The future of Lithium batteries and sustainable Gigafactories

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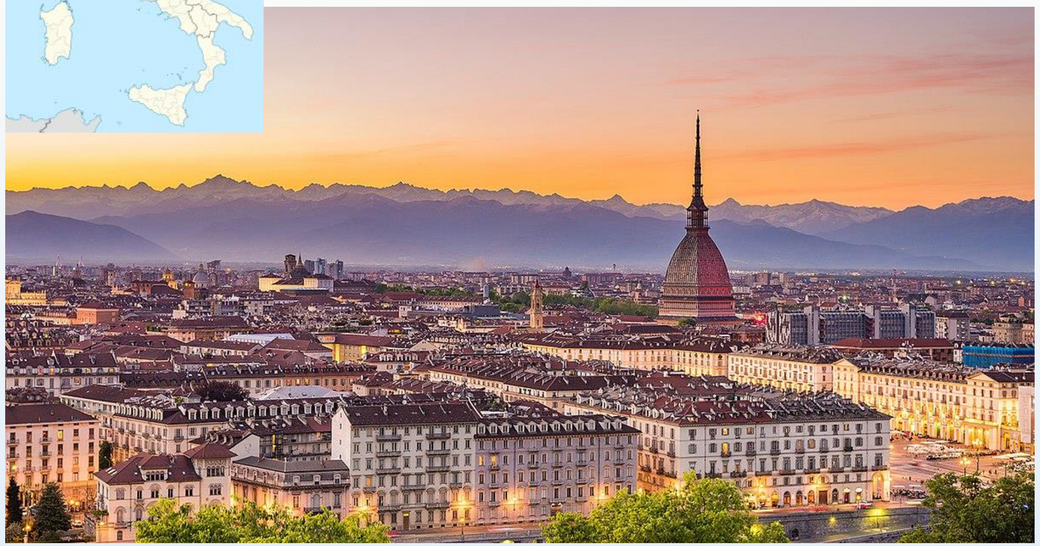
Electrochemistry Group
Department of Applied Science and Technology
Politecnico di Torino, Italy

Politecnico di Torino



Politecnico di Torino
RESEARCH IN NUMBERS

HUMAN CAPITAL

247 Full Professors
399 Associate Professors
337 Researchers
889 Administrative Staff

16 PhD Programmes
696 PhD students

HR EXCELLENCE IN RESEARCH

ORGANIZATION OF RESEARCH

4 Campus
11 Departments
13 Interdepartmental Laboratories

Politecnico is present in :
Tashkent - Turin Polytechnic University in Tashkent (Uzbekistan)
Shangai - Tonji University (Cina)
Guangzhou - South China University of Technology (Cina)

RESEARCH GRANTS
since 2014

305 European and International Projects **101Mln €**

192 National and regional Projects **36Mln€**

Research contracts with the private sector: **19,2 Mln€** (2019)

SCIENTIFIC PUBLICATIONS AND PUBLIC ENGAGEMENT
YEAR 2018

2579 Publication in scientific journals

892 Contributions to scientific conferences published

more than **400** conferences and public lectures
more than **450** students engaged in outreach actions
more than **3000** media mentions on research and technology transfer activities

RESEARCH IN ACTION

248 **Horizon 2020** Projects **95 Mln €**

17 **ERC** (European Research Council) Projects **21 Mln€**

53 **MSCA** (Marie Sklodowska Curie Actions) Projects **16 Mln€**

106 **Industrial Leadership / Societal Challenges/ Joint Technology Initiative** Projects **36 Mln €**

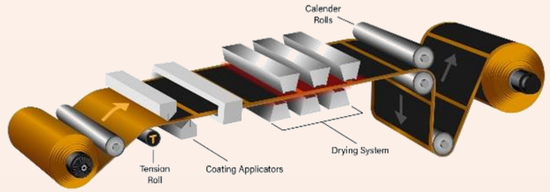
3 **EIT Communities** partners :
10 Inno Energy / EIT Digital / EIT Manufacturing
Open Research Infrastructures

5 Departments of Excellence selected by ANVUR

Main research topics

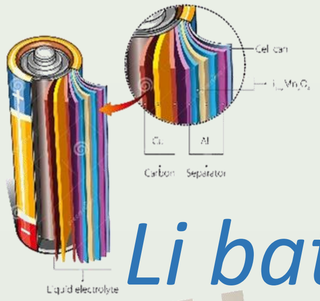
Scale-up

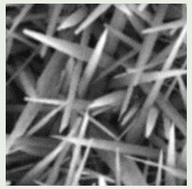
- Testing of modules & packs
- Prototyping pilot line



BATTERIES *from TRL-0 to TRL-6*

- Li-ion, Li-metal, Li-S, Li-O_2/N_2
- Sensors & Self-healing
- Solid-state electrolytes
- Sustainable materials
- Potassium batteries

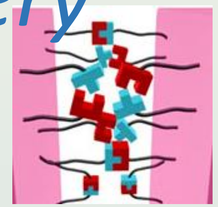




Li battery

Nanomaterials

Polyme



Sensors

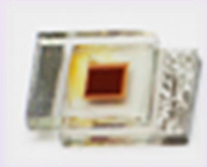
Self-healing components

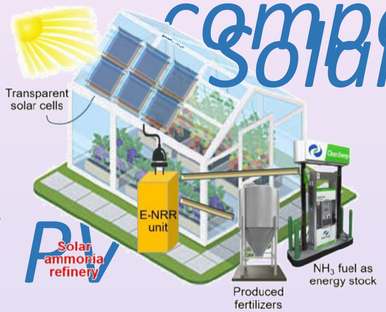
Biosourced

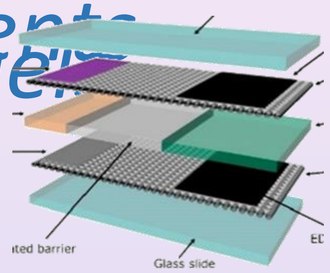
Solar fuel

Energy conversion & Integrated devices

- Dyes/Perovskites-based PV
- Smart materials for solar fuels
- PV + storage integration
- Electrochemical N_2 reduction







