Hybrid4All:

A low voltage, low cost, mass-market hybrid solution

Daniel BENCHETRITE, System and Integration Dept. Manager
Valeo Powertrain Systems

October 2013

Agenda

1. Market Analysis
2. Main issues of Hybrid / Electric vehicles
3. Simulation approach
4. Valeo Components
5. Conclusions

Agenda

1 **Market Analysis**

2 Main issues of Hybrid / Electric vehicles

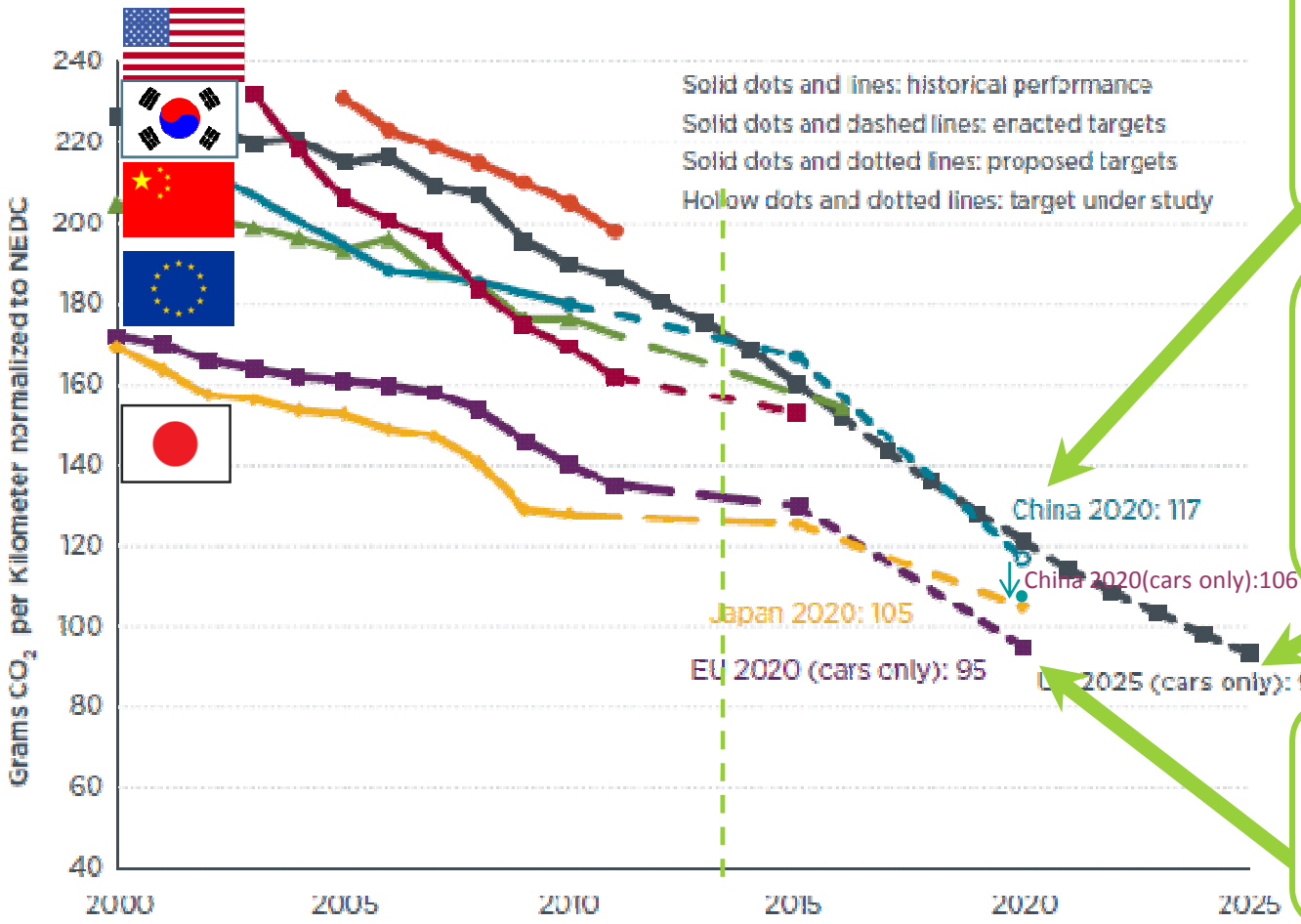
3 Simulation approach

4 Valeo Components

5 Conclusions

Regulation is the main driver of Powertrain evolution

Consensus on regulation target



2020
5 l/100 km (117g)
4,5l/100km (106g)
for P Cars

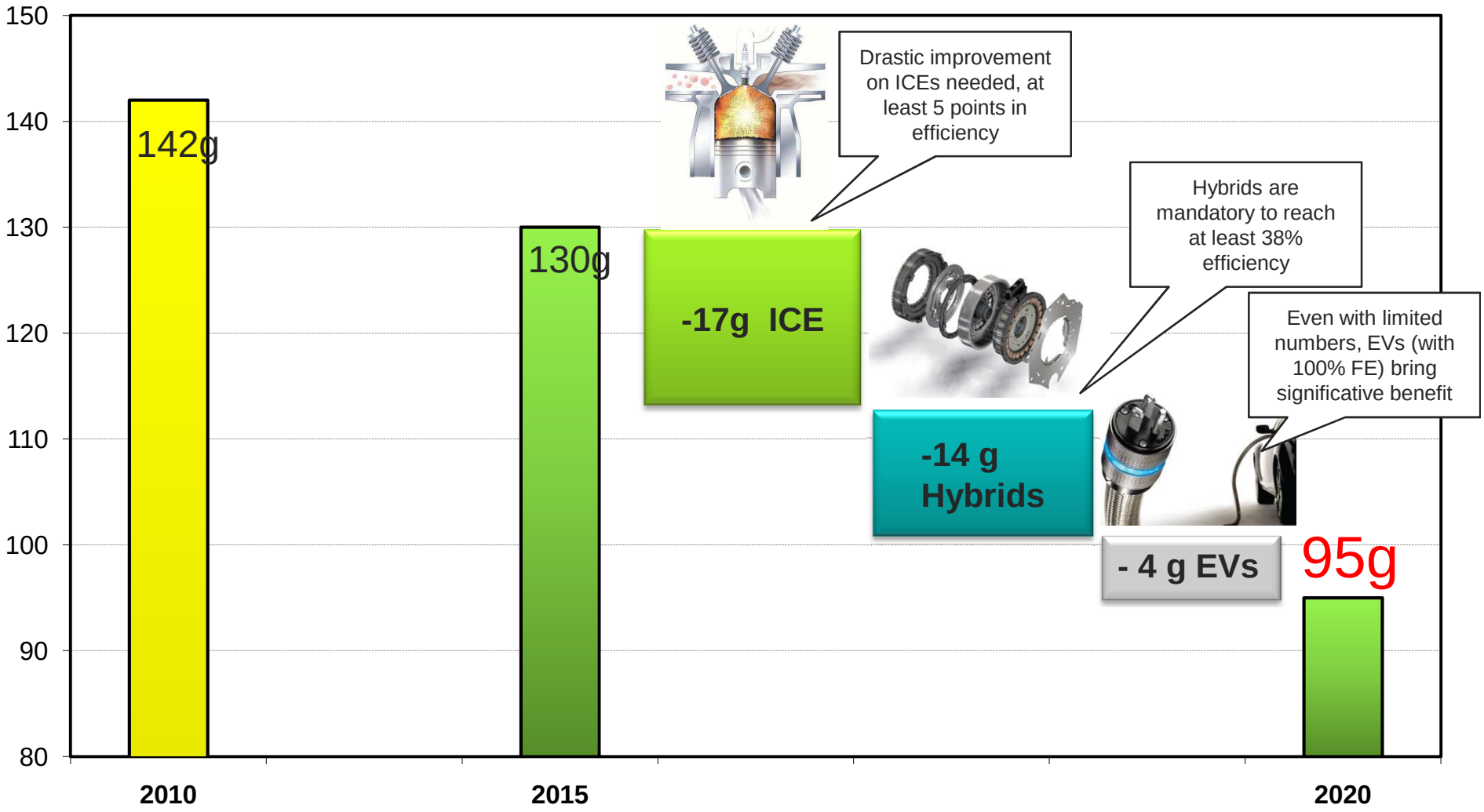
2025
54.5 mpg
93g CO_2/km eq
NEDC for P Cars
3.9 l/100 km

