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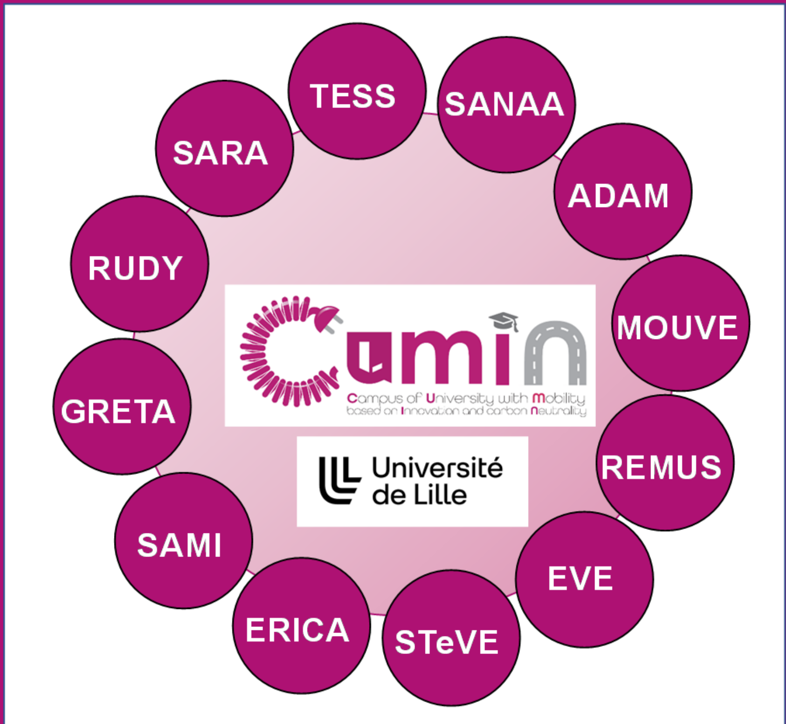

Charging strategies for electric vehicles to minimize battery aging

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MEGEVH French network on HEV's

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Ampere

Outline

1. Position, context and objective of the thesis
2. Vehicle and battery models
3. Case study: influence of charging frequency
4. Characterization tests of the Nissan Leaf's cells

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1. Position, context and objective of the thesis

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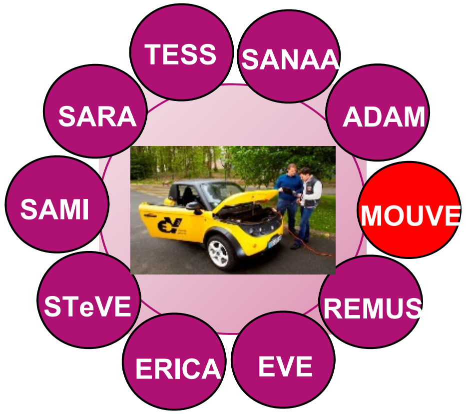
Ampère

Position of the thesis

CUMIN: Campus of **U**niversity with **M**obility based on **I**nnovation and carbon **N**eutral



MObility and **U**se of electric **VE**hicles based on dedicated charging infrastructure

(interconnection between charging infrastructures and user attitude)

Collaborating laboratories :

Déploiement d'infrastructures de recharge pour VEs
J. Frotey Septembre 2021

Consommation d'un VE
A. Desreveaux Mars 2020

Modèle électrothermique de batterie
R. German and al. Janvier 2020

VEs sous conditions climatiques sévères
D. Ramsey Novembre 2021

Vieillissement des batteries de VE basé sur des profils d'usage réels
M. Ben Marzouk Décembre 2020

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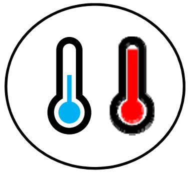
Stratégies de charge d'un VE
Thèse de A. Ndiaye

[German 20] [Ramsey 21] [Desreveaux 20] [Frotey 21]

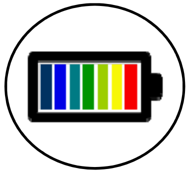
Context of electric vehicles

EV driving range is affected by the state of health of the battery.

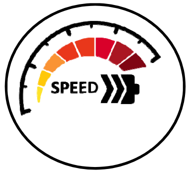
Stressors of battery aging during charging:



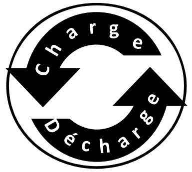
Charging temperature



SoC level



Current level



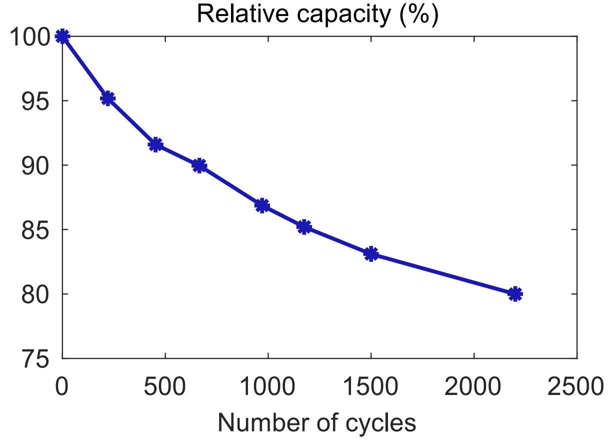
Charging frequency

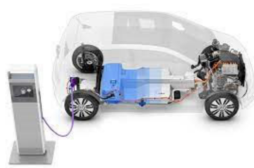
EV users' needs: long range and short charging time: (**vicious circle**)

