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Accounting for the Aging of Li-Ion Batteries in a LCA Model: motivations and development of an open-source tool

edlb+
L'école de la batterie

Brightcon – 15.10.2025

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Opération soutenue par l'État dans le cadre de l'AMI « Compétences et Métiers d'Avenir » du Programme France 2030, opéré par la Caisse des Dépôts

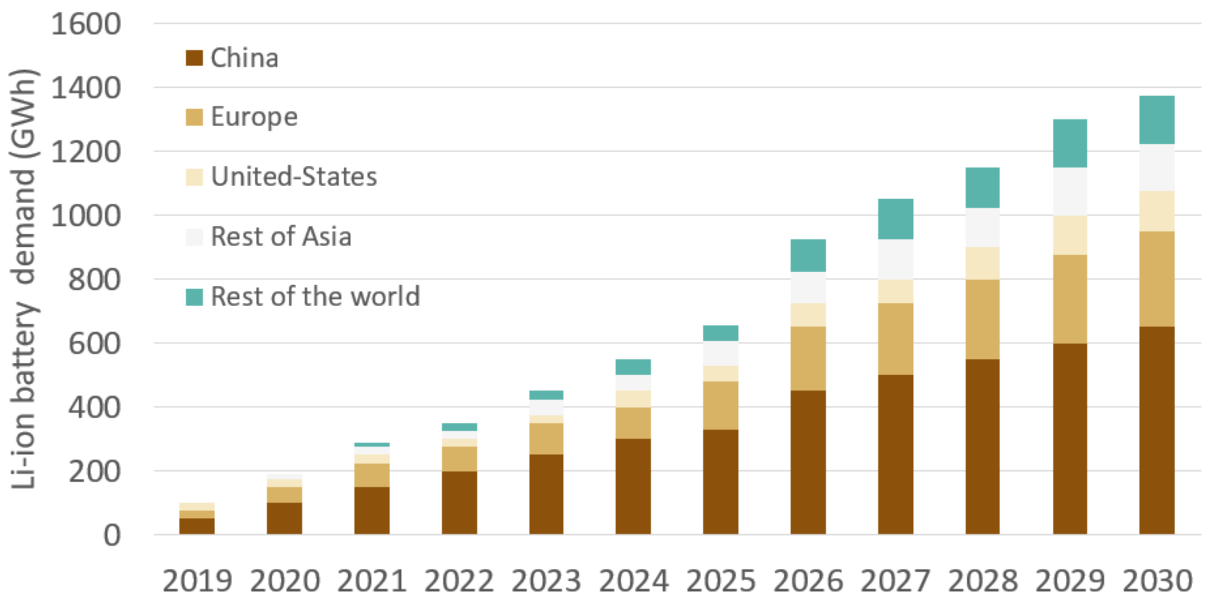
Context

Strategic Critical Raw Materials

Lithium-ion Batteries

Li Lithium	**C** Carbon	**Al** Aluminium
Co Cobalt	**Ni** Nickel	**Cu** Copper
	Mn Manganese	

