

GREEN VEHICLE TECHNOLOGIES

Topic #3. Types of Green Vehicles

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Sustainable Transportation within the Framework of Green Deal - SPHERE

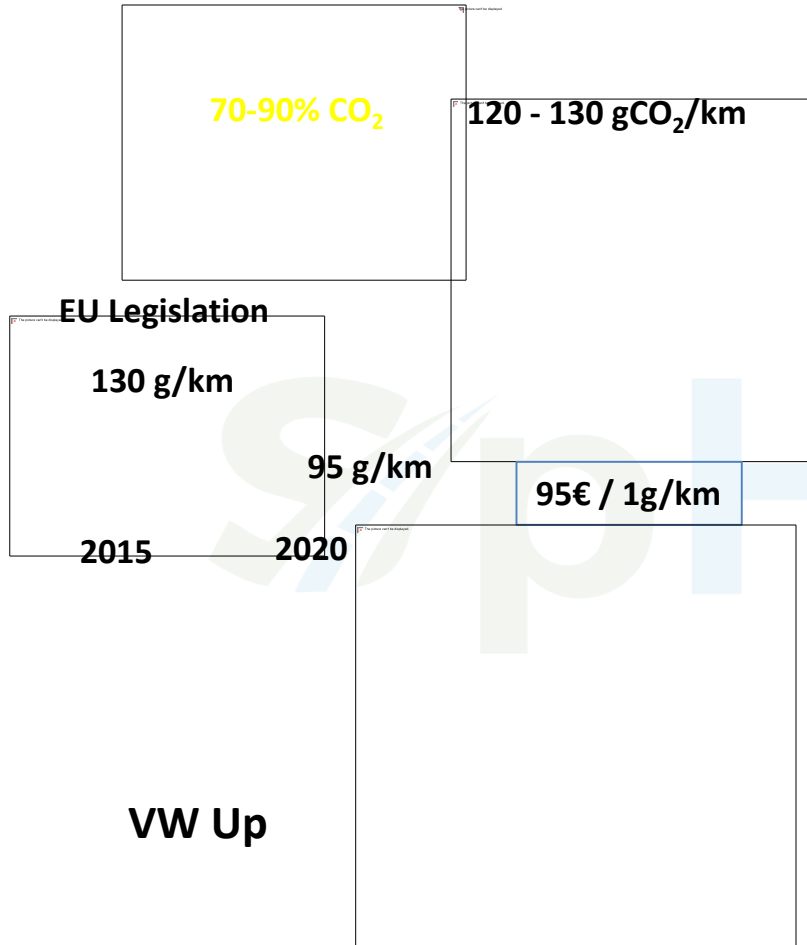
Call: ERASMUS-EDU-2023-CBHE-STRAND-2

Project Number: 101128065

Agenda

- Introduction to Green Vehicle Technologies
- Types of Green Vehicles
- Policy and Regulations on green vehicles
- Future Trends and Innovations

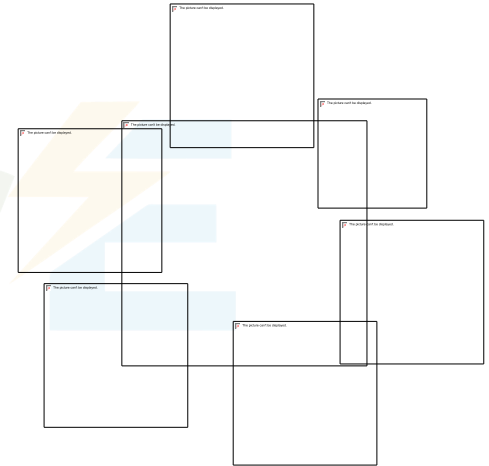
Motivation behind electrification of powertrain



