CUMIN - REMUS

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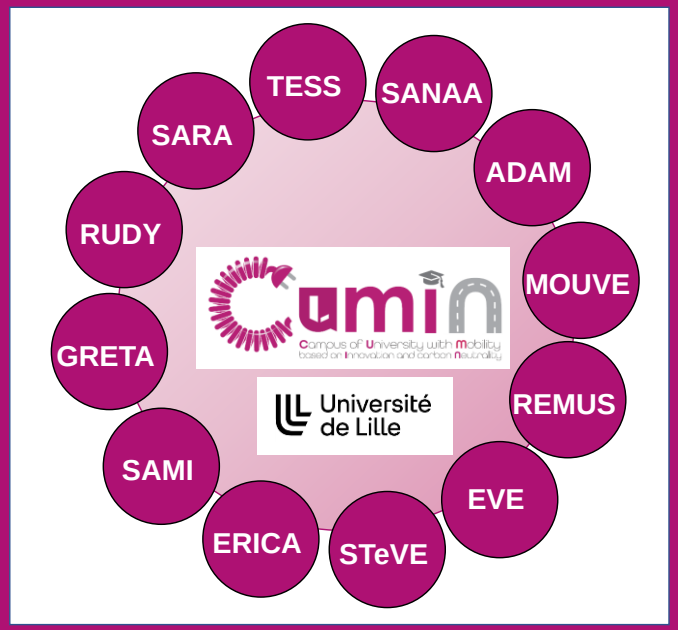

Subway Energy Consumption

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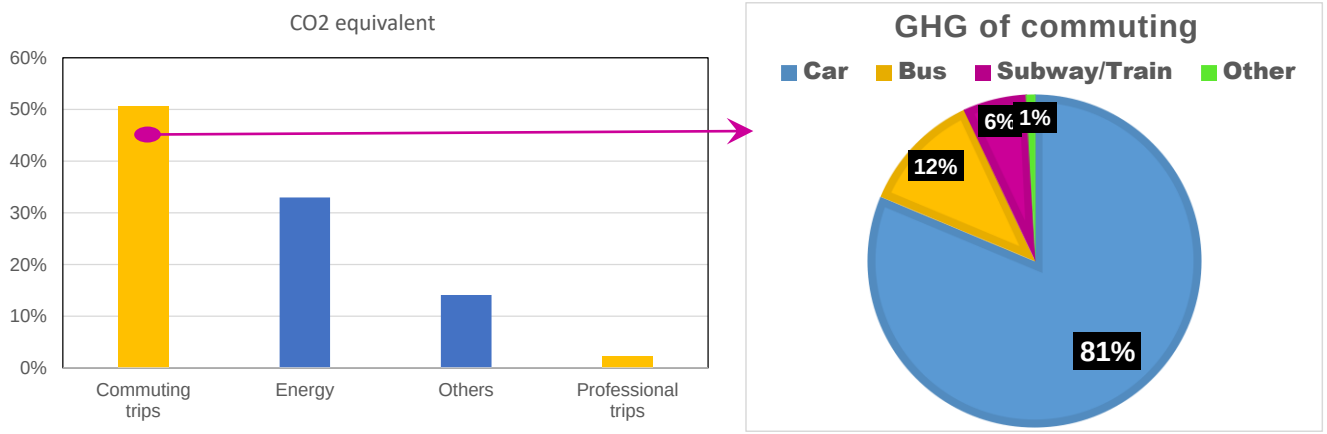
University of Lille, L2EP
European Metropolis of Lille (MEL)

with the support of Région Hauts-de-France

Context and Objective

REMUS – Recovery of Metro Braking Energy for a Sustainable University

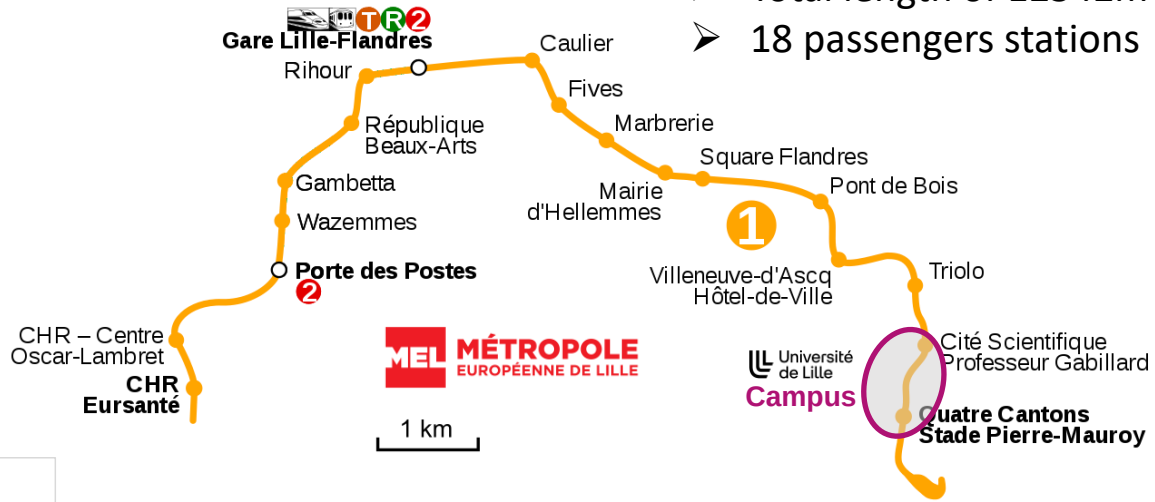
- Reduce the global GHG Emission in ULille



- Increase the metro line 1 capacity with new subway

Actual vehicle

New vehicle



- Total length of 12542m
- 18 passengers stations

Reduction of the energy consumption of the new metro line ?

