizes a high voltage battery > 190+ V
- ❖ Nickel metal hydride batteries
- ❖ Batteries recharged by
 - ◆ ICE motor (generator mode)
 - ◆ Regenerative braking

ICE : IC Engine



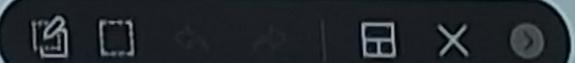
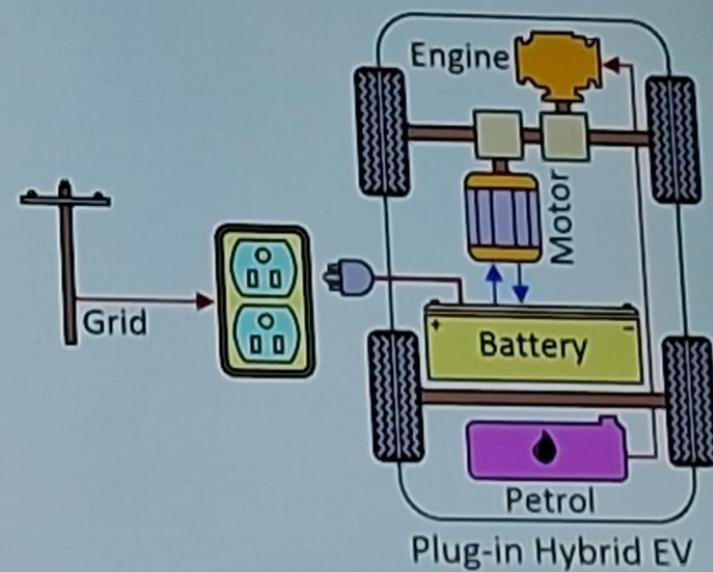
PLUG-IN HYBRID

- ❖ Vehicle can be driven solely on electricity at higher speeds and for longer distances
- ❖ ICE only runs when batteries are depleted ($SOC < 30\%$) or extra torque is needed
- ❖ Traction motor provides all the torque needed
- ❖ Utilizes a high voltage Li-ion batteries, $> 225+ V$
- ❖ Vehicle is recharged at night via on board 110 V
charger and during regen. braking



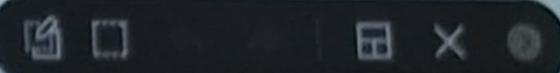
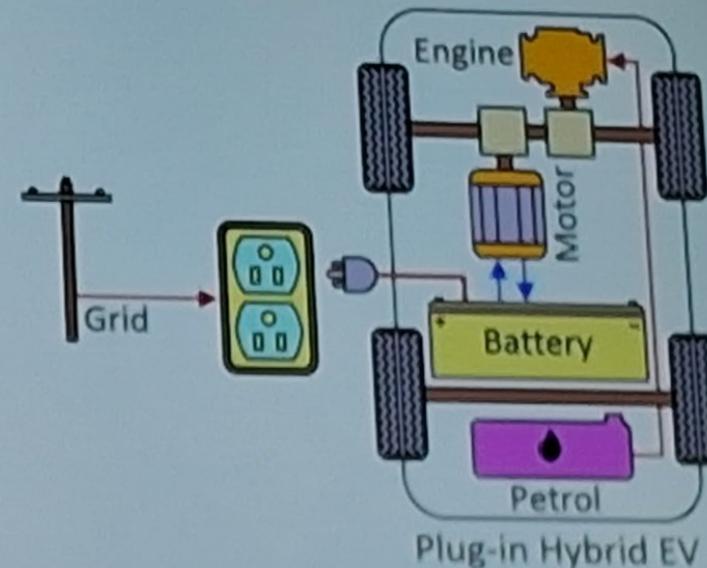
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HYBRID CARS IN INDIA

- ◆ Toyota Prius
- ◆ Honda Accord Hybrid
- ◆ Toyota Camry
- ◆ MG Hector
- ◆ Maruti Suzuki Ciaz
- ◆ Maruti Suzuki Swift
- ◆ Maruti Suzuki Ertiga
- ◆ Mahindra Scorpio Intelli hybrid
- ◆ Maruti Suzuki Baleno (mild hybrid)
- ◆ Toyota Glanza (mild hybrid)
- ◆ Volvo XC90 T8 Excellence
- ◆ BMW i8

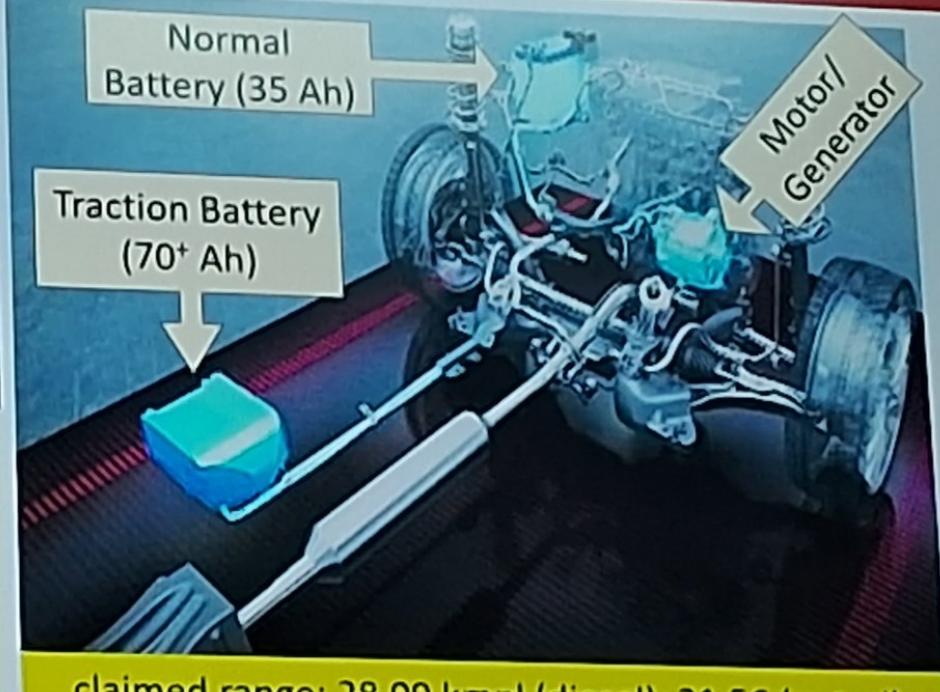


MARUTI CIAZ: MILD HYBRID



- ❖ Configuration: Parallel hybrid
- ❖ Ciaz uses two batteries for:
 1. Normal SLI purpose
 2. Recovering Breaking energy

