E^4T

ETUDE ENERGETIQUE, ECONOMIQUE ET ENVIRONMENTALE DU SECTEUR TRANSPORT

Cross analysis of energetic, economic and environmental impact of electrification on transportation sector

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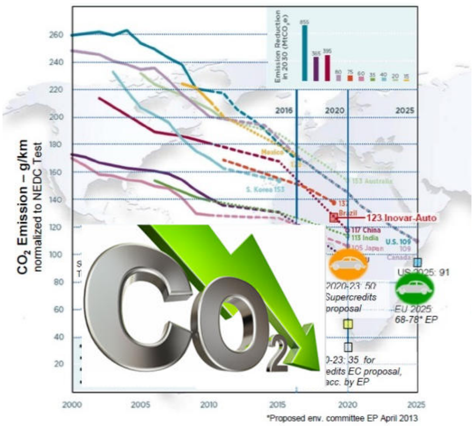
ADEME
Agence de l'Environnement et de la Maîtrise de l'Energie

CONTEXT

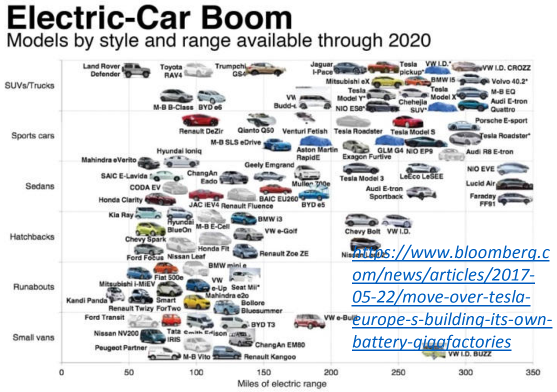
SUSTAINABLE MOBILITY



CO_2 emission reduction

#Dieselgate

Pollutant emission reduction



https://www.bloomberg.com/news/articles/2017-05-22/move-over-tesla-europe-s-building-its-own-battery-gigafactories

Towards electric car boom ?

New opportunities for electrification :
48V network, charging infrastructures

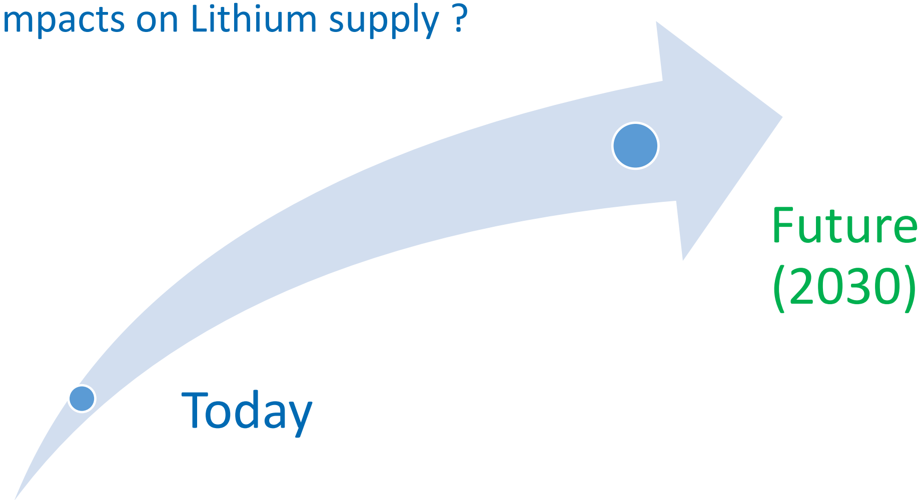
Transportation Electrification :

a necessary and irremediable evolution…

… BUT how to make it an optimal solution for the planet ?

OBJECTIVES

- **To develop recommendations** on technology choices based on mobility needs by 2030 based on environmental and economic criteria
- **To provide answers** to many outstanding questions around electrification
  - What electrification benefits on vehicle energy consumption, especially in real conditions?
  - What economic impacts on users ?
  - What environmental impacts in a global analysis ?
  - What impacts on Lithium supply ?



Transportation segmentation

Urban vehicle (A)

Medium class vehicle (C)

Upper class vehicle (D)

Commercial vehicle

Bus

Urban delivery HD

Long haul HD

Hybridization and electrification impact has been evaluated for each segmentation

ELECTRIFIED POWERTRAIN CLASSIFICATION

MHEV : Mild Hybrid Electric Vehicle (48V)
HEV : Hybrid Electric Vehicle (Full / high voltage)
PHEV : Plug-in Hybrid Electric Vehicle
EREV : Extended Range Electric Vehicle
EV : Electric Vehicle

	Micro	Mild	Full	PHEV	EREV	EV
	Stop&Start	Extended S&S ICE assistance Brake recovery	Full electric mode	Extended electric mode Network charging		
ZEV capabilities (km)	**0**	**0 to 0,5**	**0,2 to 3**	**50**	**50**	**200 to 500**
Electric power (kW)	~1 to 2	10 to 20	20 to 60	40 to 110	50 to 125	50 to 300
Batt. energy (kWh)	0,5 to 1	0,5 to 1	1 to 2	5 to 16	5 to 16	24 to …
Voltage (V)	12	48	350	350	350	350

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TYPE OF ELECTRIFICATION PER VEHICLE SEGMENT

MOBILITÉ DURABLE

Urban vehicle

- *Gasoline vehicle*
- *MHEV 48V*
- *Extended Range EV (EREV)*
- *BEV*

Mid class vehicle

- *Gasoline & Diesel vehicles (S&S)*
- *MHEV 48V*
- *Parallel HEV & PHEV*
- *Power split HEV & PHEV*
- *BEV*

Upper class vehicle

- *Gasoline & Diesel vehicles (S&S)*
- *MHEV 48V*
- *Parallel HEV & PHEV*
- *Power split HEV & PHEV*
- *BEV*

Commercial vehicle

- *Diesel vehicle*
- *MHEV 48V*
- *PHEV*
- *BEV*

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VÉHICULES PAR SEGMENT

Bus
- *Diesel vehicle*
- *Parallel HEV*
- *Serial HEV*
- *BEV*

Delivery HD
- *Diesel vehicle*
- *Parallel HEV*
- *Serial HEV*
- *BEV*

Long haul
- *Diesel*

35 modelled vehicles…
to decline for 2 time horizons
(today and 2030) !

Vehicles characteristics
2030 hypotheses (compared to today)



2030

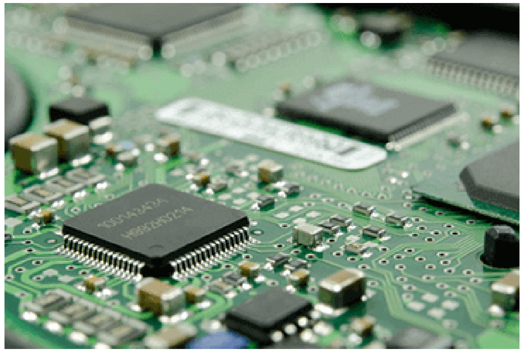
	Light Duty vehicle	Heavy duty	Long haul
Mass reduction	< 5 %	16,6 %	15.6 %
Aerodynamic drag reduction	10 %	15 %	25 %
Rolling coefficient reduction	20 %	20%	20 %

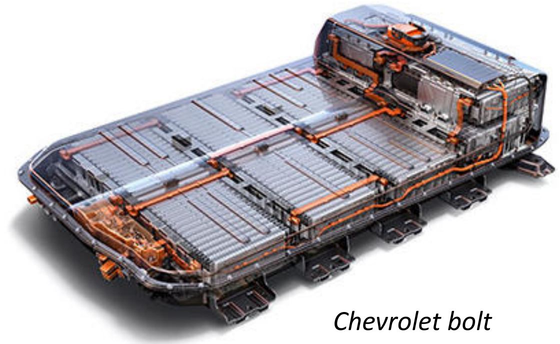
Sources : Heavy Duty Vehicles Technology Potential and Cost Study final Report for the International Council on Clean Transportation (ICCT) by Ricardo 2017

Electric system
2030 hypotheses (compared to today)

MOBILITÉ DURABLE

IFPEN – MAVEL
SA350 electric motor





Chevrolet bolt
60kWh battery
pack

Electric motor	Power electronics	Battery
Power density *x2 – x2,5*	*Power density* *x1,5*	*Energy density* *x2*

2015 → 2030 hypotheses on Internal Combustion Engine *(peak efficiency)*

MOBILITÉ DURABLE

ICE peak efficiency

	Light Duty vehicle	Heavy duty	Long haul
Gasoline engine	*36% - 40%* → ***46%***	-	-
Diesel engine	*39% - 41%* → ***48%***	*42%* → ***49%***	*45%* → ***52%***

Sources :

- *Guenter Fraidl - AVL List GmbH – SAE 2015*
- *ARGONE National laboratory - Assessment of Vehicle Sizing, Energy Consumption, and Cost through Large-Scale Simulation of Advanced Vehicle Technologies (mars 2016)*
- *Concertation experts IFPEN*