- Daily basis
- Normal operation
- Evaluation of energy losses
- Impact of mobility
- Suggest improvements

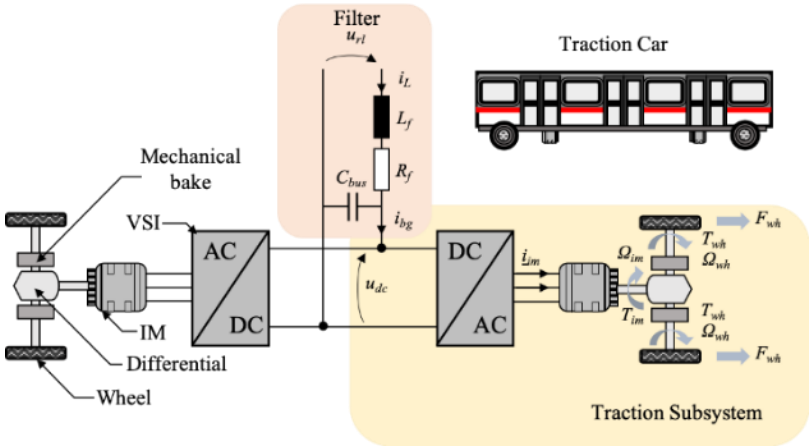
Outline

1. Simulation of the new vehicle
2. Simulation of entire subway line
3. Energy consumption of daily operation

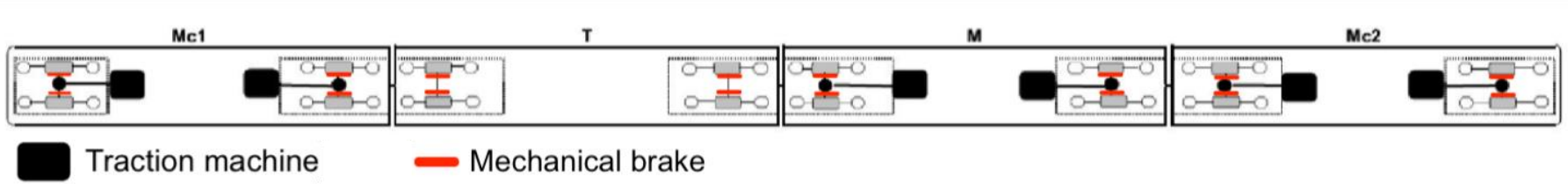
Simulation of the new vehicle

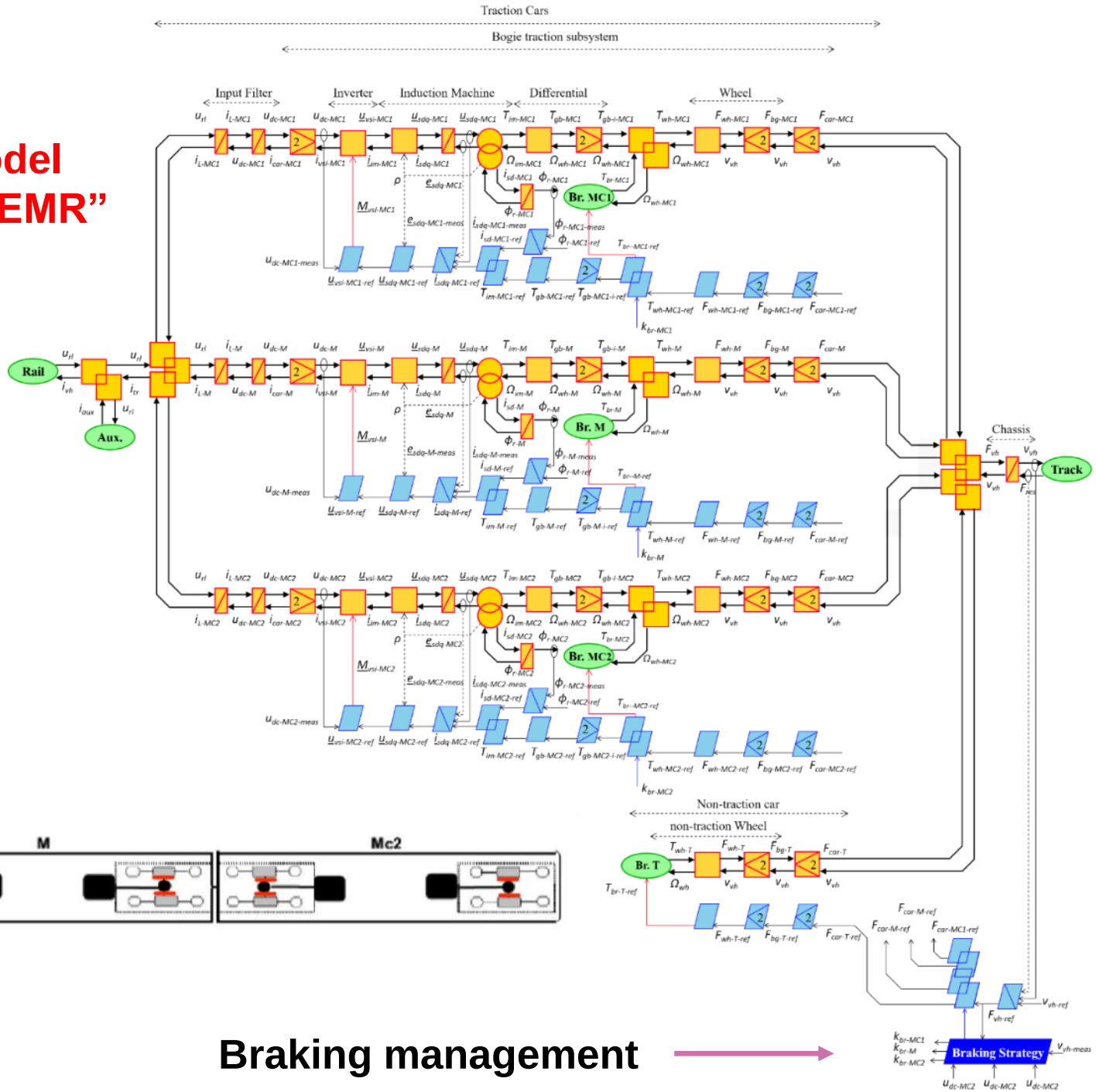
Traction car

Complex model organized by “EMR”



