CUMIN - STeVE

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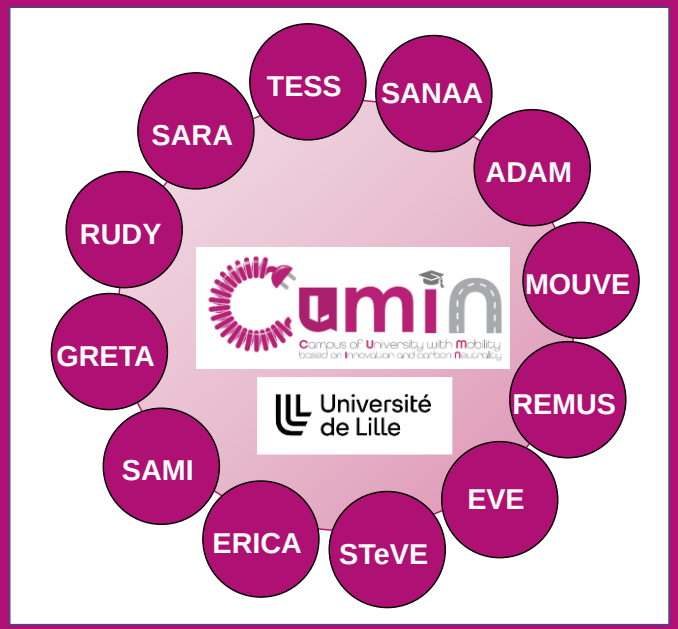

Scalable simulation framework for electric vehicles

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Outline

1. Context
2. Scalable simulation tool for different EV based-on EMR
3. Conclusion

Who Isn't Familiar with Russian Dolls?

Ref: https://www.vecteezy.com

- **Same shape, design, color, and pattern** throughout the set.
- **Easily scalable**, with each doll decreasing or increasing in proportion
- **Fast production process**

A Russian Doll Analogy: Scalability in Automotive Sector

- Wide range of automotive applications
- Same components, but diverse requirements…

ref: https://www.renaultgroup.com

Just like Russian dolls, scalability in design allows electric motors to adapt across transport applications