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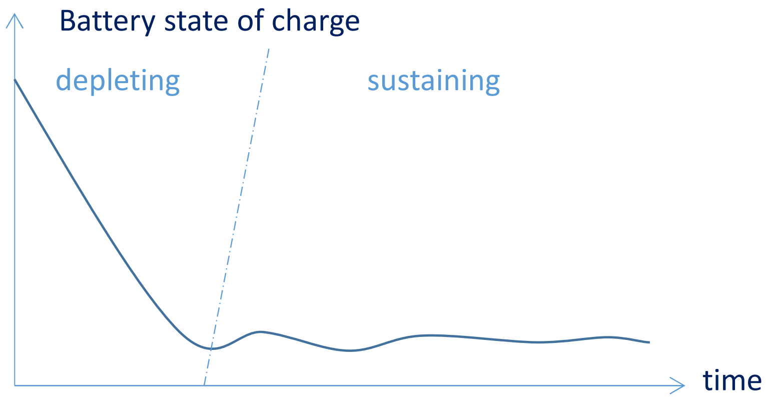
Other hypotheses

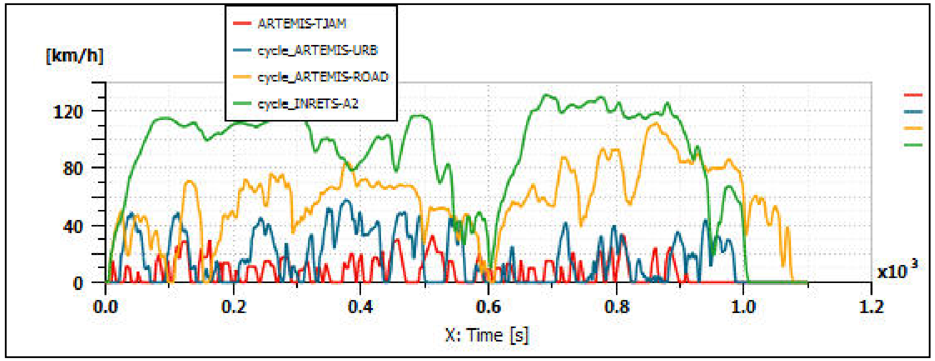
MOBILITÉ DURABLE

- French hypotheses…
  - … on electricity production mix (nuclear based)
  - … on fuel & electricity prices

    Brent: 50 $/bbl
    Gasoline: 1.32 €/l
    Diesel fuel: 1.23 €/l
    Electricity: 0.120 €/kWh
  - … on incentives (6 000 euros for EV today in France)



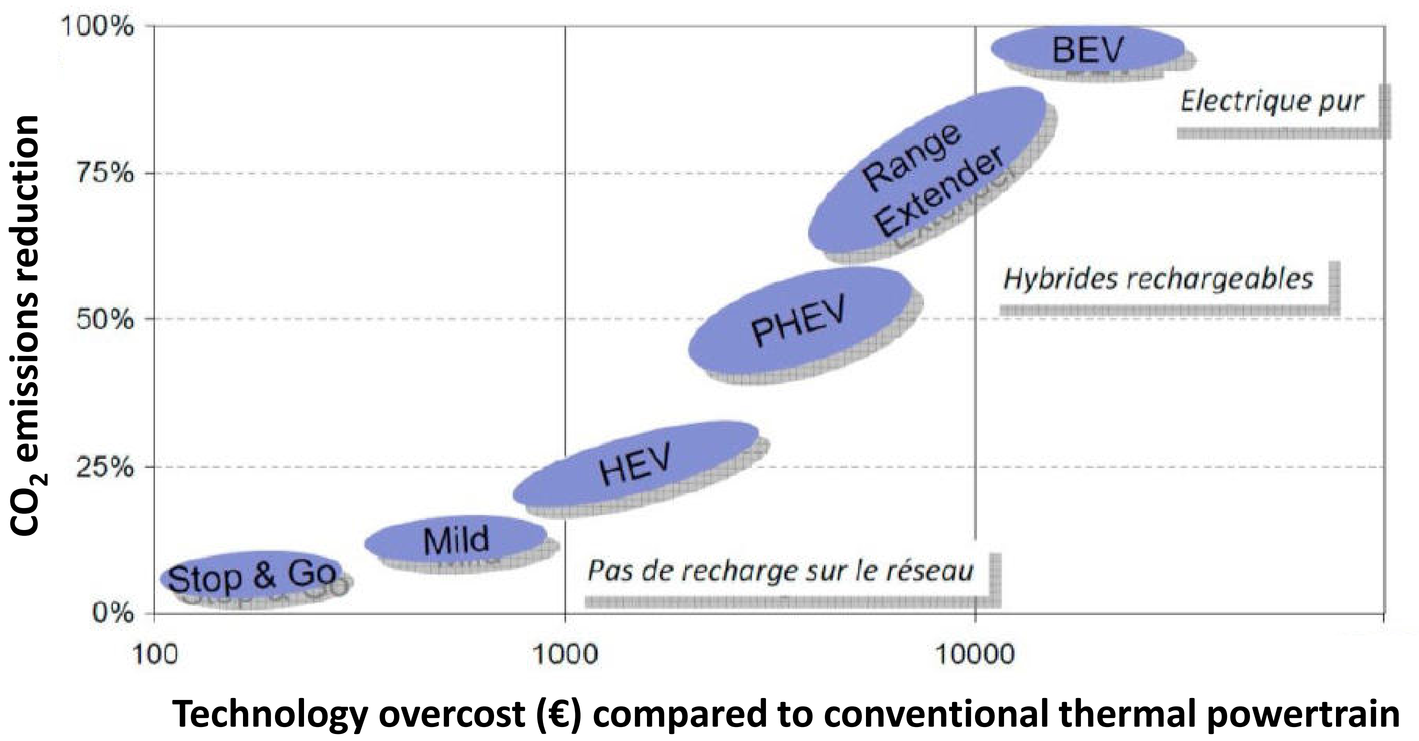
- Simulation protocol
  - HEV : sustaining mode
  - PHEV : depleting mode, then sustaining mode
  - Light duty vehicles :
    - Homologation driving cycles
    - Real driving cycles
  - Other vehicles : real driving cycles



WHY AN ECONOMIC ANALYSYS ?

SUSTAINABLE MOBILITY

- Technology cost is the most important lock towards massive market !



Trade-off « Cost/CO_2 » for the hybrid technologies

Source : PFA - CTA : perspectives de croissance des chaînes de traction automobile

TOTAL COST OF OWNERSHIP (TCO)

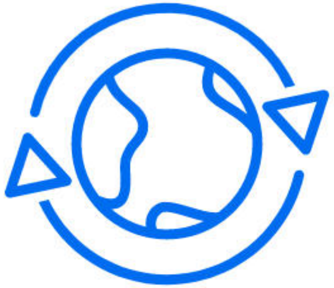
- ✓Investment
- ✓Fiscal incentive
- ✓Sale

- ✓Fuels price
- ✓Fuel consumption
- ✓Maintenance
- ✓Insurance

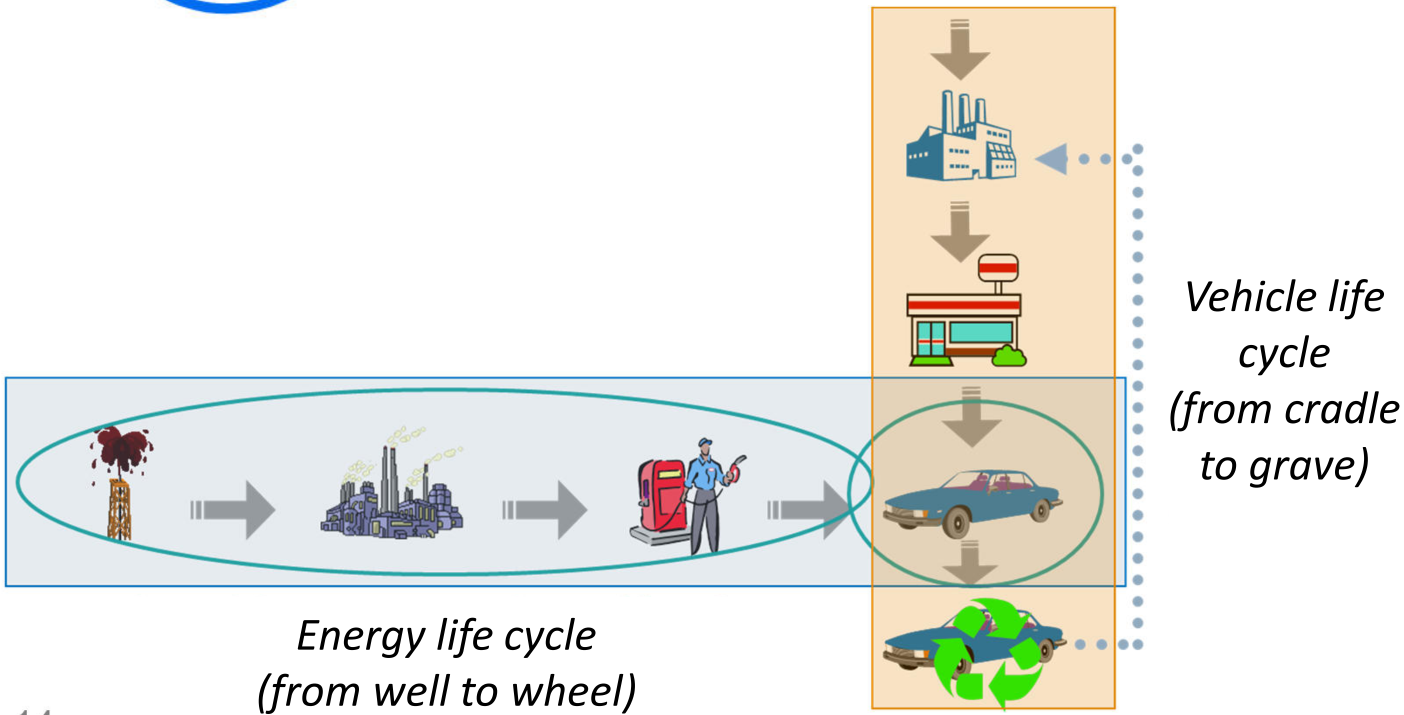
$$TCO = \frac{\text{Investment (€)} + \sum \text{discounted expenditure (€)}}{\sum \text{discounted annual mileage (km)}}$$

- ✓Annual mileage, by vehicle/technology
- ✓Possession duration

LIFE CYCLE ANALYSIS



To evaluate and analyze, with a global and complete method, the environmental impacts (GHG, pollutants…) of transport solutions (electrification…) for nowadays and for the future!