- Total of 4 cars
- 3 Traction cars (MC1, M and MC2)
- 1 non-traction car (T)

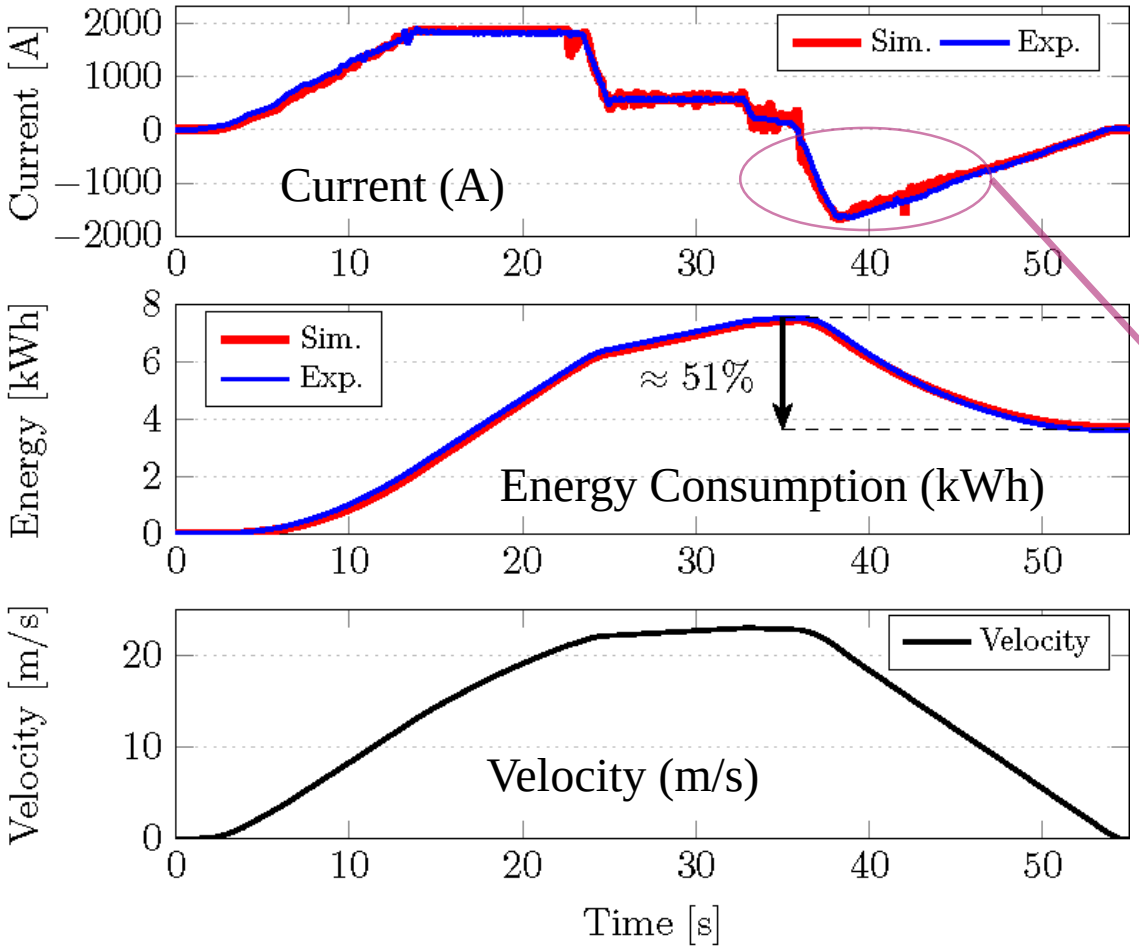


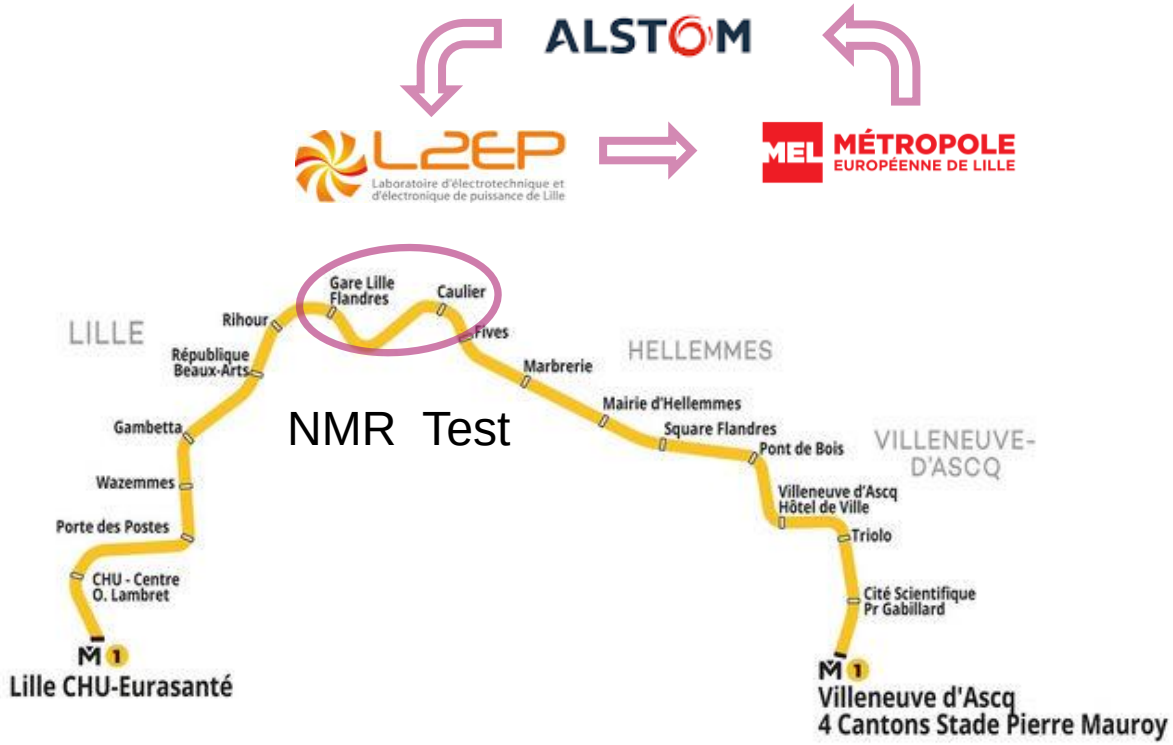


Braking management

Simulation of the new vehicle

Experimental
Simulation

