COMMENT L'ÉLECTRIFICATION VA SAUVER LES MOTEURS THERMIQUES

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Powertrain evolution drivers

Air Quality

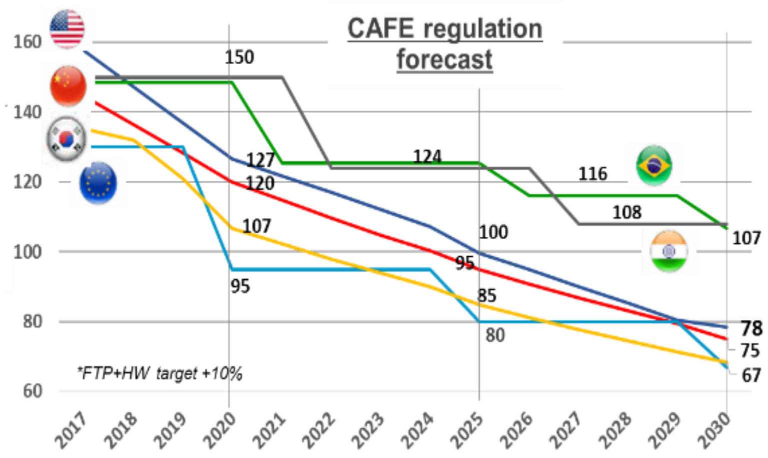
'Dieselgate'
Euro7
RDE

City Access Restriction

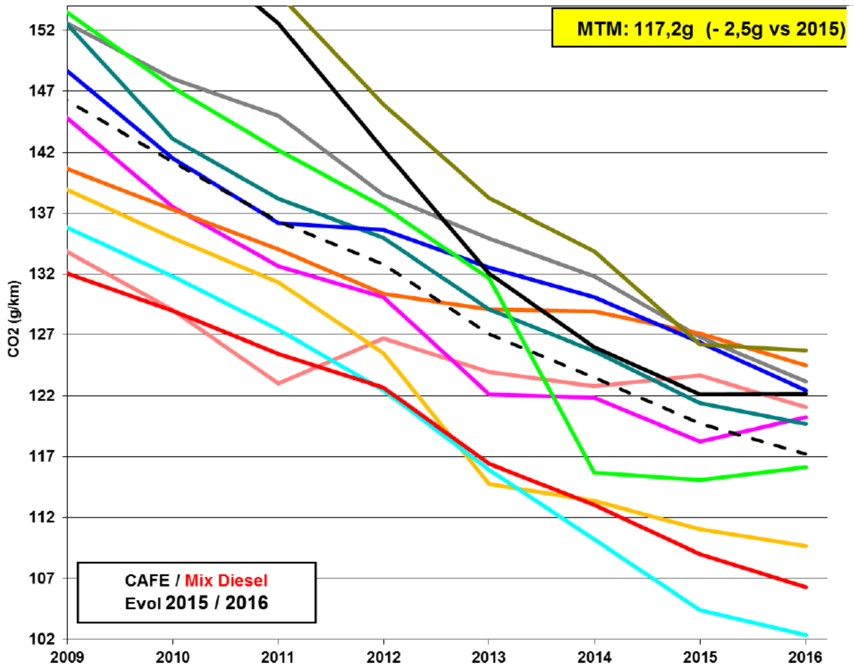
All Diesel ban anounced 2024 / 2025 Athens, Rome, Paris, Madrid, Mexico
EV > PHEV > HEV & gas > gasoline > Diesel
All ICE ban 2030 / 2040 UK, France?

CO_2

COP21 roadmap to limit 2°C global avg temperature by 2100
30% CO2 reduction between 2020 and 2030



Cafe evolution by brand to 2017

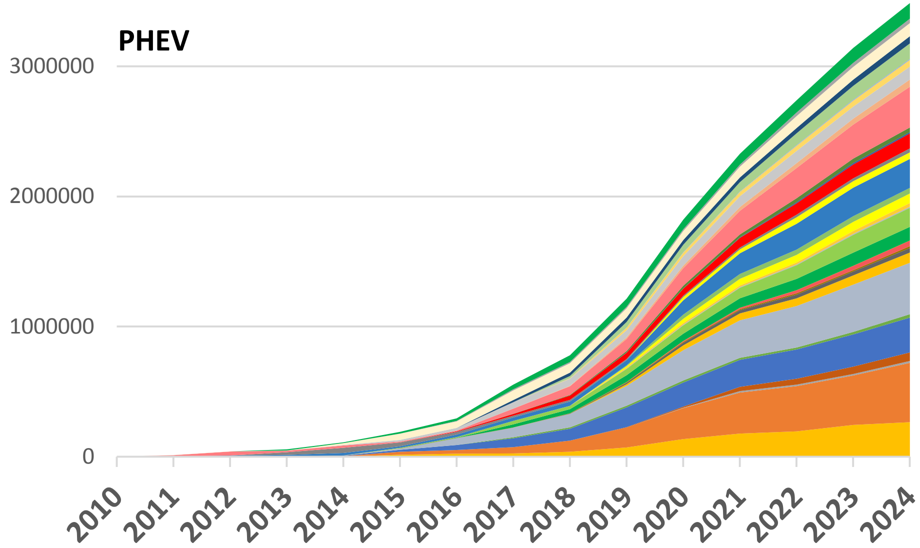


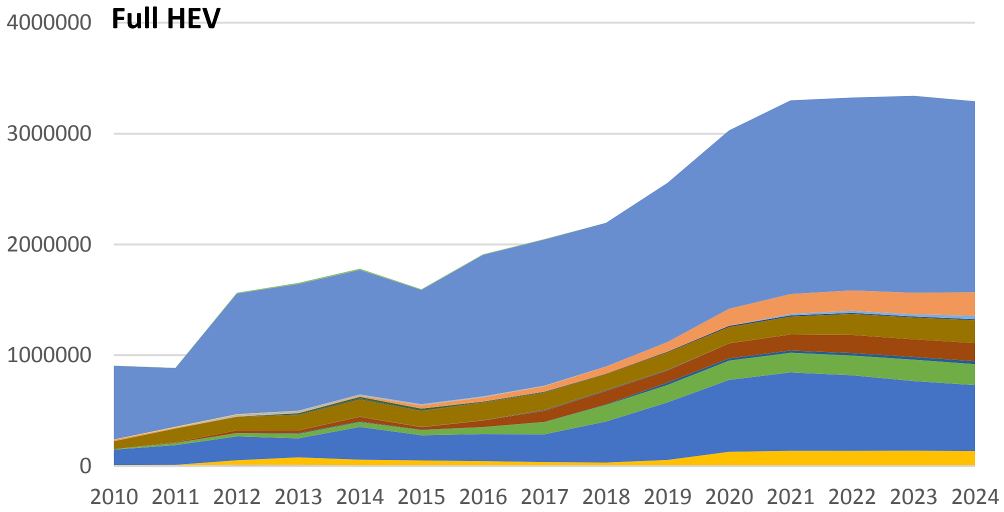
Volume	CAFE 2016	CAFE 2017	Evolution
408	106,4	103,8	-2,6
927	102,4	104,3	1,9
913	109,6	109,5	-0,1
343	116,2	116,5	0,4
64	117,3	117,2	-0,1
641	120,8	120,2	-0,7
2 047	119,6	120,7	1,1
623	120,4	121,0	0,6
548	124,7	121,3	-3,4
576	123,3	122,3	-1,0
569	122,6	123,5	1,0
167	121,8	123,9	2,1
541	126,0	126,9	0,9

Rate of CAFE reduction by OEM starts to stall in 2014
as result of Diesel sales decrease and SUV increase
Only 2 OEMs in Europe reduce their CAFE in 2017
Overall CAFE in Europe increases by 1g in 2017 vs 2016

HEV market forecast worldwide

(source IHS Markit)





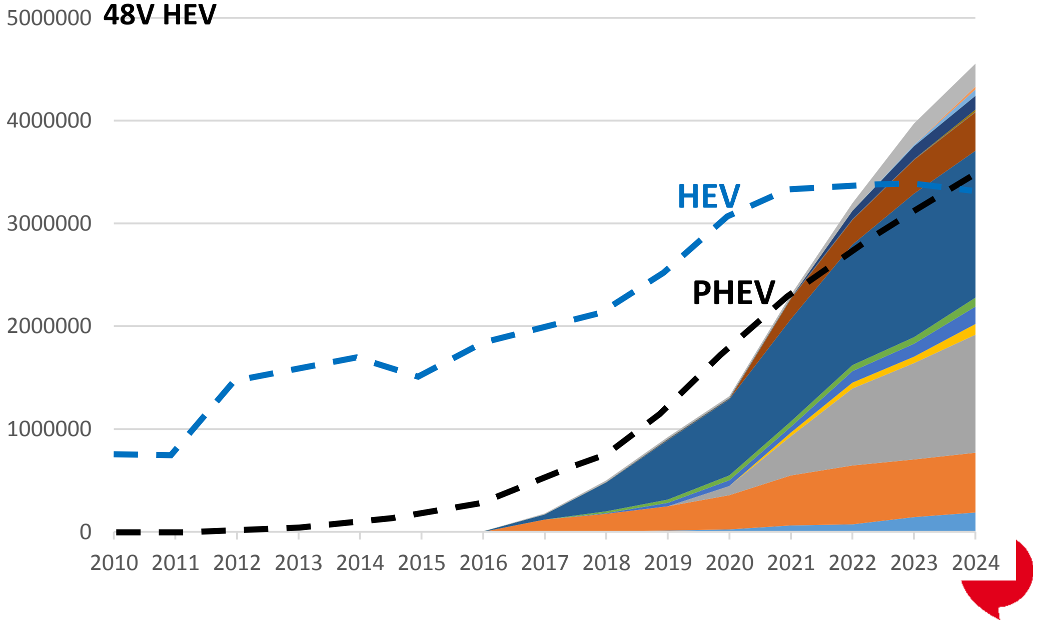
HEV growth is limited to current HEV players

PHEV and 48V HEV projected growth are huge in comparison.