More charge

Driving range

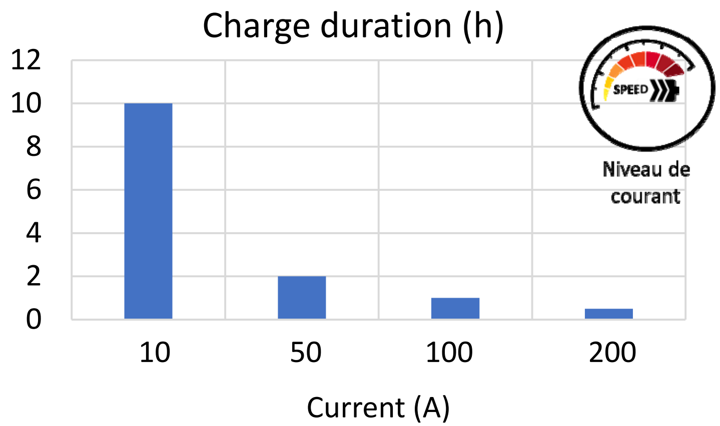
➞ affected by battery aging





Charge duration

➞ affected by the charging current



More aging

Objectives

Objective: Define charging strategies for an electric vehicle to:

- Increase battery lifetime by minimizing aging
- Reduce charging time

Battery characterization

Model of Vehicle
Model of charging station

Users' scenarios

Charging guideline?
Function of the temperature? SoC? Habits of EV users?

Studied vehicles:

Renault Zoe 2018

Modeling and simulation

Nissan Leaf 2018

Characterization tests

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2. Vehicle and battery models

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Ampère

Modeling of calendar aging of the battery

Two types of battery aging:

❑ **Calendar aging**
(park mode)

❑ **Cycling aging**
(charging or driving mode)

Assumptions:

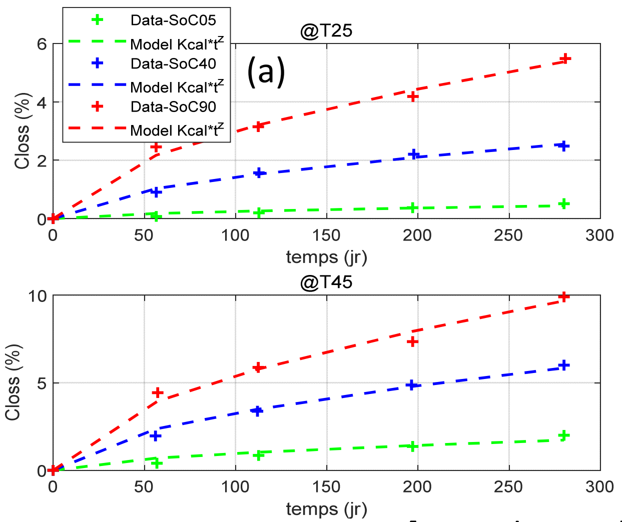
1. The total capacity loss is the sum of the calendar and cycling capacity losses

$$\Rightarrow C_{Loss-tot} = C_{Loss-Cal} + C_{Loss-Cycl}$$

2. The temperature dependence according to Arrhenius' law ➡ $k_{Cal} = A(SoC) \times e^{\frac{-E_a}{K_B \times T}}$

$$\Rightarrow C_{Loss-Cal} = A(SoC) \times e^{\frac{-E_a}{K_B \times T}} \times t^z$$

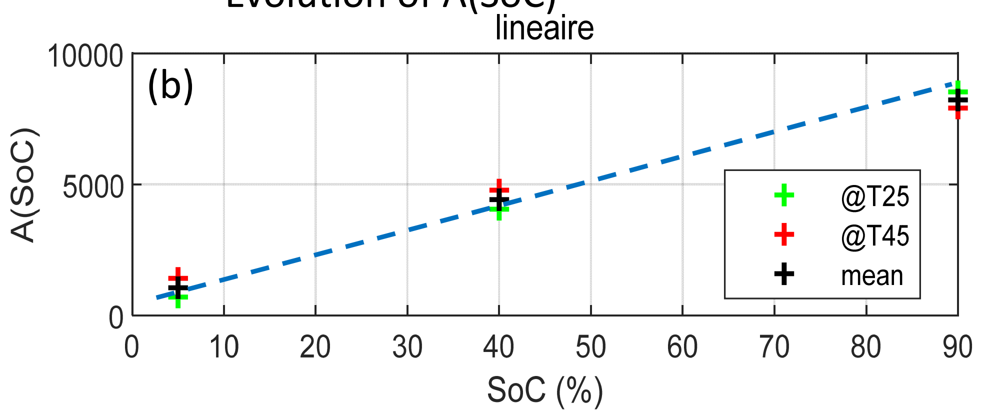
By numerical optimization, we find:
$z = 0{,}54$ et $E_a = 0{,}27\ eV$



[Renault 2018]

Test conditions:
-T(°C) = [25, 45]
-SoC (%) = [05, 40, 90]

Evolution of A(SoC)



Linear evolution:

$$A(SoC) = (A_0 + B \times SoC) \Rightarrow \begin{cases} A_0 = 798{,}61\ \%/jr^z \\ B = 83{,}79\ \text{p.u}/jr^z \end{cases}$$

Modeling of battery aging during cycling

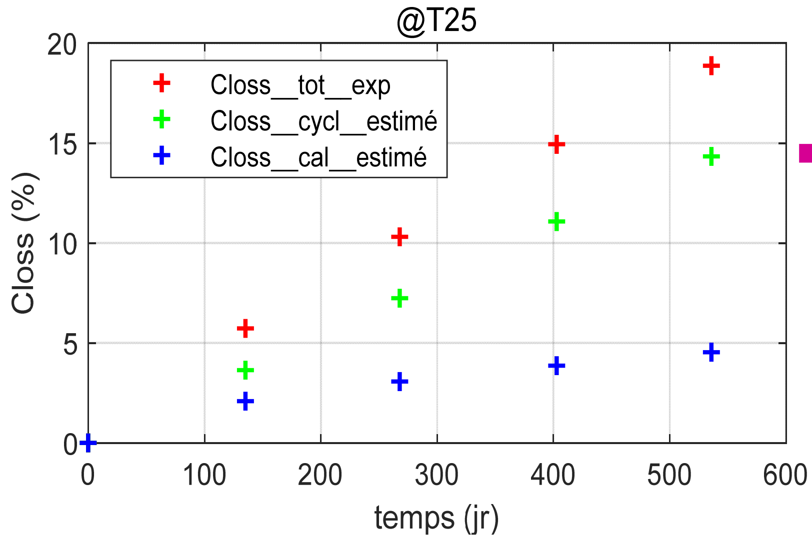
Two types of battery aging:

- **Calendar aging** (park mode)
- **Cycling aging** (charging or driving mode)

$C_{Loss-Cal}$ estimated from the previous calendar aging model

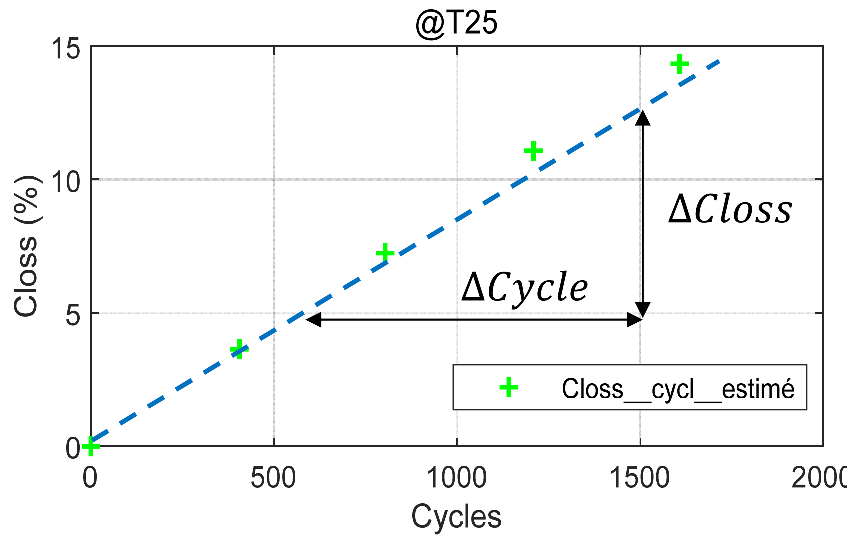
$$\Rightarrow C_{Loss-Cycl} = C_{Loss-tot} - C_{Loss-Cal}$$

(a)



[Renault 2018]

(b)



Cycling capacity loss is linear with the number of cycles $\Rightarrow$ $C_{Loss-Cycl} = k_{Cycl} \times Cycle$

$$k_{Cycl} = 0{,}009\ \%/cycle$$

Validation of the battery aging model

- **Complete aging model:**

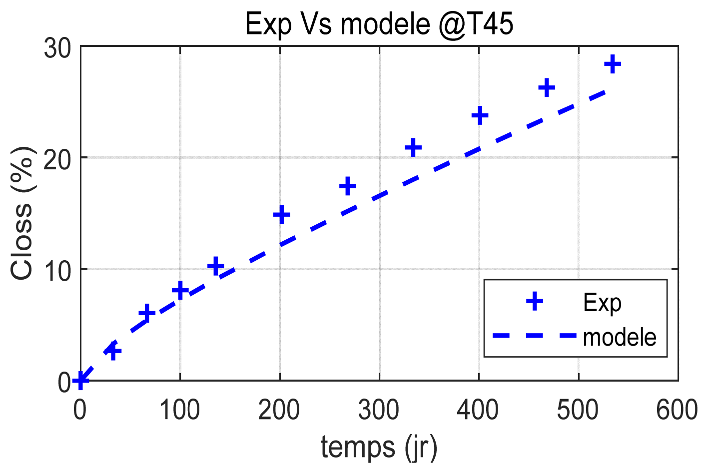
$$\Delta Closs_{tot} = \underbrace{(A_0 + B \times SoC) \times e^{\frac{-E_a}{K_B \times T}} \times \Delta t^z}_{C_{Loss-Cal}} + \underbrace{K_{Cycl} \times \Delta Cycle}_{C_{Loss-Cycl}}$$

A_0	$798{,}61\ \%/jr^z$
B	$83{,}79\ \mathrm{p.u}/(\%.jr^z)$
E_a	0,27 eV
z	0,56
K_{Cycl}	0,009 %/cycle

- Validation of the aging model

Comparison between experimental results at T45°C and model.

☛ Results not used to identify model parameters.

