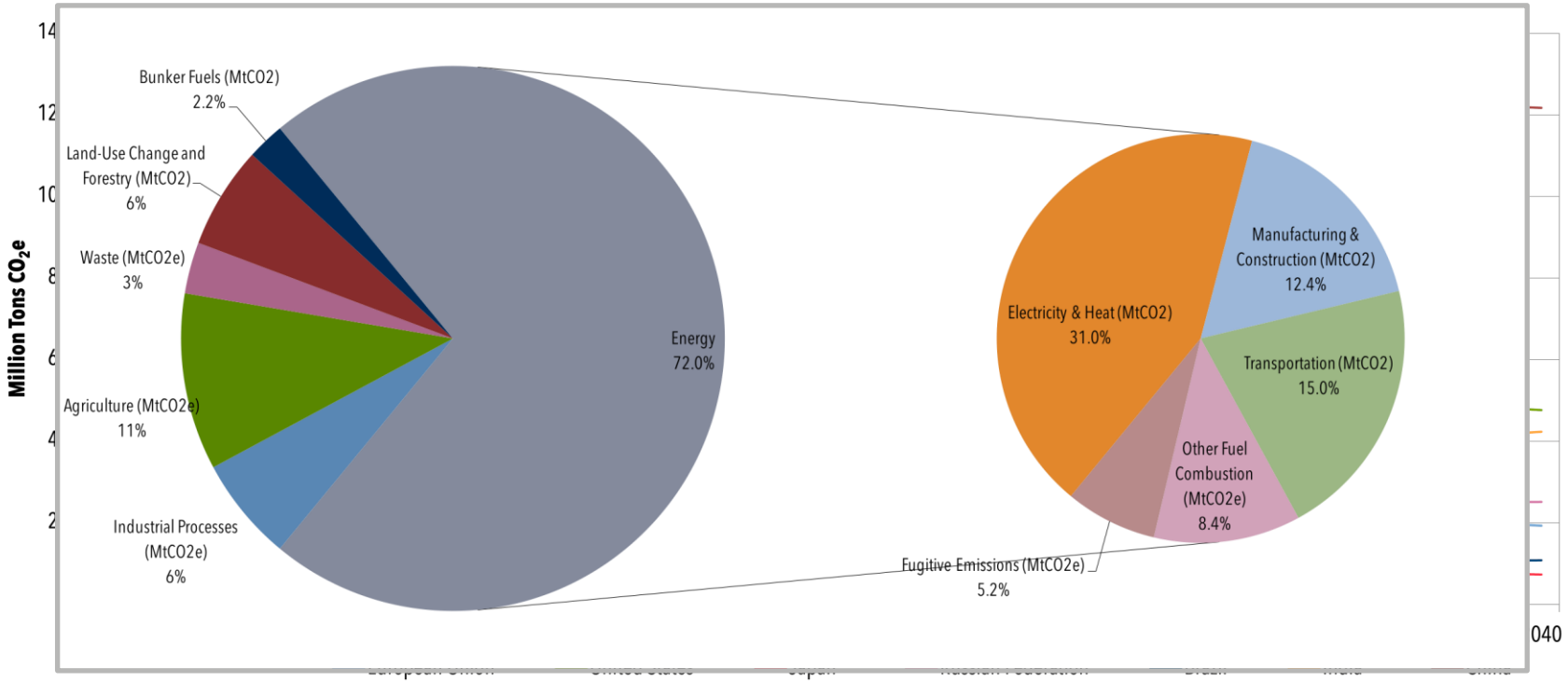
UiO : Centre for Materials Science and Nanotechnology
University of Oslo

Energy storage and batteries: the landscape.

Alexey Y. Koposov

General introduction



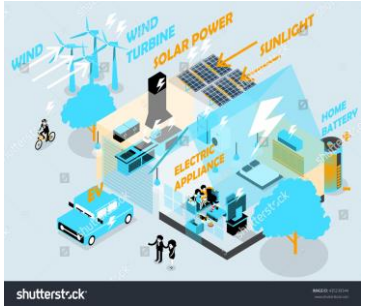
https://www.c2es.org/content/international-emissions/