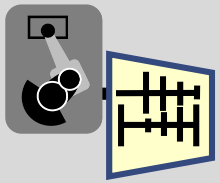
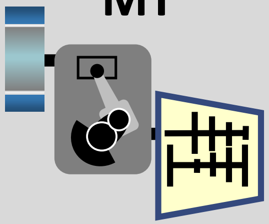
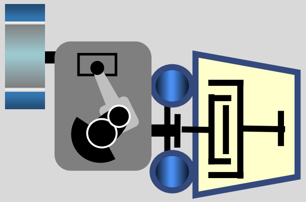
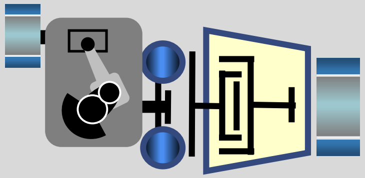
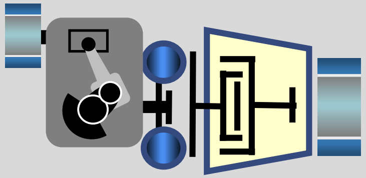
For PHEV, all OEM on many segments, as long term investment for high CO2 impact

48V category is mix of micro-mild BSG type and full HEV architecture aiming at reasonable cost products

48V and Full HEV segments conceivably overlap

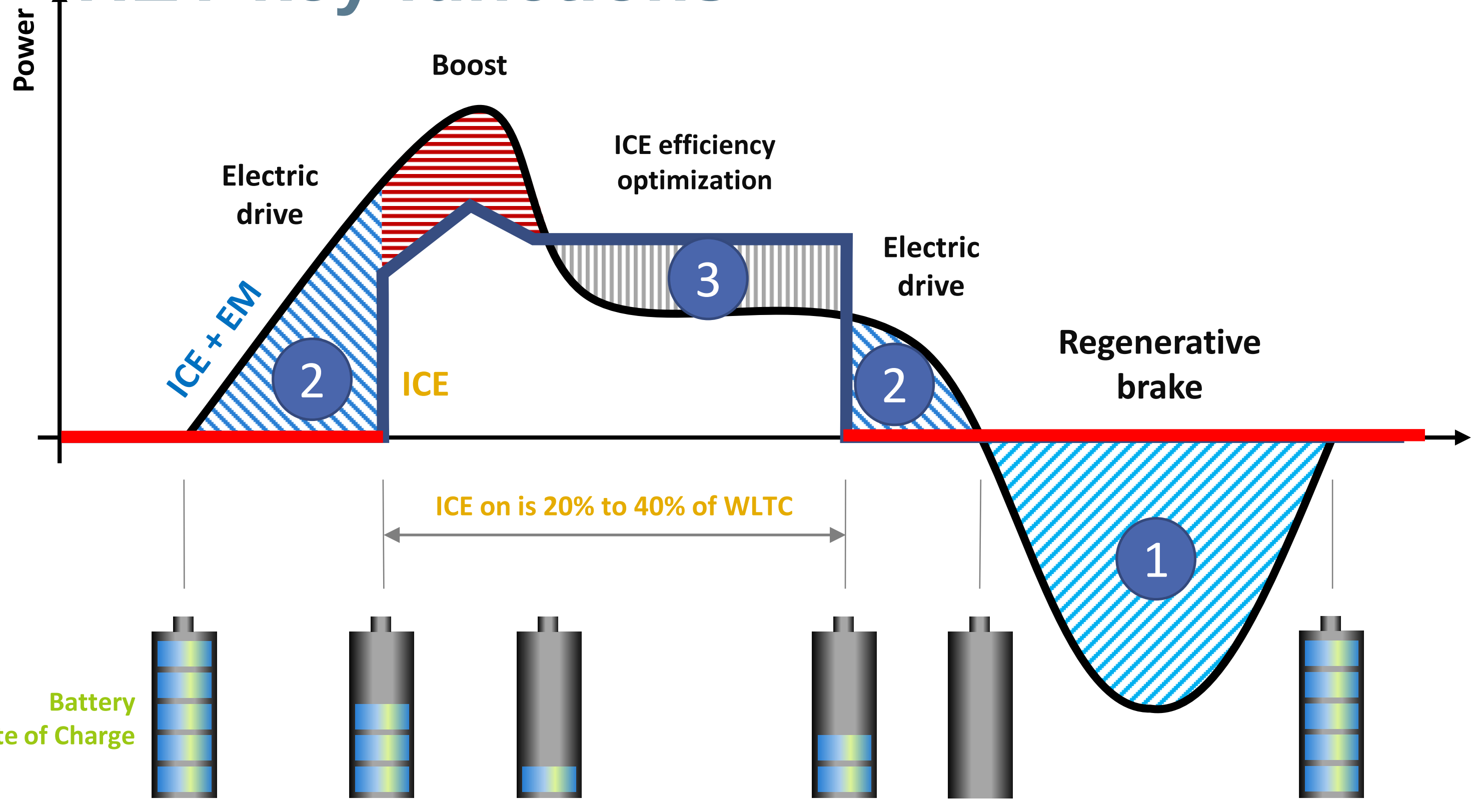


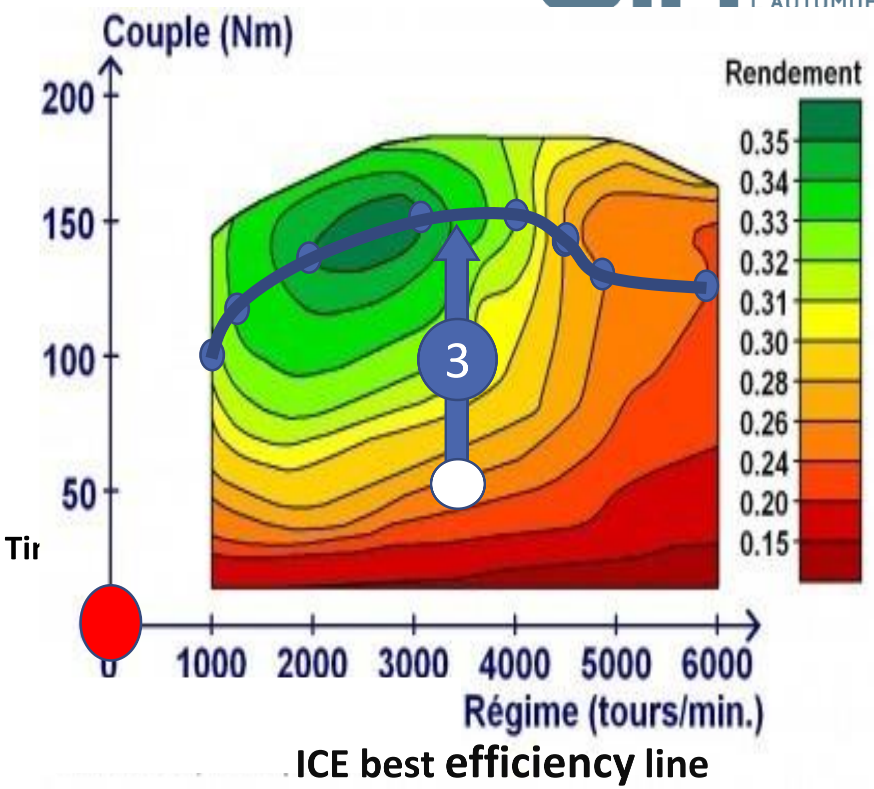
Electrification steps from BSG to PHEV

	Ref.	Mild HEV		HEV		PHEV
		P0		48V	HV	
	MT 	MT 	2 Pedal 	2 Pedal 		2 Pedal 
Regen Power		6 – 15kW		15-30kW	30-60kW	> 50kW
Drive Functions						

Hybrid ‘scaling’ from mild P0 to PHEV… from S&S to weekday full EV ability
Usually HEV is 2 pedal technology and EV driving
Some HEV functions available without 2 Pedal : brake regen, extended stop and start, sailing stop
Wide scale of architectures and potential for CO_2, but with roughly constant cost / value
Marketability by segment and line-up coverage with limited diversity are key OEM challenges

HEV key functions





Hybrids are controlled through complex energy management in HCU

But key levers of CO_2 optimization are the following

1 *Electric regen braking*

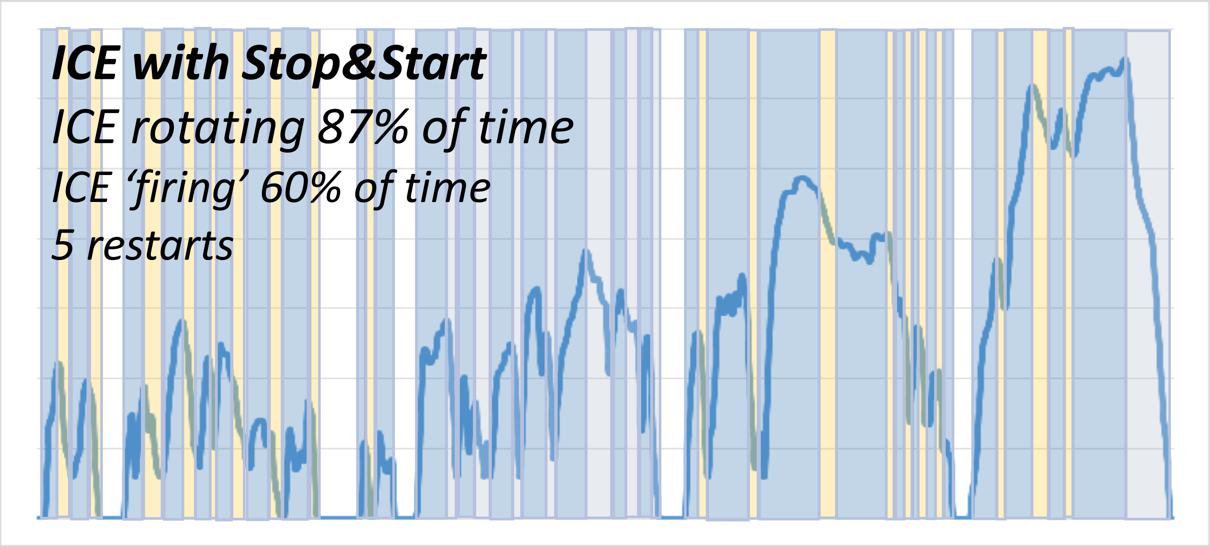
2 *Engine-off as much as possible (remove fixed losses especially in low load/speed operation)*

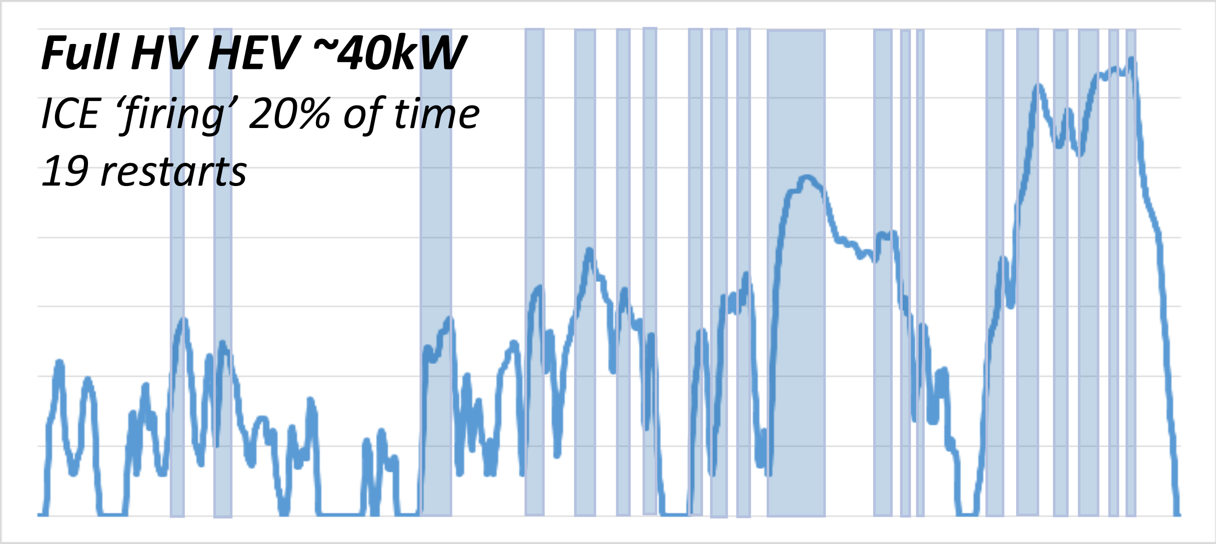
E-drive as much as possible (all low γ situations)