4,3 l/100km

$4,3 \times 1,8 \text{ €} = 7,74 \text{ €/100 km (Italy)}$

$4,3 \times 0,65 \text{ €} = 2,8 \text{ €/100 km (Uzbekistan)}$



12,7 kWh/100km

$12,7 \times 0,45 \text{ €} = 5,7 \text{ €/100 km (Italy)}$

$12,7 \times 0,0255 \text{ €} = 0,33 \text{ €/100 km (Uzbekistan)}$

Green Vehicles

- Green vehicles are vehicles that are **more efficient** and **less polluting** [1]
- Green vehicles use such advanced vehicle technologies as hybrid electric vehicles, plug-in hybrid electric vehicles, battery electric vehicles, hydrogen and fuel-cell vehicles
- Green vehicle can use alternative fuels as natural or liquidified gas, biodiesel and ethanol fuels

HEVs

- Alternative Fuels Data Center of US Department of Energy defines the HEVs as [2]:

“Hybrid electric vehicles are powered by an internal combustion engine and one or more electric motors, which uses energy stored in batteries. A hybrid electric vehicle cannot be plugged in to charge the battery. Instead, the battery is charged through regenerative braking and by the internal combustion engine.” [2]

- Hybrid electric vehicles (HEVs) use two power sources (a primary power source and a secondary power source) [3]

PHEVs

- Alternative Fuels Data Center of US Department of Energy defines the PHEVs as [4]:

“Plug-in hybrid electric vehicles (PHEVs) use batteries to power an electric motor and another fuel, such as gasoline, to power an internal combustion engine (ICE). PHEV batteries can be charged using a wall outlet or charging equipment, by the ICE, or through regenerative braking. The vehicle typically runs on electric power until the battery is nearly depleted, and then the car automatically switches over to use the ICE.” [4]

Fuel cells

- Alternative Fuels Data Center of US Department of Energy defines the FCEVs as [5]:

“fuel cell electric vehicles (FCEVs) use electricity to power an electric motor, however, this electricity is produced a fuel-cell powered by hydrogen. Although automakers could design an FCEV with plug-in capabilities to charge the battery, most FCEVs today use the battery for recapturing braking energy, providing extra power during short acceleration events, and to smooth out the power delivered from the fuel cell with the option to idle or turn off the fuel cell during low power needs.”

BEVs

- Alternative Fuels Data Center of US Department of Energy defines the BEVs as [6]:

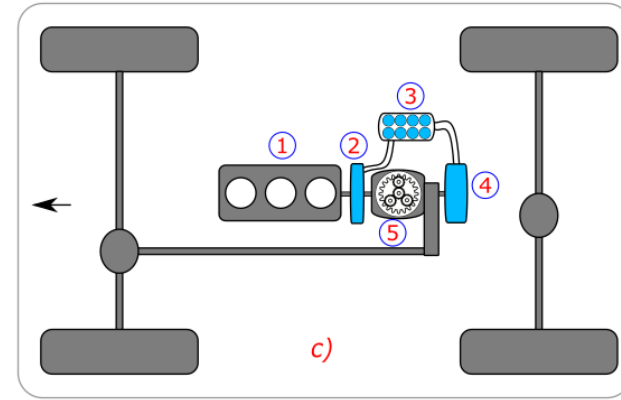
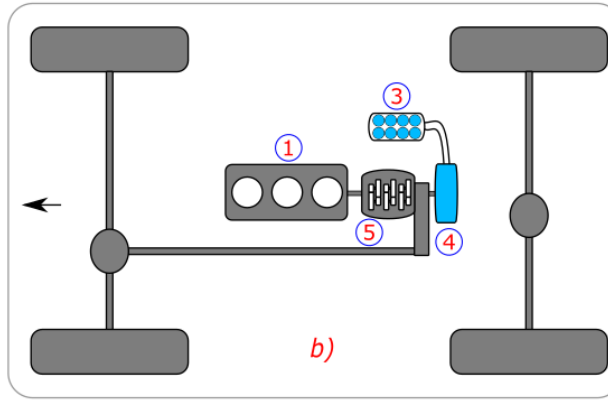
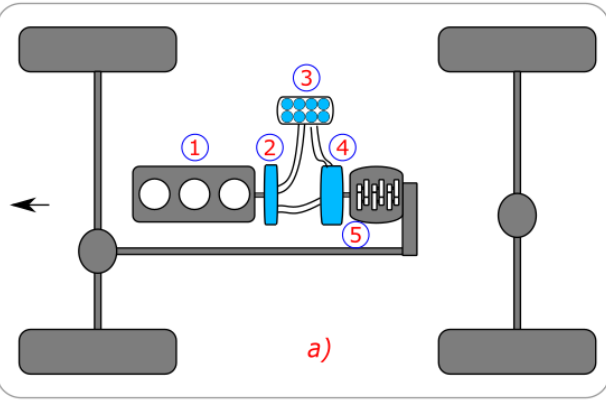
“All-electric vehicles, also referred to as battery electric vehicles (BEVs), have an electric motor instead of an internal combustion engine. The vehicle uses a large traction battery pack to power the electric motor and must be plugged in to a wall outlet or charging equipment, also called electric vehicle supply equipment (EVSE). Because it runs on electricity, the vehicle emits no exhaust from a tailpipe and does not contain the typical liquid fuel components, such as a fuel pump, fuel line, or fuel tank” [6]