Link with CUMIN project

- Need for fast energy consumption assessment of different solutions

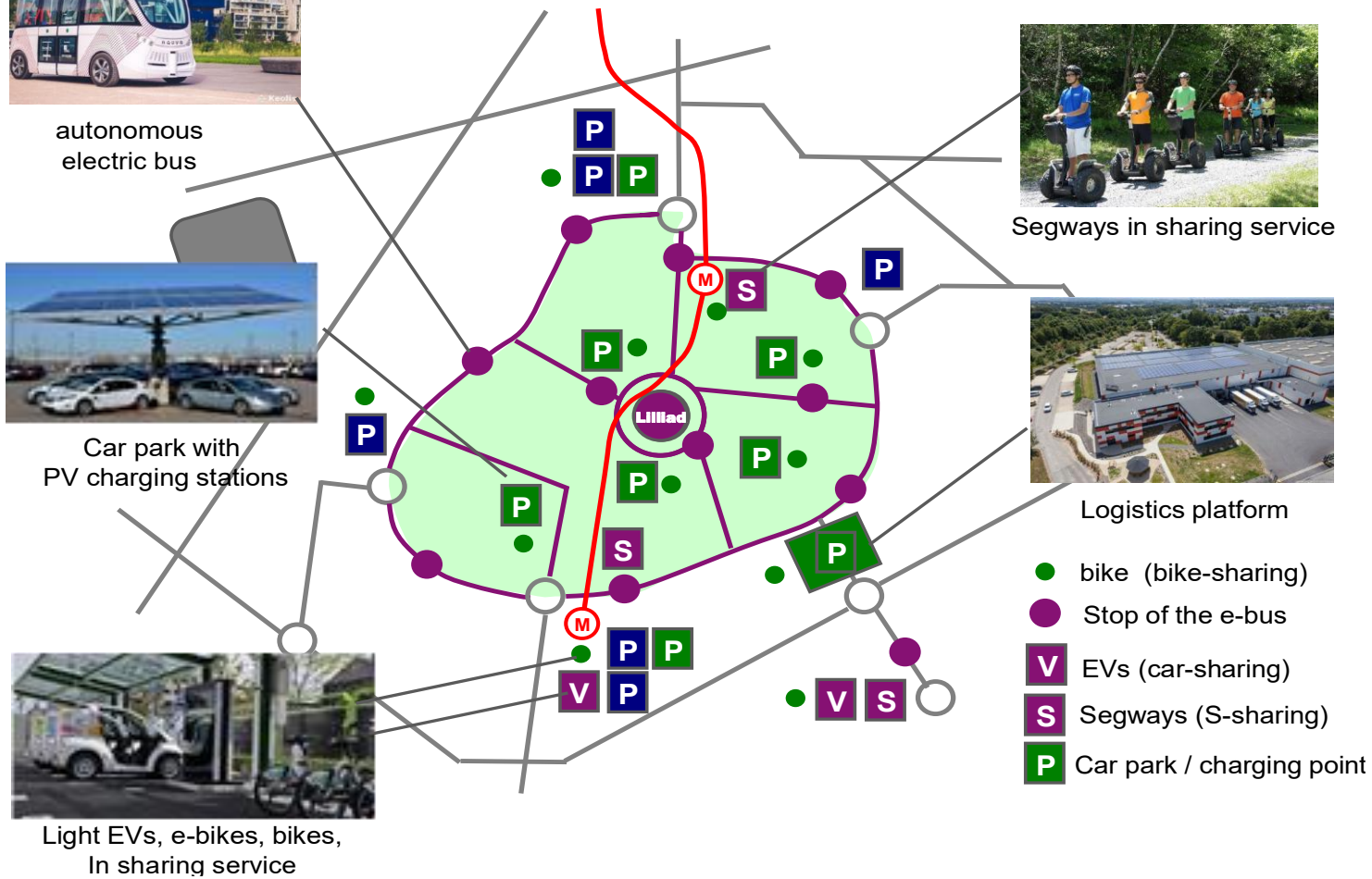
autonomous
electric bus

Car park with
PV charging stations

Light EVs, e-bikes, bikes,
In sharing service

Segways in sharing service

Logistics platform



- Objective: Develop a simulation tool for transferring/scaling the design solutions of a reference component to promptly derive others

Outline

1 Context

2 **Scalable simulation tool for different EV based-on EMR**

3 Conclusion

Case study: scaling of an electric motor of a passenger car

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Affordable version
Limited performances

Sporty version
Improved performances

Downscaling

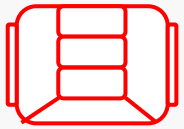
54 kW

↘ Top speed

↘ Acceleration time 0-100 km/h

Reference e-axle

80 kW

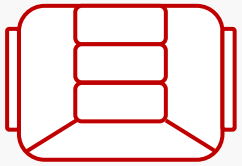


Top speed : 144 km/h

Acceleration time 0-100 km/h: 9.9 s

Upscaling

110 kW



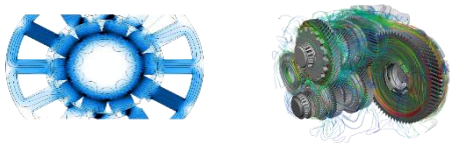
↗ Top speed

↗ Acceleration time 0-100 km/h

Power scaling: 0.67

Power scaling: 1.33

How to achieve this?