Estimated demand for Li-ion batteries for electric vehicles



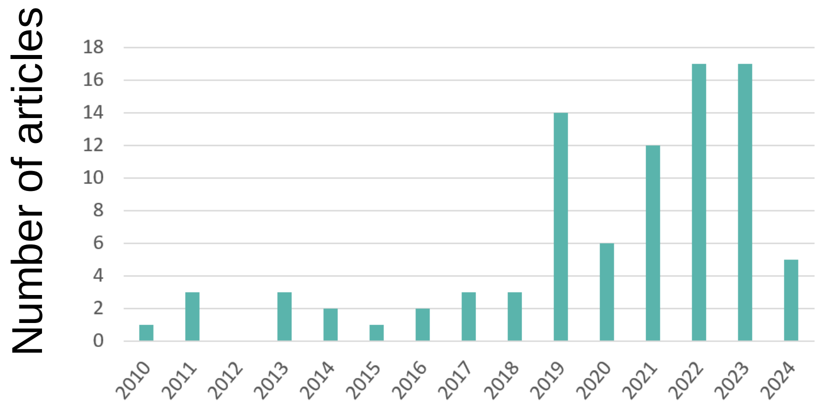
Source : *Martins et al., 2021*

Study of rebound effects

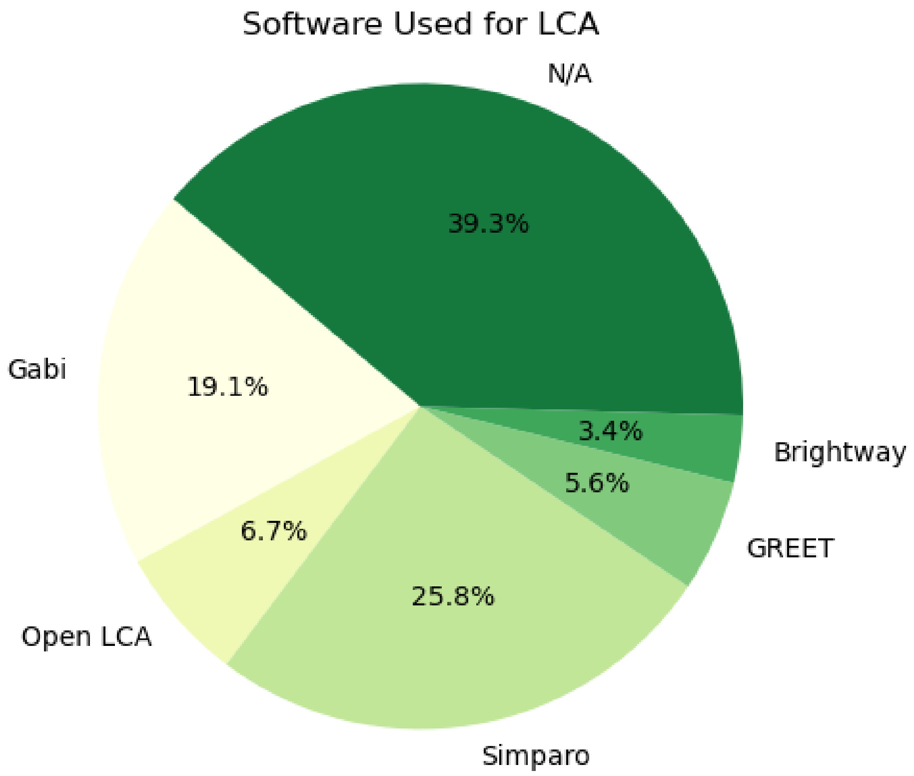
Summary

I. Review on LCA of Batteries
II. Battery Sustainability Tool
III. Perspectives

90 papers
24 review
LCA



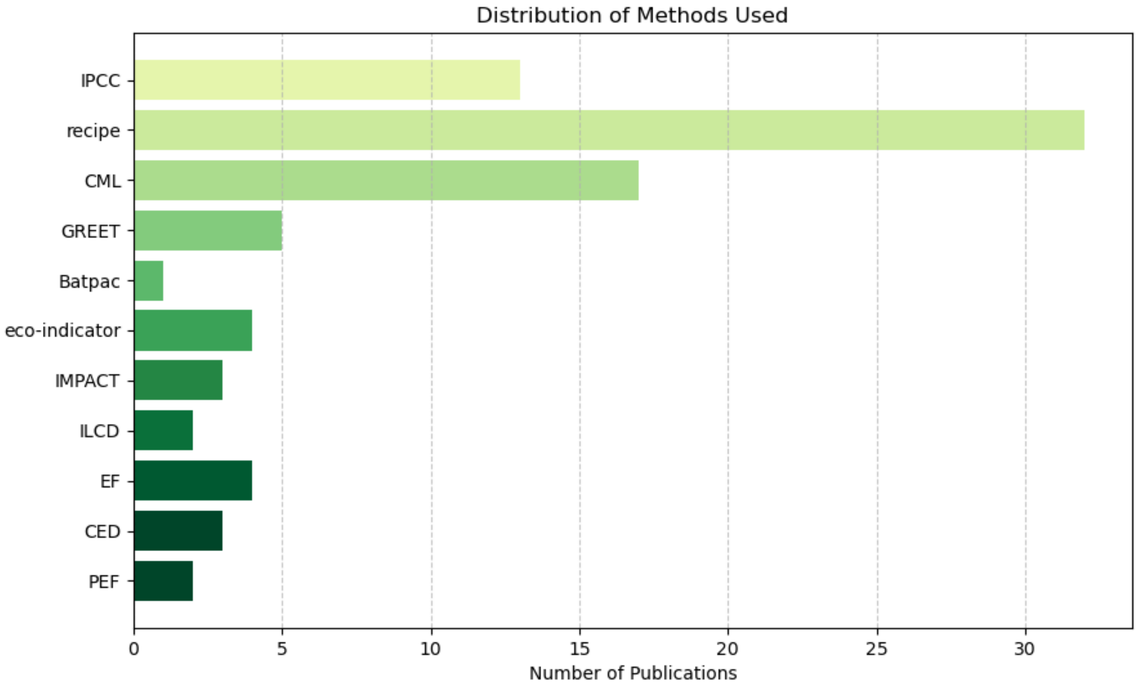
Breakdown of the 90 papers reviewed on Li-ion battery LCA by year

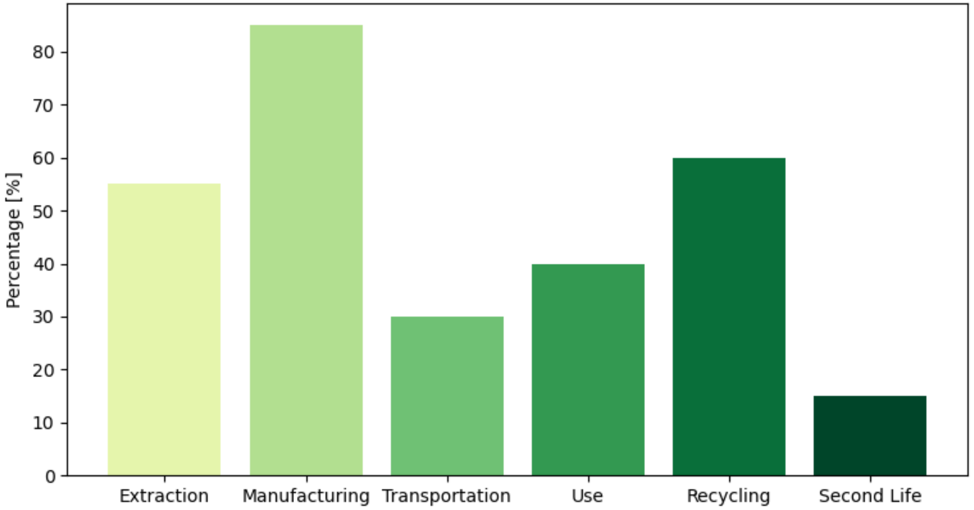


Life Cycle Assessment (LCA)

“The results of various life cycle analyses or inventories can only be **compared** when the **assumptions and context of each study are the same**”

"Due to the inherent complexity of life cycle assessment, transparency is an important guiding principle in conducting LCAs, in order to ensure that the **results can be properly interpreted** [...] ISO 14044 **requires total transparency**"





ISO 14040

Results of the Review

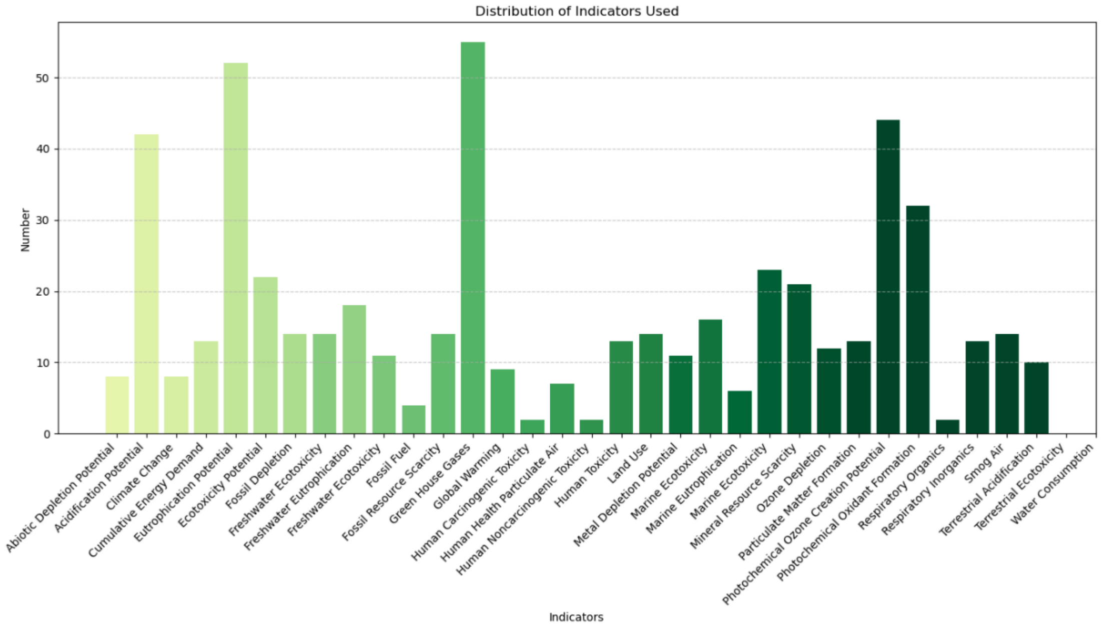
- Heterogeneity of **tools** (database, software) and **methods** (methods, indicators) used and **domain** (chemistry, life cyle) studied

- Lack of access to **reliable data**

- Generable conclusions and recommendations are difficult to extract

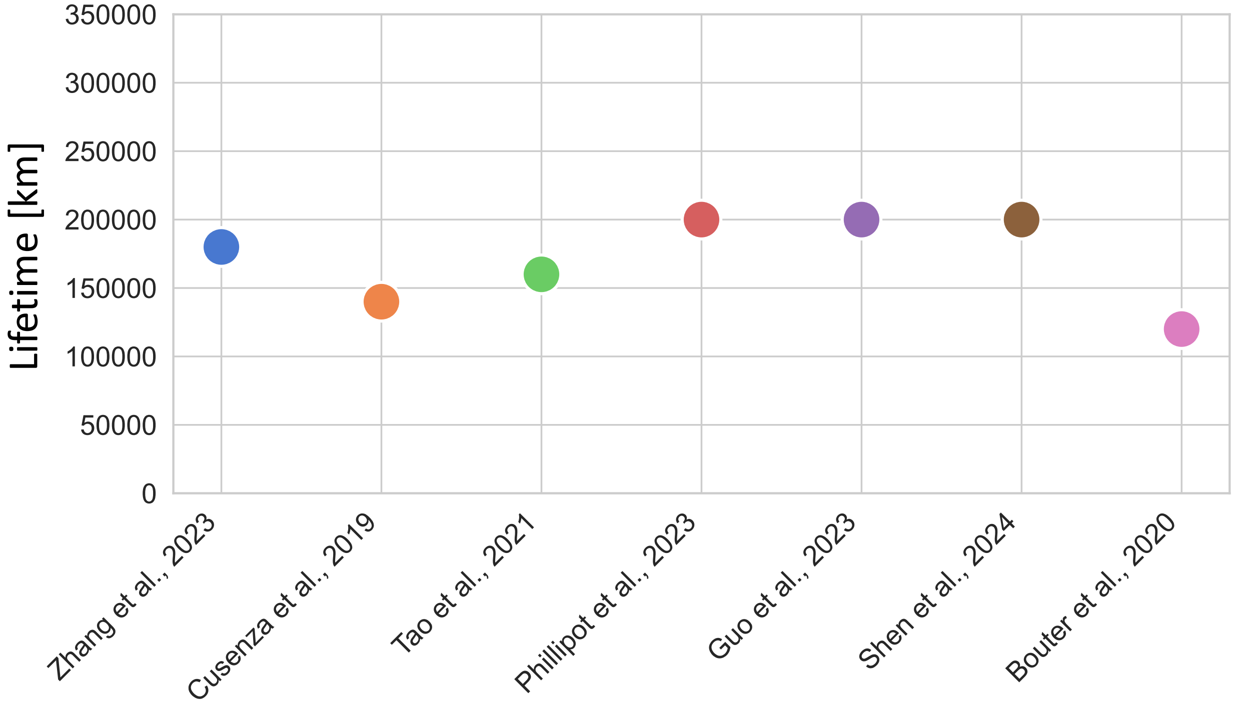
- Lack of link between **battery aging** and **LCA**