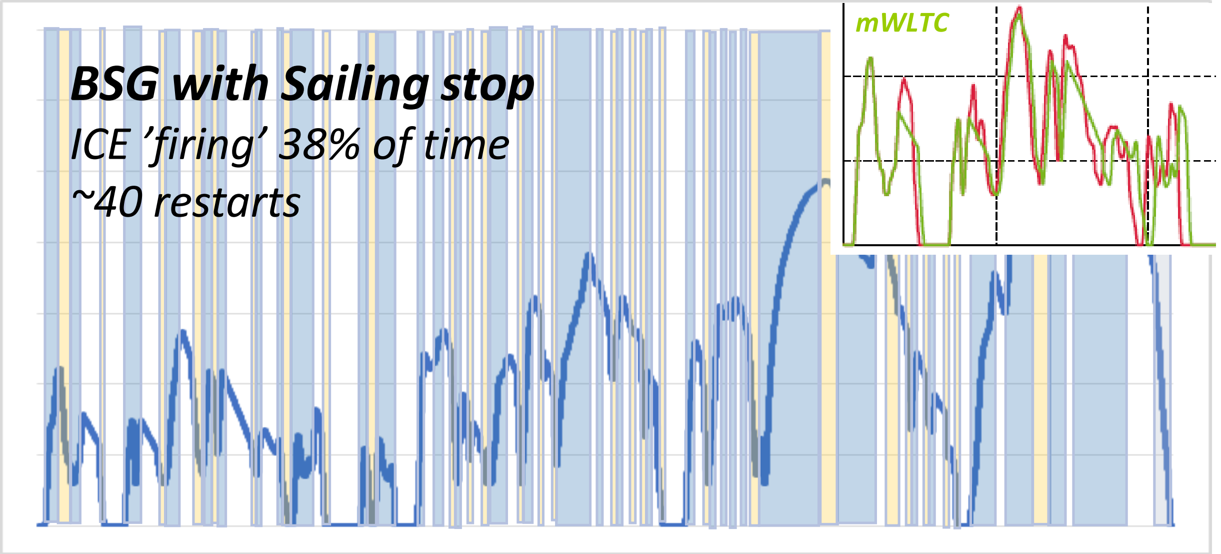
3 *Engine 'on' only on Best Efficiency line*

When ICE 'on', Δ between customer Power demand is either e-boost or batt recharge

ICE ‘firing’ time fraction







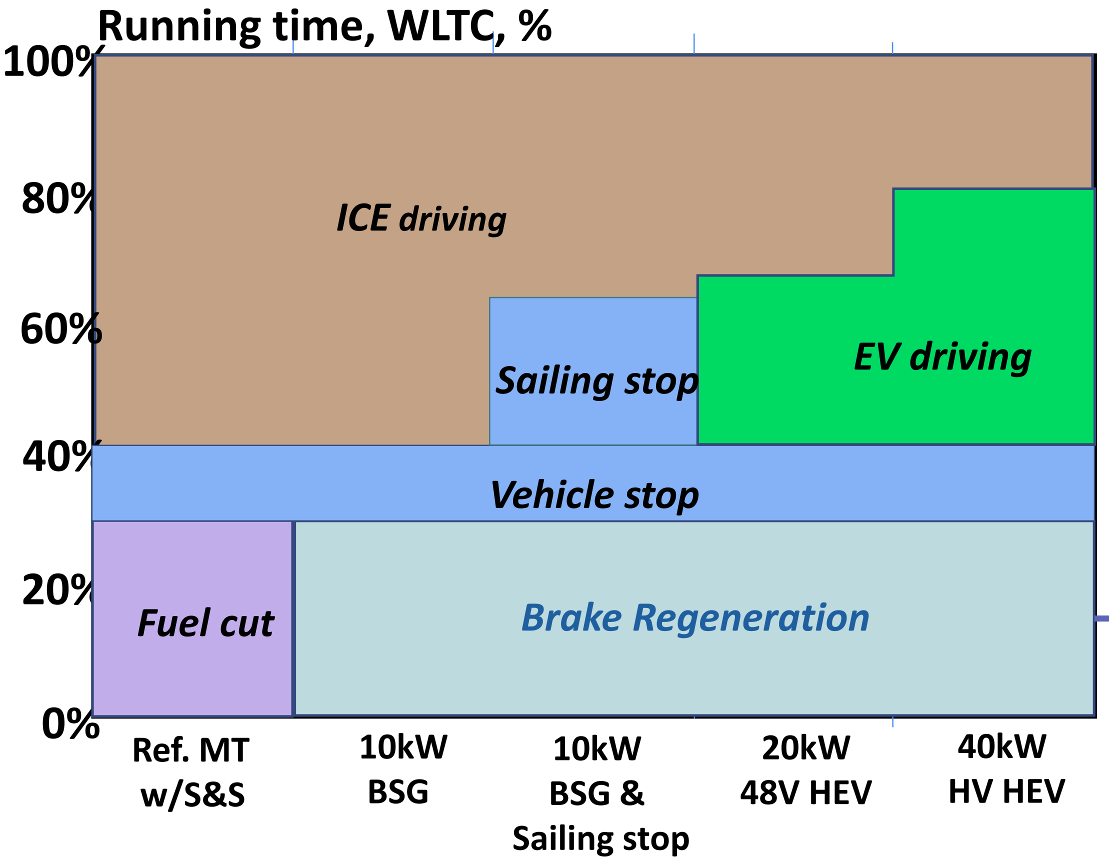
ICE is on ***ICE motoring with fuel cut***

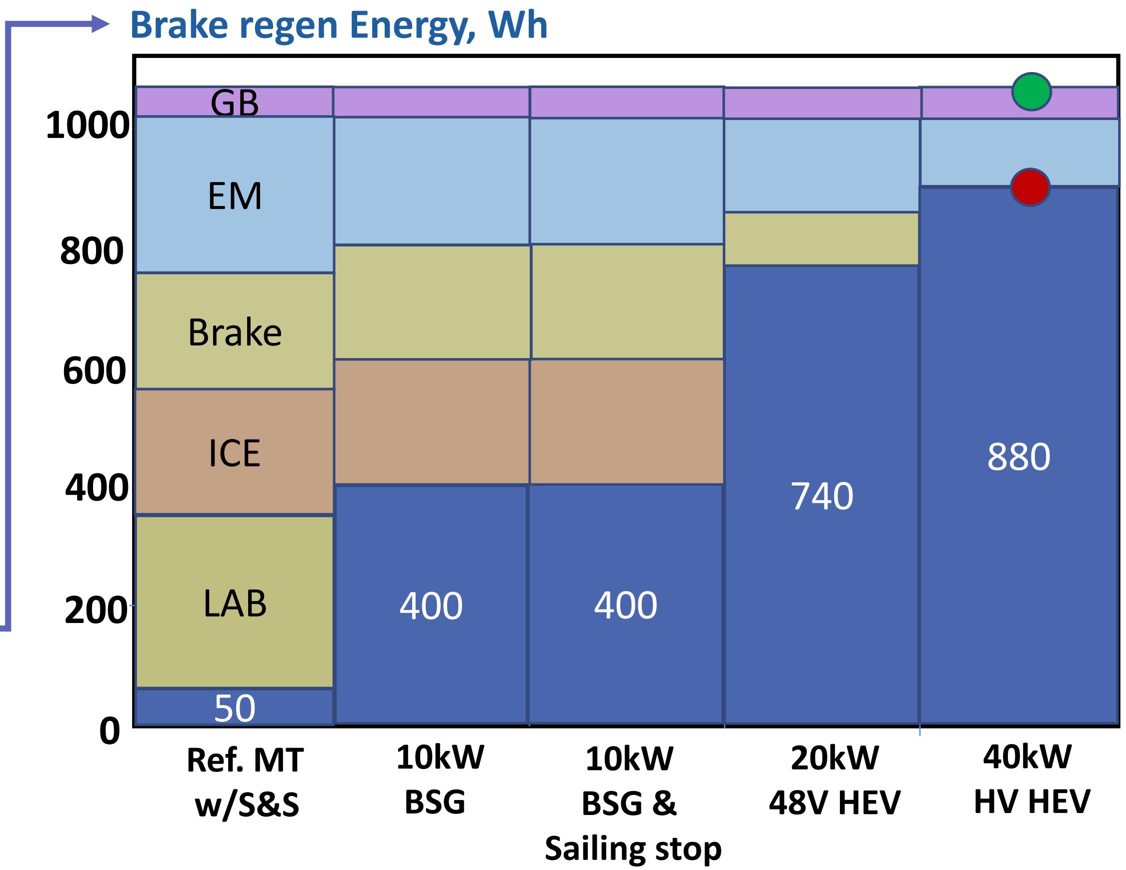
On full HEV, ICEngine firing time is 3x lower than with reference MT powertrain

For Sailing stop, on WLTC certification, ICE firing time will be the same as with BSG only, there are no sailing events

With mWLTC, adapted for eco-innovation, there can be up to 30 sailing events which reduce ICE firing time by over 20% and for overcost similar to BSG system

