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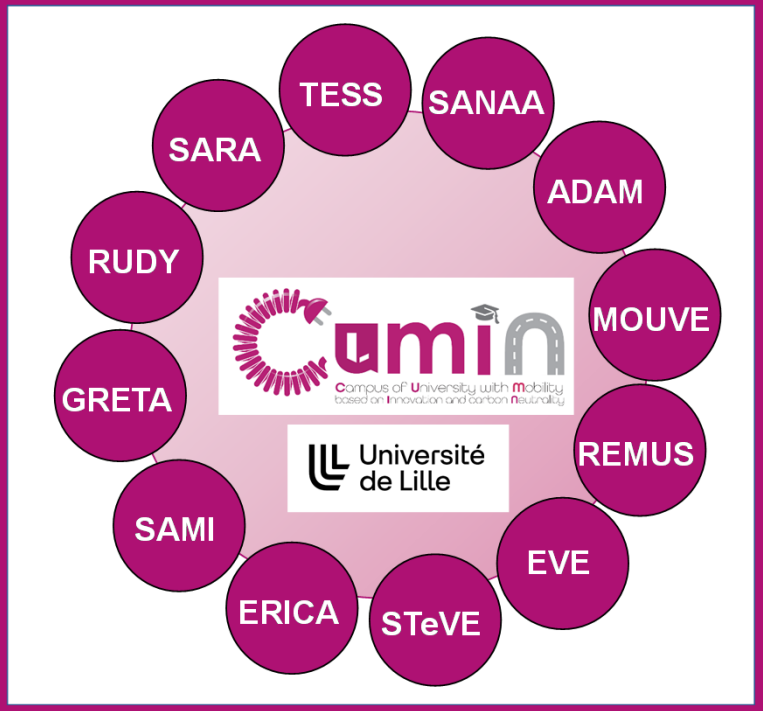

CUMIN – EVE / eCAMPUS

Energy consumption and GHG emissions of electric vehicles

Alain BOUSCAYROL
David RAMSEY
Anatole DESREVEAUX
Loïc BOULON
Elodie CASTEX
Eric HITTINGER
Gabriel SIRBU
Rochdi TRIGUI

Outline

1. EVE & driving conditions
2. EVE & climatic conditions
3. EVE & GHG emissions

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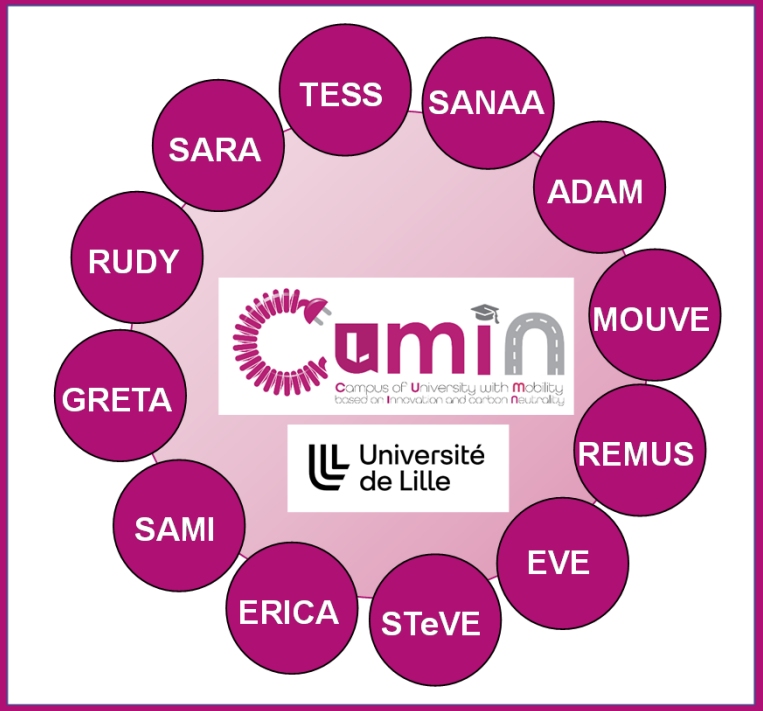


EVE & driving conditions

PhD A. Desreveaux

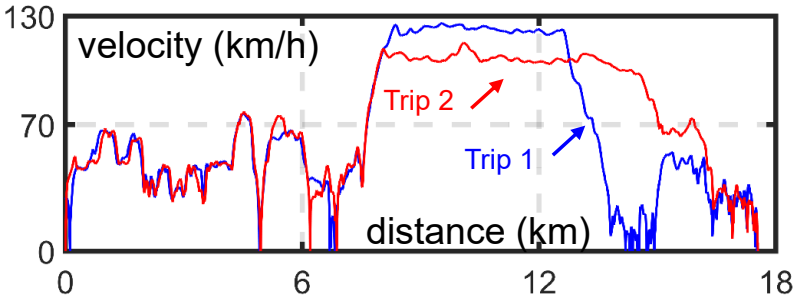
H2020 PANDA / EVE

Interest of digital models

Trip Campus – Baisieux 21 km
Trips measured with a Renault Zoé

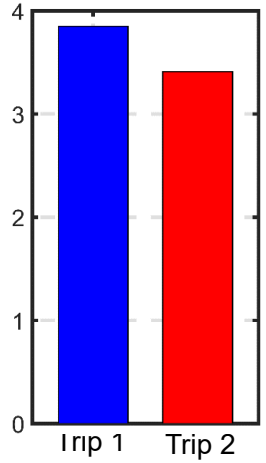
Realised with gpsvisualizer.com

measurements
on real vehicles



Impact of random conditions

Energy Consumption (kWh)



Difference : 13 %

Difficulty of reproducibility
Difficulty to decouple the different effects

Development of a digital model

Tazzari Zero

Université de Lille

1

$$J\frac{d}{dt}\Omega_{gear} = T_{dcm} - T_{gear} - f\Omega_{gear}$$

$$L_{arm}\frac{d}{dt}i_{dcm} = u_{chop} - e_{dcm} - R_{arm}i_{dcm}$$

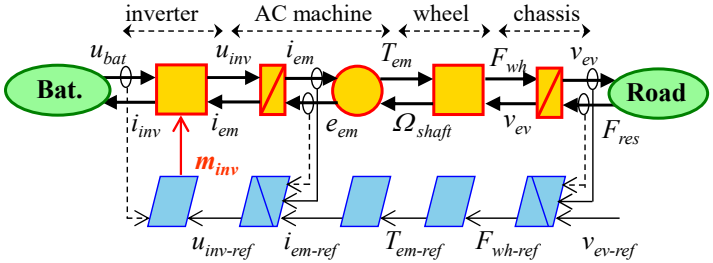
$$\begin{cases} u_{chop} = m_{chop}\, V_{bat} \\ i_{chop} = m_{chop}\, i_{dcm} \end{cases} \qquad \begin{cases} T_{dif} = k_{dif}\, T_{gear} \\ \Omega_{dif} = k_{dif}\, \Omega_{wh} \end{cases}$$

$$\begin{cases} T_{dcm} = k_{dcm} i_{dcm} \\ e_{dcm} = k_{dcm}\Omega_{gear} \end{cases} \qquad \begin{cases} T_{gear} = k_{gear}\, T_{dcm} \\ \Omega_{gear} = k_{gear}\, \Omega_{diff} \end{cases}$$