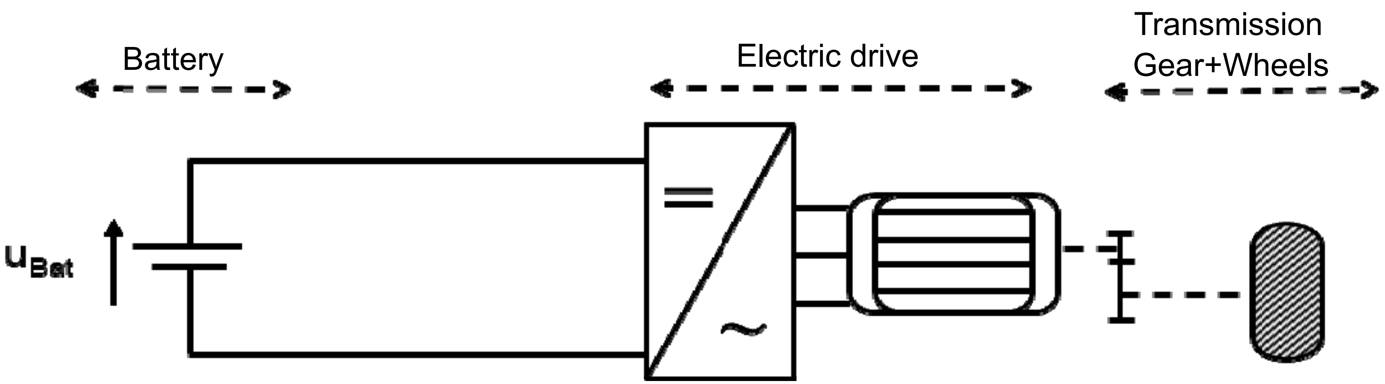


$$Err_{mean} = 1{,}73\ \%$$

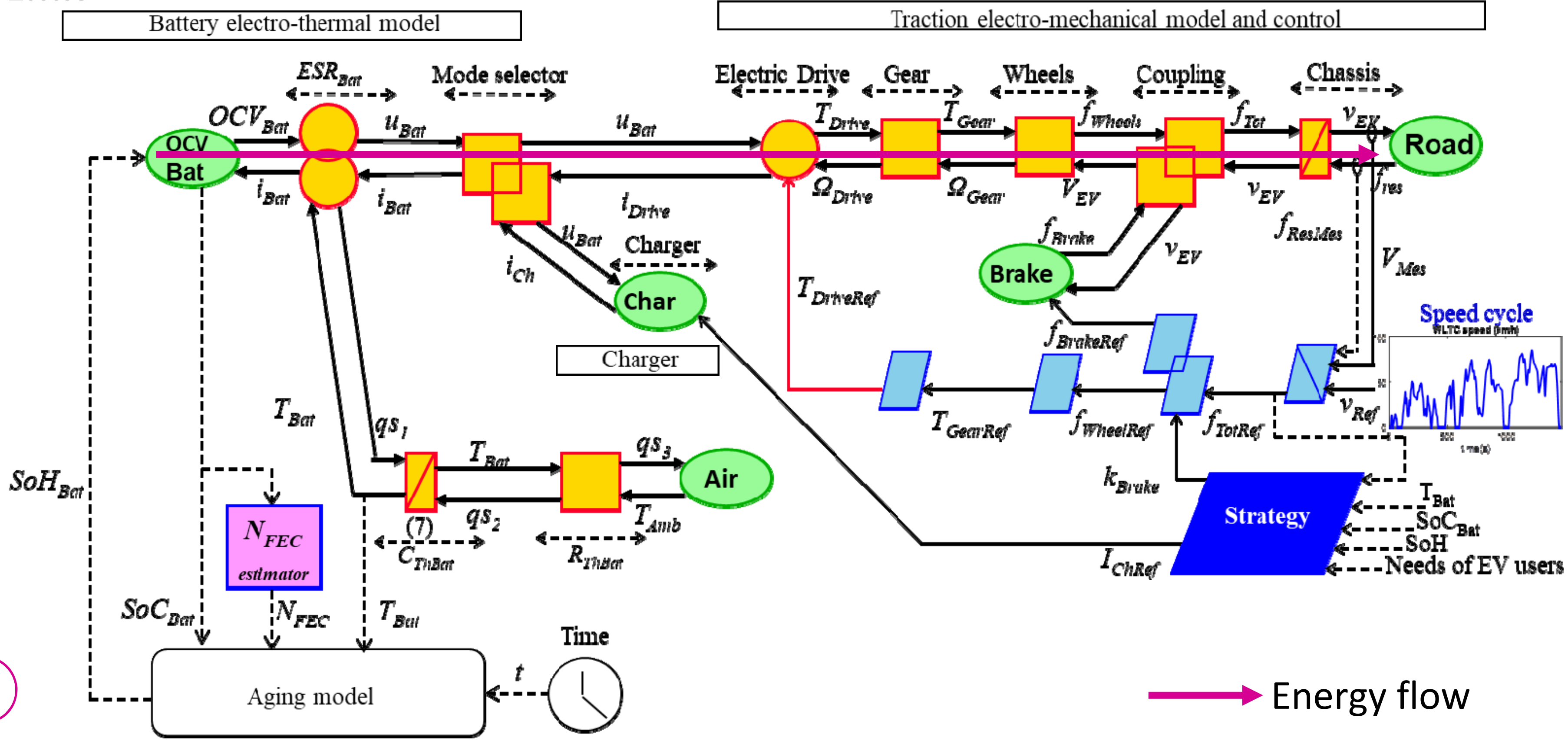
[Renault 2018]

