FIAT CHRYSLER AUTOMOBILES

Propulsion systems for future mobility: FCA view

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The CO_2 Challenge

Environment protection, technology evolution and social demand

- Pollution, city congestion and awareness of climate changes are impacting society, policy makers, legislation.
- "CO_2 emissions related to transportation" are definitely under the spotlight
- New transportation patterns, jointly with more eco friendly solutions, are requested to offer a significant improvement of this situation.

The CO_2 Regulation

NORTH AMERICA
GHG regulation

EMEA
2020 CO_2 target

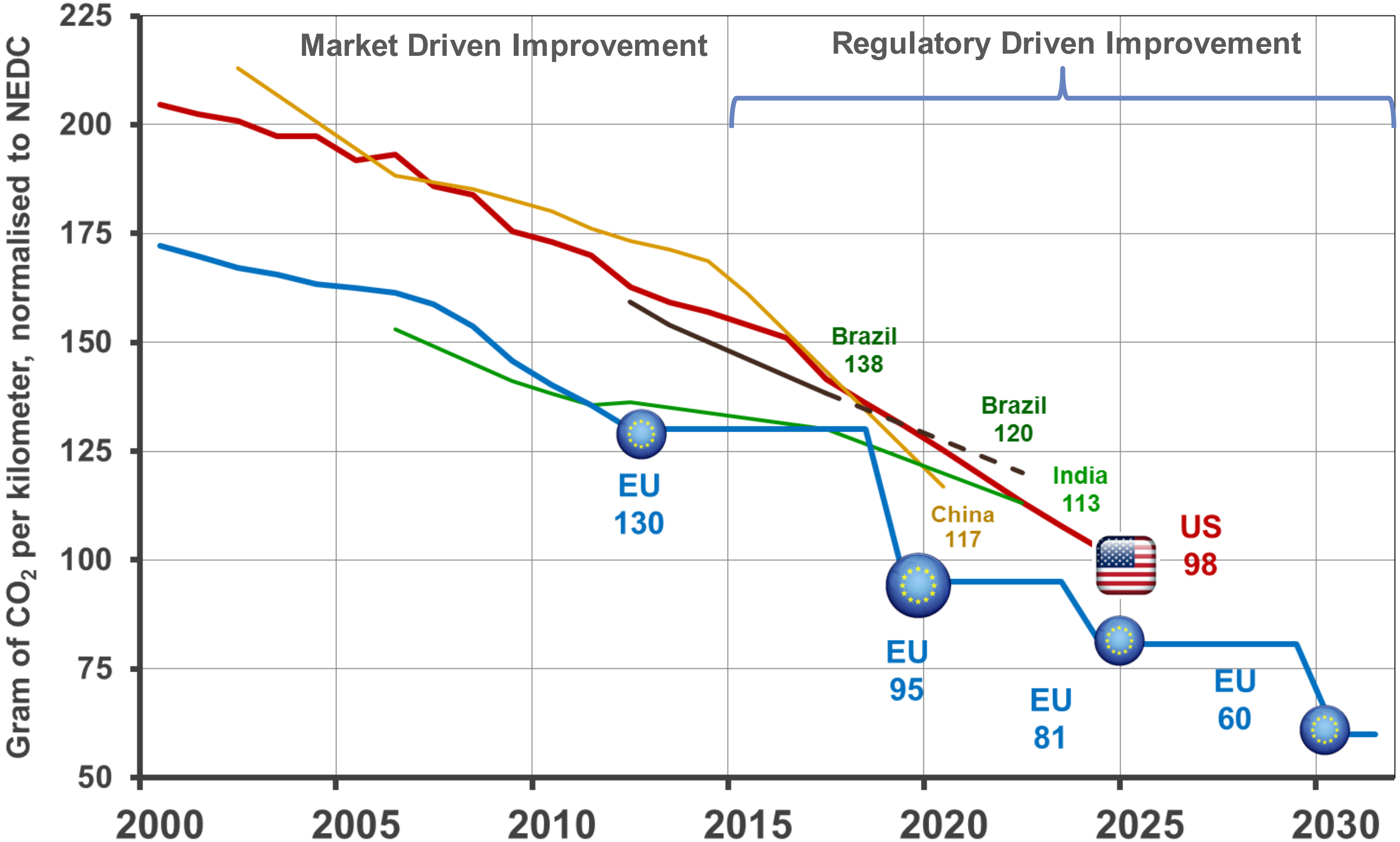
LATAM
ROTA 2030

APAC
CAFC
BS VI

CO_2 emission targets differ world-wide.