2020
95g CO_2/km
4.0 l/100 km

US Speeding up, China have set up the rules
➔ All catching up on Europe

2020 European 'CAFE' prospective

Breakthroughs are a necessity



To reach 95g, ICE and transmissions efficiency is not enough.
Hybrids and EVs will be necessary

There are a lot of Hybrids

From simple Start-Stop to ZEV mode

Micro Hybrid

Mild Hybrid

Full Hybrid

Plug In Hybrid Extender

Range Battery EV Fuel Cell EV

Nissan Leaf

GM Volt

Toyota Prius3

Honda Insight

Buick LaCrosse

Smart

+ Electric drive

+ Electric take off

+ Engine Torque assistance

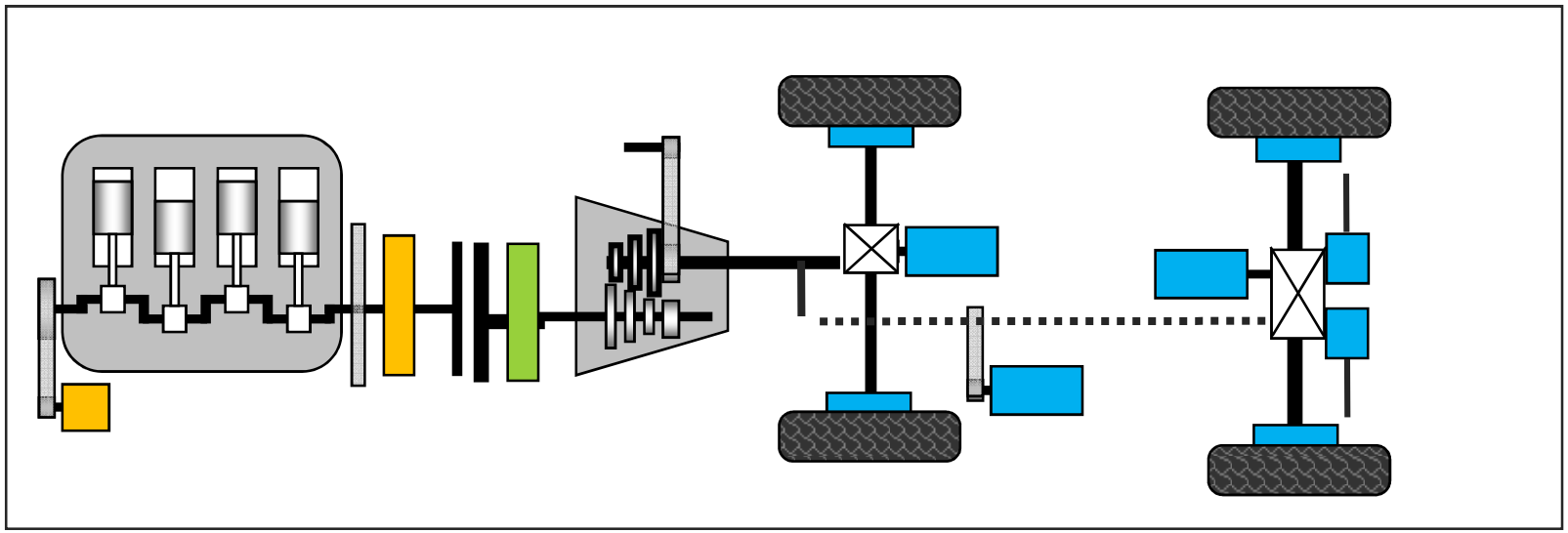
+ Kinetic Energy recovery

Stop & Start

Valeo

There are a lot of Hybrids

By definition, an Hybrid has 2 DNAs ; combustion and electric engines



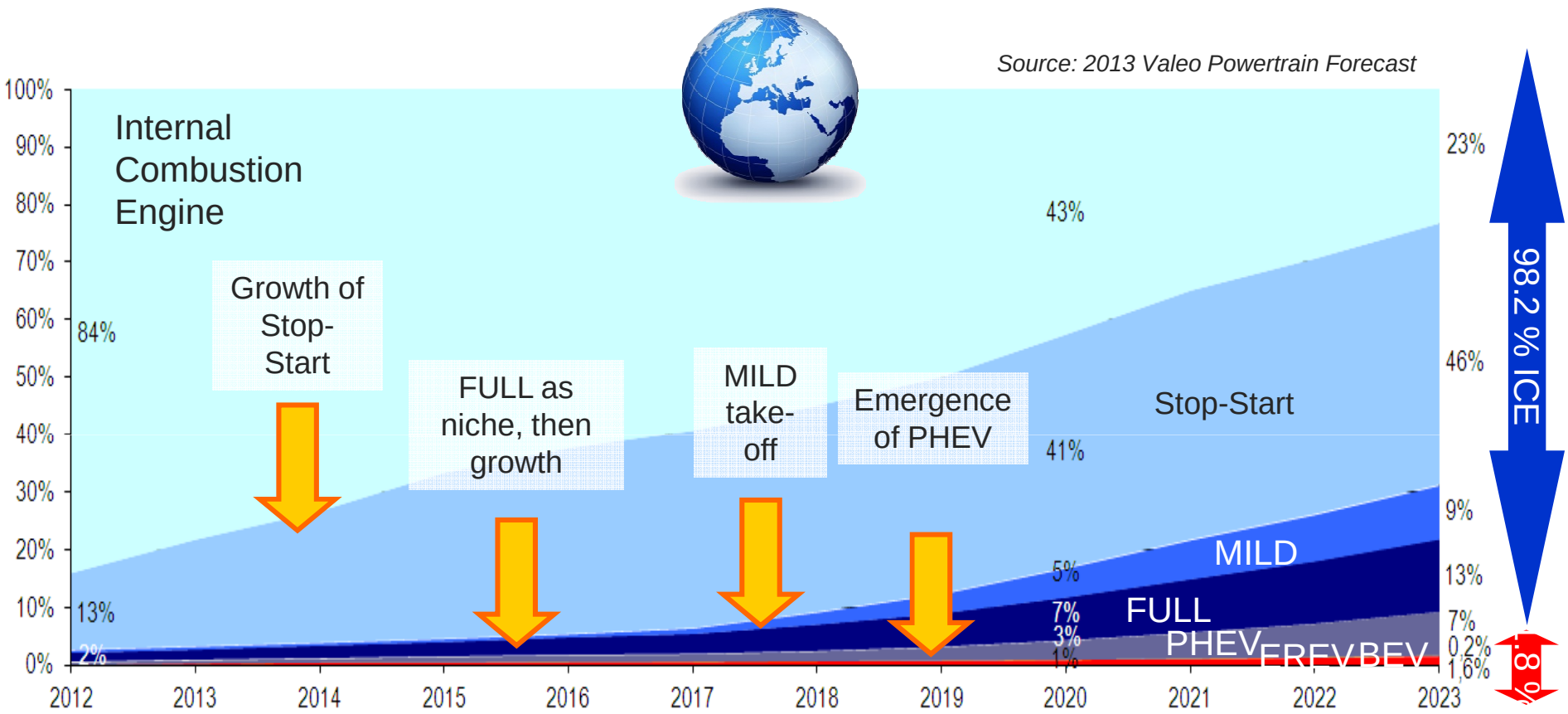
Electric motor on Combustion Engine (Buick LaCrosse)

Electric motor in transmission (Toyota PRIUS)

Electric motor on rear axle (PSA 3008 HY4)

