INVESTIGATIONS ON REAL WORLD FUEL CONSUMPTION REDUCTION POTENTIAL OF HYBRID ELECTRIC AND CONVENTIONAL POWERTRAIN AND VEHICLES USING A DEDICATED SIMULATION PLATFORM

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GROUPE RENAULT

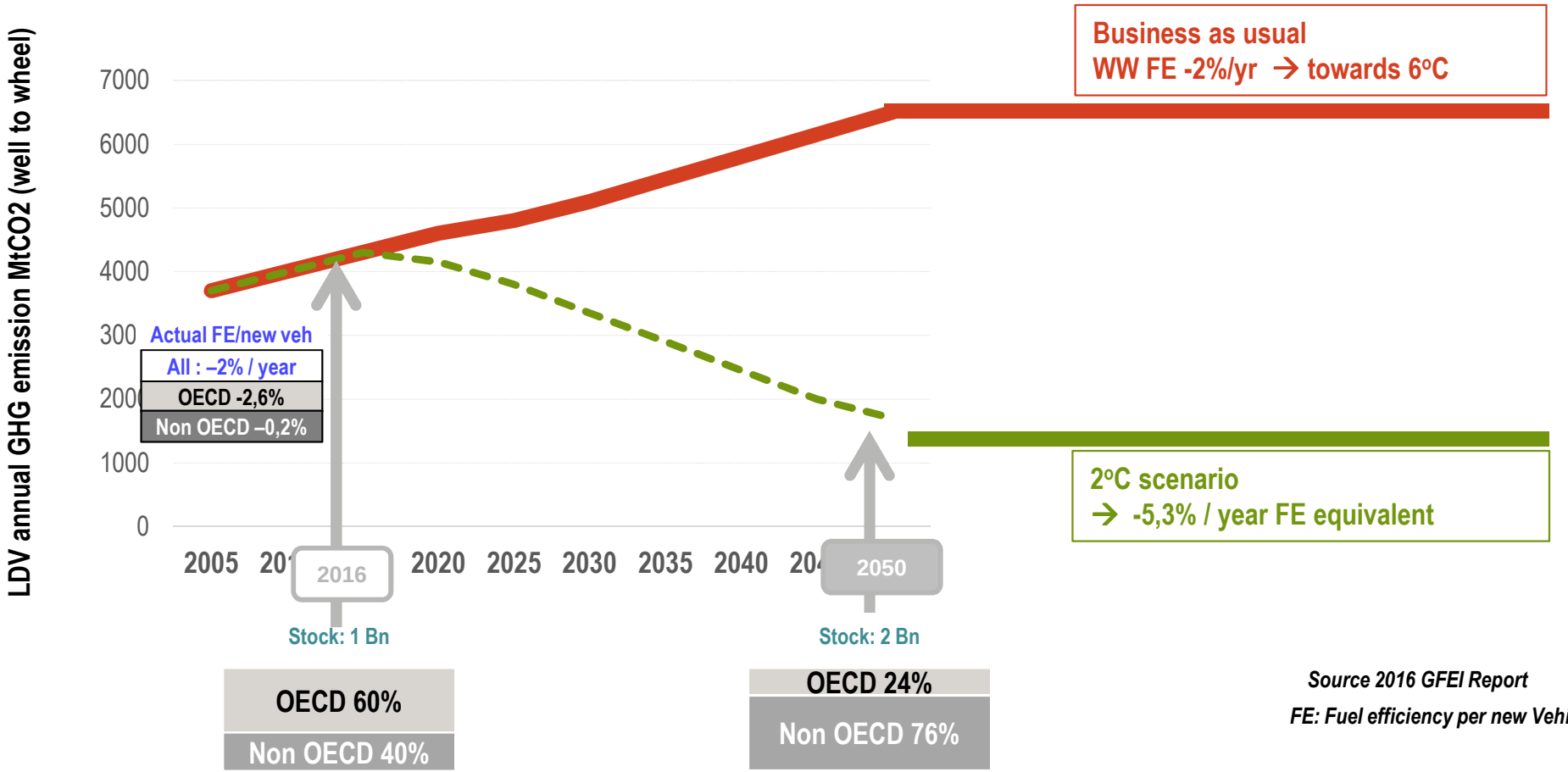
AGENDA

01

MANY CHALLENGES AHEAD

1- CO2 Emissions

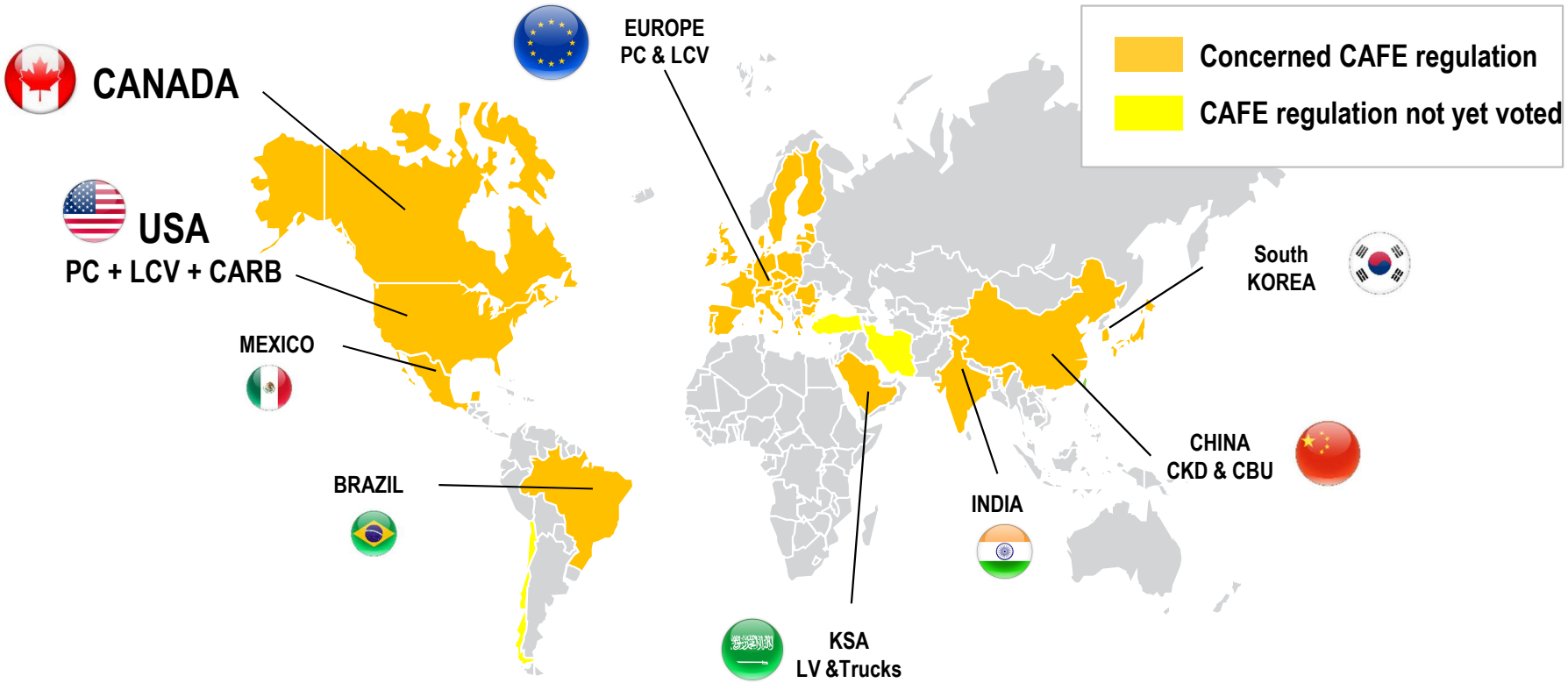
GFEI 2016 REPORT (COP21)



Source 2016 GFEI Report

FE: Fuel efficiency per new Vehicle

WORLDWIDE VIEW OF CO2 / FC REGULATION

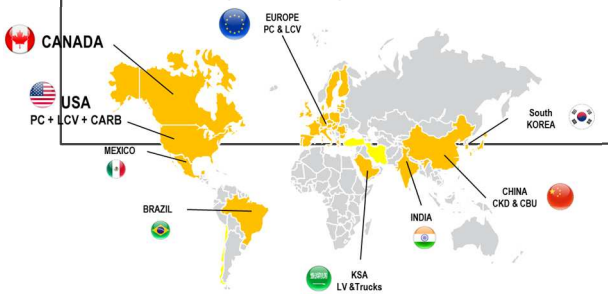


CAFE STANDARDS EVOLUTION

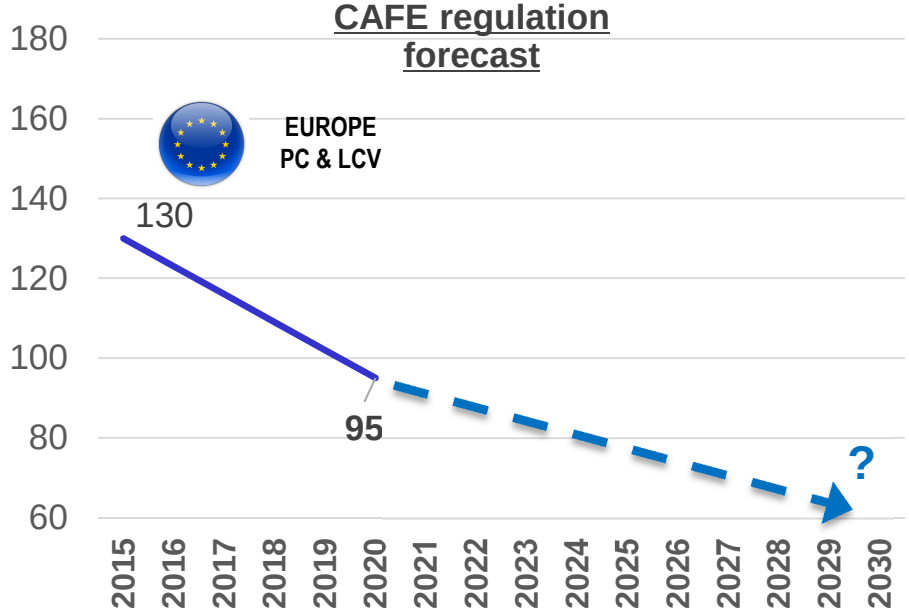
CAFE standards evolution

Actual regulation

Zone	Year	CAFE
Europe	2021	95
NAFTA *(PC + LT)*	2025	117
China	2020	120
India	2022	113
Brazil	2017-2019	**135**
Korea	2020	97