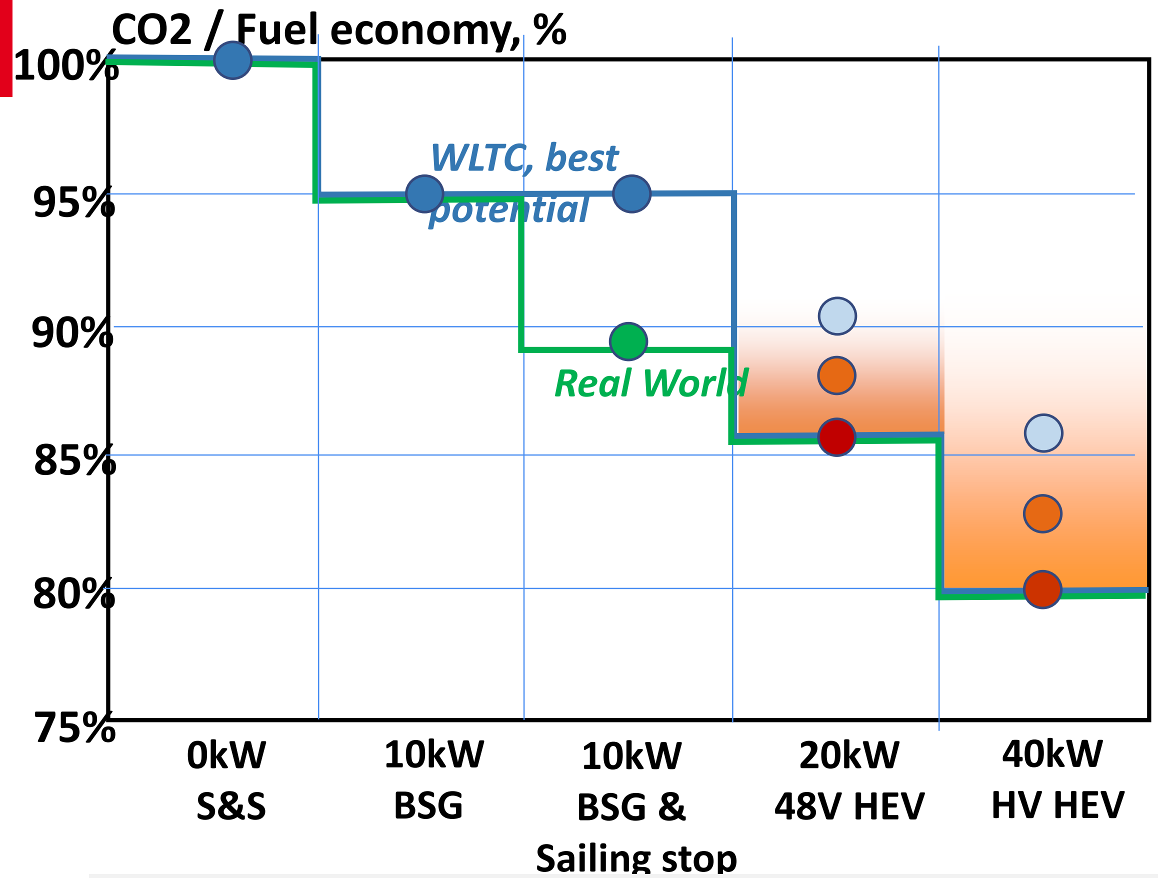
HEV driving modes / regeneration energy

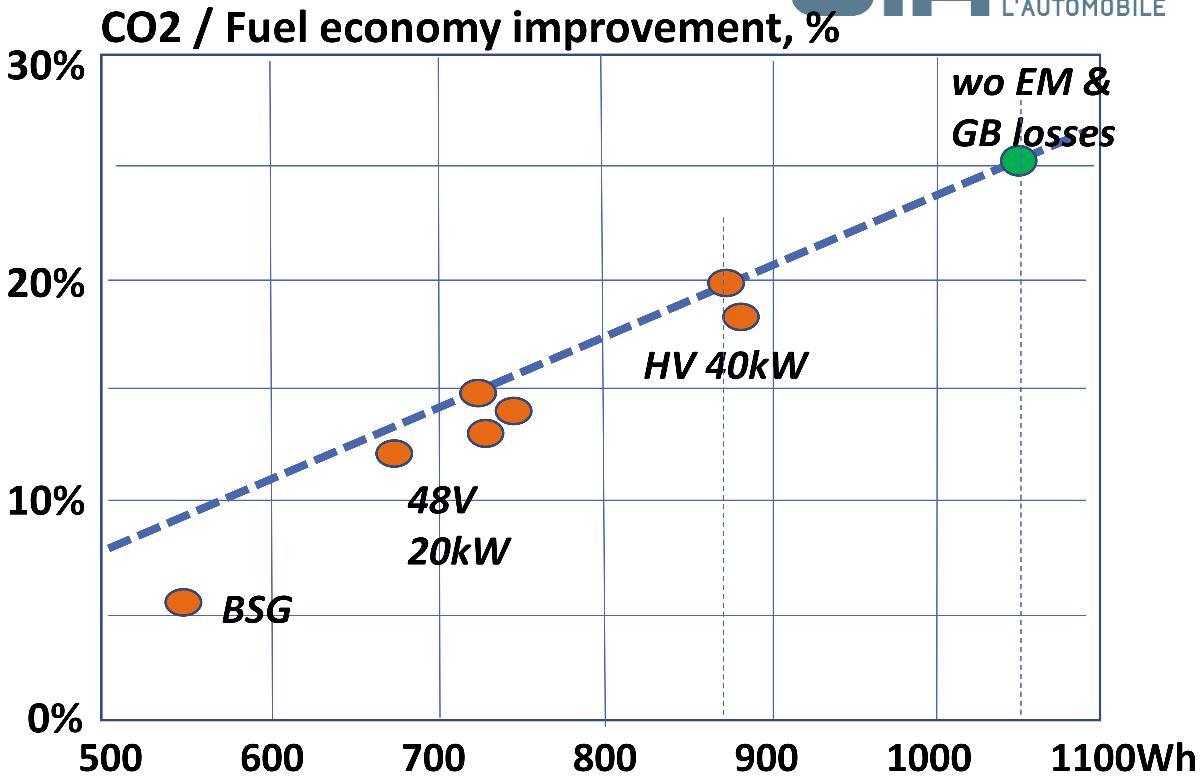




Breakthrough in ICE 'off' time starts with Sailing Stop
Sailing Stop total time is close to 48V HEV EV-drive time
Full HEV allows to divide ICE firing time by 3
In brake regeneration phase there are 4 main losses that prevent full regeneration of brake energy
With full HEV, 85% of full deceleration energy can be recovered

CO2 improvement of HEV





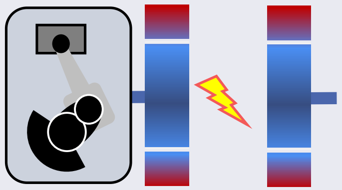
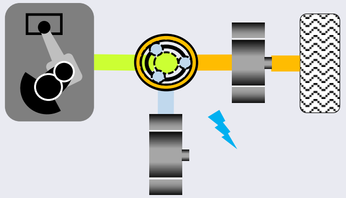
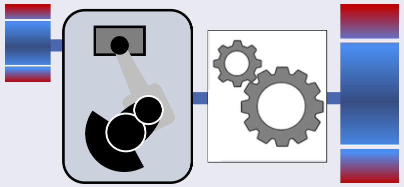
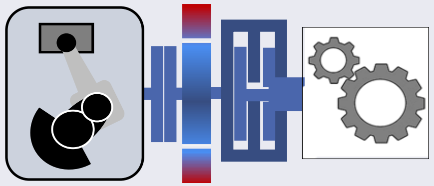
Best HEV CO2 improvement is about 20% vs MT, but depends on the full HEV architecture and tuning choices

48V HEVs can achieve about ¾ or the CO2 gains of full HV HEV

Asymptotic (zero losses) value of full HEV CO2 improvement would be only 25%

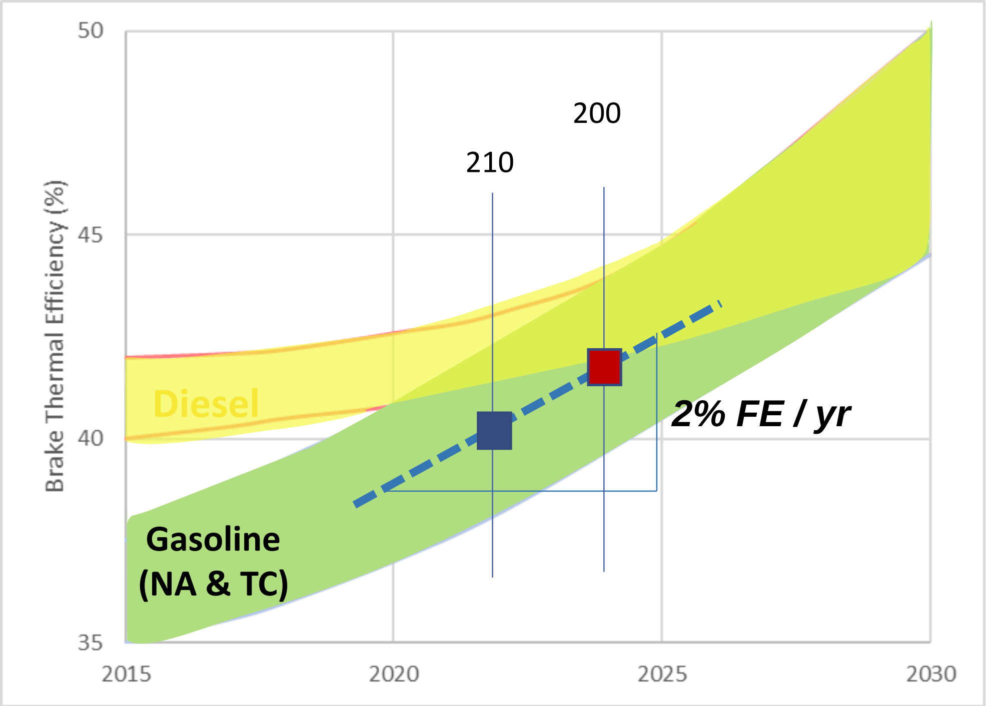
Beyond these values of CO2 improvement, other solutions have to be tapped, either higher Electrification (PHEV) or strong weight and CdA reduction

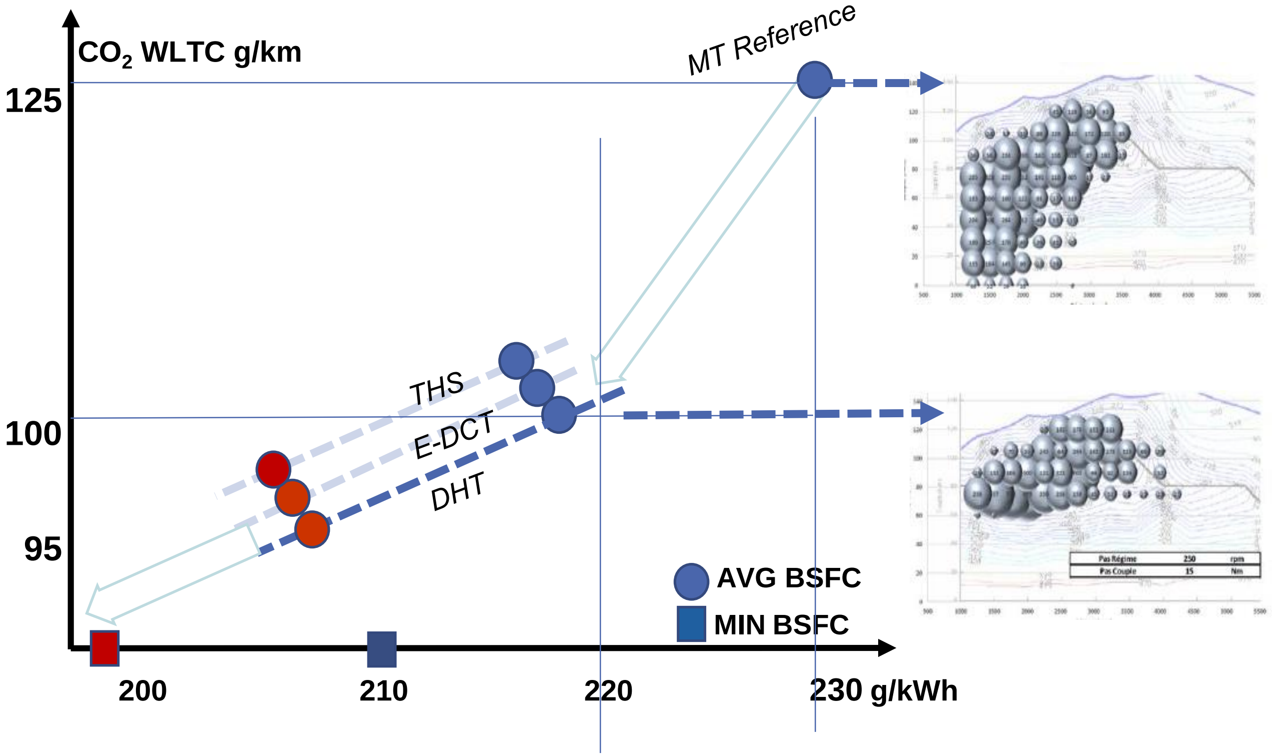
Full HEV architecture solutions

	Series	Series / Parallel		Parallel
	e-Power	**T-HS**	**DHT**	**e-DCT**
What				
Who	Nissan	Toyota / FORD		Hyundai / VW
How it works	All E-drive ICE is a stationary generator	City and low load e-drive. Epicyclic gearset provides continuous ratio variation for ICE	All electric 1st gear (series like) and EM-ICE blending in all other drive conditions	City and low load e-drive. EM-ICE blending in all other drive conditions
HW	Reuse EV technology: • 2 e-motors with higher power than ICE • Transmission is just a simple reducer	Transmission includes: • 2 E-machines • 1 epicycloid gearset.	Transmission includes: • 2 e-machines • MT type gearsets • 3 dog clutches w/ electric actuation	Reuse DCT technology Transmission includes: • 1 e-machine • 3 friction clutches • HSG on engine