Energy landscape



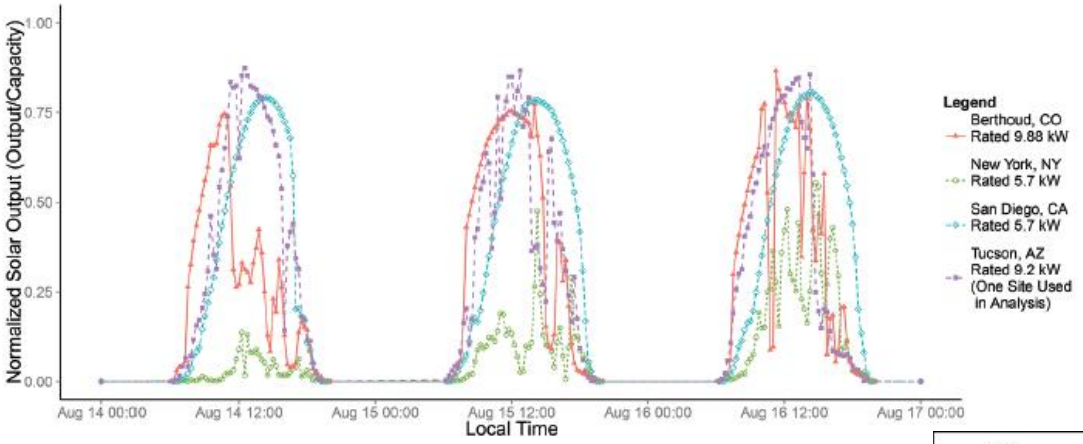






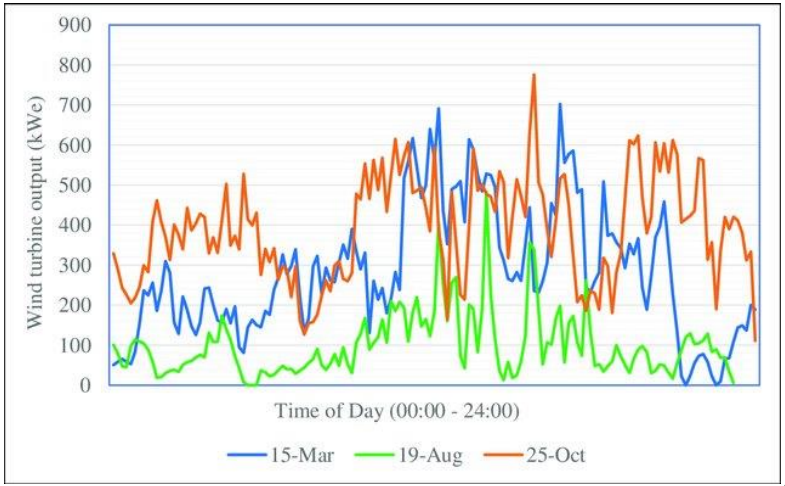


Solar and wind



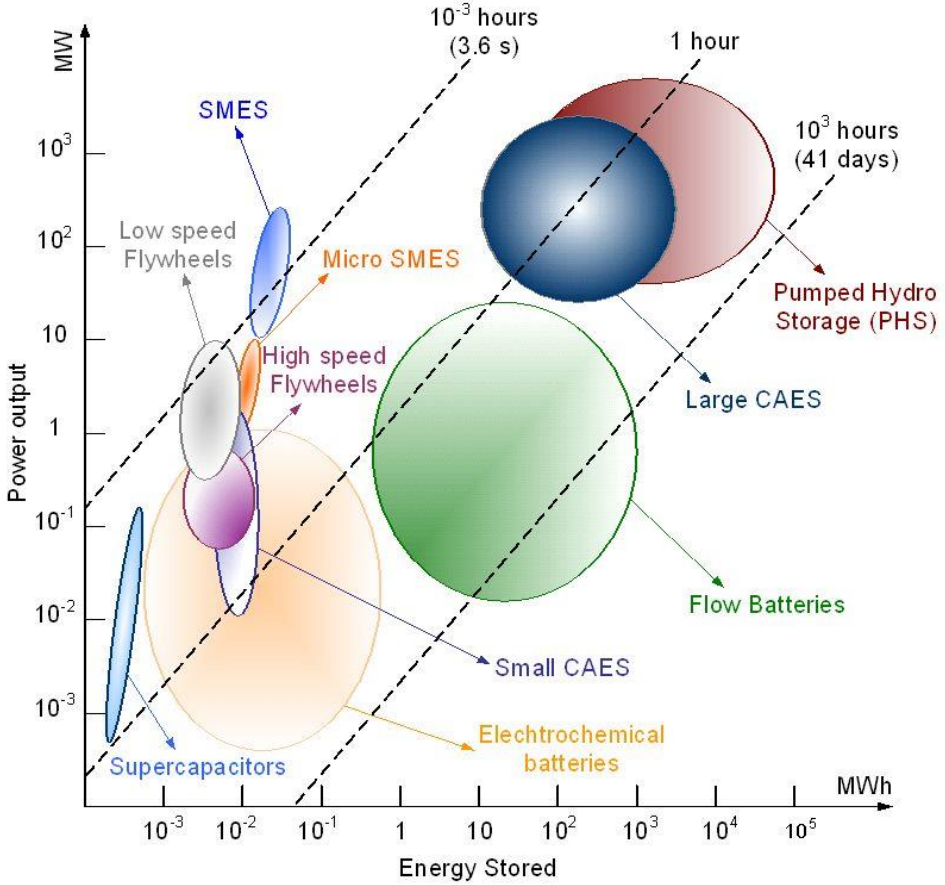


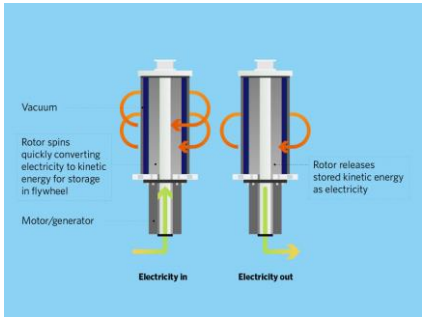


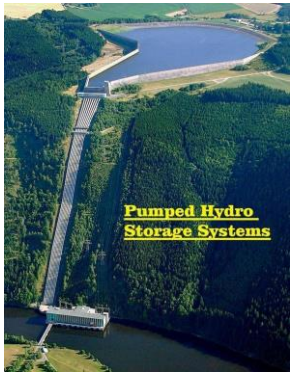


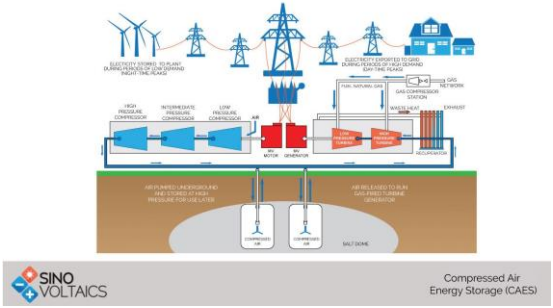
DOI:10.1086/686733 DOI: 10.1088/1755-1315/188/1/012075

Energy storage









- Battery technology is just one of energy storage technologies.

Modern applications of batteries

- Consumer electronics, electric vehicles (also combustion vehicles)
- **Space**: satellites, spacecraft, rovers
- **Transport**: forklifts, mobility, high speed trains, airplanes, drones
- **Defense**: communications, military vehicles, portable power, submarines, even certain machine guns





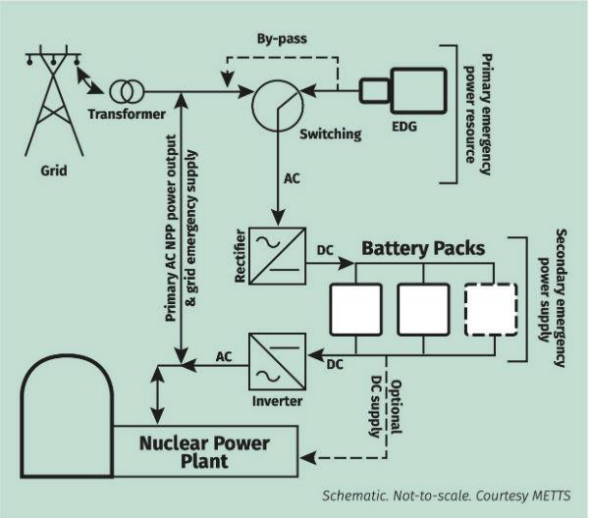


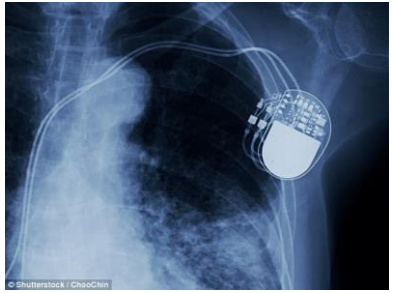




Other applications of batteries

- **Electric power grids**: frequency modulation and regulation for solar/wind
- **Nuclear**: backup power
- **Sensors**: remote photography, thermal cameras, security cameras, motion sensors, chemical sensors, smoke detectors
- **Biomedical**: pacemakers, hearing aids







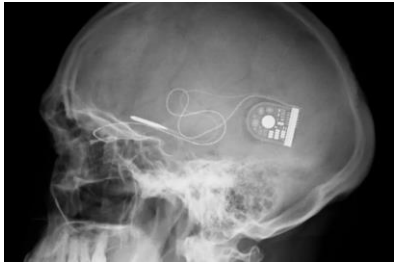




Future applications

- **Consumer/biomedical:** Wearable electronics, implantable electronics
- **Electric power supply:** microgrids, load balancing
- **Transport:** ferries, cargo ships, airplanes, helicopters, drones
- **Communication:** Internet of Things/VR/Metaverse(?)
- **Robots**







Domino's delivery robots are invaded Europe

Which begs the question: How much do you tip a robot?



M. Moon
@mariella_moon
March 30th, 2017

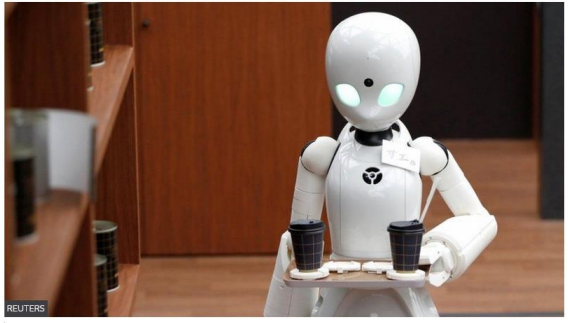
In this article: culture, dominos, drone, food and drink, food-and-drink, foodanddrink, germany, netherlands, pizza, robots



Sponsored Links

Japanese cafe uses robots controlled by paralysed people

6 December 2018



The robots served drinks and cleared tables in the cafe

Batteries: the story

Aless



Taking it from another point of view, we have sought to collect the secondary currents and to make use of them, thus accumulating the energy of the voltaic battery.

We have found, as may be seen in the preceding researches (20), that the secondary E.M.F. of a voltameter with lead plates in water acidulated with sulphuric acid, was higher and more lasting than that of any of the other metals, and that it surpassed that of the strongest voltaic element known--that of Grove or Bunsen.

With such an E.M.F., it only remained, in order to form a secondary element of great power, to endow it with a very low resistance, or to increase its surface to the greatest possible extent. This was so much the more easy from the fact that the two plates necessary to form it were of the same nature and of a metal so extremely flexible and malleable as lead.

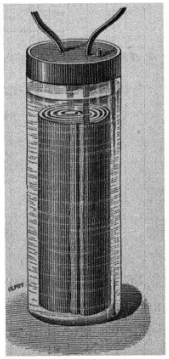


Fig. 7.

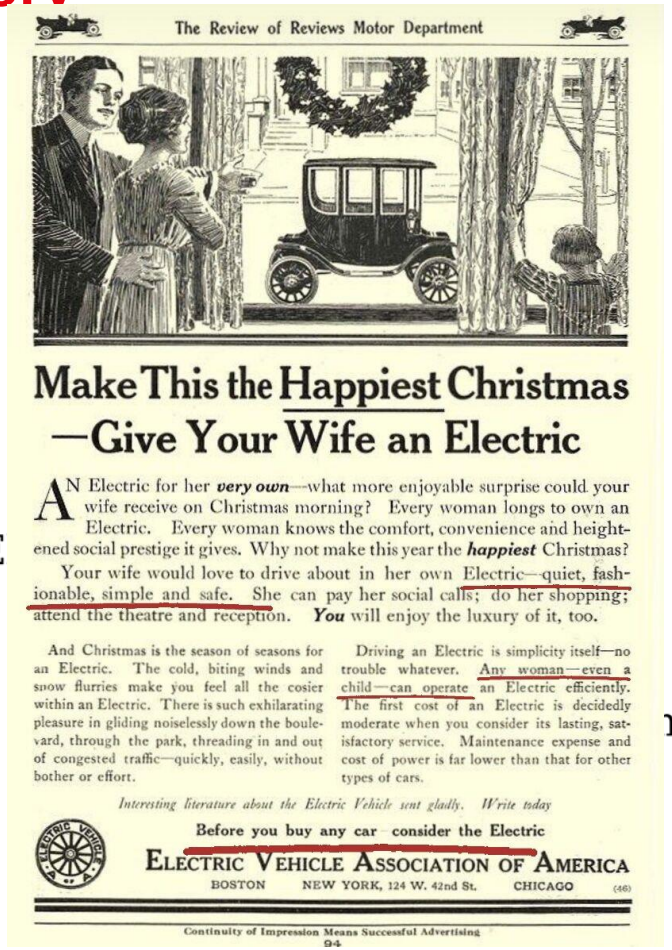
37. **Secondary cell with coiled lead plates.**—It is thus that we were led to construct, in 1860,[1] a secondary element of great power or quantity, by using an arrangement similar to that which Offershaus and Hare had employed for the voltaic cell proper, namely, by rolling two long, wide lead plates into a coil, separated one from the other by a thick cloth, and then immersing them in a glass jar full of water acidulated with a tenth part sulphuric acid.