CAFE regulation forecast

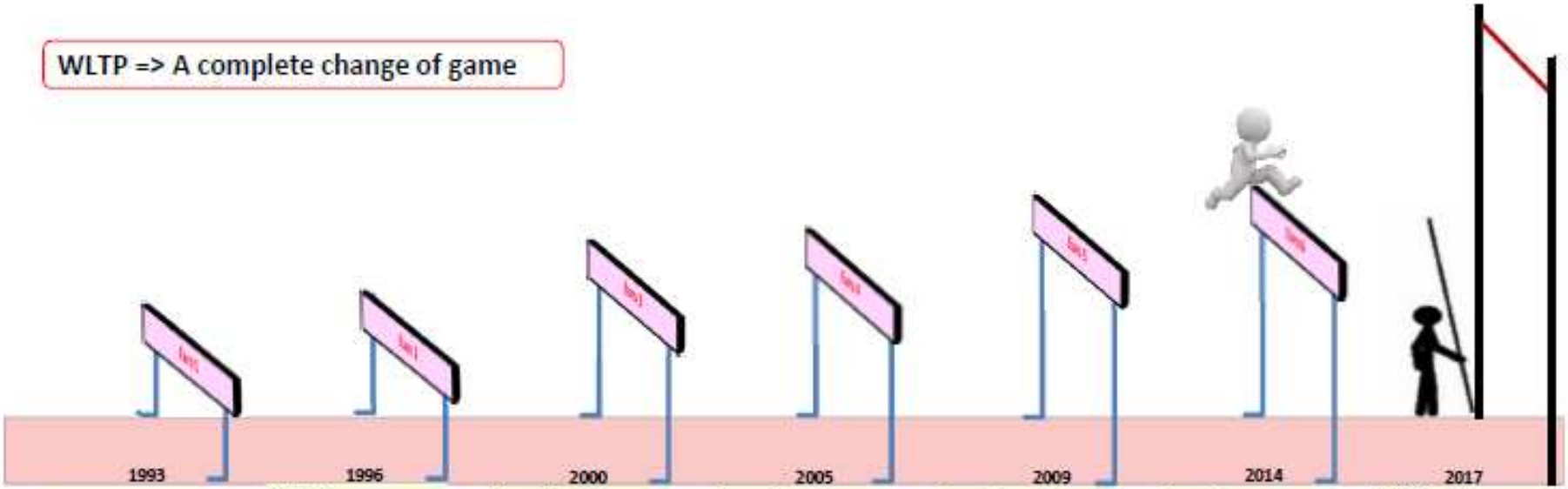


01

MANY CHALLENGES AHEAD

2- WLTP (Worldwide Light duty Vehicle Test Procedure)

WLTP : REDUCE GAP BETWEEN HOMOLOGATION AND REAL WORLD



Euro 1
- NEDC with 40 s
- Lower limits
- CO_2
- Evaporative emission

Euro 2
- New limits
- Tighter inertia weight class

Euro 3
- NEDC w/o 40 s
- New limits
- OBD
- -7° C test
- New evap test
- In-use
-

Euro 4
- New limits
- In-use 100k km

Euro 5
- New limits
- Durability 160k km
- Part number
- IUPR

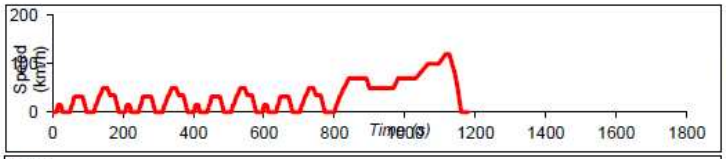
Euro 6
- New limits
- New OBD
- PN GDI
- ...

WLTP
- New drive cycle
- End of inertia class
- Increased test mass
- Additional test at 14° C
- .....

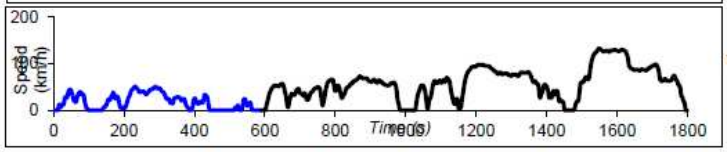
WLTP VS NEDC

Cycle Definition

	NEDC	WLTC
Duration [s]	1180	1800
Distance [km]	11	23,26
Stop time [%]	23	13
Average speed [km/h]	33,6	46,5
Max speed [km/h]	120	131,3
Acceleration [m/s²]	-1,4 – 1.0	-1,5 – 1.6



NEDC



WLTC

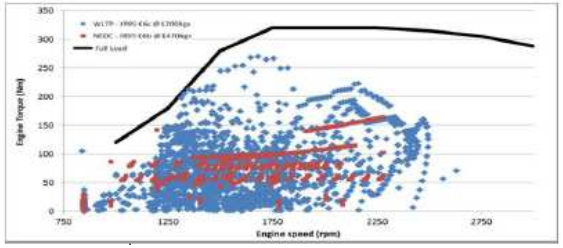
Procedure

Gear shifting	imposed	variable (GSI like)
Battery load	free	Iso SOC
Test temp.	~25° C	~14° C
COP margin	8%	2~4%
Vehicle data :Mass /Scx/ Tyres / brakes :	Flexible (I. class)	Imposed (close to real)

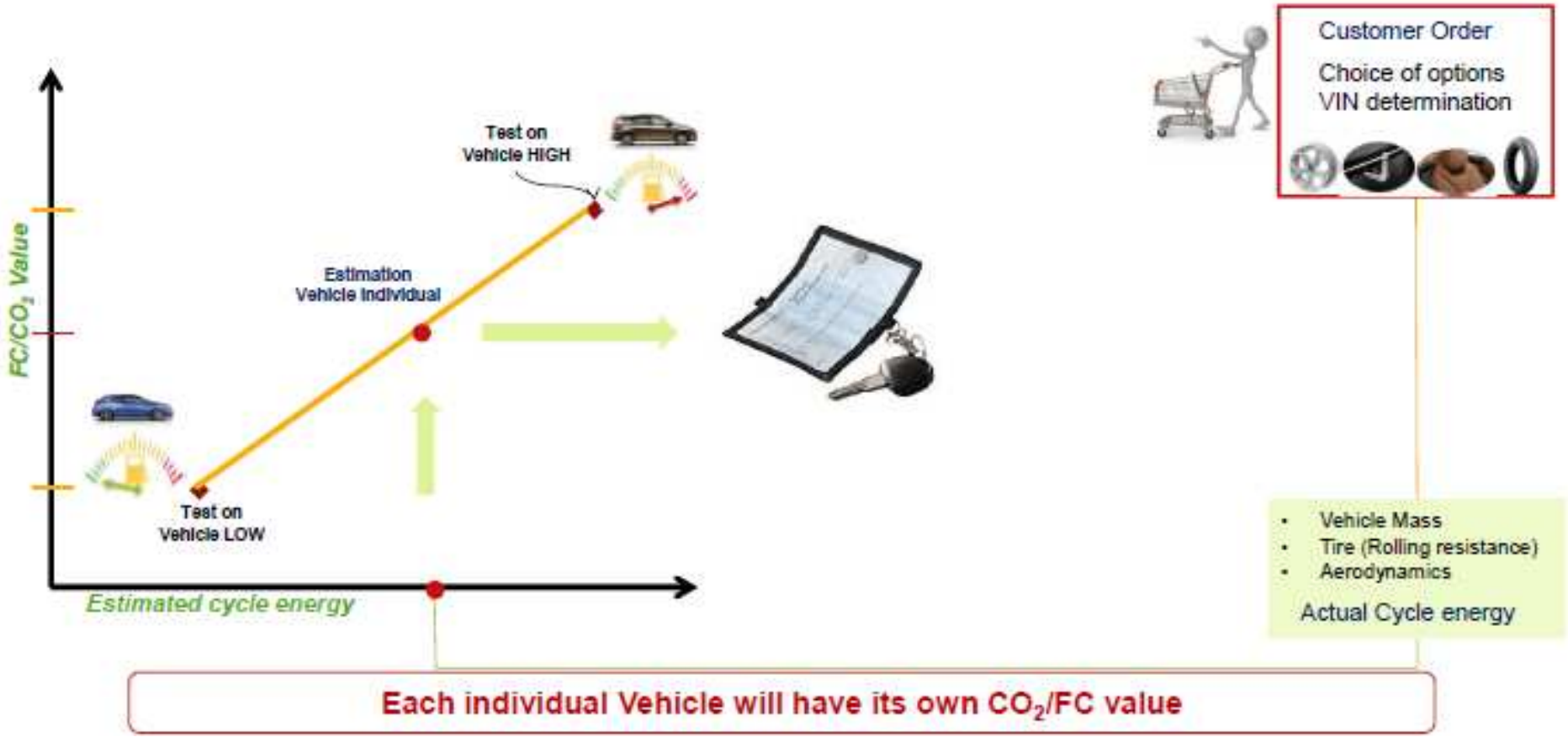
Impact

	Cycle		*Procedure*	
	NEDC	=> WLTC	WLTP Veh. Low	WLTP Veh. High
Energy MJ/km	ref	~ +20%	~ +35%	~ +55%
F.E. gCO2/km	ref	~ +3%	~ +16%	~ +24%