Functional unit :

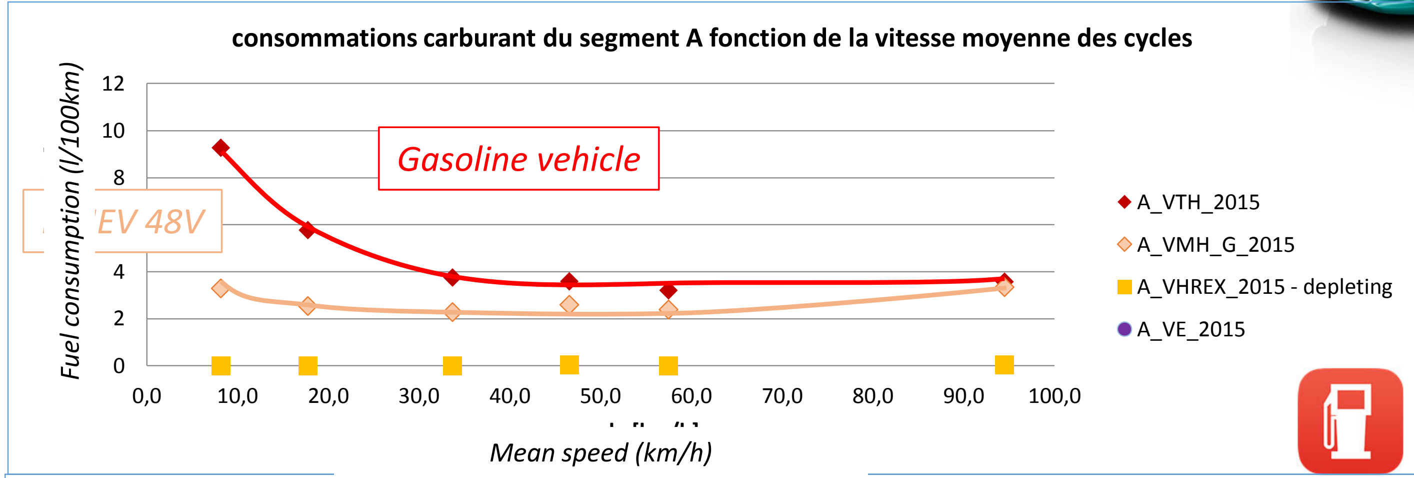
to move 1 person on 1 km

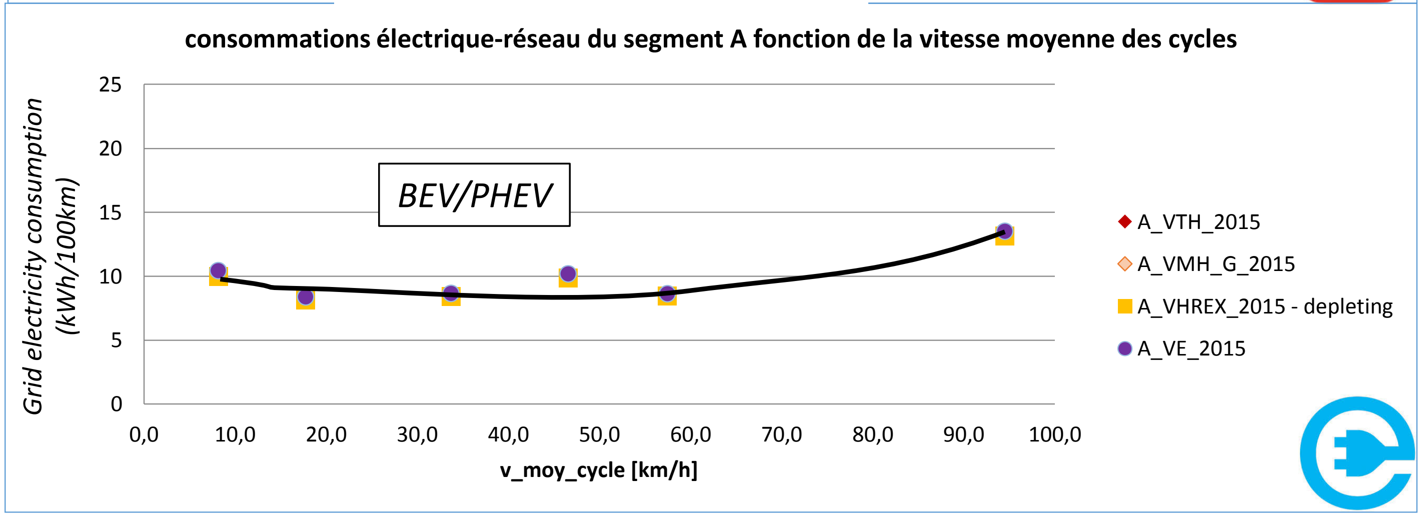
or

To move 1 kg on 1 km

URBAN VEHICLES - 2030

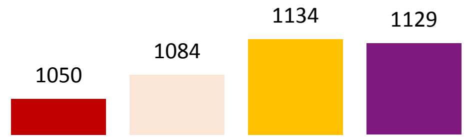
MOBILITÉ DURABLE





- A_VTH = Gasoline vehicle
- A_VMH_G = MHEV 48V
- A_VHREX = EV with Range extender
- A_VE = EV

Vehicle mass (kg)

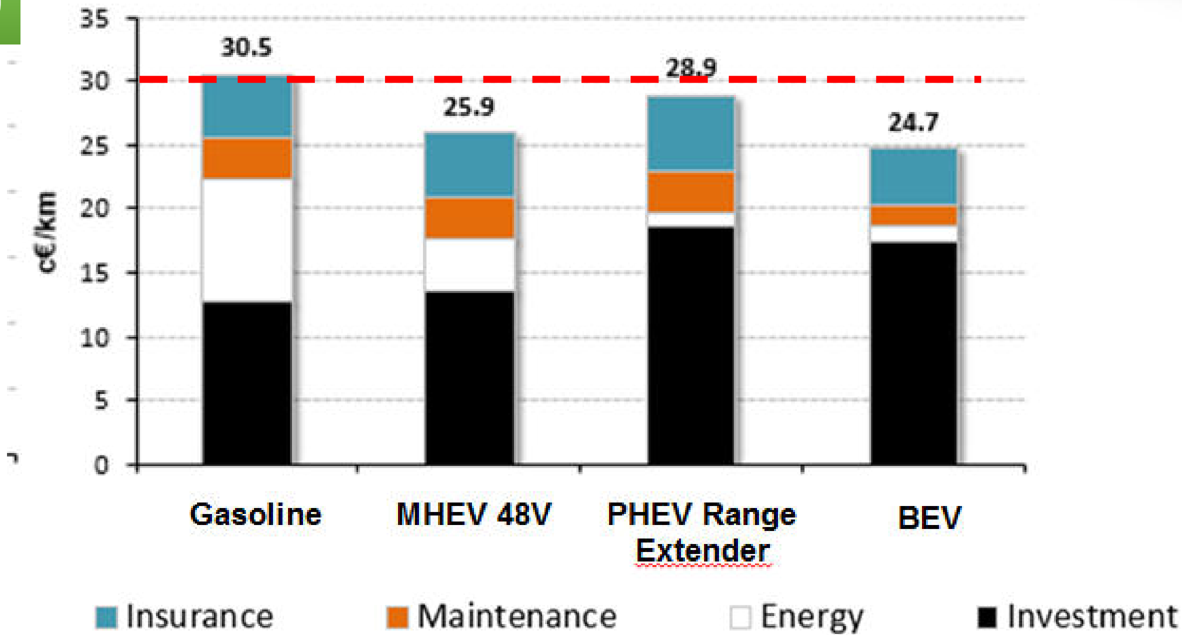


URBAN VEHICLES

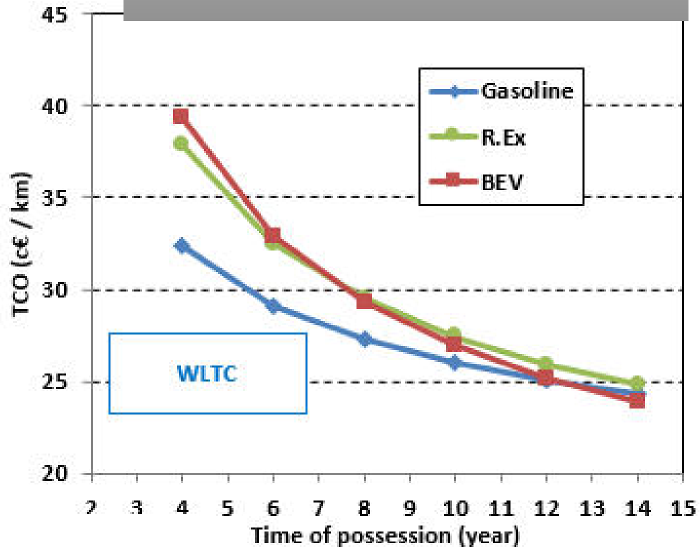
12 000 km/year
10 years
Urban driving cycle

SUSTAINABLE MOBILITY

2030



TCO vs time of possession (present time)



With battery cost reduction, BEV would be economically profitable in 2030 without incentive… but probably highly challenged with future low cost hybrid systems.

