Sustainable Energy Systems: Towards the Electrification of the Society

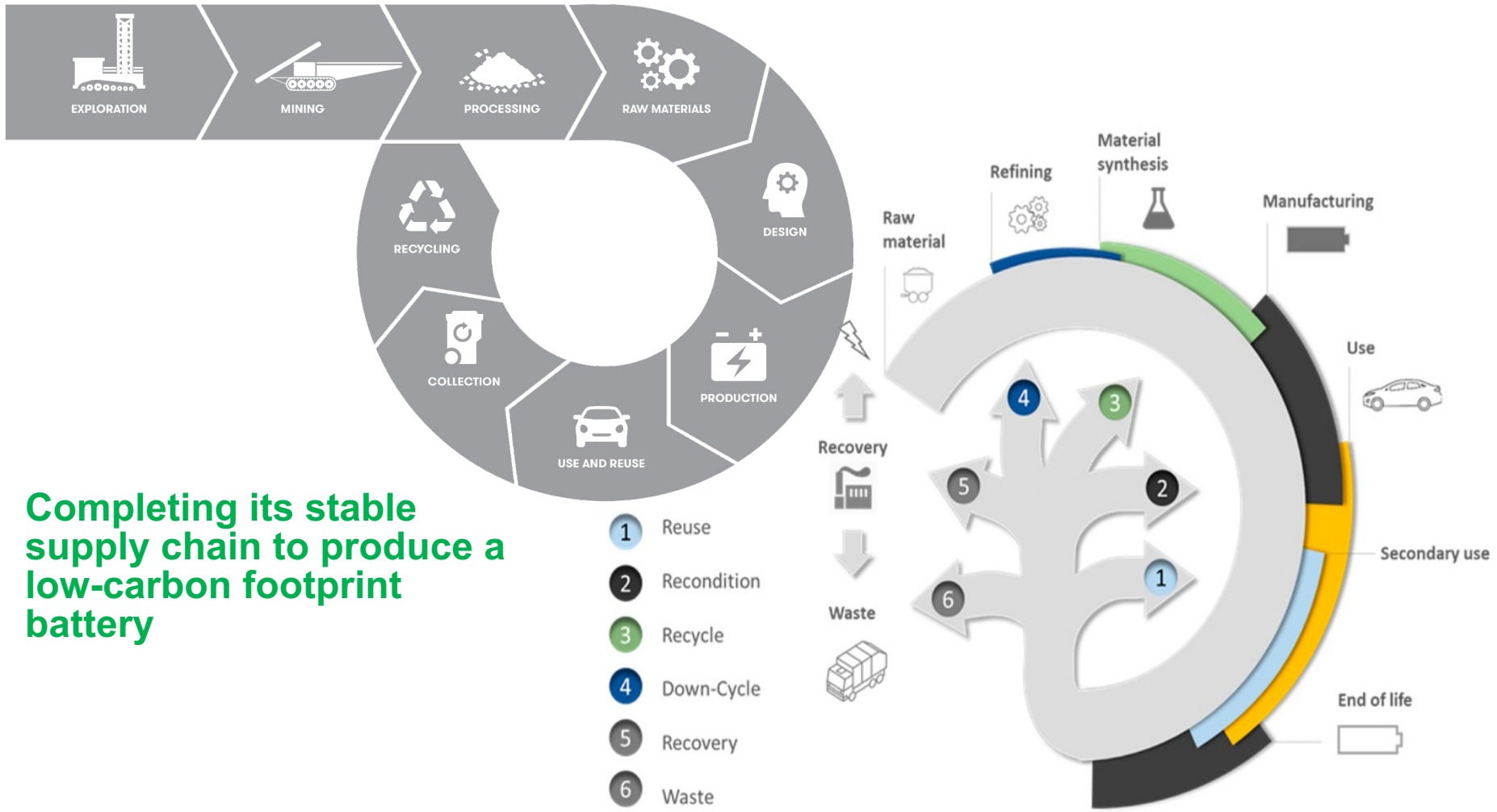
Karim Zaghib
Professor of Chemical and Materials Engineering

World Materials Forum
Nancy, France
June 16th – 18th

Agenda

- Canada Strategy towards Sustainable Electrification (What, How, Who and When)
- Some Key Technology Breakthrough to Make it Happen (LFP, H_2 solid-state, photobattery)