MARUTI CIAZ: MILD HYBRID



claimed range: 28.09 kmpl (diesel), 21.56 (petrol)

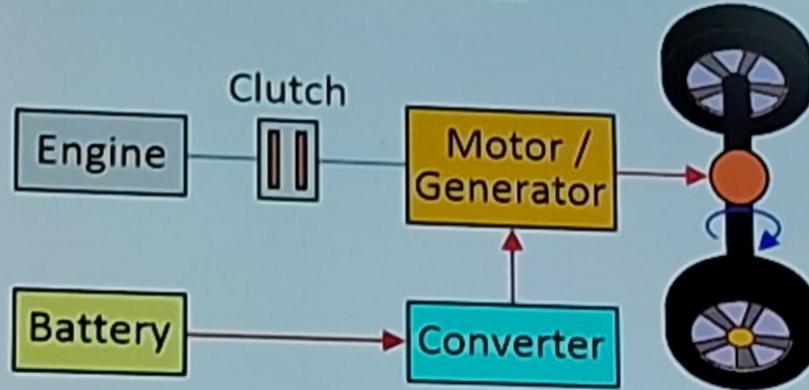
- ❖ Configuration: Parallel hybrid
- ❖ Ciaz uses two batteries for:
 1. Normal SLI purpose
 2. Recovering Breaking energy
- ❖ Purpose of the second battery:
 - ◆ stores energy during braking
 - ◆ assists the idle engine stop-start function
 - ◆ provides extra torque along with engine during acceleration

HYBRID OPERATION PHILOSOPHY

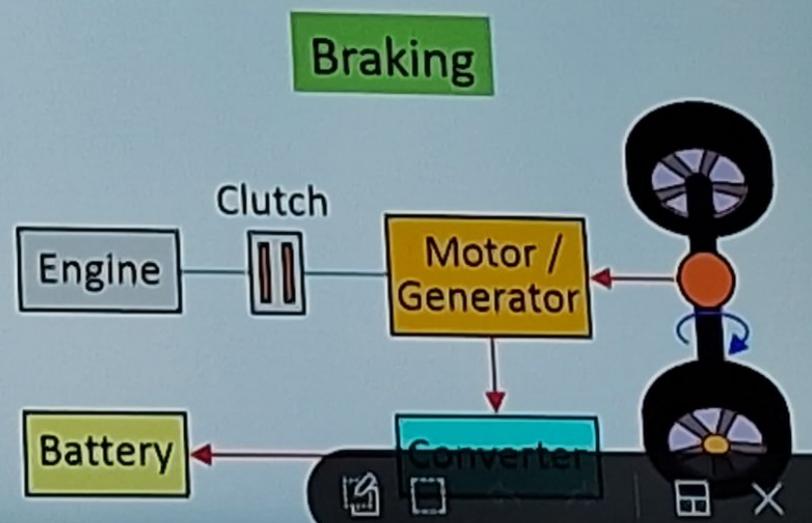
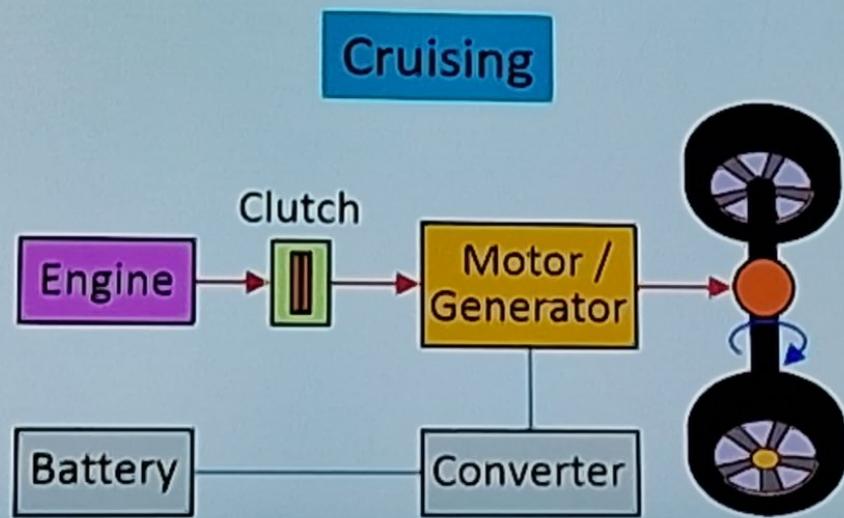
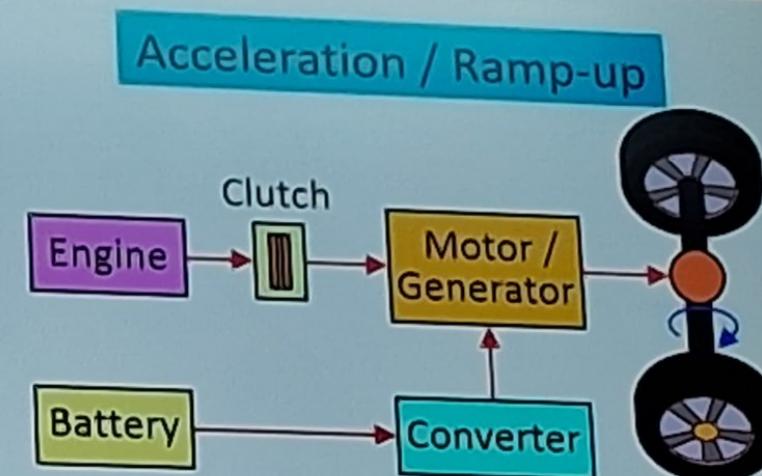
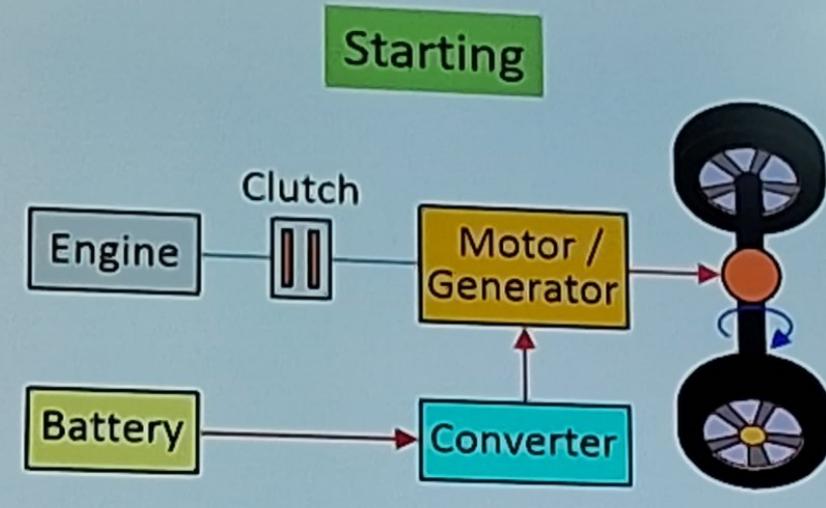
- ❖ The efficiency of IC engines is low, typical values around 25%.
- ❖ The efficiency of motors is higher, typical values above 85%.
- ❖ The round trip efficiency of battery is moderate, around 70% - 80%.
- ❖ Overall hybrid design/operation philosophy has three aspects:

HYBRID OPERATING MODES

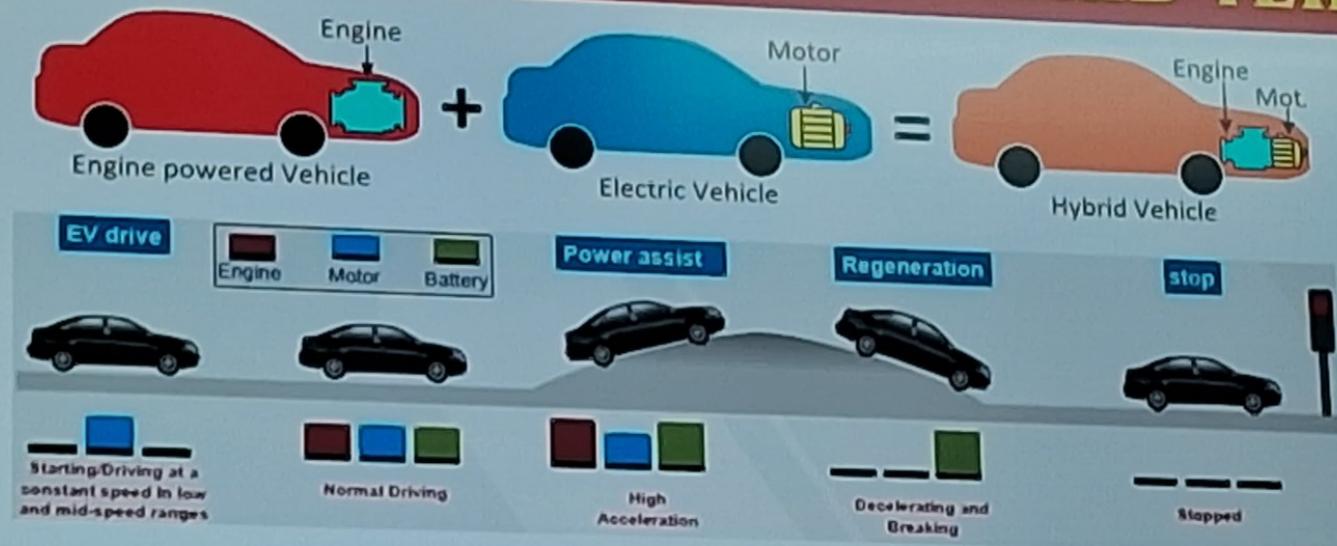
Starting



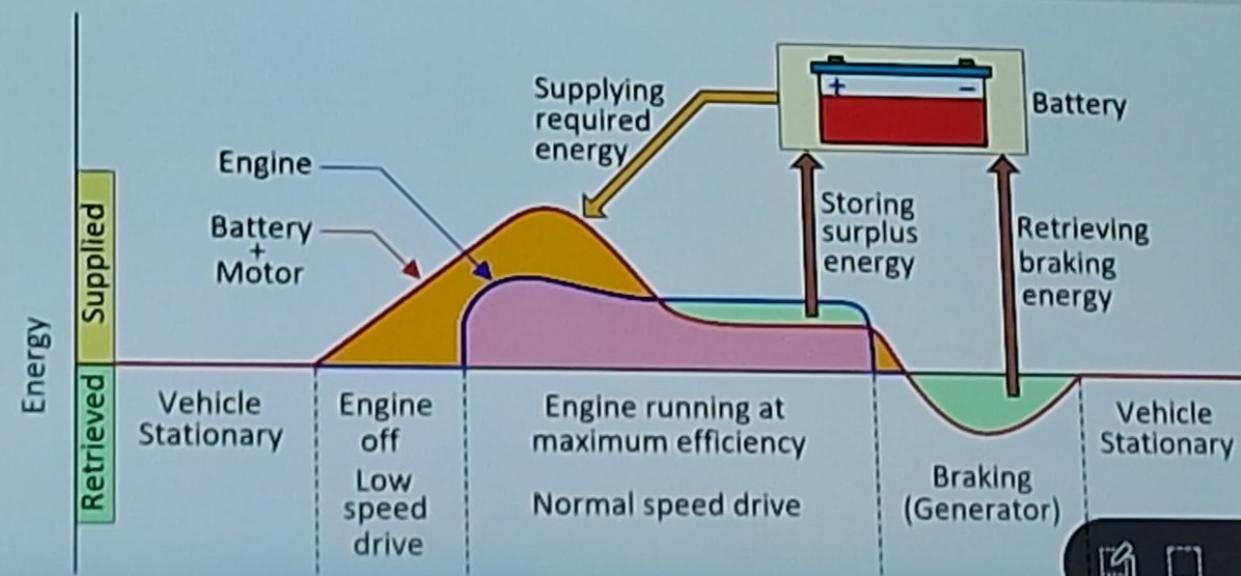
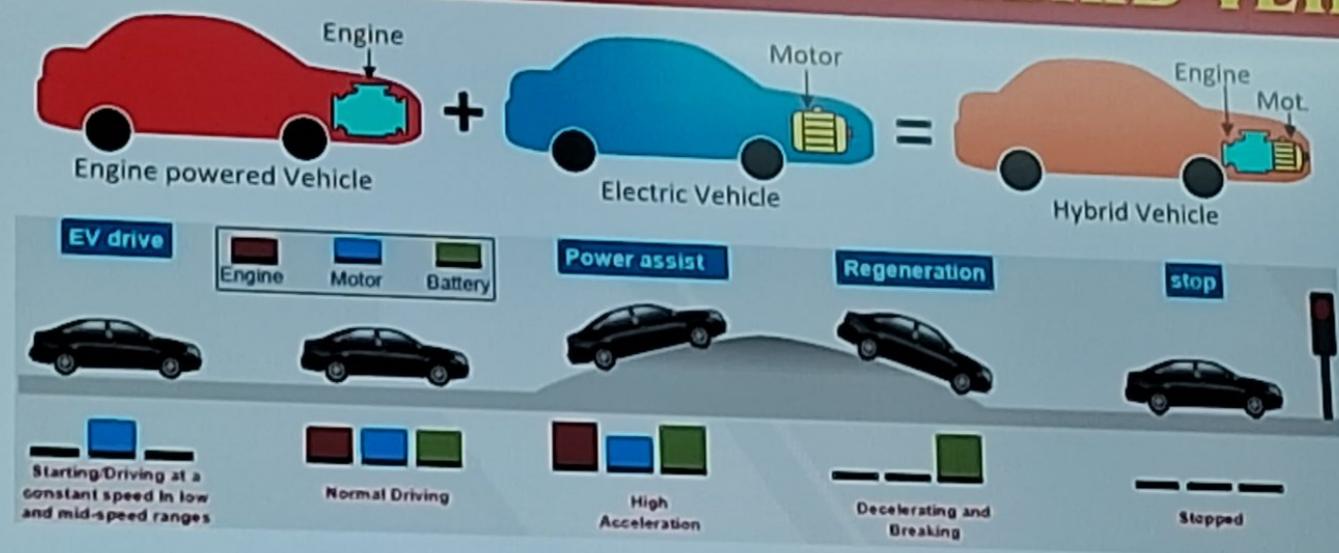