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

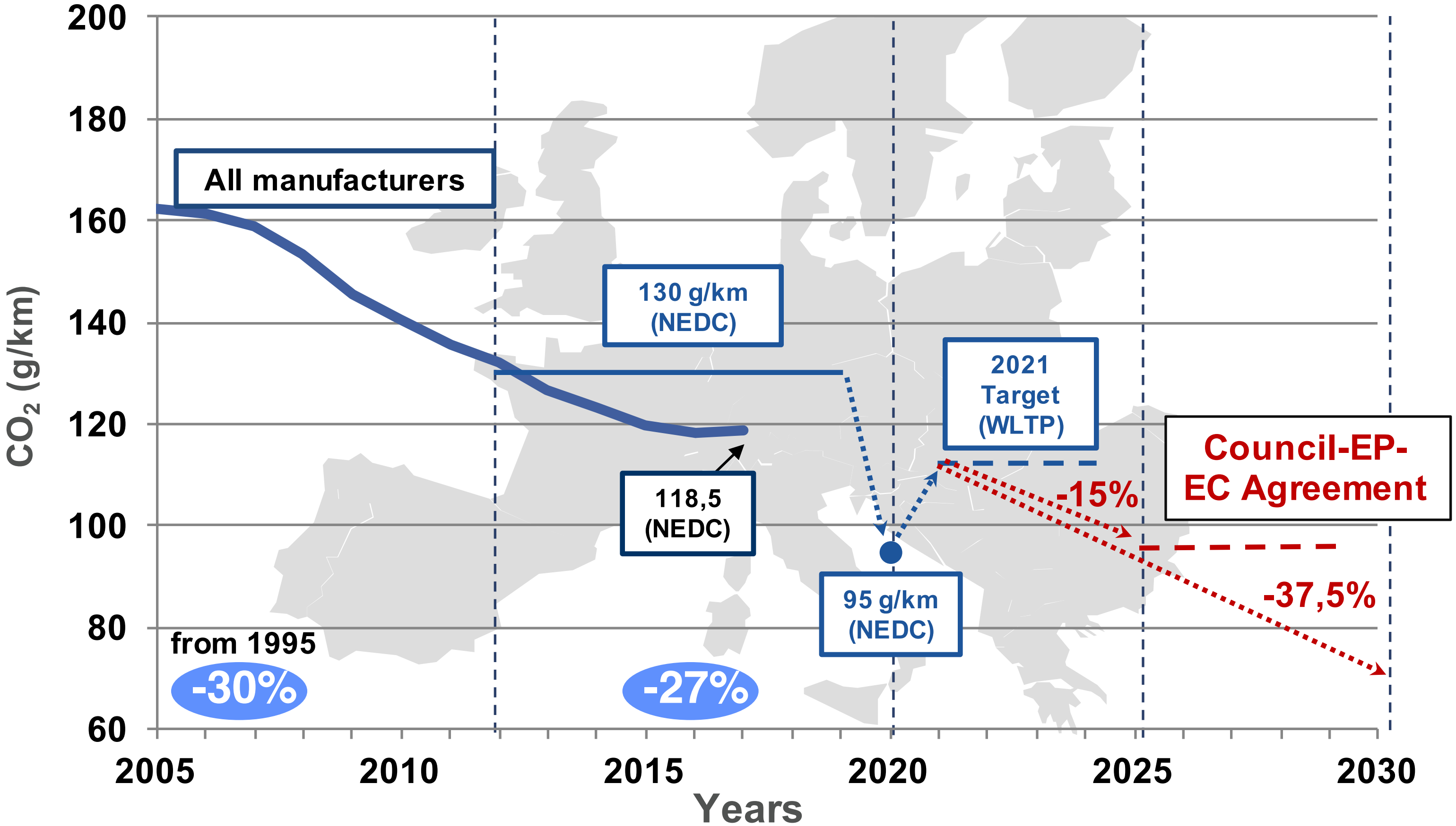
Worldwide CO_2 walk of passenger cars



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

The CO_2 Regulation: Focus on Europe Eu28



OEM view: CO_2 compliance target at sold fleet level

Customer view:

- Taxation based on CO_2
- Operating cost
- Restrictions in city centers access

Which Technologies for CO_2 Compliance?