Vehicle model during driving mode

- Structural representation



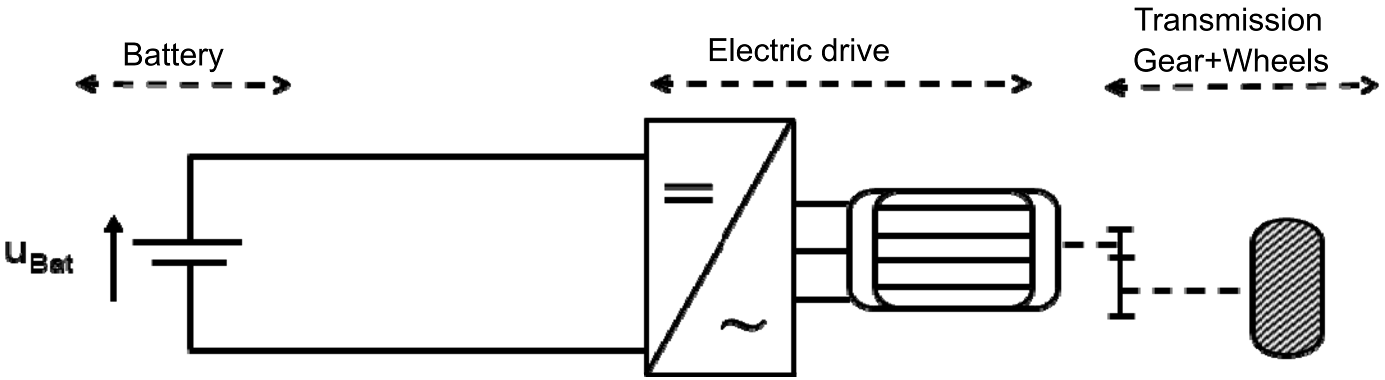
- EMR



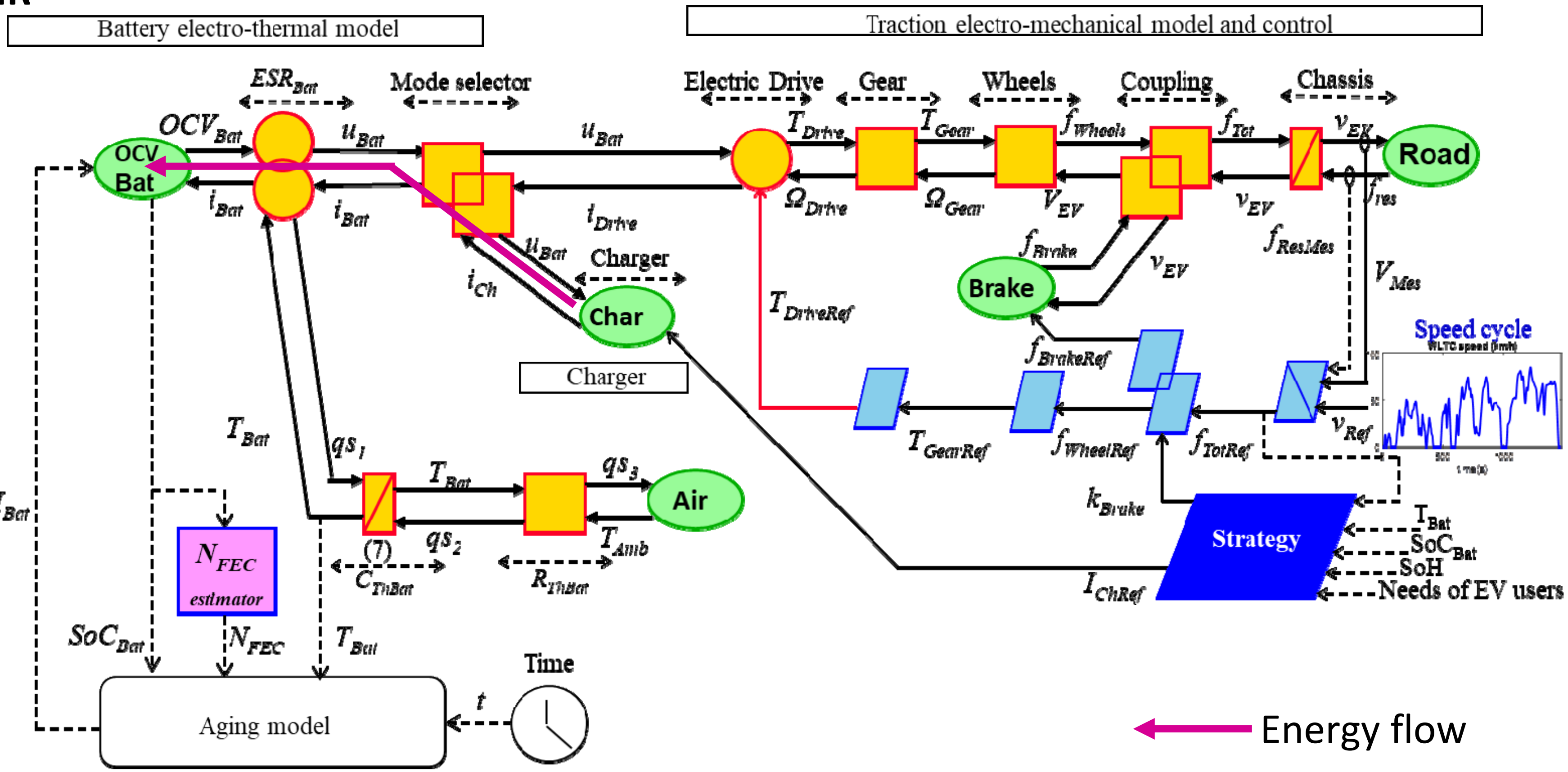
Energy flow

Vehicle model during charging mode

❑ Structural representation



❑ EMR



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3. Case study: influence of charging frequency

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Charging scenarios

Case study: daily use: round trip to work

Daily travel distance: 46 km $\begin{cases} 1\ Cycle\ WLTC\ home-to-work \\ 1\ Cycle\ WLTC\ work-to-home \end{cases}$

Charging protocol: CCCV C/6 / 4,2V / C/20 @T_amb = 25°C

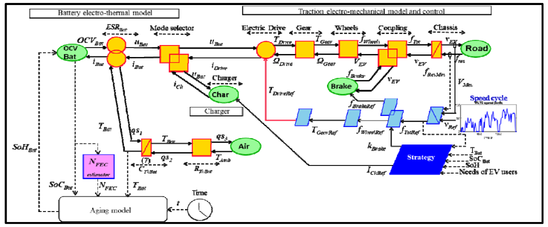
Charging scenario S1

(daily)

Charging scenario S2

(once a week)

EMR&Control of vehicle



Step time 10 ms

(T_{Bat} , SoC)

(C)