Recycling + manufacturing NMC pack in China	
Articles Studied	GWP Score (CO2 eq)
J. Šimaitis et al., 2023	90
E. Kallitsis et al., 2022	170



Indicators used in the battery LCA litterature

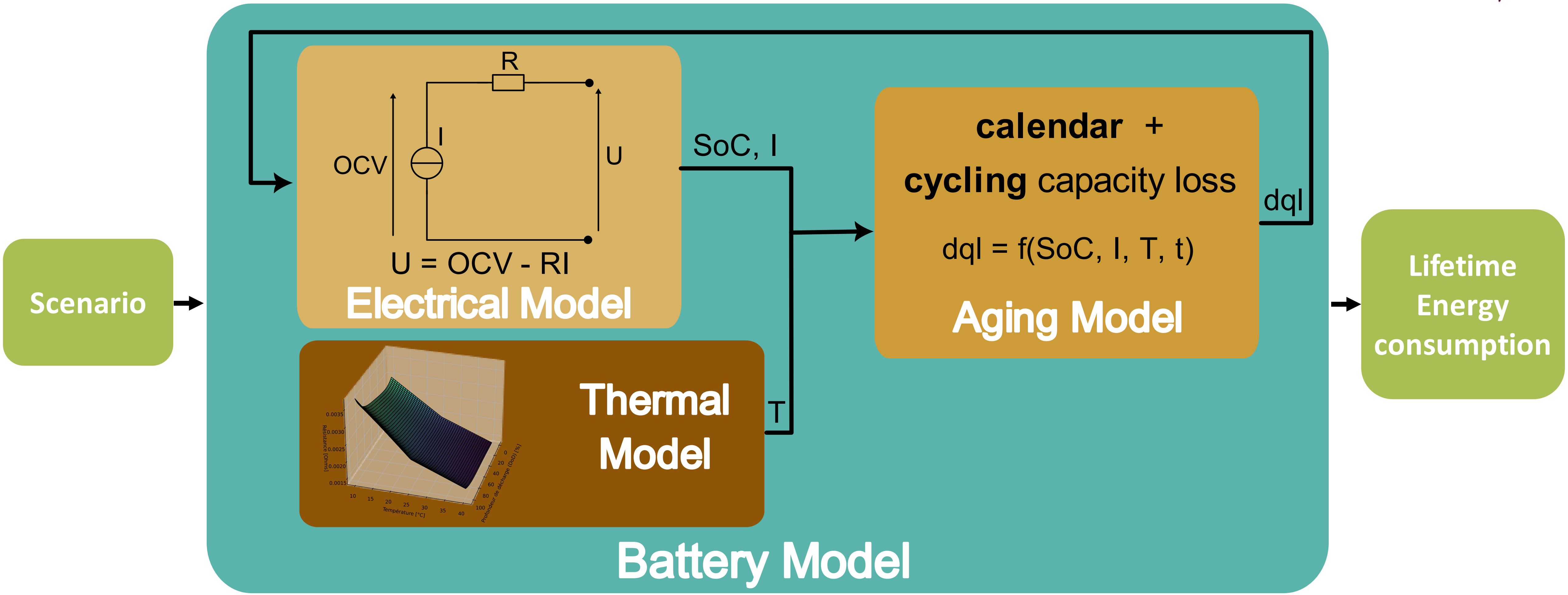
Results of the Review



Fixed Lifetime of the Batteries in the LCA Litterature

- **Fixed lifetime of 200.000 km over 10 years in average**
- **Not accounting for the scenario or external conditions**

Battery Model



[1] E. Redondo-Iglesias, P. Venet, et S. Pelissier, « Eyring acceleration model for predicting calendar ageing of lithium-ion batteries », J. Energy Storage, vol. 13, p. 176-183, oct. 2017, doi: 10.1016/j.est.2017.06.009.

[2] A. Houbbadi, E. Redondo-Iglesias, S. Pelissier, R. Trigui, et T. Bouton, « Smart charging of electric bus fleet minimizing battery degradation at extreme temperature conditions », in 2021 IEEE Vehicle Power and Propulsion Conference (VPPC), oct. 2021, p. 1-6. doi: 10.1109/VPPC53923.2021.9699367.

Battery Model

BANANES : Battery **A**gei**N**g **AN**alysis and **ES**timation

Calibrate the ageing model coefficients [1] and [2] based on data obtained from ageing tests

calendar +
cycling capacity loss

dql = f(SoC, I, T, t)

Aging Model

https://gitlab.com/dattes/bananes

[1] E. Redondo-Iglesias, P. Venet, et S. Pelissier, « Eyring acceleration model for predicting calendar ageing of lithium-ion batteries », J. Energy Storage, vol. 13, p. 176-183, oct. 2017, doi: 10.1016/j.est.2017.06.009.
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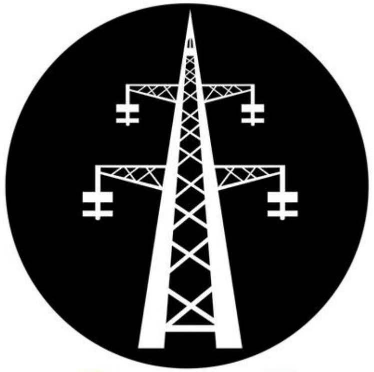
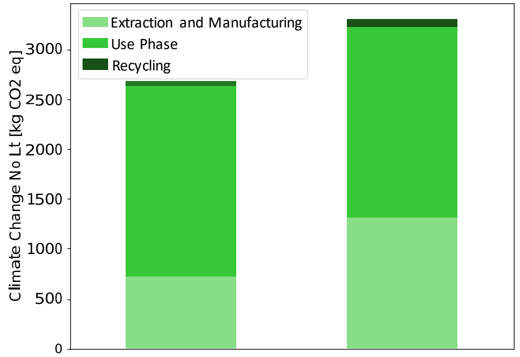
Battery Sustainability Tool