Classification of HEVs

Series

Parallel

Compound (Complex)



Power-split

Series-Parallel

a) Series, b) Parallel and c) Compound (or Complex) HEVs arrangements of powertrain components of Hybrid Electric Vehicles.

1 - Internal combustion engine (ICE), 2 - generator (GEN), 3 - battery (BAT), 4 - electric motor (EM), 5 - gearbox

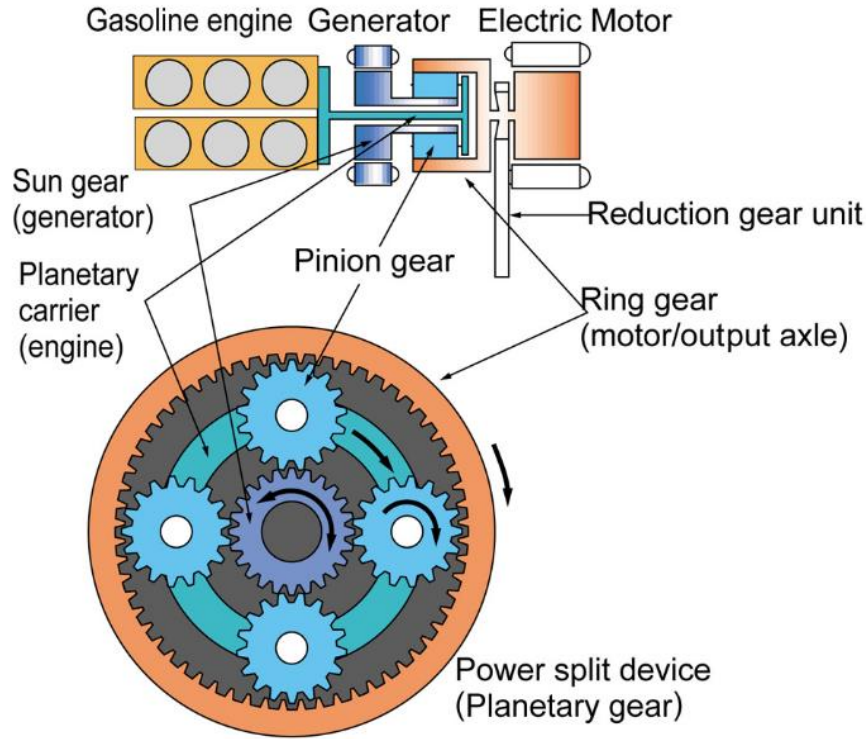
Compound HEV

Advantages:

- ✓ ICE and wheels are mechanically coupled and can be decoupled;
- ✓ Series and Parallel operation modes are possible;
- ✓ Regenerative braking can be accomplished by both electric machines.

