Context

In the recent years the focus has shifted from reducing noxious emissions – NOx, particulate, HC,CO - to **drastically lowering CO_2 emissions**

Source: M.G. Lisbona, FCA, ICE2019

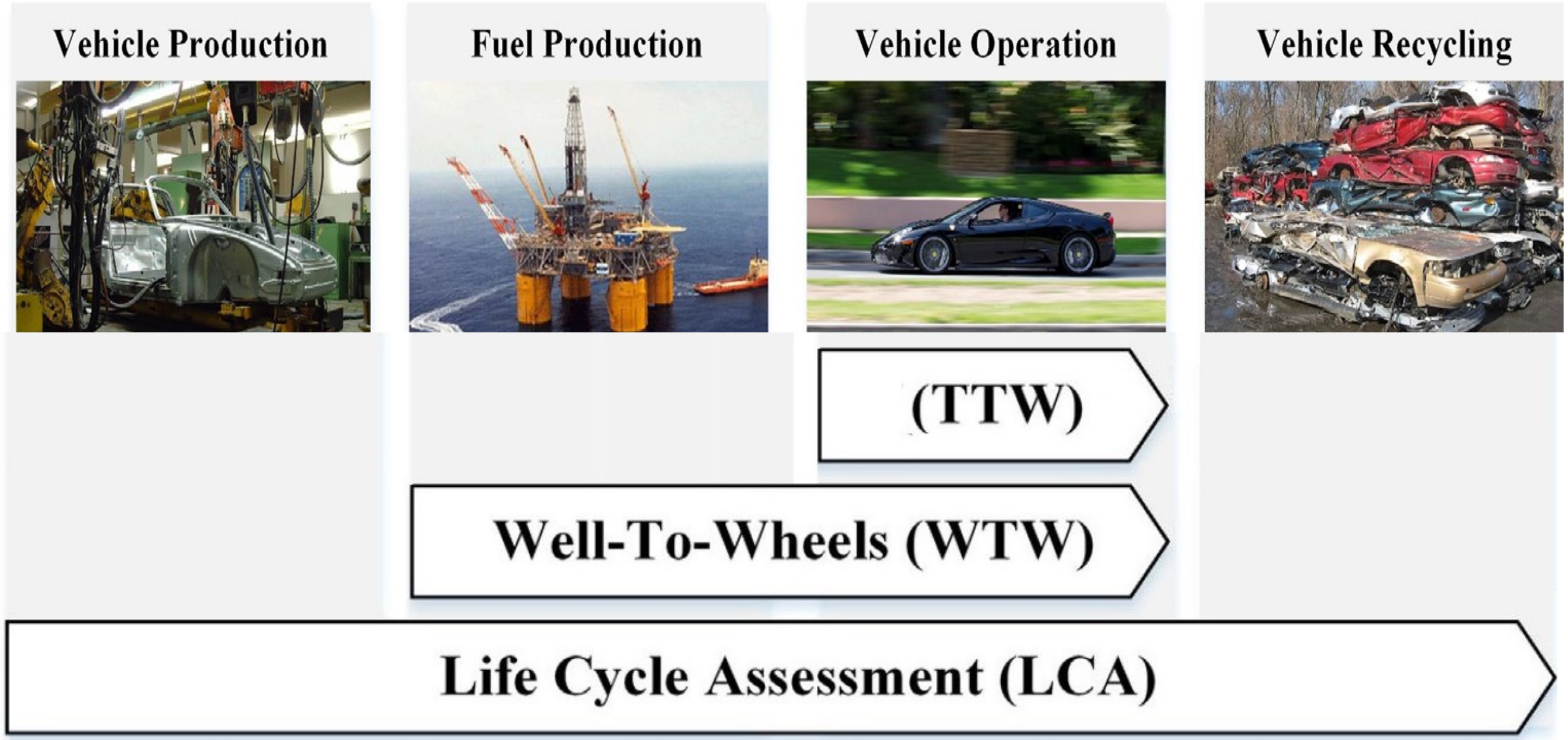
Context

Three different points of view:

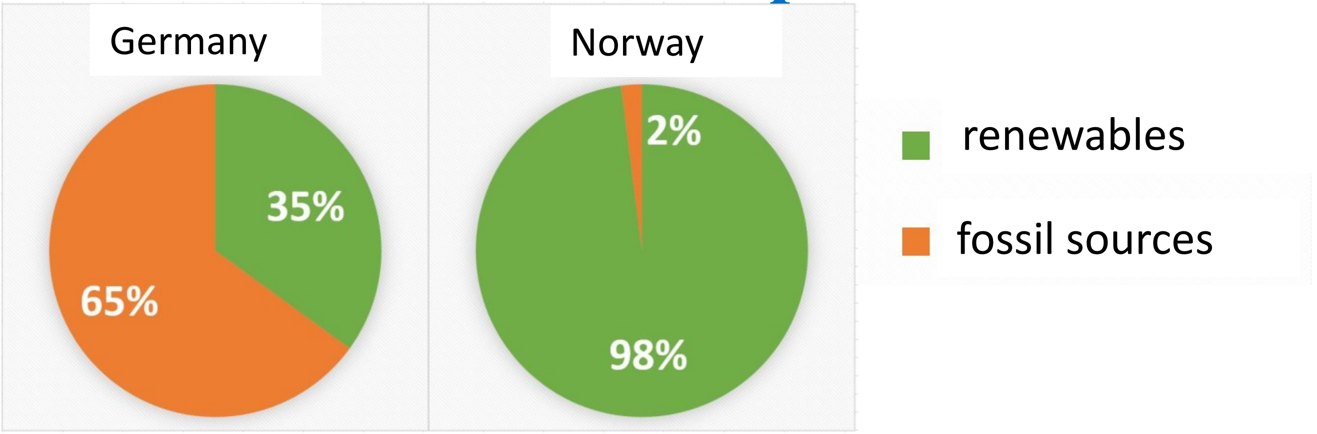
1. Scientists;
2. Vehicle manufacturers (OEMs)/ Agency;
3. Final User.