- Battery **NMC532** of 62 kWh ;
- Scenario : **20 000 km/year**, calibrated on WLTC ;
- Data **Ecoinvent**
- Method of impact assessment **EF3.1**

$$x\ \textbf{kWh} * impact/kWh$$



$$impact/year = \frac{total\ impact}{lifetime}$$



Battery Lifetime : 20 years 10 years

Operating Cycle
External Temperature

↓

Battery Model with Ageing

↓

Lifetime
Energy Consumption

↓

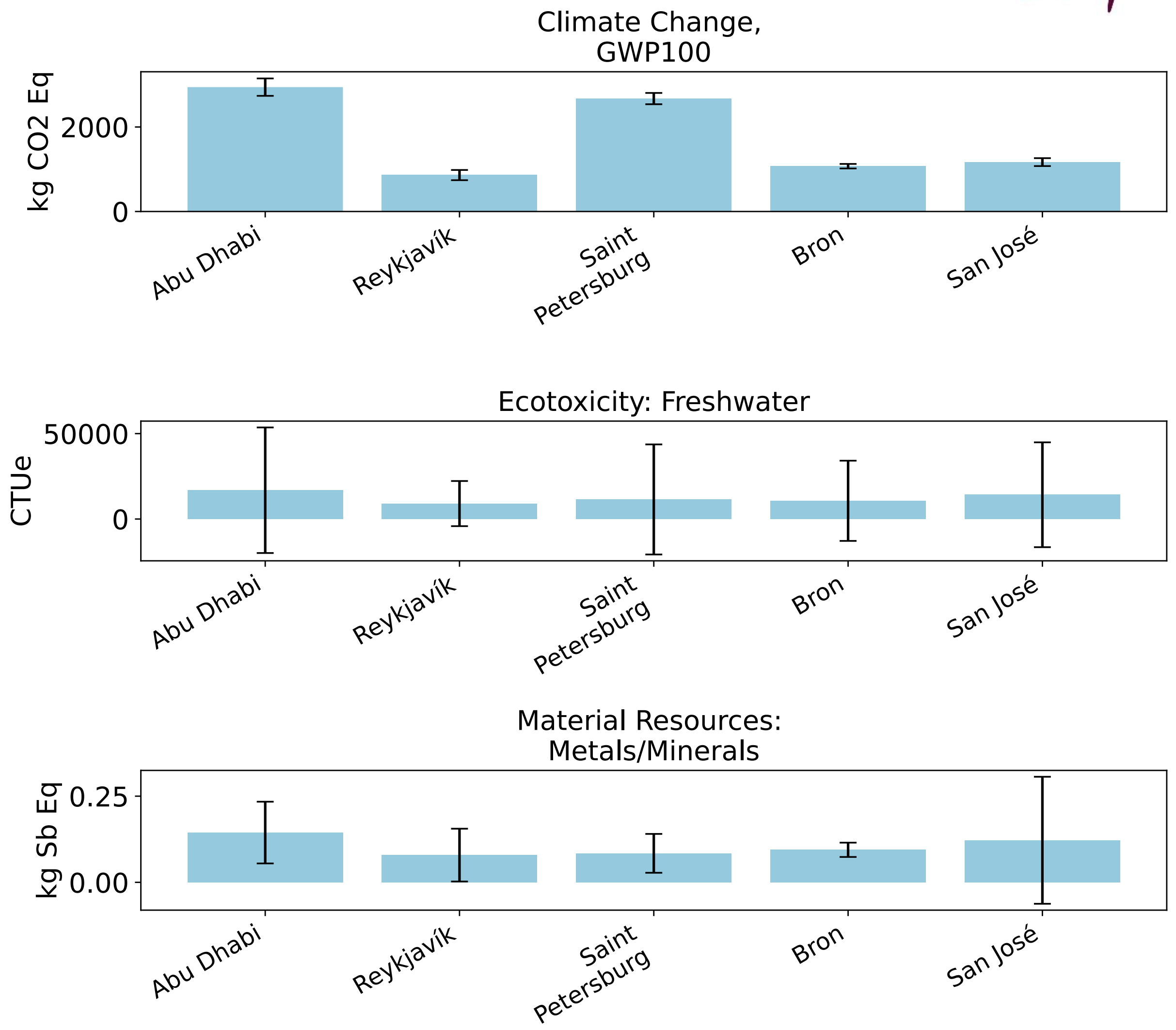
Life Cycle Assessment

Brightway 25

Results and Analysis

Battery model assumptions:

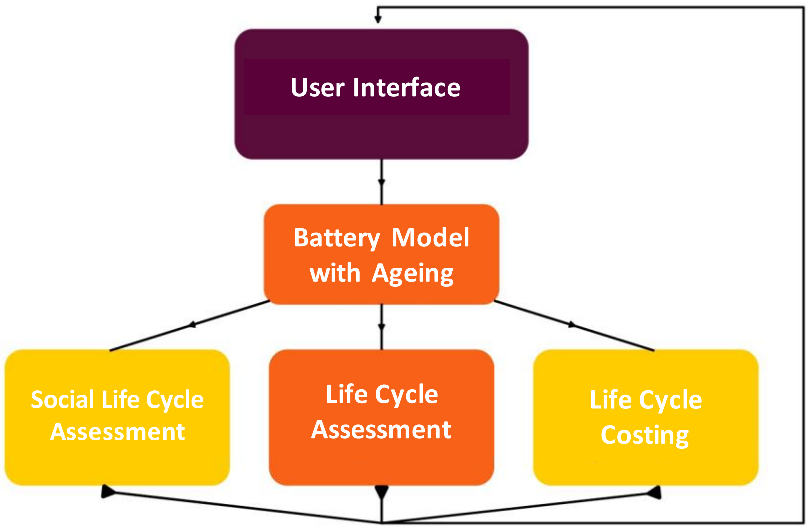
- Very simple thermal model;
- Recharging at 20/25 °C;
- Ageing valid over a limited temperature range;
- Ageing calibrated based on decharging data.