Mild Hybrid

RAM 1500

Plug-in Hybrid

Chrysler Pacifica

Full Hybrid

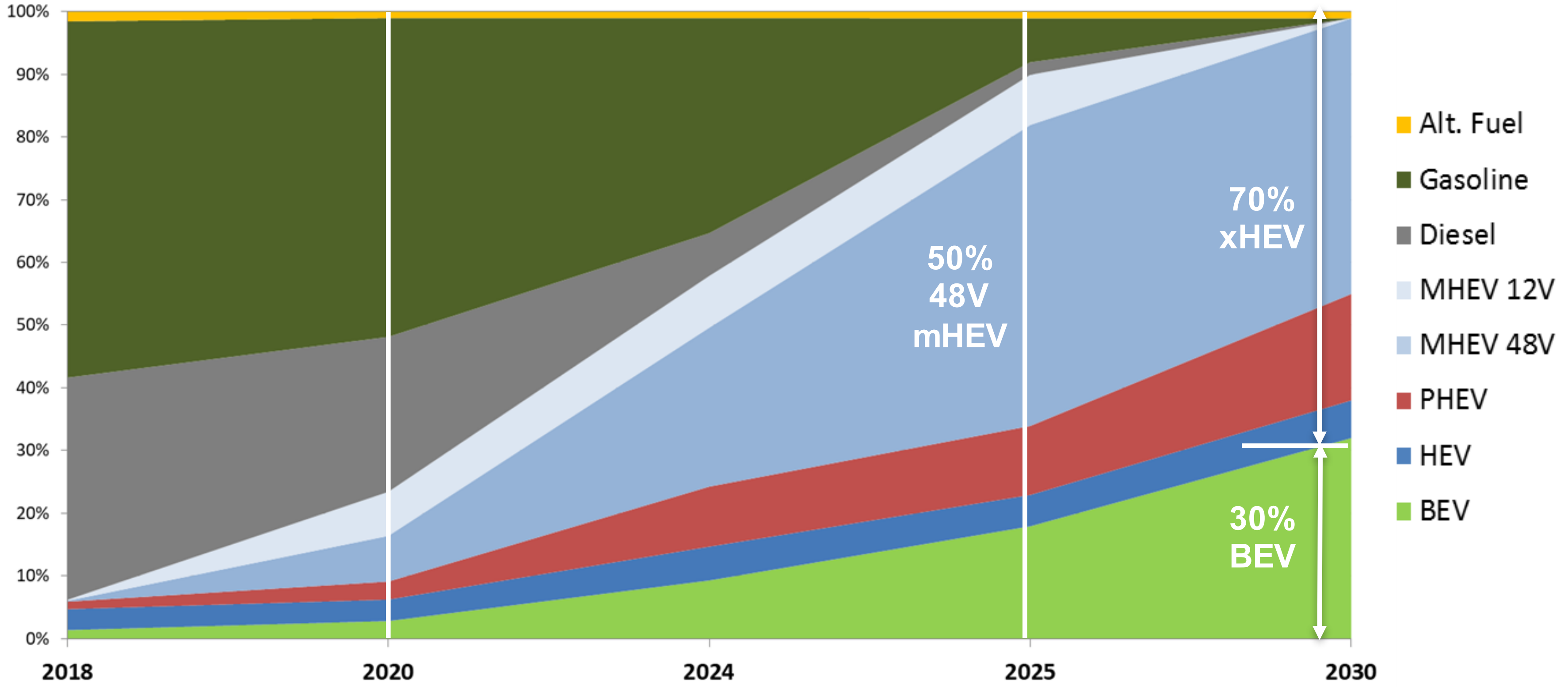
Toyota C-HR

BEV

Tesla Model 3

- ICE technical evolution is not sufficient for CO_2 compliance
- Powertrain electrification is mandatory to fulfill CO_2 limits
- Multiple electrification solutions are available: BEV, Plug-in Hybrid, Mild- and Full-Hybrid with different complexity, cost and CO_2 performance

Technology mix for a compliant European fleet



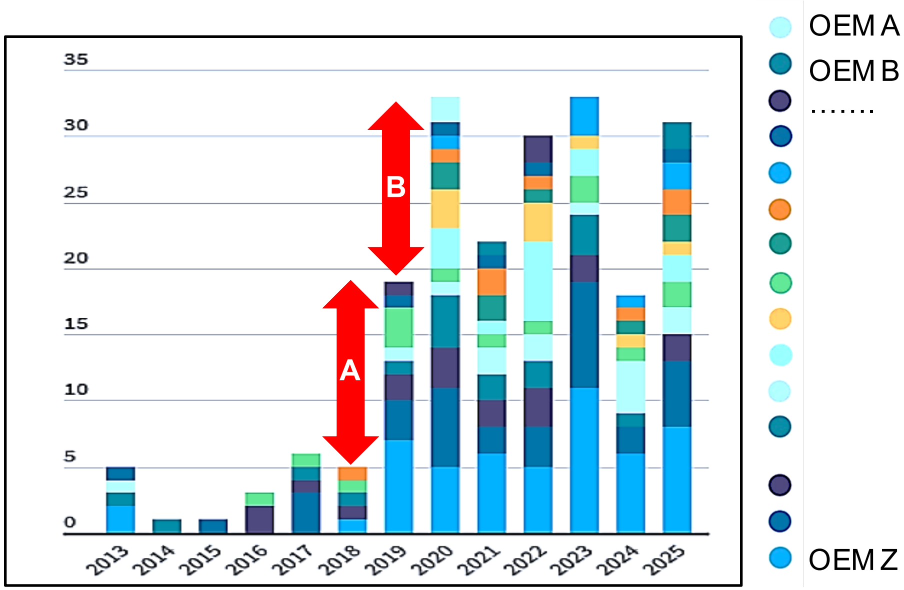
- Sharp increase of electrified Powertrains from 2020 onwards
- 48V mHEVs show the highest penetration rate reaching 50% in 2025
- BEV share increases but remains small compared to xHEVs (30% in 2030)
- By 2030 nearly all vehicles will be electrified