- more energy demands, higher vehicle speed
- engine operating at higher load, less idle



CO2 / FUEL CONSUMPTION FOR INDIVIDUAL VEHICLE

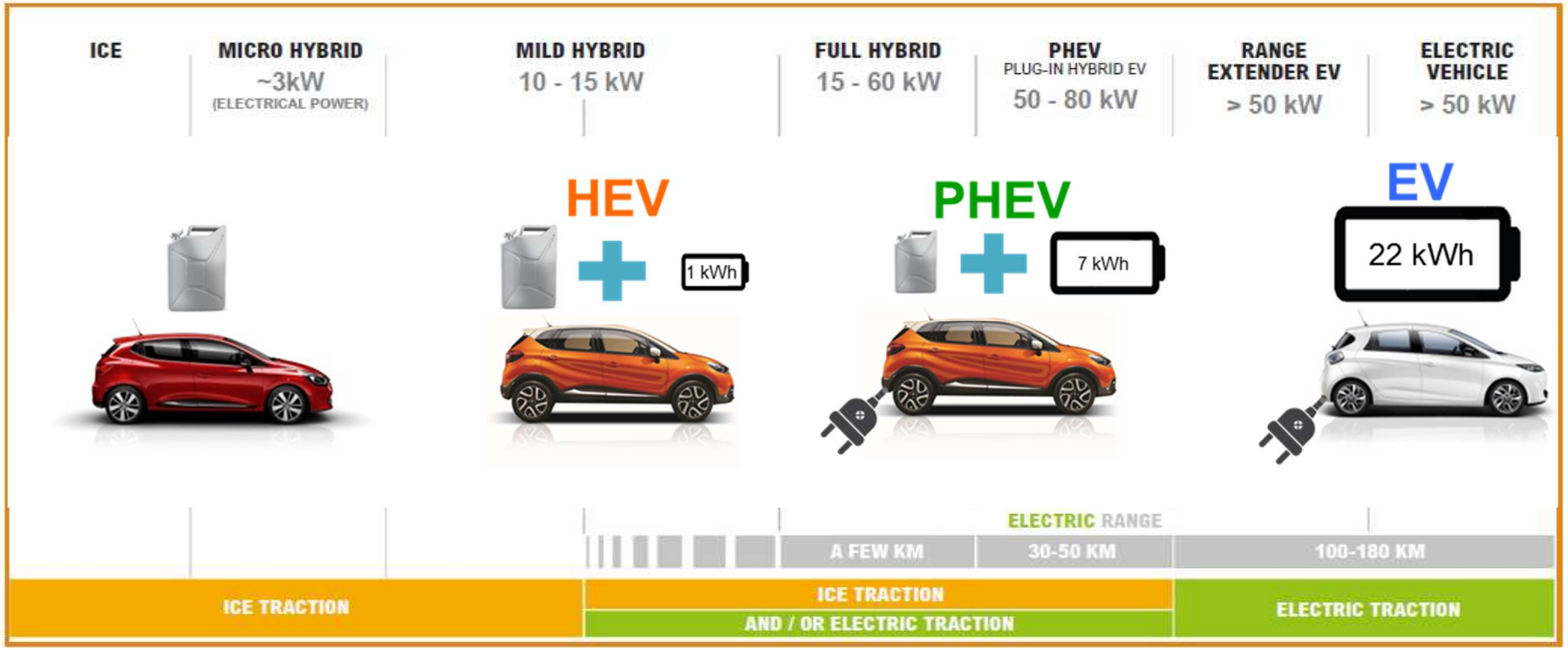


01

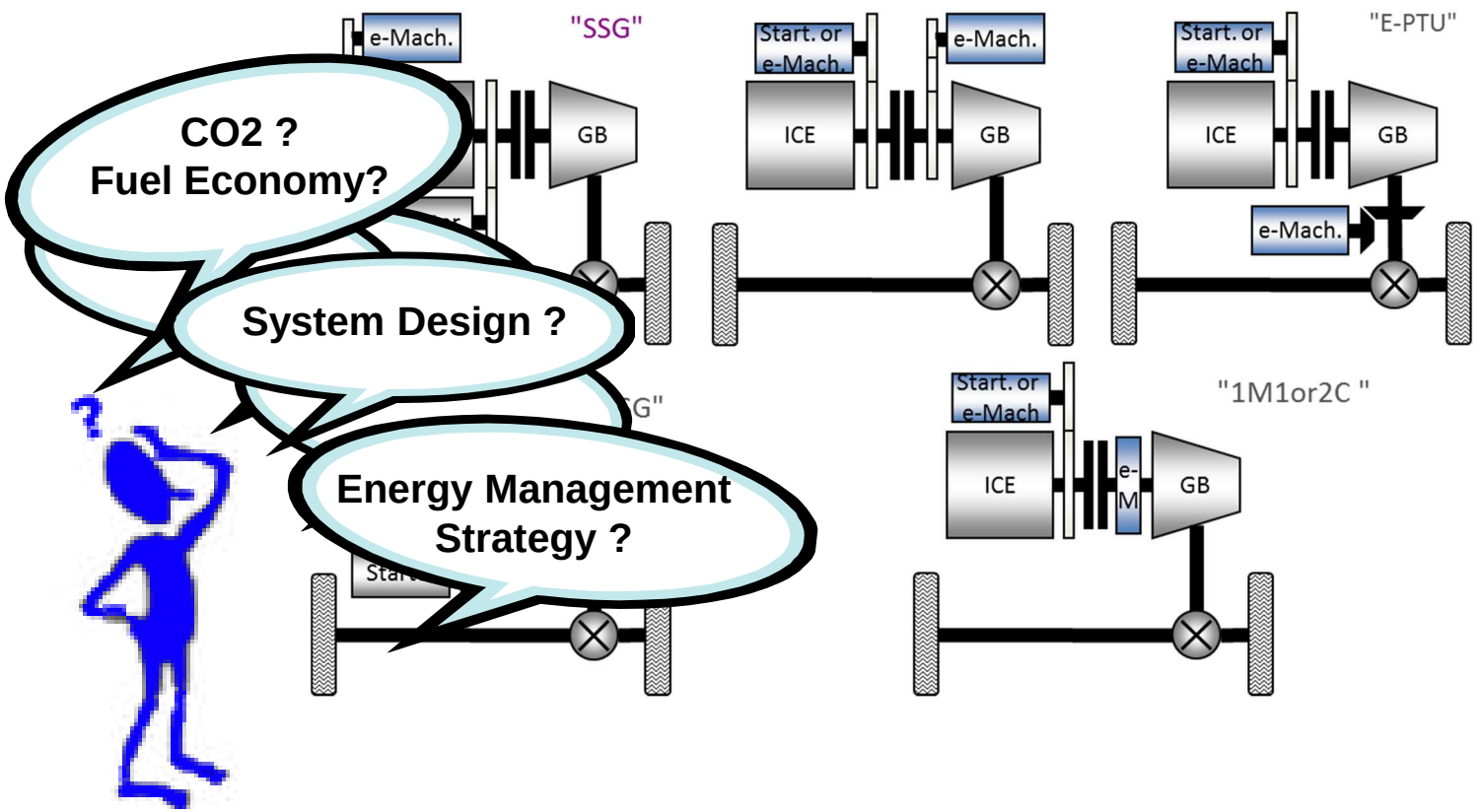
MANY CHALLENGES AHEAD

3- Vehicle Electrification

HYBRID AND ELECTRIC POWERTRAINS ARE MANDATORY TO REACH CO_2 GOALS



DILEMMA OF HYBRID ARCHITECTURE



New Projects

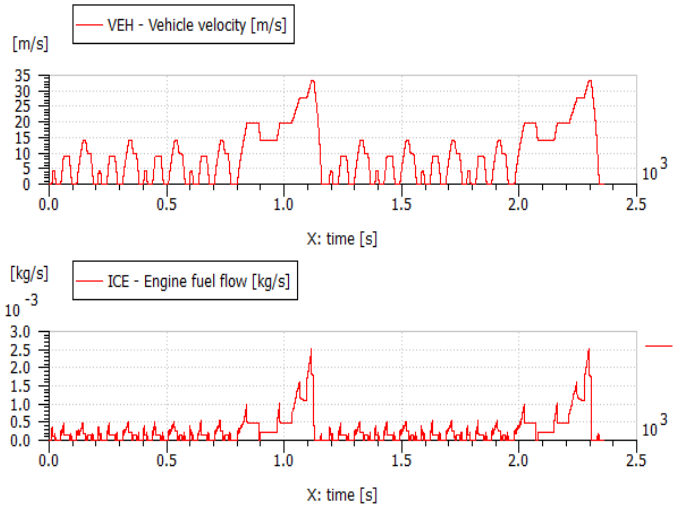
02

SIMULATION OF FUEL CONSUMPTION AND CO2 EMISSIONS

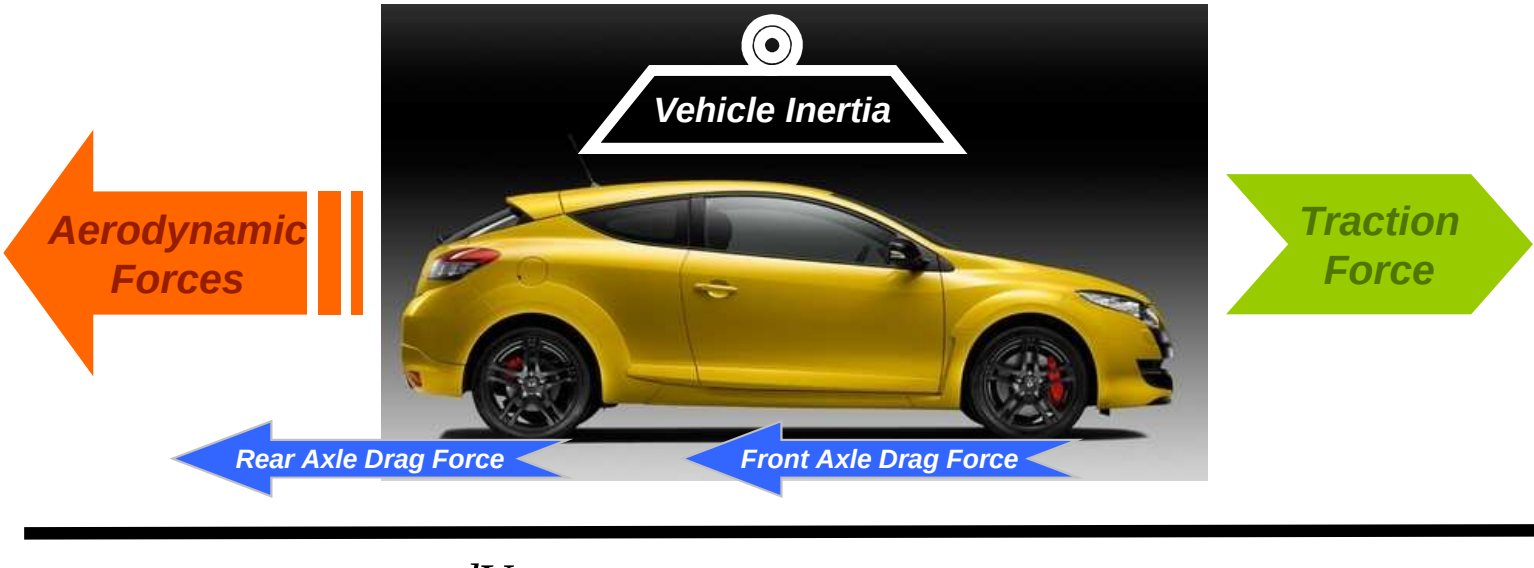
Why, how, when

WHY SIMULATE FUEL CONSUMPTION ?

- **Support early phase design : optimal technical definition and architecture (cost, fuel efficiency …)**
- **Secure vehicle project development time**