Electrification Forecast: Worldwide

Vehicles <6T, Oil barrel $120 2020, Li-Ion Battery 300 €/kWh 2020

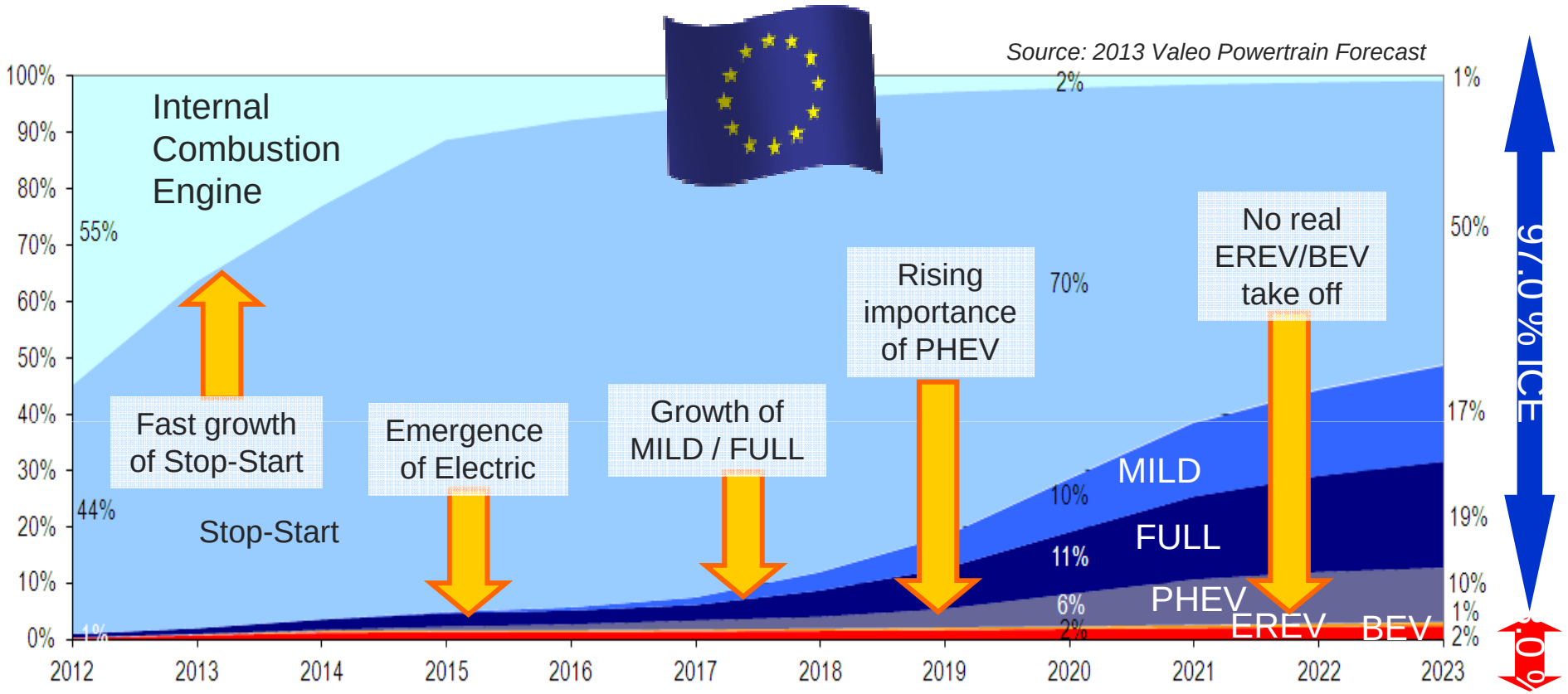


Trends

BEV/FCEV : only 1.6% in 2023, still a limited market (lower segments), urban usage or image product
EREV : not confirmed
FULL / PHEV : faster growth than in last forecast, growing weight of PHEV from 2018 – 2019
MILD : market take off delay, rather in 2018
Stop-Start : getting mainstream with regular growth from now – still 23% CONV, mainly in BRICS

Electrification Forecast: Europe

Vehicles <6T, Oil barrel $120 2020, Li-Ion Battery 300 €/kWh 2020



Trends

BEV/FCEV : lower forecast than in the past (A / B / C + LCV), EREV remaining a niche
FULL / PHEV : growing significance, with higher weight of PHEV in sales
MILD : somewhat postponed – take off expected in 2018
Stop-Start : becoming standard within the next 6 years, almost 0% conventional engines in 2023
Significant Hybrid growth expected before 2020 to reach 95 g (expected 103g 2020, 88 g 2023)

Agenda

1 Market Analysis

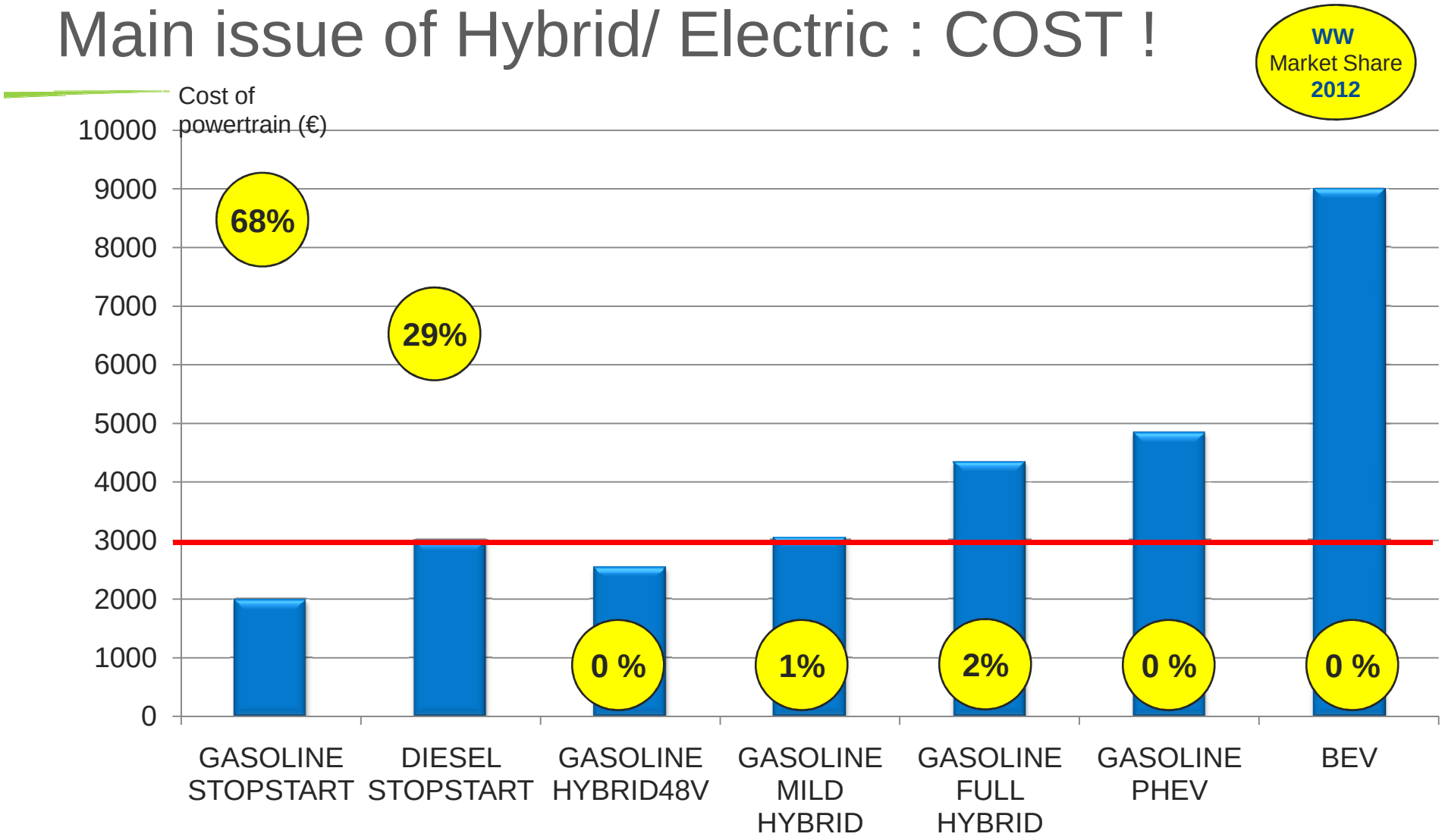
2 **Main issues of Hybrid / Electric vehicles**