HYBRID OPERATING MODES



ENERGY MANAGEMENT IN HYBRID VEHICLES

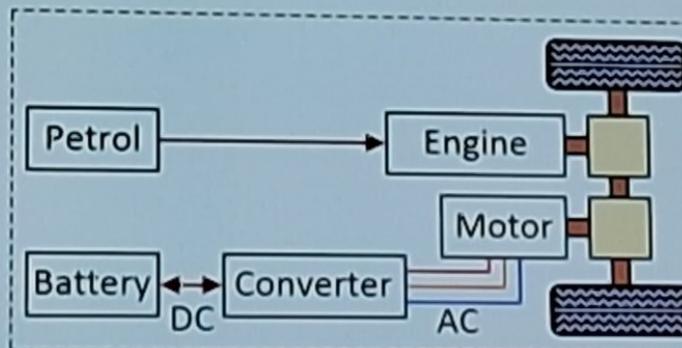
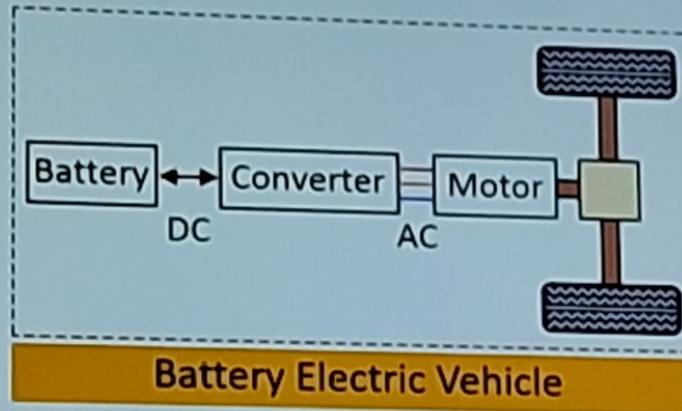