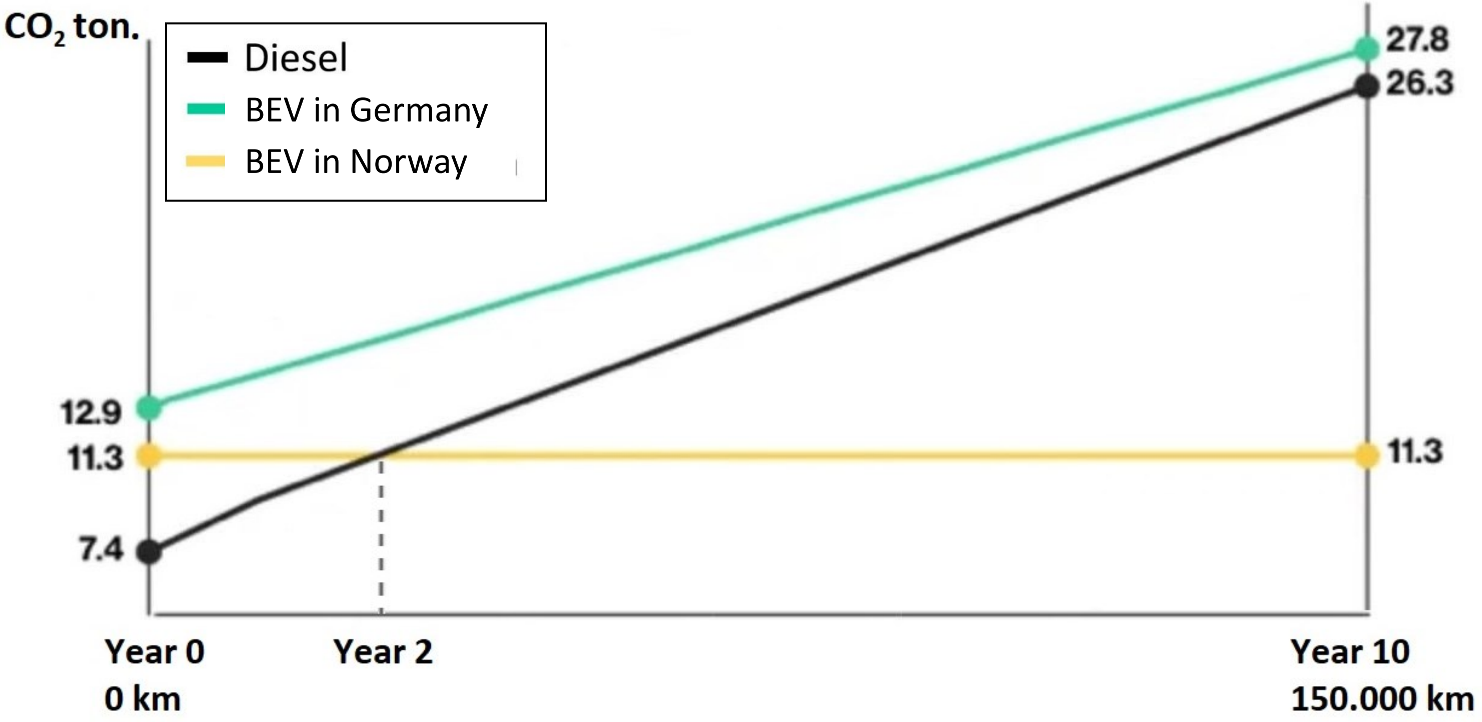
Context : 1. Scientist point of view

Three possible approaches:

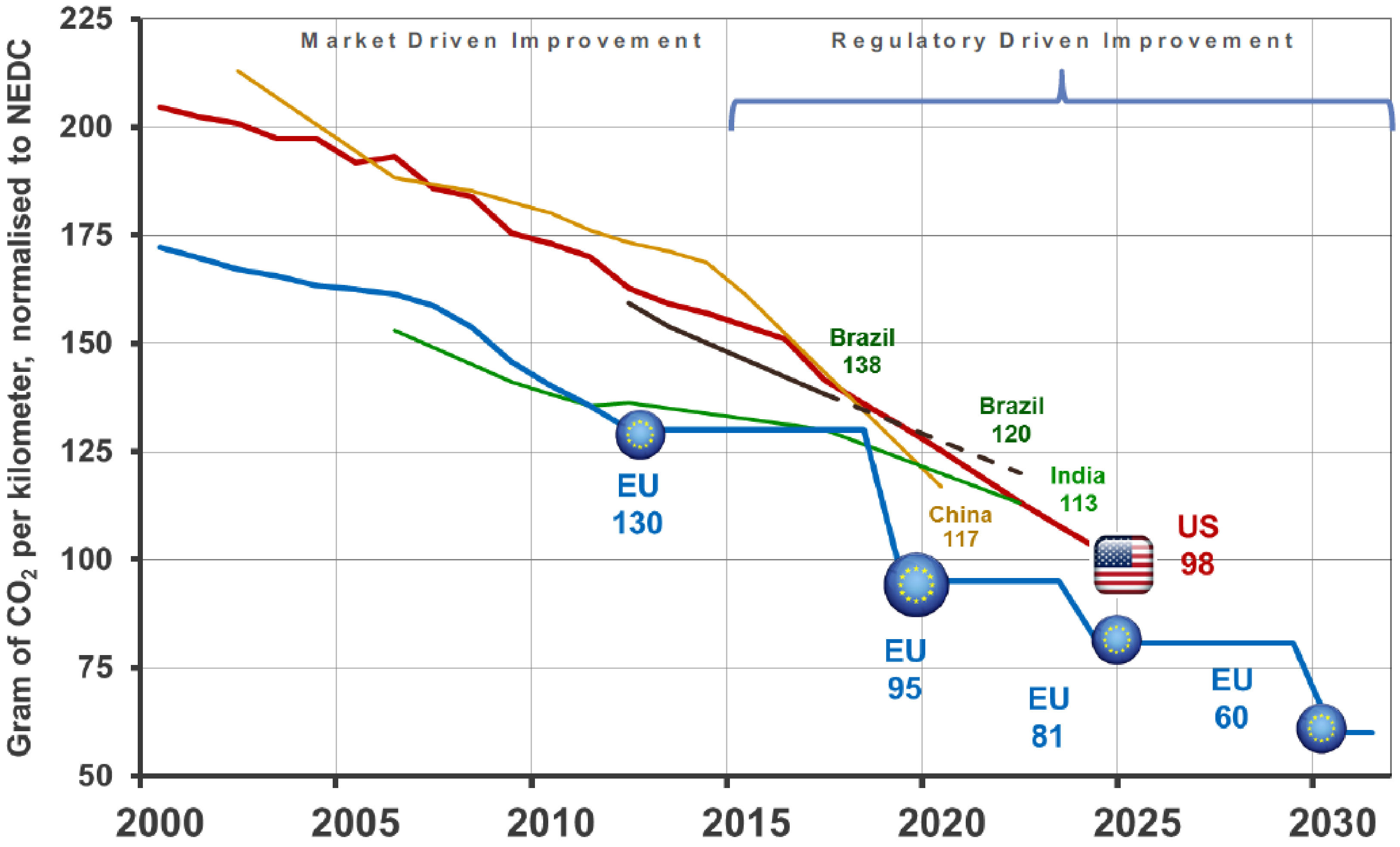


Context : 1. Scientist point of view





Context : 2. Vehicle manufacturers (OEMs) point of view



data from http://www.theicct.org/global-pv-standards-chart-library

Worldwide CO_2 emission reduction is driven by **binding regulations**
In Europe from 2015 to 2030 **a reduction of about 54%** is required

Context : 2. Vehicle manufacturers (OEMs) point of view

<u>Regulation on passenger cars CO_2 emissions:</u>

- **95 g/km of CO2 for 2020** for the new car fleet for the average car mass (1379,88 kg)
- for every 100 kg additional vehicle weight, the emission of 3.33 g/km more of CO_2 is allowed.
- Audi SQ8 TDI quattro tiptronic (2.440 kg) 130 g_CO_2/km
  Fiat 500 (960 kg) 81 g_CO_2/km
- Excess emission premium for manufacturers failing to meet their emissions target: <u>€95 for every g/km of excess emissions per vehicle</u>

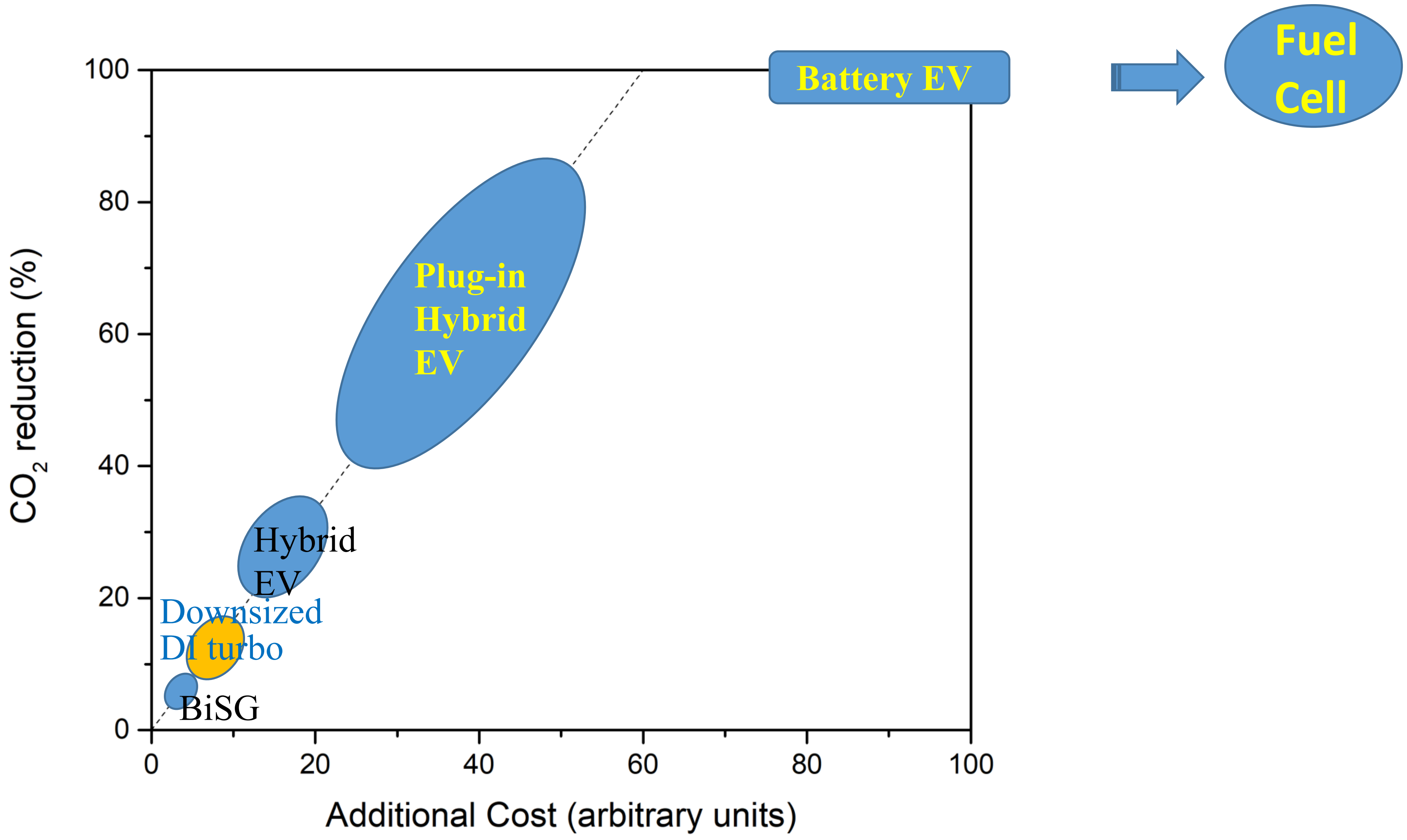
OEM view: CO_2 compliance target at sold fleet level