Still, in 2030, 70% of these electrified vehicles will have an IC engine !

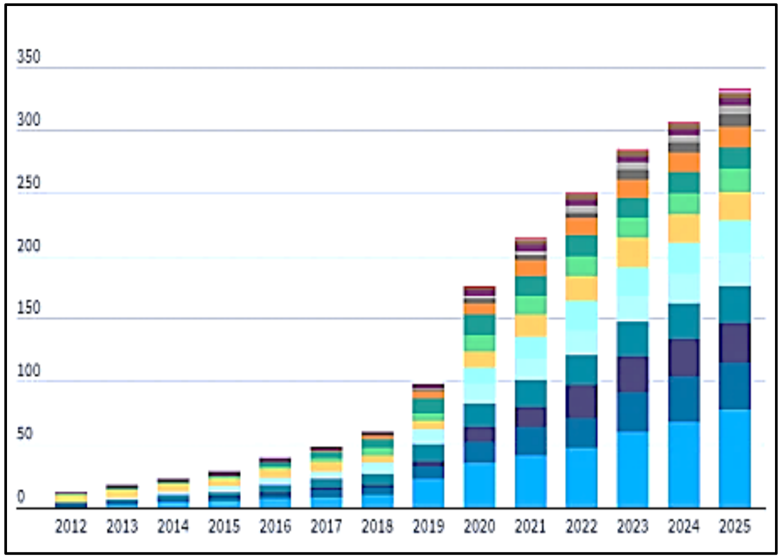
Sources:
2018 Jato Dynamics – 2020, 2024 forecasted by IHS – 2025, 2030 BEV and PHEV forecasted by Bloomberg (FCA elaboration)

And a very crowded arena…

New BEV models coming to the market in Europe (*)



Yearly



Cumulative

OEMs immediate reaction to the CO_2 legislative scenario:

A) 2018 – 2019 : New BEV model launches rise from 5 to 19

B) 2019 – 2020 : New BEV model launches rise from 19 to 32

(*) Source: European Federation for Transport and Environment, July 2019

Challenges for the Powertrain Community

Technical Challenges: New Systems, New technologies
Safety, complexity, reliability

Cost Challenges: ICE de-content/customization not enough to offset electrification cost

Timing Challenges : Shorter lifecycle, different solutions

New Business Players : Driven by new technologies

The IC Engine in the electrified powertrain

The IC engine will be part of the majority of electrified powertrains but has to be adapted to their characteristics

These vary significantly according to the electrified powertrain architecture and installed electric traction power:

- **12V mHEVs** involve **frequent engine stop/start events**
- **48V mHEVs** also **modify transient engine performance requisites**
- **HEVs** make **less use of the engine's maximum torque features**
- **PHEVs** also involve **long engine-off periods**

Conventional powertrains will co-exist with the electrified ones and must guarantee the highest possible efficiency and comply with most stringent emissions regulation