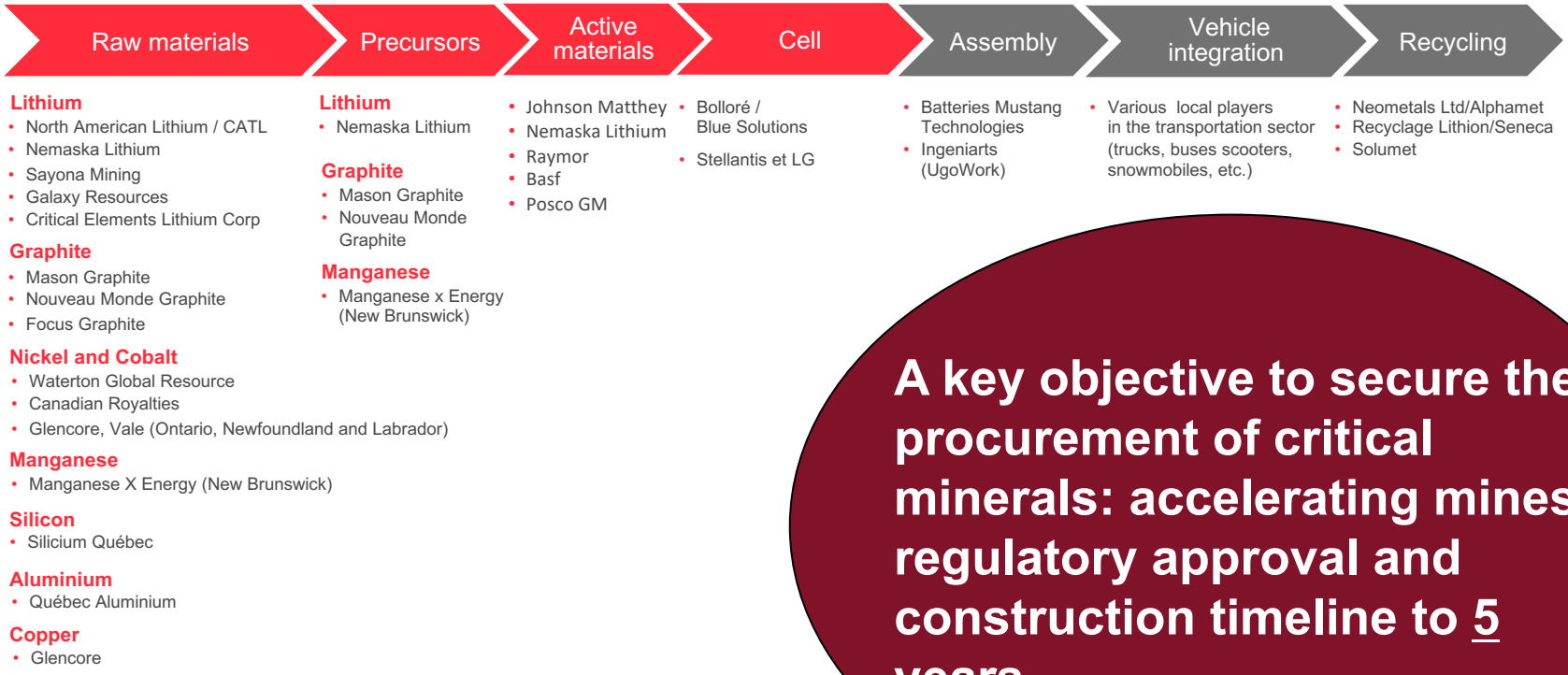
Québec's roadmap for a circular economy



Completing its stable supply chain to produce a low-carbon footprint battery

Beaudet A, Larouche F, Amouzegar K, Bouchard P, Zaghib K.
Key Challenges and Opportunities for Recycling Electric Vehicle Battery Materials. *Sustainability*. 2020; 12(14):5837.