- **Reduce project cost (avoid tests and late component change)**
- **Ability to simulate lots of combinations of vehicles / engine / gearboxes : upstream and development / validation phase**
- **Forecast CAFE Values (Product Planning)**



HOW TO SIMULATE FUEL CONSUMPTION

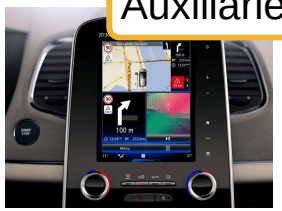


$$M_{Vehicle} * \frac{dV}{dt} = F_{Traction} - F_{Aero} - F_{Front\_Axle} - F_{Rear\_Axle}$$

+ « Forward » Simulation from driver to wheels

WHAT IS NEEDED TO SIMULATE FUEL CONSUMPTION

Auxiliaries



Battery (14V, 48V, 400V,…)

Driver model

Control

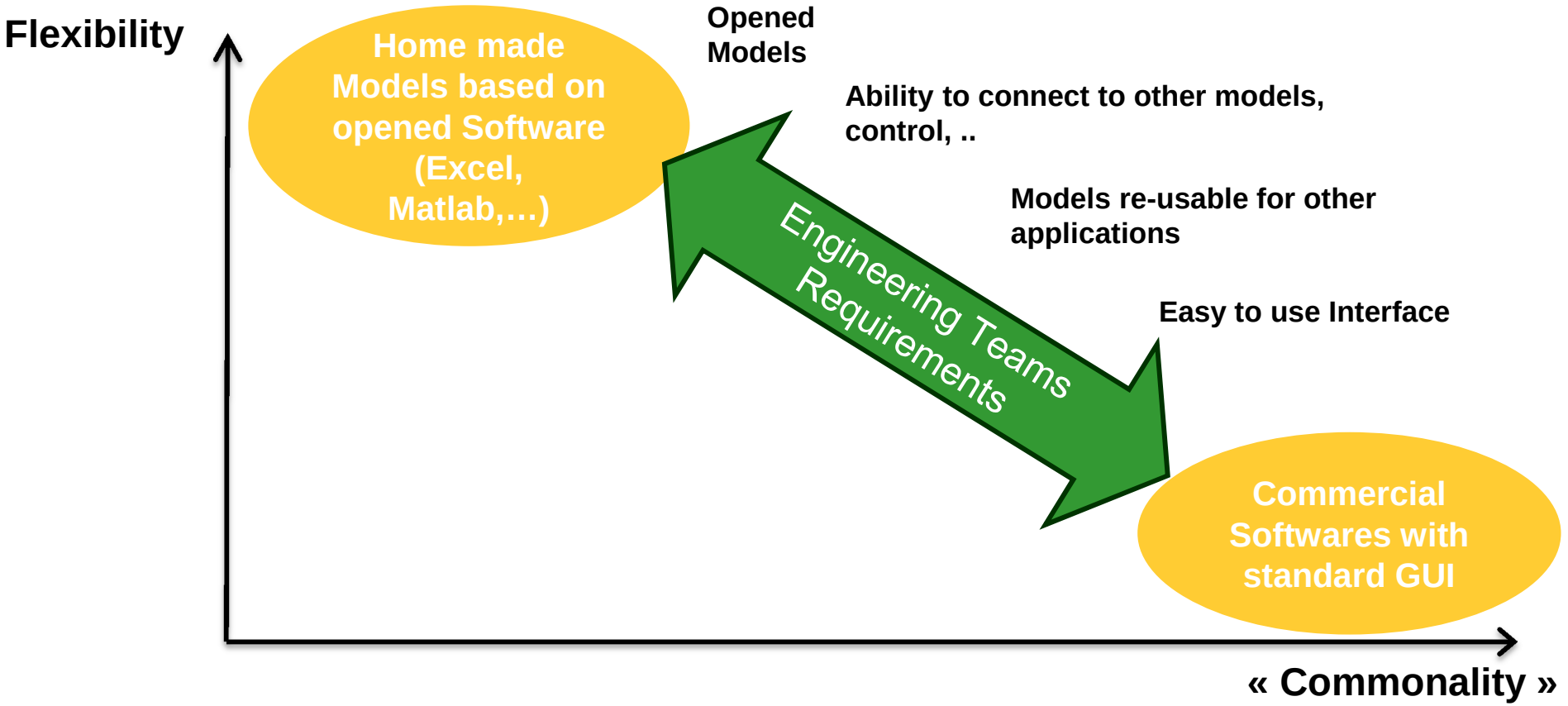
Engine, e-motors

Aerodynamics

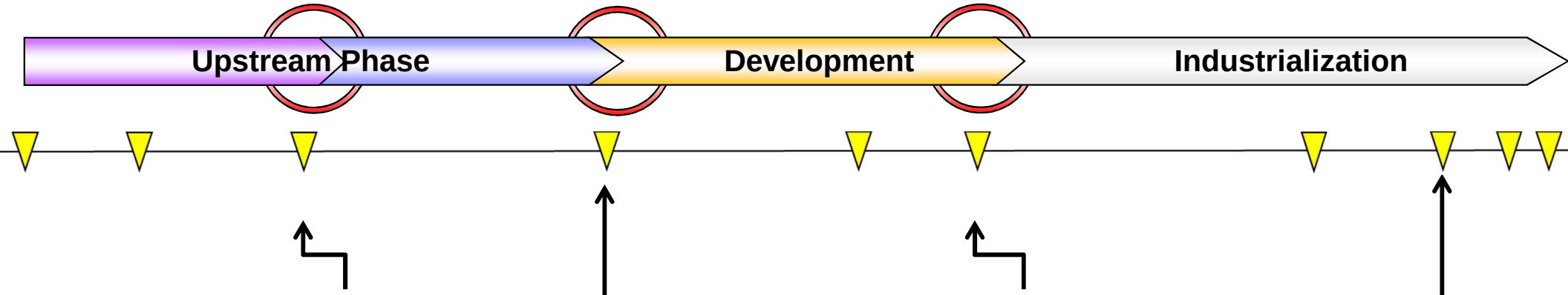
Tire friction

Gearbox

REQUIREMENTS FROM ENGINEERING TEAMS



WHEN IS IT USED IN VEHICLE PROJECTS ?