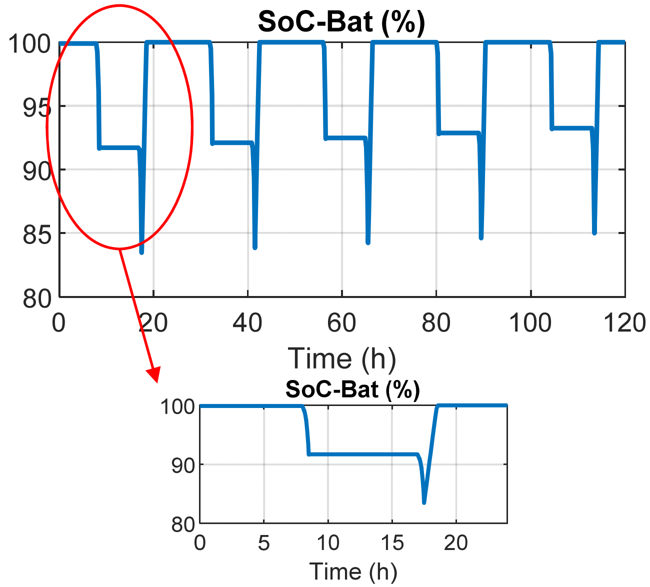
Step time 10 s

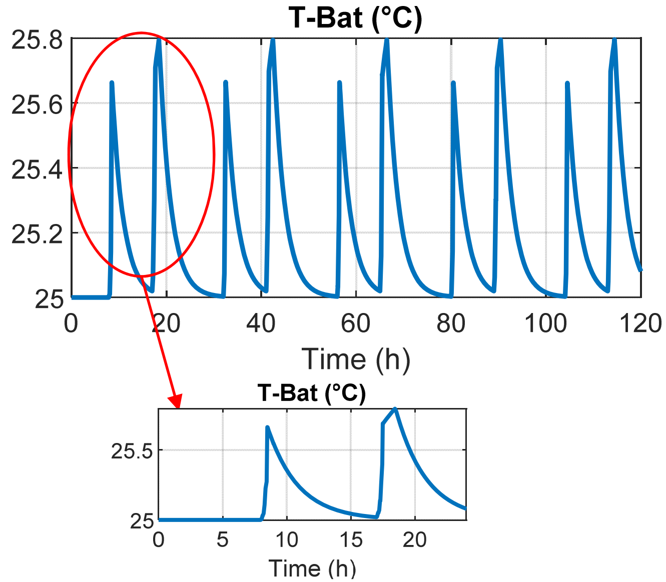
Aging Model

$$\Delta Closs_{tot} = (A_0 + B \times SoC) \times e^{\frac{-E_a}{K_B \times T}} \times \Delta t^z + K_{Cycl} \times \Delta Cycle$$