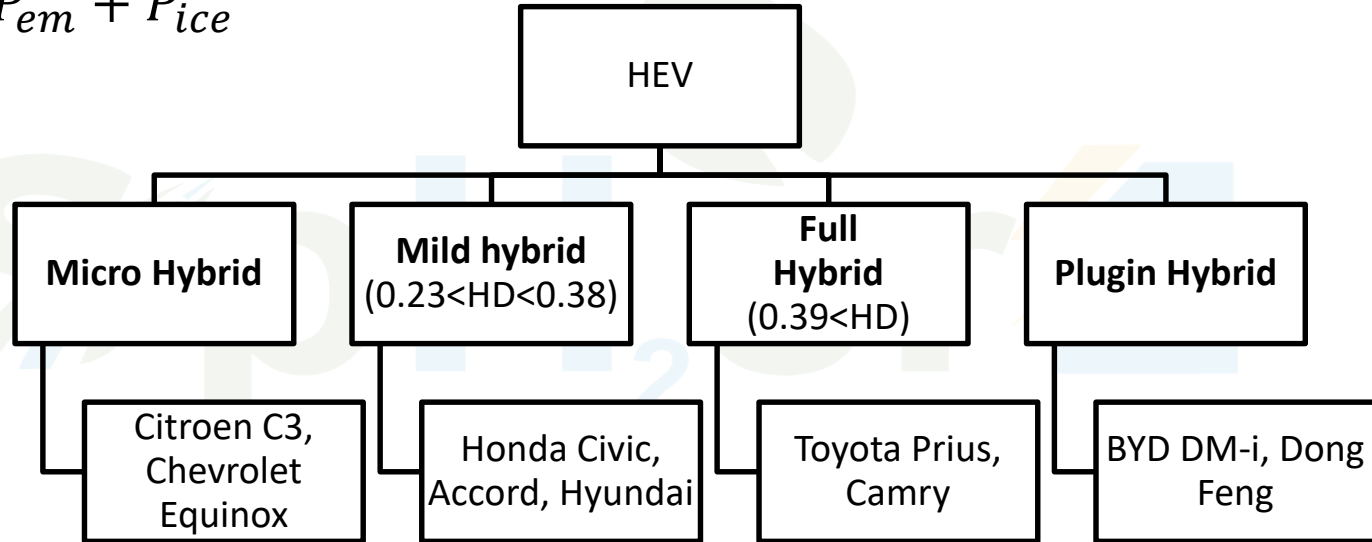
Disadvantages:

- ✓ Two electric machines are required
- ✓ Pure ICE mode is not possible in case of power-split HEV (i.e. in THS) therefore higher consumption compared to Parallel HEVs at highways;
- ✓ Multi-step energy conversion in series mode.

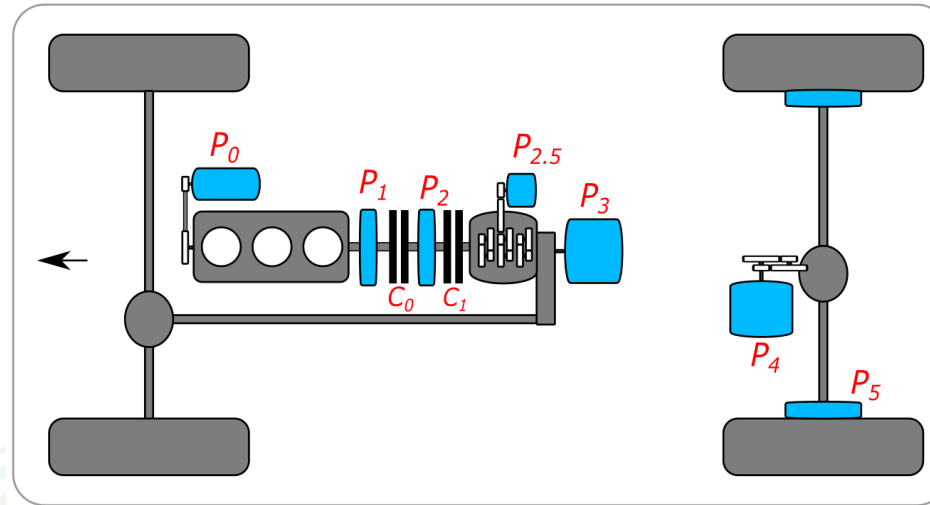


Classification based on degree of hybridisation (Parallel)

$$HR = \frac{P_{em}}{P_{em} + P_{ice}}$$



Classification based on position of electric machine



Source: [8]