- Hybrid Powertrain Architecture Definition
- Fuel Economy and CO2 Requirements
- Subsystem and Components Early Phase Design

- Fuel Economy and CO2 Requirements Convergence
- Sensitivity / Robustness Analysis

03

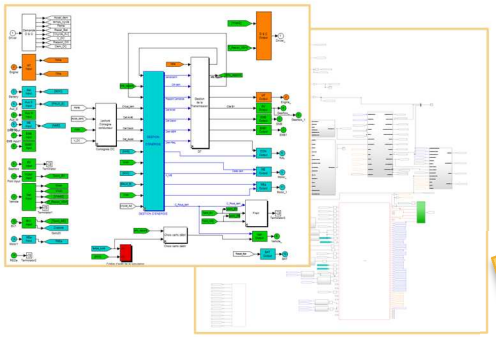
DEDICATED SIMULATION PLATFORM

GREEN

03 DEDICATED SIMULATION PLATFORM

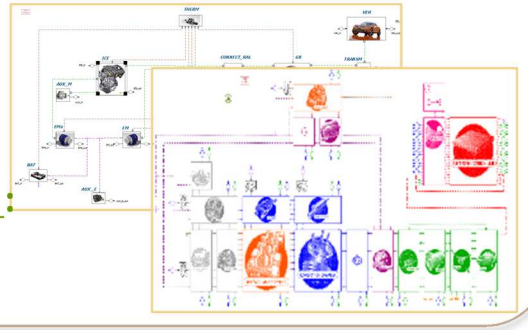
« GREEN » SOFTWARE ARCHITECTURE

Control :
Matlab-Simulink



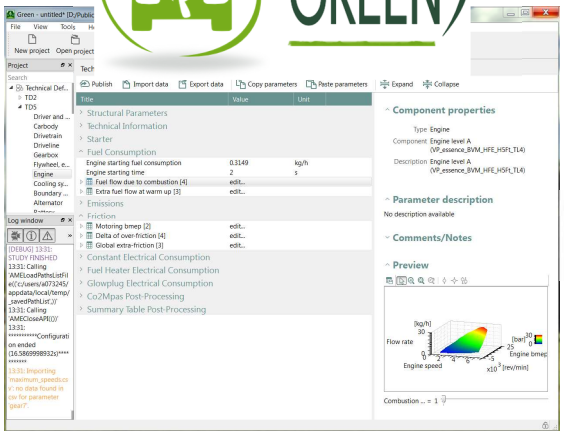
Co-simulation

Physical models :
Amesim



RENAULT-NISSAN GREEN

HMI :
Python



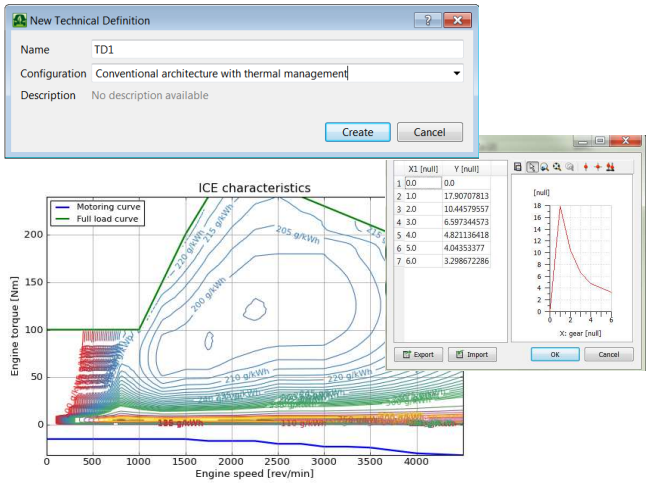
Scripts :
Several code

SIEMENS Ingenuity for life

PE RENAULT

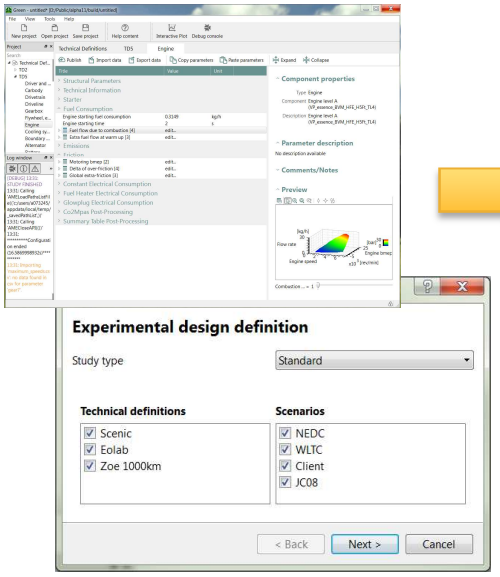
GREEN USAGE

Choose powertrain architecture, Input data, pre processing



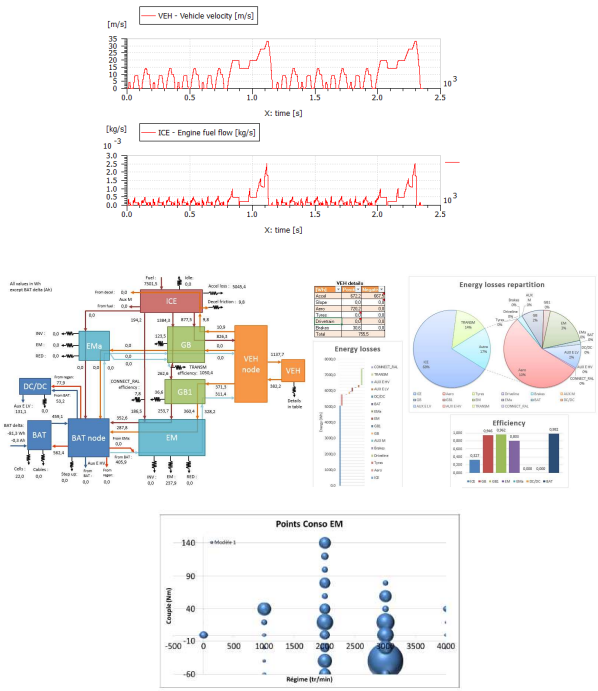
Air drag, tire resistance, ICE fuel flow map, ICE limits, GB losses, GB ratios, Control parameters, …

Choose scenarios and design of experiment, run simulation



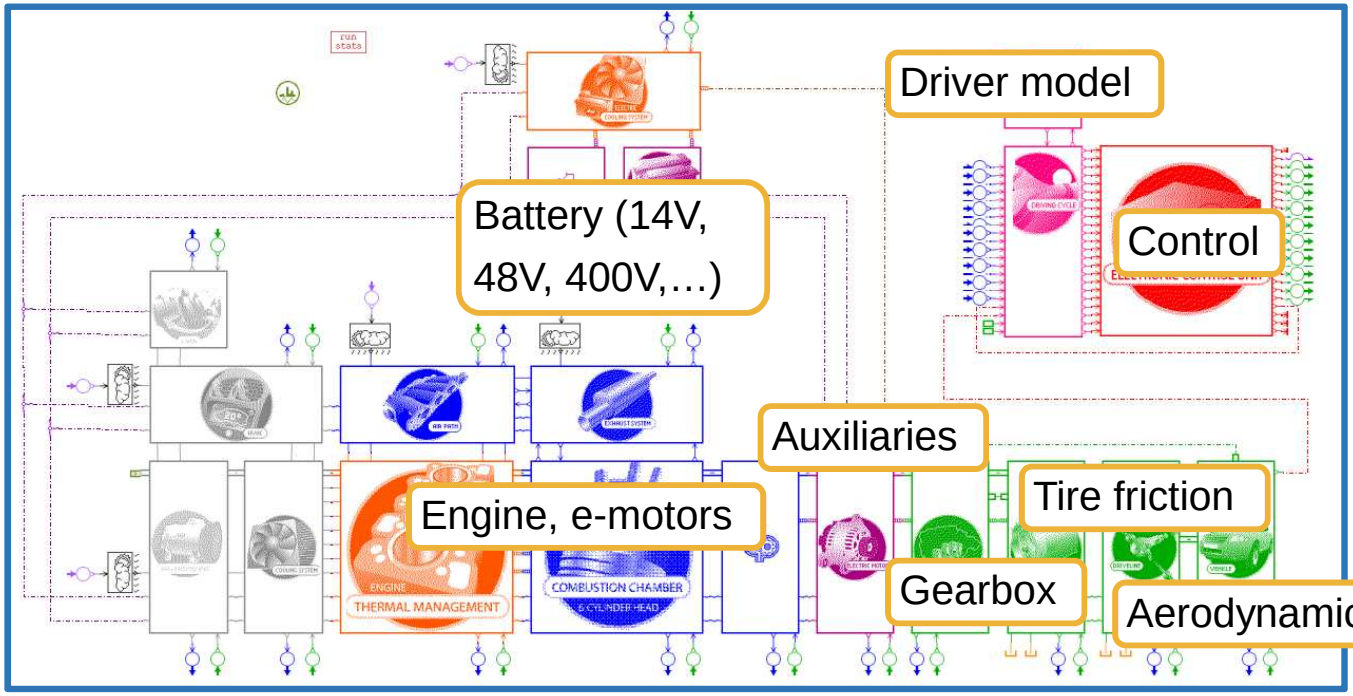
Associate technical definition with drive requests / scenarios