3 Simulation approach

4 Valeo Components

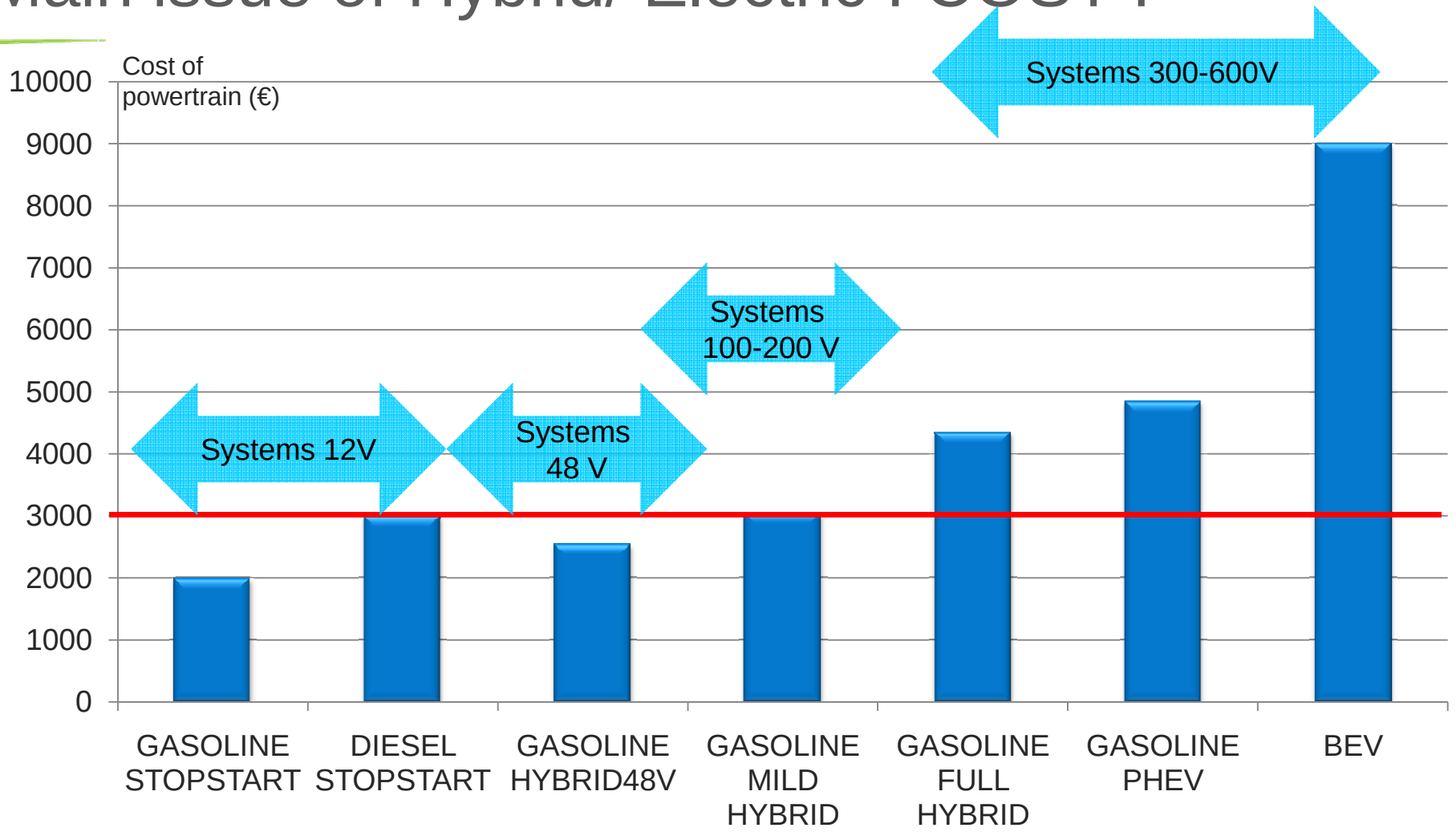
5 Conclusions

Main issue of Hybrid/ Electric : COST !



Diesel today just represent the upper limit customers are ready to pay for
→Hybrids won't develop in mass market without a clear cost breakthrough

Main issue of Hybrid/ Electric : COST !



Main reason of high cost is battery voltage.
The higher the voltage, the higher the cost

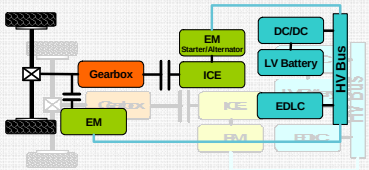
Agenda

1. Market Analysis
2. Main issues of Hybrid / Electric vehicles
3. **Simulation approach**
4. Valeo Components
5. Conclusions

Optimized hybrid : simulation approach

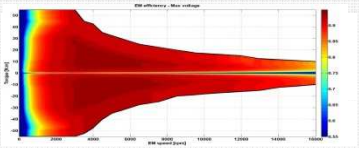
Architecture study

(e-Machine location)



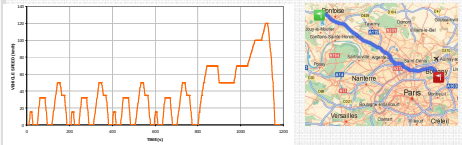
Electric motor & battery

(Technology, Power, Voltage, Capacity)



Mission profile

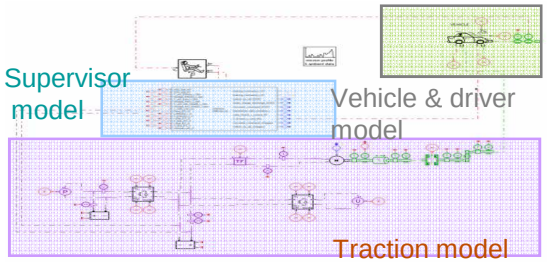
(NEDC, WLTC, Artemis Urban)



Vehicle platform

(Engine displacement, segment)

HEV simulation platform



Energy Management

- Voltage and current curves
- Operating modes
- Energy storage

Fuel consumption

- CO2 saving
- Cost / gCO2

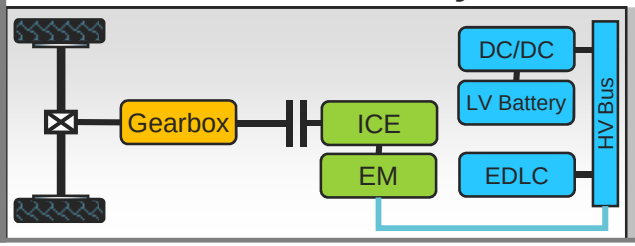
➔ **Optimized system**

Valeo

Architecture study

BSG

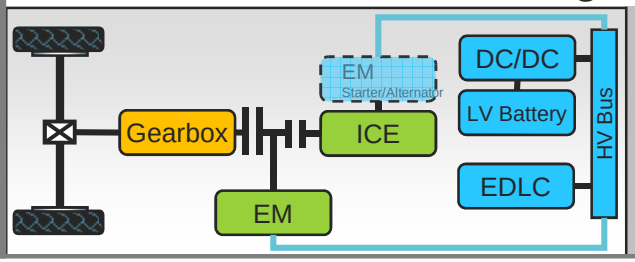
Electric Motor directly on the crankshaft of the engine



- ☺ Single Electric Machine
- ☺ Easy integration in case of belt driven system
- ☹ Low global efficiency due to engine losses
- ☹ Engine losses compensation by EM

CMG

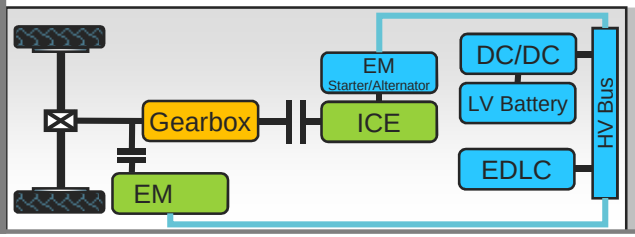
Electric Motor between engine and gearbox with an additional clutch



- ☺ No engine losses to compensate
- ☹ Original clutch to be controlled & additional clutch required
- ☹ Integration issue on transversal engine
- ☹ Potential additional starter / alternator
- ☹ Torque control during engine start