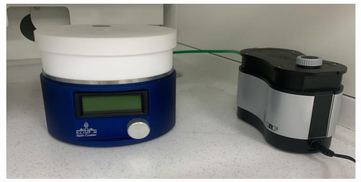
Hybrid PV

PV + sto

Facilities

Lab scale facilities

Tip-sonicator



Spin coater

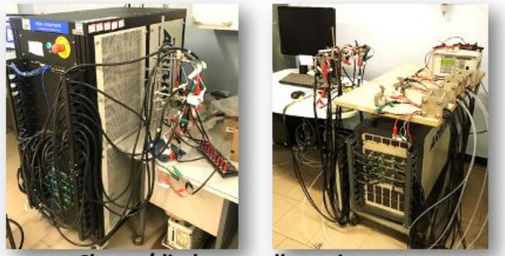
Liophilizer

UV-Vis-NIR spectrophotometer

Spectrofluorometer

Ultrasonic-spray coater

Vis and NIR detectors



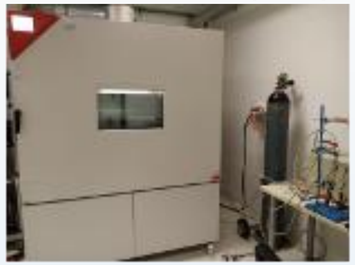
Charge/discharge cells testing systems

Battery testing facility (abuse/safety)

Cycler for single cells (5V – 100-200 A)

Accelerating rate calorimeter

Climate chamber (720L)



Container for battery packs testing

Battery tester for modules and packs (600V, 260A)

Environmental Park

Green Electrochemistry Lab

Small Pilot Line (MTI)

Task force on Batteries @PoliTO

Materials, Nanosensors & New cell designs
Silvia Bodoardo (DISAT): batteries
Fabrizio Pirri (DISAT): nanotechnologies

Modeling
Daniele Marchisio (DISAT): materials production processes
Pietro Asinari (DENERG): electrode/electrolyte interfaces
Massimo Santarelli (DENERG): electrochemical and thermal modelling

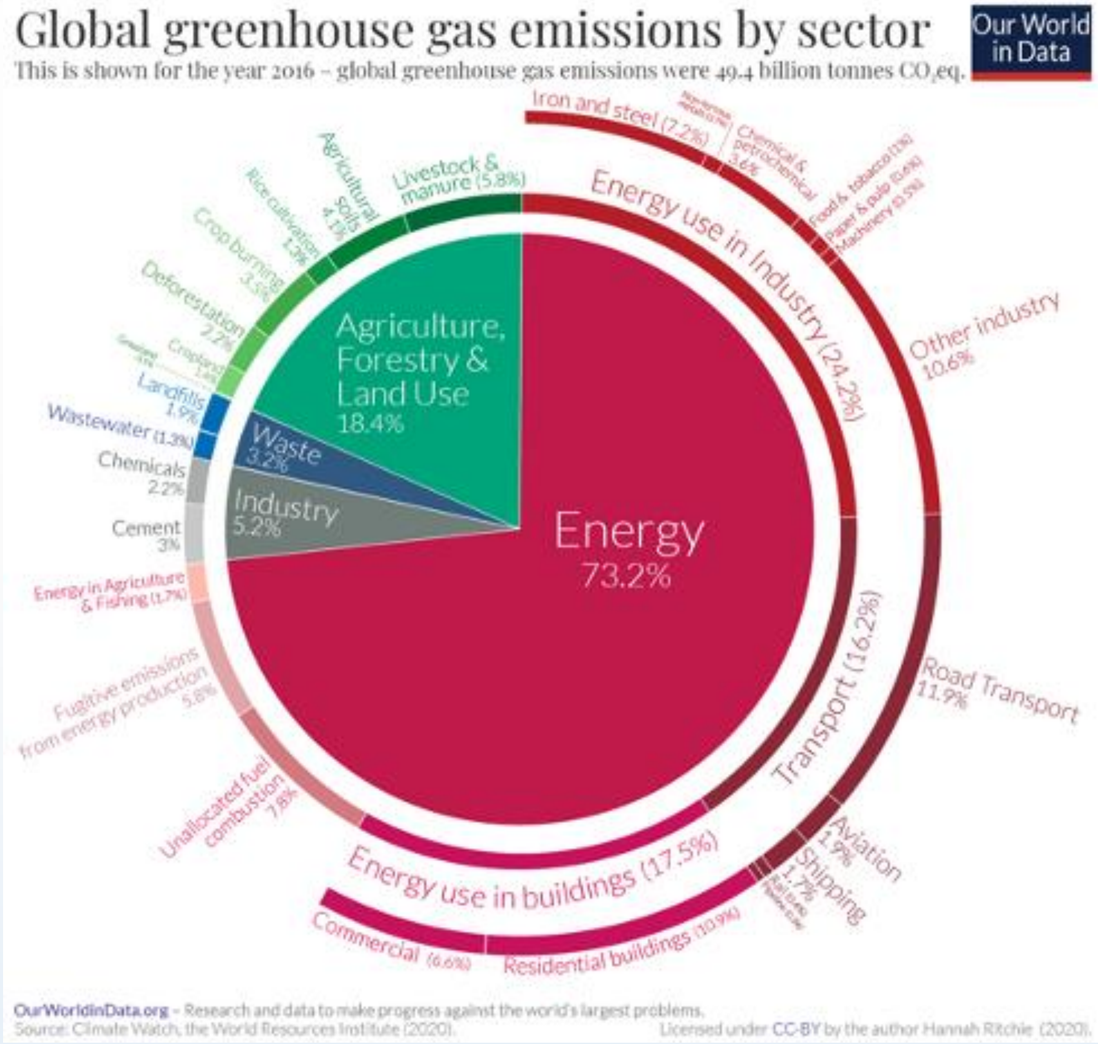
Battery packs
Paolo Guglielmi (DENERG): assembly
Radu Bojoi (DENERG): BMS
Michele Pastorelli (DENERG): power electronics

LCA & Recycling
Silvia Fiore (DIATI)