Outputs, Post processing



Temporal plots, energy flow, energy repartitions, synthesis table, …

OVERVIEW OF MODEL ARCHITECTURE



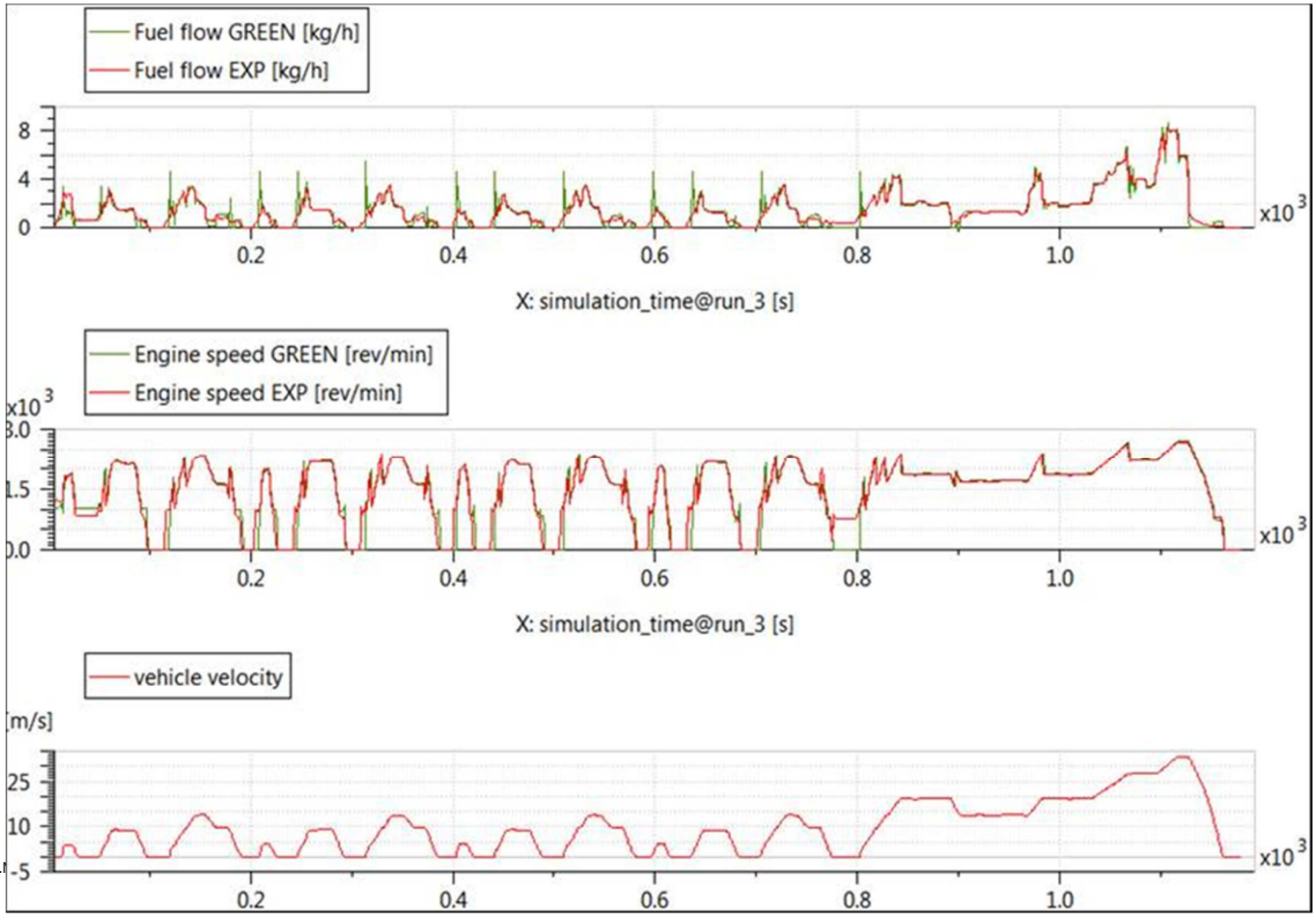
For Simulation of Fuel Consumption:
-> Mainly map-based models (« level A »)
-> Over 100 parameters (scalar or xD maps)

VALIDATION AGAINST EXPERIMENTAL DATA

1.2l Tce (Turbo GDI; Manual Transm.)

NEDC measurement : 5,79 l/100 km

GREEN Simulation Result : 5,75 l/100 km

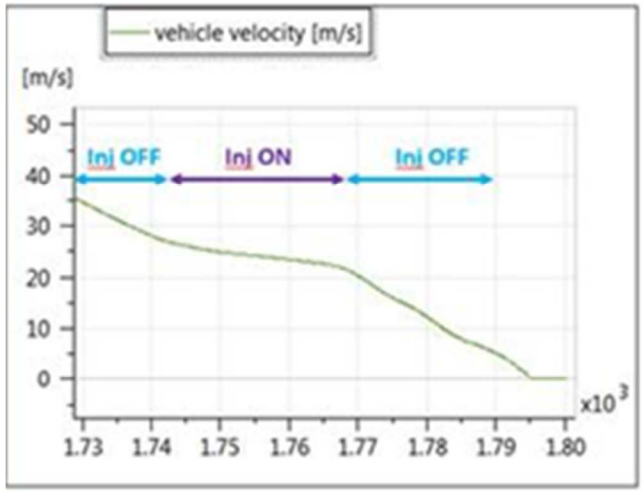


04

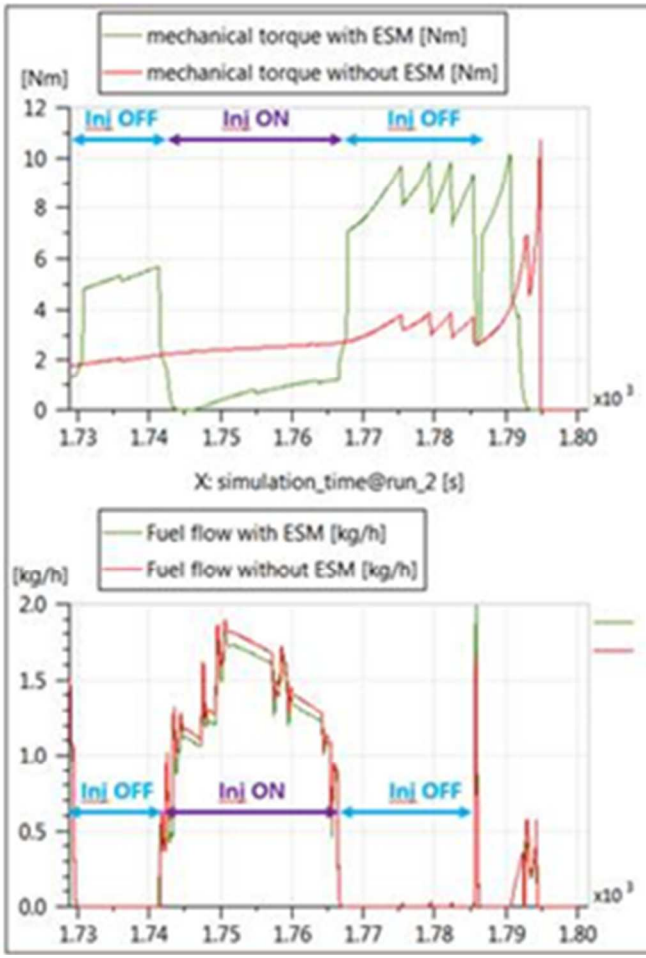
APPLICATIONS

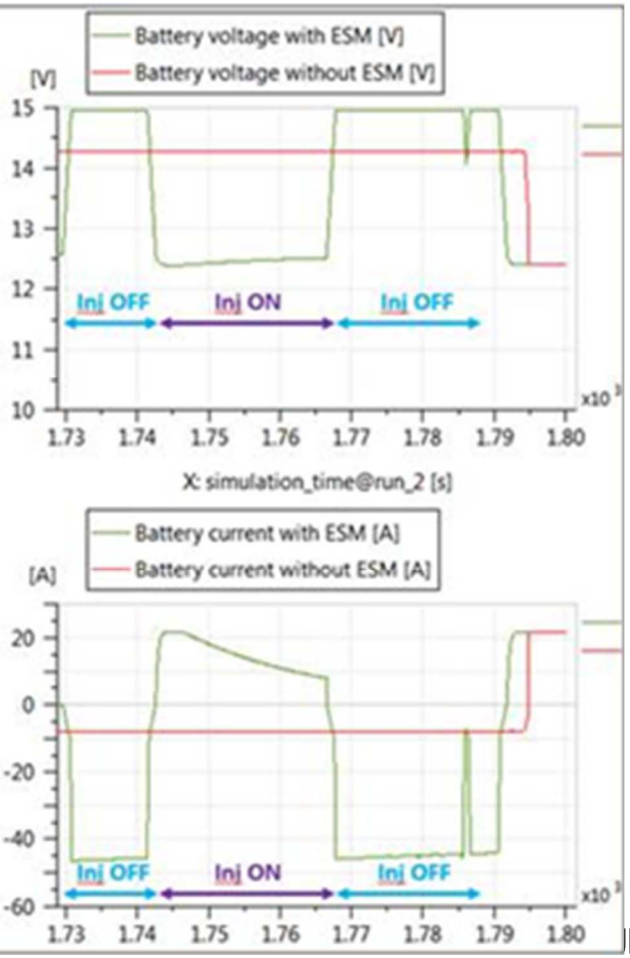
Conventional, Hybrid, E.V.