ENERGY MANAGEMENT IN HYBRID VEHICLES

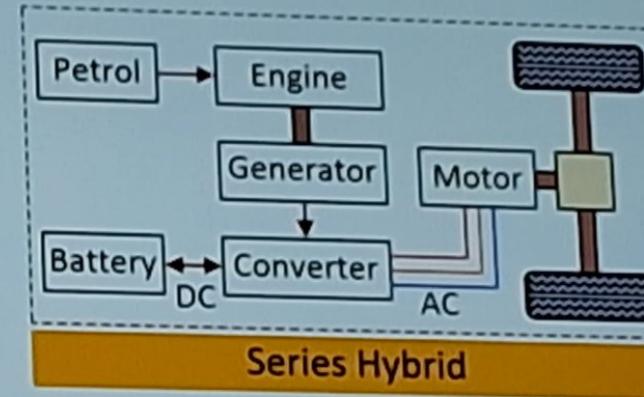


CLASSIFICATION BASED ON DRIVE TRAIN

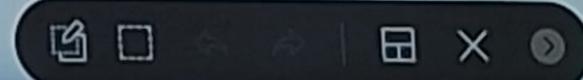
- ❖ Based on the drive train, hybrid electric vehicles are classified as:
 - ◆ Series Hybrid
 - ◆ Parallel Hybrid
 - ◆ Series-Parallel Hybrid



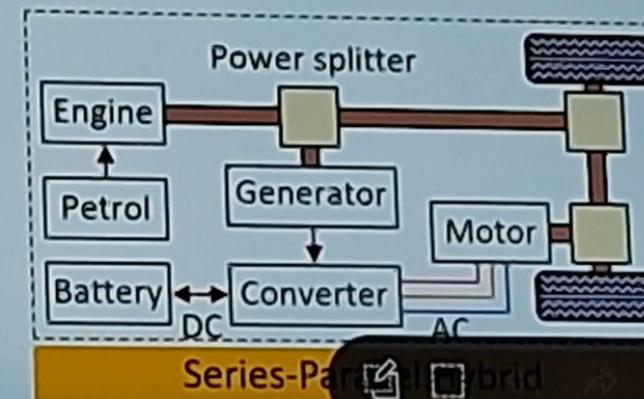
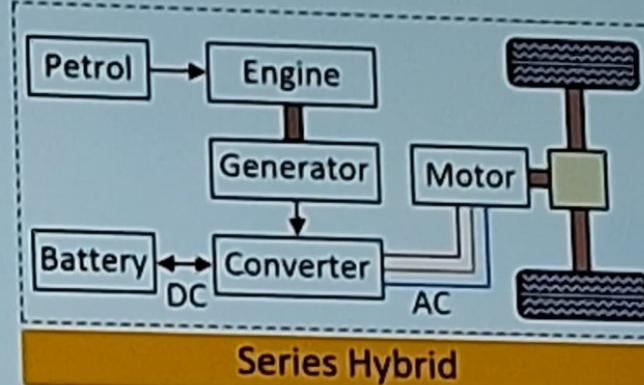
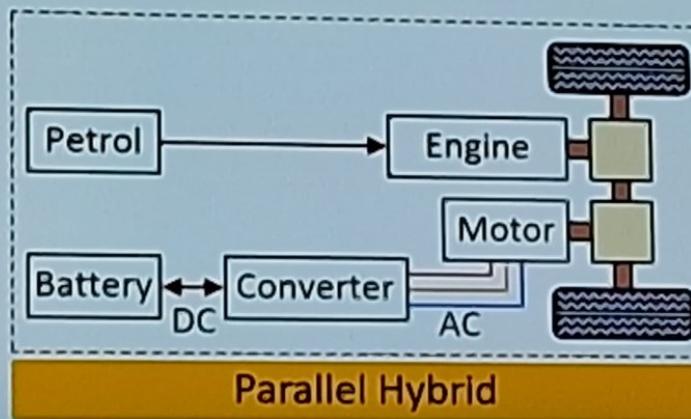
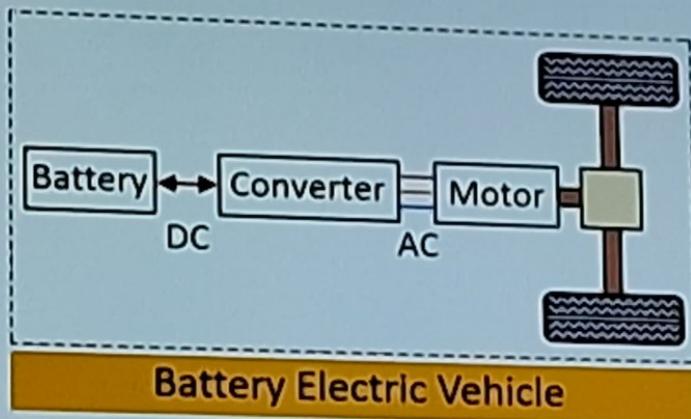
Parallel Hybrid