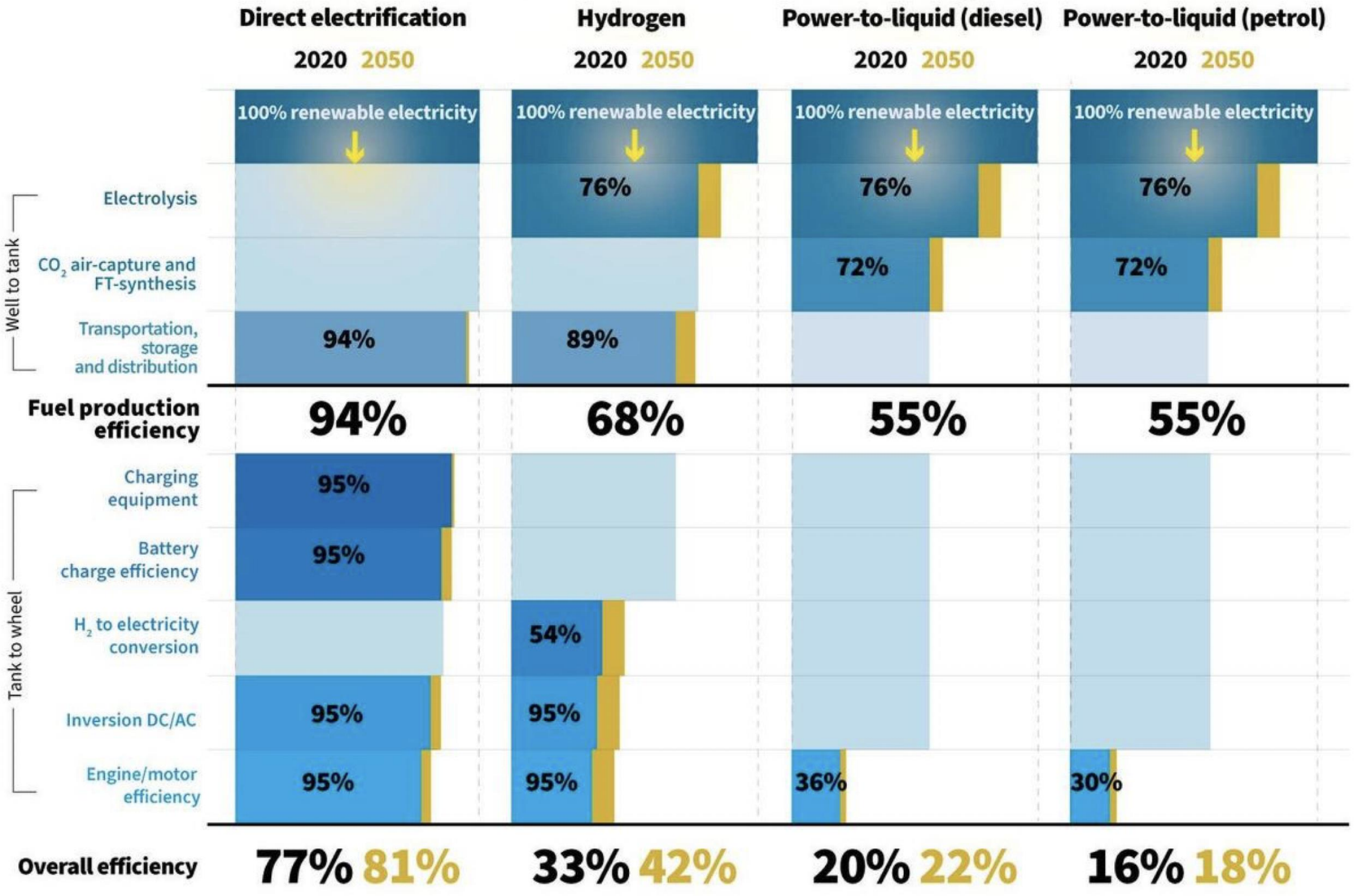
Electric vehicle applications and integration
Massimiliana Carello (DIMEAS)

why batteries?

Carbon footprint



Cars: direct electrification most efficient by far



Notes: To be understood as approximate mean values taking into account different production methods. Hydrogen includes onboard fuel compression. Excluding mechanical losses.

TRANSPORT & ENVIRONMENT transportenvironment.org

Sources: Worldbank (2014), Apostolaki-Iosifidou et al. (2017), Peters et al. (2017), Larmanie et al. (2012), Umweltbundesamt (2019), National Research Council (2013), Ricardo Energy & Environment (2020), DOE (no date), ACEA (2016).

Global CO_2 Emissions

Transport Sector is Contributing Significantly to CO_2 emissions

Approximately one-quarter of global CO_2 emissions are accounted by transportation sector.

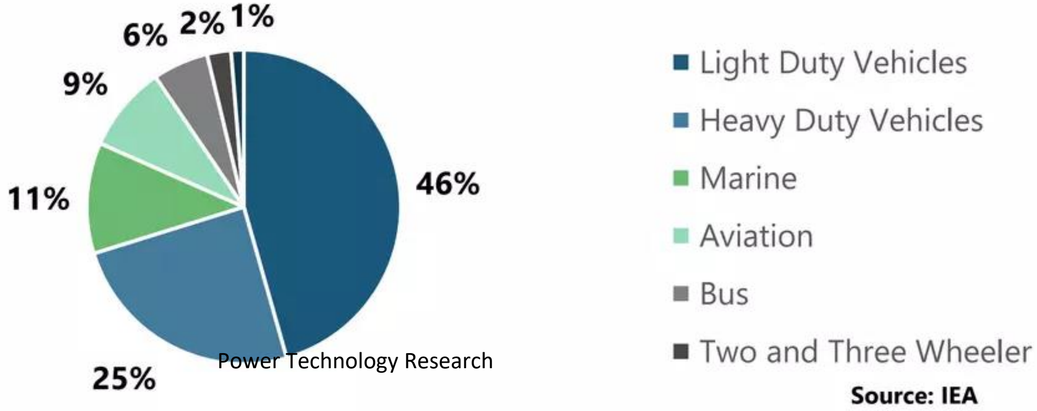
With a share of 23%, the transport industry was the second-largest source of CO_2 emissions.

U.S., China, EU, and India account for 46% of the global CO_2 emissions from transportation.

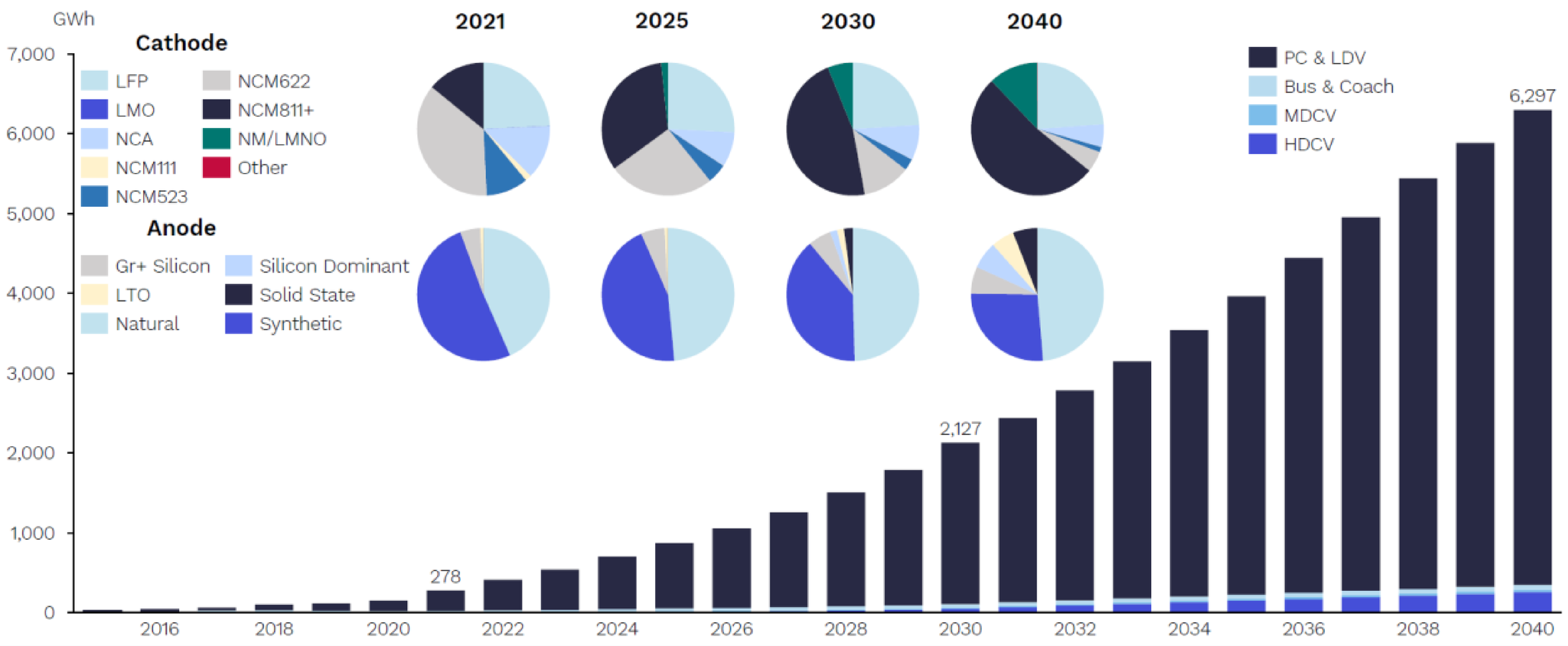
Post Covid-19, the demand for transport sector has rebounded and is expected to rise continuously.