Figure 7 shows the construction of a secondary cell of this kind.

(1) Comptes rendus, t. L, p. 640. Mars 1860.



E



The Review of Reviews Motor Department

Make This the Happiest Christmas —Give Your Wife an Electric

AN Electric for her ***very own***—what more enjoyable surprise could your wife receive on Christmas morning? Every woman longs to own an Electric. Every woman knows the comfort, convenience and heightened social prestige it gives. Why not make this year the ***happiest*** Christmas?

Your wife would love to drive about in her own Electric—quiet, fashionable, simple and safe. She can pay her social calls; do her shopping; attend the theatre and reception. ***You*** will enjoy the luxury of it, too.

And Christmas is the season of seasons for an Electric. The cold, biting winds and snow flurries make you feel all the cosier within an Electric. There is such exhilarating pleasure in gliding noiselessly down the boulevard, through the park, threading in and out of congested traffic—quickly, easily, without bother or effort.

Driving an Electric is simplicity itself—no trouble whatever. Any woman—even a child—can operate an Electric efficiently. The first cost of an Electric is decidedly moderate when you consider its lasting, satisfactory service. Maintenance expense and cost of power is far lower than that for other types of cars.

Interesting literature about the Electric Vehicle sent gladly. Write today

Before you buy any car consider the Electric

ELECTRIC VEHICLE ASSOCIATION OF AMERICA

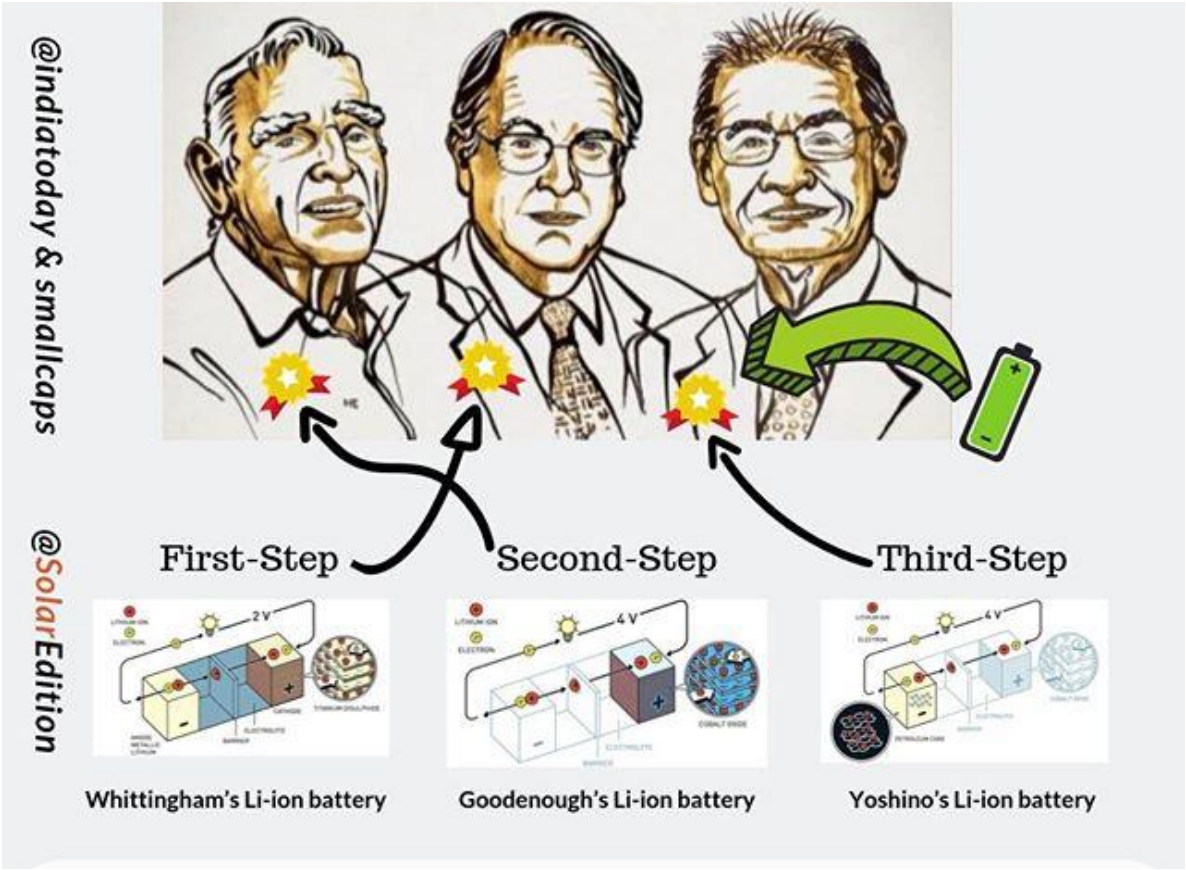
BOSTON NEW YORK, 124 W. 42nd St. CHICAGO (46)

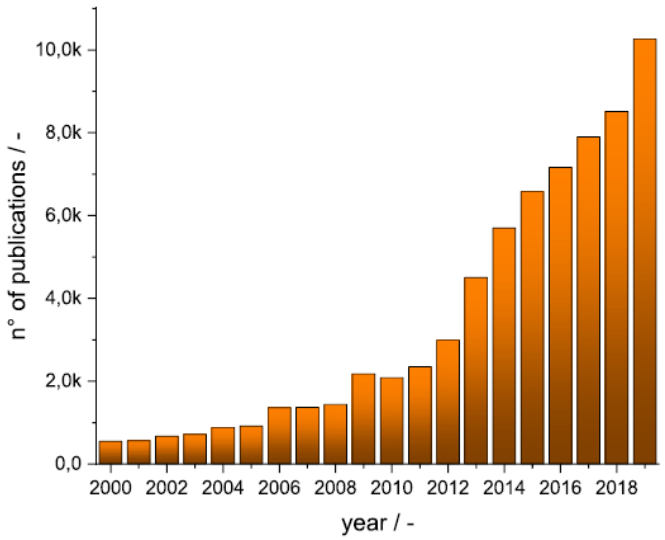
Continuity of Impression Means Successful Advertising