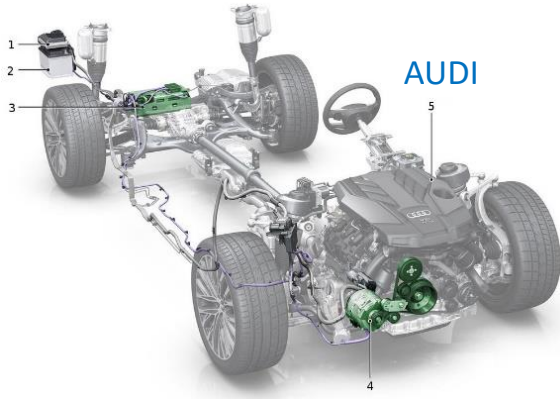
	Position of Electric Machine (EM) Installation
P0	BISG – Belt Integrated Starter Generator. EM is installed instead of conventional alternator
P1	IMA – Integrated Motor Assist. EM is installed on (IMA)
P2	EM is installed at the gearbox input shaft (two friction clutches C0 and C1)
P3	EM is installed at the gearbox output shaft
P4	EM is installed at the input of the final drive
P5	In-wheel motor (Hub motor)

Micro Hybrid



- Enhanced starter
- EM power 2 – 4 kW
- Enhanced battery
- Enhanced cables
- ECU reprogramming
- Option to disable the feature
- Minimal expenses to integrate in the existing system
- ICE restart requires fuel consumption
- Efficiency in different driving conditions

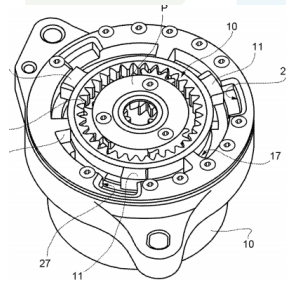
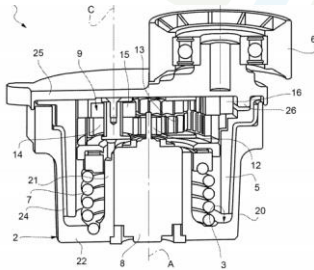
Mild Hybrid – P0



CONTINENTAL 48V



DAYCO SMARTEN



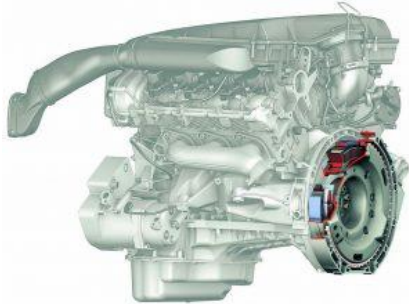
- **Specification:**
 - High EM speed (>18000 rpm)
 - EM max power 12 – 14 kW
 - EM torque 50 Nm
- **Advantages:**
 - Minimal integration cost
 - Modularity
 - Starter and Generator is integrated
- **Disadvantages:**
 - Low power
 - Losses to drive ICE in electric traction
 - Belt drive to be modified
 - Belt tensioner (2)
 - Strengthening the belt (4)

Mild Hybrid – P1

Source: [13]



Honda Integrated Motor Assist (IMA)



Mercedes Benz S400 BlueHybrid

- More efficient regenerative braking compared to P0 HEV, as there are no belt transmission losses;
- The EM can assist the engine and can be used as an active damper to reduce vibrations in the powertrain; it can also be used as an active damper to reduce vibrations in the powertrain;
- No need for a dedicated engine flywheel;
- Replacement of low efficiency alternator and starter. Both are known to have an efficiency of around 65%, compared to 85% for EM;
- Cranking of the engine can be quiet, as the EM can have a higher torque even at higher angular speeds.
- Sailing mode can be integrated;
- Small installation space requires high torque density of EM at limited axial length, resulting in high component cost;
- There are still friction losses in the engine and it is not possible to disengage it.