However, the Net-Zero Emissions target requires global transport sector to reduce its emissions by 20%.

The electrification of the transportation sector is necessary for the sector's transition to achieve low-emission targets.

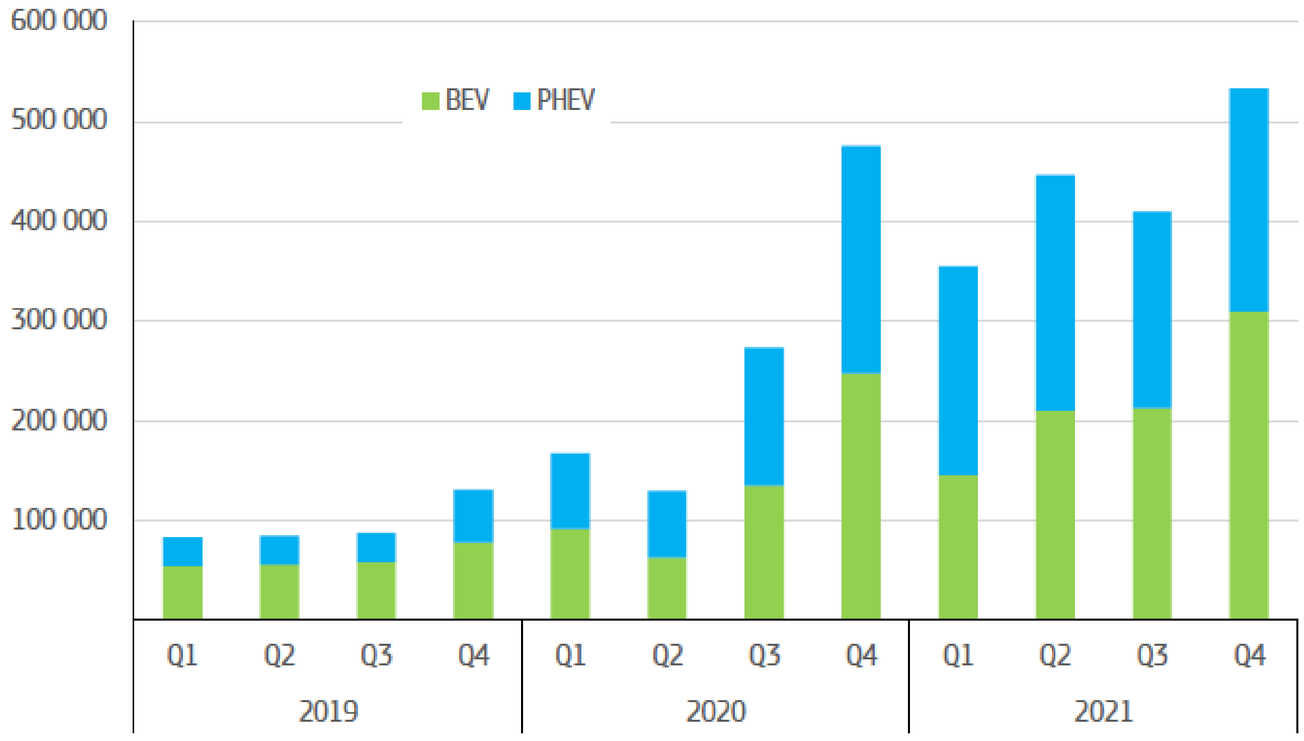


EV battery demand outlook in division per vehicle class and chemistry



Source: RhoMotion, EV & Battery Quarterly Outlook Q4 2021, 2021

EU quarterly sales of electrified vehicles

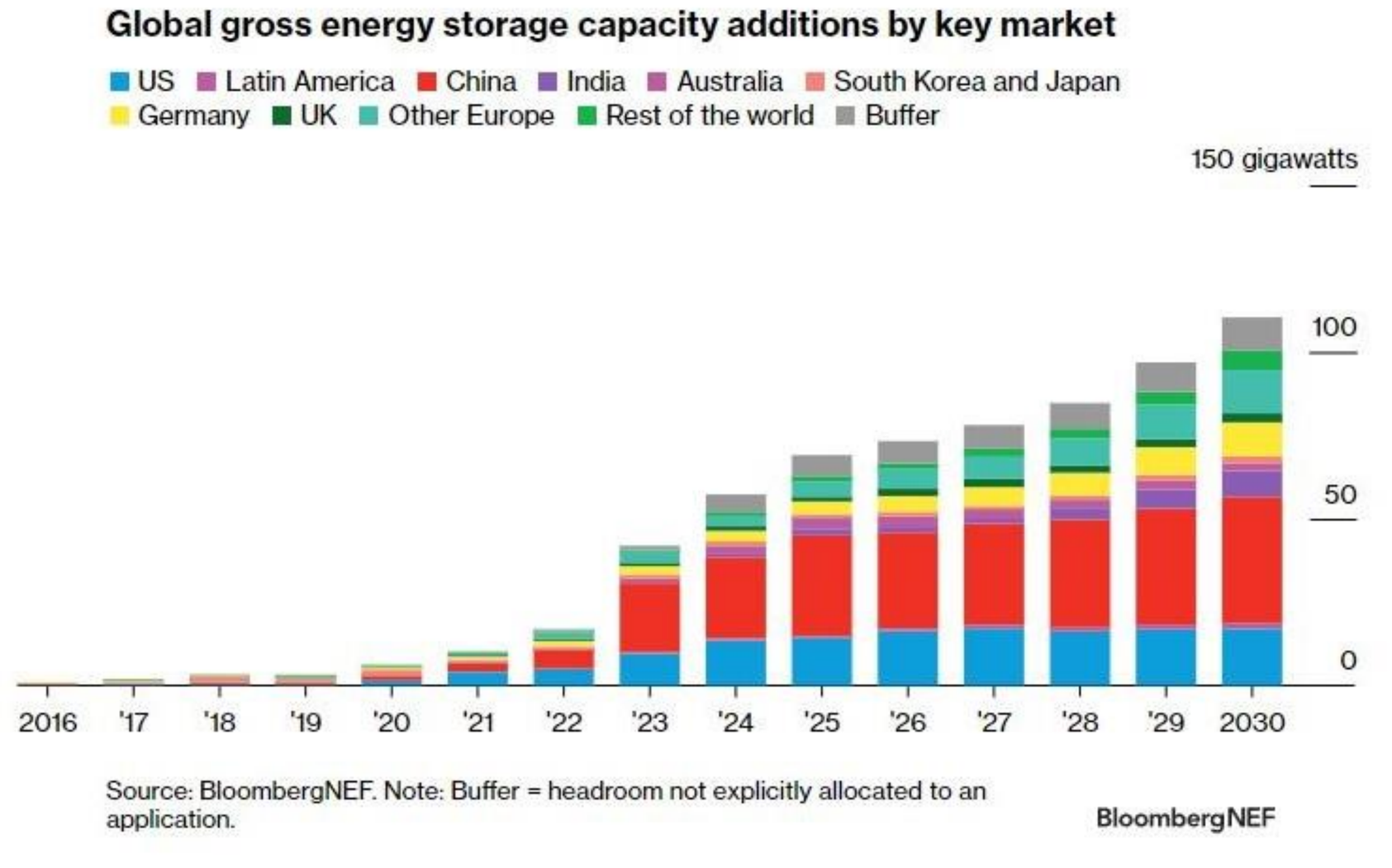


Source: EU based on ACEA data.

During 2021 the number of electrified vehicles on the EU roads almost doubled reaching four millions, an equivalent of almost 150 GWh storage capacity given an average battery capacity of 55 kilowatt-hours (kWh) for BEVs and 14 kWh for PHEVs.19