94

ment

Li-ion batteries

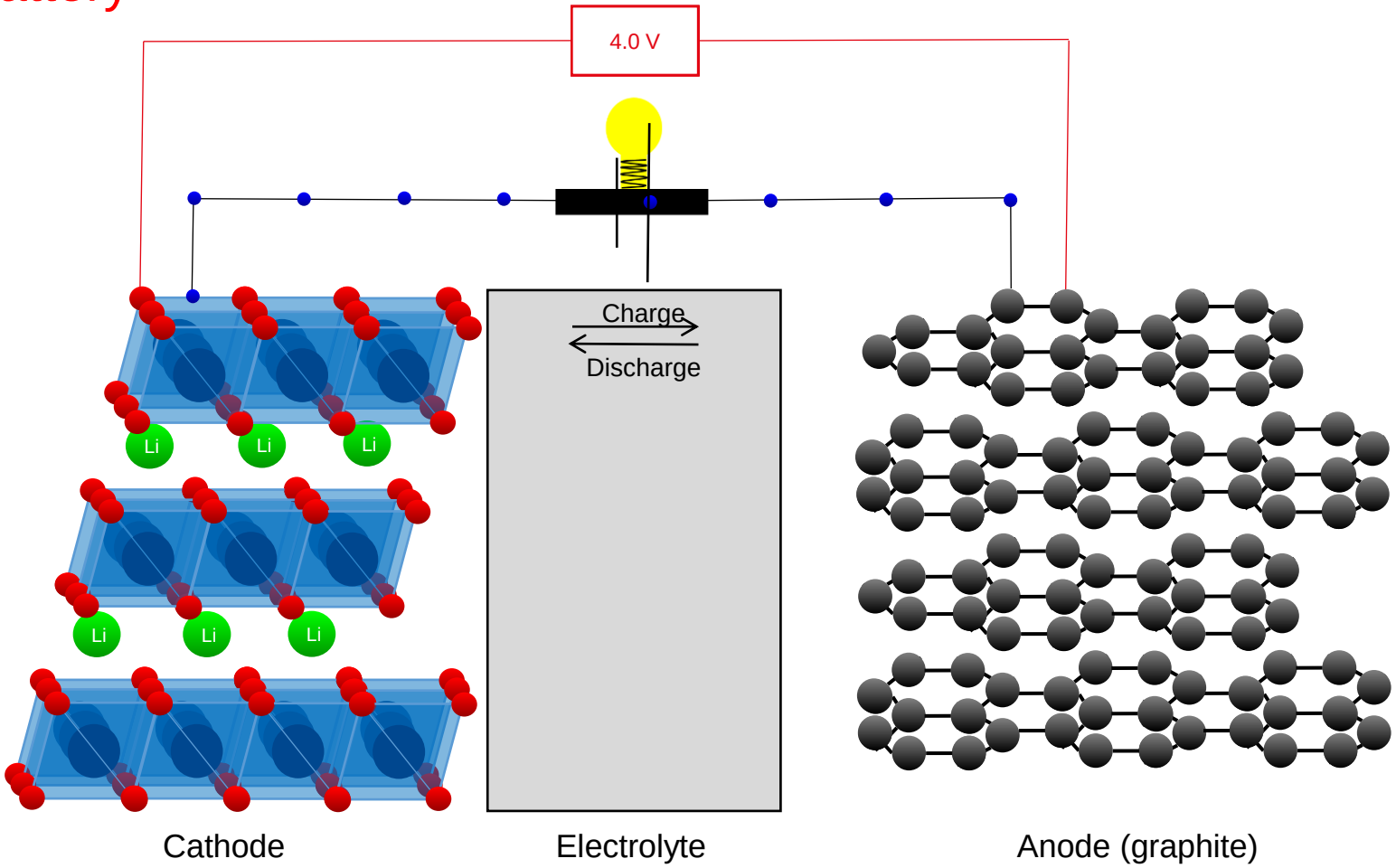




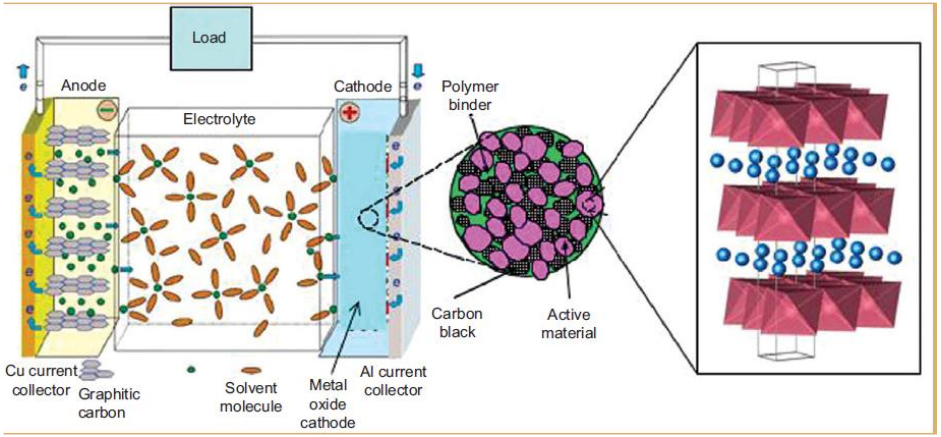
- *The principles of Li-ion chemistry could be applied to other battery chemistries*

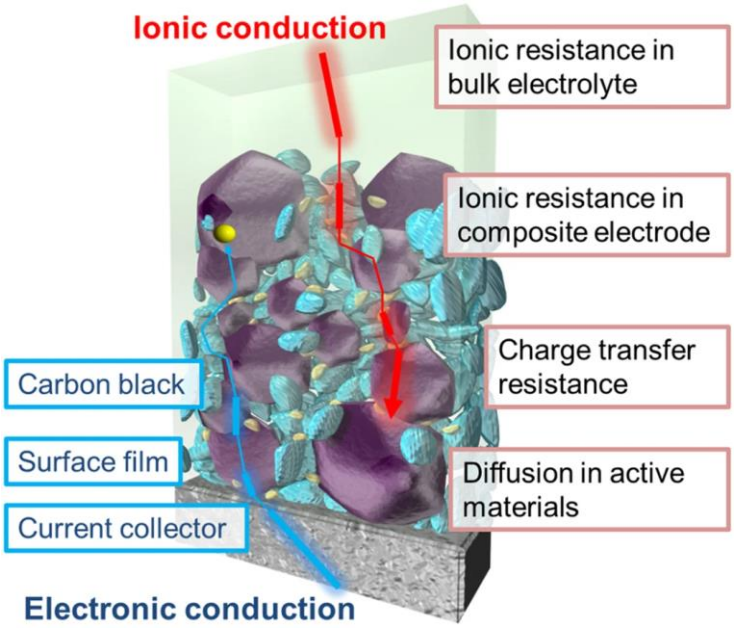
Journal of Power Sources, **2020**, *459, 228073*

Li-ion battery



Batteries: quick glance

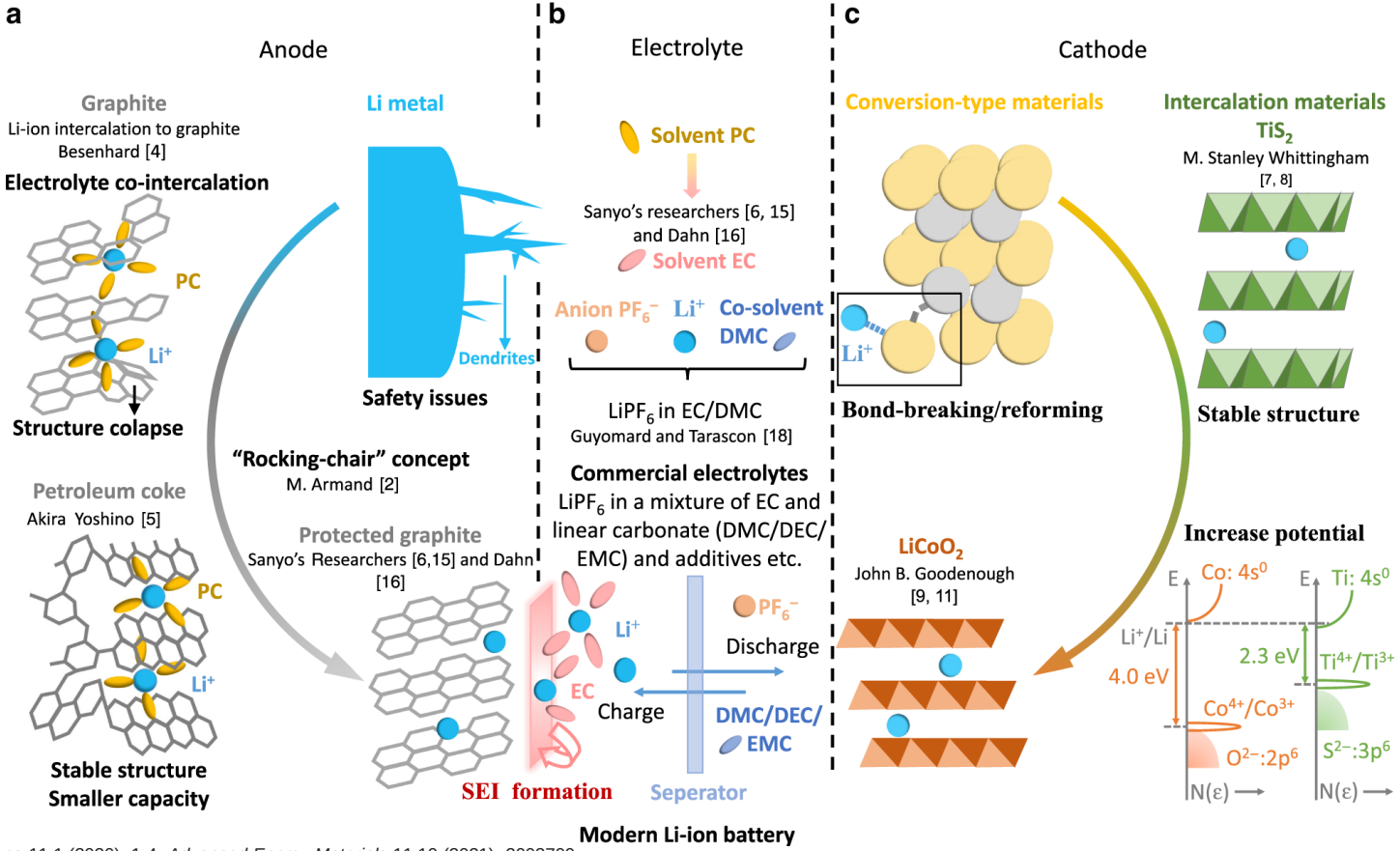




Charge: ions move from cathode to anode
Discharge: ions move from anode to cathode