Source: [14]

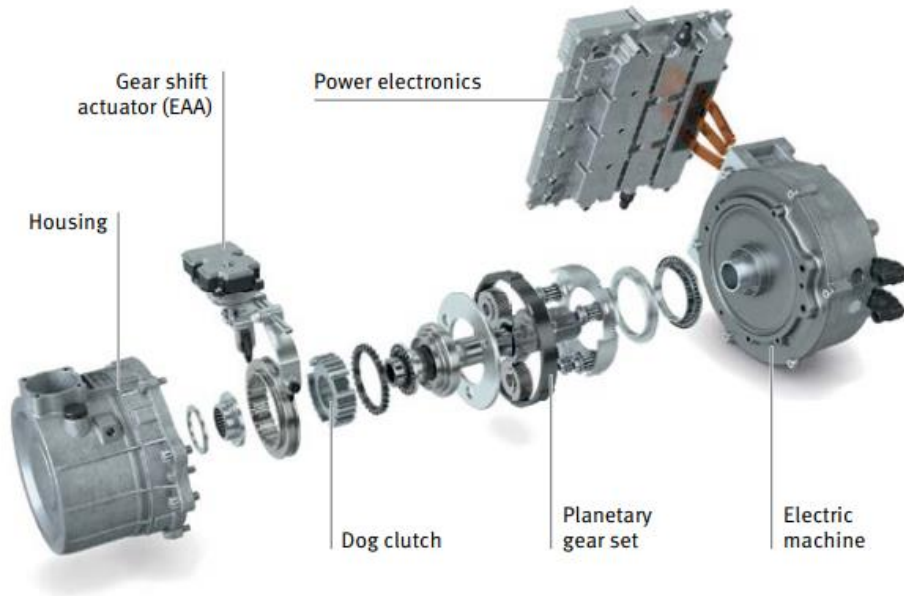
Mild Hybrid – P2



- As the main clutch C0 can disengage the engine, only electric traction is possible;
- EM operates in the high-efficiency zone as it is located before the input shaft of the gear, so different ratios can be used for different load requirements selected
- It is possible to start the engine with the EM. However, this requires an additional clutch C1 to be integrated into the system;
- No ICE friction losses in electric traction and regenerative braking modes as the EM can be disengaged from the engine using the main clutch C0, hence higher operation efficiencies in these modes;
- The mounting of the EM on the axis requires its larger radial dimensions;
- EM can be mounted off-axis, reducing the radial dimensions of the EM and increasing its axial length;
- Battery can be recharged while vehicle is stationary by disengaging clutch C1 and engaging main clutch C0;
- The presence of two clutches make the solution more complex and expensive;
- Losses in belt/chain drive when EM mounted off axis and additional belt tensioner is needed;
- High cost of implementation due to presence of above mentioned components;
- Axial length requirement is critical (in case of on-axis EM mounting);
- Axial length requirement is less critical (in case of off-axis EM mounting).



Mild Hybrid – P3



- Electric motor can be placed at the shaft output;
- High regenerative braking efficiency as the braking power is not transmitted through the gearbox or other transmission units;
- With the EM installed on the gearbox output, electric traction is possible during shifting, which is called power shift process;
- EM traction in neutral gear is possible;
- Electric motor volume is constrained;
- P3 positioning of the EM requires complete redesign of the overall gearbox;
- EM should cover all the speed ranges as it is installed after the gearbox;
- Idle charge of the battery is not possible as the EM and traction wheels are always connected.

Mild Hybrid – P4



Valeo 48V Electric Rear Axle Drive

- The electric motor is placed on an axle other than that of the main traction axle;
- Motor torque flows through additional differential to the traction wheels;
- Parallel-Through-the-Road, hence can be a modular solution;
- It can be retrofitted as an aftermarket solution to the manufactured vehicles;
- Regenerative braking efficiency is maximized as the EM is located close to traction wheels;
- High potential for full electric driving;
- Makes the vehicle AWD;
- Can be combined with other HEV configurations;
- Rear axle and suspension redesign required;
- Engine cranking with electric motor is not possible as the torque must pass “through the road”. Hence a traditional starter is required;
- Battery charging is “through the road” as well, hence idle charge of the battery is not possible;
- Vehicle stability must be carefully controlled.