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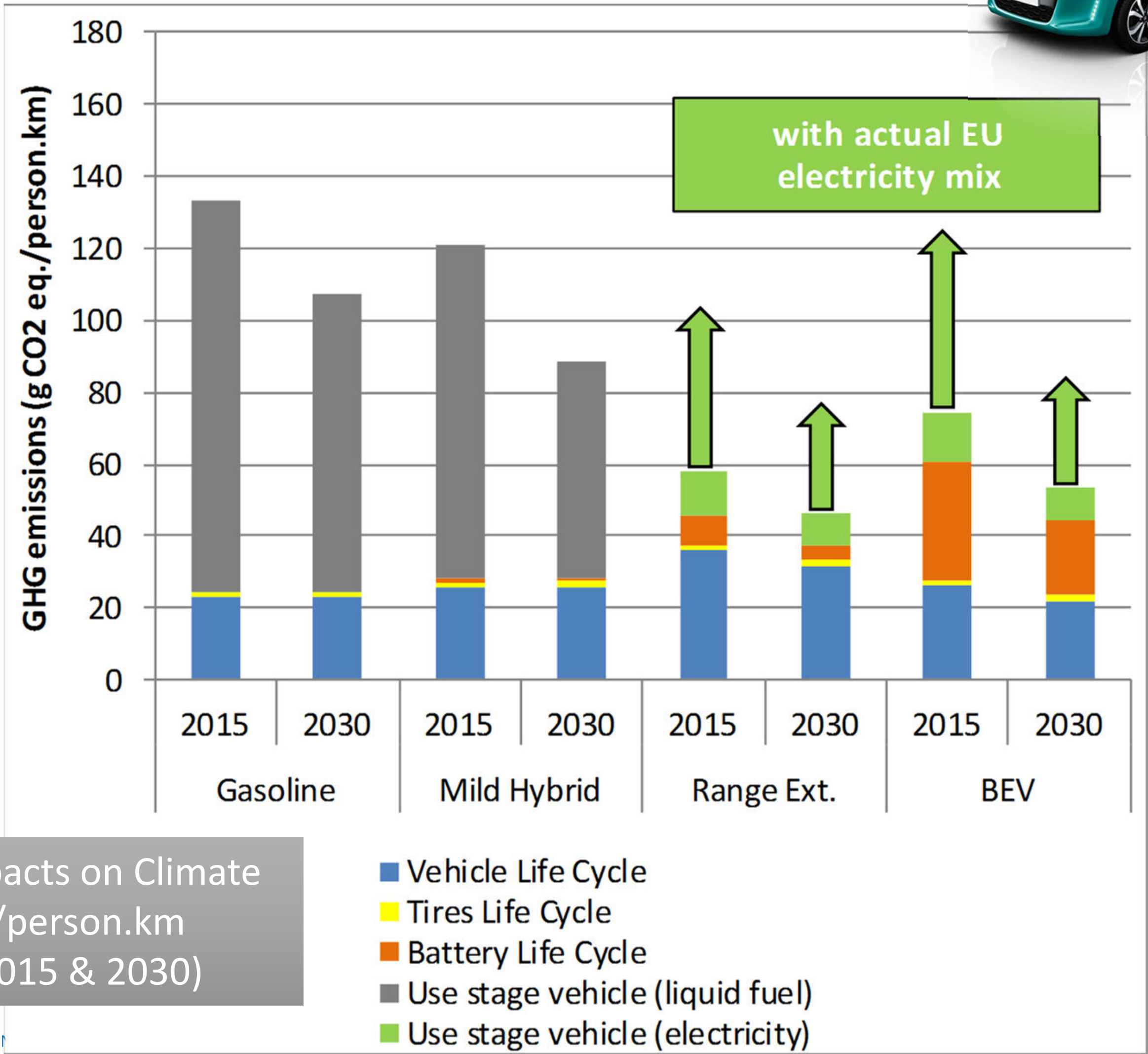
LCA FOR URBAN VEHICLES



Potential impacts on Climate Change /person.km
(WLTC - 2015 & 2030)

BEV & PHEV :
Best solutions !
but

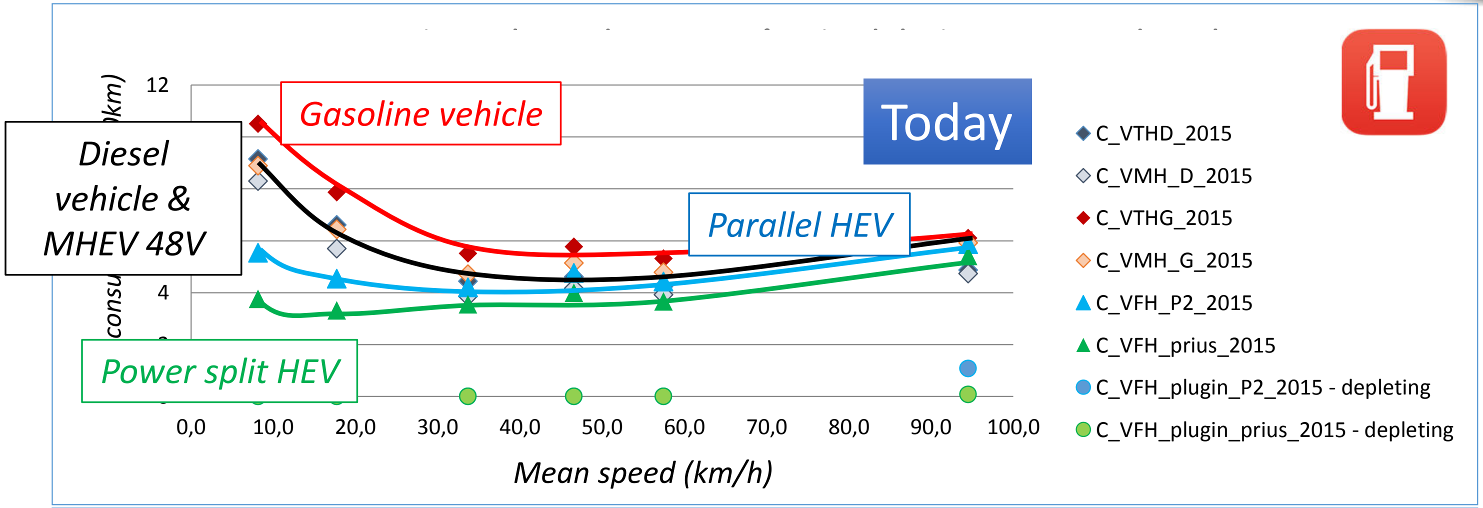
PHEV results are sensitive to charging profiles & driving cycles

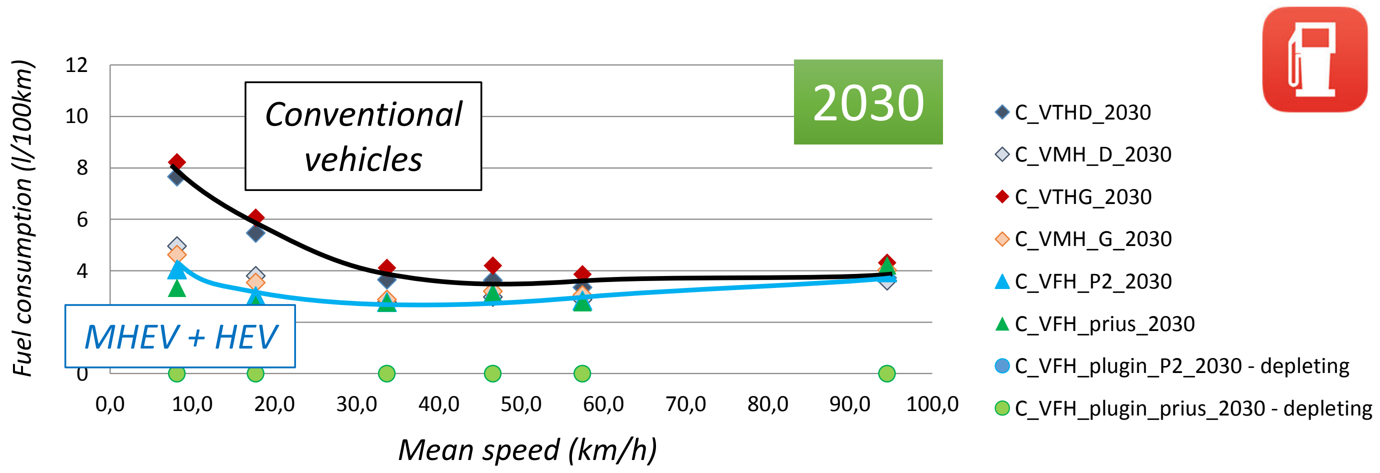
BEV results are sensitive to battery size (total range)