Industrial clusters along the Canadian supply chain

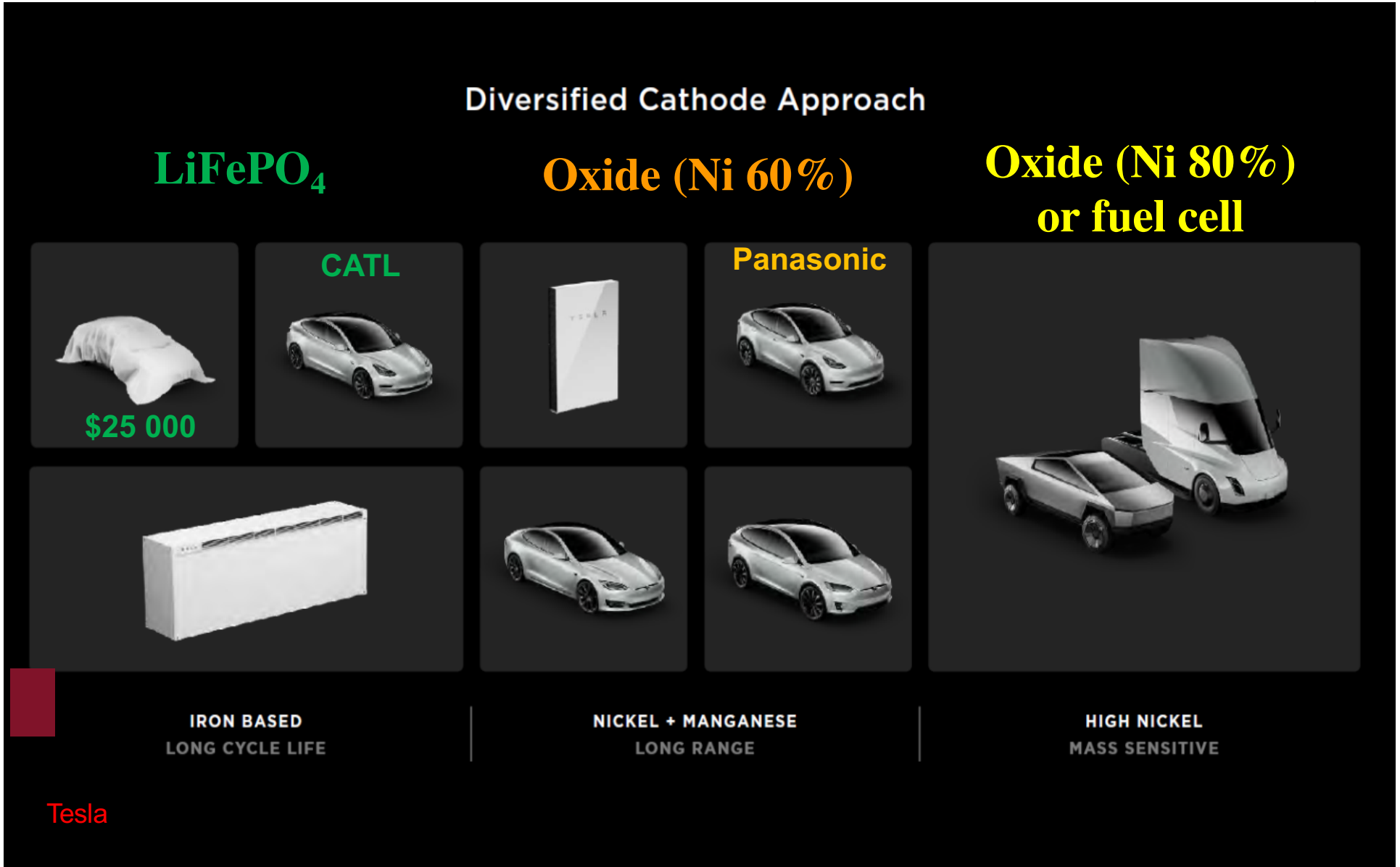


A key objective to secure the procurement of critical minerals: accelerating mines' regulatory approval and construction timeline to 5 years.

Zaghib, K. Testimony: Canada—United States Relationship on the Electric Vehicles Industry, House of Commons Standing Committee on International Trade, Ottawa, February 2022

Zaghib, K. Testimony: Sourcing and Processing of Critical Minerals, House of Commons Standing Committee on Industry and Technology, Ottawa, February 2022

Trend: electrification choices adapted according to use



OEM and $LiFePO_4$ (LFP)

"Last year, Tesla also announced it is "shifting to Lithium Iron Phosphate (LFP) battery chemistry globally" for "standard range vehicles."