$$M\frac{d}{dt}v_{ev} = F_{tot} - F_{res}$$

modelling equations

2

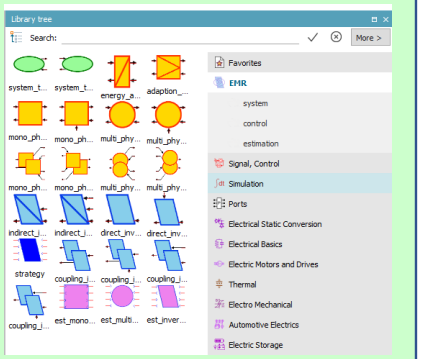


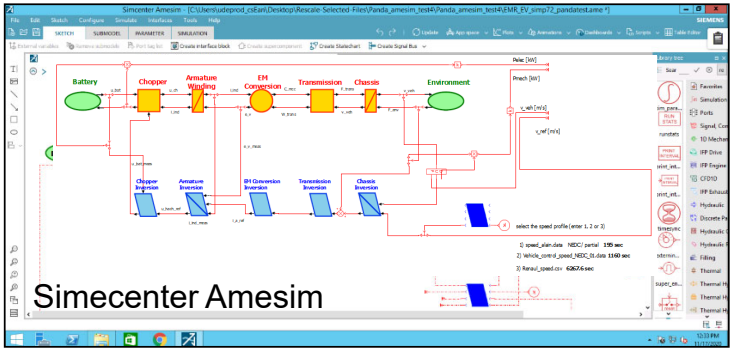
model & control organization using EMR

3

New EMR library Simcenter Amesim

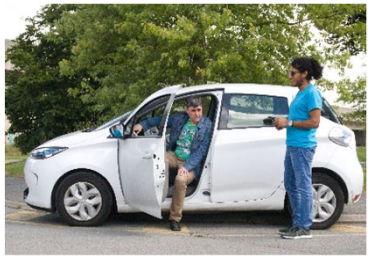
SIEMENS





Digital model

Digital Model & validation

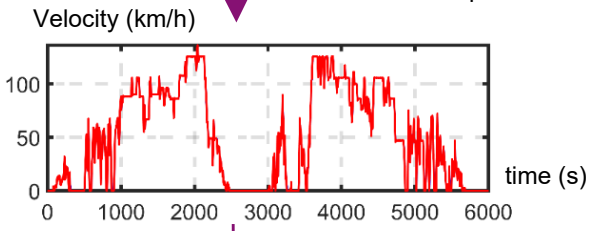


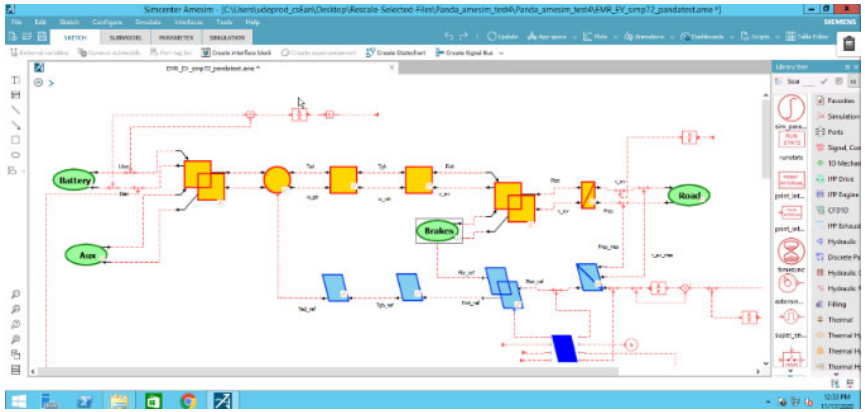
GROUPE RENAULT

measurements

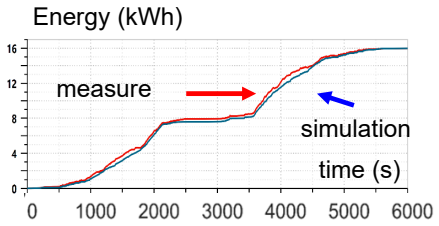
Extra-urban real driving cycle

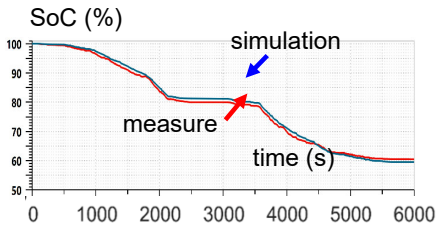
input





results





Error on energy < 2% for different driving cycles

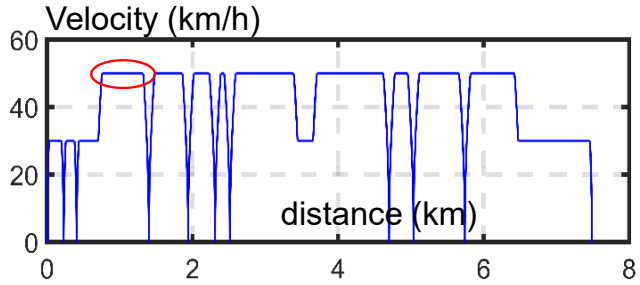
(different real driving cycles from RTR track)

Impact of the velocity

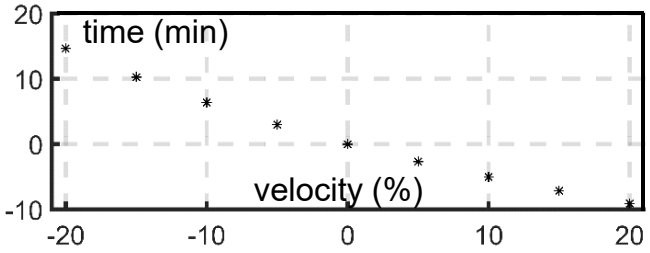
Urban trip – 7.5 km

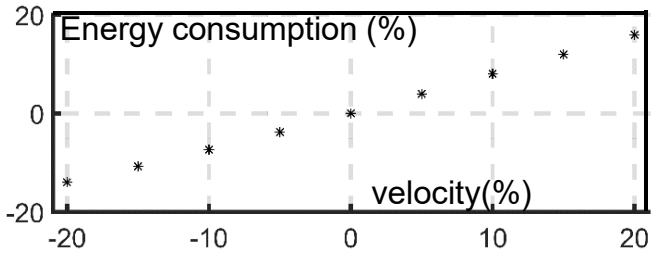
change of the **maximal velocity**

keeping the same acceleration



only possible with simulation





Trip	- 20 % (kWh)	Reference (kWh)	+ 20 % (kWh)
Urban	0,88 (-14,0)	1,03	1,19 (+16,0)
Periurban	2,11 (-18,0)	2,57	3,13 (+21,5)
Highway	3,67 (-24,2)	4,84	5,36 (+10,7)

Strong impact of velocity on energy consumption

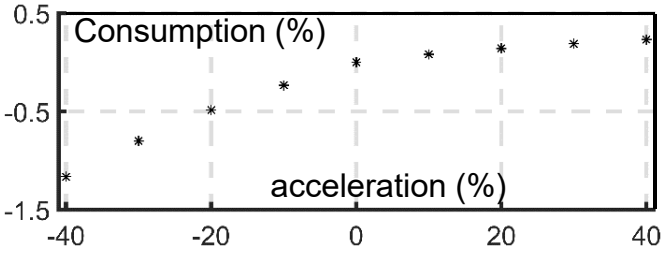
[Desreveaux 2020]