Sci. Rep., **2016**, *6*, 26382

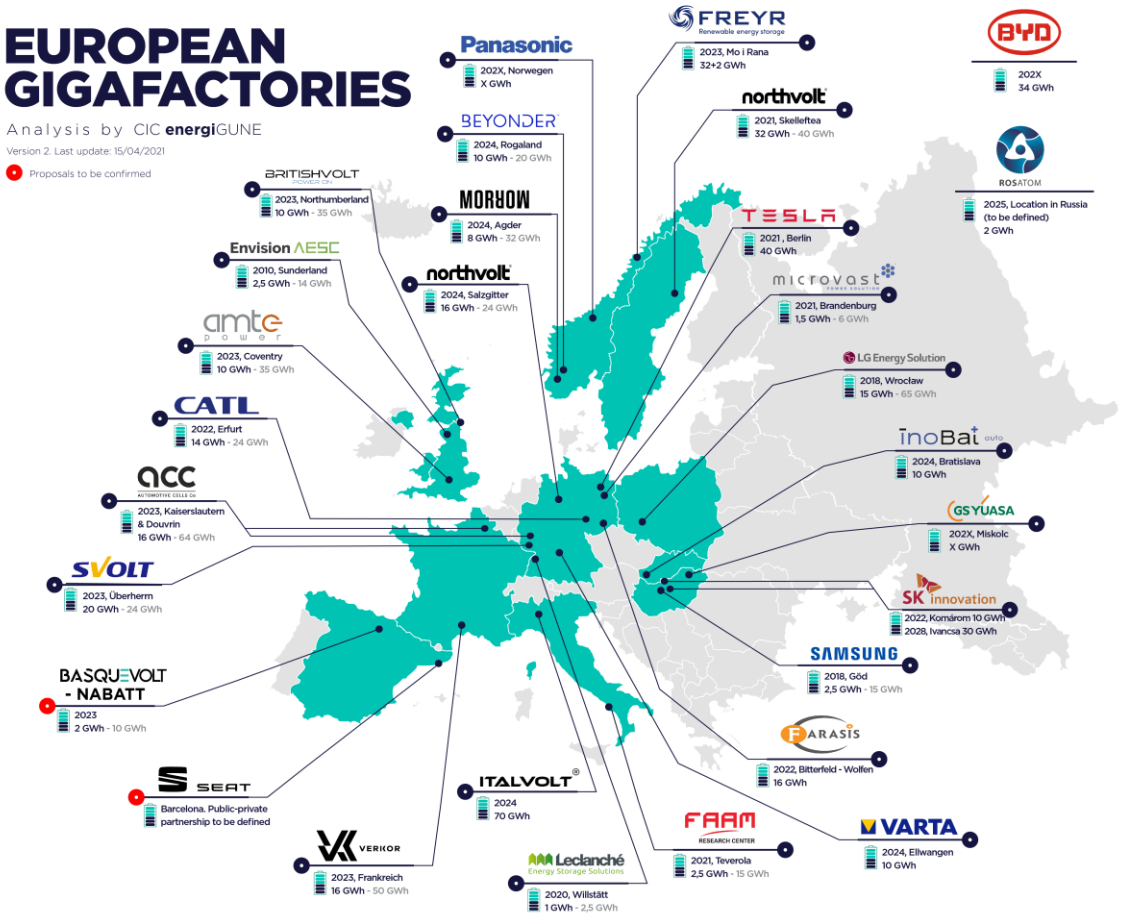
Processes in batteries



Modern Li-ion battery

Nature Communications 11.1 (2020): 1-4. *Advanced Energy Materials* 11.10 (2021): 2003700.
A Machine-Generated Summary of Current Research. Cham: Springer International Publishing (2019).
Advances in lithium-ion batteries. Springer Science & Business Media, 2007.
Lithium-ion batteries. Vol. 1. New York: Springer, 2009