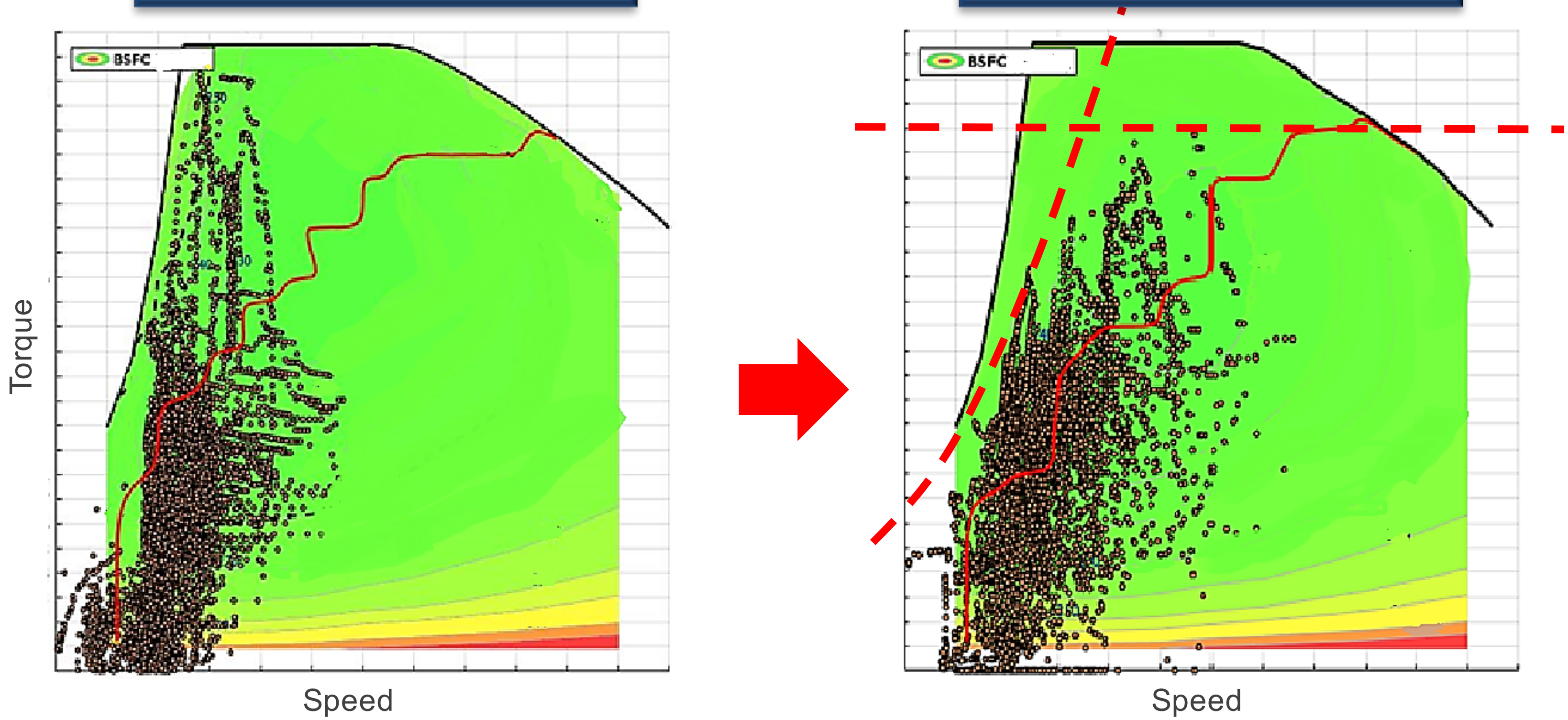
Therefore, **the IC engine has a challenging future.** It must:

- Satisfy efficiently a large variety of missions
- Achieve this target with the minimal possible hardware proliferation

IC Engine mission in the electrified powertrain

An example: C-Segment vehicle: IC Engine operating points in the WLTC(H)

Conventional powertrain | **Hybrid powertrain**



- The IC Engine mission in the hybrid powertrain is radically modified:
  - Low- and Medium-speed peak torque can be significantly reduced
  - Its operating range is restricted

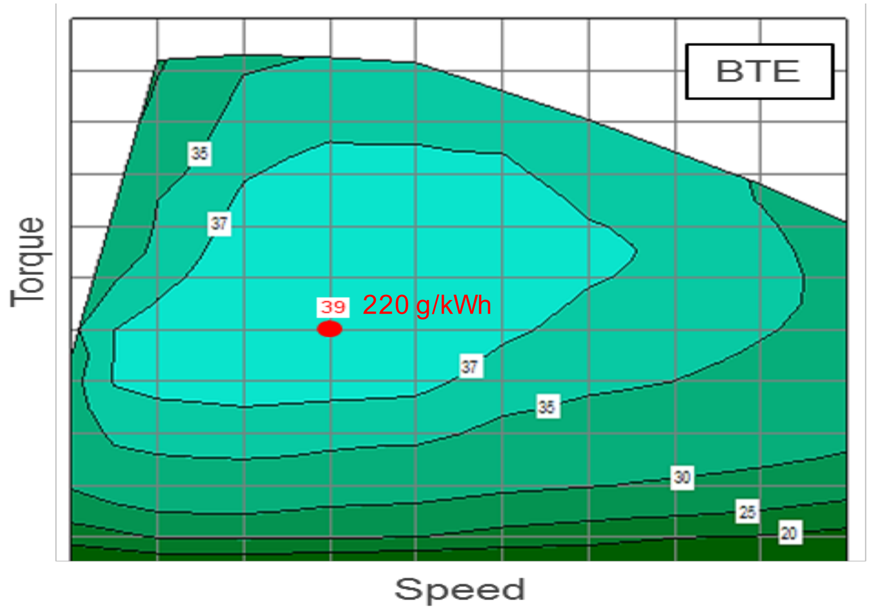
Opportunities for targeted ICE efficiency optimization