Context : 2. Vehicle manufacturers (OEMs) point of view

- ICE technical evolution is not sufficient for CO_2 compliance;
- Powertrain electrification is mandatory to fulfill CO_2 limits;
- Multiple electrification solutions are available:
  - Mild
  - Full-Hybrid
  - Plug-in Hybrid
  - BEV

  with different complexity, cost and CO_2 performance.

Context : 2. Vehicle manufacturers (OEMs) point of view



Context : 3. Final User point of view

- Advantages
  - ✓ Improved performance (fun-to-drive), features and comfort;
  - ✓ Lower operation costs and environmental impact;
  - ✓ Access to city centers.

- Disadvantages
  - ✓ Novelties in driving habits may not be welcome by everyone;
  - ✓ Increased purchasing cost is unavoidable;
  - ✓ Charging problems for PHEV and BEV;

Electrified configurations

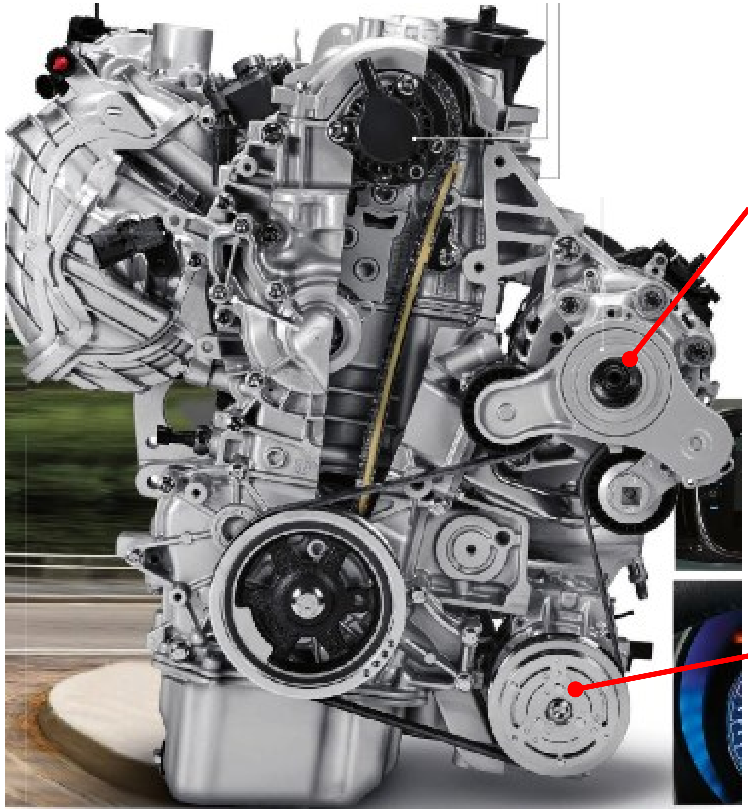
	Electrified Vehicle Types				
Functions	Micro	Mild (MHEV)	Full (FHEV)	Plug-in (PHEV)	Battery Vehicles (BEV)
Idle stop/start	✓	✓	✓	✓	
Electric torque assistance (fill-boost)		✓	✓	✓	✓
Energy Recovery (regenerative braking/coasting)	✓	✓	✓	✓	✓
Electric driving			✓ 1÷2 →15 km	✓ 30÷70 km	✓ >100_km
Battery charging (during driving)	✓	✓	✓	✓	
battery charging (from the grid)				✓	✓

Electrified configurations

Two major cost drivers:
- the impact on the existing powertrain components
- the high voltage battery.

To minimize the integration costs, the vehicle and transmission architecture should be kept the same as for a conventional vehicle.

The easiest way is to integrate the 12-48V electric machine into the already existing engine accessories belt drive, by replacing the 12V alternator.