BEV & PHEV results are sensitive to electricity production mix

MID SIZE VEHICLES

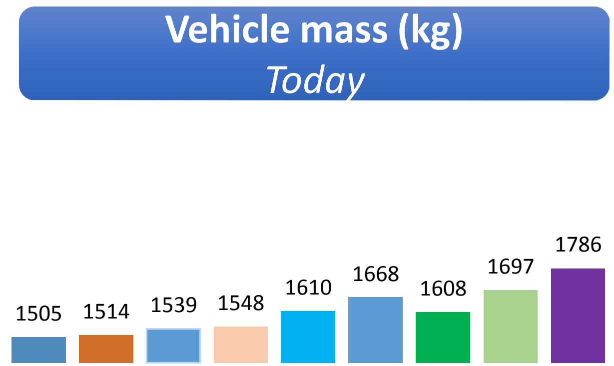
MOBILITÉ DURABLE





Véhicules segment C - moyenne gamme

- C_VTHD = Disel conventional vehicle(S&S)
- C_VTHG = Gasoline conventional vehicle (S&S)
- C_VMH_D = Diesel MHEV (P0)
- C_VMH_G = Gasoline MHEV (P0)
- C_VFH_P2 = Parallel HEV
- C_VFH_prius = Power split HEV
- C_VFH_plugin_prius = Power split PHEV
- C_VFH_plugin_P2 = Parallel PHEV
- C_VE = BEV

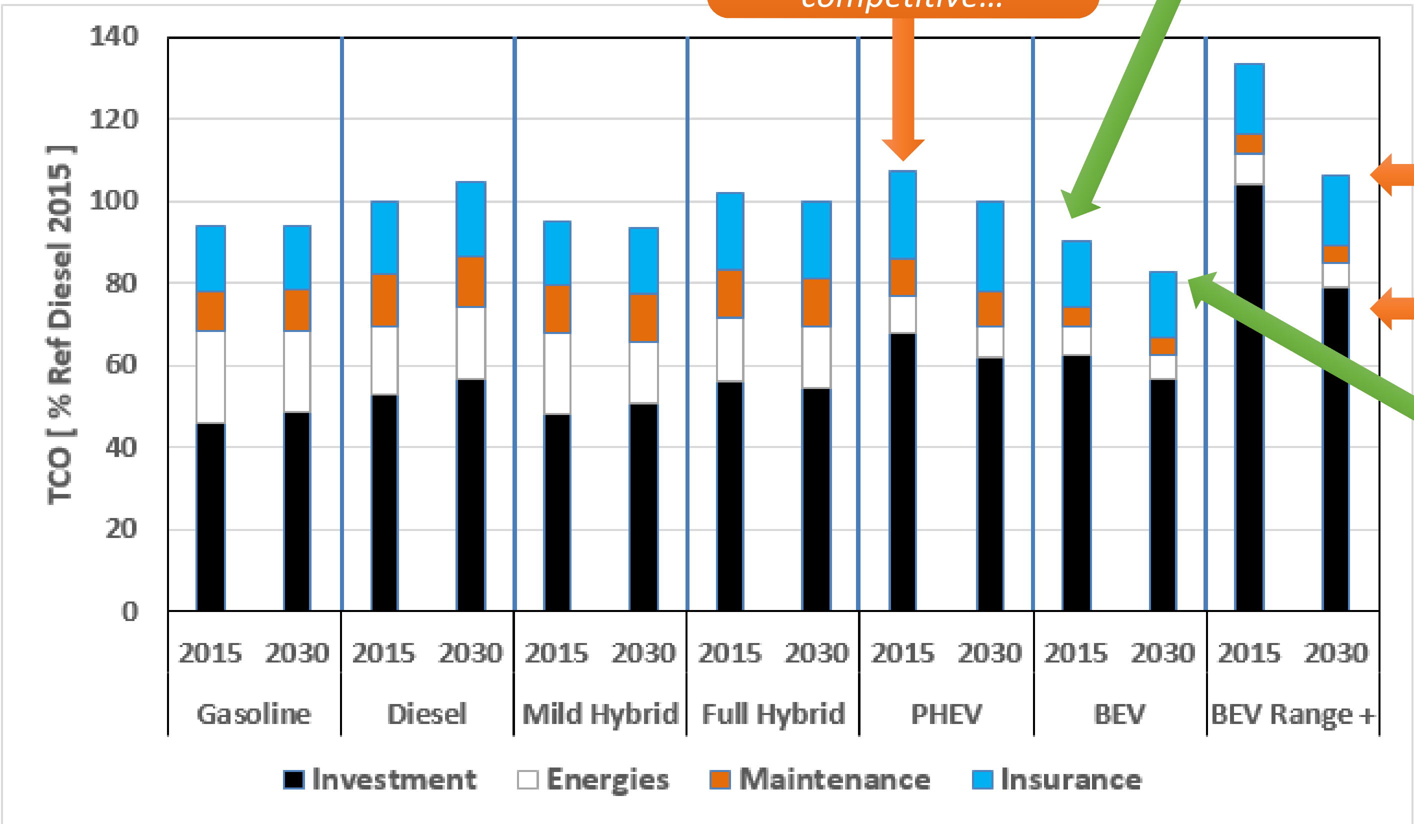


MID SIZE VEHICLES

15 000 km/year
10 years
Cycle: WLTC

Without incentive, PHEV are less competitive…

Nowadays BEV is profitable with 6000 € incentive

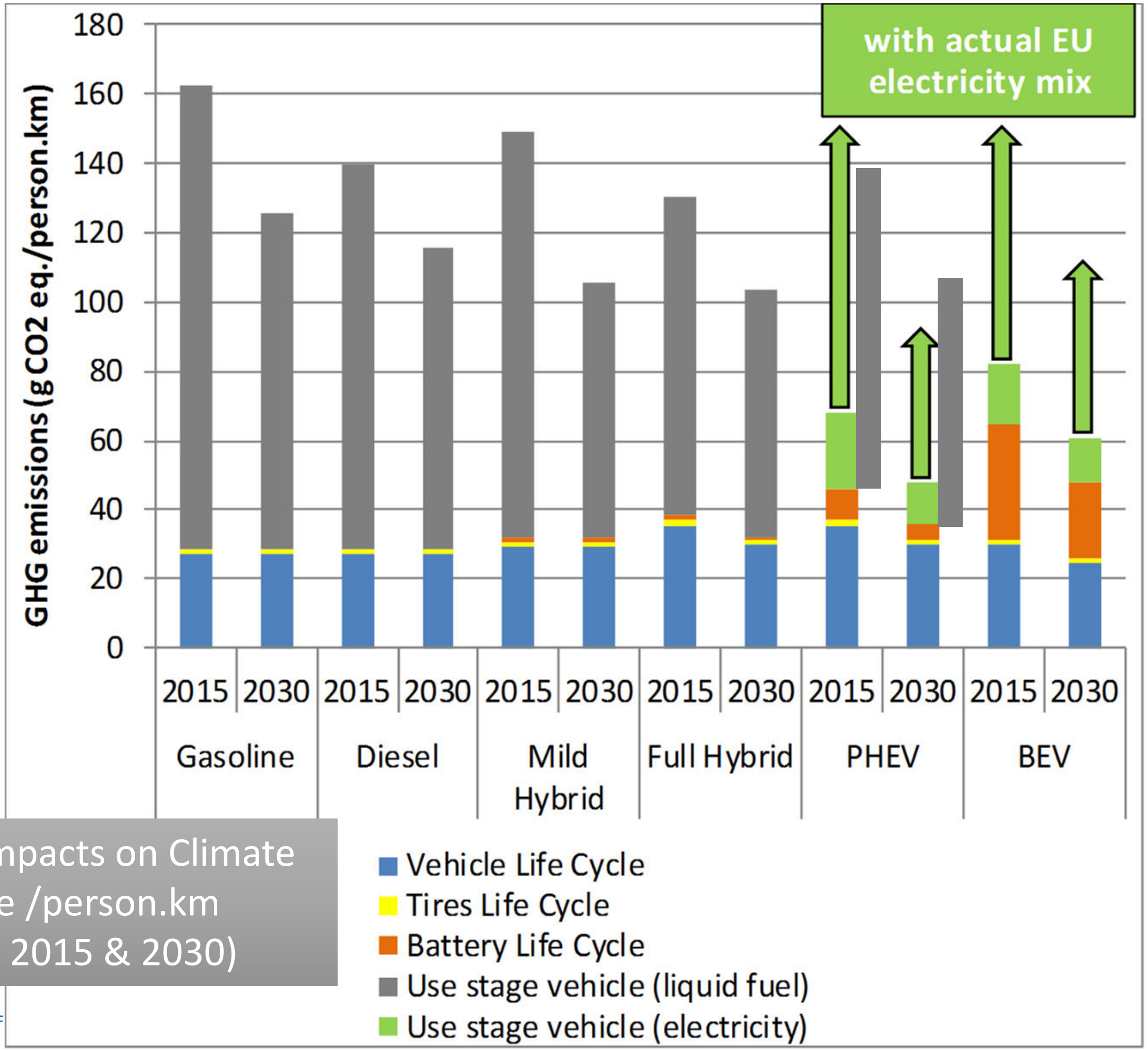


… but with reasonable battery size! (cf. TCO & investment)