The further growth of sales in EU is expected to reach 3.5 million vehicles in 2025 (31% of all vehicles in this class sold in 2025), 7 million in 2030 (55%) and about 11 million in 2040 (87%) RhoMotion, EV & Battery Quarterly Outlook Q4 2021, 2021

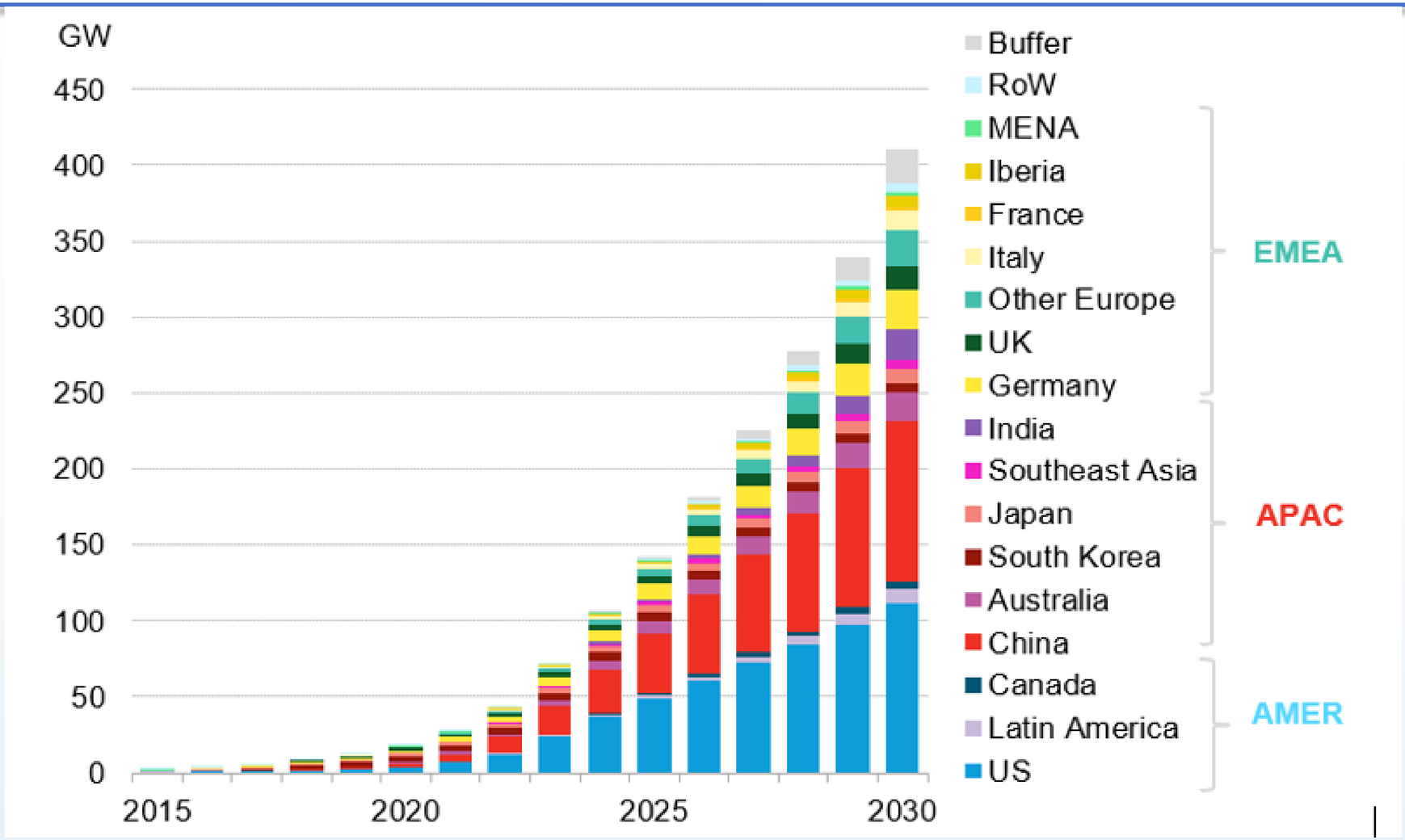
renewable energy ...
is not continuous..
and needs to be stored
—> We need BATTERIES



Cumulative energy storage installations will go **beyond the terawatt-hour** mark globally **before 2030** excluding pumped hydro, with lithium-ion batteries providing most of that capacity,

BloombergNEF's forecast of installations to the end of 2030 by key global region.