ENERGY SMART MANAGEMENT



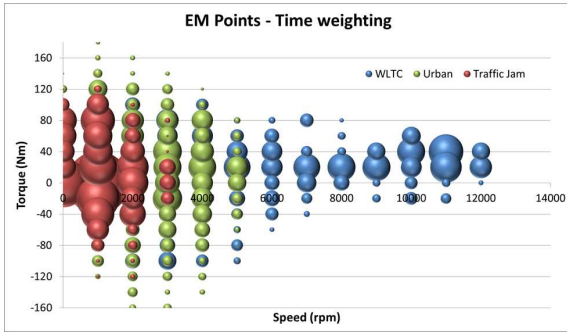
- When there is no fuel consumption, ESM allow maximum energy recovery.
- During powered phase, this energy is used and the alternator torque is lower (reduction of fuel consumption)

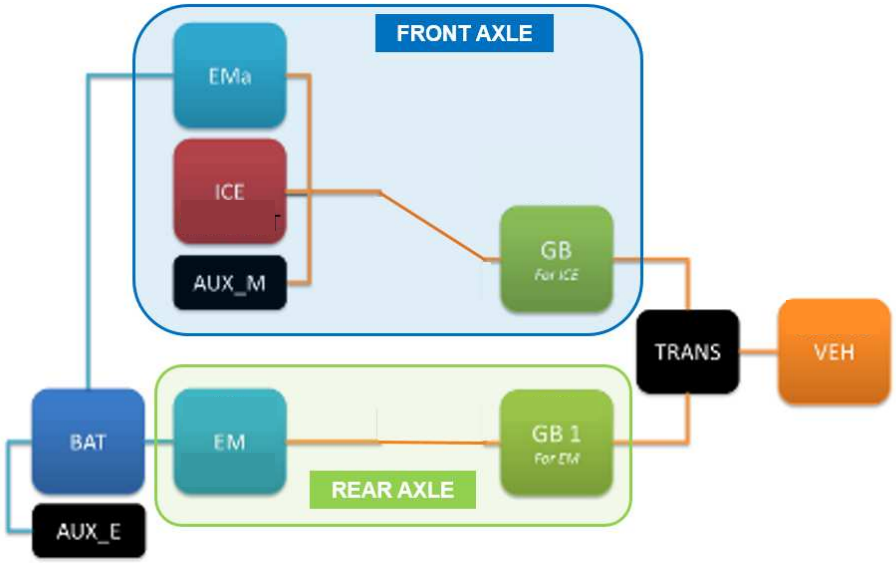


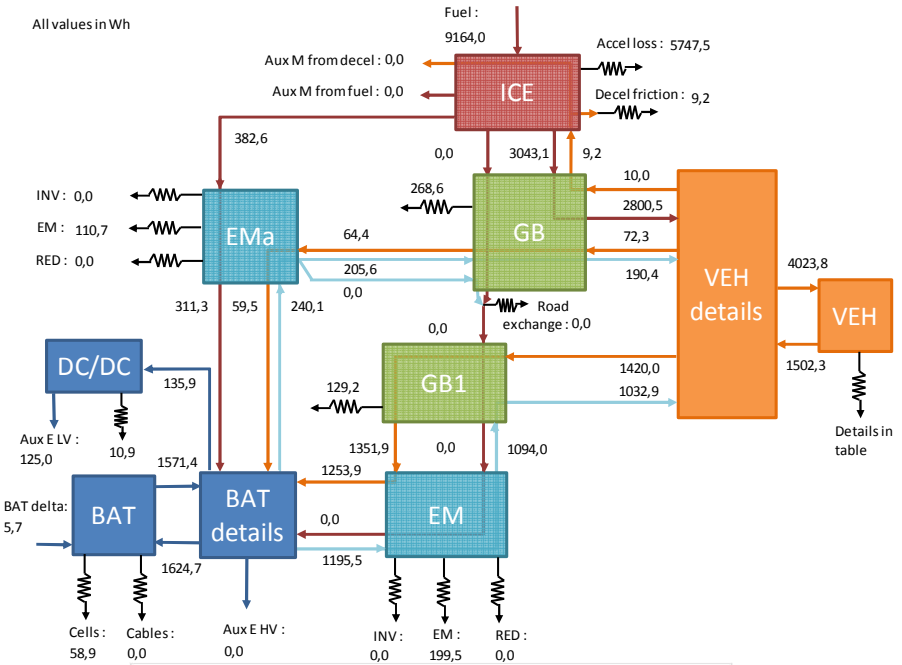


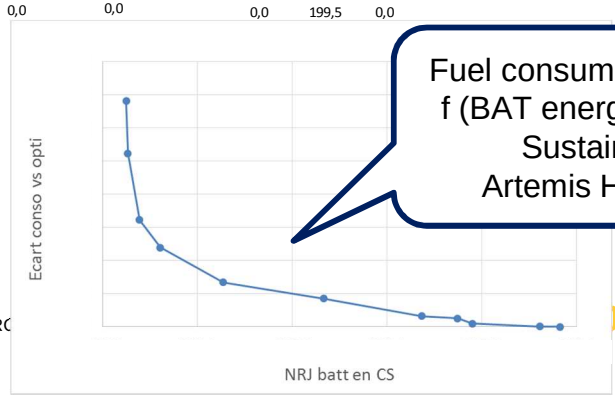
HYBRID POWERTRAIN DESIGN

Study case :
eAWD example



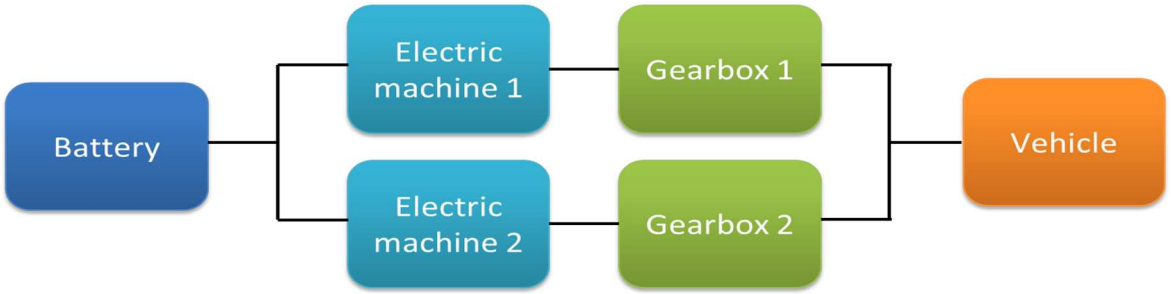






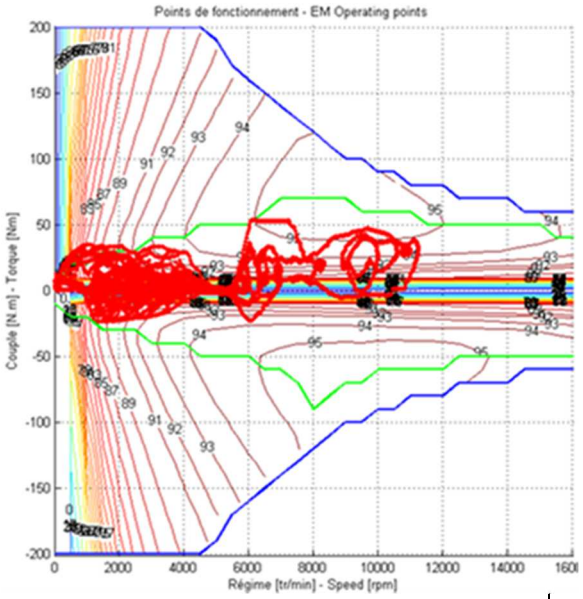
Fuel consumption gap = f (BAT energy in Cycle Sustaining)
Artemis Highway