2030 BEV would the most profitable powertrain with no incentive…

LCA FOR MID SIZE VEHICLES

SUSTAINABLE MOBILITY



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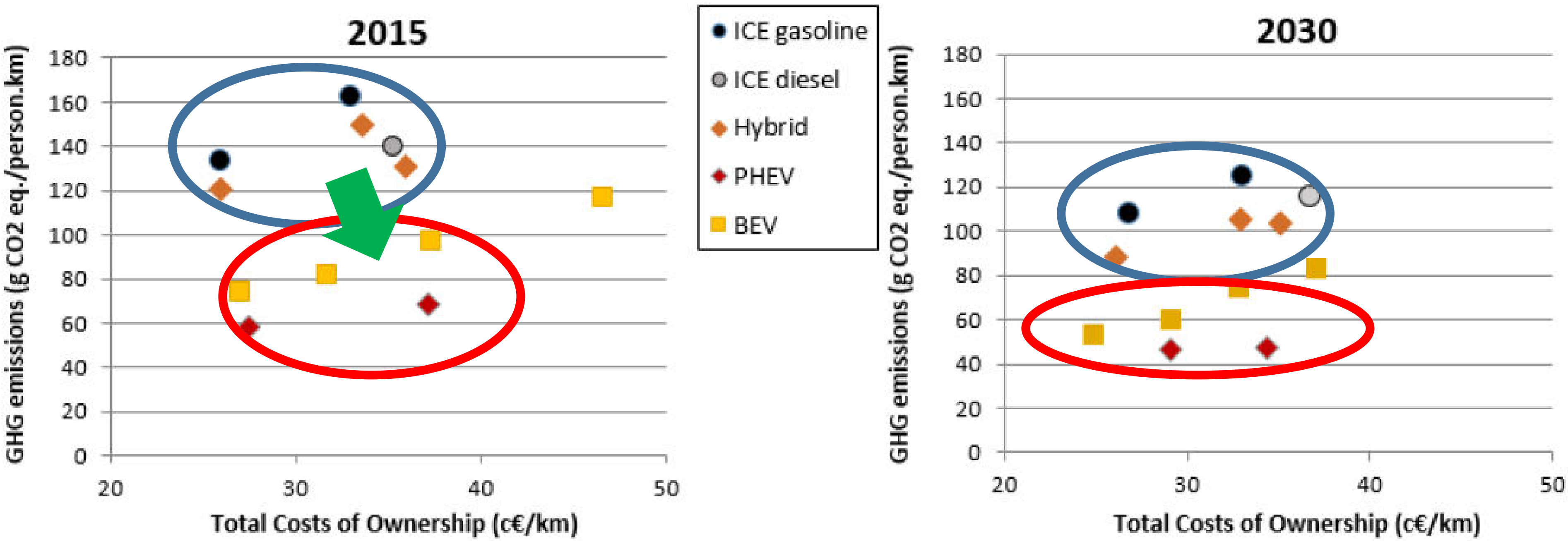
TCO / LCA FOR MID SIZE VEHICLES

SUSTAINABLE MOBILITY

GHG emissions and TCO for light duty midsize cars for WLTC cycle, 2015 and 2030



CO2 emissions emitted by ICEVs decrease between today and 2030, whereas their TCO raise

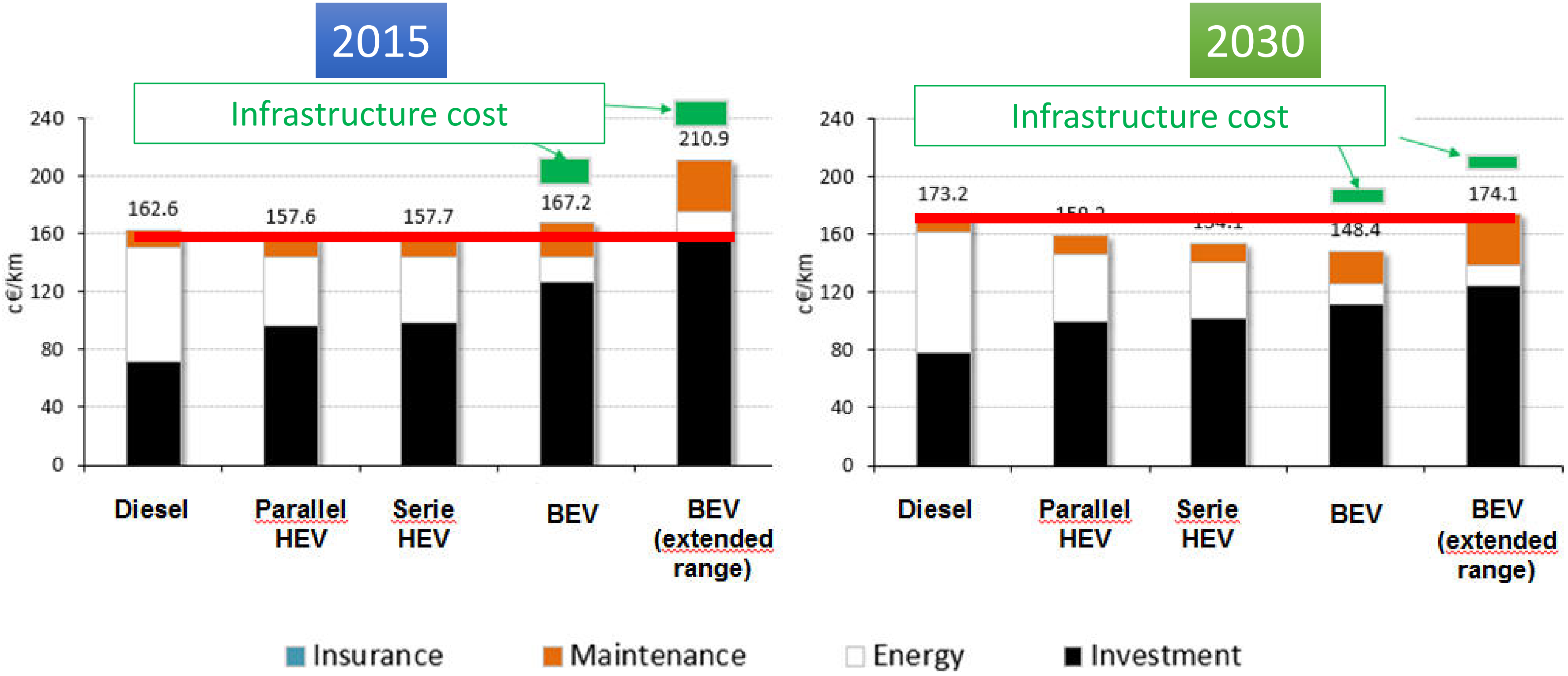
The powertrain electrification offers higher gains, even with mild-hybrid or full-hybrid vehicles

In French context, Alternative powertrain technologies (PHEVs and BEVs) exhibit lower lifecycle GHG emissions than ICEVs but do not necessarily cost the consumer more

BUS

40 000 km/an
12 ans
Bus

SUSTAINABLE MOBILITY



Short term : hybridization already a profitable solution
Long term : electric buses for zero emission capabilities