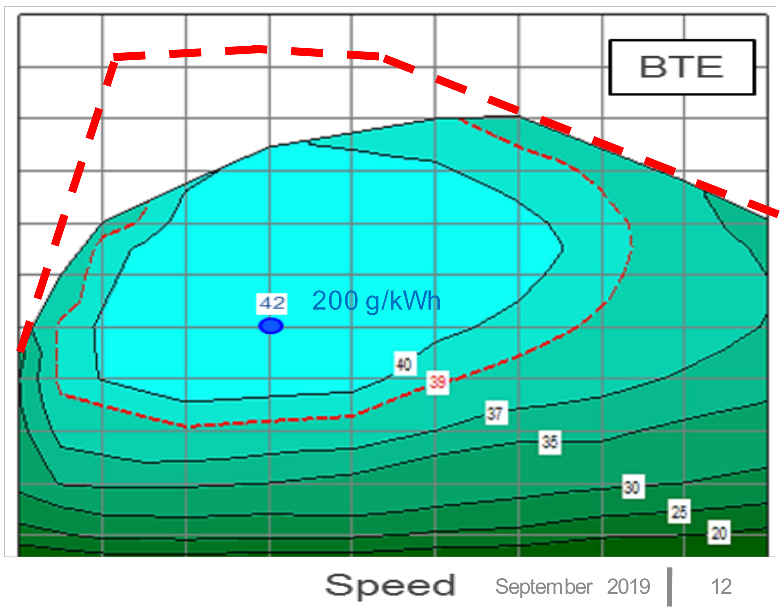
Targeted IC Engine optimization

Objective: To optimize and extent the maximum Brake Thermal Efficiency **(max BTE)**

Targets: 42% ÷45% maximum BTE
Significant extension of >40% BTE area
Full Stoichiometric map

Measures
- Improve Thermodynamic Efficiency
- Reduce Losses – Exhaust, Coolant, Pumping, Friction
- Control Cold Emissions
- Increase Knock Resistance





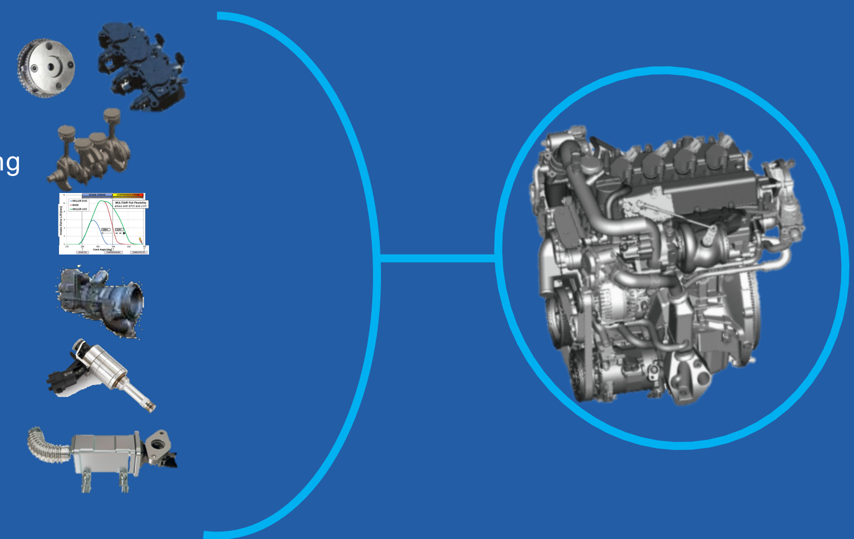
ICE Evolution for hybrid application

Objective

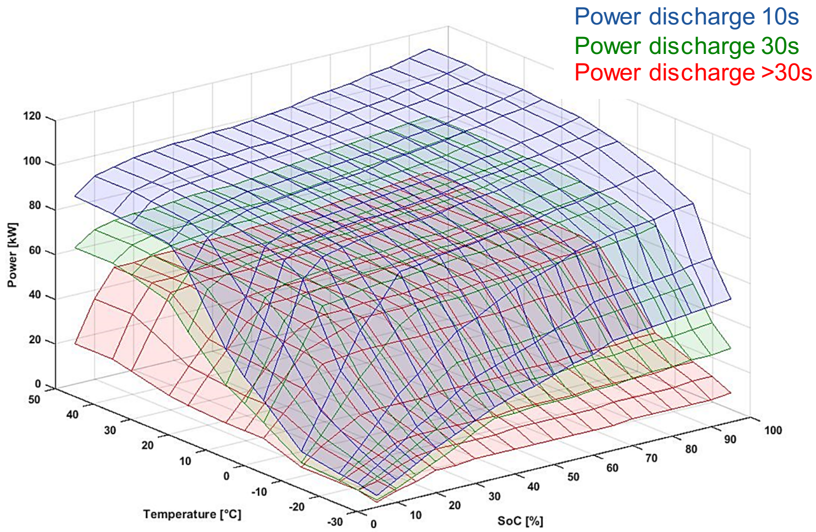
- 200g/kWh <-> 42% Break Thermal Efficiency "sweet spot"
- Enable full stoichiometric map without performance decrease