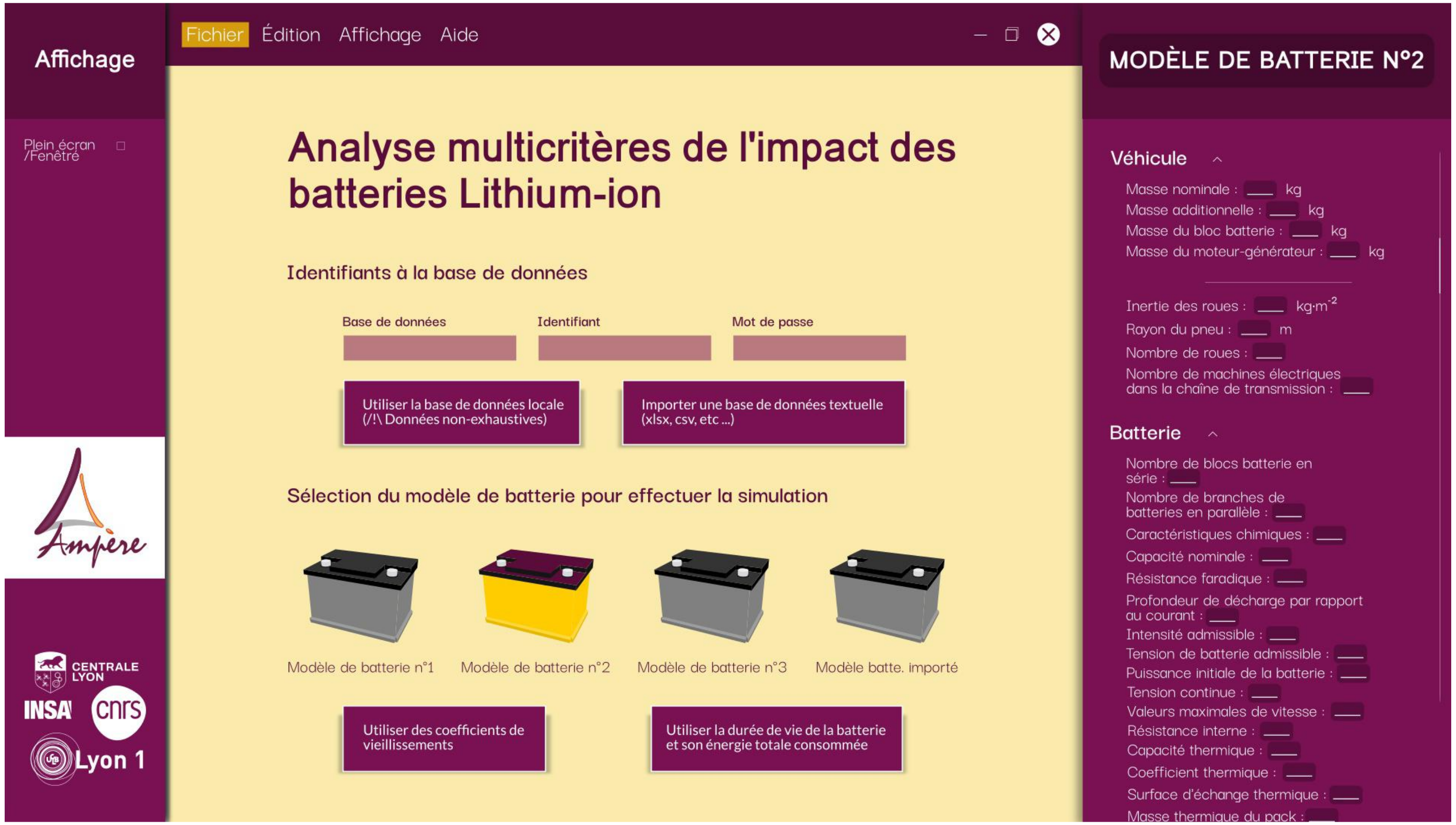


- **Impact of outside temperature on battery life**
- **Impact of the composition of the electricity mix**
- **Impact of the battery model (and choice of model)**

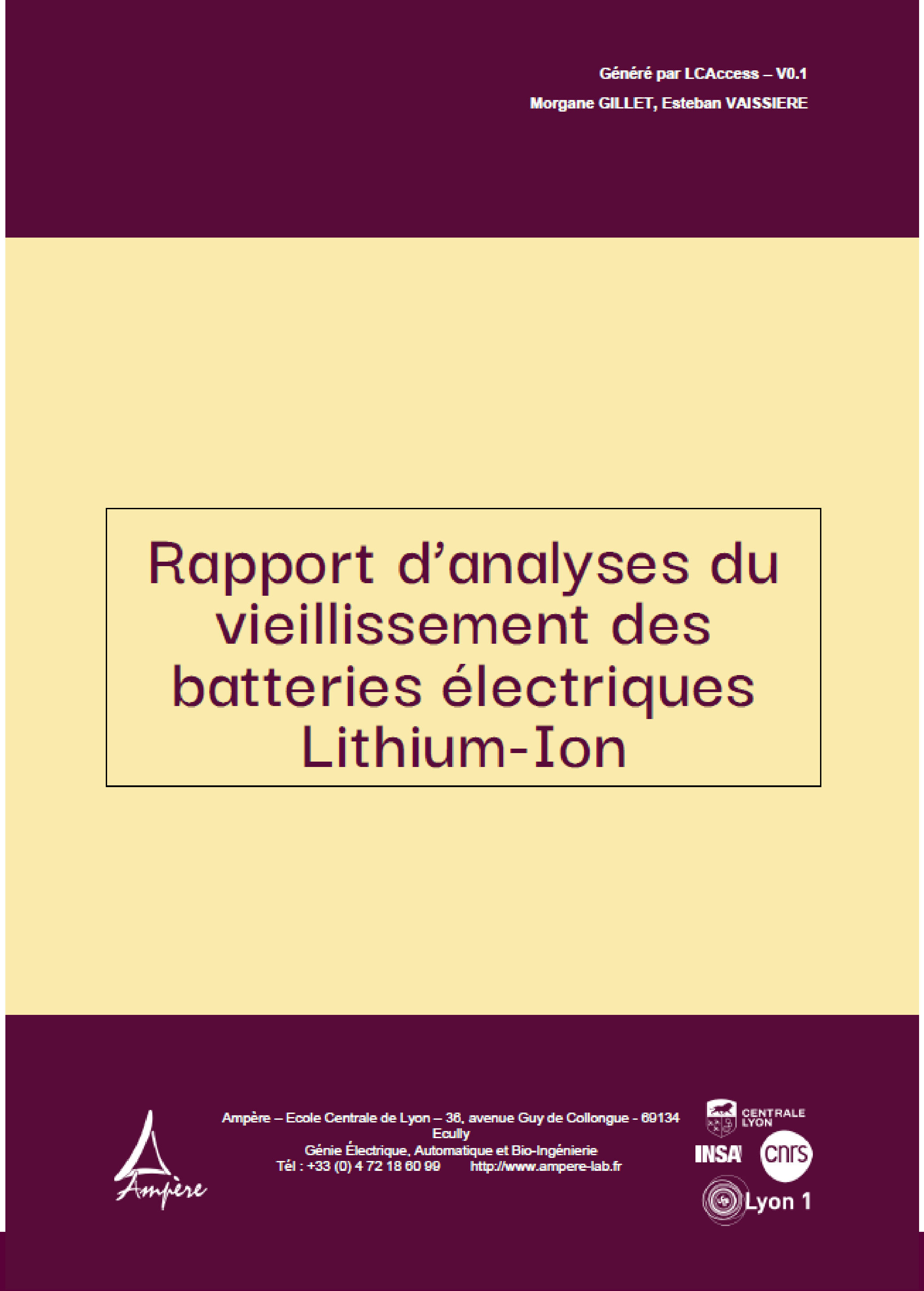
Battery Sustainability Tool

Graphical application developped by Esteban Vaissière:





https://gitlab.in2p3.fr/esteban.vaissiere/lcaccess



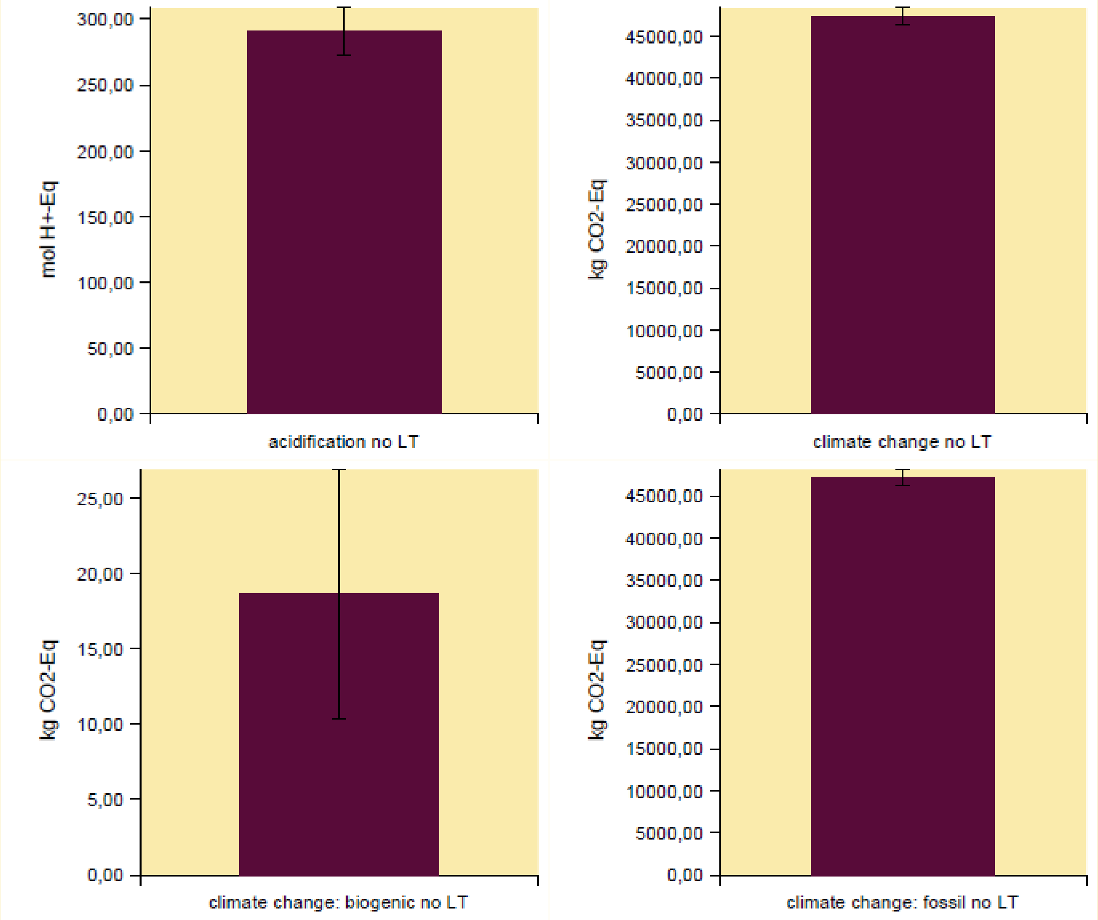
Généré par LCAccess – V0.1

Morgane GILLET, Esteban VAISSIERE

Rapport d'analyses du vieillissement des batteries électriques Lithium-Ion

Ampère – Ecole Centrale de Lyon – 36, avenue Guy de Collongue - 69134 Ecully
Génie Électrique, Automatique et Bio-Ingénierie
Tél : +33 (0) 4 72 18 60 99 http://www.ampere-lab.fr

Résultats obtenus

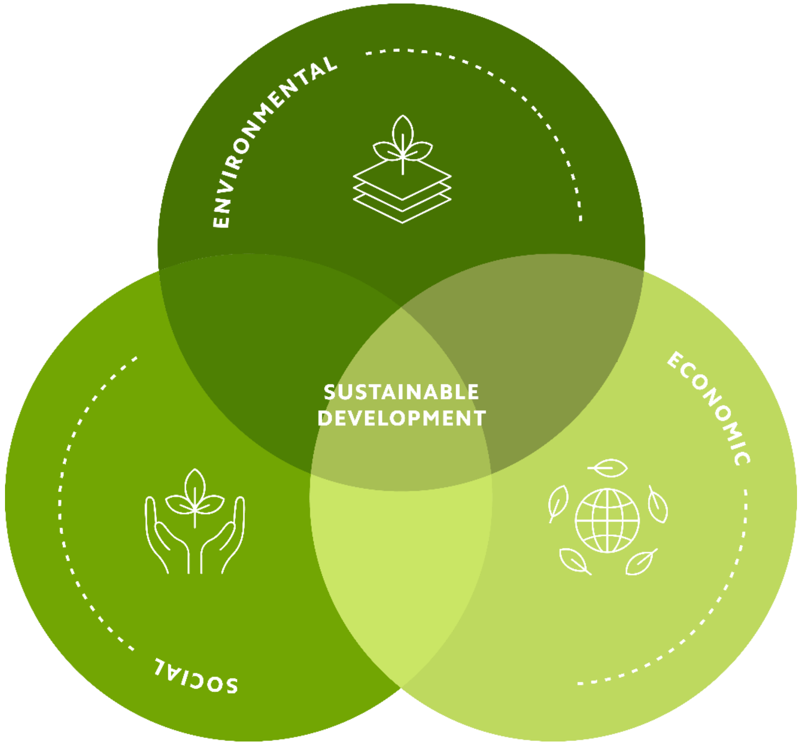


Conclusions

- Development of a customisable tool that is transparent for the community

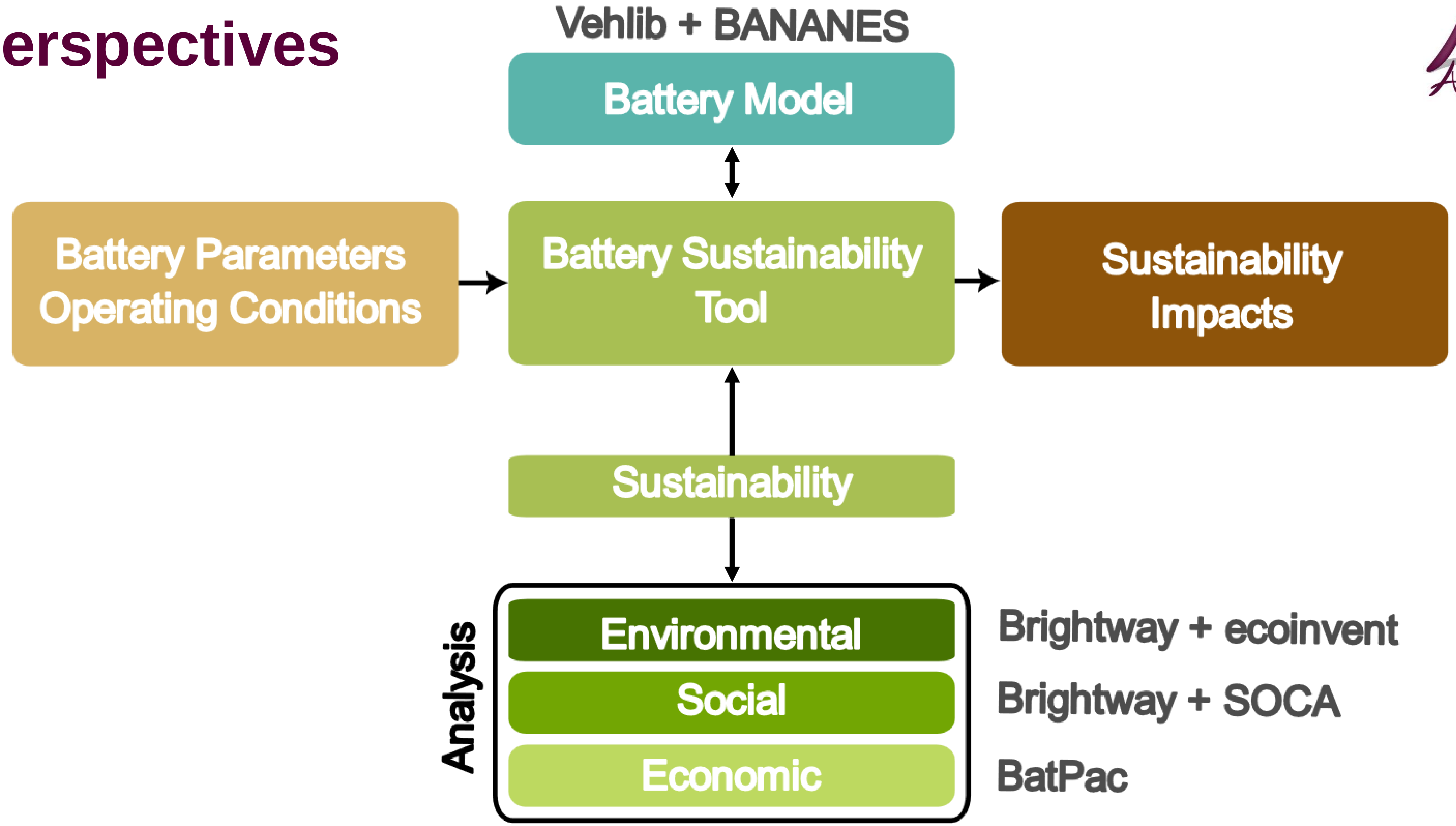
- Importance of incorporating a battery model to estimate environmental impacts:
  - Temperature → battery ageing
  - Location → electric mix composition
  - Scenario → battery ageing

- Impact of battery model selection



Source : *Better Future Factory*

Perspectives



https://gitlab.in2p3.fr/morgane.gillet/vieillissement

morgane.gillet@univ-lyon1.fr

Thank you for your attention

aging_combined.py → tant que ql < qlim

Calendaire :

Perte de capacité journalière :

$$dql_{cal} = \frac{A_{cal} * T^{n} * e^{\frac{E_{acal}}{k*T}} * e^{B_{cal}*SOC}}{1 + \ b_{cal} * ql^{c_{cal}}}$$