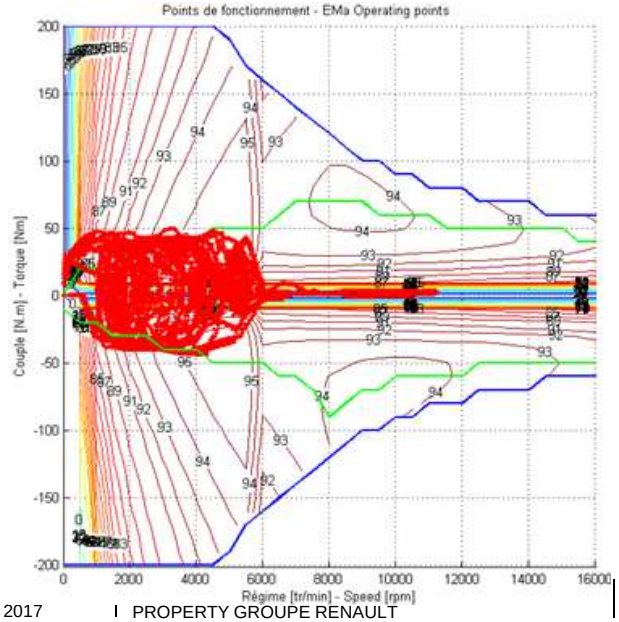
E.V. DESIGN

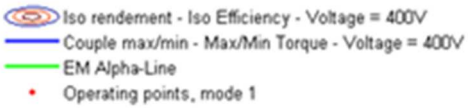


WLTC Cycle

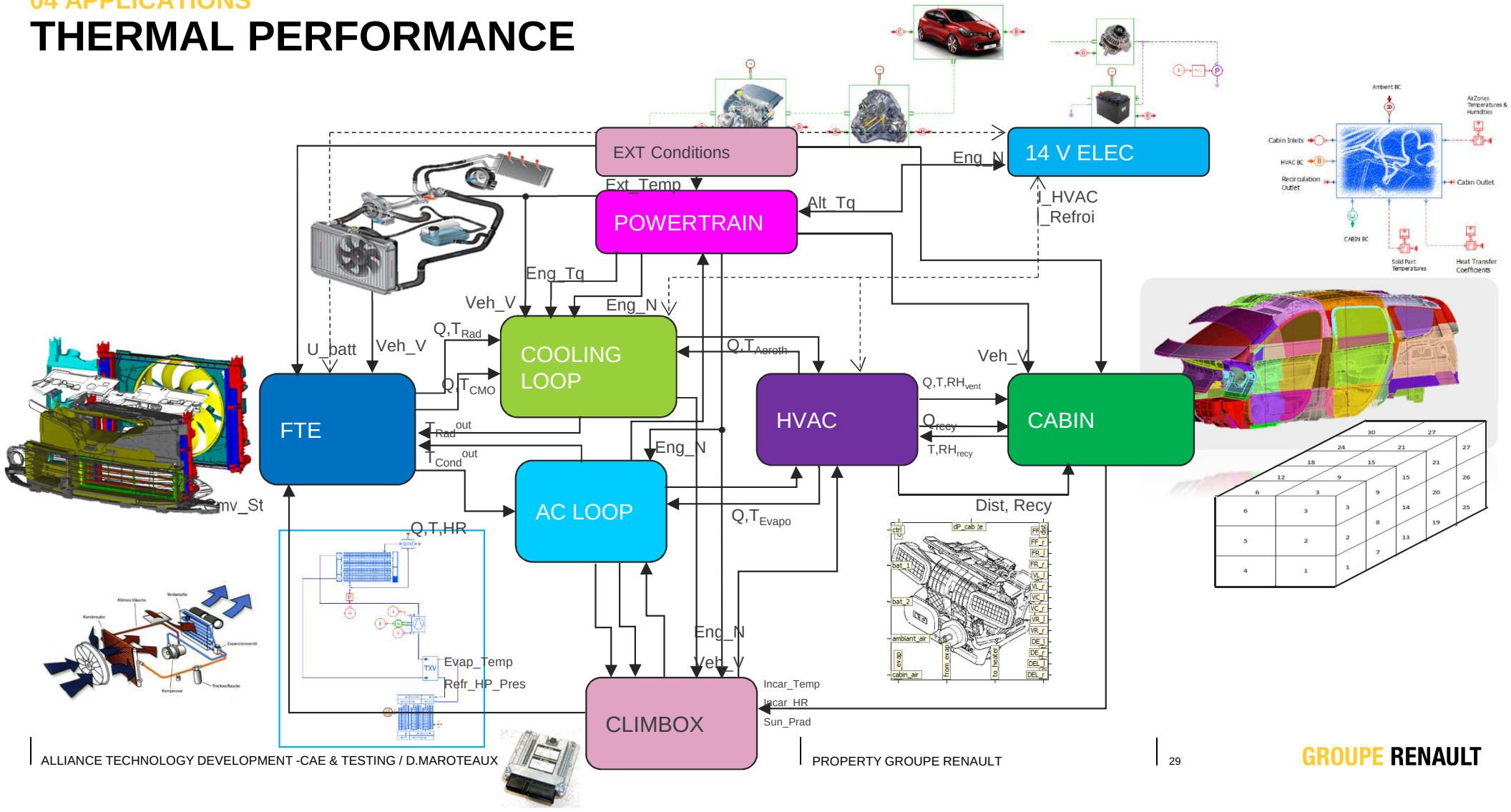
Architecture	Energy Consumption	Difference
Machine 1	16,1 kWh/100km	reference
Machine 2	16,2 kWh/100km	+ 0,6 %
Machine 1 & Machine 2	15,9 kWh/100km	- 1,2 %







THERMAL PERFORMANCE



05

PERSPECTIVES & FURTHER STEPS

Multi Performance, Real World

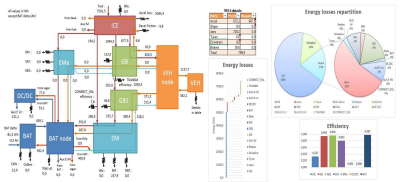
SUMMARY

Dedicated database management

RENAULT-NISSAN GREEN

One Alliance tool for fuel economy, and dynamic performance simulation

All architectures can be simulated



Improved workflow (pre/post processing, simulation time…)

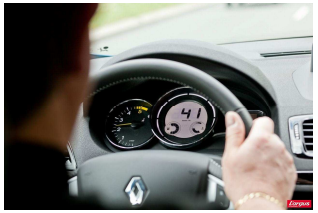
New tool adapted for new regulations

Flexible and easy to update

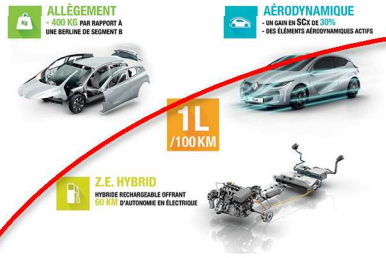
PERSPECTIVES

Multi attributes

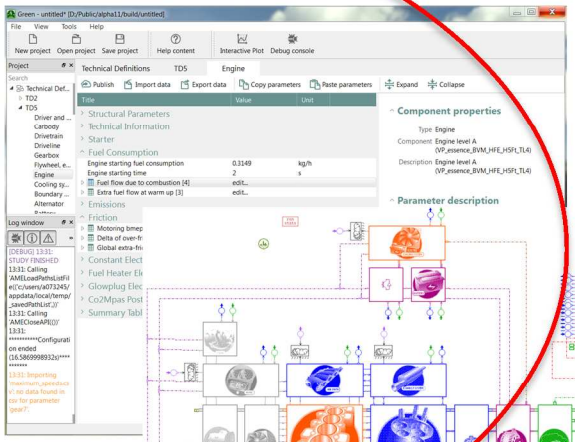
Emissions



Drivability

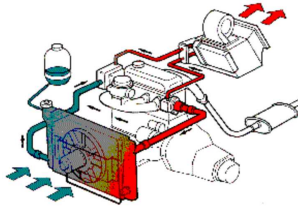


Fuel economy



Performance

Currently covered



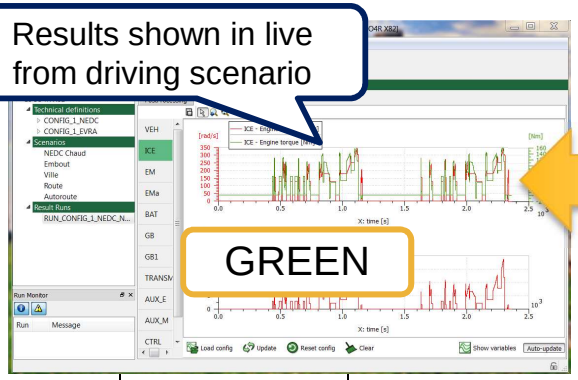
Thermal Performance

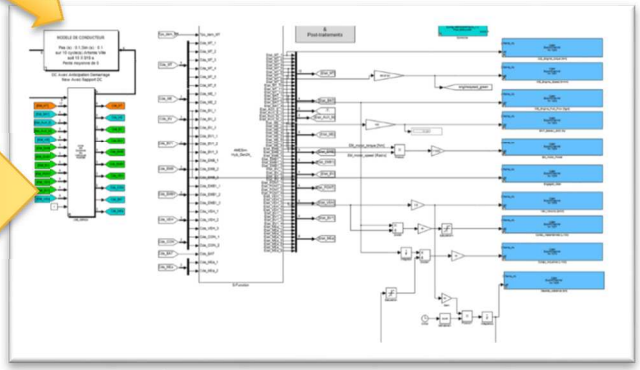
PERSPECTIVE: REAL WORLD

Can be used for driver in the loop simulation

- FE with ACC
- FE with sailing stop (traffic light, traffic jam, …)
- HMI test and validation (power display)

Results shown in live from driving scenario





THANK YOU