Engine Technologies

- High Compression Ratio (≥ 15:1)
- VVL - Variable Valve Lift or VVT - Variable Valve Timing
- Miller Cycle – Early or Late Intake Valve Closing
- Variable Geometry Turbo
- Higher Injection pressure (>350bar)
- Cooled Exhaust Gas Recirculation



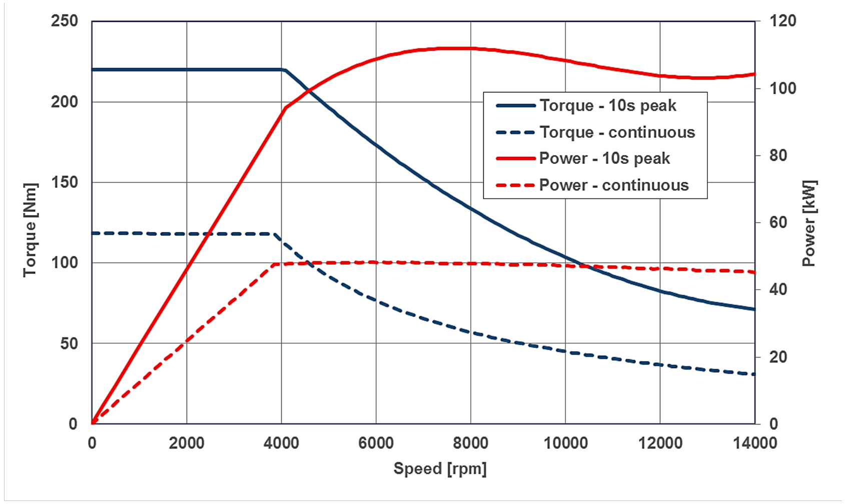
Electrified Powertrain – Peculiarities



Available Battery Power is not constant:

- It depends on Temperature, State of Charge, Duty cycle, State of Health, ….

Dedicated control strategies are needed to mitigate impact on drivability



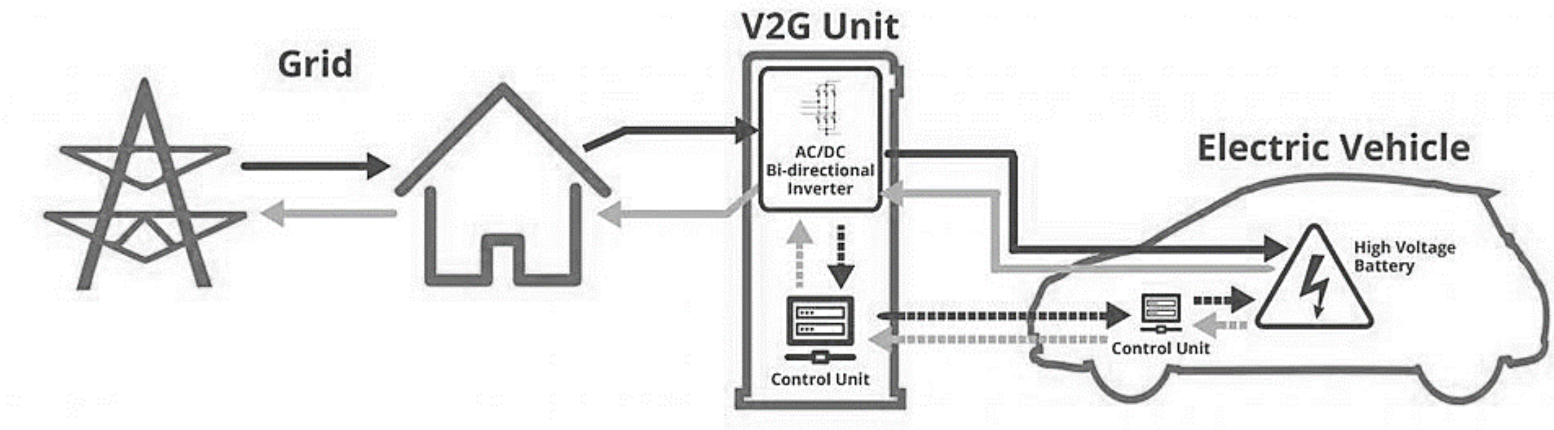
Available e-Drive power is not constant:

- It depends on actuation time and duty cycle

e-Drive thermal management is critical

Virtual analysis at component and system level is necessary in order to address these peculiarities

Electrified Vehicle: Opportunities - 1



The opportunities offered by the electrified vehicle are based on the commonality of its energy vector -electricity - with that of the civil infrastructure.