Batteries in Europe



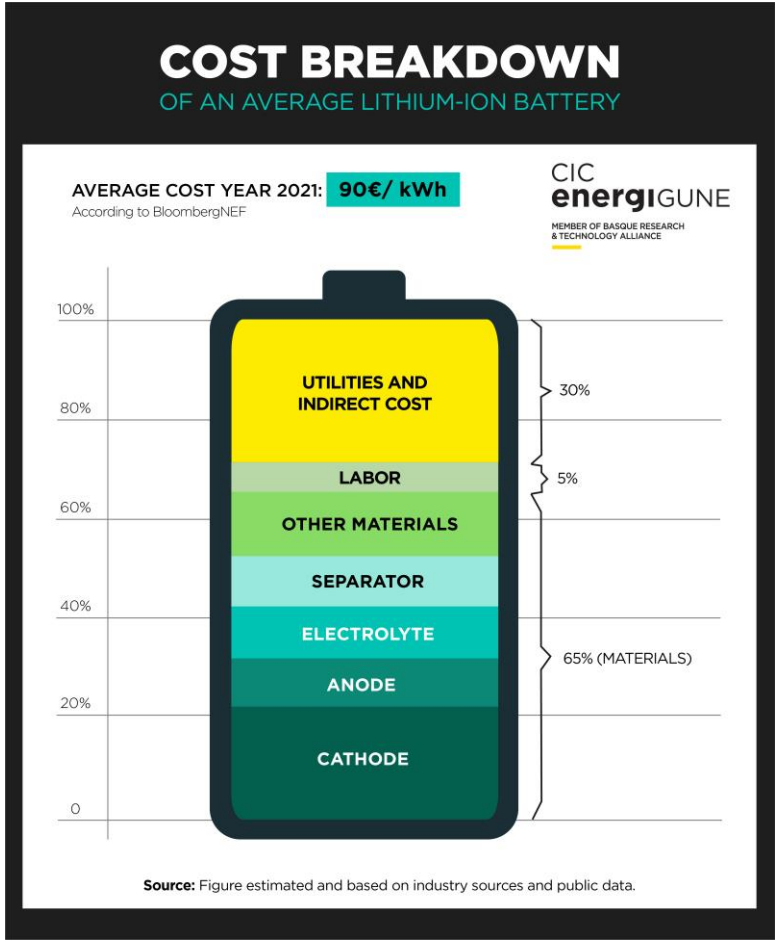
Batteries in Norway

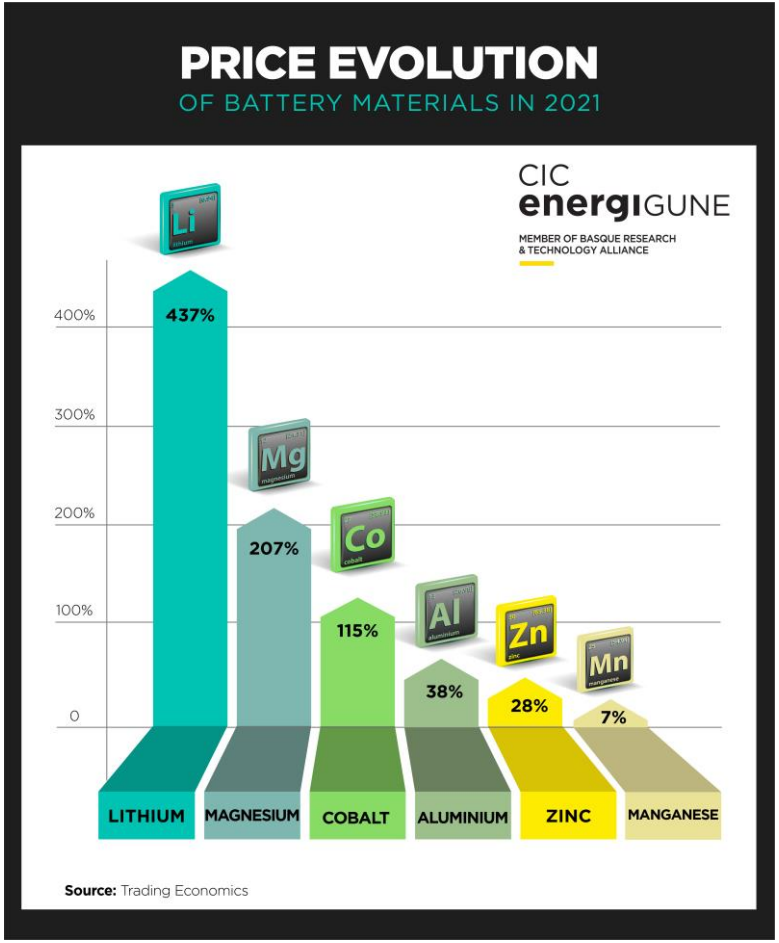




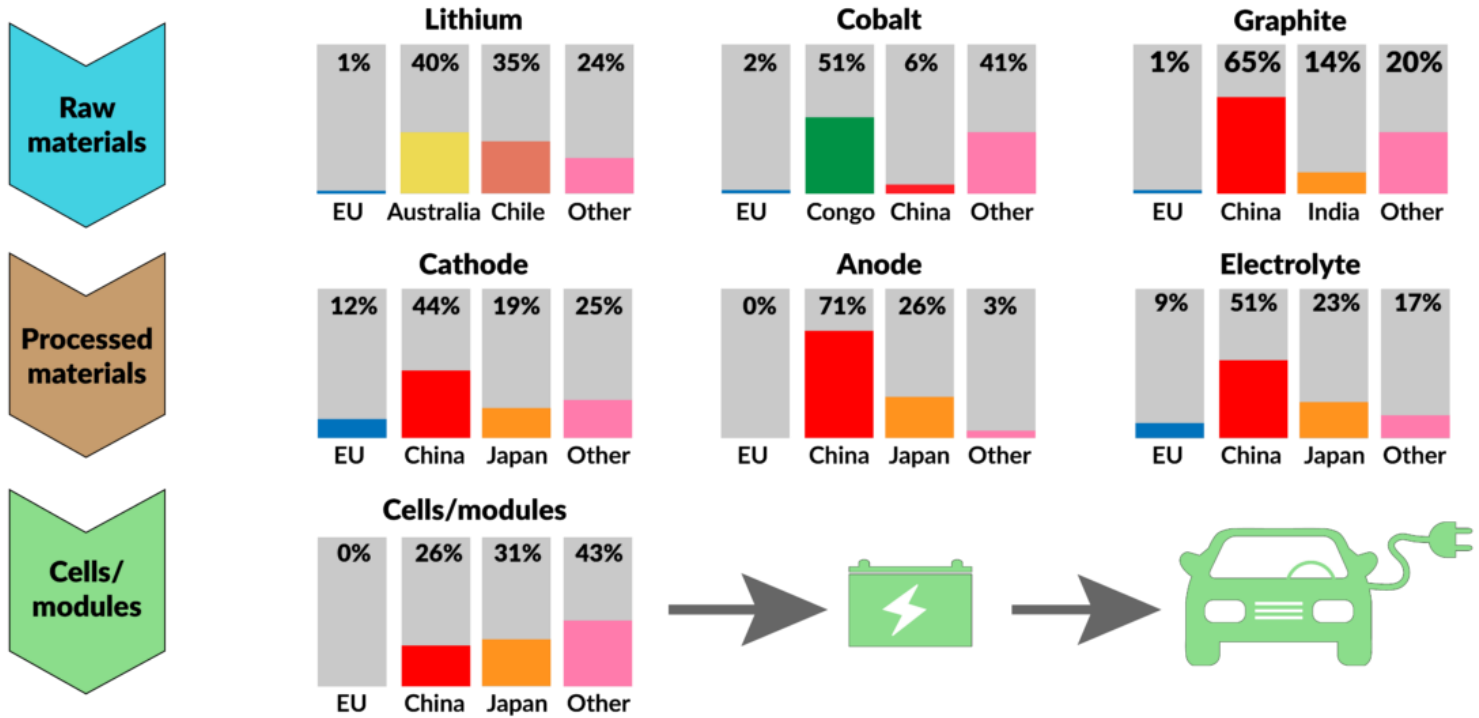


Materials and problems





Materials and problems



https://www.gisreportsonline.com/r/critical-raw-materials/

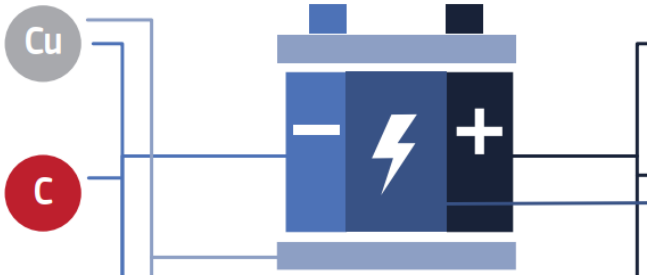
Materials and problems

Copper: as current collector foil at anode side, in wires and other conductive parts

Graphite: natural or synthetic high-grade purity in anode electrode in all Li-ion battery types

Silicon: in (future) anodes to enhance energy density

Titanium: in future anode materials and coatings, in LTO, for battery packaging



Aluminium: for battery packaging or as current collector foil (cathode), in NCA batteries

Niobium: in future anode and cathode material (coatings) to improve stability and energy density

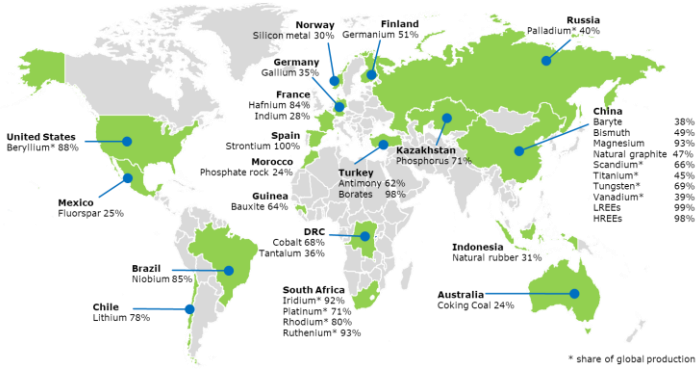
Cobalt: in cathode materials in LCO, NCA and NMC batteries

Lithium: as lithium-cobalt oxide (cathode) and as salt (electrolyte) in Li-ion battery

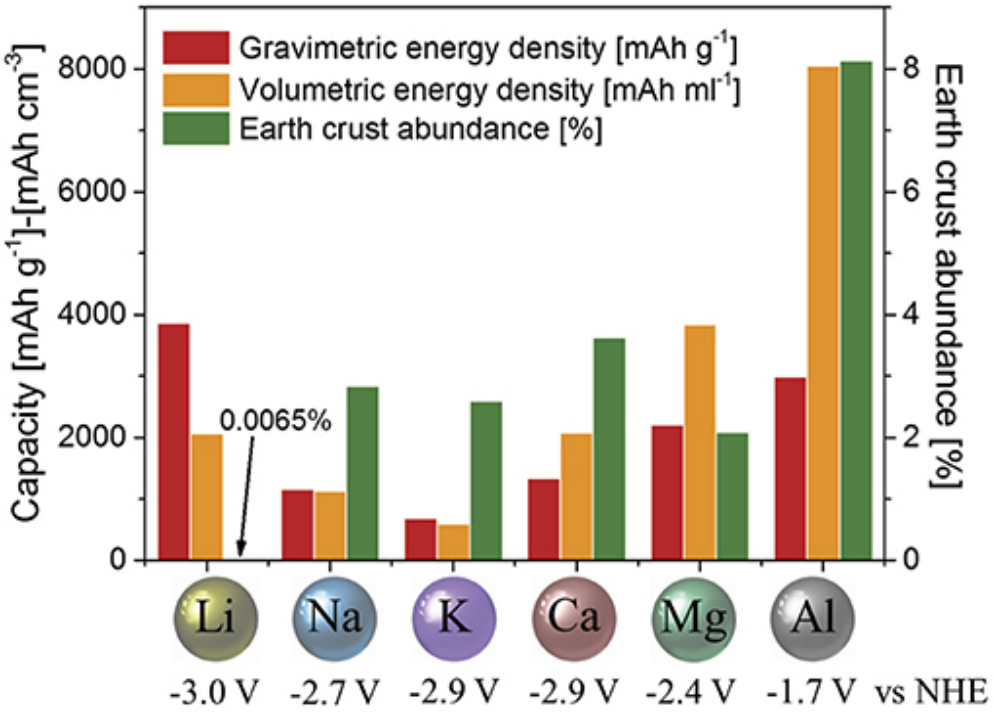
Manganese: in cathode materials for NMC and LMO batteries