GMG

Electric Motor behind the gearbox through a disconnect clutch

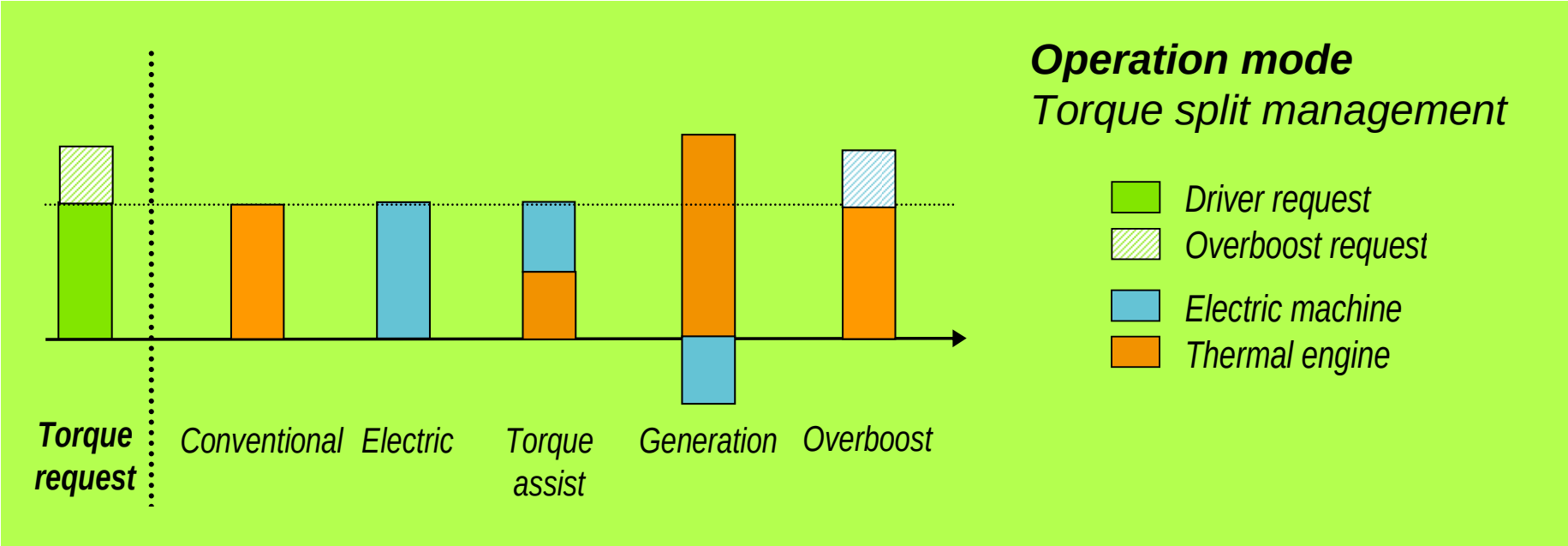


- ☺ No engine nor gearbox losses to compensate
- ☺ Torque continuity during gear change
- ☹ Original clutch to be controlled & additional clutch required
- ☹ Additional starter / alternator
- ☹ Speed range issue for electric motor efficiency

First conclusion: Easiest / cheapest system is with belt-driven machine

Operation modes

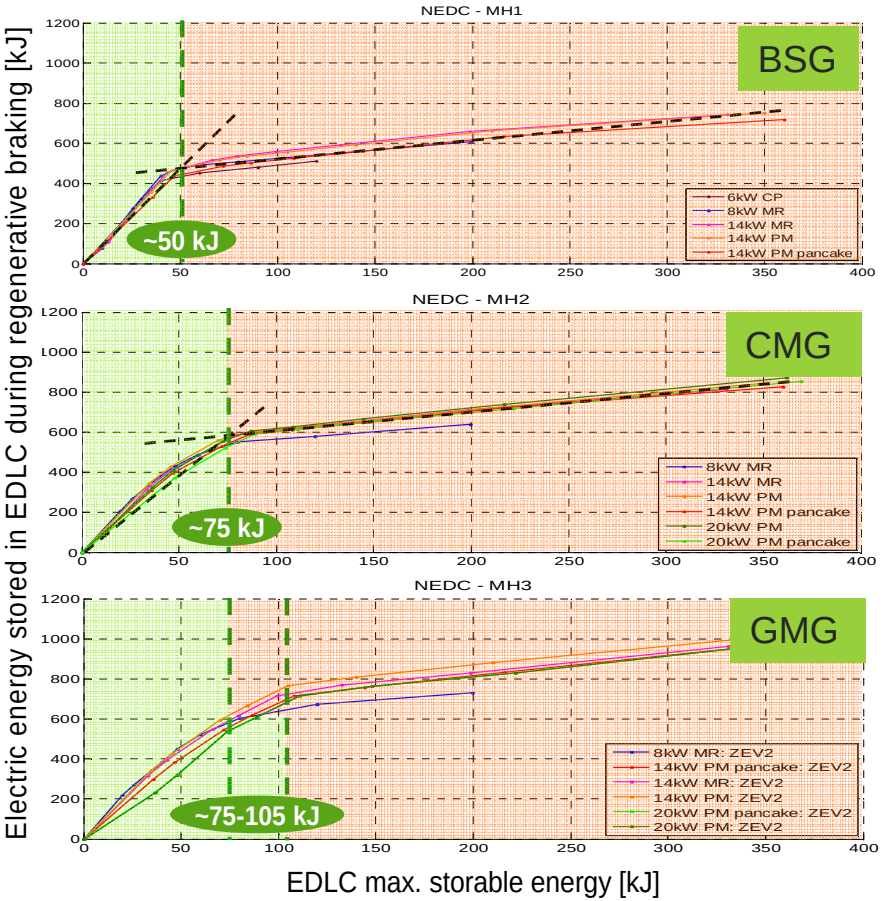
- Extended Stop / Start (even with manual gearbox), coasting
- Electric mode: running and take off (even with belt driven system)
- Generation mode & regenerative braking
- Torque assist / Overboost