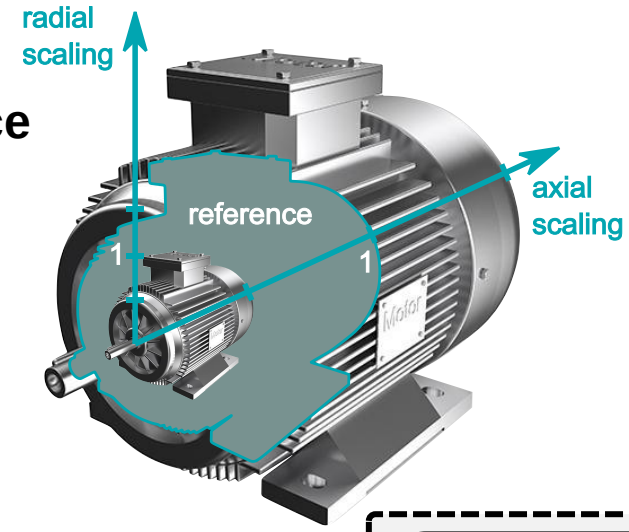


Numerical models
Testing results

Data of a reference component

Scaling laws

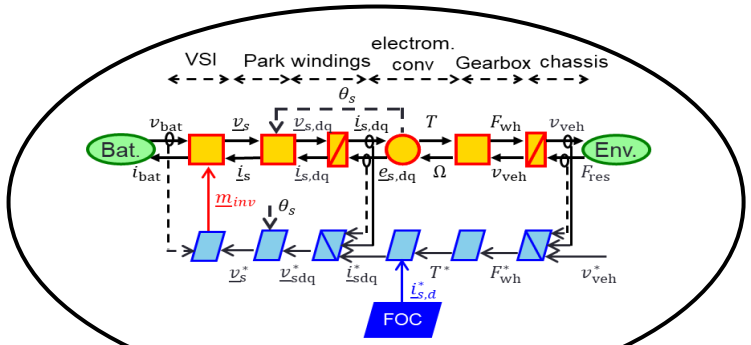
Time-consuming and effort-intensive

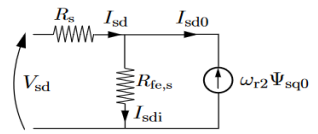


Scaled Data

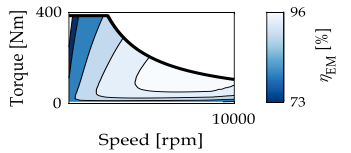
Distinct geometries
Different power rating