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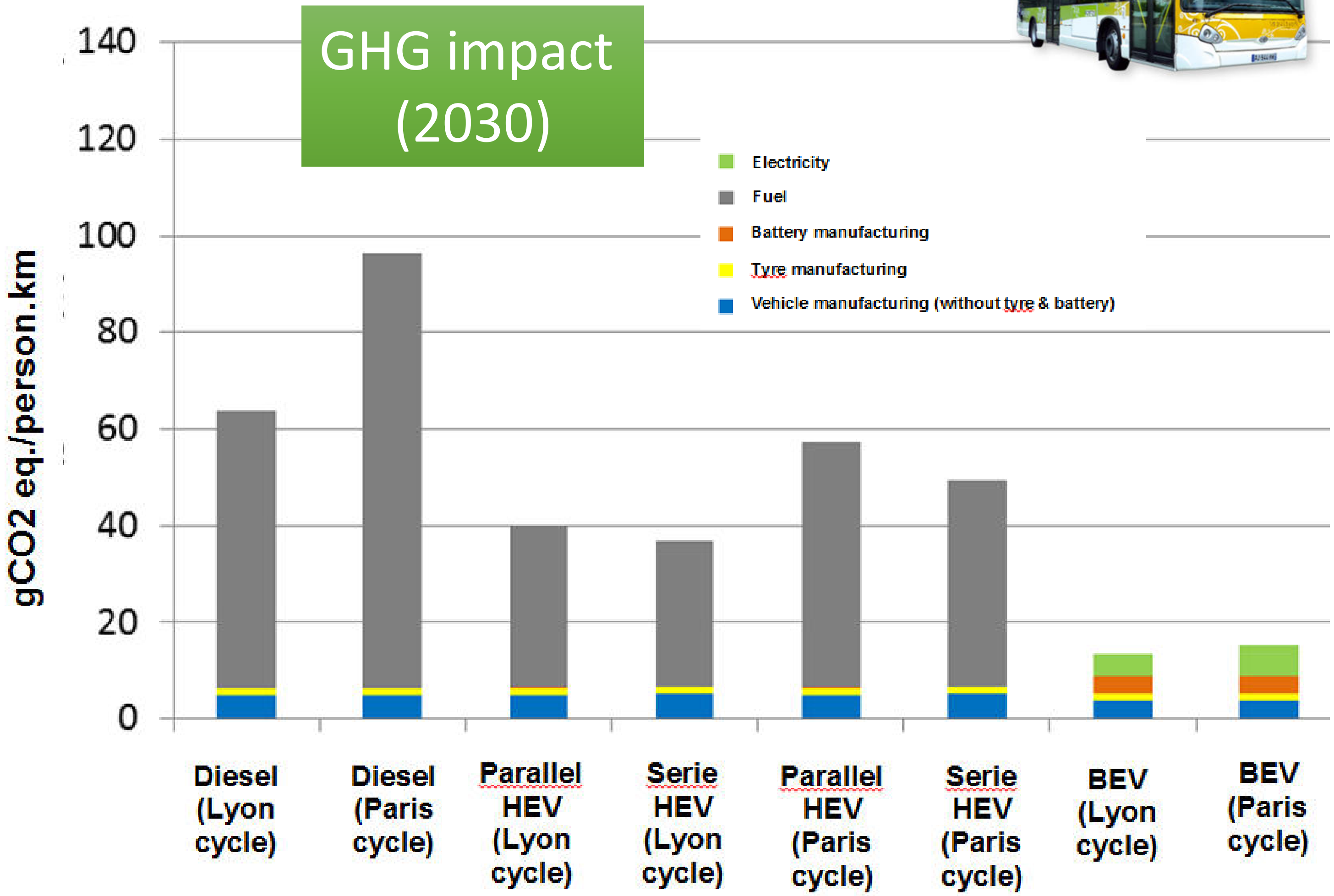
LCA FOR BUSES

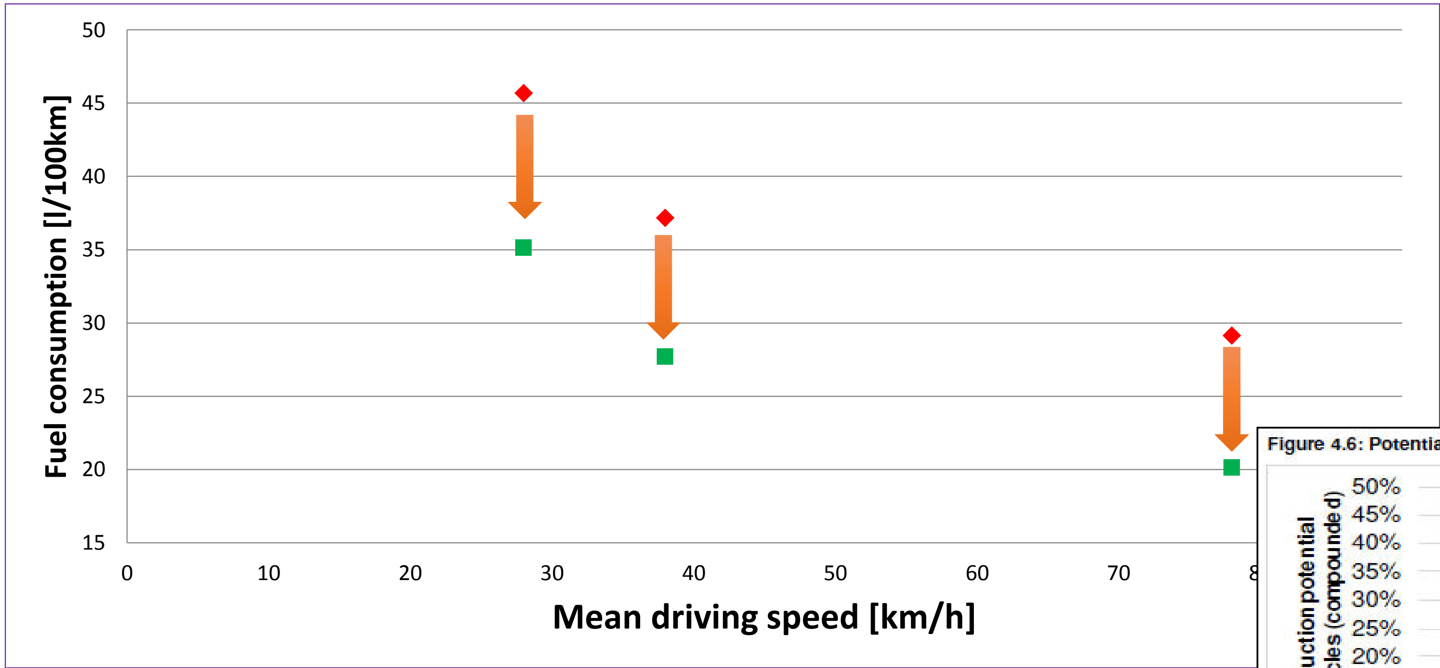
SUSTAINABLE MOBILITY



Hybridization : a relevant transition toward all electric buses (good compromise between TCO and GHG emissions)

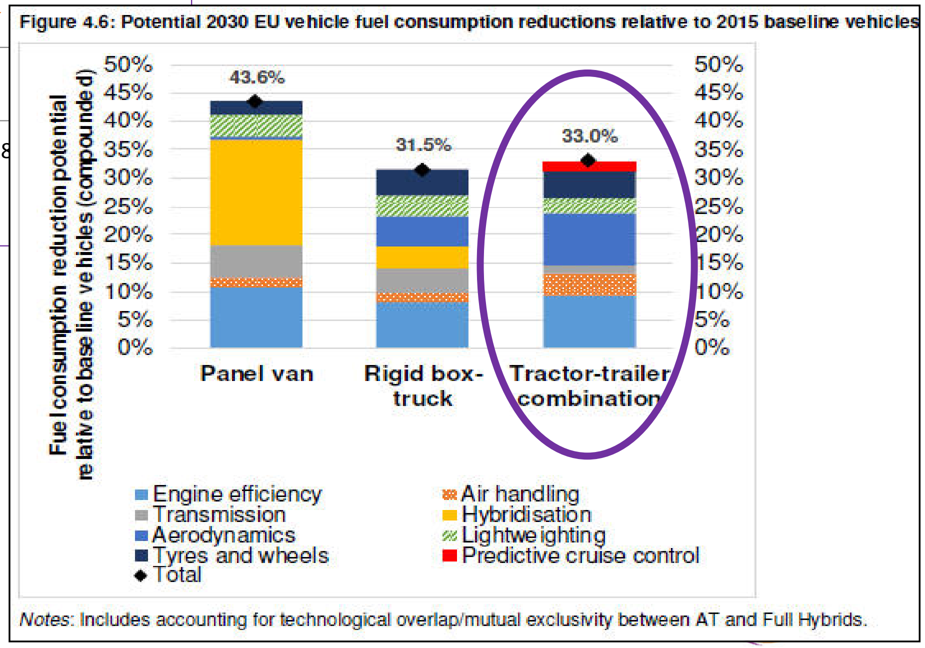
BEV : best solution in terms of GHG (and local pollutants)

LONG HAUL VEHICLE



2015

2030



Fuel consumption reduction

= around **30 %** on various driving cycles

(similar to ICCT – Ricardo values)

Source : ICCT - Ricardo

CONCLUSIONS & PERSPECTIVES

SUSTAINABLE MOBILITY

Conventional vehicles

Nowadays, still the most affordable solution in terms of investment…

… but will be highly challenged with hybrid and electric vehicles in terms of TCO in the future

… and cannot be the answer to future challenges to reduce CO_2 emissions and pollutants

Power split HEV ➔ Best hybrid vehicle !