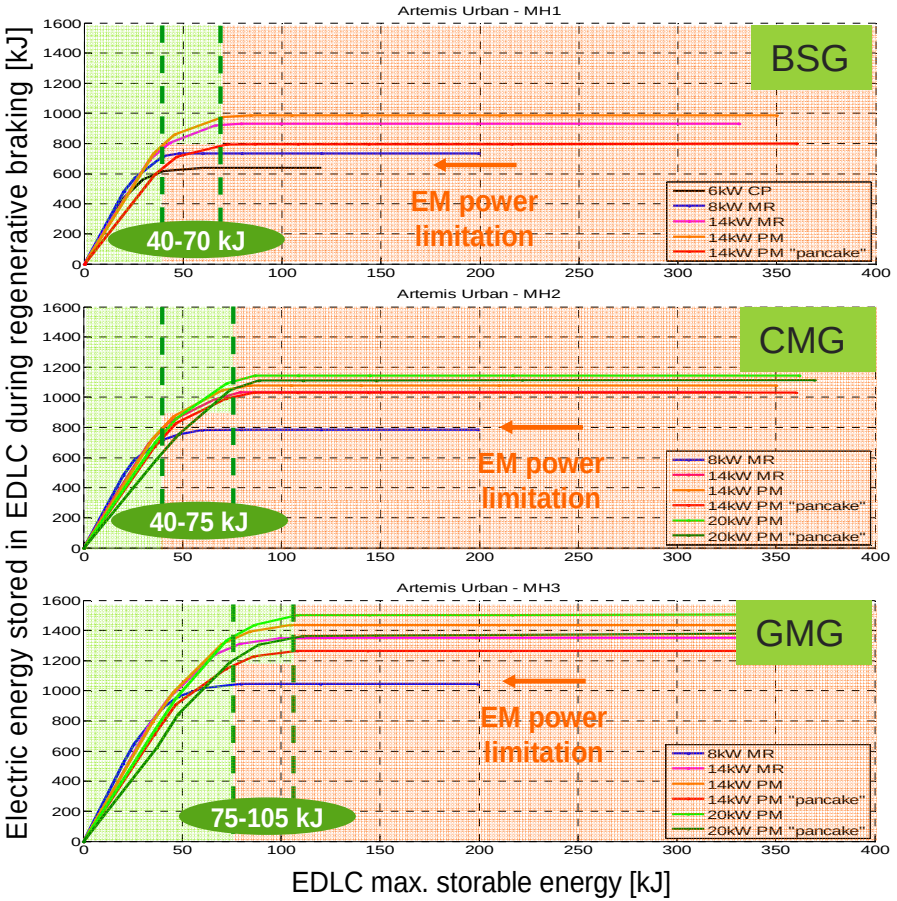
Battery capacity sizing

Simulation results on B segment vehicle

NEDC results



Artemis urban results



Second conclusion: Best value usable energy capacity < 100 kJ

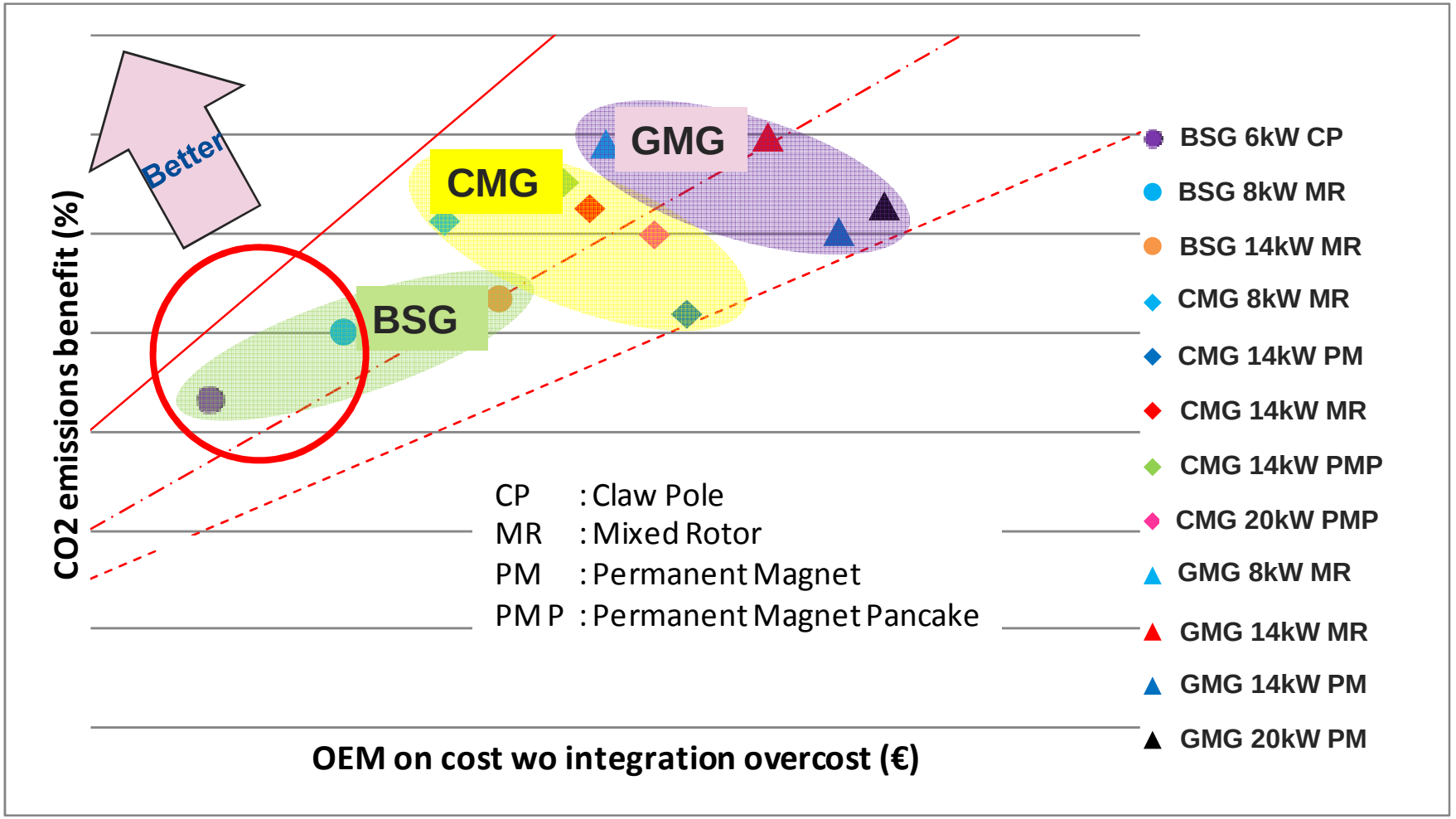
Battery capacity sizing

- 100 kJ is the optimal usable level of energy
- However, to size the storage pack, need to apply SOC and safety factors
  - Using ultracapacitors, the only limit in SOC is voltage drop. To keep voltage at nominal level, we have then considered a maximum 50% depletion in use:
    - *We then considered the size of UCAPs pack at ~200kJ*
  - Using Li-Ion batteries, it is necessary to limit the SOC swing in order to have a good lifetime (ex : 30%). Also, the peak currents (12kW under 48V gives 250Amps) might seriously damage the battery. Hence , in accordance with battery makers, we have applied an additional safety factor of 2 to 3.
    - *We then considered the size of the Li-Ion pack at ~600-900 kJ (~180-270Wh) – therefore, a Li-ion cell around 6Ah*

Third conclusion: Small storage capacity is enough (< 900 kJ)

Electric Motor sizing

Simulation results on NEDC cycle
B segment vehicle



Fourth conclusion: best cost to value with a 6-8 kW BSG motor

Agenda

1 Market Analysis

2 Main issues of Hybrid / Electric vehicles

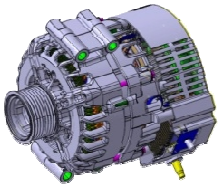
3 Simulation approach

4 **Valeo Components**

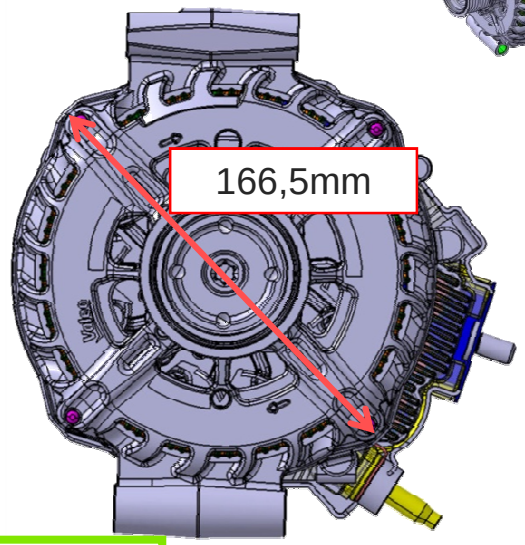
5 Conclusions

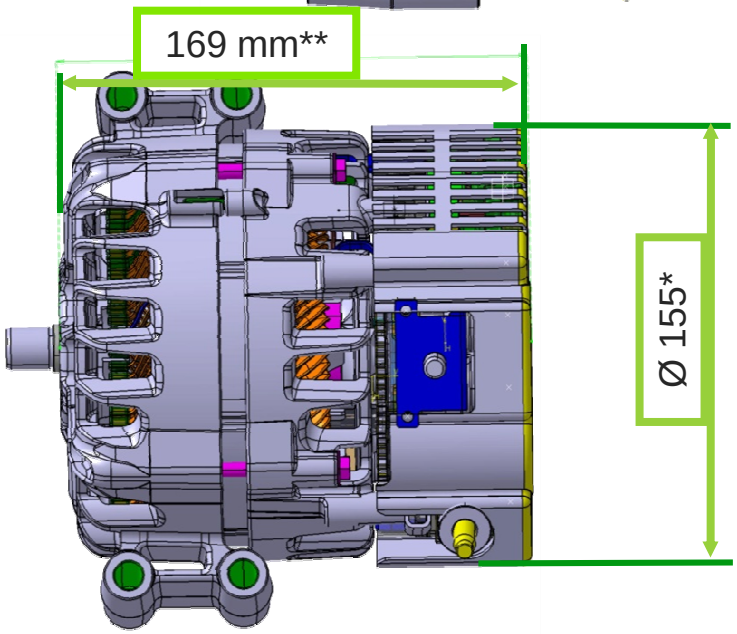
Valeo i-BSG Product Definition

E-machine description



- ***Claw poles number : 8pp***
- ***Interpolar magnets type : Low Dy rate***
- ***Stator type : U pins***
- ***Stator length : 42mm***
- ***Phases number : 2 x 3***
- ***Stator thermal sensor***
- ***Cooling : Forced air convection***
- ***Electronics : Integrated inverter***
- ***Protection level : IP25***
- ***Weight : 9,5kg***