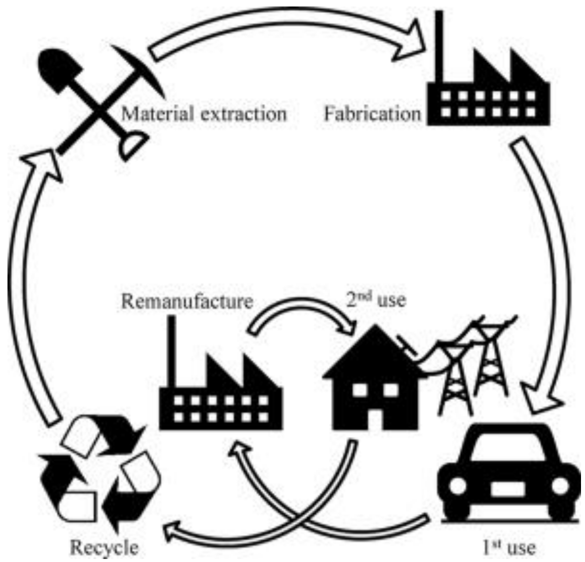
Some examples:

1- Vehicle to Grid applications:

- The vehicle, while connected to the network for battery charging, can be used for **energy buffering** to smooth-out the network's peak power requests
- The resulting energy savings improve overall supply efficiency and can have **economic benefits for the vehicle user**

Figure: Forbes, Electric Vehicle-To-Grid Services Can Feed, Stabilize Power Supply

Electrified Vehicle: Opportunities - 2



2 - Battery Second Life applications:

- The vehicle's battery is considered at its end of life **when its capacity is reduced at 70% of its initial value**
- The remaining capacity can be **used for the network's energy buffering** in, less demanding, stationary applications

Such applications require coordination of the electrified vehicle's hardware and control systems with the electricity supply infrastructure.

The vehicle becomes part of a wide and complex energy management system

Figure: Journal of Environmental Management, Volume 232, 15 February 2019

FCA & Electrification – Global view

RAM 1500 MHEV

Pentastar 3.6l V6 305hp / 365 Nm
HEMI 5.7l V8 395hp / 556 Nm

48V eTorque Technology:
+122 Nm on 3.6l V6
+176 Nm on 5.7l V8

CHRYSLER PACIFICA PHEV

Pentastar 3.6l V6 260 hp / 320 Nm
Electric Range up to 51 km
eFlite electrically-variable transmission

JEEP GRAND COMMANDER PHEV

Most recent launch
In China

FCA & Electrification – Renegade & Compass PHEV

RENEGADE PHEV eAWD

COMPASS PHEV eAWD

CO_2	< 50 g/km
Electric Range	50 km
Max Power	240 hp
Engine	1.3l

Off Road Capability, Power, Performance

FCA & Electrification – EMEA Market

First BEV manufactured in Italy

New Generation

old sister launched in USA in 2013

- FCA is investing 700 million euros to build the production line for the new Fiat 500 electric in the Mirafiori plant in Turin.
- Production will start in the second quarter of 2020.

FCA & Electrification – ENEL X and Engie partnership

…to develop new e-mobility solutions to boost the uptake of electric vehicles

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enel x

engie

- Intelligent charging solutions for plants, offices, R&D centers:
  700 stations in Italy in 2 years
- Dealership installations: Italy, Spain, Portugal
- In 2020 JuiceBox charging stations available

- e-Mobility solutions in 14 European countries
- For dealers and customers: hybrid and BEV
- About 2800 dealers involved
- A new dedicated app for easy localization, booking, use and payment

Final remarks

For OEMs…

Design

- We are facing a **technical revolution** rather than the usual evolution
- **New engineering disciplines** are needed for the design and development of the electrified vehicle

Systems

- The vehicle becomes a **complex system** and is integrated in the communication and energy supply infrastructures
- The development, investment and direct material costs **increase significantly**

Final remarks

…and for Users

Added value

- Improved performance, features and comfort should **be well accepted**
- **Lower operation costs** and environmental impact may also be attractive

Worries

- **Novelties** in driving habits may not be welcome by everybody
- **Increased purchasing cost** is unavoidable : Is the user prepared to pay more for this commodity?