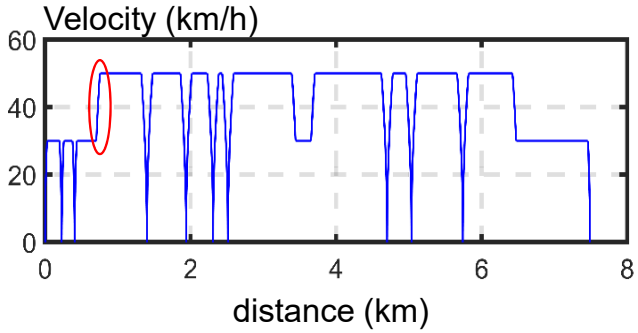
Impact of the acceleration

Urban trip – 7.5 km

change of the **acceleration**

keeping the same maximal velocity





only possible with simulation

Trip	- 40 % (kWh (%))	Reference (kWh)	+ 40 % (kWh (%))
Urban	1,013 (-1,06)	1,024	1,026 (+0,23)
Periurban	2,553 (-0,63)	2,569	2,576 (+0,24)
Highway	4,792 (-0,77)	4,829	4,842 (+0,28)

Low impact of acceleration on energy consumption

[Desreveaux 2020]

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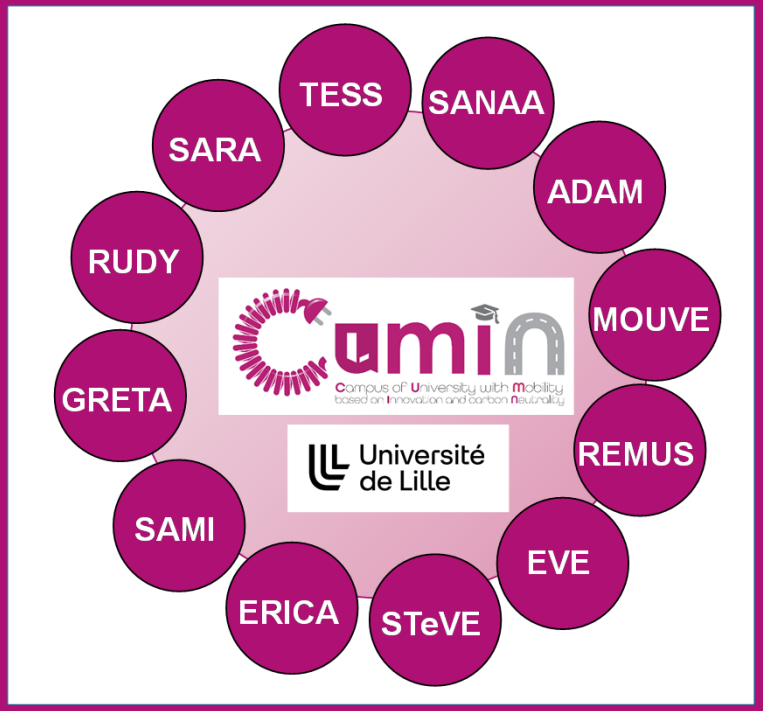


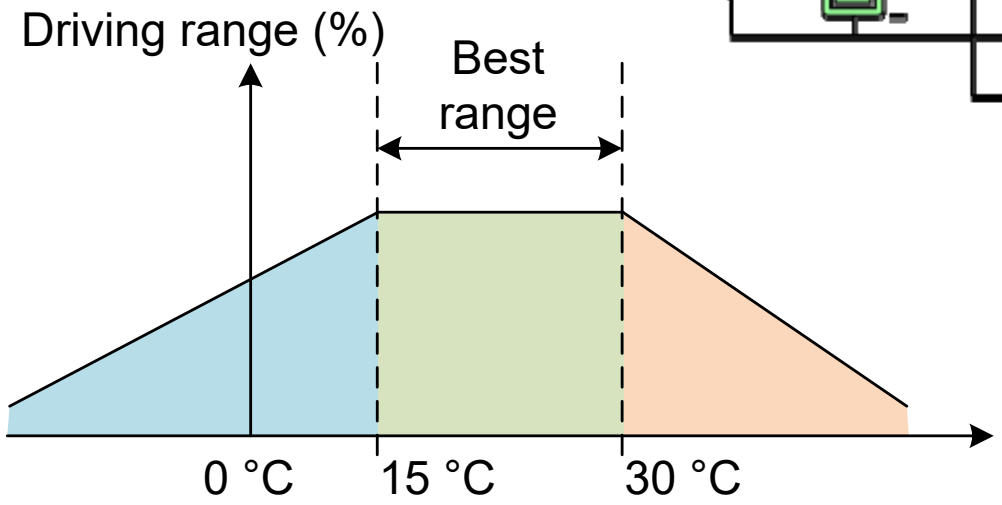
EVE & climatic conditions

PhD D. Ramsey
eCAMPUS /EVE
(L2EP / IRH)

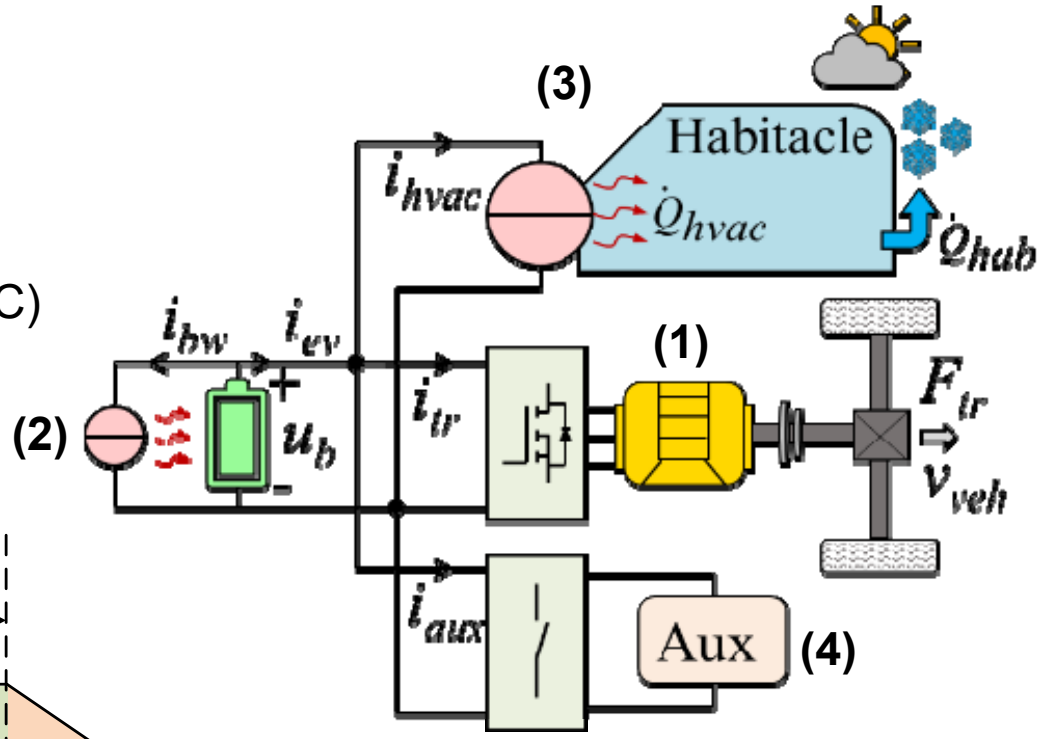
EV consumption & Climatic condition

Main subsystems of an EV

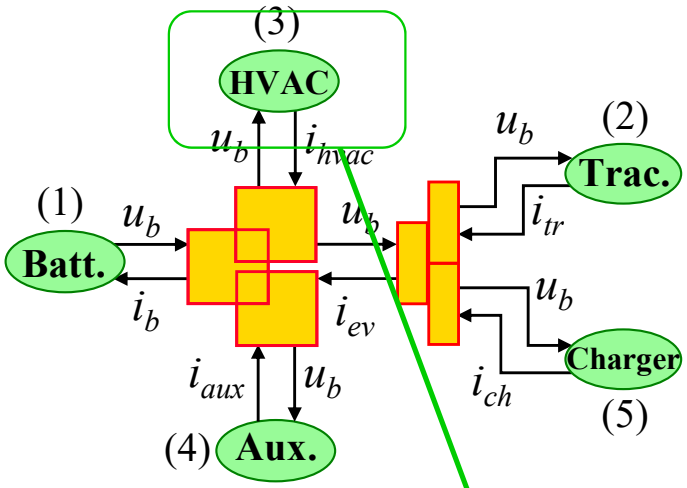
1. Electric powertrain
2. Energy storage
3. Comfort subsystem (HVAC)
4. auxiliaries