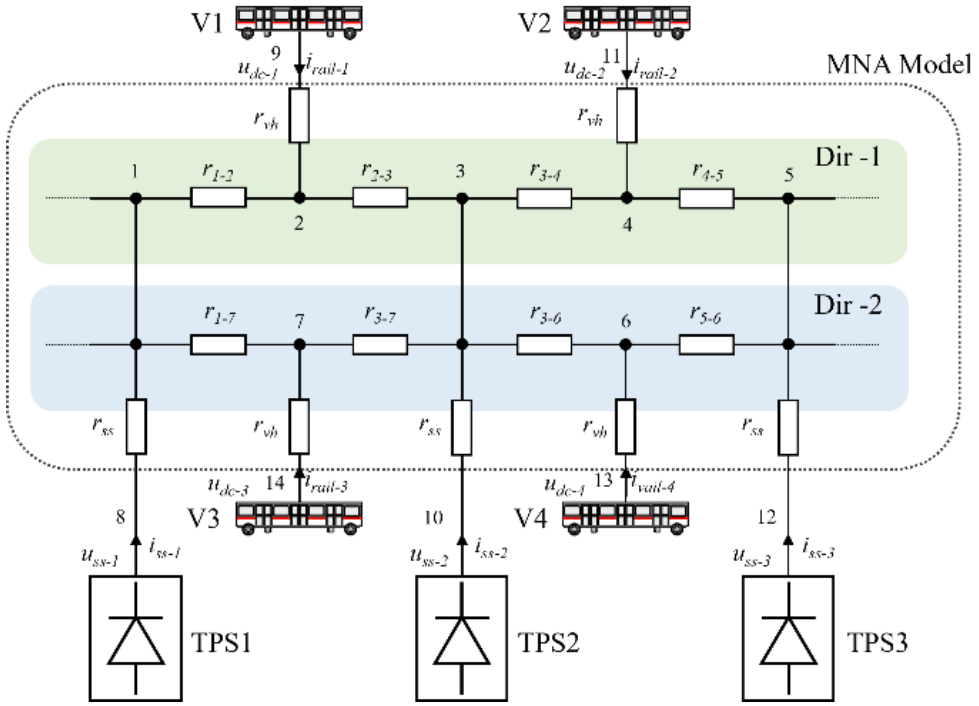




- Energy recovery phase
- 2.1% difference in energy consumption
- **Validation of the simulation tool**

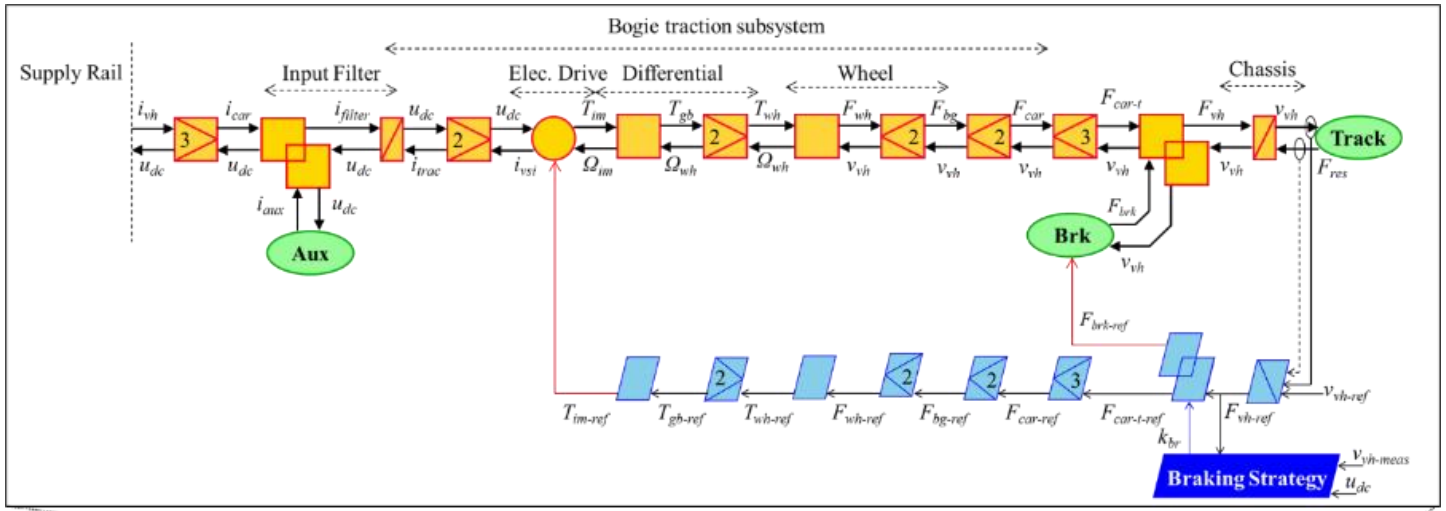
Accurate simulation for study various cases