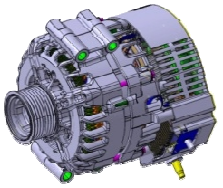


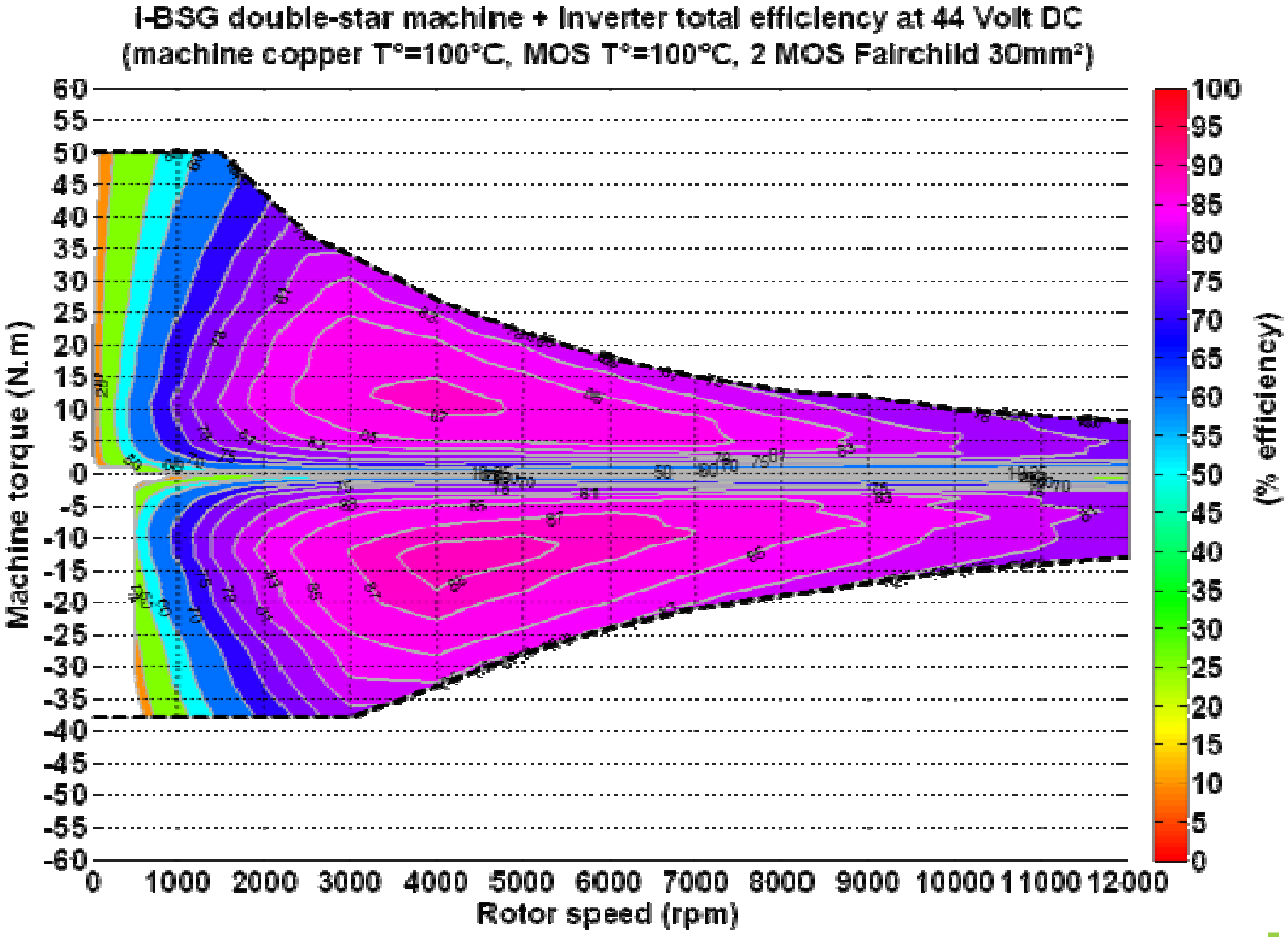
* Bracket diameter

** Without pulley

Valeo i-BSG Product Definition

E-machine Mappings





Valeo DC/DC Converter Definition

Prototype – Specifications

Item	Value
Electronic	Reversible buck (pre-charge and/or boost feature) Uninsulated chopper with embedded EMC filters in LV side
Input Voltage Range	Buck: 24 – **48** – 54V Boost: 36 – **48** – 52V
Output Voltage Range	Buck/Boost: 8 – **14** – 16V Derating between 8 and 10V
Max Rated Power	2,5kW @ 14,5V
Efficiency	96% @ 500W 93,5% @ 2500W
Weight	< 3,1kg
Cooling	Air cooled with minimal air velocity 2m/s
Full Temperature Range	-30 to +75℃ Derating between 75 and 105℃
Protection class	IP67, IPX9X
Energy Storage	Full compliance with Li-Ion battery (bidirectional power flow when Vin > Vout)

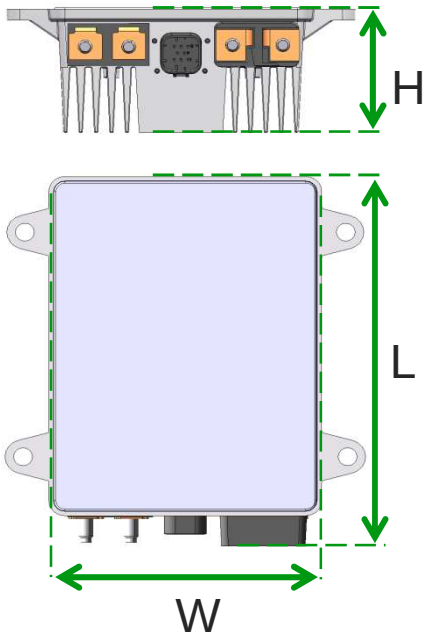
- Bi-directional power flow → Can supply the energy storage unit with power
- High safety class (ASIL C), high power (2,5kW)

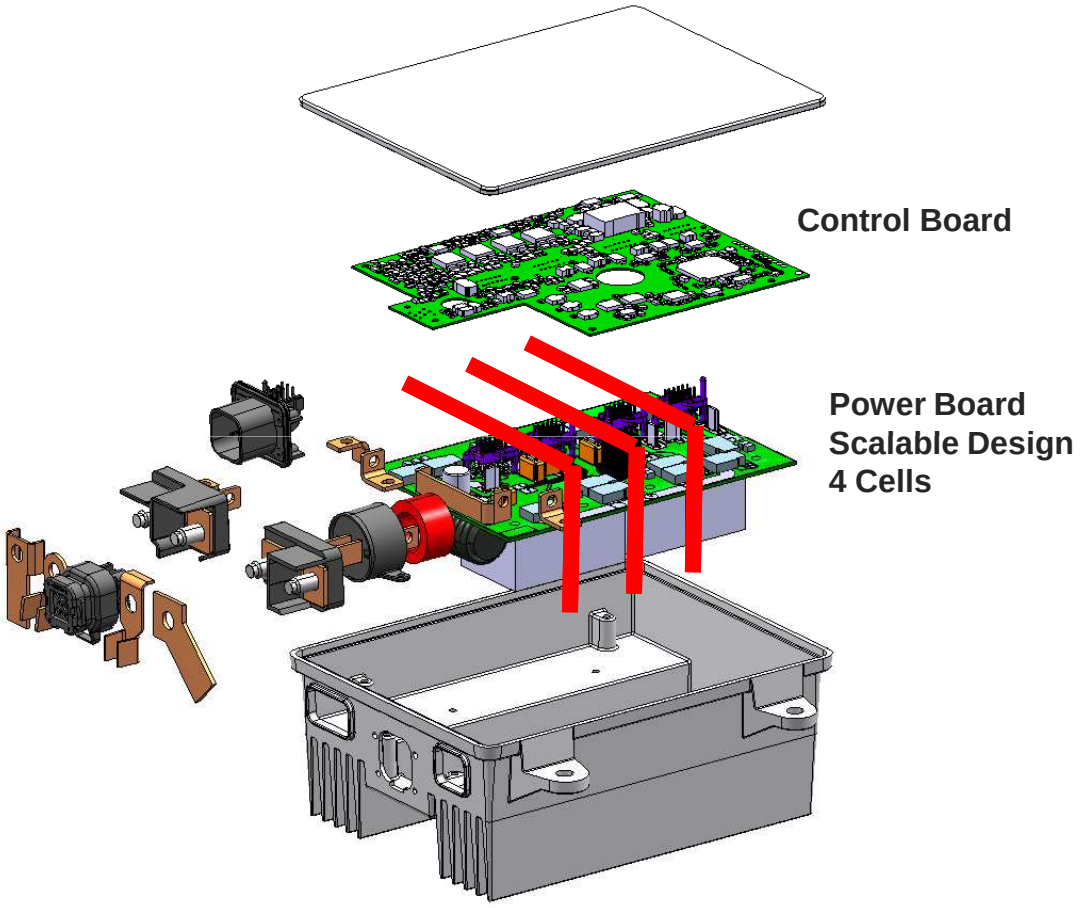
Valeo DC/DC Converter Definition

Prototype – Packaging

- ***Dimensions***
  - ***Length: 218mm***
  - ***Witdh: 152mm***
  - ***Height: 78mm***
  - ***Volume: 2,6l***