Mild Hybrid – P5

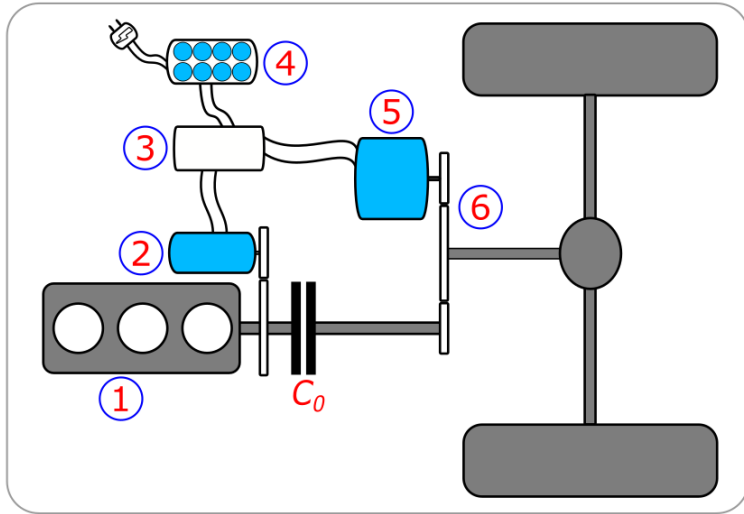


- The electric motor is placed on an axle other than that of the main traction axle;
- Motor torque flows through additional differential to the traction wheels;
- Parallel-Through-the-Road, hence can be a modular solution;
- It can be retrofitted as an aftermarket solution to the manufactured vehicles;
- Regenerative braking efficiency is maximized as the EM is located close to traction wheels;
- High potential for full electric driving;
- Makes the vehicle AWD;
- Can be combined with other HEV configurations;
- Rear axle and suspension redesign required;
- Engine cranking with electric motor is not possible as the torque must pass “through the road”. Hence a traditional starter is required;
- Battery charging is “through the road” as well, hence idle charge of the battery is not possible;
- Vehicle stability must be carefully controlled.

Main features of electrified vehicles

	Micro Hybrid	Mild HEV			HEV	PHEV	EV
		<i>P0</i>	<i>P1</i>	<i>P2</i>			
EM Power [kW]	2-4	10-15	15-20	15-25	25-60	40-100	> 60
Voltage [V]	12	48	< 160	48	150-350	< 400	< 450
Cold engine start							
ICE stop/start							
Optimal operation of ICE							
Assisting ICE							
ICE decoupled							
Regenerative braking							
Only EM mode							
Charging from grid							