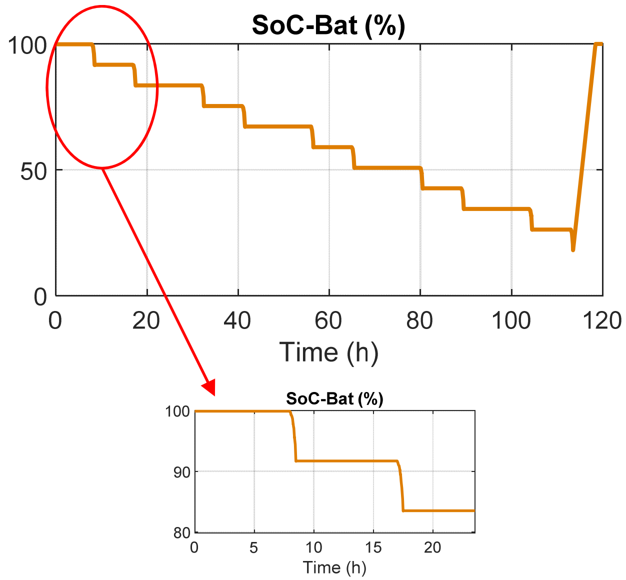
Simulation results

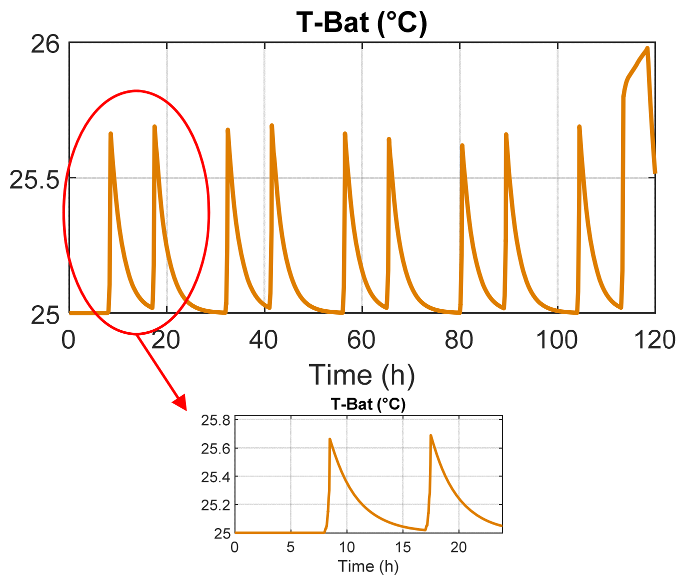
Scenario S1: charge every day



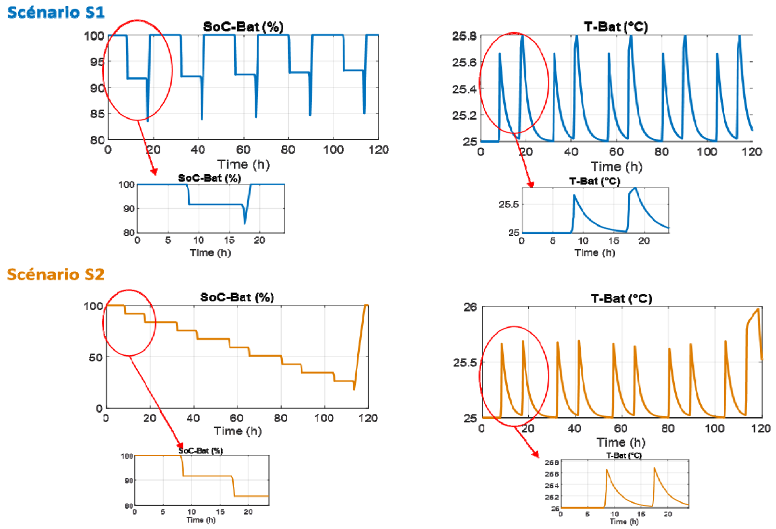


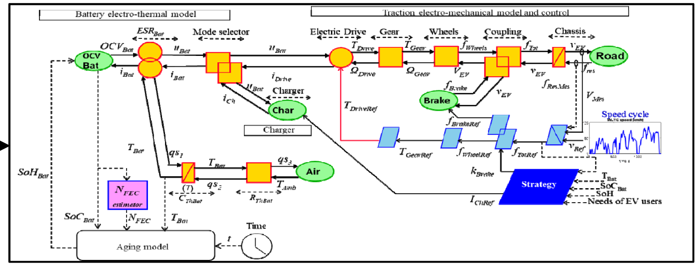
Scenario S2: charge once a week





Simulation results

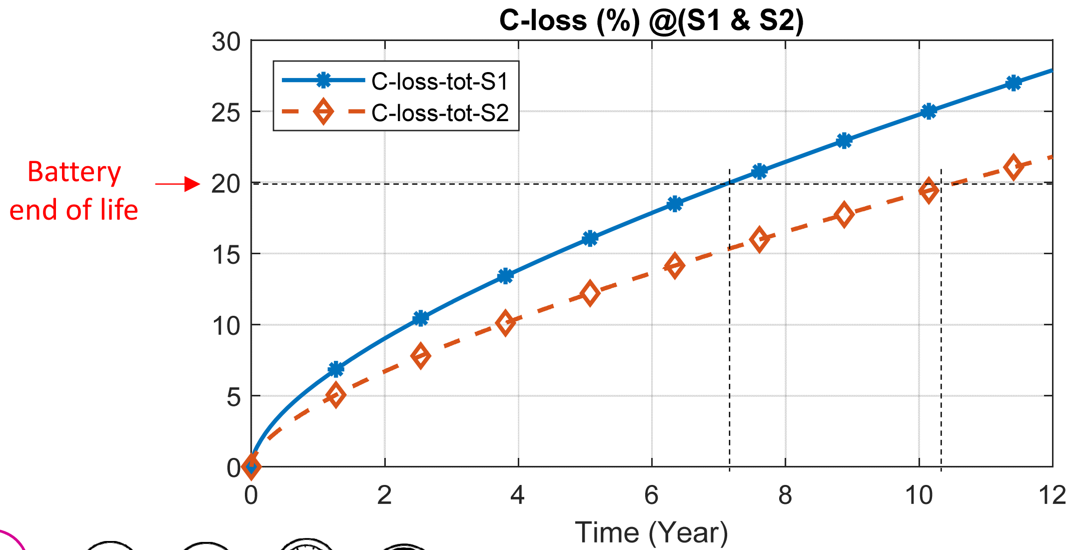




Aging Model

$$\Delta Closs_{tot} = (A_0 + B \times SoC) \times e^{\frac{-E_a}{K_B \times T}} \times \Delta t^z + K_{Cycl} \times \Delta Cycle$$

⇒ Simulation results:

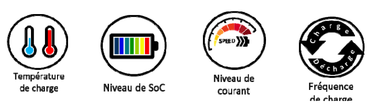


for the same kilometers:

S1 : 7,17 years

S2 : 10,6 years (+30%)

Charging the vehicle every day accelerates the aging of the battery



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4. Characterization tests of the Nissan Leaf's cells

Technical characteristics of the vehicle and the battery

Nissan Leaf 2018

Battery

Module (x24)

8 modules acquired for characterization:

- ❖ Funded by the University of Lille in the context of the CUMIN program
- ❖ Instrumented in the lab to acquire data (SoC, battery current, ...)

Main technical characteristics

Electrical machine		85 kW
Weight		1880 kg
Range (WLTC3)		270 km
Battery	Technology	Li-ion (NMC_{532})
	Voltage	350 V
	Energy	40 kWh
	Modules	24
	Cells	96s/2p

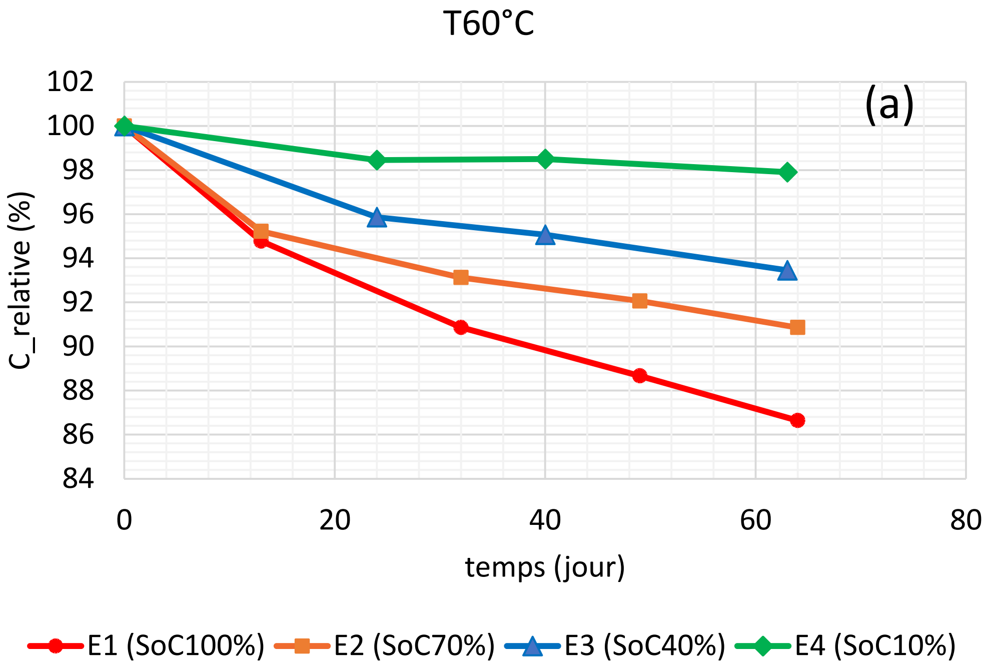
Objective: to determine the electrical, thermal and aging parameters of the cells.