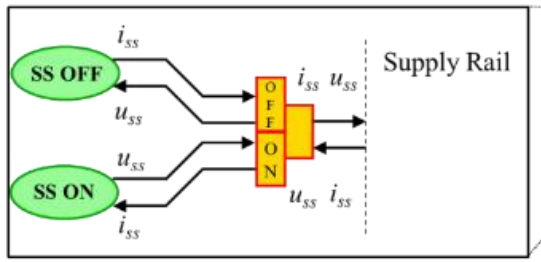
Simulation of the entire subway line



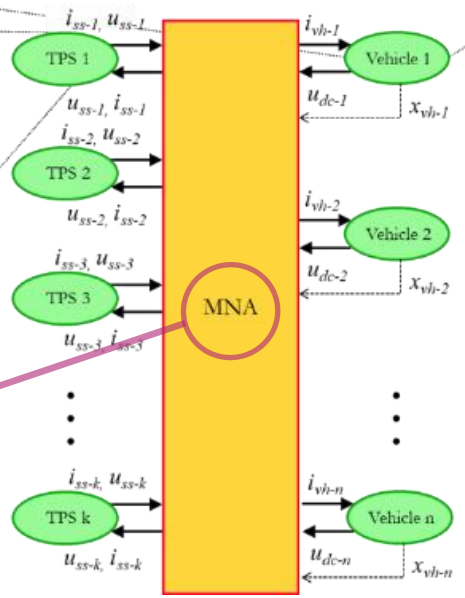
- **MNA** to solve circuit
- Line pure resistive
- Vehicle → as voltage source
- TPS → non-linear
- **Considering DC bus of vehicles**

Vehicle model





TPS model



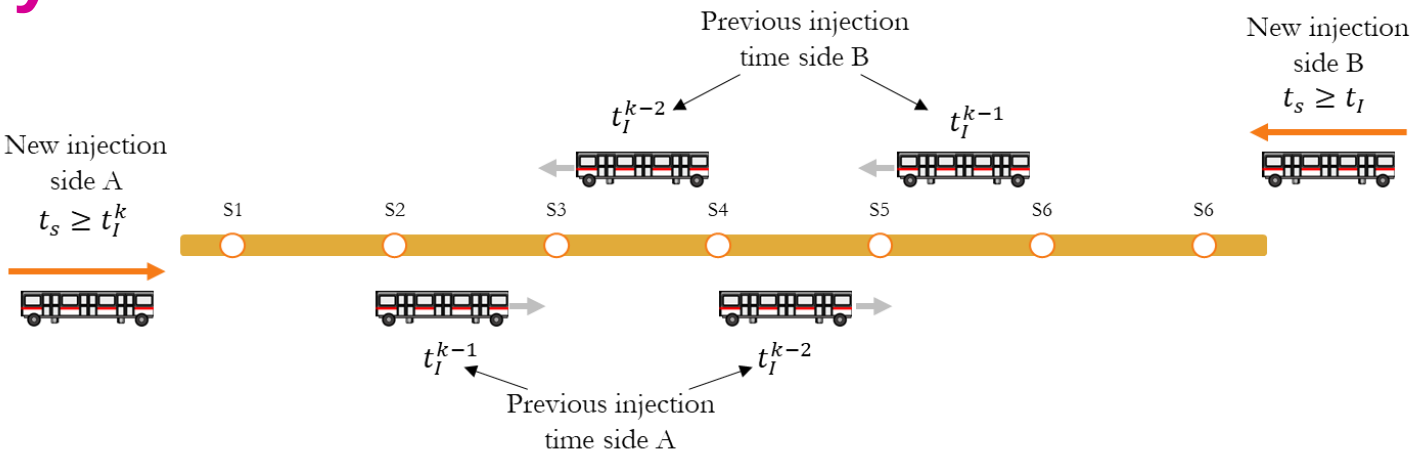
$$\begin{bmatrix} G & B \\ B^T & D \end{bmatrix} \begin{bmatrix} U \\ J \end{bmatrix} = \begin{bmatrix} I \\ V \end{bmatrix}$$