[Mansour 18]

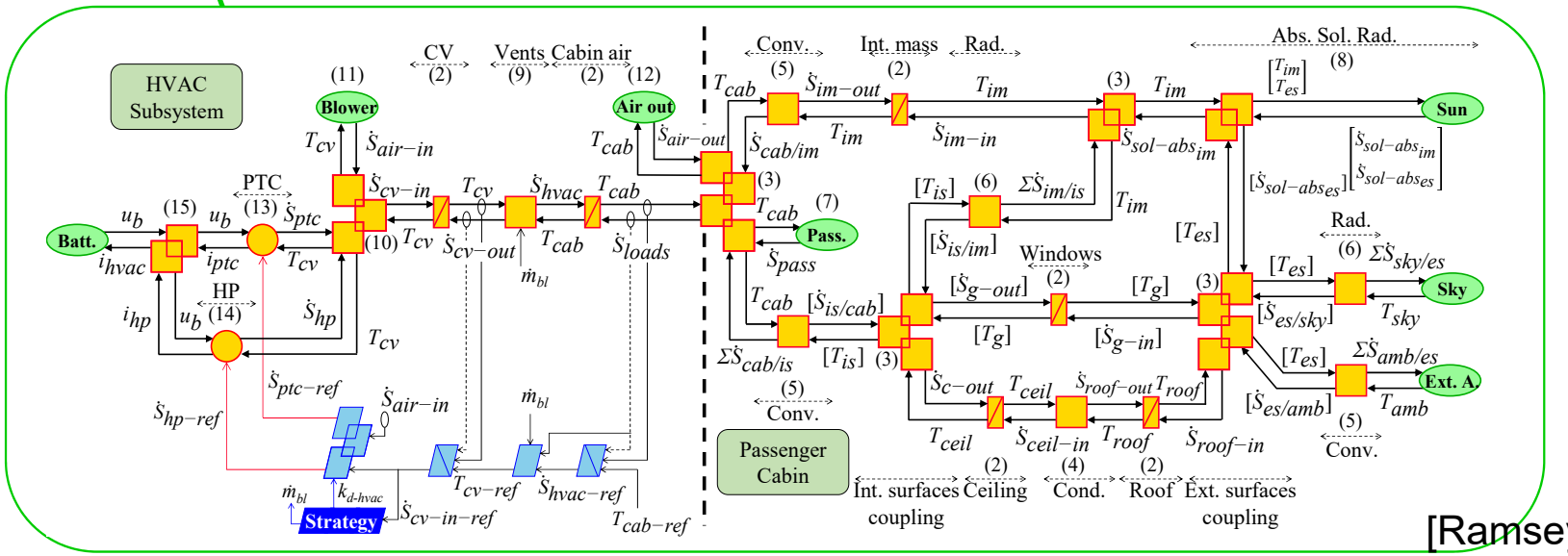


Flexible simulation model



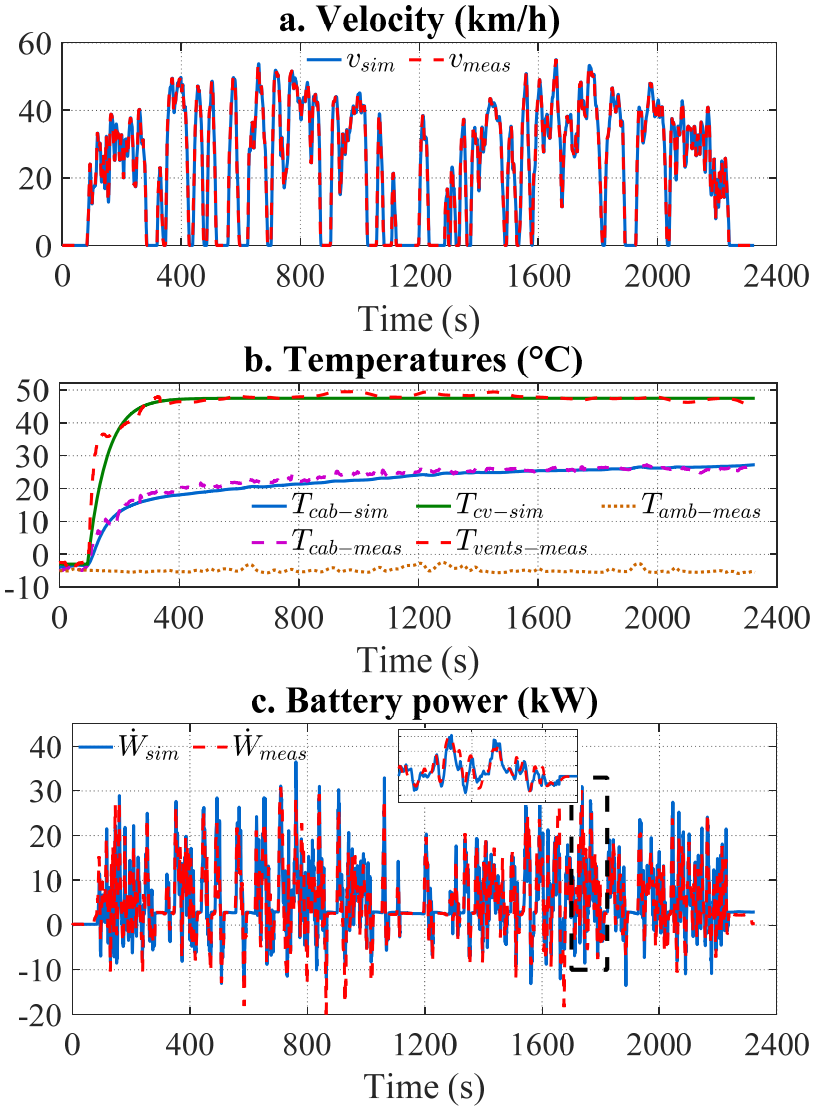
EMR (Energetic Macroscopic Representation) formalism to interconnect multi-physical models of different subsystems

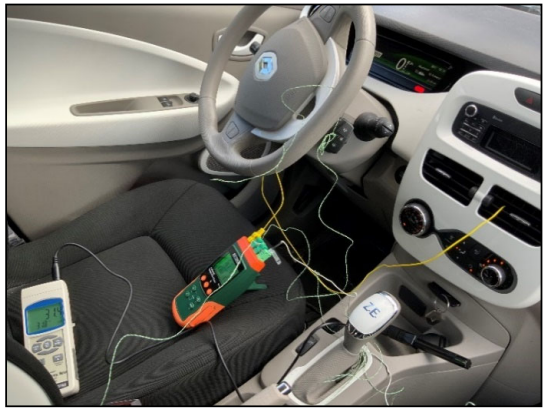
Management of the complexity while ensuring high flexibility



[Ramsey 2022]