System-level simulation
Vehicle model



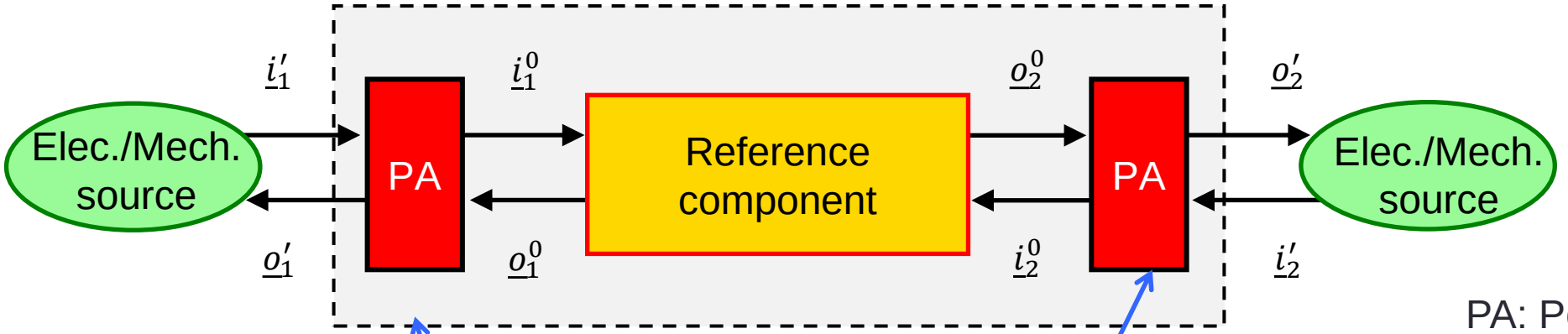


Analytical models



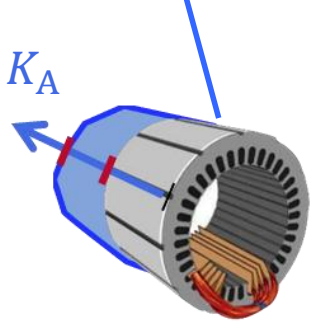
Mapping-based models

New structuration of the scaled electric motor model based on scaling laws

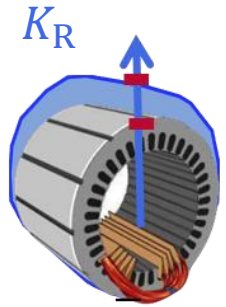


PA: Power Adaptation

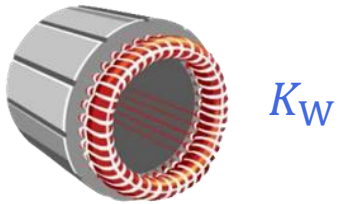
Electric motors scaling



- Axial scaling



- Radial scaling

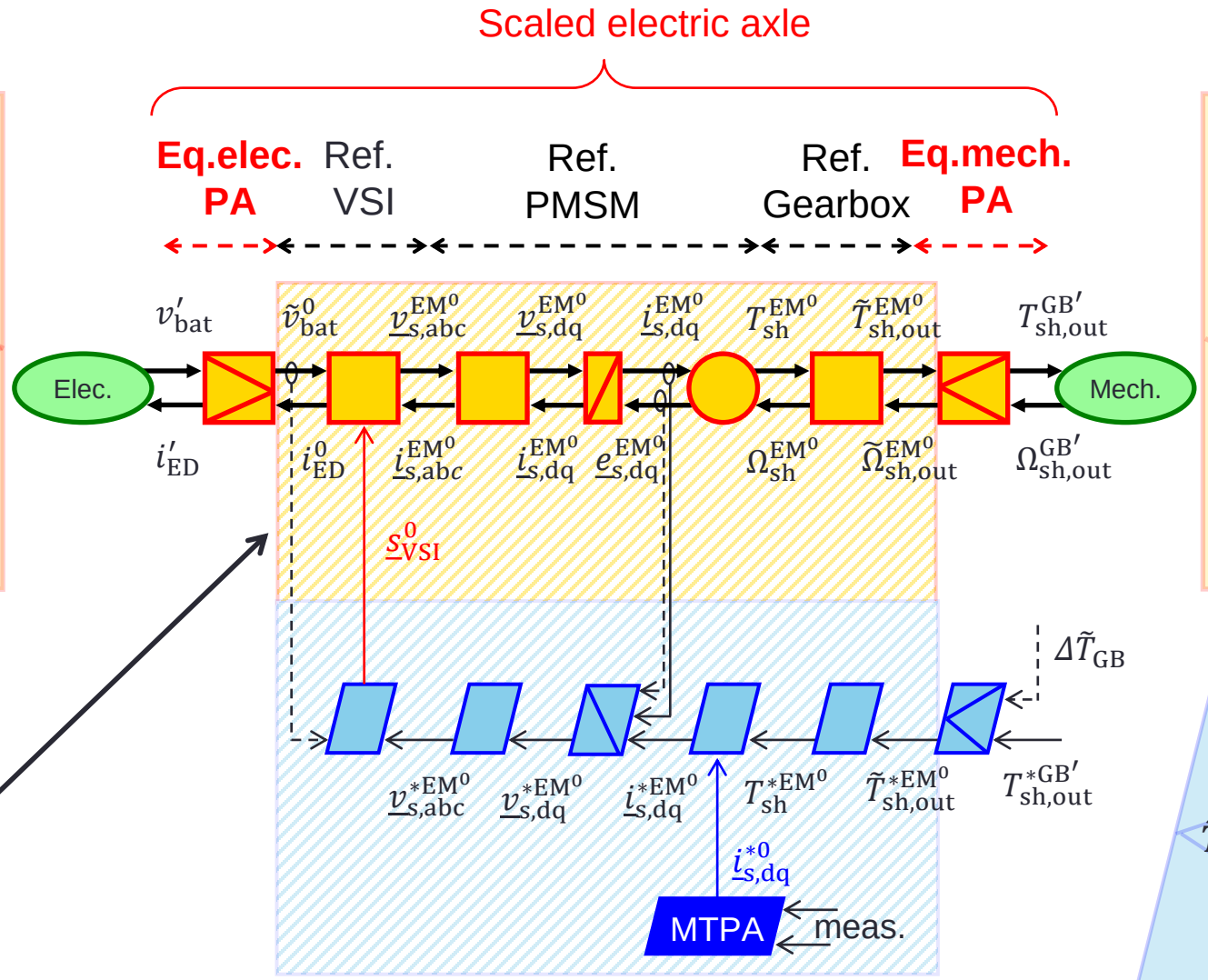


- Rewinding

[Lhomme 20]