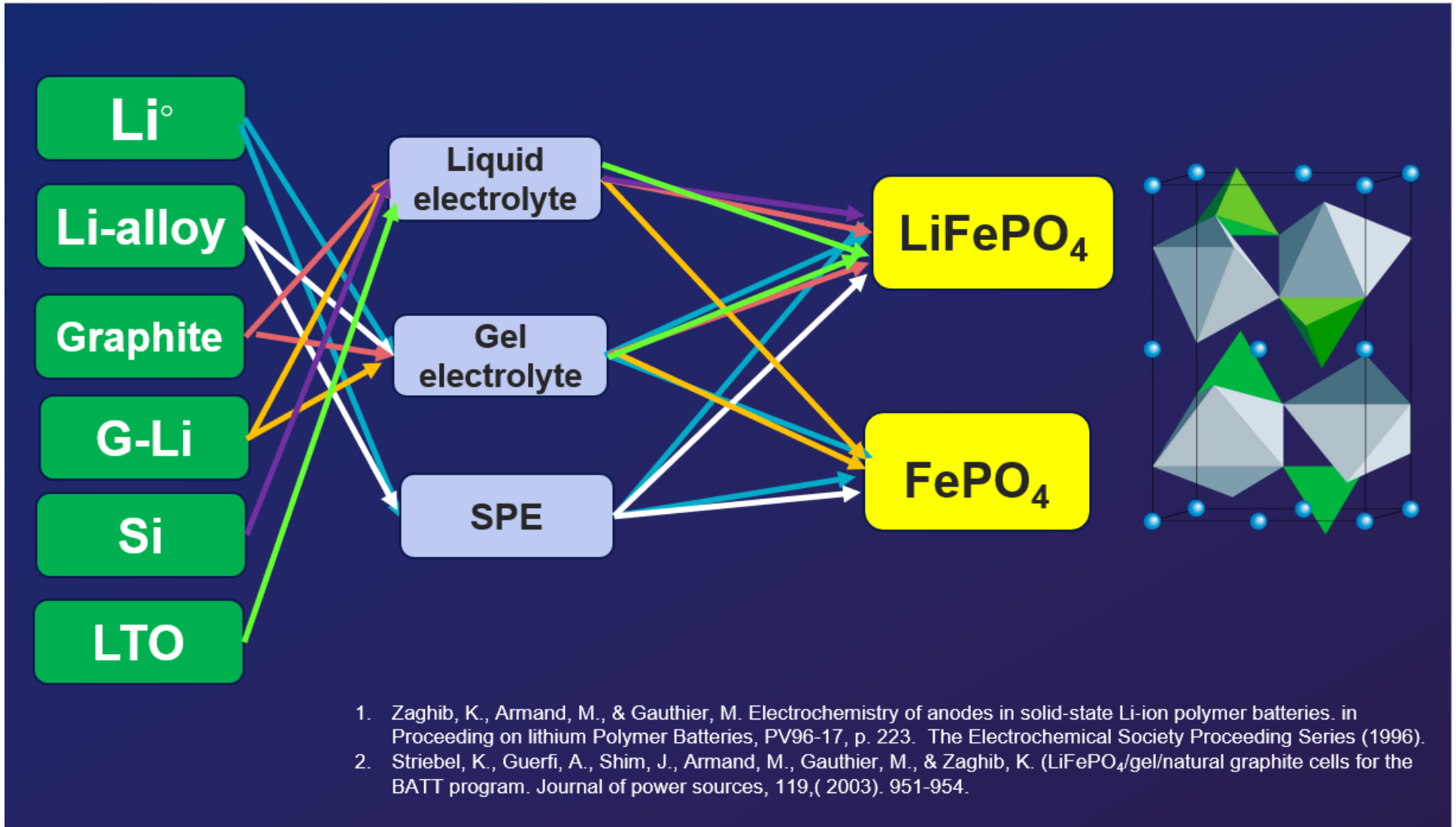
It confirmed that the automaker planned to switch the Model 3 Standard Range, also known as Model 3 Rear-Wheel-Drive, being produced in the Fremont factory to LFP cells, too. Now with the release of **Tesla's Q1 2022 financial results,** Tesla confirmed that nearly **half** of all vehicles produced are now using LFP batteries:"

https://electrek.co/2022/04/20/tesla-tsla-q1-2022-results/

https://www.ft.com/content/2b97227c-07c2-4c69-9db4-9e19f87a9a79

$LiFePO_4$ and $FePO_4$ combinations

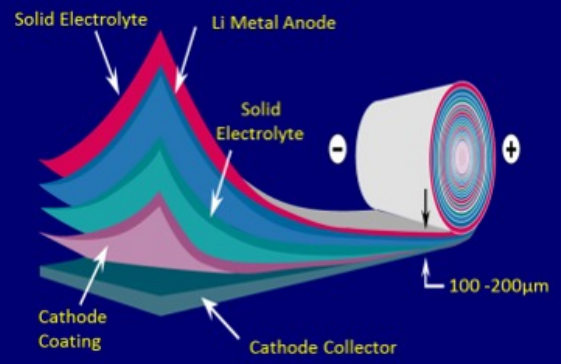
Next is high-density $LMn_xFe_{1-x}PO_4$ (260 Wh/kg), by 2025