Validation of the digital model



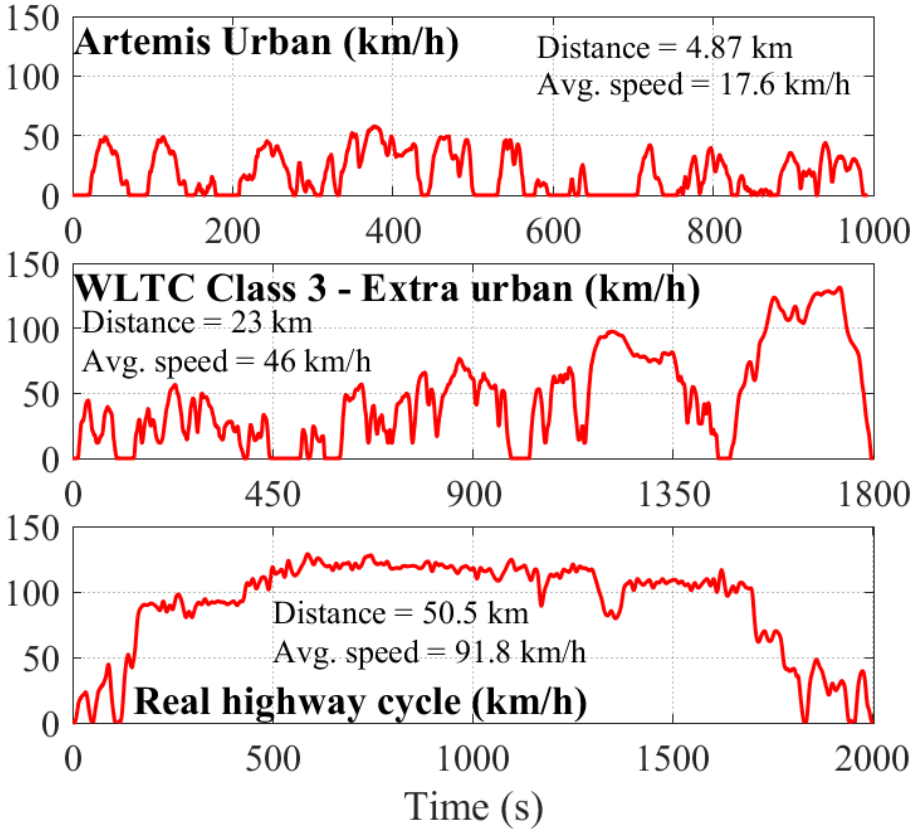


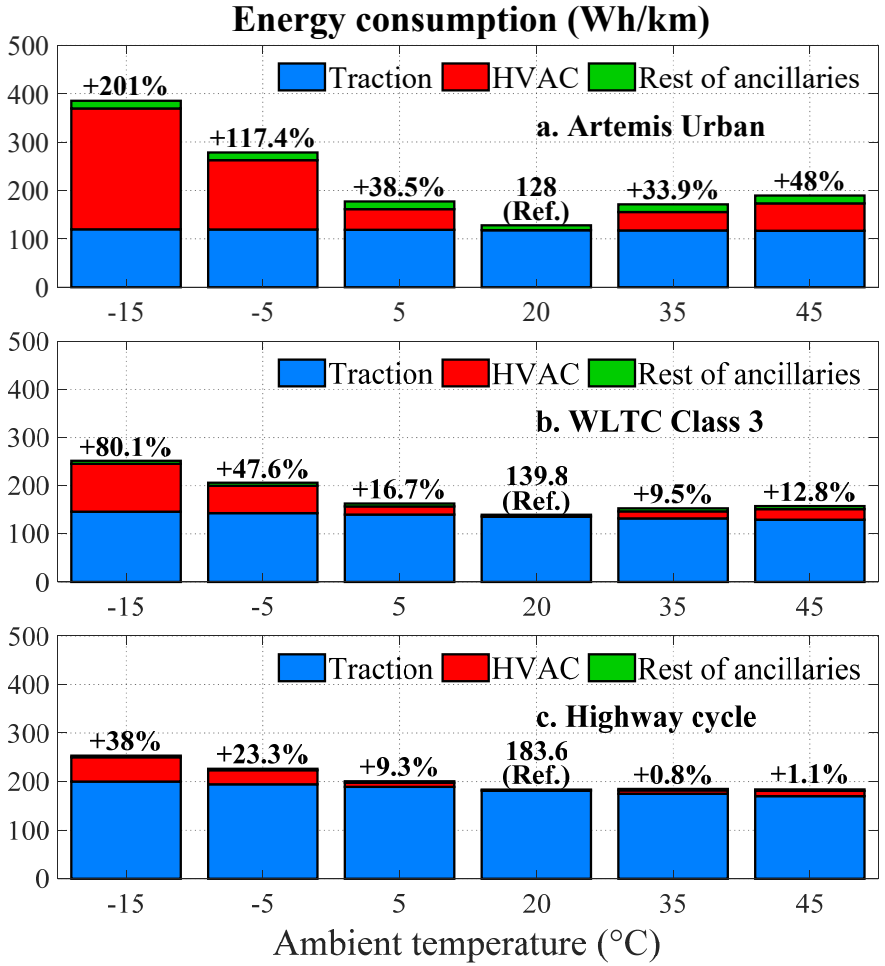
Error on the energy consumption = 2.8%

[Ramsey 2022]

Consumption vs. climate & driving cycle

- battery thermal effect neglected
- Cabin T. to 20 °C





[Ramsey 2022]

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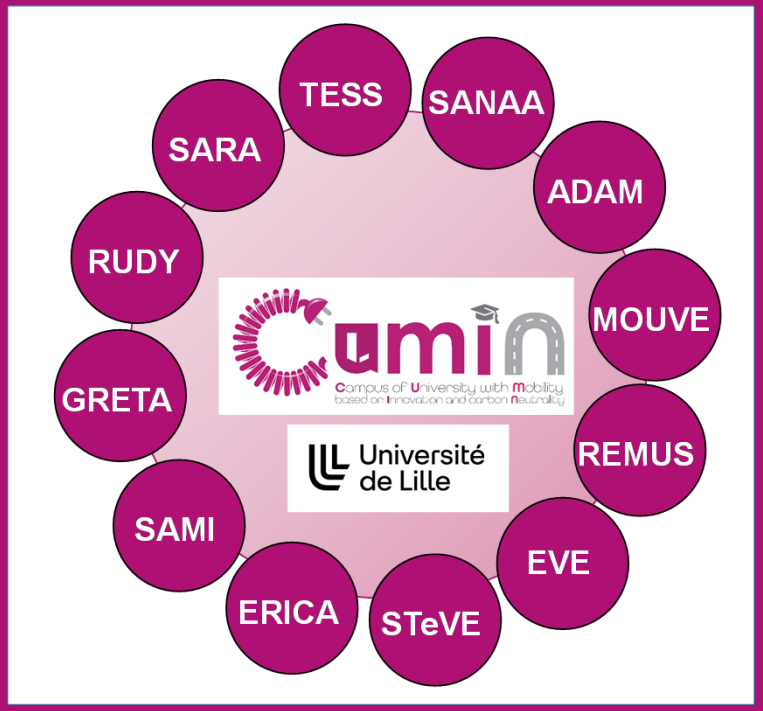