Series Hybrid

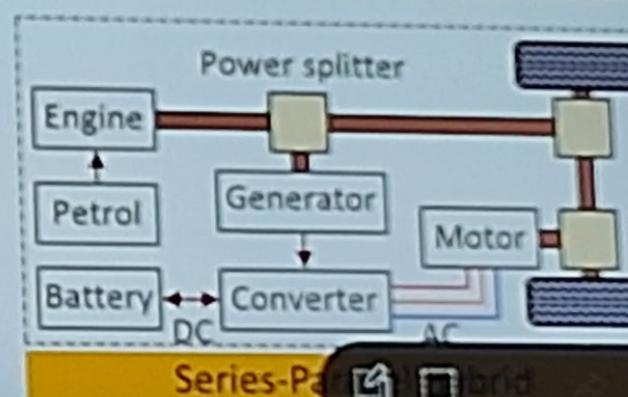
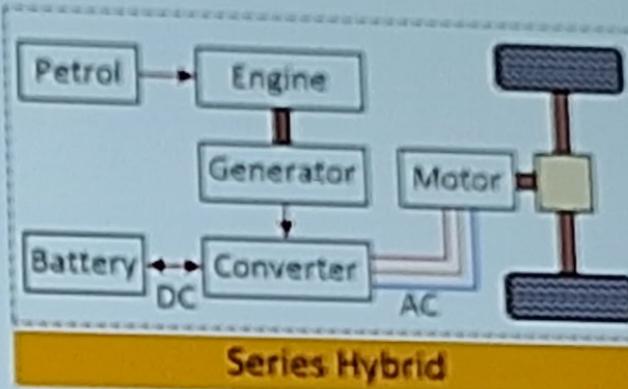
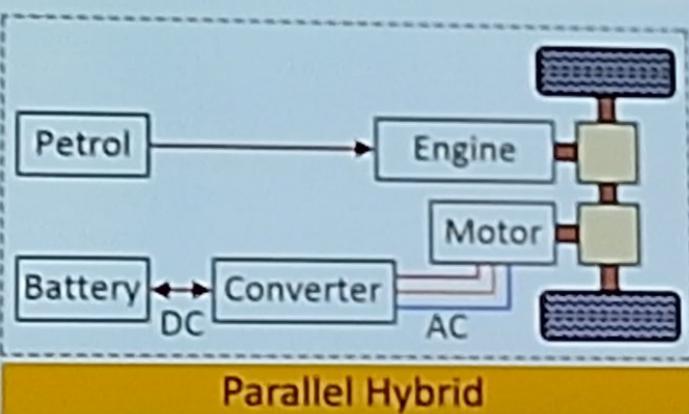
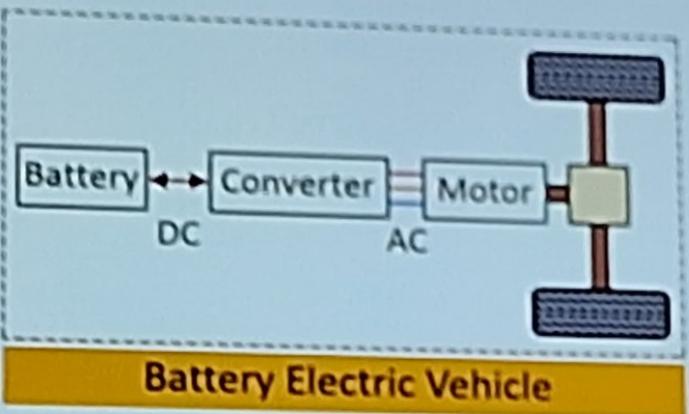


- Parallel Hybrid
- Series-Parallel Hybrid



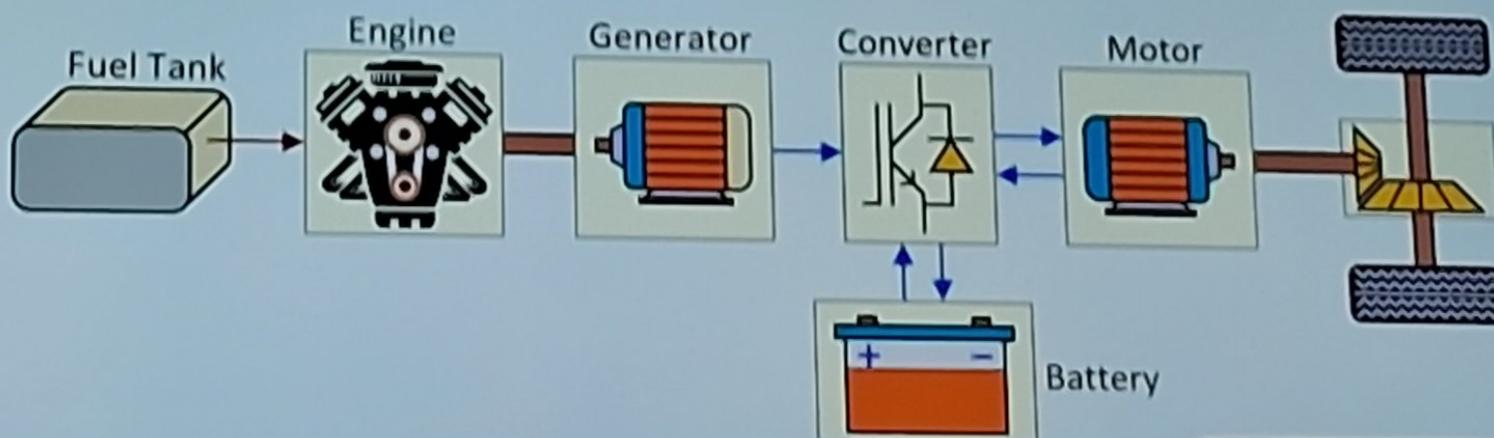
CLASSIFICATION BASED ON DRIVE TRAIN

- Based on the drive train, hybrid electric vehicles are classified as:
 - Series Hybrid
 - Parallel Hybrid
 - Series-Parallel Hybrid



SERIES HYBRID ELECTRIC VEHICLES

- ❖ In series-hybrids, power flow from the energy source to the wheels is in series: i.e., from engine-to-generator, generator-to-motor and then from motor-to-wheel.
- ❖ A hybrid series uses a small IC engine running at a constant speed that generates and supplies electricity to the traction motor, and also charges the battery.