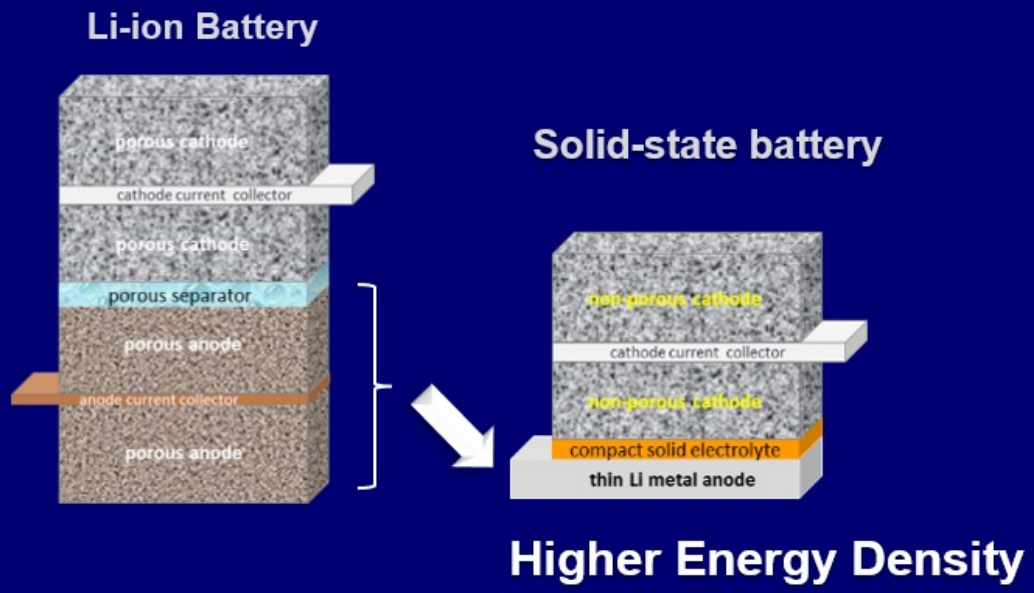
1. Zaghib, K., Armand, M., & Gauthier, M. Electrochemistry of anodes in solid-state Li-ion polymer batteries. in Proceeding on lithium Polymer Batteries, PV96-17, p. 223. The Electrochemical Society Proceeding Series (1996).
2. Striebel, K., Guerfi, A., Shim, J., Armand, M., Gauthier, M., & Zaghib, K. ($LiFePO_4$/gel/natural graphite cells for the BATT program. Journal of power sources, 119,(2003). 951-954.