Storage capacity by area



latest analysis of the sector, the firm has forecast that by the end of 2030, cumulative installations worldwide will reach 411GW and 1,194GWh.

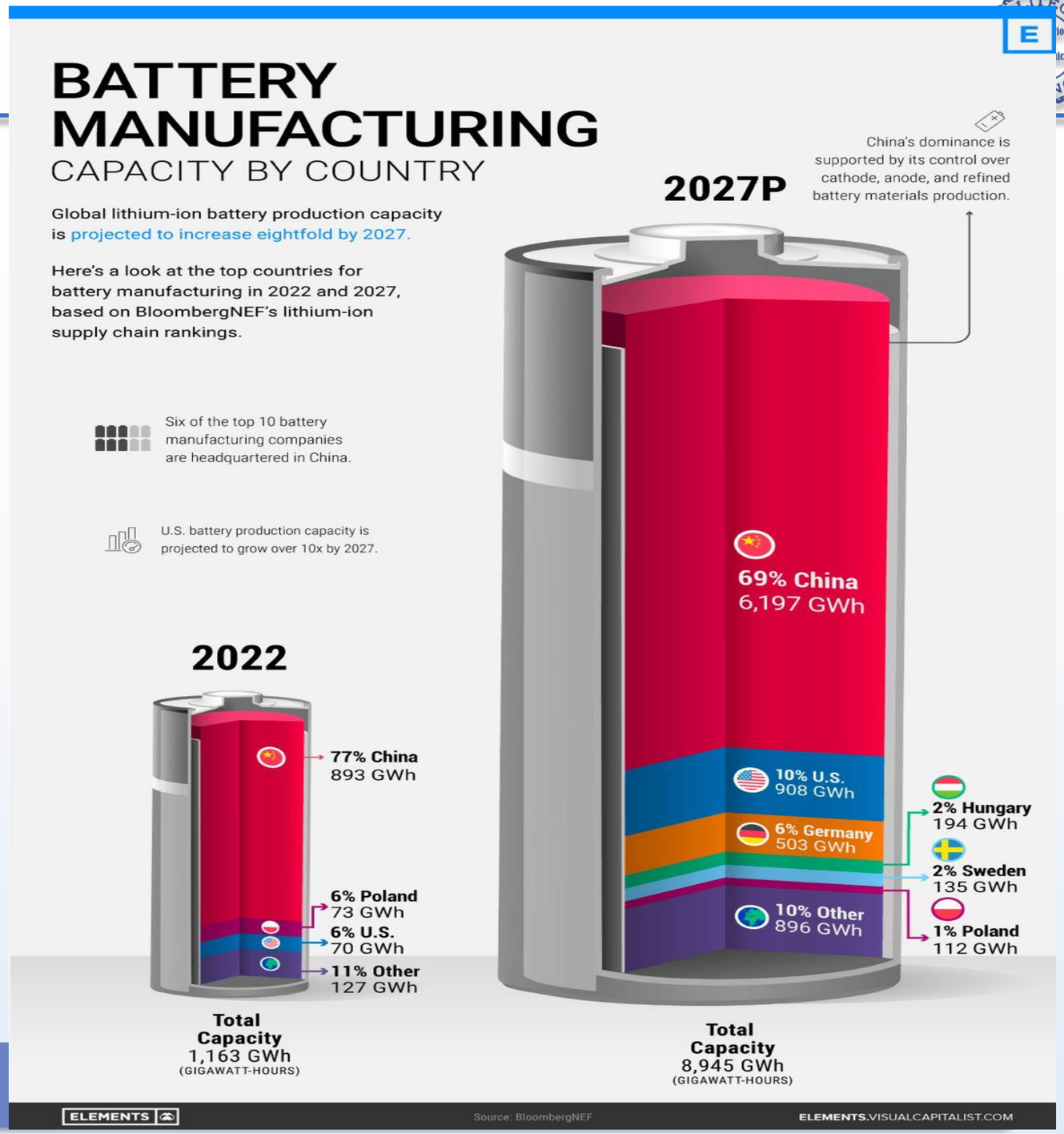
Reported and projected cumulative global installations by region. with 'RoW' representing the 'Rest of the World' and 'Buffer' markets and use cases for which there is low visibility, BloombergNEF

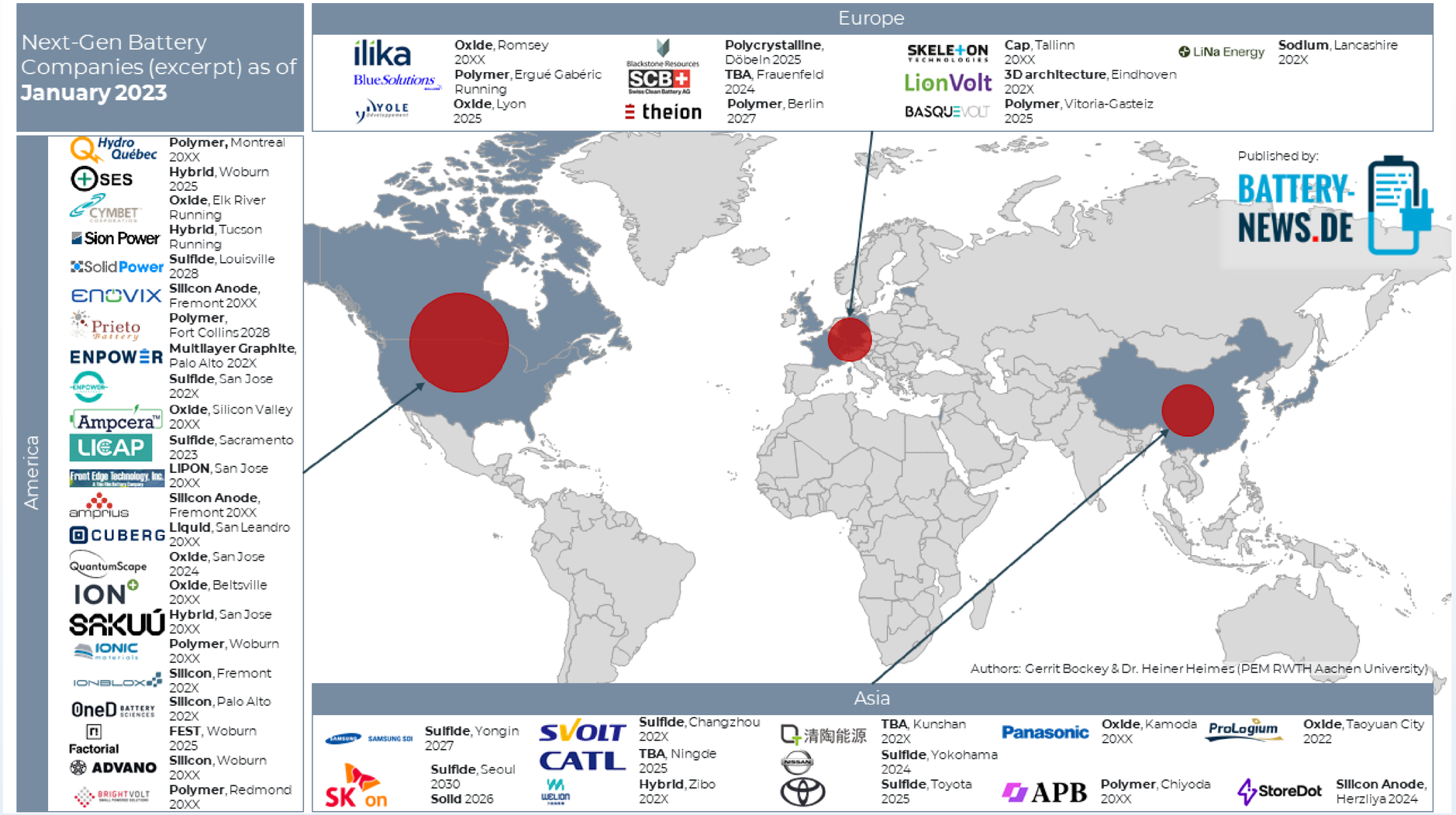
The most of the cell production is still in Asia