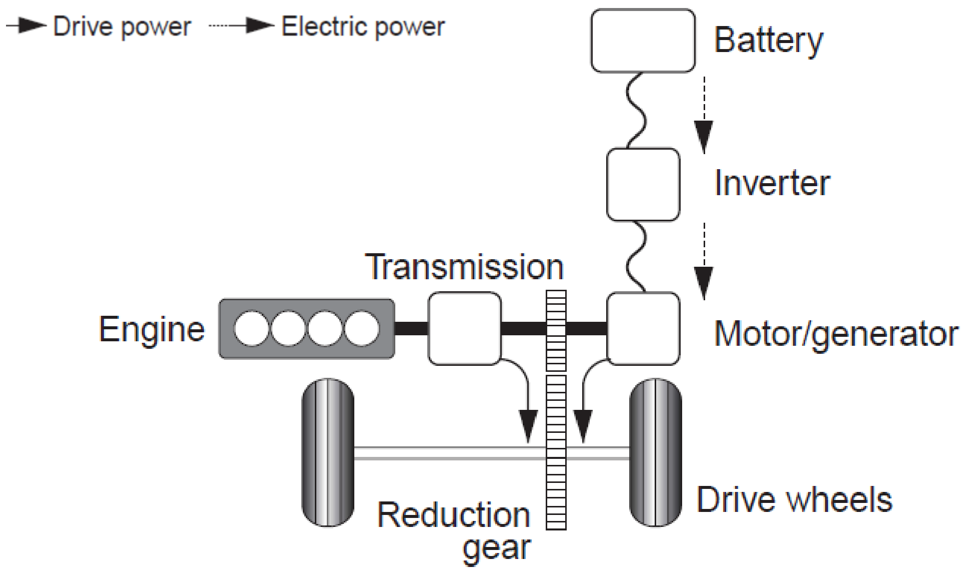
Starter/Generator

AC Compressor

Electrified configurations

- 4 Basic configurations
  - Parallel
  - Series
  - Combination of Series and Parallel
  - Electric (BEV – Battery Electric Vehicles)

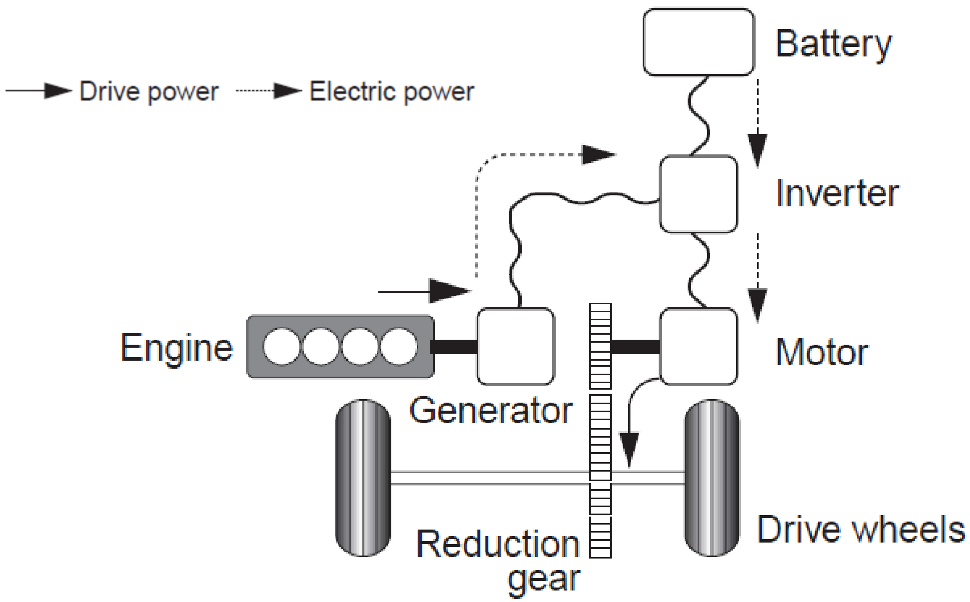
Electrified configurations: Parallel hybrid system



Power can flow to the wheels from either the internal combustion engine, an electric motor or from both in parallel.

- Advantages
  - Significant reuse of base powertrain components can reduce investment
  - Many choices for the location of the electric machine(s)
  - Battery power can be directly added to the base powertrain for increased performance
- Disadvantages
  - Independent speed control of the ICE not possible (exception is a CVT)
  - Losses inherent in base transmission remain
  - Additional gearing adds to mechanical losses