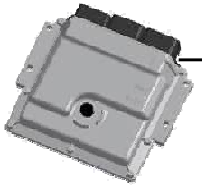
➔ ***Estimated weight: 3kg***





Vehicle implementation

Engine & Powertrain Control Unit

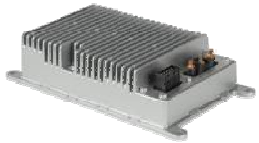


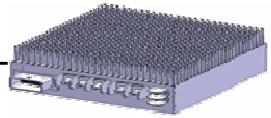
Energy Storage

BSG

e-machine

DC/DC Converter



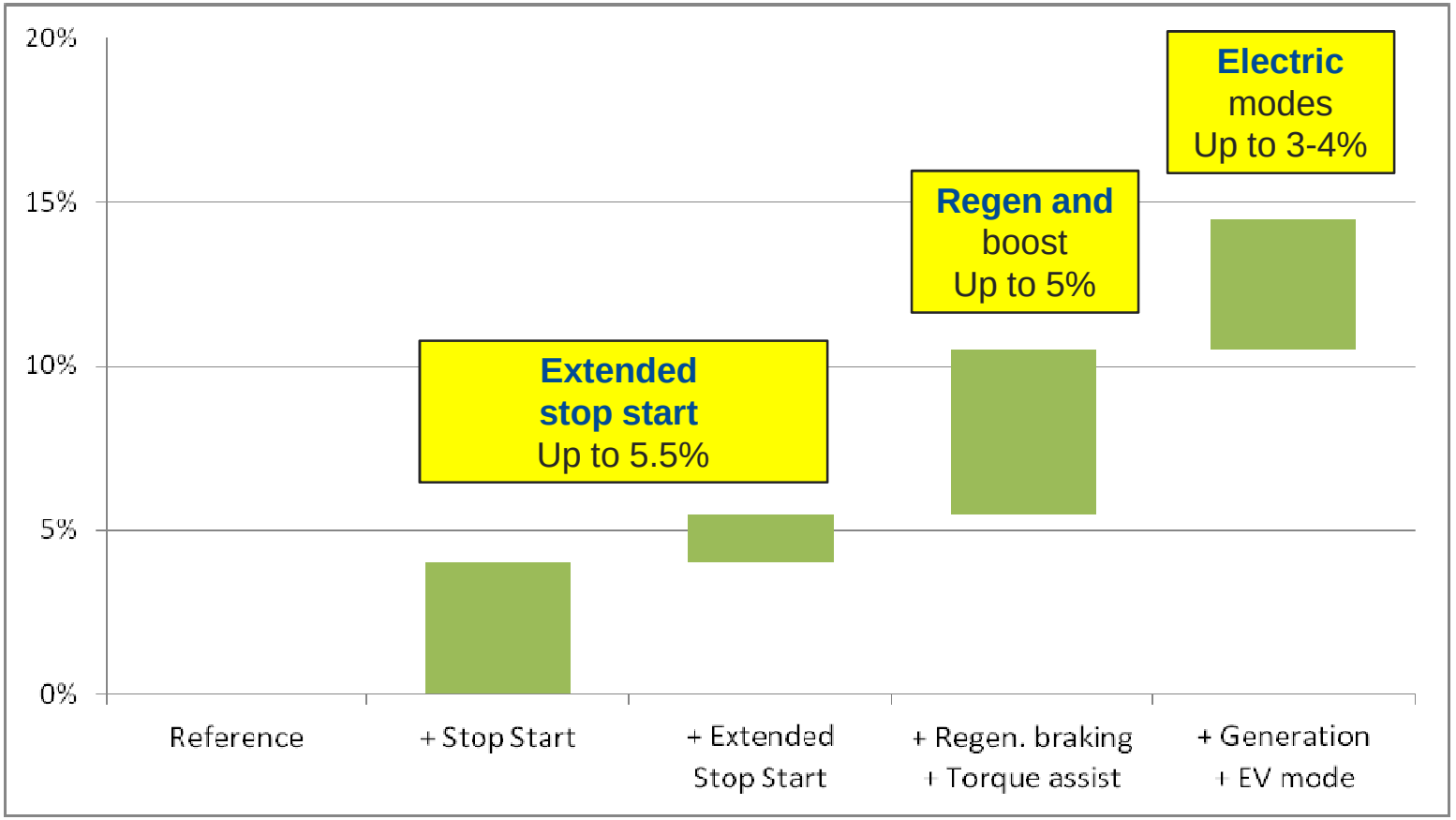


Inverter

Demonstrator : BSG implementation on 1,6l Turbo GDI M/T : i-BSG integration scheduled

Fuel economy results

Simulation results on NEDC cycle
B segment vehicle



13- 15% Fuel economy can be achieved

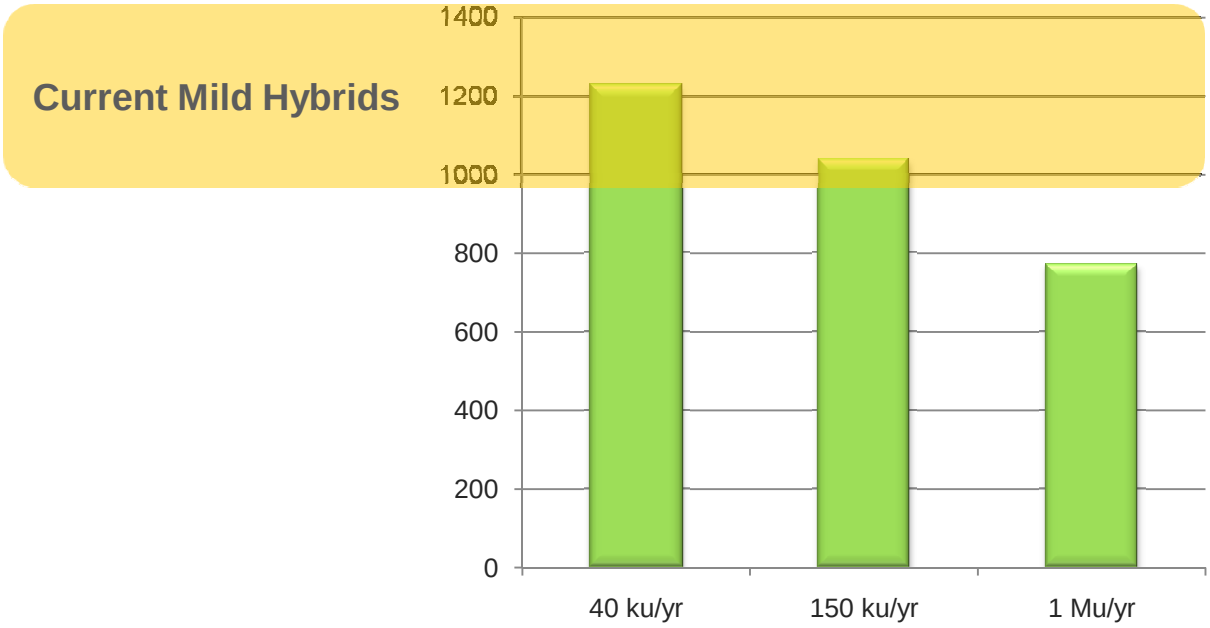
Vehicle assessment

- Stop Start extended function
  - Faster starting with BSG machine than starter / starter generator
  - Very low vibration level and silent cranking
  - Capability of Reflex start & coasting up to 70kph
  - Excellent Engine stop assistance : -70% stop time & oscillation
- Torque assist
  - Transparent to the driver,
  - Turbolag compensation at low revs
- Electric mode in running & take Off conditions
  - Transparent switch from thermal to electric mode even in take off
  - Up to 30kph electric drive possible in steady state conditions, up to 20% driving time in city conditions

Overall excellent driveability

Cost estimate

- Total system cost estimate (Machine, Inverter, Battery, DCDC and ancilliaries) in €
- Production volume sensitivity with projection up to 1 Mu/yr.



The value equation turns very positive with mass production volumes, in the 40€/g CO_2 range

Agenda

1 Market Analysis

2 Main issues of Hybrid / Electric vehicles

3 Simulation approach

4 Valeo Components

5 **Conclusions**

Conclusion

- A 48V mild hybrid system can deliver 13 - 15% fuel economy
- A 48V system allows, through rightsizing of the storage element, to cut cost of current mild hybrids by half
- This is why we believe mild hybrids could go to mass-market and reach a 10-12% WW market shares in 2020 .

Thank you

Automotive technology, naturally