Electric component sizing .vs. mechanical complexity

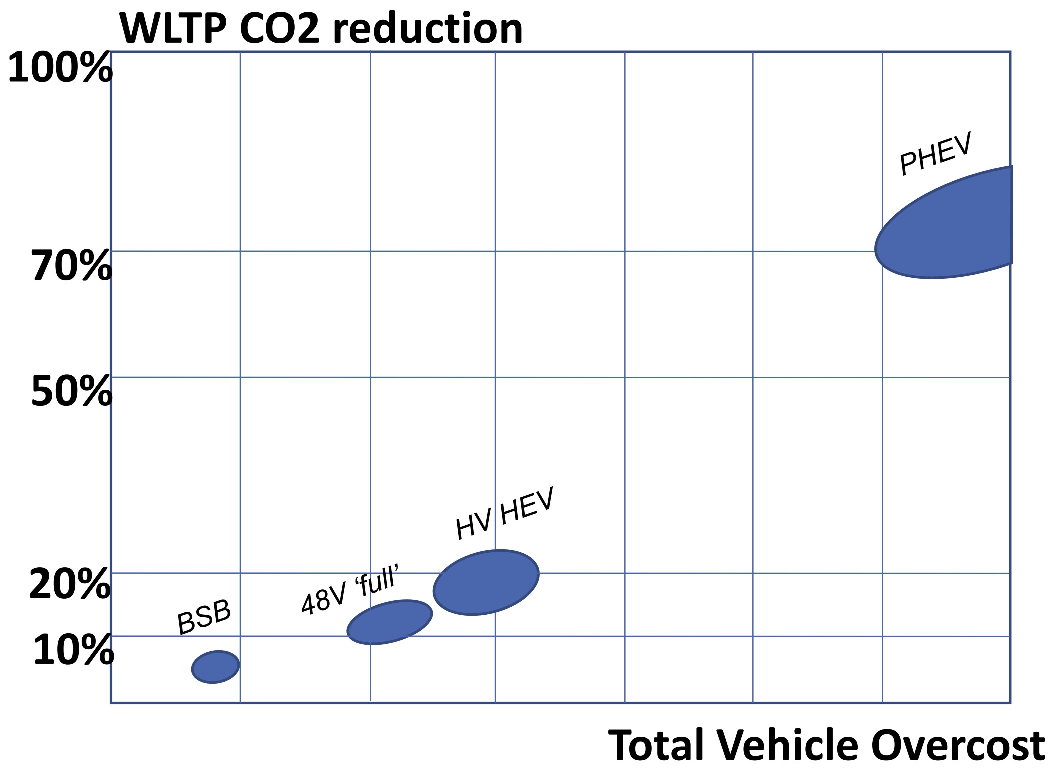
HEV / ICE contributions to overall efficiency

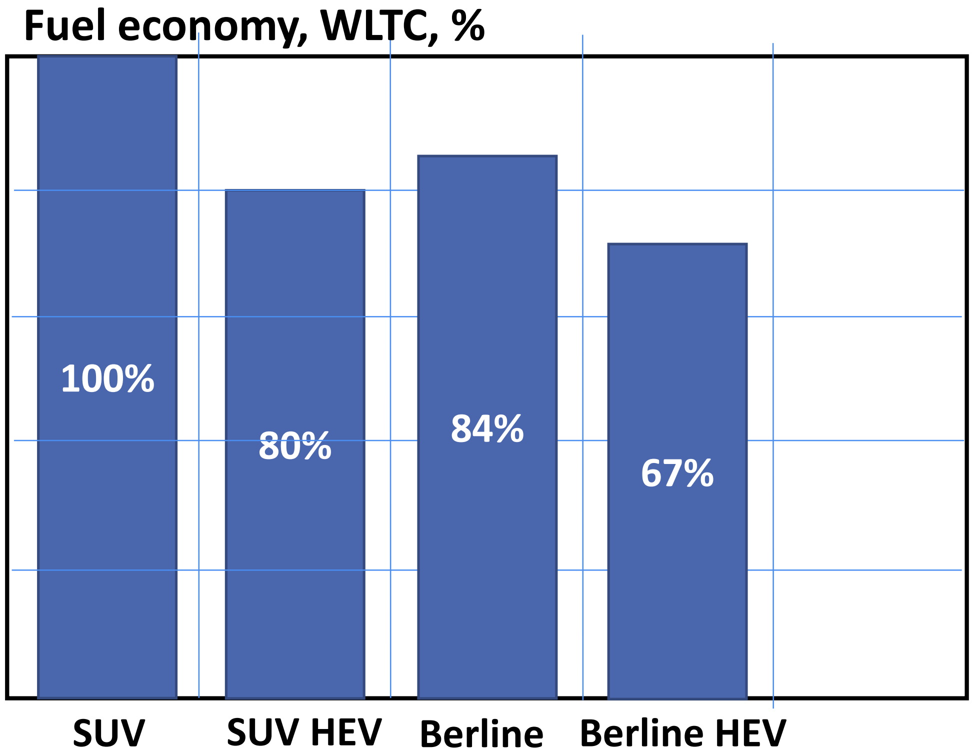




ICE BSFC improvement forecast is ~2% FE per year
Hybridization strongly improves the average operating BSFC on WLTC cycle
Ref MT operates at 229g/kWh avg while DHT HEV operates at 218 for an engine min BSFC of 210
But Avg BSFC alone cannot rank hybrid solutions, as seen by THS and E-DCT position.
Future improvements on ICE BSFC alone can be added fully to HEV fuel economy
This is equally true for all HEV architectures

Cost of HEV versus other FE reduction actions

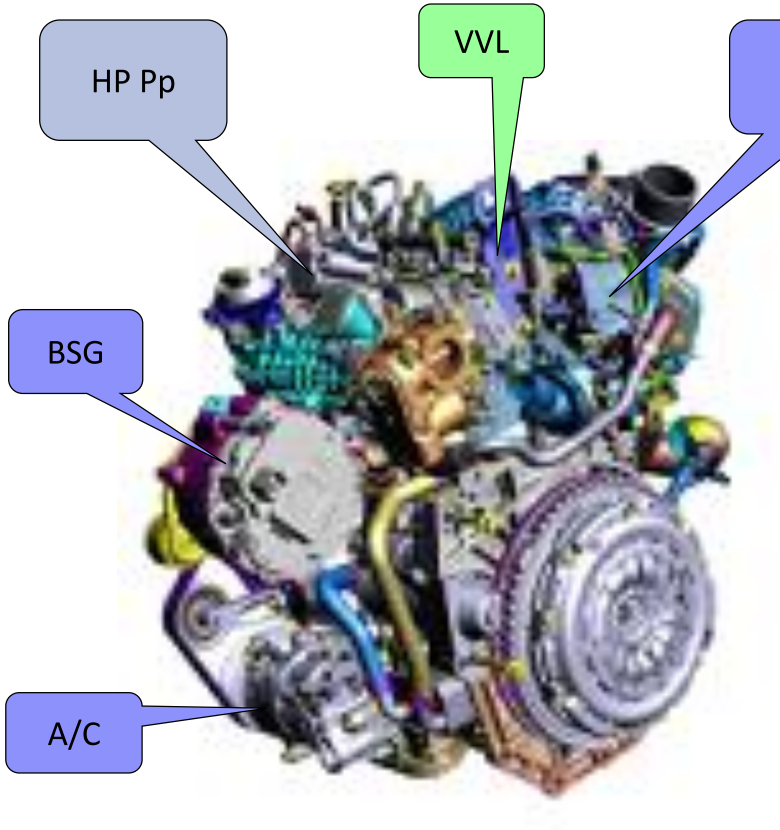


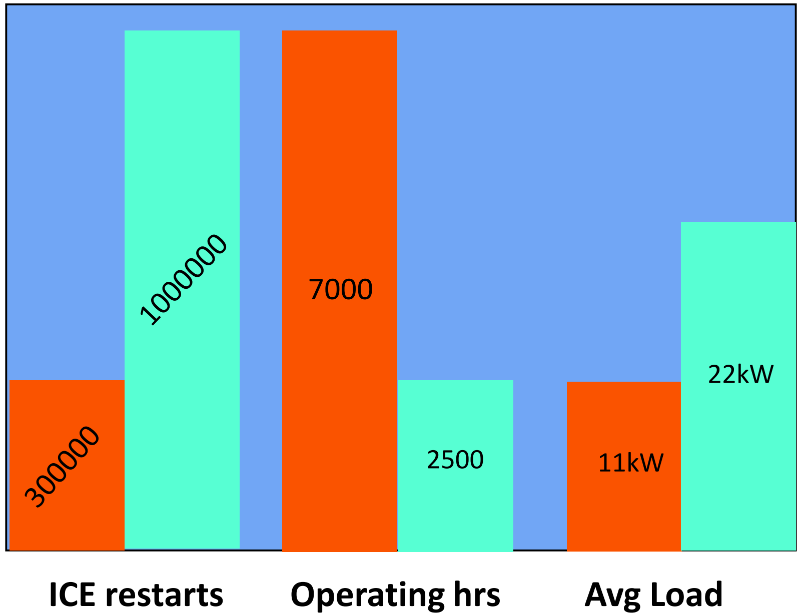


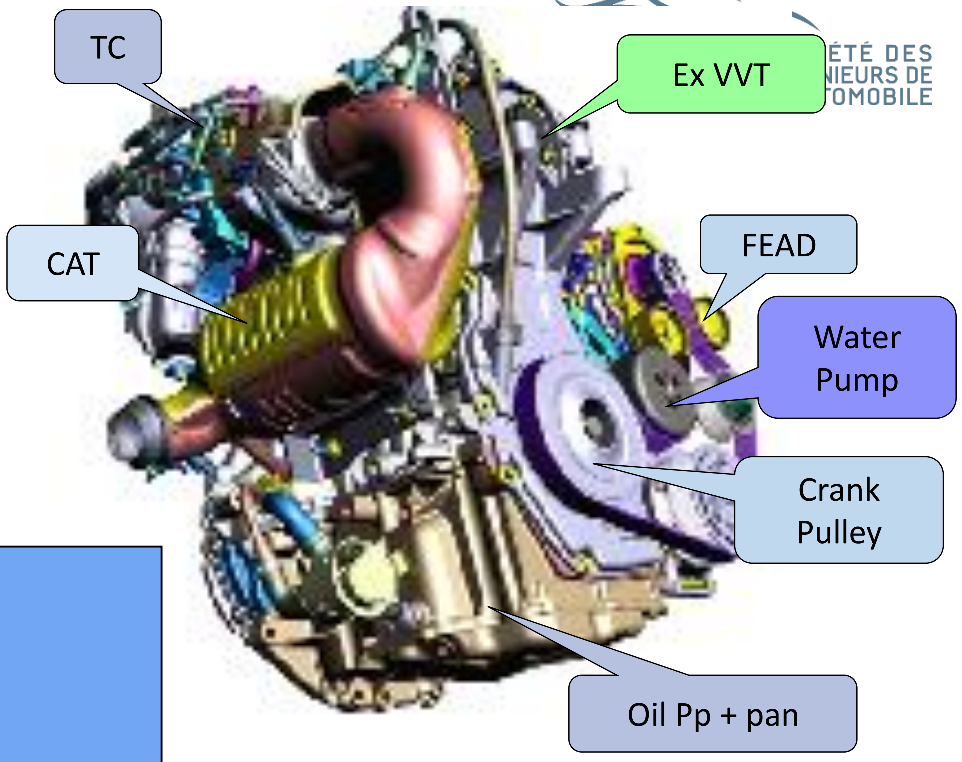
	SUV	Berline
Mass	1750	1600
Mass w/HEV	1900	1750
SCx	0,84	0,57

Beyond high voltage HEV, overcost step to PHEV is very wide
Other, less costly, CO2 reduction actions will be needed in parallel
Mass and CdA reduction remain key levers
A full hybrid SUV is similar in fuel eco to the Sedan of same segment