Structure of solid-state Li metal battery

Energy densities of 500 Wh/kg, 1000 Wh/L by 2030

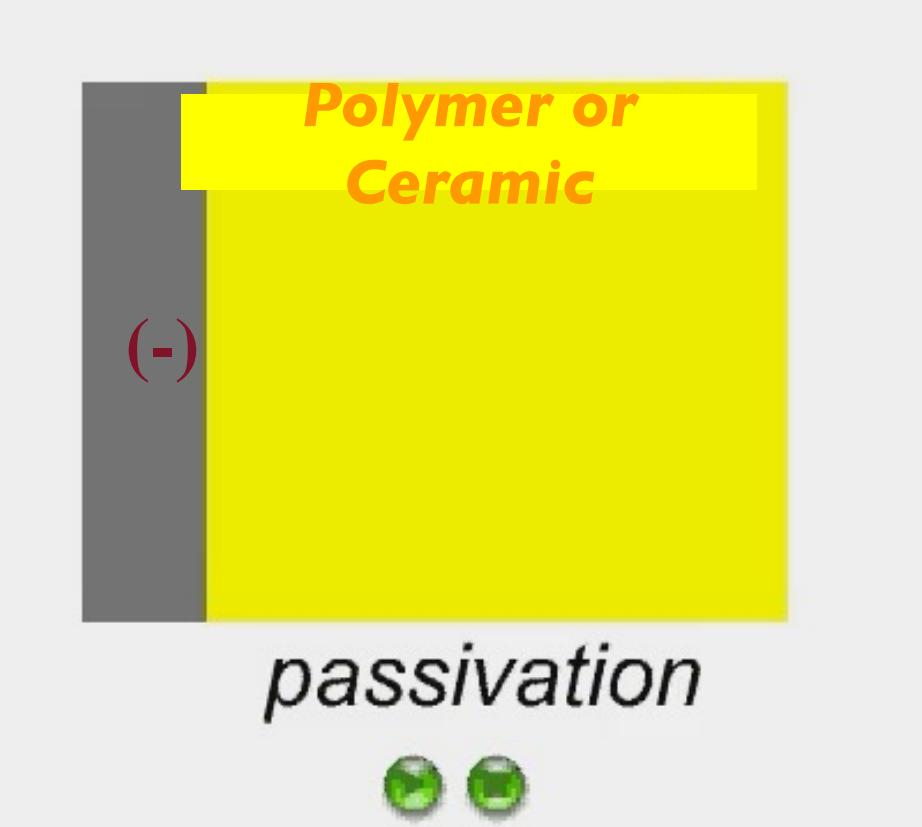


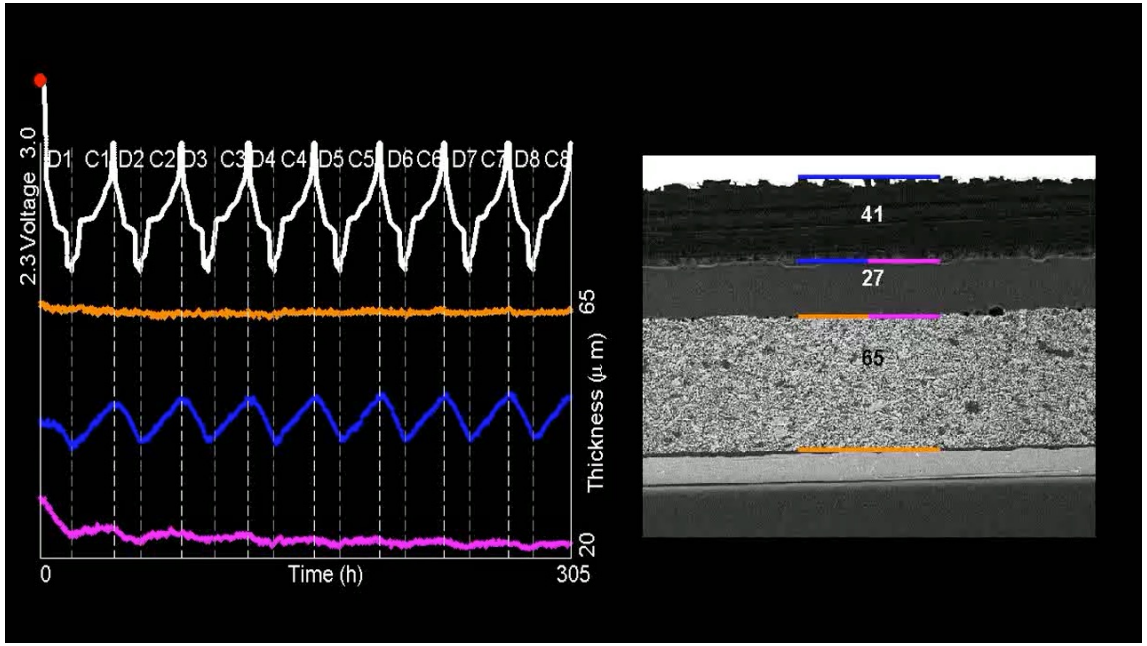
- No flammable liquid (All Solid State)
- Highest energy density anode (Ultra thin Li metal)
- No current collector for anode electrode (no Cu foil, no heavy metal)



Hovington, P., Lagacé, M., Guerfi, A., Bouchard, P., Mauger, A., Julien, C. M., Armand, M. & Zaghib, K. (2015).
New lithium metal polymer solid state battery for an ultrahigh energy: nano C-LiFePO4 versus nano Li1. 2V3O8. *Nano Letters*, *15*(4), 2671-2678.

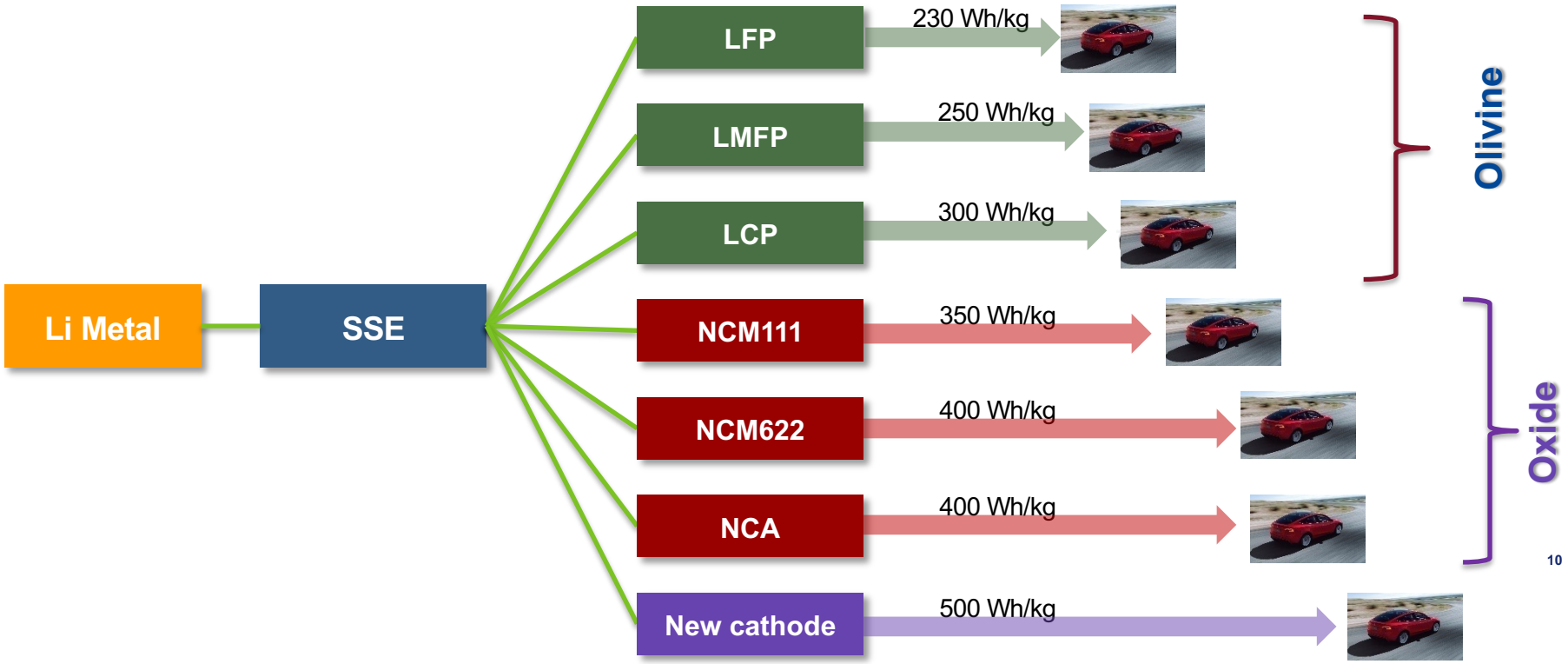
Lithium solid-state batteries via *in situ* scanning electron microscopy