EVE & GHG emissions

Post-Doc A. Desreveaux

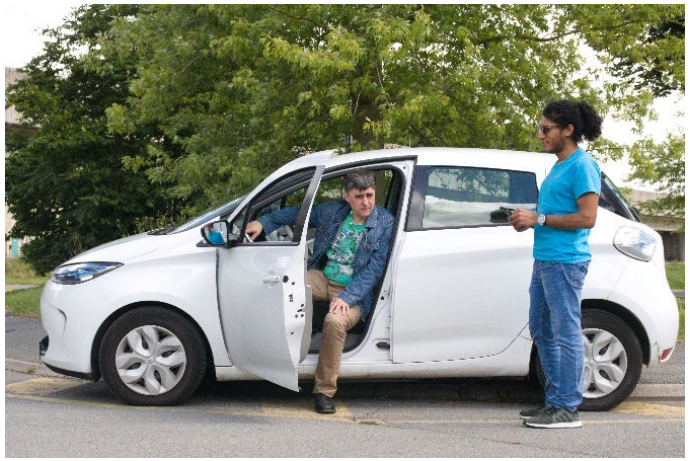
H2020 PANDA / TESS

Reference vehicles

Diesel Car

Renault Clio

Electric Vehicle

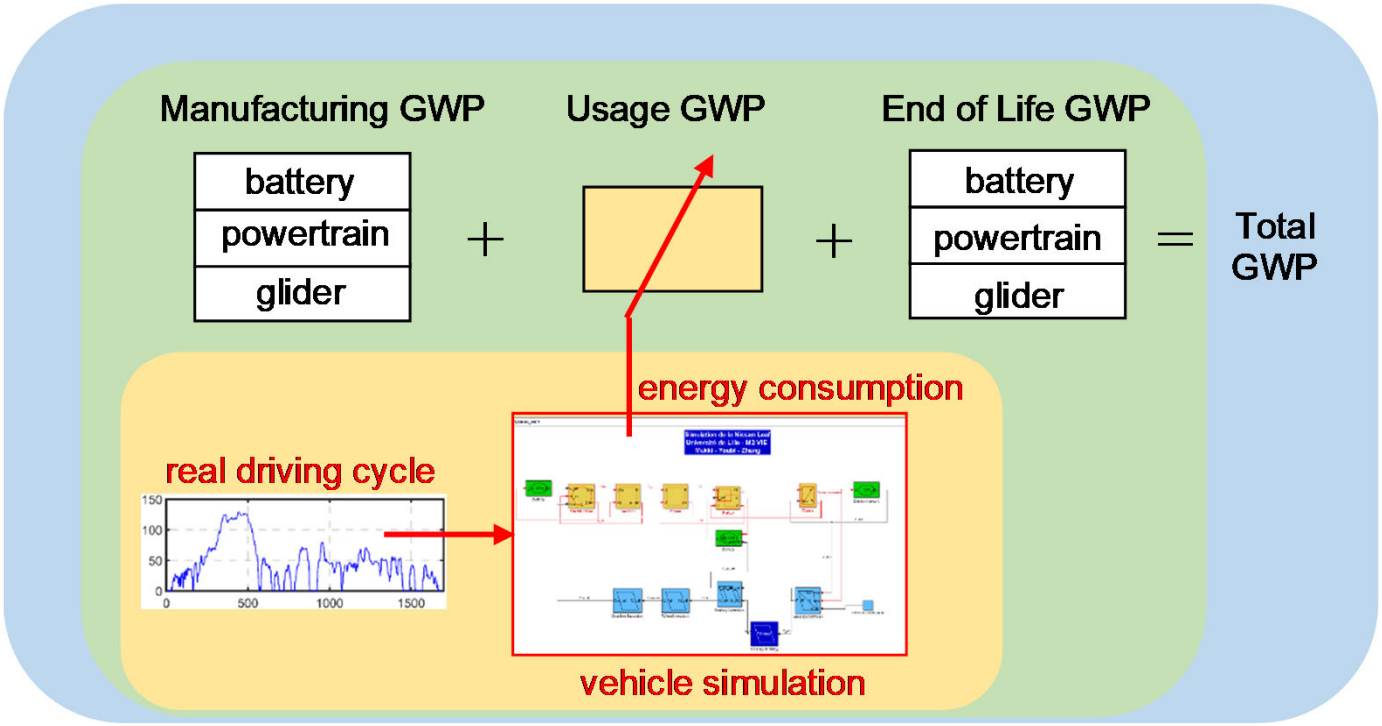


Renault Zoé

Motor	Diesel 1,5 DCI 51 kW
Weight	1185 kg

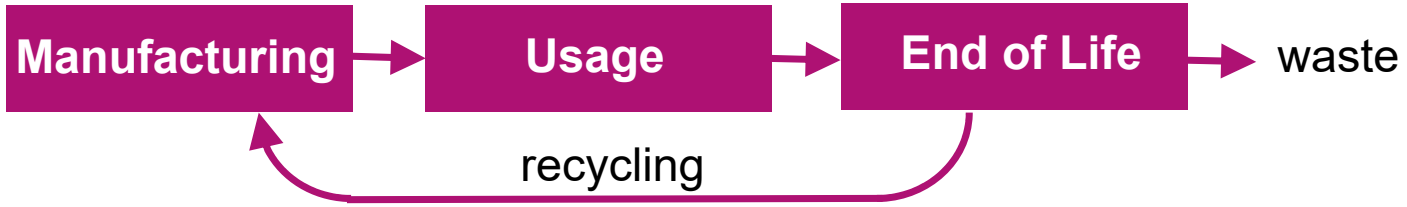
Battery	Li-ion 41 kWh
Electric Machine	SM 65 kW
Weight	1480 kg

Computation of the Global Warming Potential



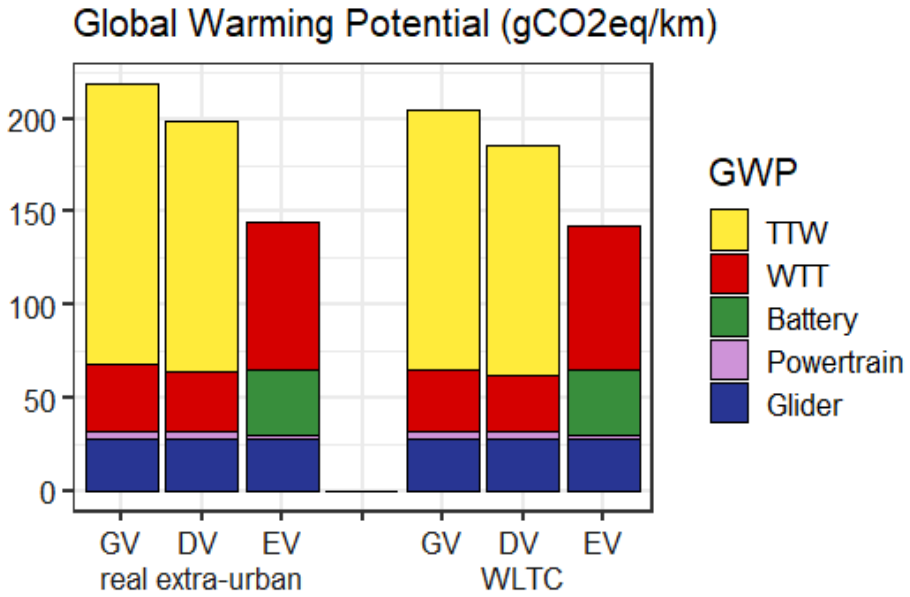
GWP coefficients
from JRC (EU)
and PANDA (H2020)

GWP usage computed
by L2EP (ULille)
Renault TR
and Univ. Eiffel



[Desreveaux 2023]

GWP for extra-urban driving cycle



150 000 km

Electricity 450 g CO2eq/kWh
(average European mix)