Impact of HEV on ICE hardware







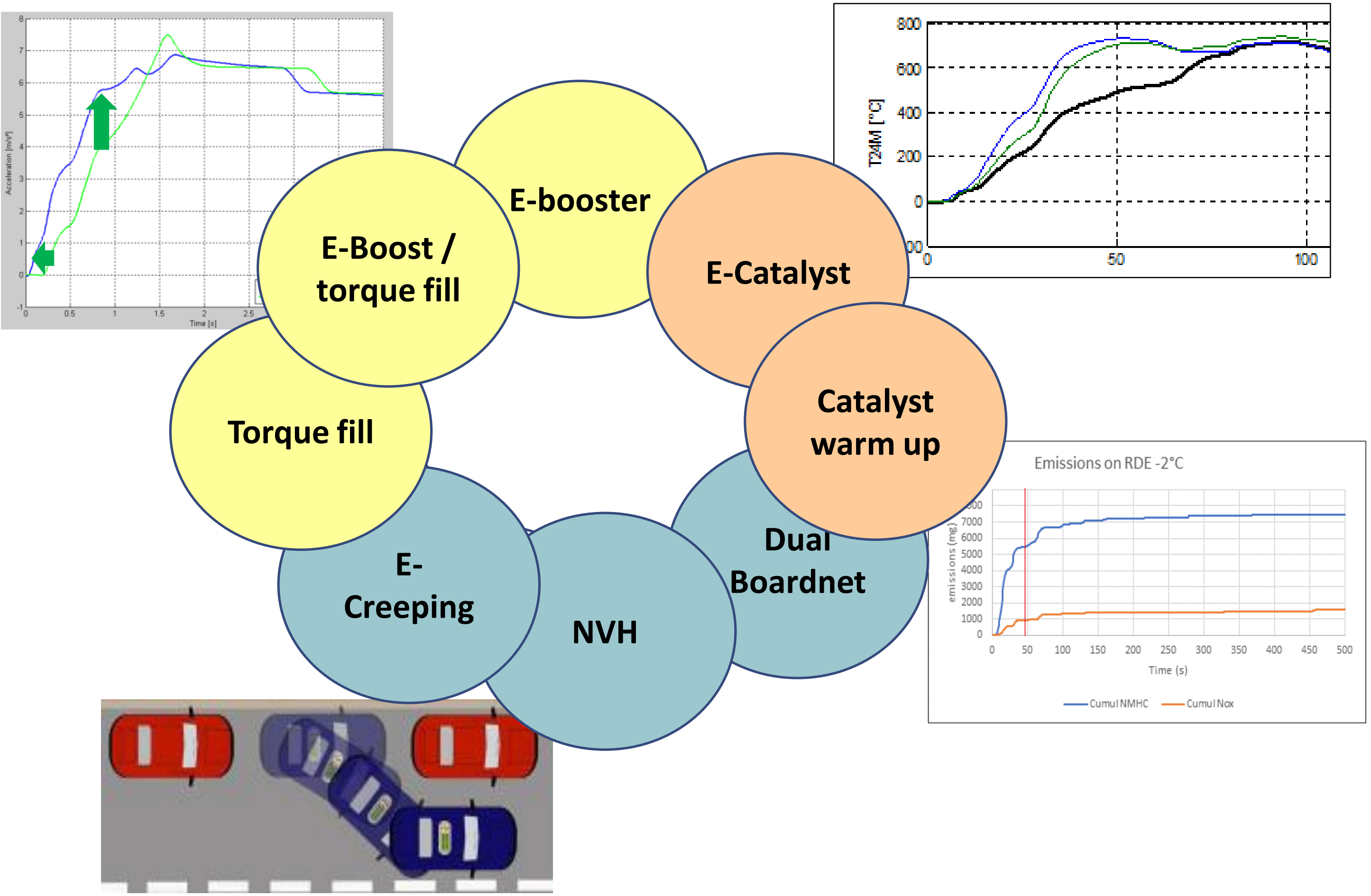
Functional removal

No longer needed

Restart lube reqt.

Low speed op. becomes electric

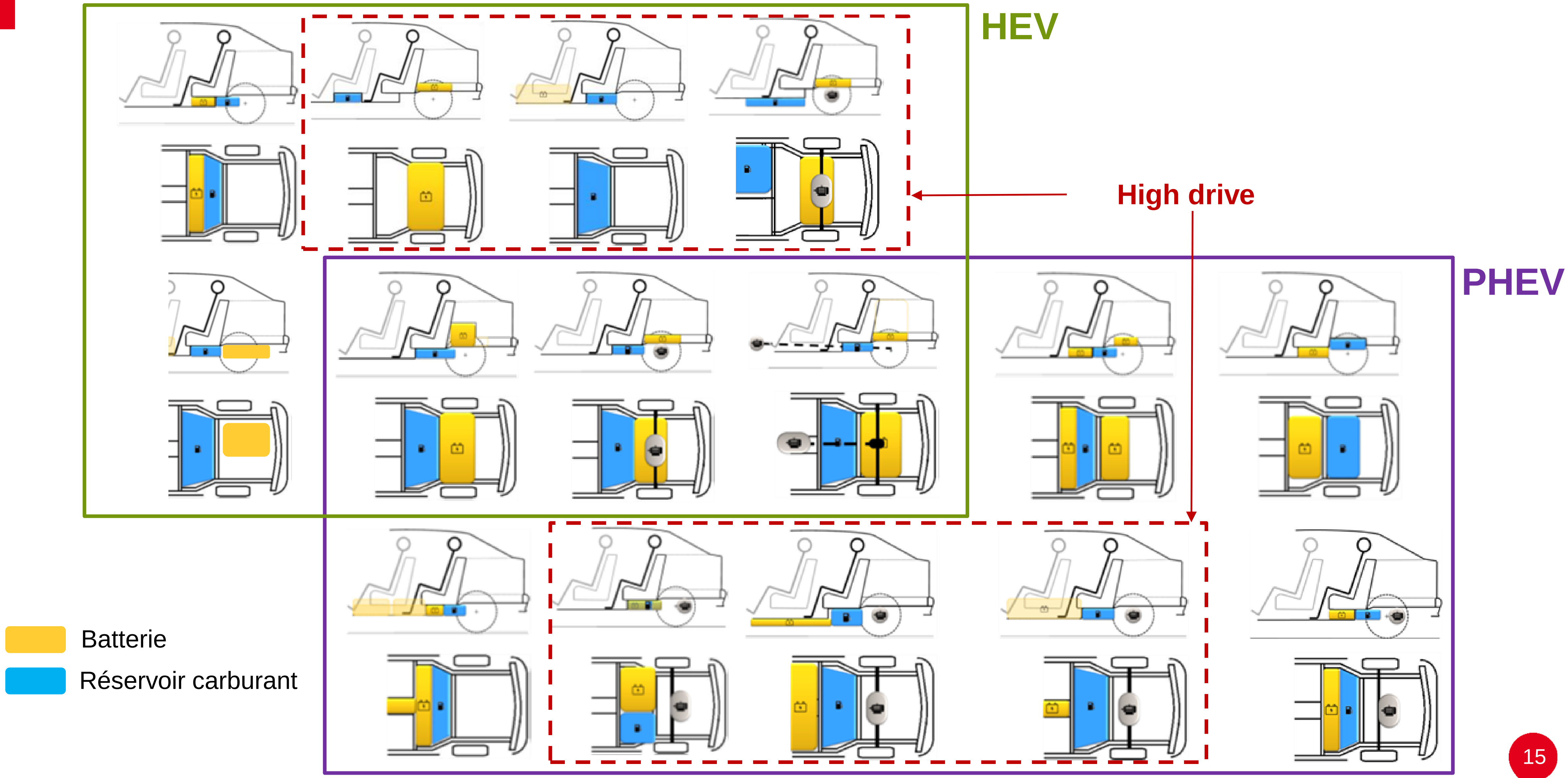
Other HEV functions and vehicle impacts



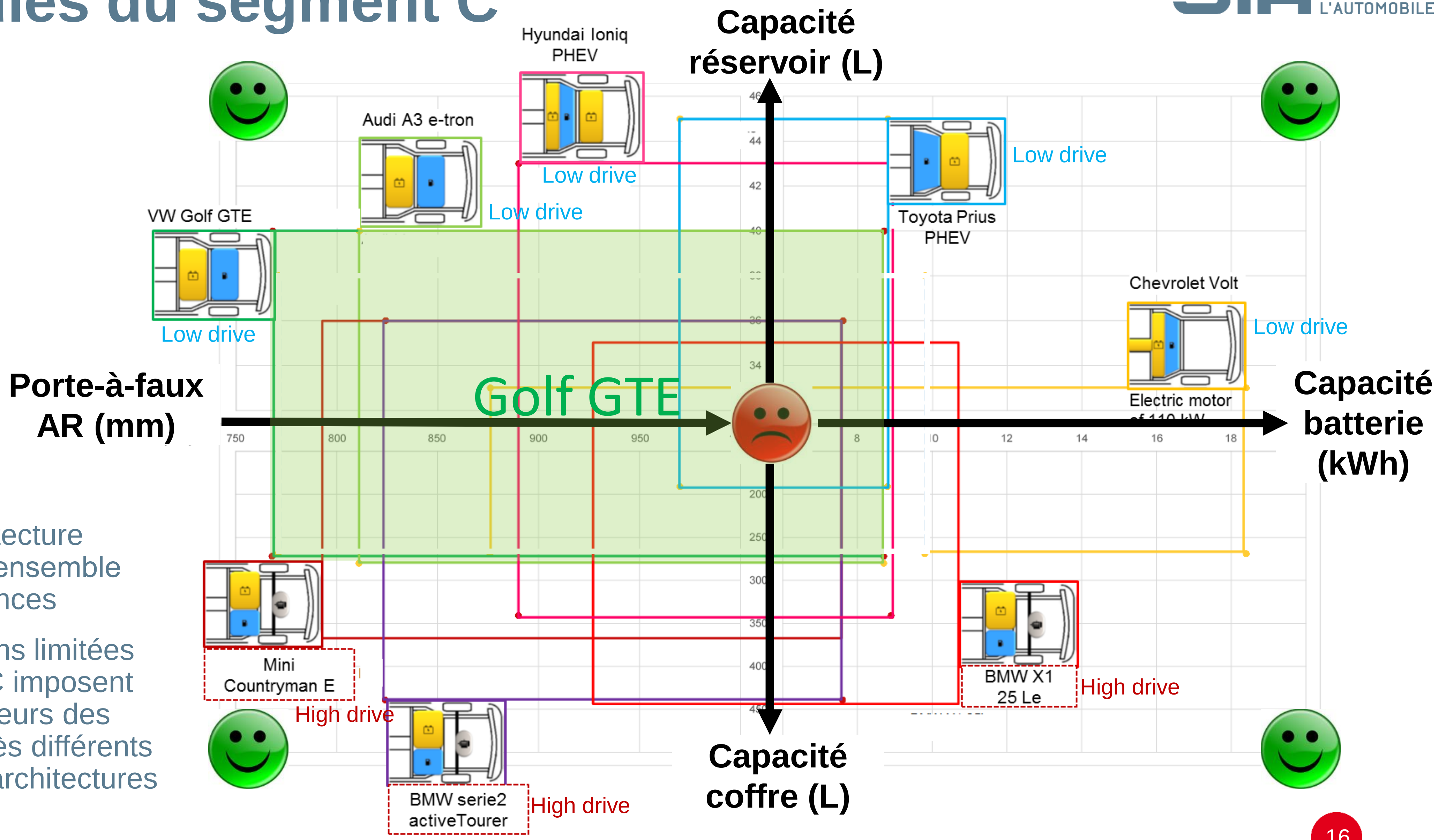
HEV approx. component weight and volume increase (C-segment car)