BYD DM-i technology



Scheme of BYD DM-i technology

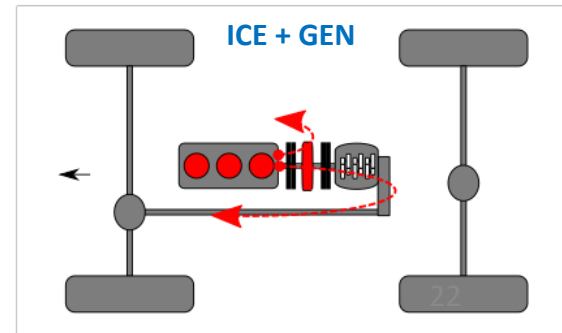
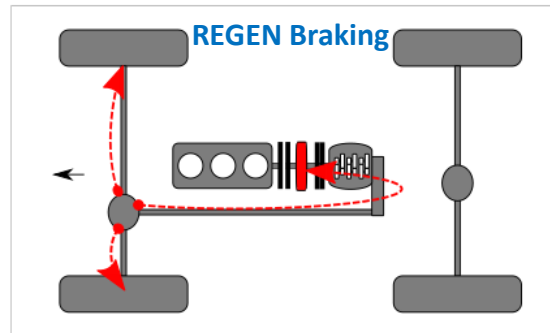
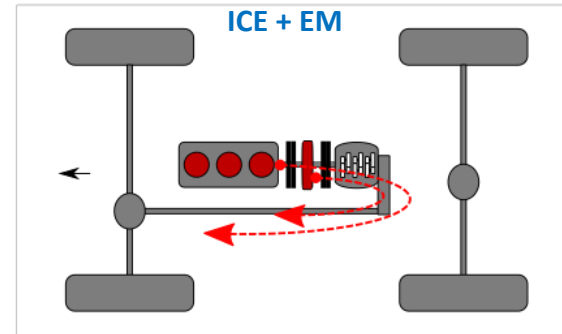
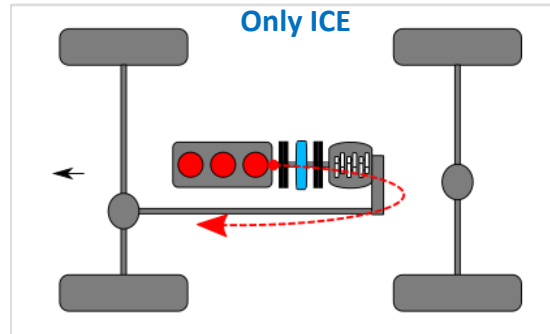
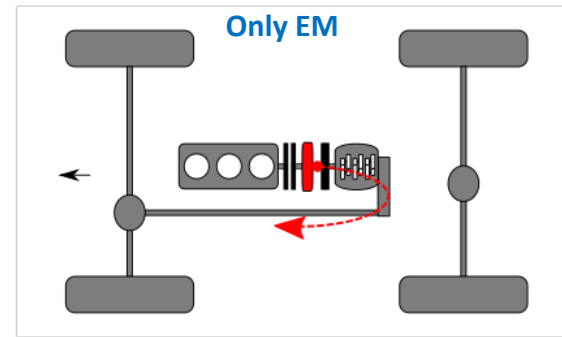
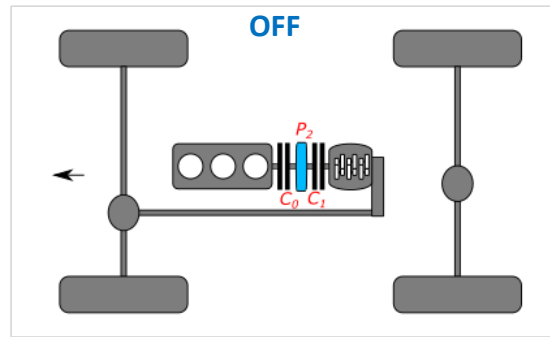
(combination of P1 and P3) [18, 19, 20].

1 – ICE, 2 – generator, 3 – inverter, 4 – electric traction battery, 5 – electric motor, 6 – gearbox, C0- main friction clutch

- The schematic diagram of the DM-i technology is shown in Figure. The ICE 1 is connected to the generator 2 via the gear pair. Generator 2 can charge the battery 4 or supply electric energy to the electric motor 5 via the inverter 3.
- EV mode –in electric-only mode, the clutch C0 is disengaged and traction is transferred to the wheels via the electric motor 5 and gearbox 6. In this mode the energy is supplied by the electric battery 4. However, the power can also be supplied by generator 2, which is driven by ICE 1.
- Hybrid mode – in this mode, the ICE 1 drives the traction wheels via the engaged clutch C0 and the electric motor 5 and the gearbox 6. The electrical power can be supplied by the battery 4 or by the ICE 1 via the generator 2.
- ICE mode – the ICE 1 drives the traction wheels via the engaged clutch C0 and gearbox 6. This mode is effective at high speeds when the ICE is operating in its high efficiency range.

Working modes of P2 HEV

- Only EM
- Only ICE
- ICE + EM
- Regenerative braking
- ICE + Generator



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Thank you for your attention!