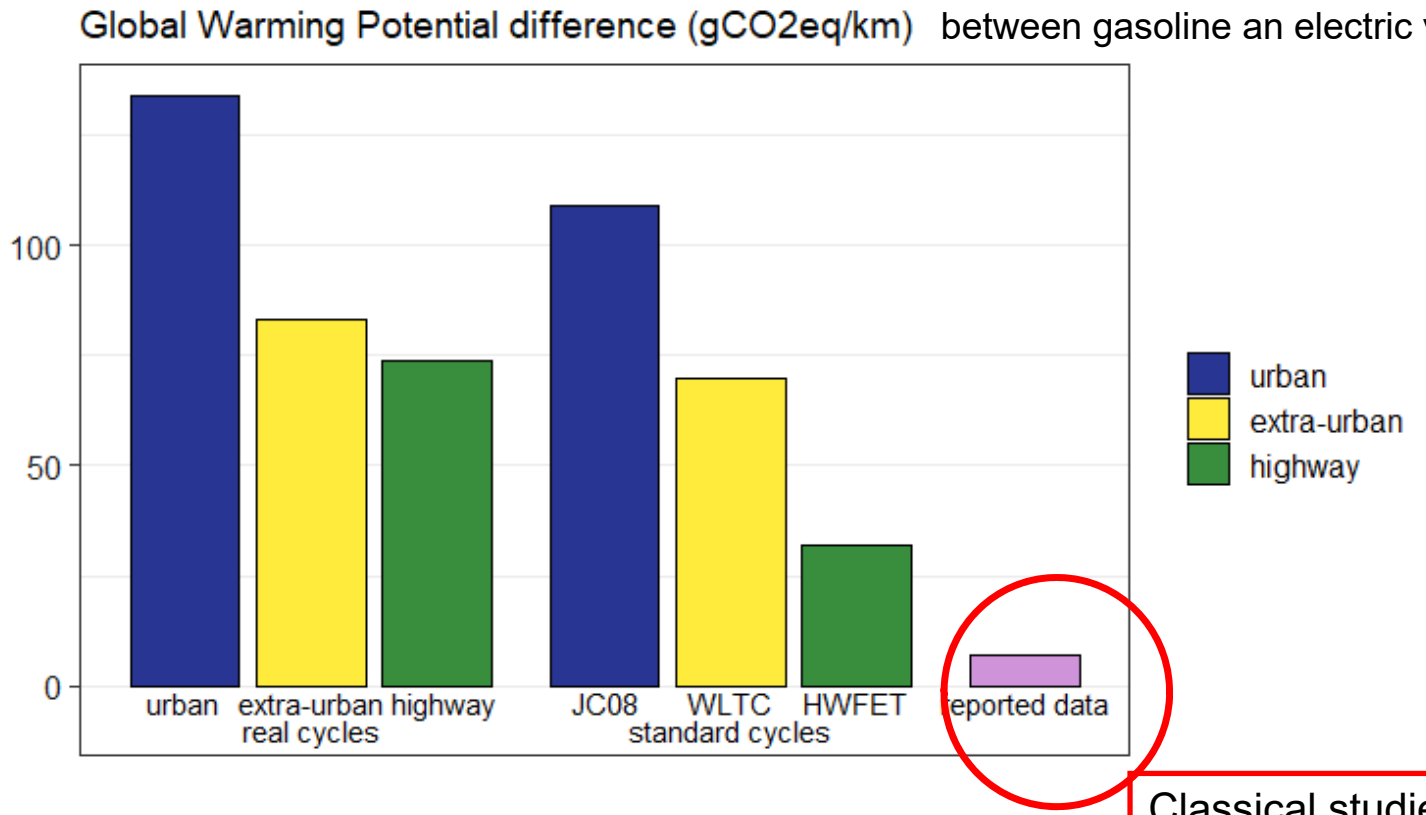
GHG= CO_2+CO+CH_4+NO_2

GV: Gasoline Vehicle
DV Diesel Vehicle
EV: Electric Vehicle

real driving cycles increase the benefit of EV

[Desreveaux 2023]

GWP for different driving cycles

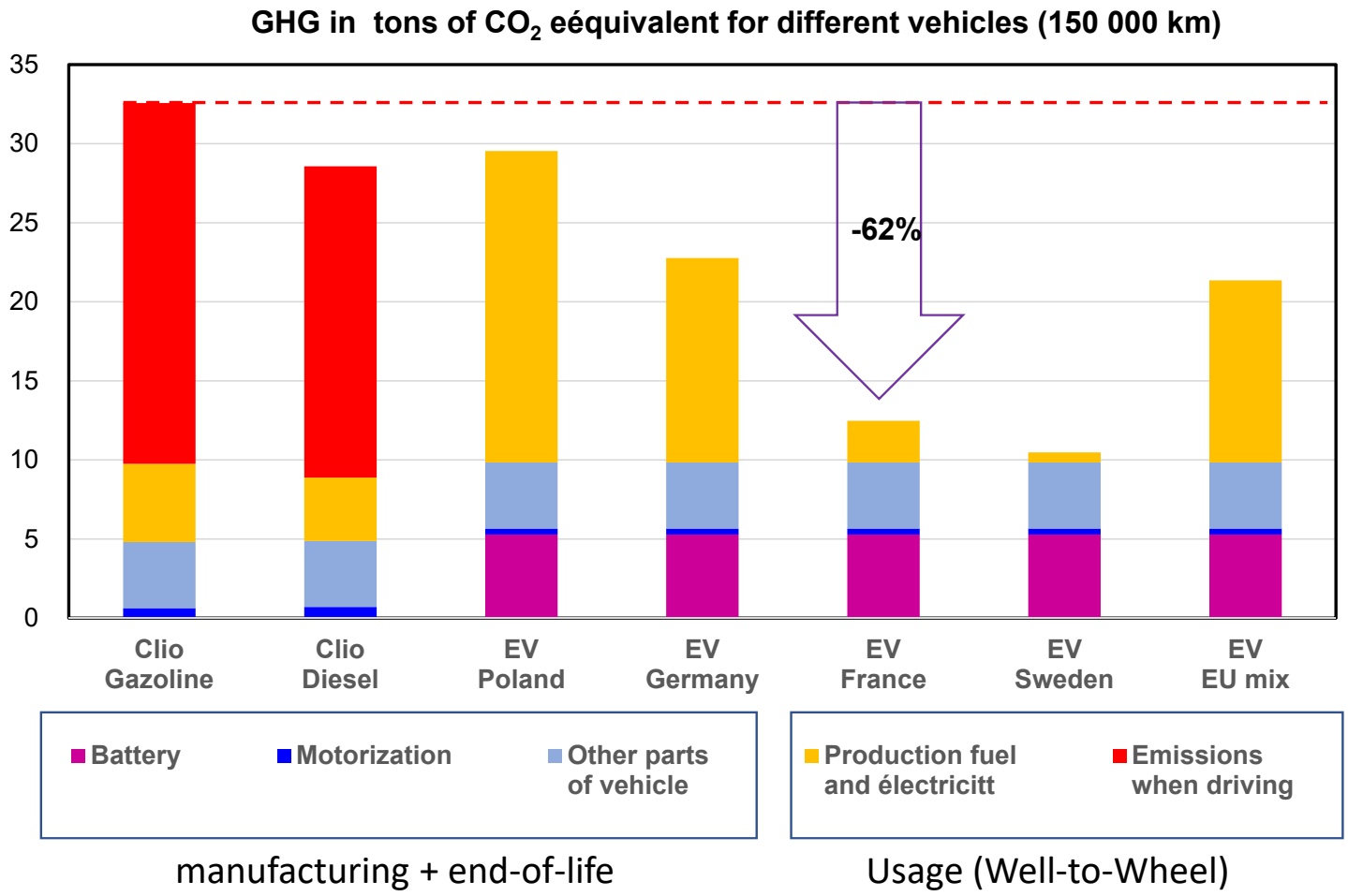


urban driving cycles increase the benefit of EV

Classical studies underestimate the EV benefit

[Desreveaux 2023]