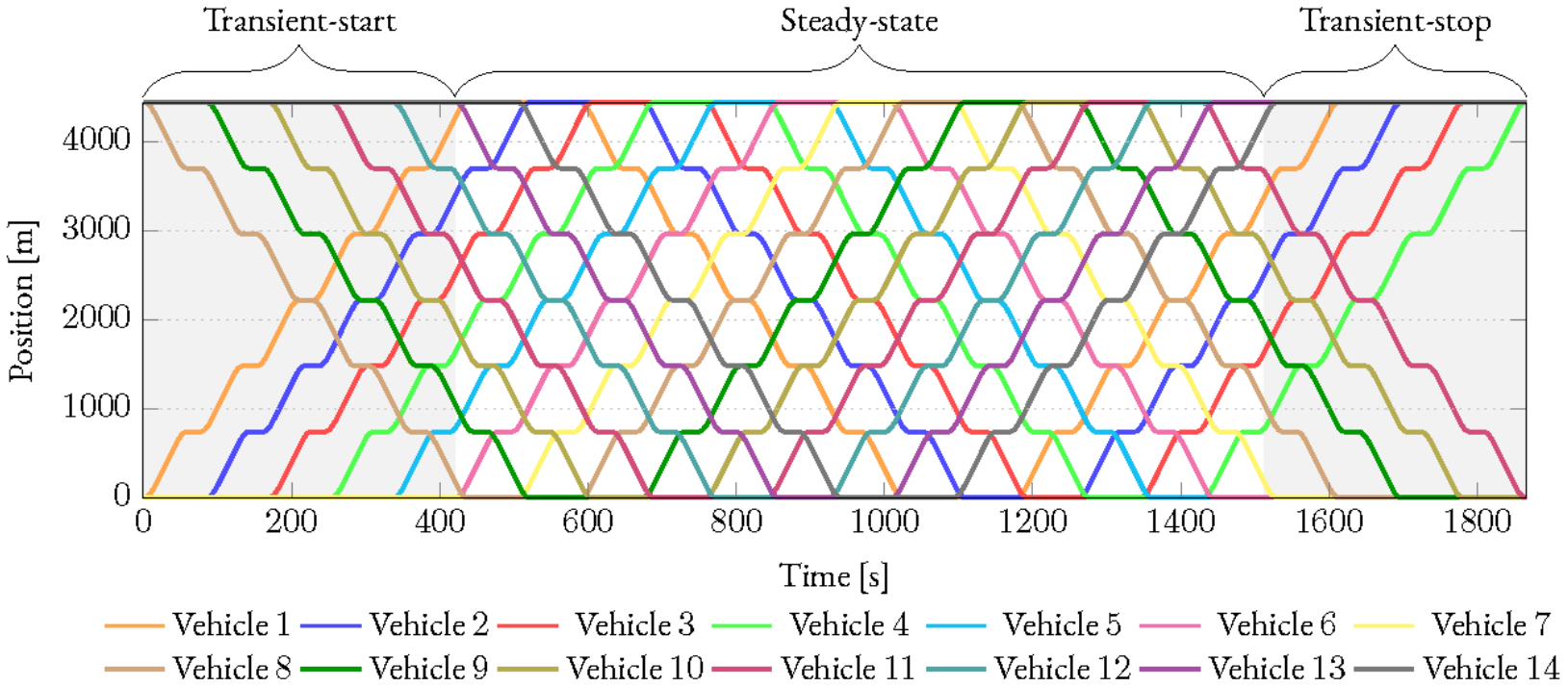
Simulation of the entire subway line

Traffic management

Moment at which a vehicle is introduced

$t_I^k = t_I^{k-1} + H_k.$ headway





Adaptation?

- Traffic (headway)
- Speed profile
- Stop time
- Etc.

Energy consumption of daily operation

Carousel simulation (normal operation)

Multiple vehicles circulation
34 vehicles on peak-hours & 10 TPS

Respecting timetable
About 19h of operation

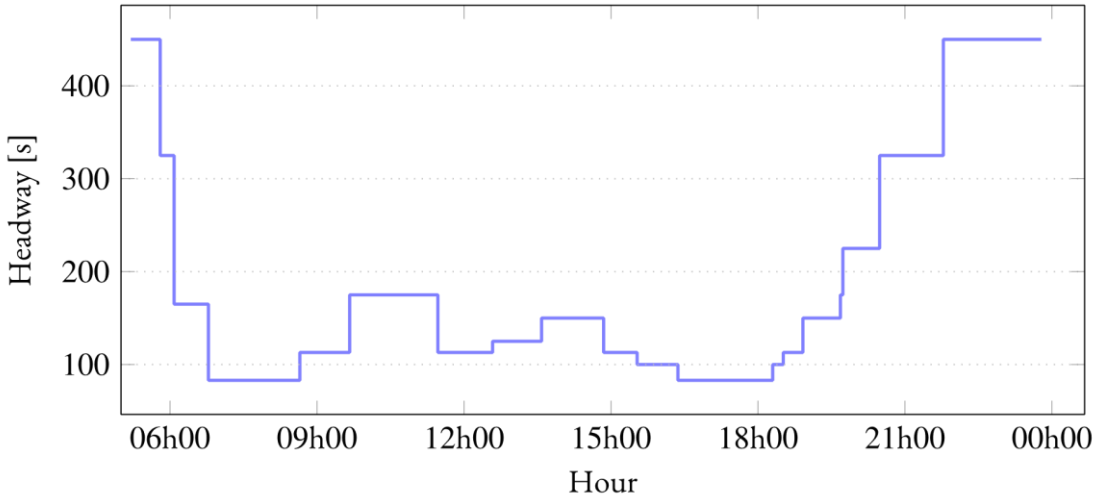
Daily key numbers:

Total energy: 82.6 MWh
Total distance: 10653.6 km
426 round trips
306 passengers per vehicle in average

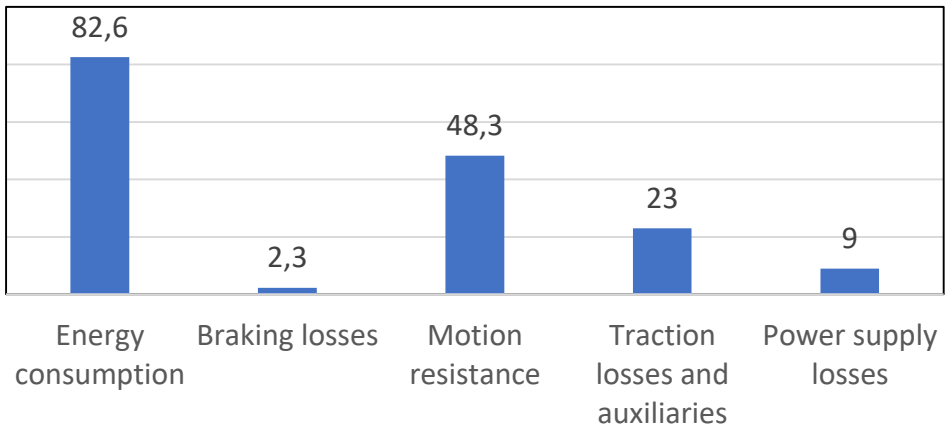
25.34 Wh/pass.km
0.81 gCO2eq/pass.km

32 gCO2eq/kWh (RTE, 2023)