Nickel: as hydroxide or intermetallic compounds in NMC, NCA batteries

Critical Raw Material

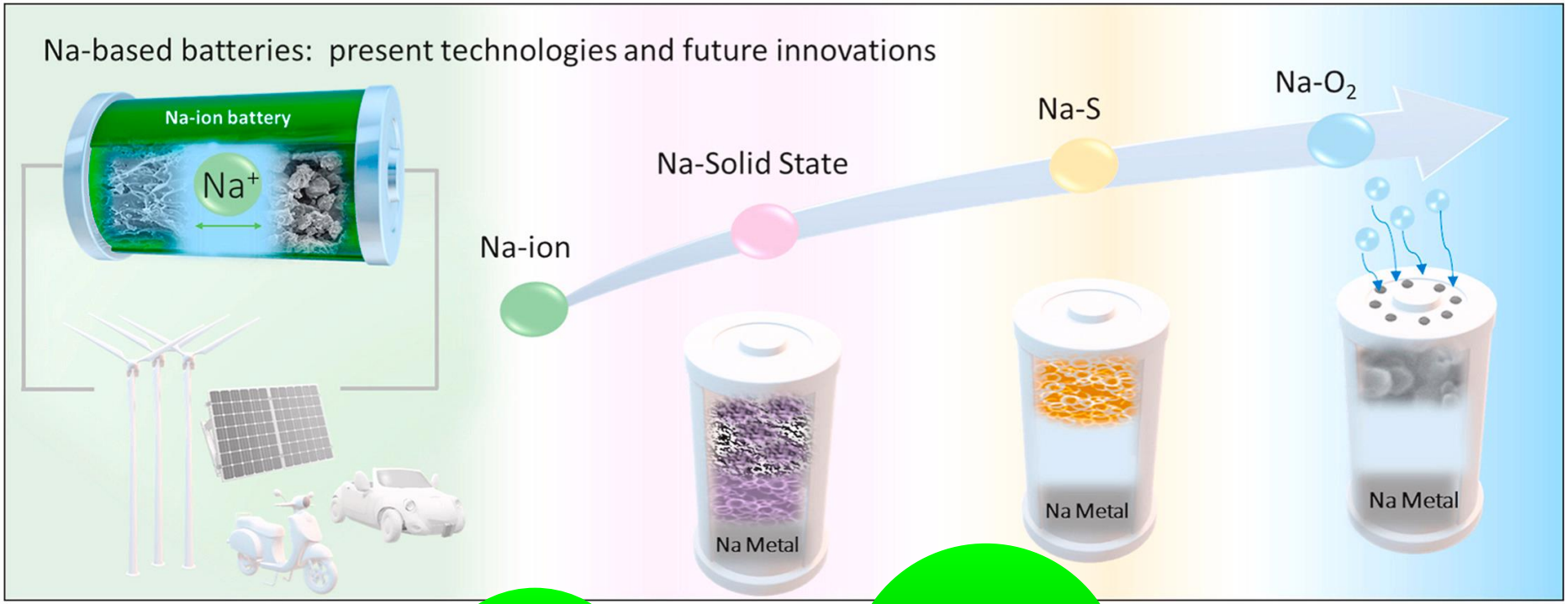


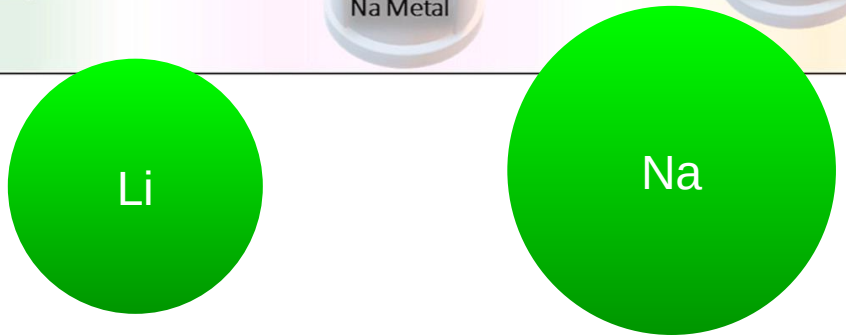
Beyond Li-ion batteries



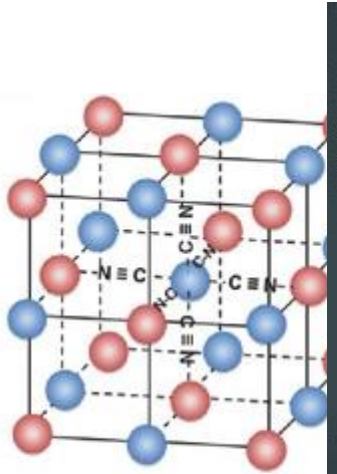
10.3389/fchem.2019.00268

Na-ion batteries



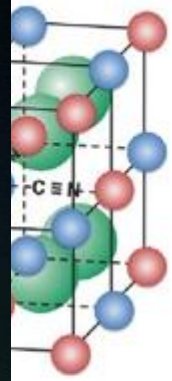


Na-ion batteries: cathodes - PBAs

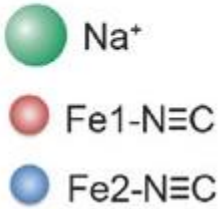


$Fe^{III}Fe^{III}(CN)_6$
Prussian Yello



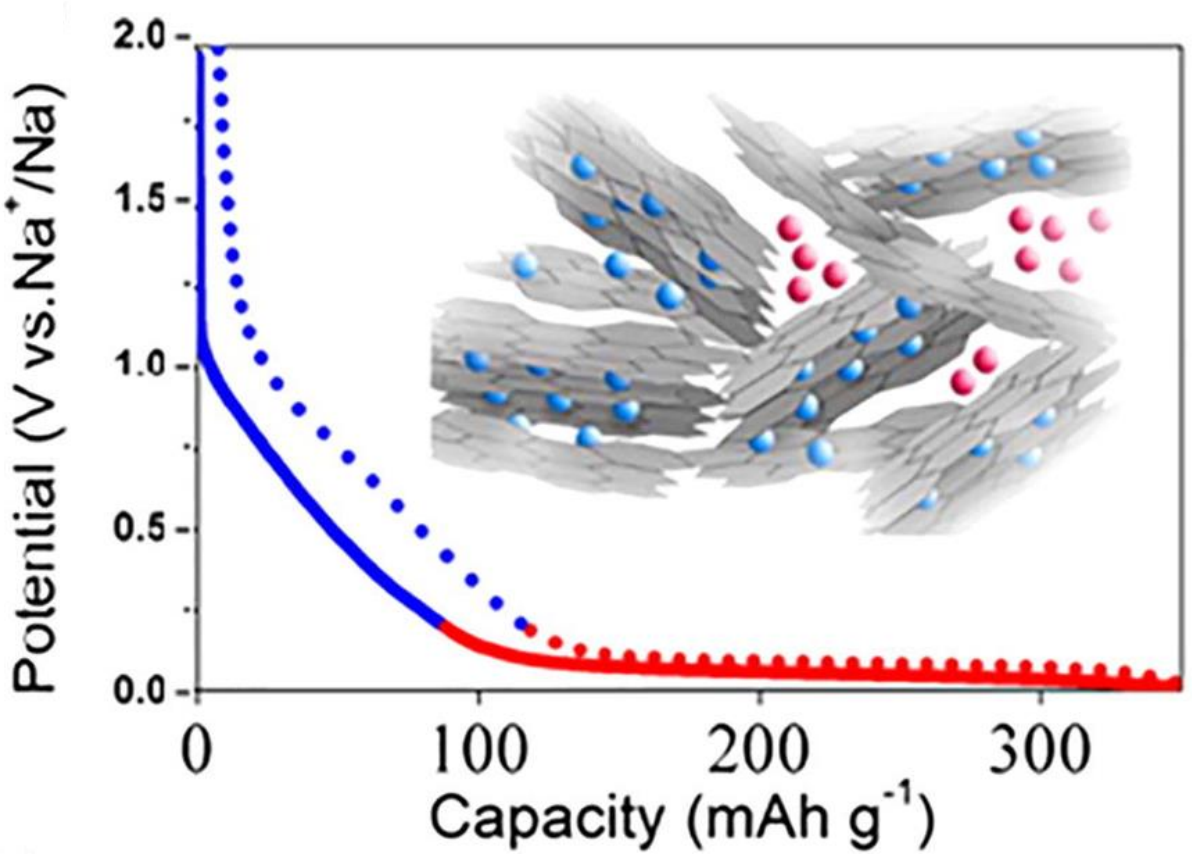


$Fe^{II}(CN)_6$
Blue



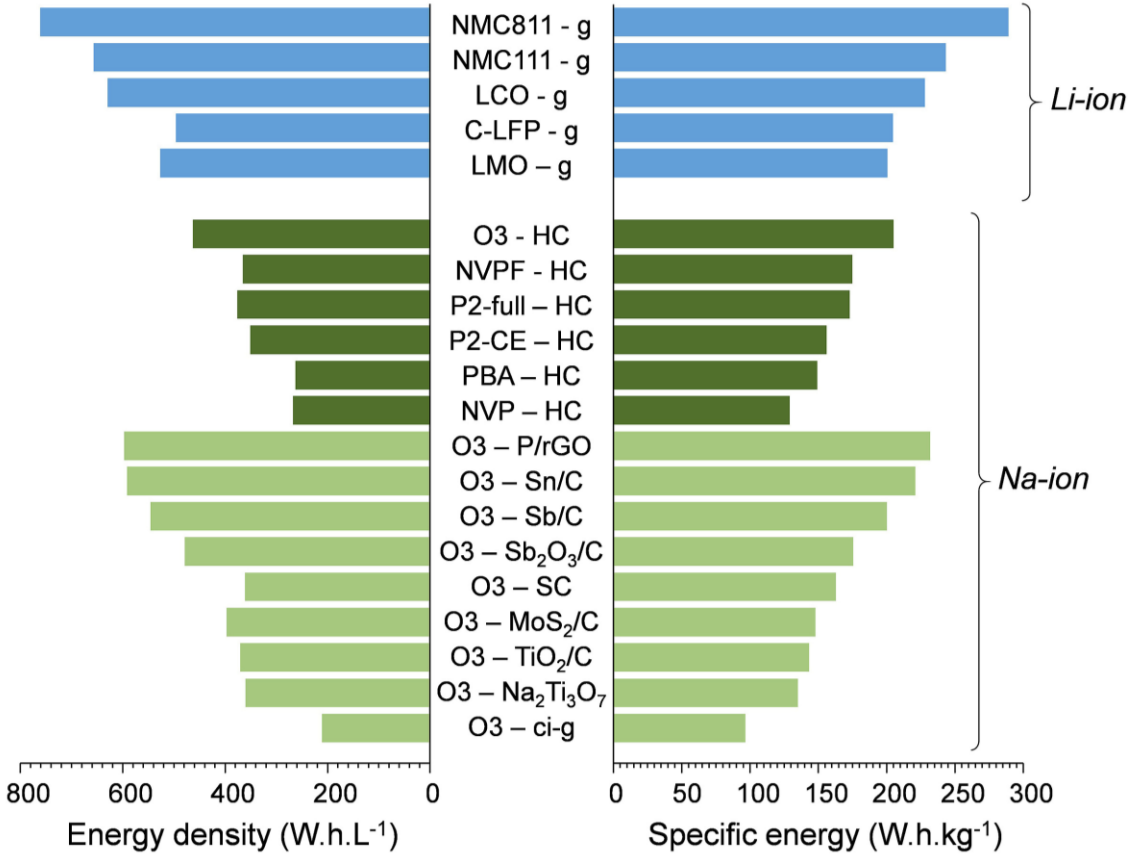
10.1002/aenm.201702619

Na-ion batteries: anodes – hard carbon



10.1016/j.mattod.2018.12.040