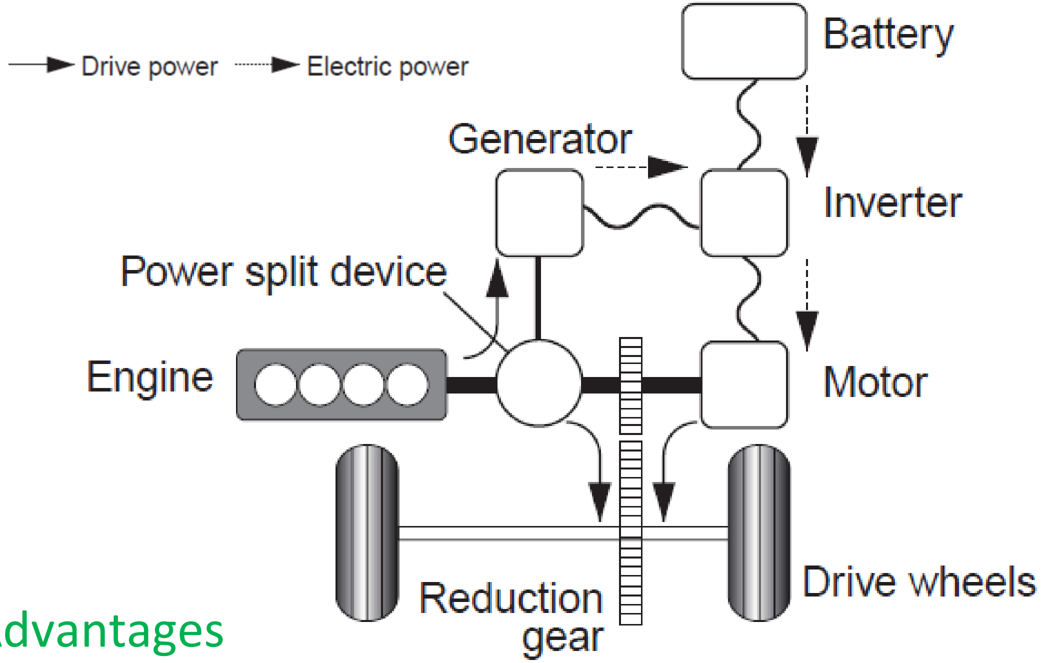
Electrified configurations: Series



Power from the internal combustion engine used to generate electrical power which then flows serially to an electric traction motor

- Advantages
  - Typically sized to provide the customer with full EV experience in charge depleting mode
  - Large amount of electrical power in combination with independent speed and torque control of the internal combustion engine result in very efficient city driving
- Disadvantages
  - Inefficient charge sustaining highway driving due to lack of mechanical path
  - High cost system due to high level of electrical power in addition to maintaining the ICE
  - Sizing of the ICE is a trade-off between vehicle performance in charge sustaining mode, cost, NVH

Electrified configurations: Series - Parallel

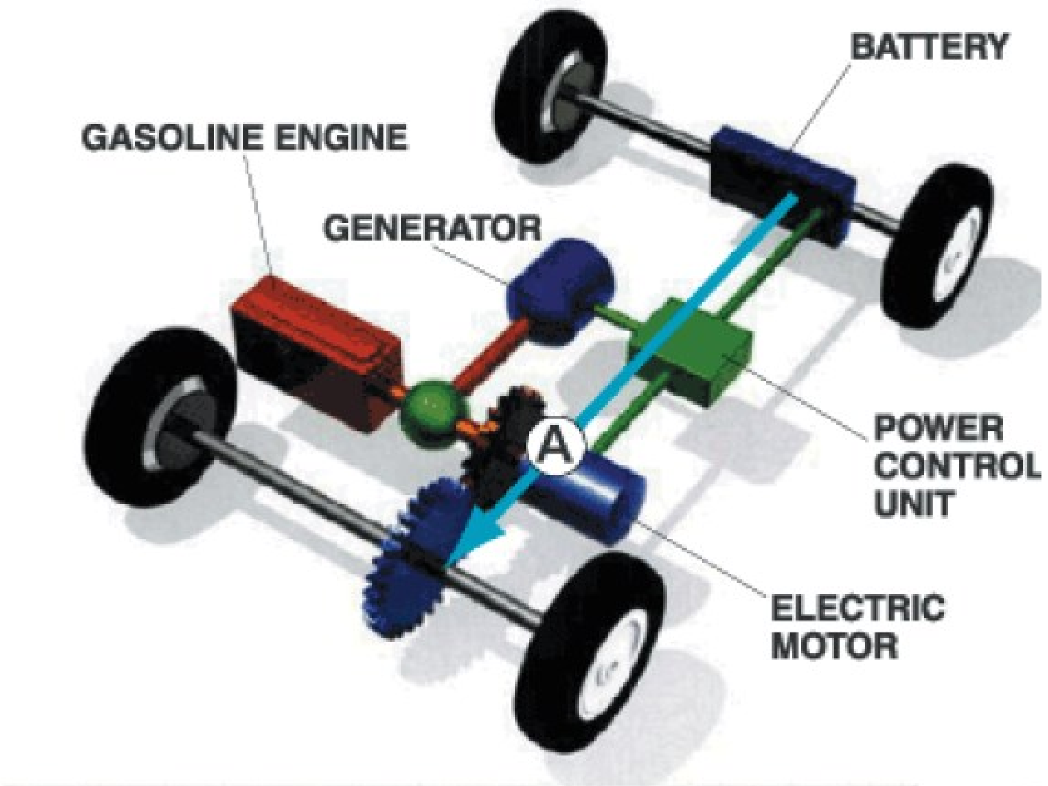


Power flows in series through the electrical path;
Power flows in parallel through
the mechanical path;

- Advantages
  - Independent speed and torque control of the internal combustion engine
  - Simplified gear train and lack of clutches and valve bodies minimizes mechanical system losses
  - Typical packaging allows for efficient motor designs that can deliver significant electric drive power
  - Typically the most efficient powertrain for combined city and highway driving cycles