Cyclage :

Perte de capacité journalière à chaud :

$$dql_{hot} = \frac{A_{h} * |I| * T^{n} * e^{\frac{-E_{ah}+C_{h}*|I|}{k*T}} * e^{B_{h} \ *SOC}}{1 + \ b_{h} * ql^{c_{h}}}$$

Perte de capacité journalière à froid :

$$dql_{cold} = \frac{A_{c} * |I| * (T0 - T)^{n} * e^{\frac{-E_{ac}+C_{c}*|I|}{k*(T0-T)}} * e^{B_{c} \ *SOC}}{1 + \ b_{c} * ql^{c_{c}}}$$

Cumul de perte de capacité :

$$ql(t+1) = ql(t) + (dql_{hot} + dql_{cold} + dql_{cal}) * \Delta t$$

E. Redondo-Iglesias, P. Venet, et S. Pelissier, « Eyring acceleration model for predicting calendar ageing of lithium-ion batteries », *J. Energy Storage*, vol. 13, p. 176-183, oct. 2017, doi: 10.1016/j.est.2017.06.009

Results and Analysis

Battery model assumptions:

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- Recharging at 20/25 °C;
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- **Impact of outside temperature on battery life**
- **Impact of the composition of the electricity mix**
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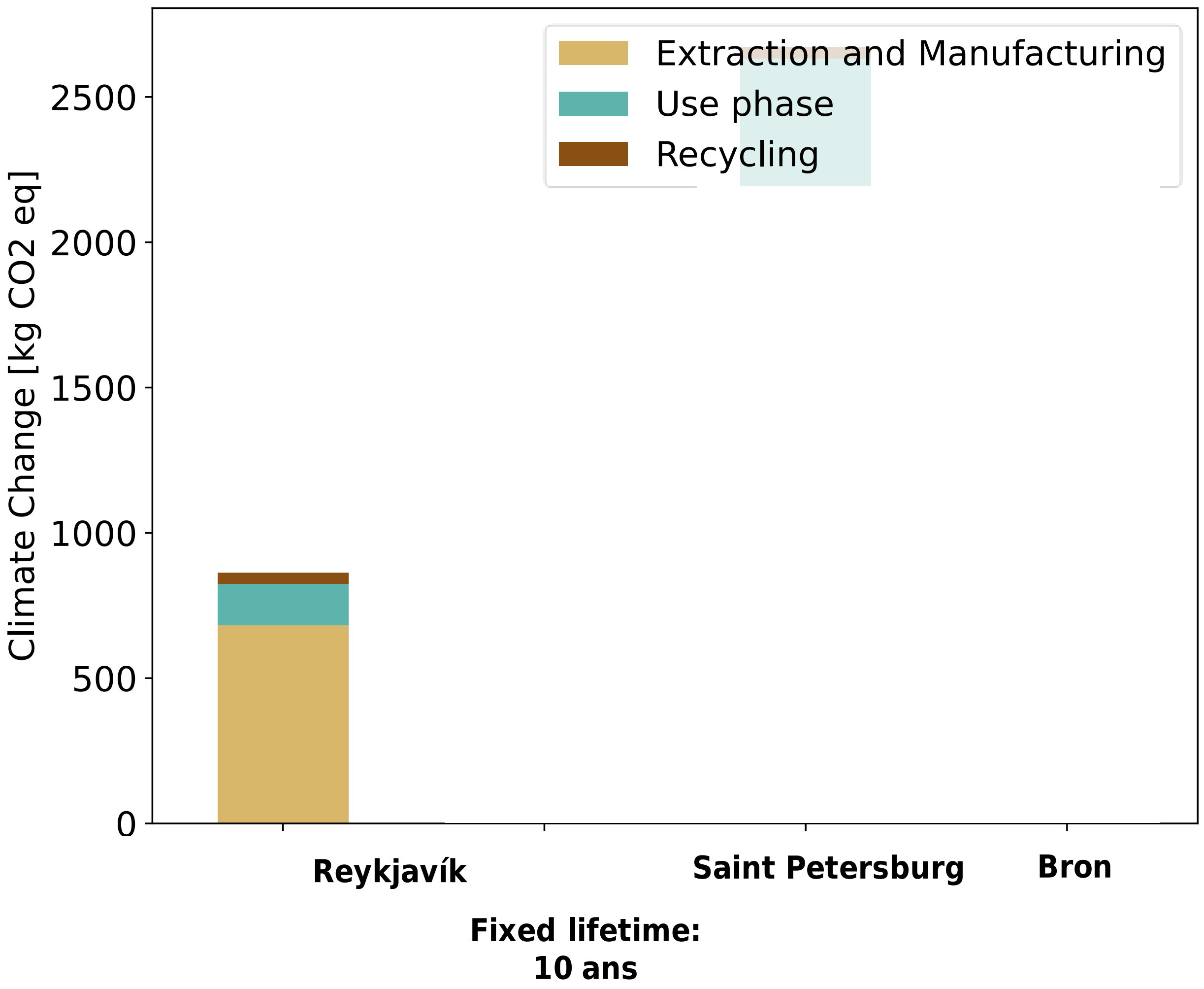
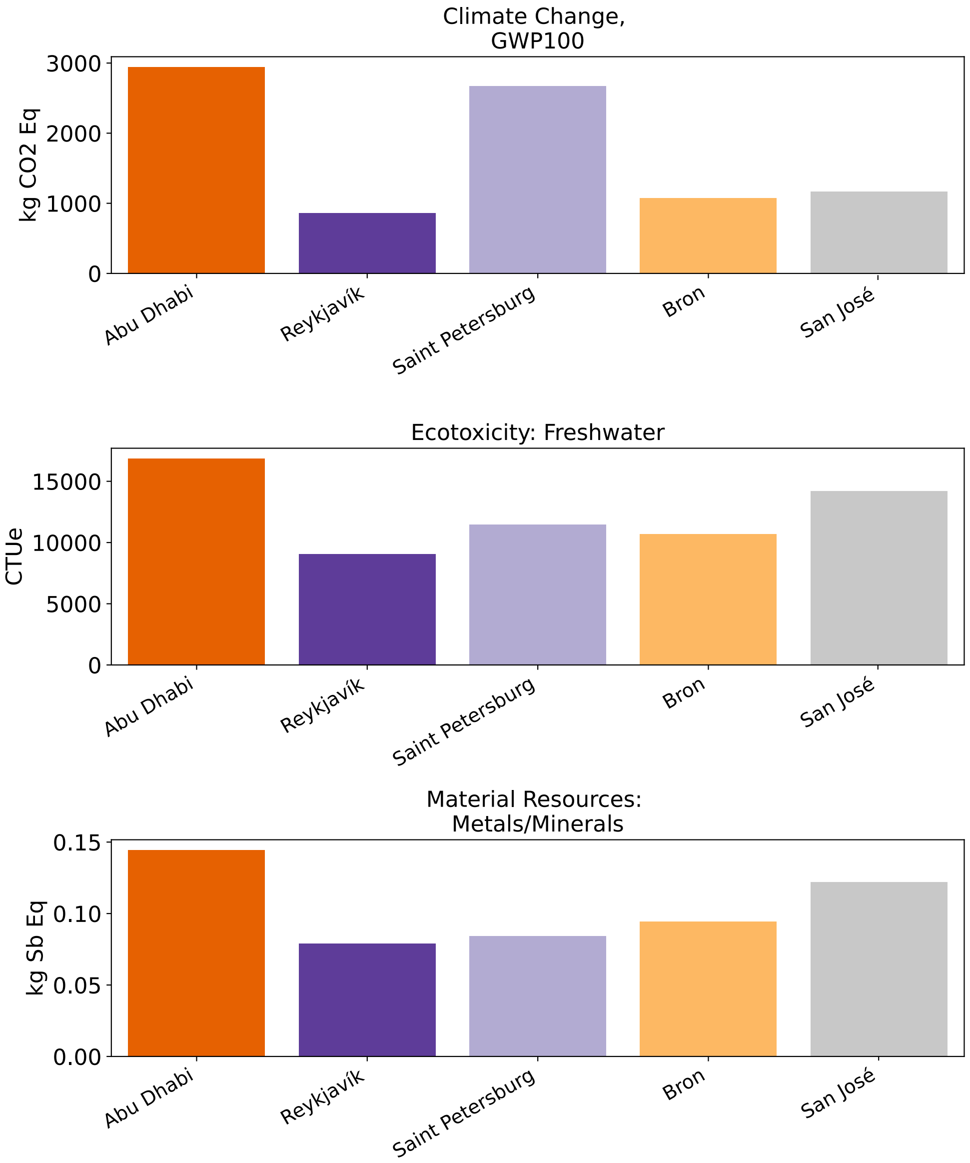
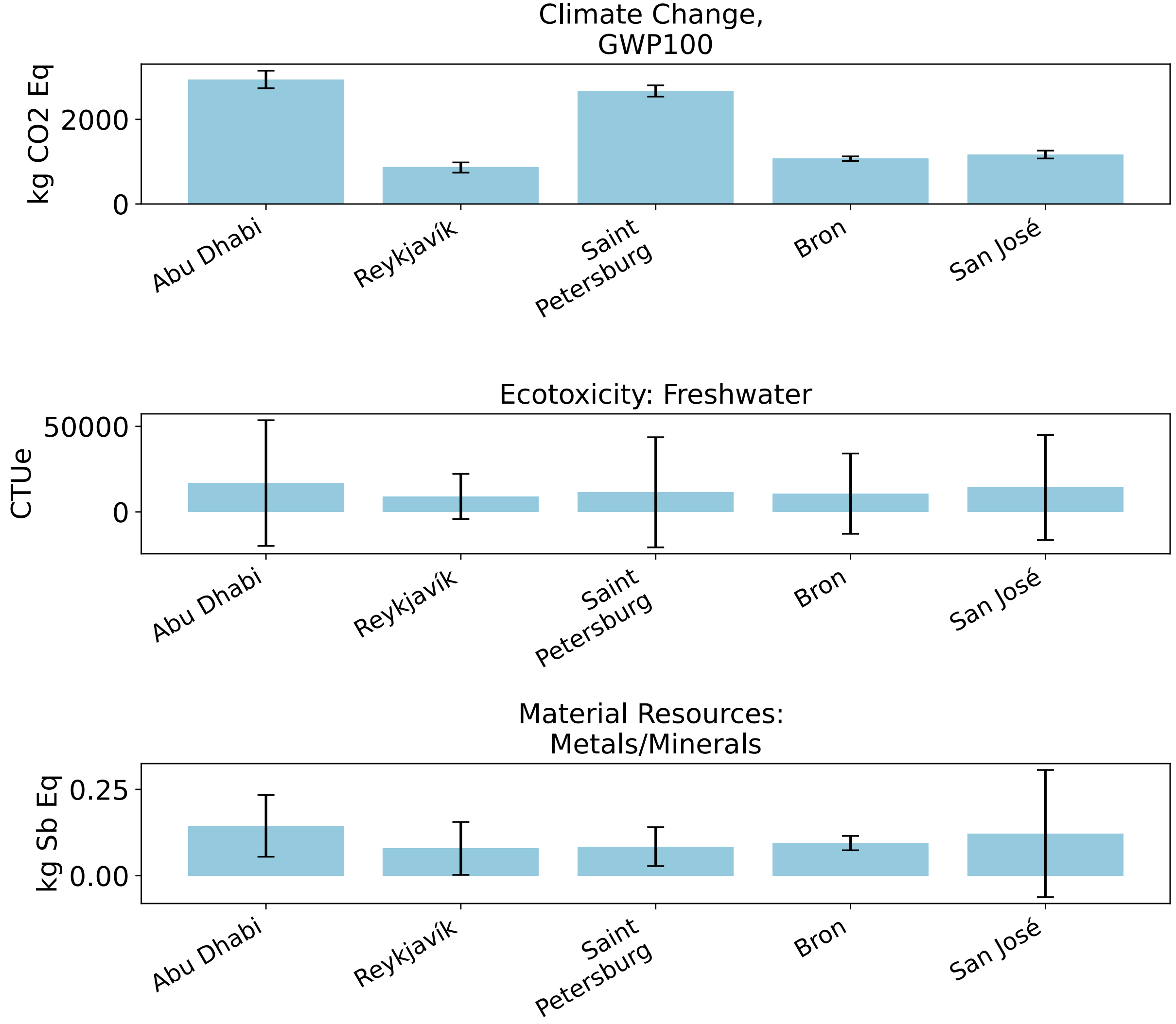