EMR-based scaling laws

$$\begin{cases} \tilde{v}^{0}_{\mathrm{bat}} = v'_{\mathrm{bat}} - \dfrac{\Delta P_{\mathrm{cu}}}{\eta^{0^{\gamma}}_{\mathrm{VSI}} i^{0}_{\mathrm{ED}}} \\ i'_{\mathrm{ED}} = K_{\mathrm{i}}^{\mathrm{PMSM}} i^{0}_{\mathrm{ED}} \end{cases}$$



$$\begin{cases} T^{\mathrm{GB}'}_{\mathrm{sh,out}} = K_{\mathrm{kgb}} K_{\mathrm{T}}^{\mathrm{PMSM}} T^{\mathrm{EM}^0}_{\mathrm{GB,out}} - \Delta\tilde{T}_{\mathrm{GB}} \\ \tilde{\Omega}^{\mathrm{EM}^0}_{\mathrm{sh,out}} = K_{\mathrm{kgb}} \Omega^{\mathrm{GB}'}_{\mathrm{sh,out}} \end{cases}$$

Model of the reference electric axle

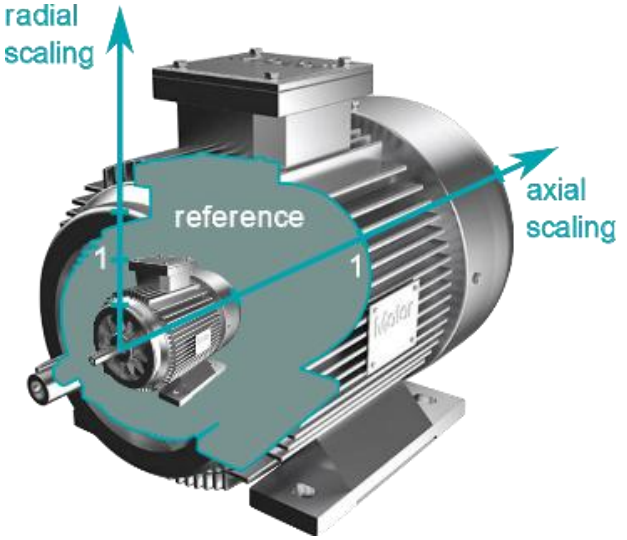
Scalable inversion-based control of the reference electric axle

$$\tilde{T}^{*\mathrm{EM}^0}_{\mathrm{sh,out}} = \frac{T^{*\mathrm{GB}^0}_{\mathrm{sh,out}} + \Delta\tilde{T}^{\mathrm{meas}}_{\mathrm{GB}}}{K_{\mathrm{kgb}} K_{\mathrm{T}}^{\mathrm{PMSM}}}$$

[Aroua 21]

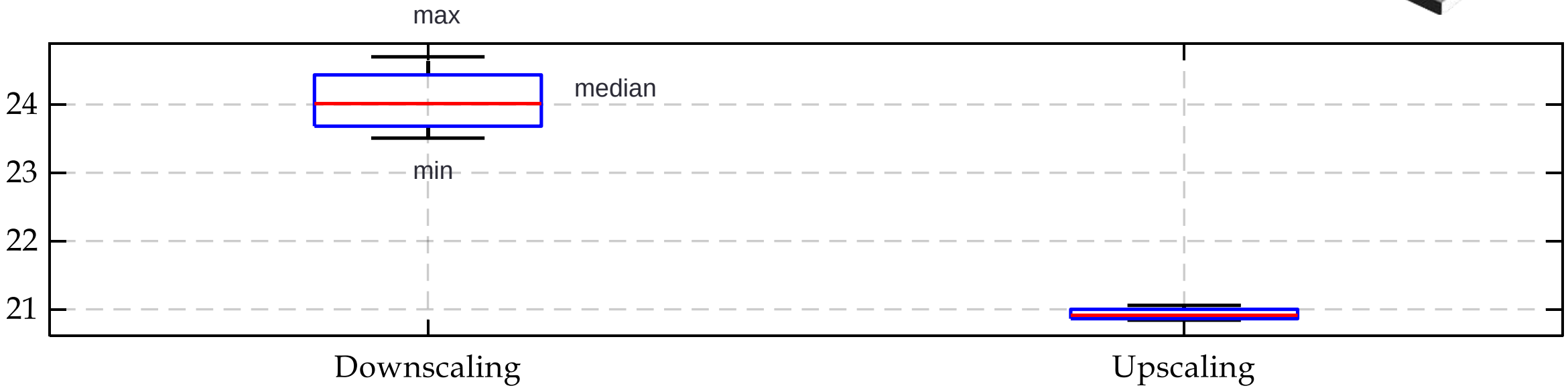
Energy consumption assessment

Distinct geometries/designs



$E_{bat}[kWh/100km]$

NYCC urban driving cycle



Conclusion

- Scalable simulation framework to analyze the performance of a broad range of EV
- New organization of the scaling laws
- Ease of incorporation of scalability to speed up the system-level simulations