For all the using conditions (notably urban)

Will be challenged by MHEV & PHEV in 2030

Best vehicles for the TCO (2030) :

MHEV 48V

Electric vehicles with reasonable battery size (range : 200 - 250 km) and high mileage

Best vehicles for the environment ***(with low carbon energy mix) :***

PHEV if correctly used (regularly recharged)

Electric vehicles with reasonable battery size (range : 200 - 250 km) and high mileage

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CONCLUSIONS & PERSPECTIVES

- Electrification (BEV, PHEV, HEV and MHEV) is the necessary choice to reach the future emission reduction challenges in a world of renewable energy supply
- 2025 sales forecasts suggest a penetration of BEV lower than 10%, and more than 55% of hybrid powertrains

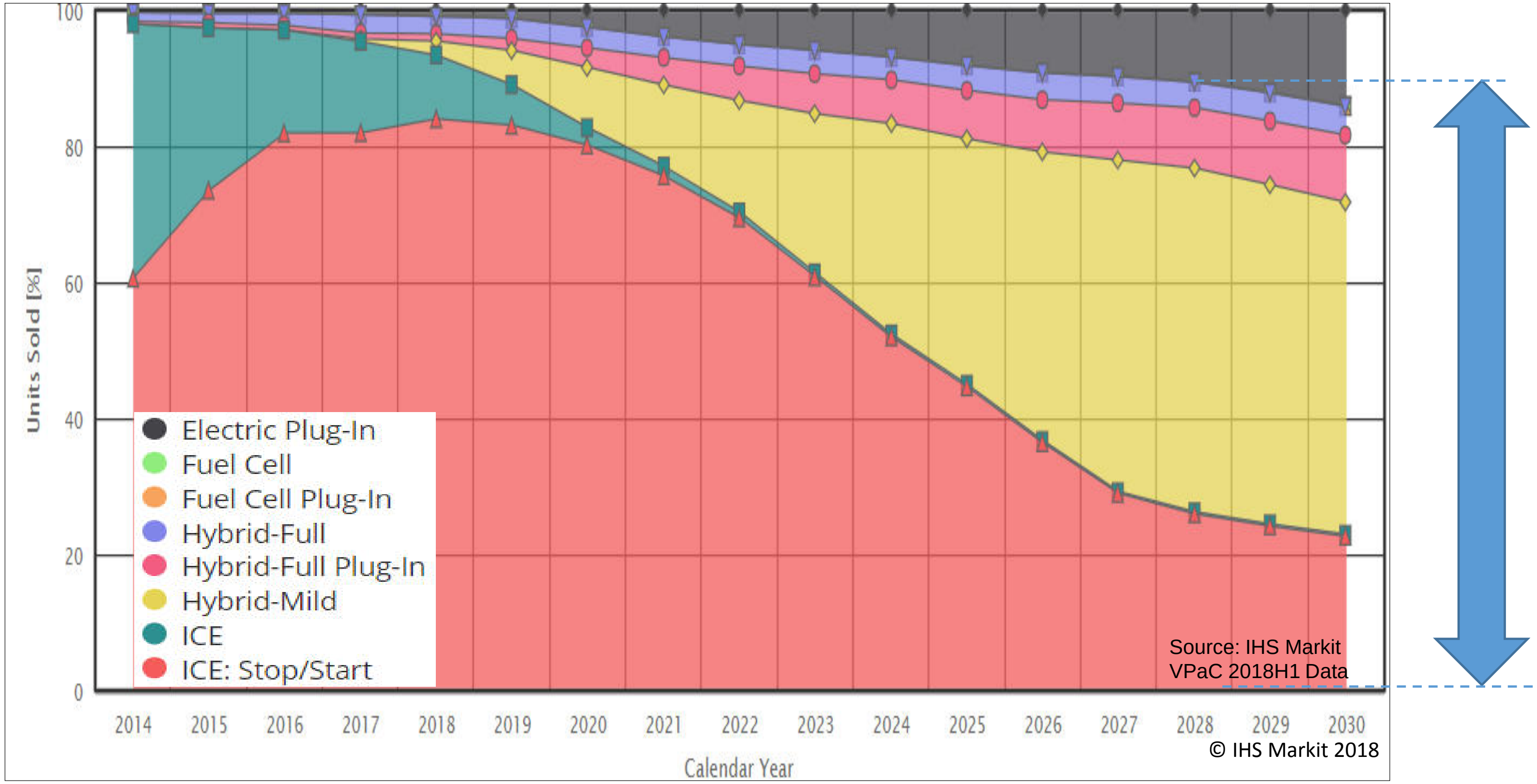
➔ Electrification of the European fleet has to accelerate, in order to compensate the strong reduction of the Diesel share

➔ The R&D effort on ICE efficiency improvement has to be maintained high because this is the only affordable technology for massive market for the moment

➔ Electric systems need to help the ICE to be cleaner and more efficient in the vehicle, to earn time to improve its weak points and becoming a massive market technology

- ➔ Technology cost
- ➔ Battery manufacturing impact on environment
- ➔ Access to critical material (Li, Co, Ni…)
- ➔ Transition towards a sustainable production mix

And the future powertrain will be…



… clearly based on an **efficient combustion system** *(around 90% of the vehicles sold in 2028 will have a thermal engine)…*

… and (at least) **one electric system** to propose an efficient, optimized and eco-friendly powertrain !

Innover les énergies

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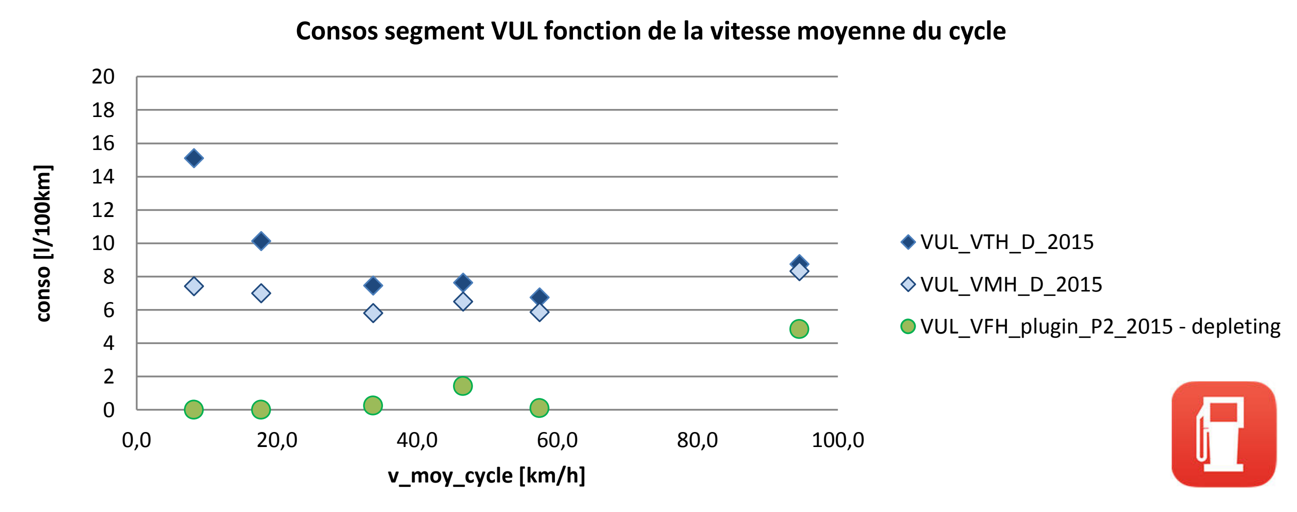
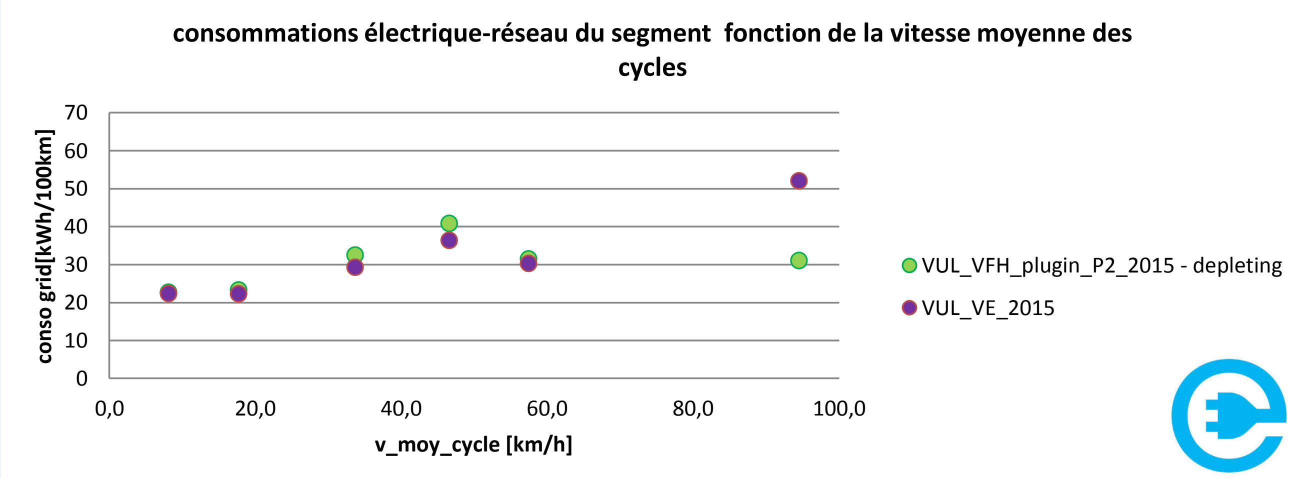
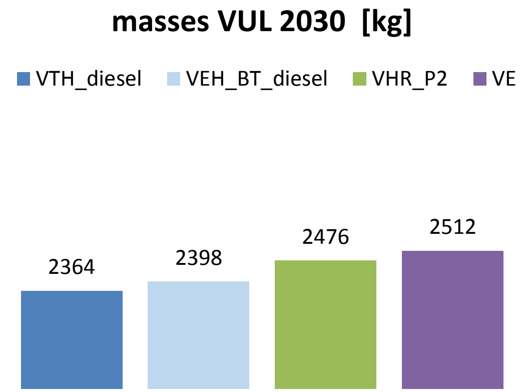
RÉSULTATS - SEGMENT VUL 2030





MOBILITÉ DURABLE



Intérêt des technologies 48V pour limiter la consommation en usage urbain

L'intégration d'une fonction « plug-in » permet une utilisation urbaine en pur électrique en évitant l'augmentation de la consommation électrique sur autoroute nécessitant une batterie de taille conséquente.

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