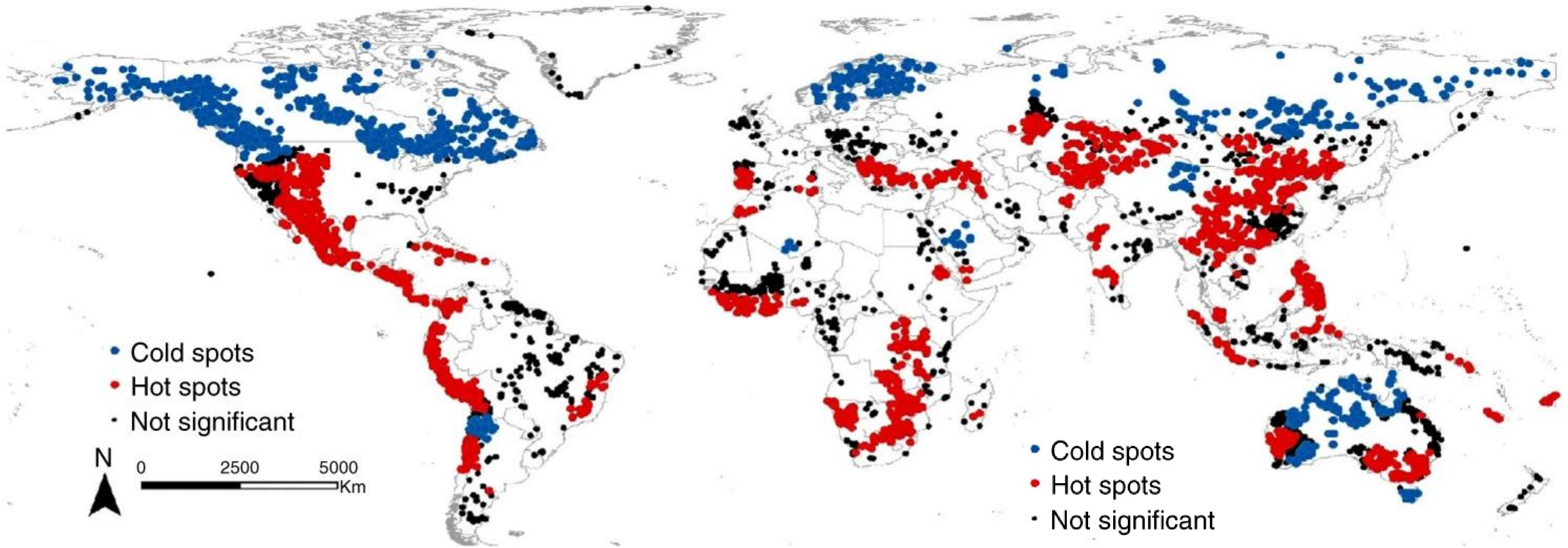
Results and Analysis

- **Importance of considering multiple indicators**
- **Impact of uncertainties**





Social Life Cycle Assessment: ISO 14075



Countries with the highest environmental, social and governance risks

Source : *Lebre et al., 2020*

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