	Δ mass	Δ volume
Transmission	it depends…	
Battery	40	40
E-machines	40	15
Inverters	20	20
Braking	10	
Chassis	15	
Harnesses	10	
HEV total Δ	140 kg	> 75 liters

Architecture des véhicules hybrides



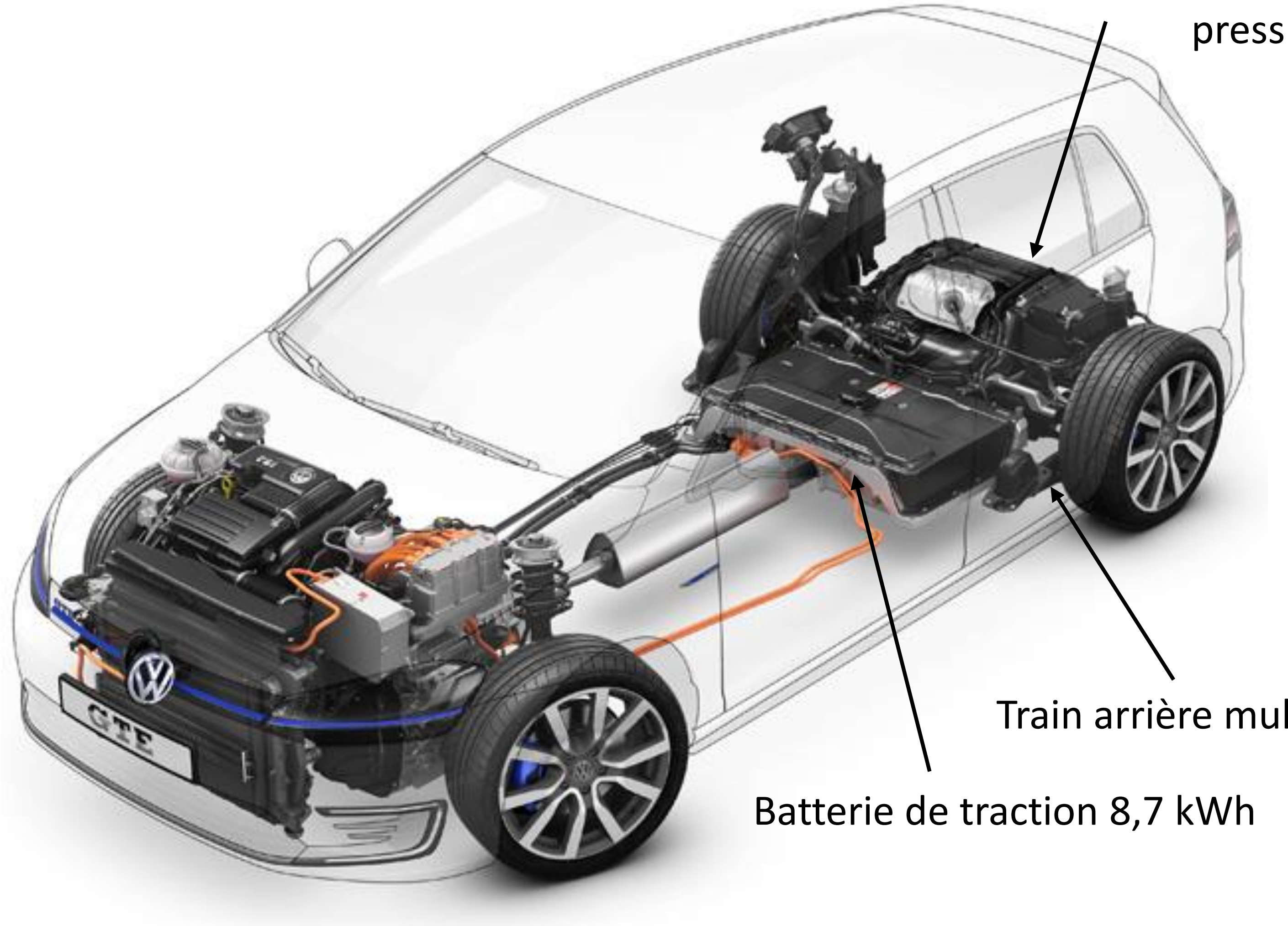
Performances des architectures PHEV
Véhicules du segment C



> Aucune architecture efficace sur l'ensemble des performances

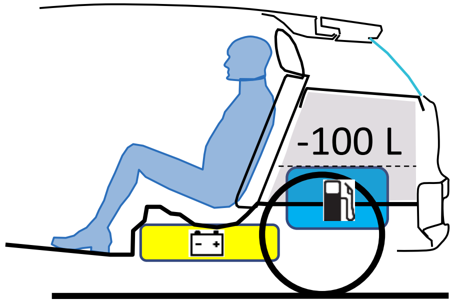
> Les dimensions limitées du segment C imposent aux constructeurs des compromis très différents fonction des architectures retenues

Exemple : architecture VW Golf GTE

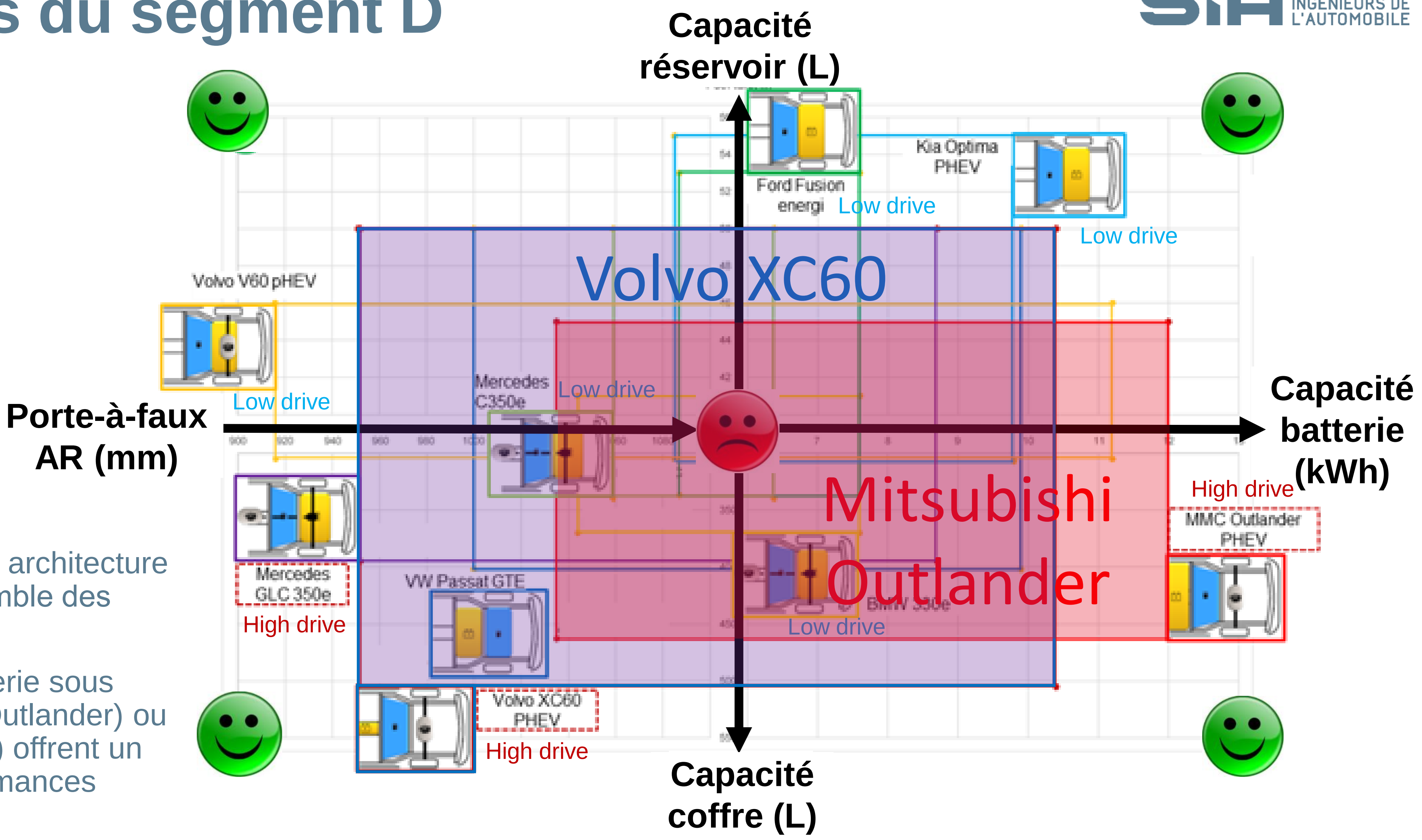


> Compromis qui préserve l'habitabilité, le confort arrière et la hauteur du véhicule d'origine

> **Mais** qui réduit
- la capacité en carburant (-10 L) afin d'assurer une taille de batterie suffisante pour une autonomie ZEV 50 km NEDC
- la capacité de coffre de près de 30%

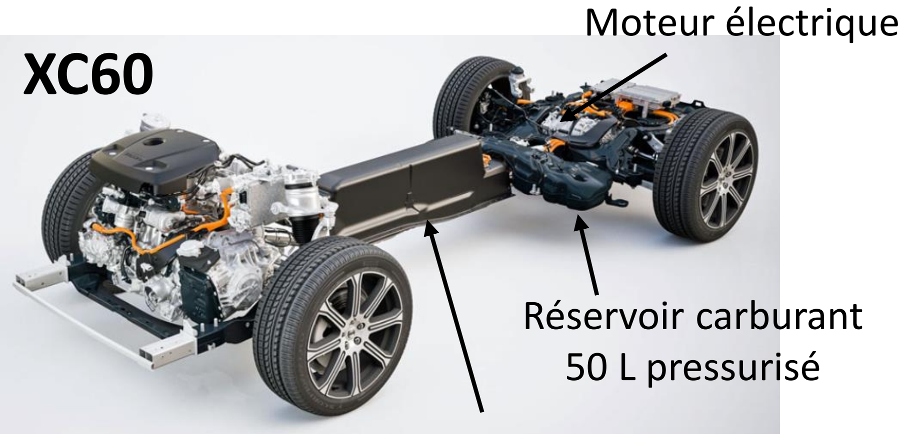


Performances des architectures PHEV
Véhicules du segment D



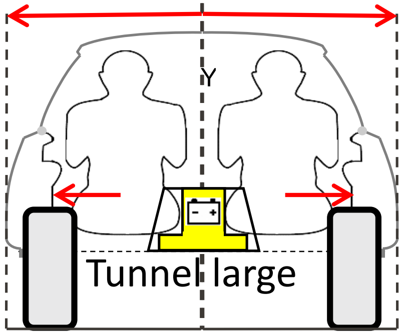
- > Low drive : aucune architecture efficace sur l'ensemble des performances
- > High drive : la batterie sous plancher central (Outlander) ou sous tunnel (XC60) offrent un potentiel de performances intéressant