Timetable



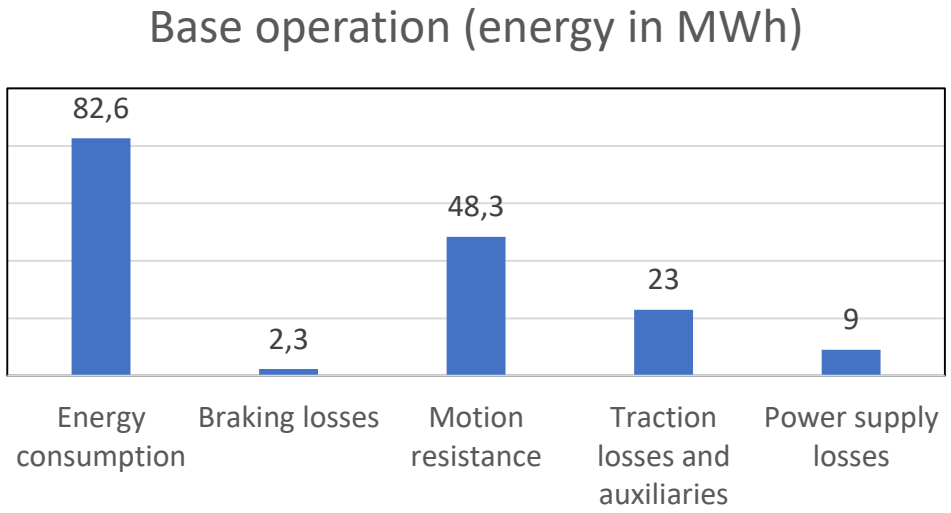
Base operation (energy in MWh)

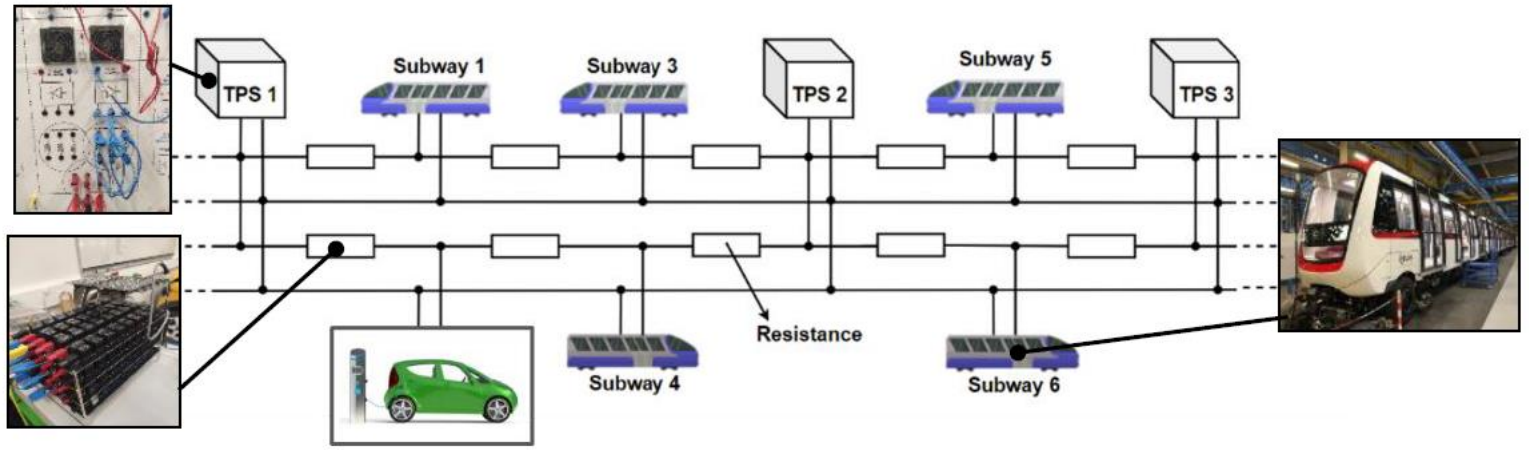


Energy consumption of daily operation

How can we improve?

Better aerodynamics?
Better speed profiles with better traffic management?
Multiple machines with better strategies?
More efficient auxiliaries?
Energy storage systems?
Charging systems for electric vehicles or buses?





Virtual platform (full scale simulation) &
Experimental platform (Reduced-scale P-HIL simulation)