➢ Perspectives:

  - Extend the application of scalability to energy storage and generation systems (battery/fuel cell)

References

[Aroua 21]: Aroua, A., Lhomme, W., Verbelen, F., Bouscayrol, A., & Stockman, K. (2021, October). Inversion-based Control of Scaled PMSM for Battery Electric Vehicles. In *2021 IEEE Vehicle Power and Propulsion Conference (VPPC)* (pp. 1-6). IEEE.

[Lhomme 20]: Lhomme, W., Verbelen, F., Ibrahim, M. N., & Stockman, K. (2020, November). Energetic macroscopic representation of scalable PMSM for electric vehicles. In *2020 IEEE Vehicle Power and Propulsion Conference (VPPC)* (pp. 1-6). IEEE.

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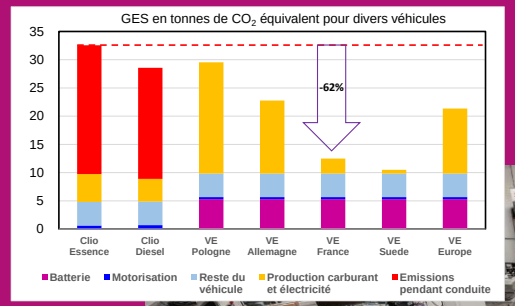

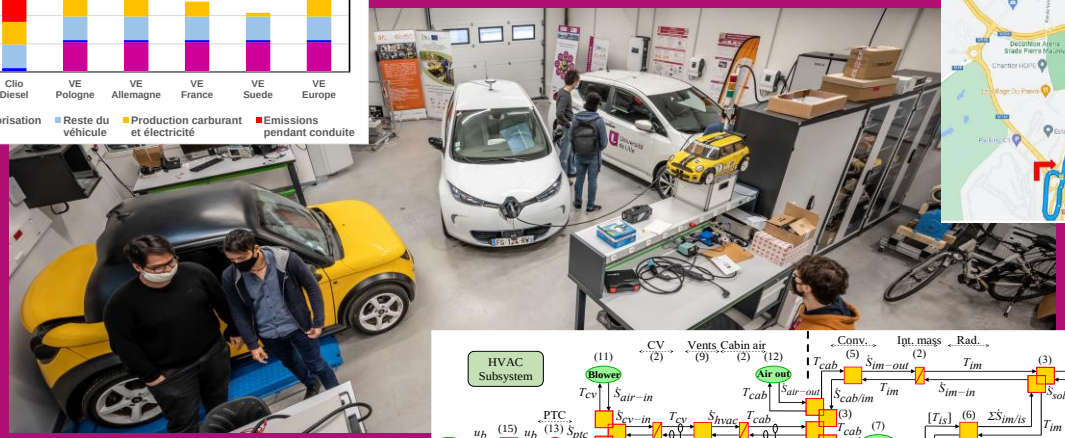

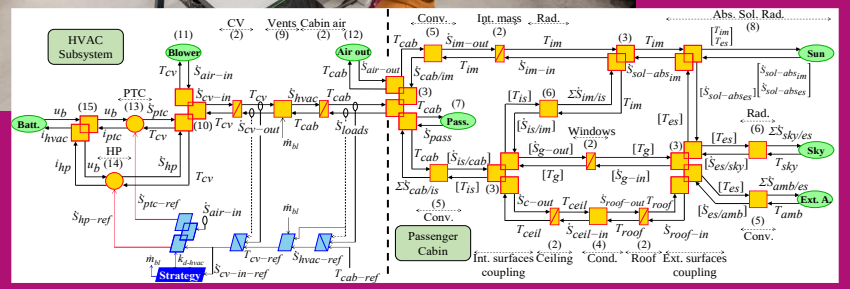

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