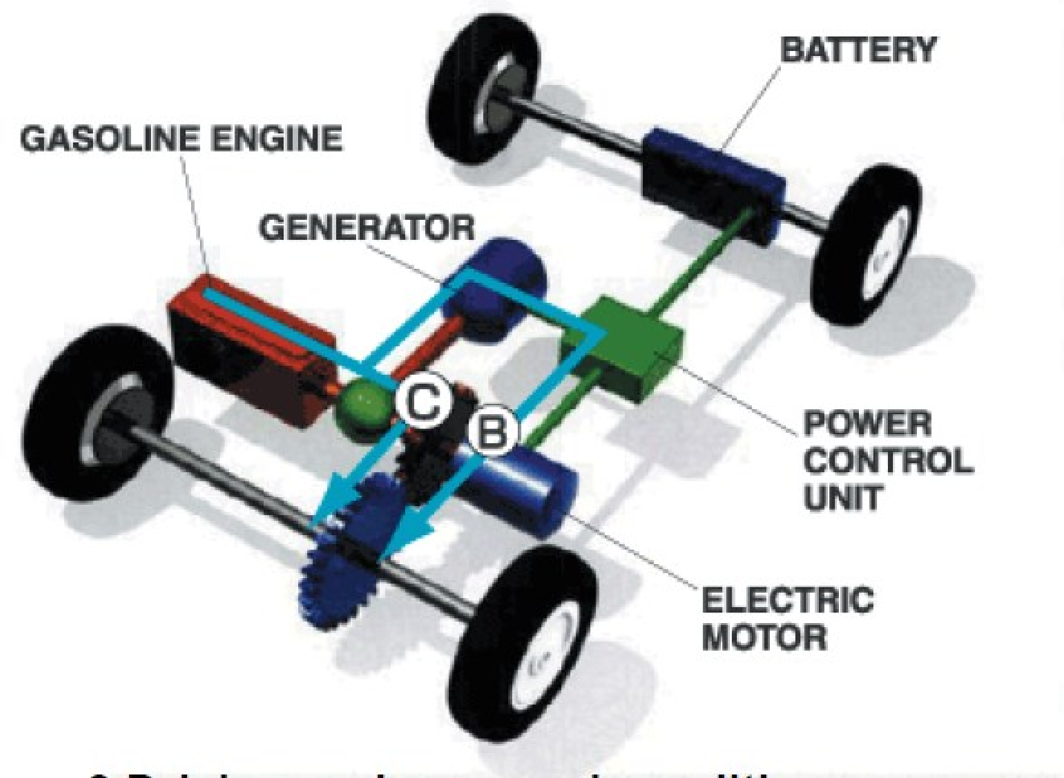
- Disadvantages
  - Power split ratio selection can lead to high electrical losses during high speed operation (>120 km/h)
  - Typically cannot deliver peak electrical and mechanical power at the same time
  - Reverse is electric drive only.

Electrified configurations: Series - Parallel



1 Start and low to mid-range speeds

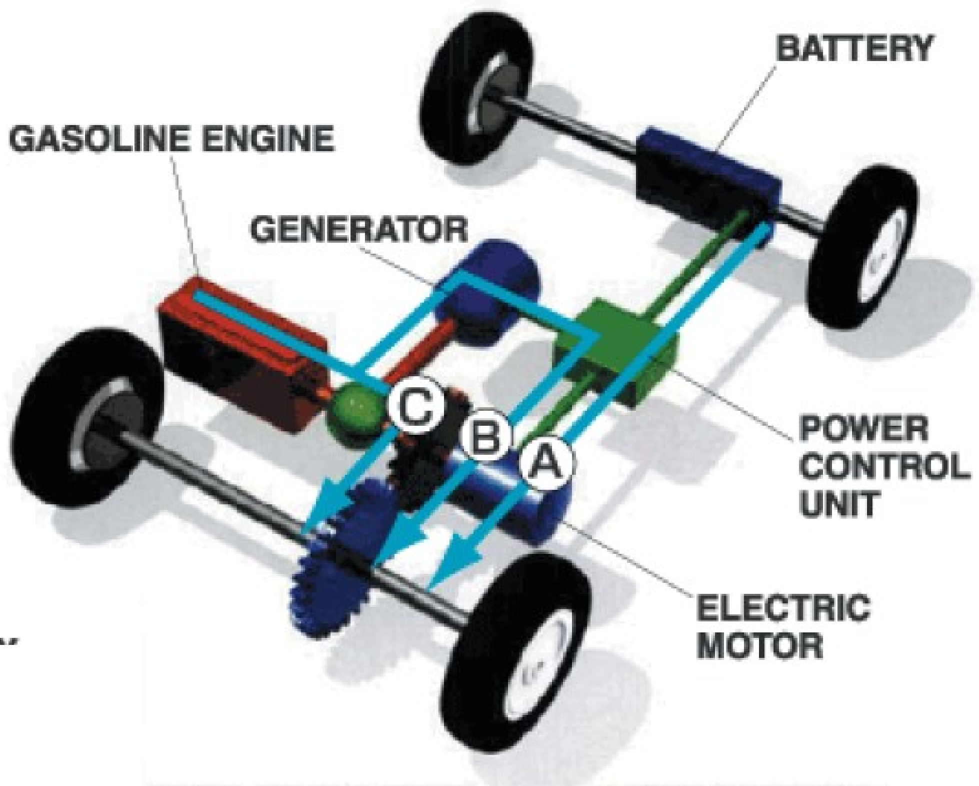
The engine stops when in an inefficient range, such as at start-up and in low to mid-range speeds. The vehicle runs on the motor alone. (A)