Exemples : architectures Volvo XC60 / Mitsubishi Outlander PHEV

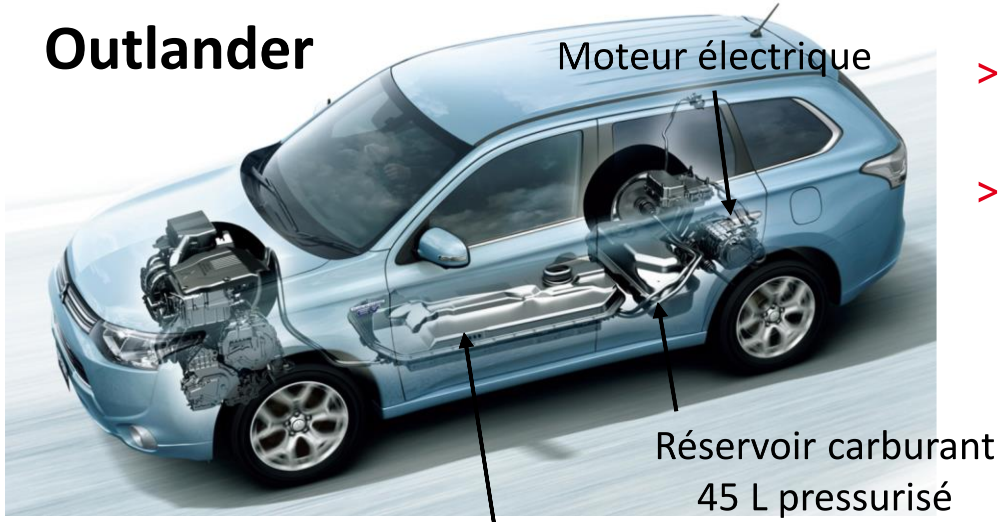


Batterie de traction 10,4 kWh implantée dans le tunnel

> Capacité batterie plus importante et autonomie carburant correcte
> Architecture compatible propulsion électrique, sièges 3e rang (XC90) et véhicules low drive (S60, S90)



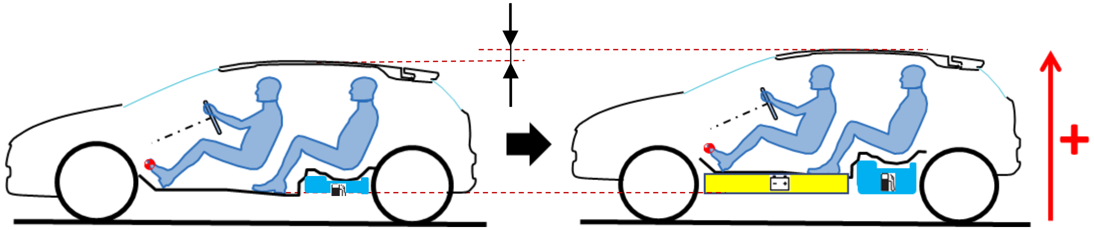
> **Mais** impose une contrainte sur
- la place centrale arrière,
- les rangements en console centrale
- l’habitabilité transversale et/ou une largeur plus importante du véhicule



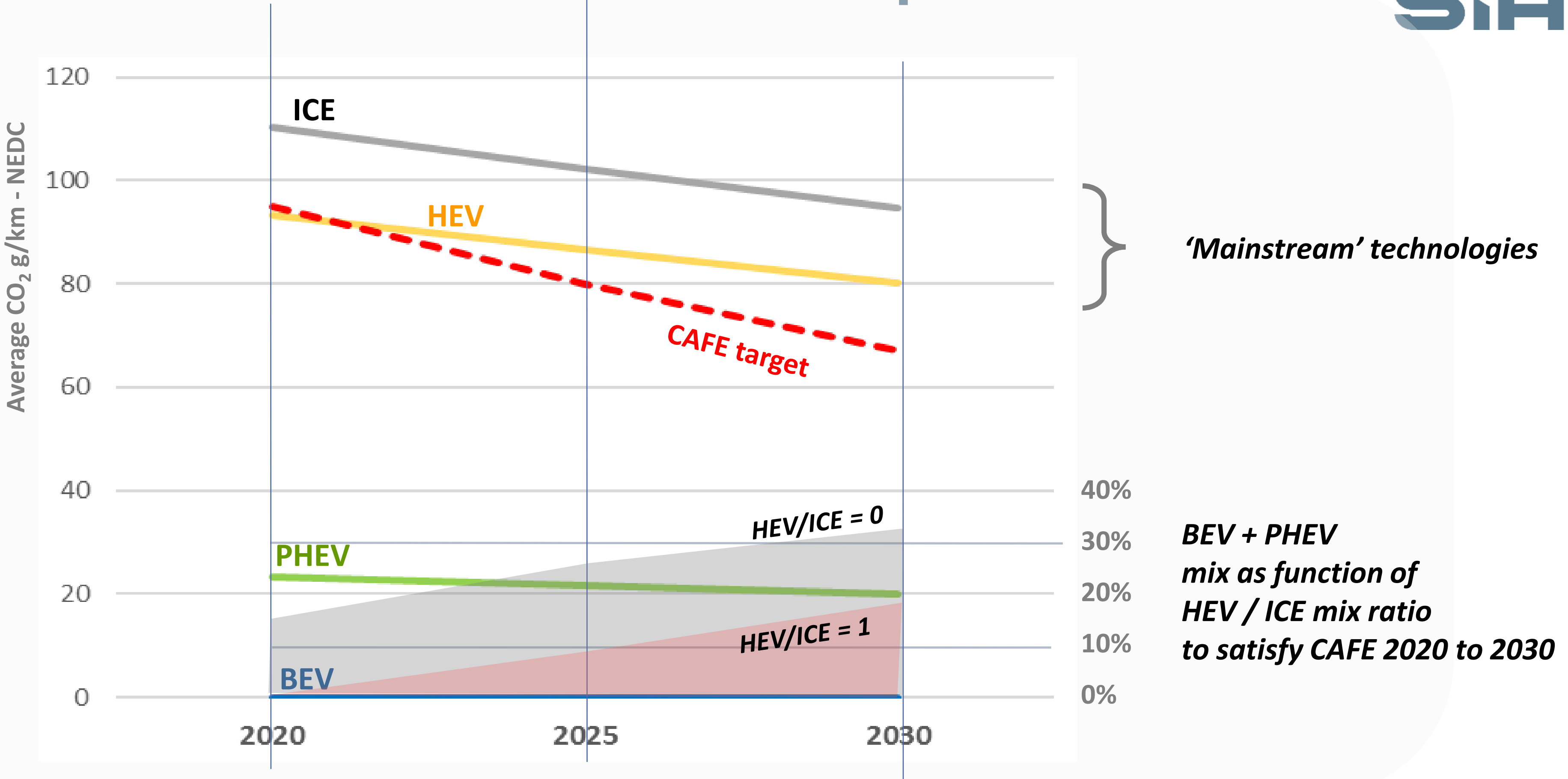
Batterie de traction 12 kWh implantée sous plancher central

> Capacité batterie plus importante et autonomie carburant correcte
> Architecture compatible propulsion électrique et/ou sièges 3e rang

> **Mais** non compatible low drive sans dégrader le confort et/ou l’habitabilité



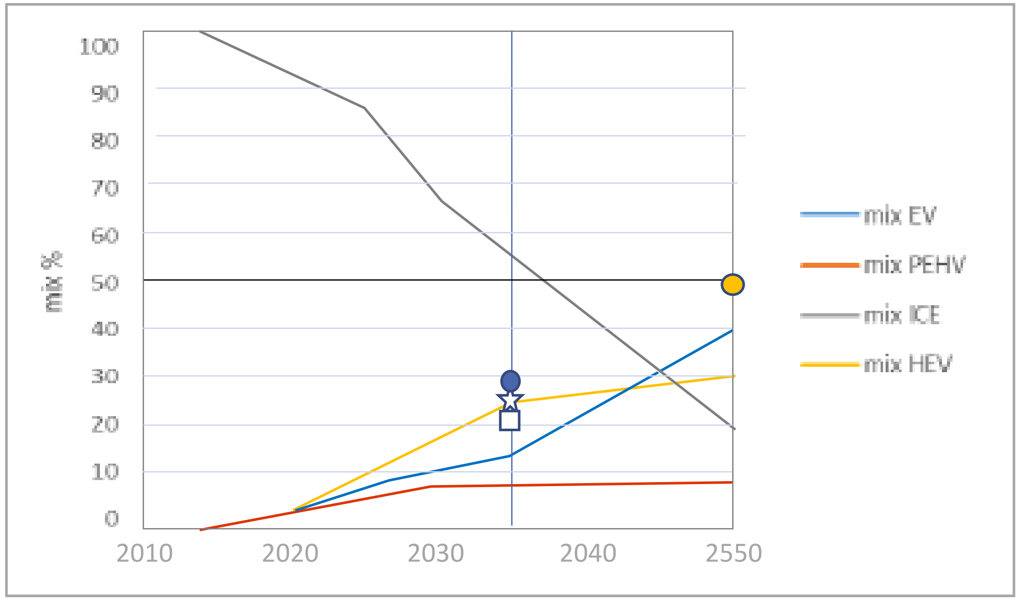
2025 – 2030 HEV mix to meet CAFE requirements



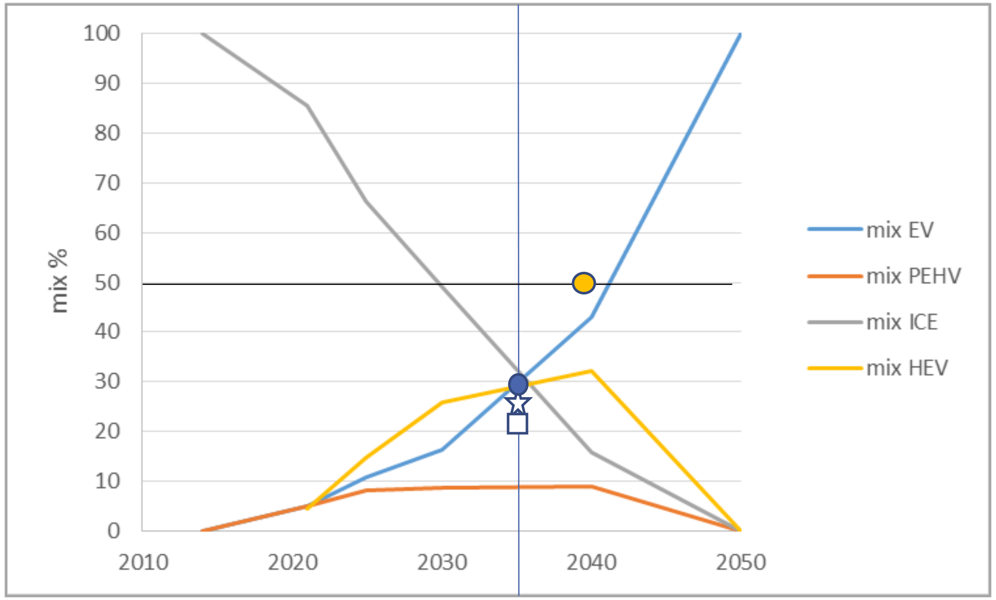
ICE alone and even full HEV cannot reach CAFE target beyond 2020
BEV + PHEV are already necessary to reach CAFE
BEV + PHEV required volumes depend on whether the rest of mainstream powertrains are HEV
If all mainstream powertrains are full HEV then necessary share of BEV + PHEV is reduced by 15%

Europe market forecast beyond 2030

Scenario 1 : CAFE = 40g CO2 in 2050



Scenario 2 : CAFE = 0g CO2 in 2050



BIPE BEV+PHEV 2035 forecast : ● ***Europe*** □ ***China*** ☆ ***USA***

● ***BEV+PHEV reach 50%***

Future scenario depends on infrastructure, material costs, legislation, green-pressure

Average scenario is CAFE decrease to 40g in 2050

Radical scenario is strict application of COP 21 to overall market (0 CO2 in 2050)

In average scenario 50% of powertrains remain 'mainstream' (HEV or ICE) in 2050

In radical scenario mainstream powertrains will decrease to 50% by 2040

MOVING FORWARD TOGETHER*

PROGRESSONS ENSEMBLE

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