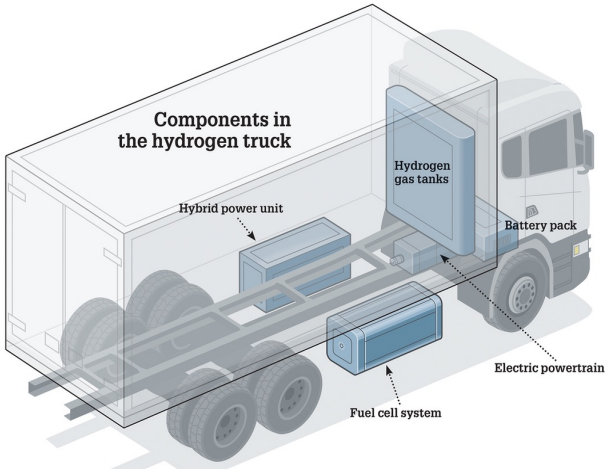
Hovington, P., Lagacé, M., Guerfi, A., Bouchard, P., Mauger, A., Julien, C. M., Armand, M. & Zaghib, K. (2015).
New lithium metal polymer solid state battery for an ultrahigh energy: nano C-LiFePO4 versus nano Li1. 2V3O8. *Nano Letters*, *15*(4), 2671-2678.

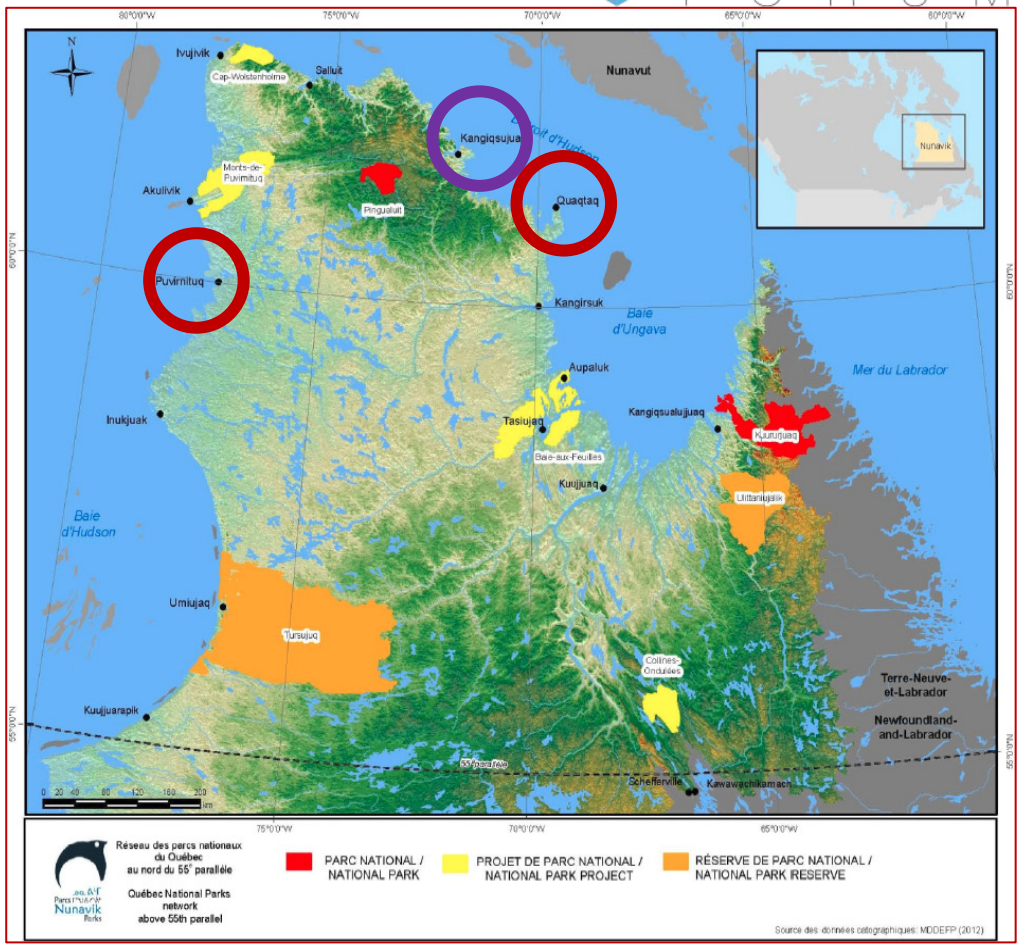
Towards higher specific energy: transportation use cases