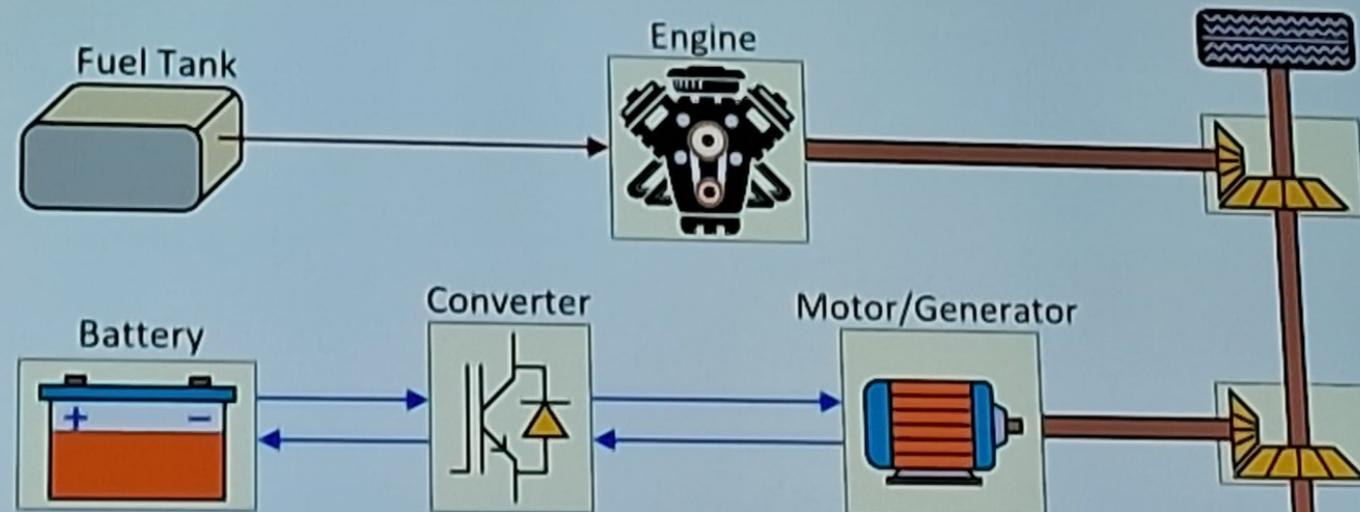


PARALLEL HYBRID ELECTRIC VEHICLES

- ❖ In a parallel hybrid system, both the engine and the electric motor drive the wheels.
- ❖ Drive power from both sources can be used according to the optimum conditions.
- ❖ It is called a parallel hybrid system because the power flows to the wheels in parallel.

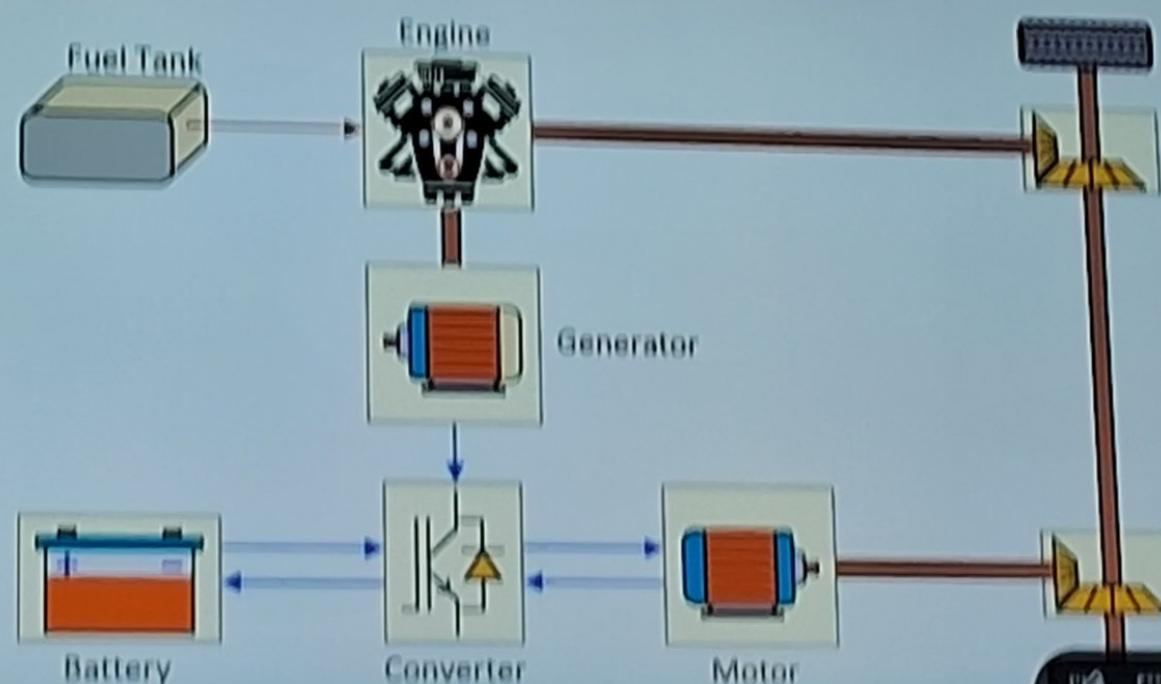
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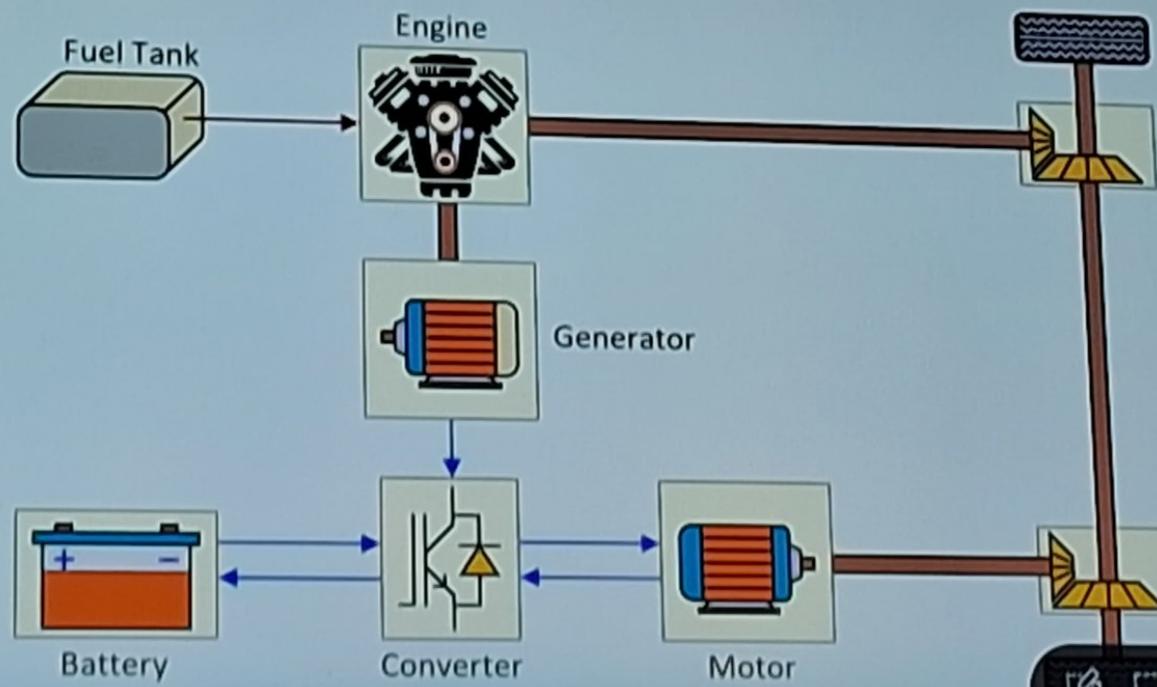
SERIES-PARALLEL (COMBINED) HYBRID EVS