Conclusion and Perspectives

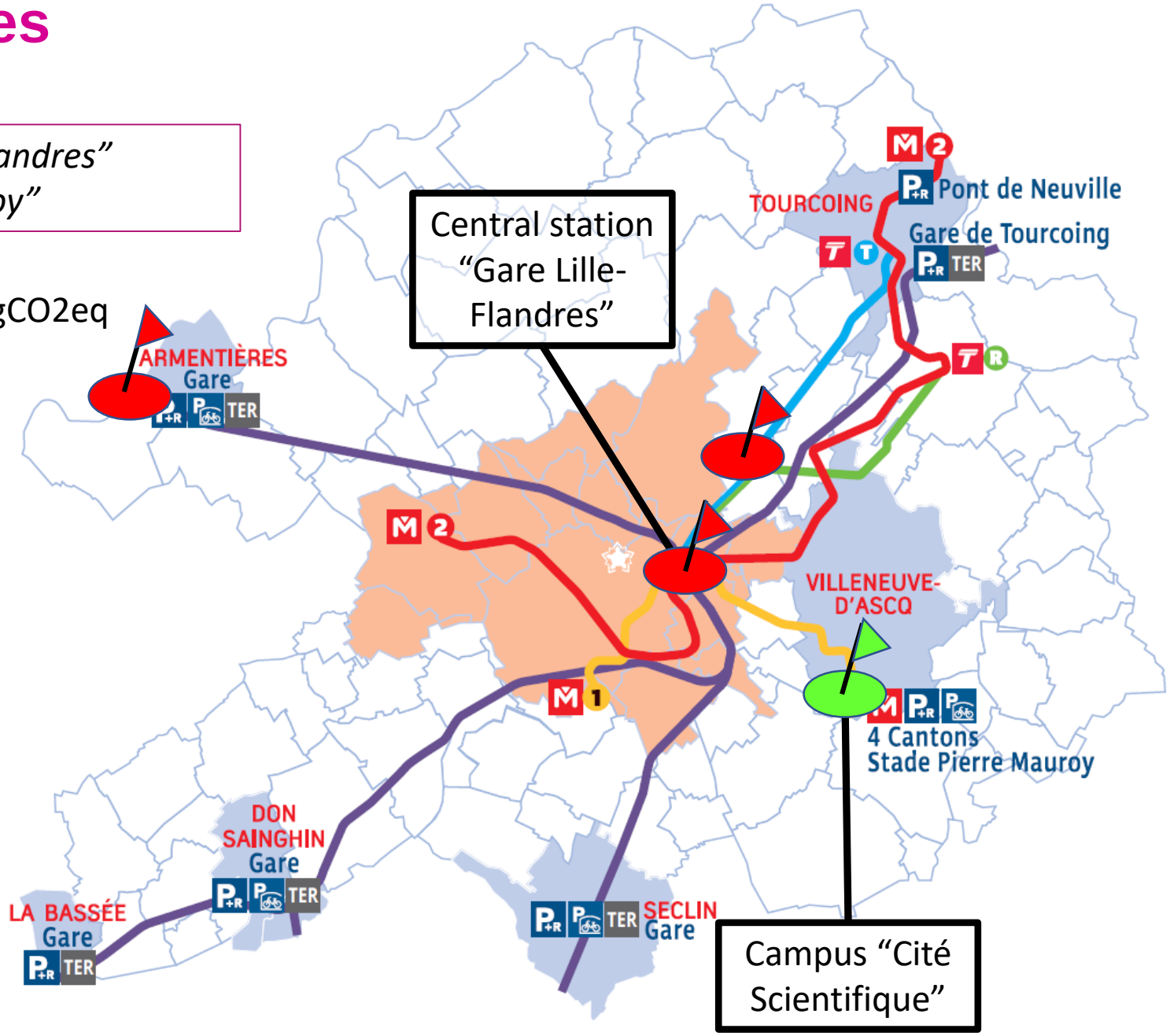
7.58 km between stations "Gare Lille-Flandres" and "4 Cantons Stade Pierre Mauroy"

Daily round trip for 1 person ≈ 384 Wh / 12.3 gCO2eq (normal operation)

What about combined with other mobility?
(tramway, regional train, bus, EV…)

How can we reduce the impact of mobility?
Innovative technologies?
Better uses?
Modal shift?
Other solutions?

Study of 2 new travels
How to extend to any travel?



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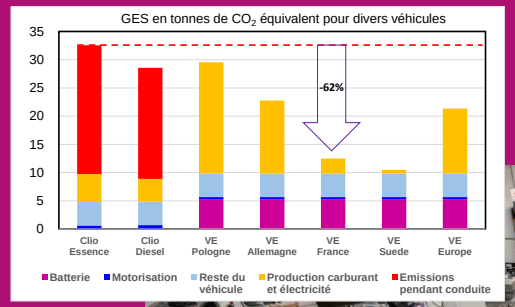

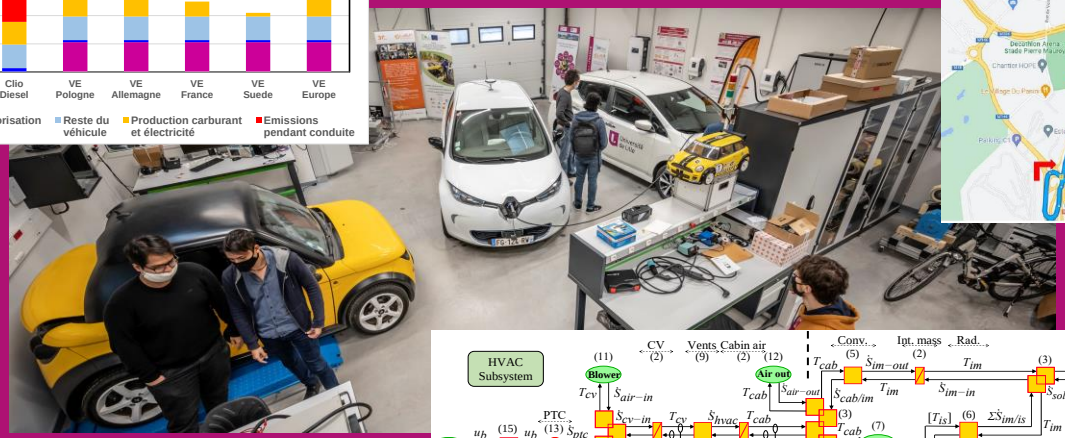

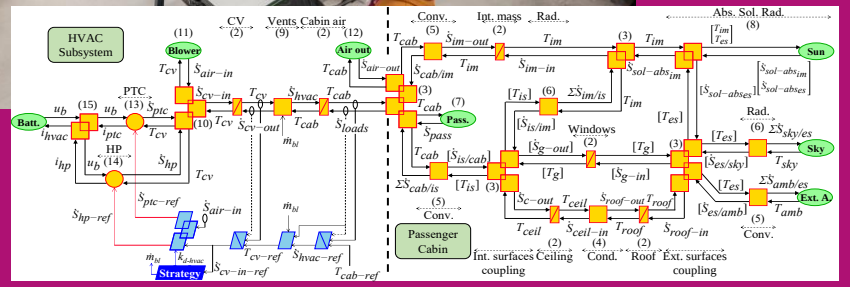

More information
PhD Thesis
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CUMIN-REMUS
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