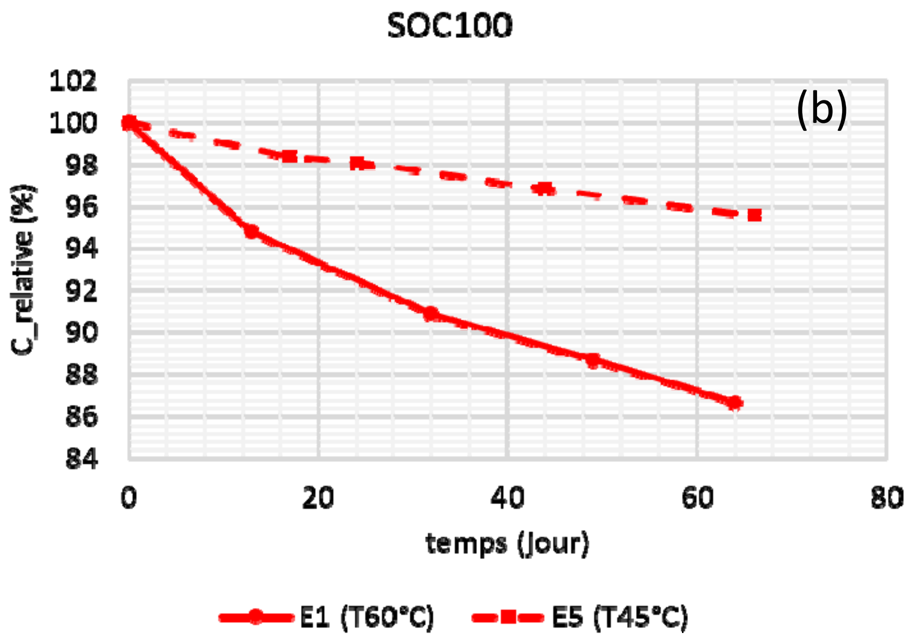
Tests conducted at AMPERE, University of Lyon 1.

Calendar aging test results

First results of calendar aging tests

E1 to E5: ➡ Cells under to different test conditions (SoC, T)





1. Storing the battery at high SoC leads to premature aging

2. High temperatures accelerate the aging of the battery

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Conclusion and perspectives

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Ampère

Conclusion and perspectives

Conclusion:

✓ The impact of charging on aging can be influenced by several factors:

-charging frequency,
-current level,
-battery temperature and
-SoC

✓ Simulation results: ➡ Charging the vehicle every day accelerates the aging of the battery

✓ Aging tests:
➡ Store the battery at high SoC
➡ Store the battery at high temperature
} Accelerate battery aging

Perspectives :

- Finish the cycling aging tests
- Determine model parameters for characterization tests
- Investigate alternative charging scenarios
- Validate the results at the level of the module and battery pack

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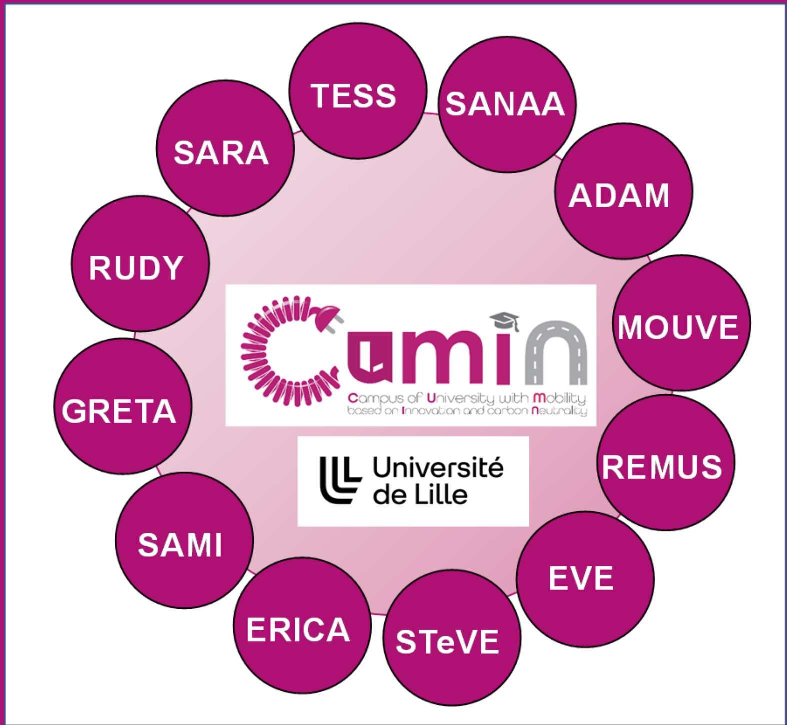
an exciting living lab
towards eco-cities!



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Ampère

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