- ❖ Parallel hybrids incorporate power-split devices, allowing for power paths from the ICE to the wheels that can be either mechanical or electrical.
- ❖ The main principle is to decouple the power supplied by the primary source from the power demanded by the driver.



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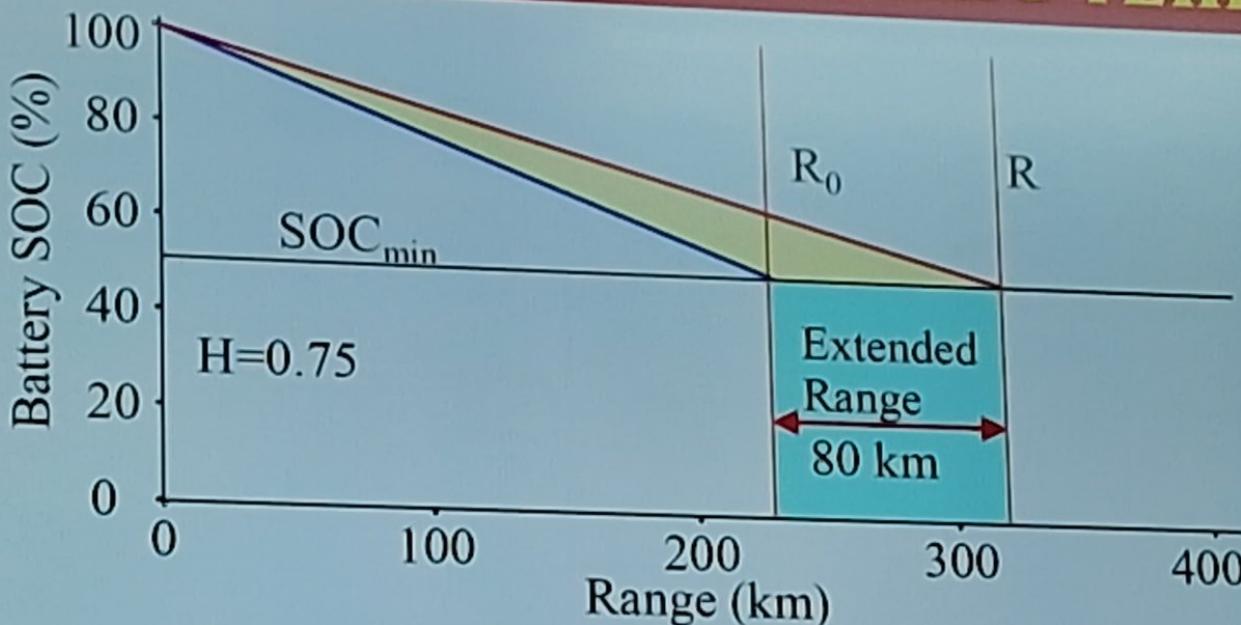


EXTENDED-RANGE ELECTRIC VEHICLE (EREV)

- ❖ Extended-range electric vehicle (EREV) is an all-electric drivetrain vehicle.
- ❖ Though EREV is a series hybrid vehicle, all of its motive power is supplied by a motor only.
- ❖ A small engine is provided to generate onboard electricity to charge a battery (10-20 kWh).



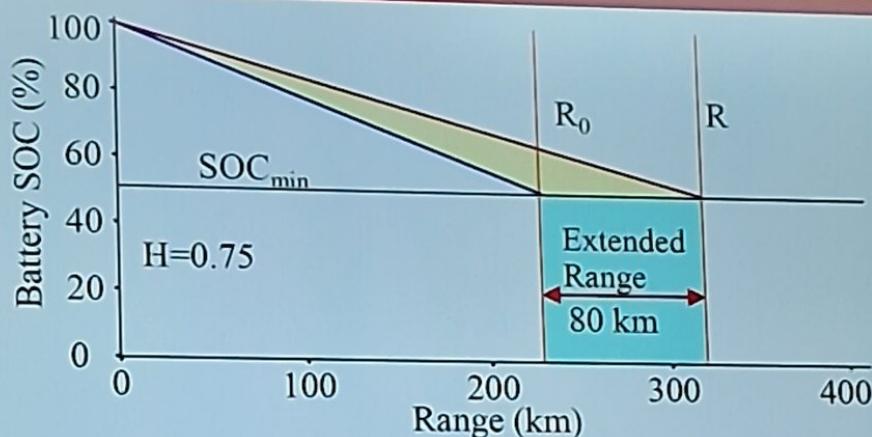
EXTENDED-RANGE ELECTRIC VEHICLES



- ❖ The range extender EV has large value for hybrid factor, H.
- ❖ For $H = 75\%$, a HEV has a very large Motor-Generator compared to the engine power.
- ❖ To supply electric power for the M-G, a large heavy battery is required.
- ❖ This is the region for a plug-in hybrid, also the region for range extender EV.



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