China controls 80% of the world's Li-ion battery raw material refining capacity, 77% of cell production capacity and 60% of battery component manufacturing capacity.

Global biggest suppliers of Li-ion batteries were: CATL, LG Energy Solution, BYD, Panasonic and SK Innovation (Q1 2022).

The EU trade deficit in Li-ion batteries continued to expand in 2021 and reached EUR 5.3 billion (+25% from 2020).

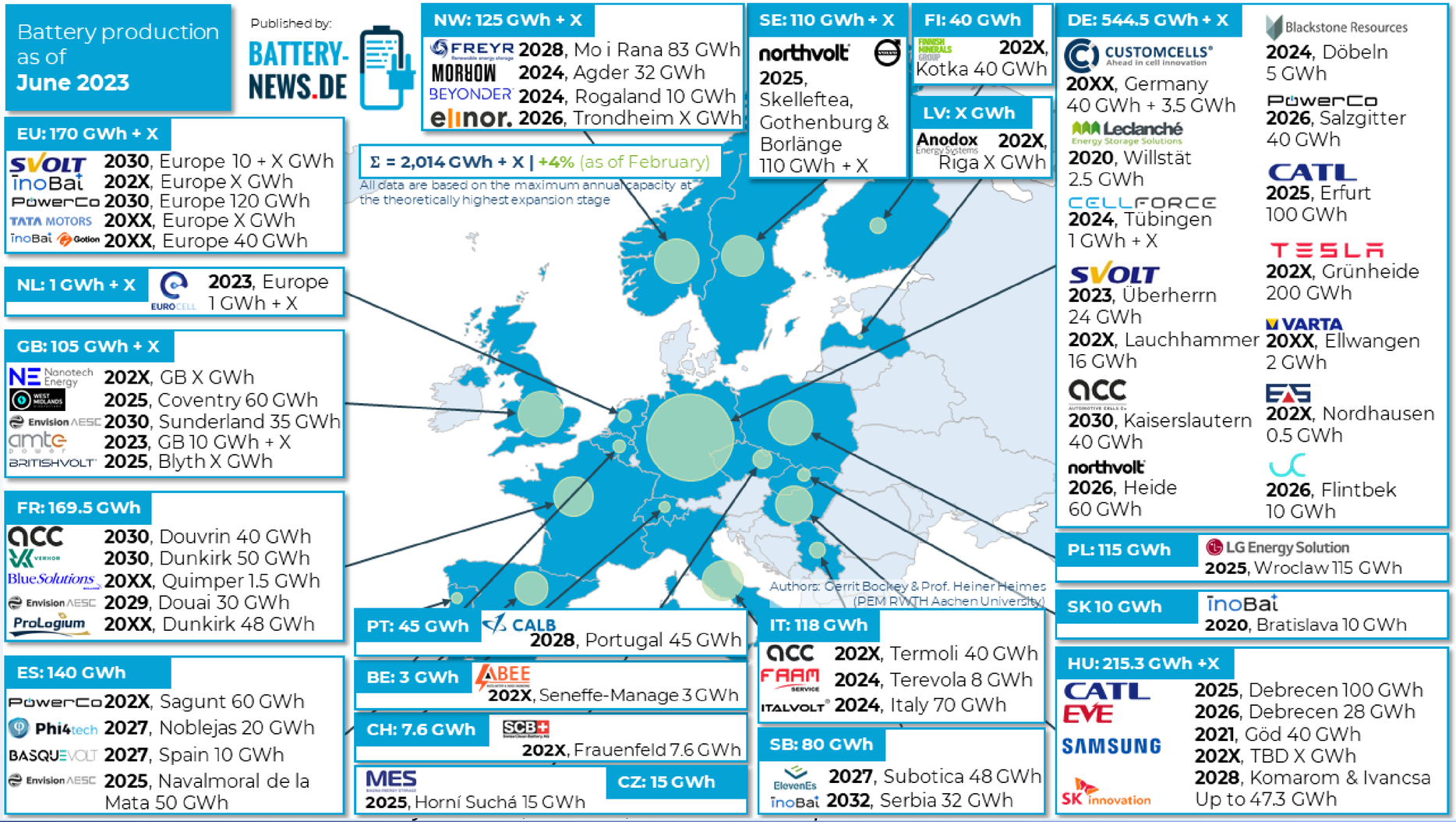



Next-Gen Battery Companies (excerpt) as of January 2023
Europe
ilika
Oxide, Romsey 20XX
Blue.Solutions
Polymer, Ergué Gabéric Running
YOLE Développement
Oxide, Lyon 2025
Blackstone Resources
SCB
Polycrystalline, Döbeln 2025
theion
TBA, Frauenfeld 2024
Polymer, Berlin 2027
SKELETON TECHNOLOGIES
Cap, Tallinn 20XX
LionVolt
3D architecture, Eindhoven 202X
BASQUEVOLT
Polymer, Vitoria-Gasteiz 2025
LiNa Energy
Sodium, Lancashire 202X
America
Hydro Québec
Polymer, Montreal 20XX
SES
Hybrid, Woburn 2025
CYMBET
Oxide, Elk River Running
Sion Power
Hybrid, Tucson Running
SolidPower
Sulfide, Louisville 2028
enovix
Silicon Anode, Fremont 20XX
Prieto Battery
Polymer, Fort Collins 2028
ENPOWER
Multilayer Graphite, Palo Alto 202X
Sulfide, San Jose 202X
Ampcera
Oxide, Silicon Valley 20XX
LICAP
Sulfide, Sacramento 2023
Front Edge Technology, Inc.
LIPON, San Jose 20XX
amprius
Silicon Anode, Fremont 20XX
CUBERG
Liquid, San Leandro 20XX
QuantumScape
Oxide, San Jose 2024
ION