GHG and electricity production



Electricity production (2018-2022):

- Poland: 70% coal
- Germany: 31% coal
- France: 70% nuclear
- Sweden: 80% renewable

[Task Force 2023]

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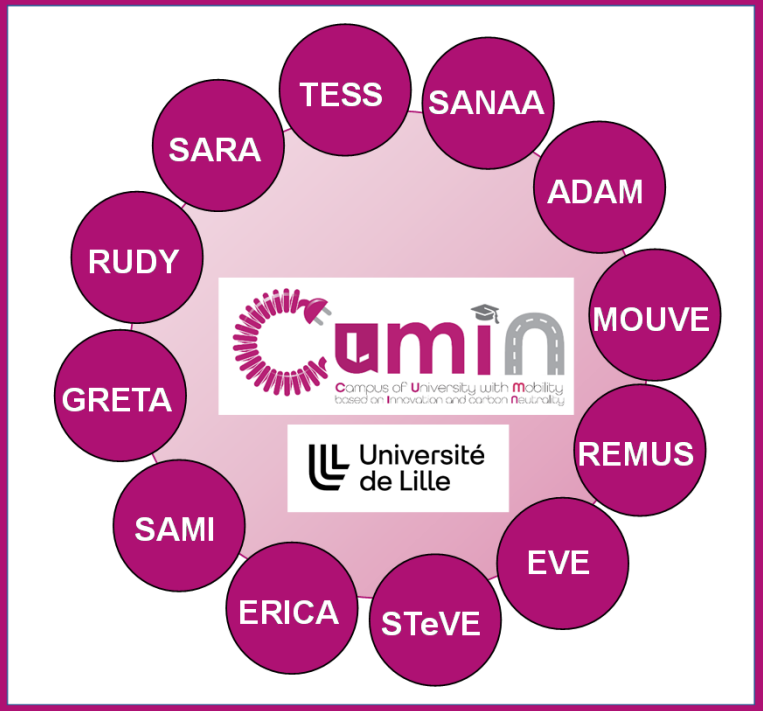

Conclusion

Conclusion

EVE = interdisciplinary / intersectorial / international project

Interdisciplinary approach

- Electromechanical aspects (traction system)
- Thermal aspects (passenger comfort)
- Environmental aspects (LCA & GHG)
- Socio-behavioural aspects (Driver usages & request)
- Economical aspects (Total Cost of Ownership) - TESS

Global framework
using the EMR formalism
as a common language

Capitalization of works

- Traction model & validation (PhD A. Desreveaux + H2020 H2020)
- HVAC model & validation (PhD. D. Ransey + eCAMPUS)
- Economical model (work of E. Hittiger, TESS)
- Driver usages & Request (ADAM & SARA)
- LCA study (Post-doc A. Desrevaux + H2020 PANDA)
- Vehicle data and model validation (MEGEVH+ H2020 PANDA)

Accurate and relevant
studies on EV
(Energy, Economics, GHG)

References

[Desreveaux 2020] A. Desreveaux, A. Bouscayrol, R. Trigui, E. Castex, J. Klein, “Impact of the Velocity Profile on Energy Consumption of Electric Vehicles", *IEEE transactions on Vehicular Technology*, Vol. 68, no.8, December 2019, pp. 11420-11426, DOI: 10.1109/TVT.2019.2949215 (common paper of L2EP, TVES and LTE-IFSTTAR, within CUMIN and MEGEVH network).

[Desreveaux 2023] A. Desreveaux, A. Bouscayrol, R. Trigui, E. Hittinger, E. Castex, G. M. Sirbu, “Accurate Energy Consumption for Comparison of Climate Change Impact of Thermal and Electric Vehicles", *Energy*, vol. 128, April 2023, ref 126637, https://doi.org/10.1016/j.energy.2023.126637 (common paper of L2EP, TVES, LTE-ISFTTAR, Rochester Inst. Tech. (USA), Renault Technology Romania, within CUMIN and PANDA H2020 project)

[Ramsey 2021] D. Ramsey, A. Bouscayrol, L. Boulon, A. Desreveaux, A. Vaudrey, “Energy consumption of a BEV in winter considering preheating. Trade-off between improved performance and total energy consumption", *IEEE Vehicular technology Magazine*, Vol. 17, no. 3, pp. 104-112, April 2022, DOI: 10.1109/MVT.2022.3158043 (common paper of L2EP Univ. Lille, an IRH Univ. Trois-Rivières within CUMIN and CAMPUS International Associated Lab)

[Ramsey 2022] D. Ramsey, A. Bouscayrol, L. Boulon, “Flexible Simulation of an Electric Vehicle to Estimate the Impact of Thermal Comfort on the Energy Consumption", *IEEE transactions on Transportation Electrification*, Vol. 8, no.2, pp. 2288-2298, June 2022, DOI: 10.1109/TTE.2022.3144526 (common paper of L2EP Univ. Lille, an IRH Univ. Trois-Rivières within CUMIN and eCAMPUS)

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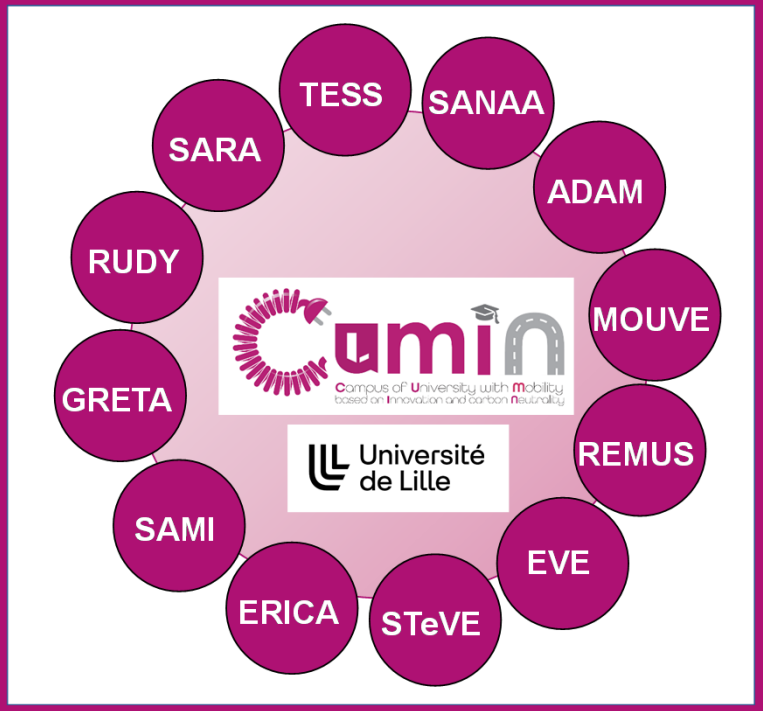

CUMIN programme

Our campus as
an exciting living lab
towards eco-cities!

L2EP Laboratoire d'électrotechnique et d'électronique de puissance de Lille
TVES Territoires Villes Environnement & Société EA 4477
Université de Lille
Région Hauts-de-France
MEGEVH French network on HEVs
Université Gustave Eiffel
IRH UQTR
UQTR Université du Québec à Trois-Rivières
E CAMPUS