Na-ion batteries: comparison



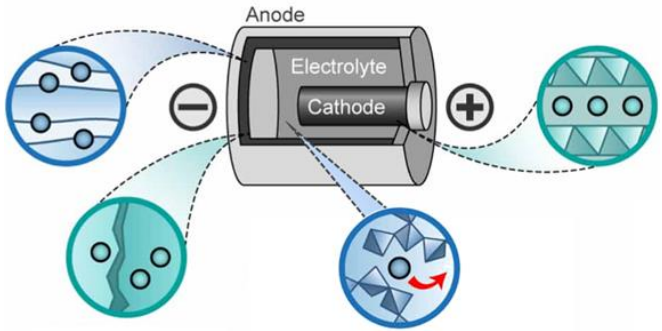
10.1016/j.jpowsour.2020.228872

Materials for batteries at UiO

- **New materials**



- **Computation and machine learning**

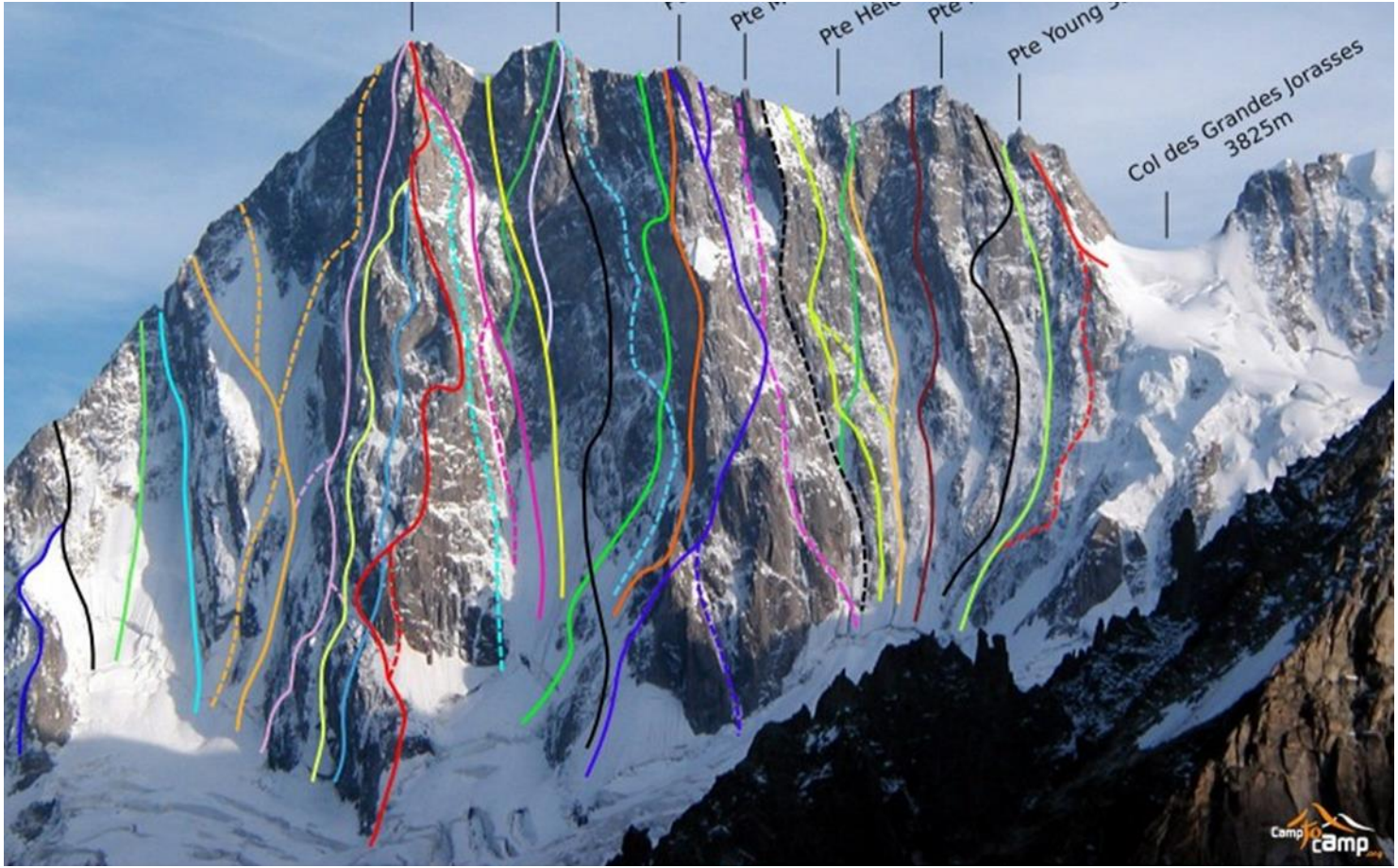




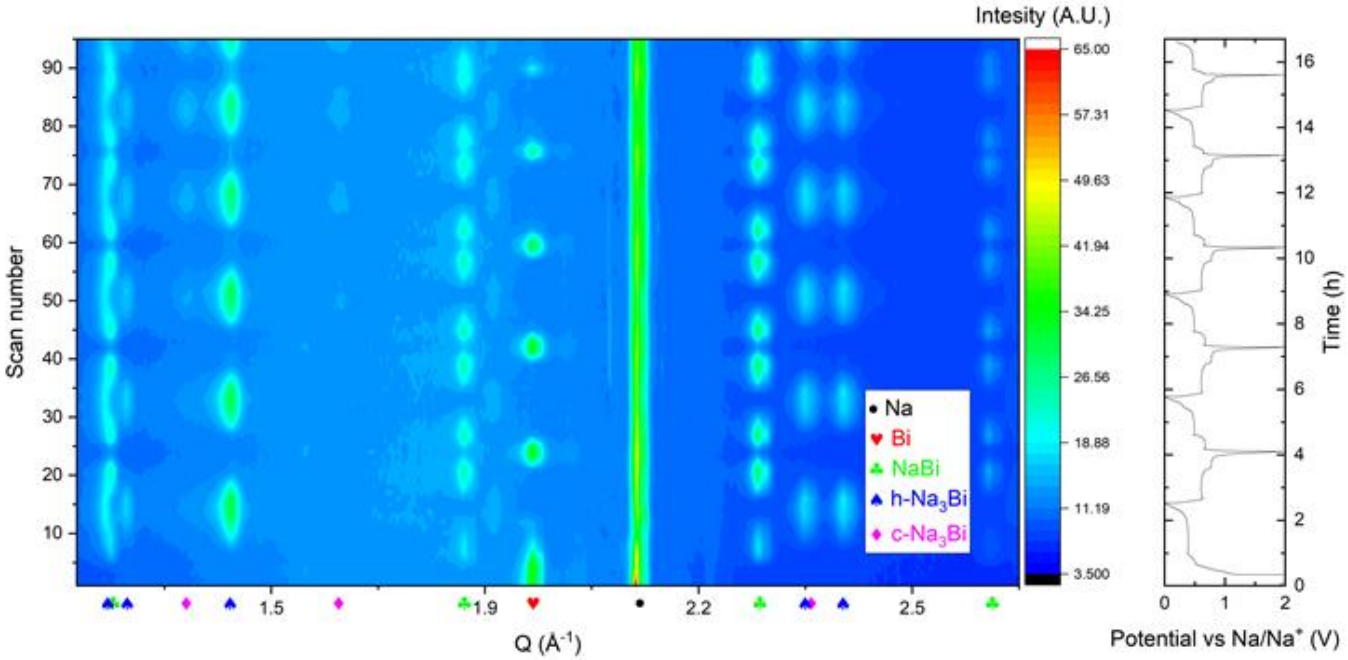
- **Operando studies**



Operando characterization



Operando Studies



Group

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- Prof. Ola Nilsen





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- Dr. Carmen Cavallo
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Thank you for your attention!

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