Hovington, P., Lagacé, M., Guerfi, A., Bouchard, P., Mauger, A., Julien, C. M., Armand, M. & Zaghib, K. (2015). New lithium metal polymer solid state battery for an ultrahigh energy: nano C-LiFePO4 versus nano Li1. 2V3O8. *Nano Letters*, *15*(4), 2671-2678.

Sustainable energy systems : H_2 and Li-ion battery





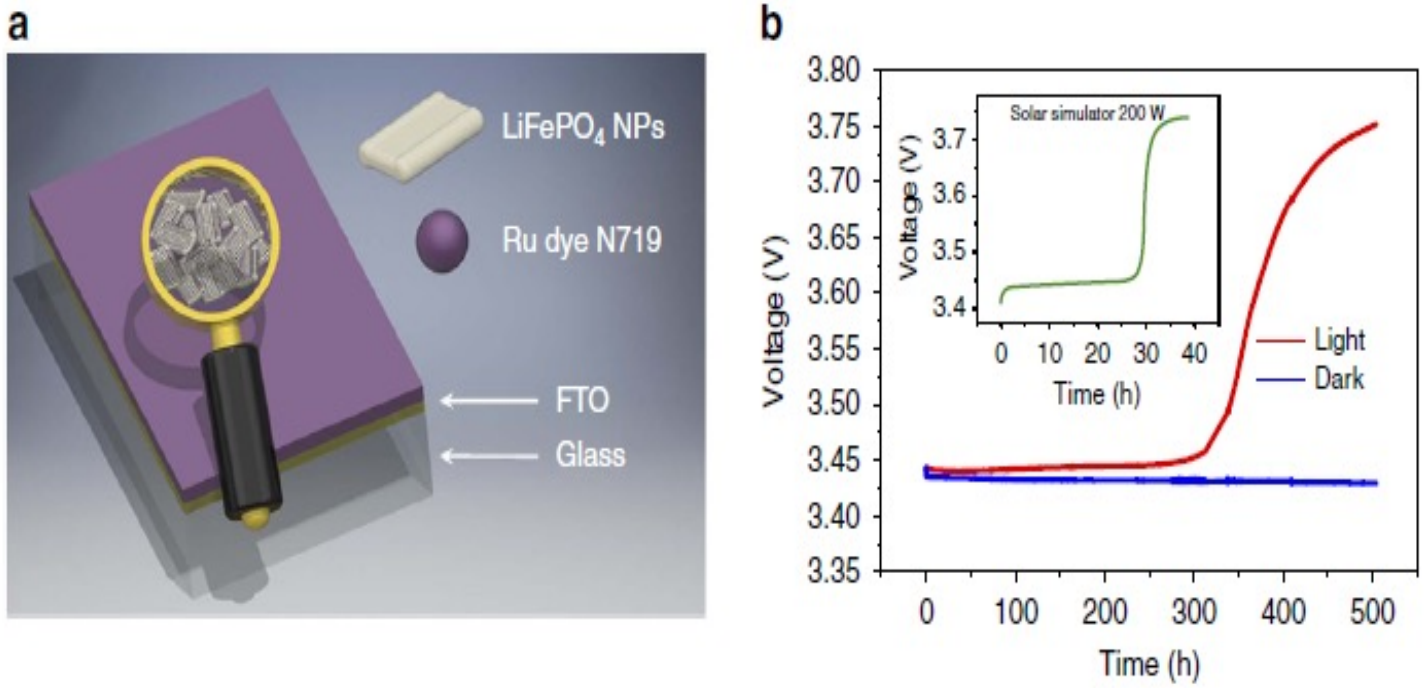
Heavy transportation electrification and large-scale energy storage for remote green communities

Offgrid :

- Solar and Li-ion

- Wind, H_2 and Li-ion

Photobattery, new technology :Not pluggable



Consumer electronics : 2030

Li-Ion Photo-Batteries: Challenges and Opportunities.
Paolella, A., Vijh, A., Guerfi, A., Zaghib, K., & Faure, C. (2020). ***Journal of The Electrochemical Society***, *167*(12), 120545.

Light-assisted delithiation of lithium iron phosphate nanocrystals towards photo-rechargeable lithium ion batteries Paolella, A., Faure, C., Bertoni, G., Marras, S., Guerfi, A., Darwiche, A., ... & KZaghib,. ***Nature communications*, *8*(1), 2017. 1-10.**