2 Driving under normal conditions

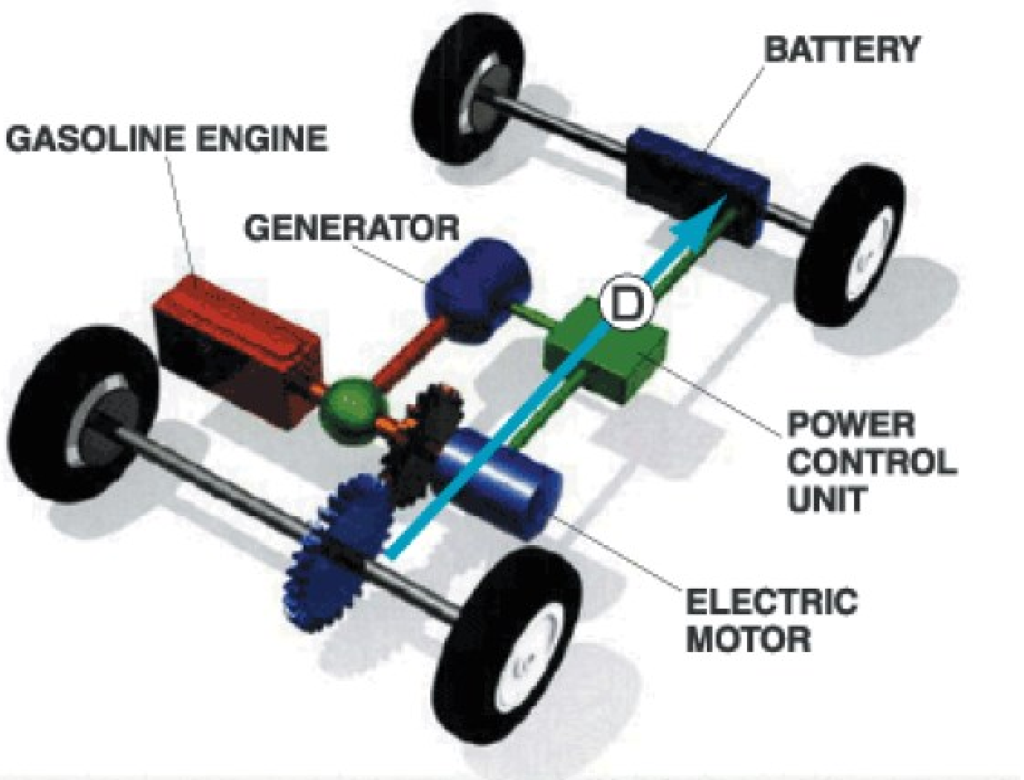
Engine power is divided by the power split device.
Some of the power turns the generator, which in turn drives the motor. (B)
The rest of the power drives the wheels directly. (C)
Power allocation is controlled to maximize efficiency.

Electrified configurations: Series - Parallel



3 Sudden acceleration

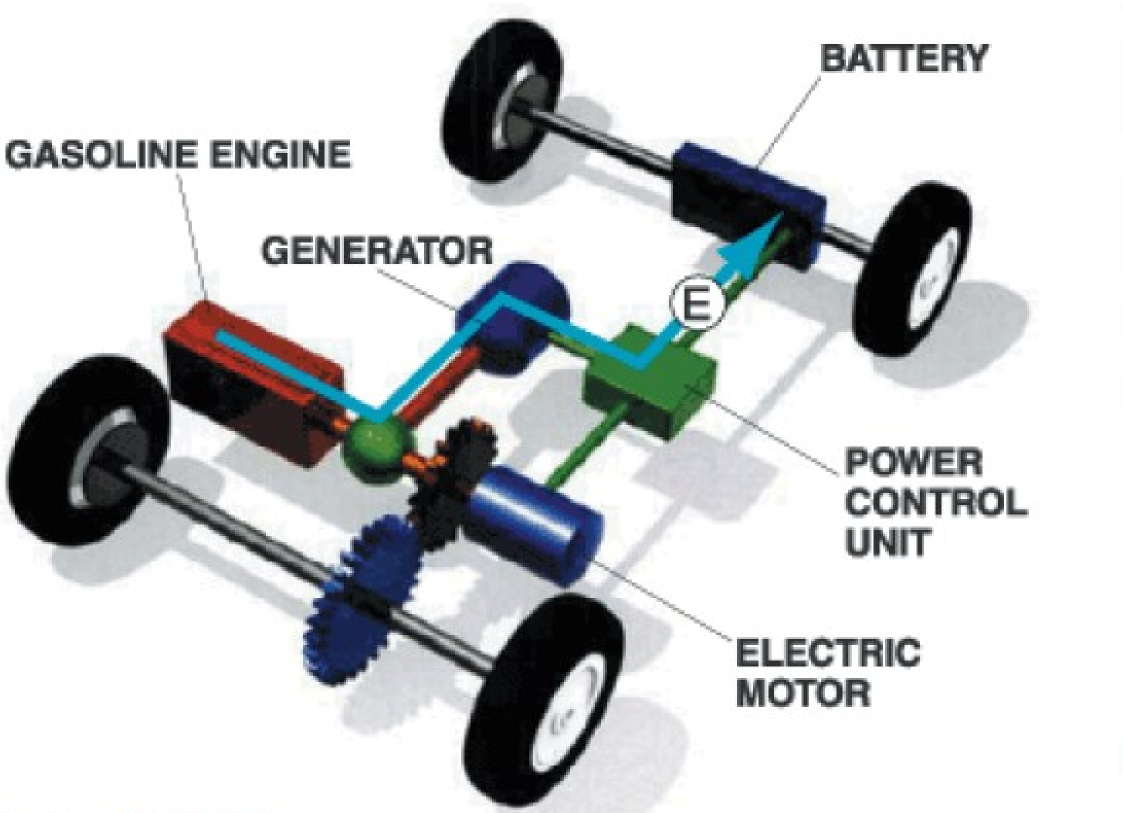
Extra power is supplied from the battery (A), while the engine and high-output motor provide smooth response (B+C) for improved acceleration characteristics.



4 Deceleration, braking

The high-output motor acts as a high-output generator, driven by the vehicle's wheels. This regenerative braking system recovers kinetic energy as electrical energy, which is stored in the high-performance battery. (D)

Electrified configurations: Series - Parallel



5 Battery recharging

Battery level is managed to maintain sufficient reserves. The engine drives the generator to recharge the battery when necessary. (E)

6 At rest

The engine stops automatically.