Oxide, Beltsville 20XX
SAKUU
Hybrid, San Jose 20XX
IONIC materials
Polymer, Woburn 20XX
IONBLOX
Silicon, Fremont 202X
OneD BATTERY SCIENCES
Silicon, Palo Alto 202X
Factorial
FEST, Woburn 2025
ADVANO
Silicon, Woburn 20XX
BRIGHTVOLT
Polymer, Redmond 20XX
Published by:
BATTERY-NEWS.DE
Authors: Gerrit Bockey & Dr. Heiner Heimes (PEM RWTH Aachen University)
Asia
SAMSUNG SDI
Sulfide, Yongin 2027
SK on
Sulfide, Seoul 2030
Solid 2026
SVOLT
CATL
WELION
Sulfide, Changzhou 202X
TBA, Ningde 2025
Hybrid, Zibo 202X
清陶能源
TBA, Kunshan 202X
NISSAN
Sulfide, Yokohama 2024
Sulfide, Toyota 2025
Panasonic
Oxide, Kamoda 20XX
APB
Polymer, Chiyoda 20XX
ProLogium
Oxide, Taoyuan City 2022
StoreDot
Silicon Anode, Herzliya 2024

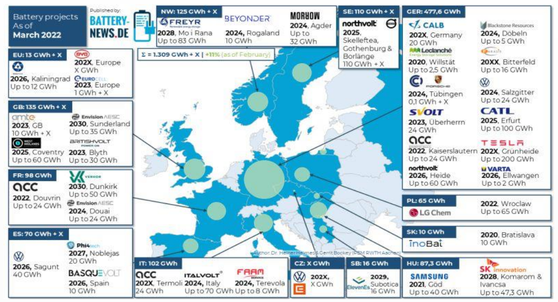
Batteries production … and Europe ?

European Gigafactories June 2023

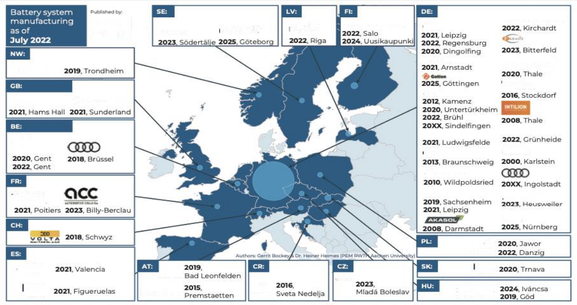
Battery cell production in Europe is picking up speed to meet the growing demand for battery cells



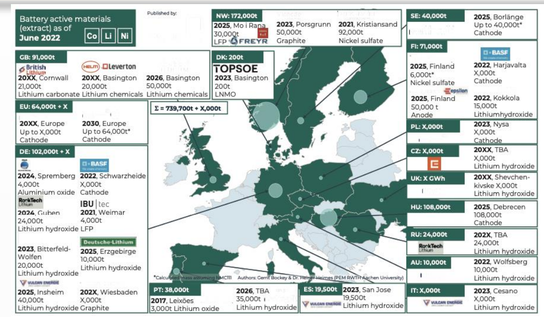
And also…



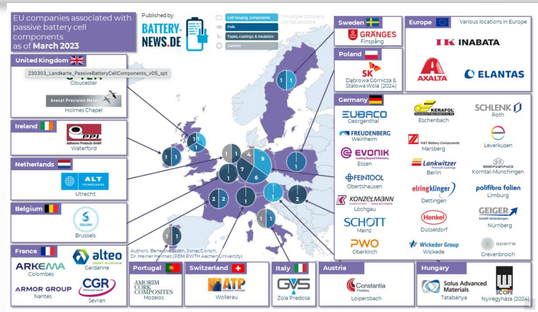
Gigafactories



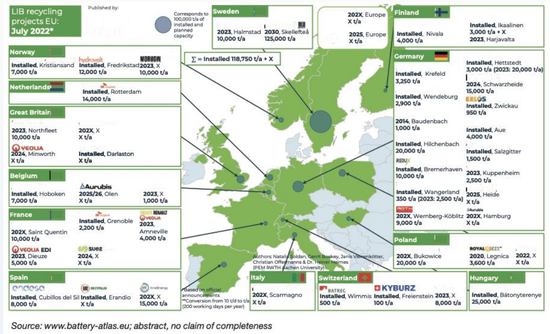
Module and pack manufacturer



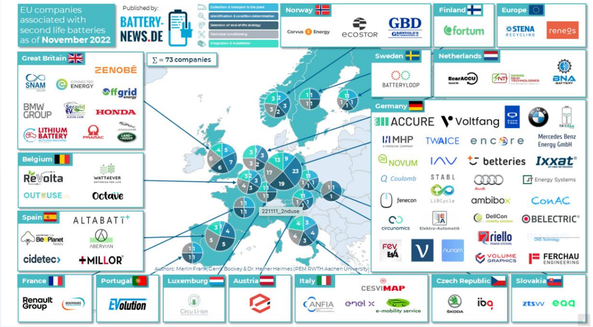
Active material suppliers



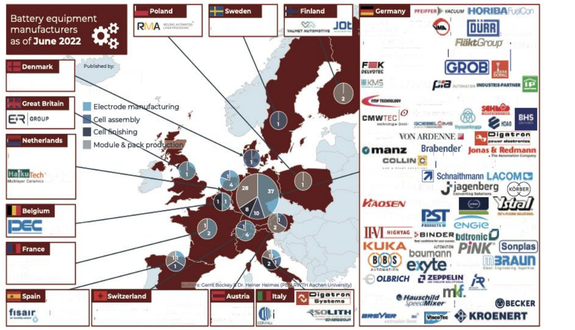
Components suppliers



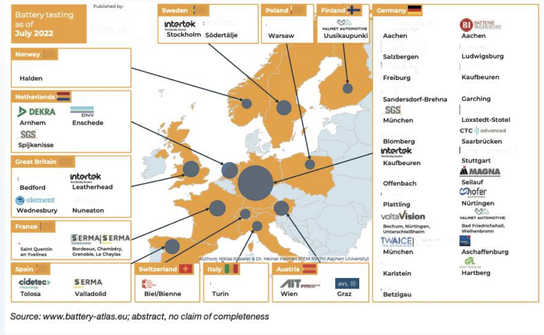
Recycling companies



Second life companies



Equipment suppliers



Battery test centers

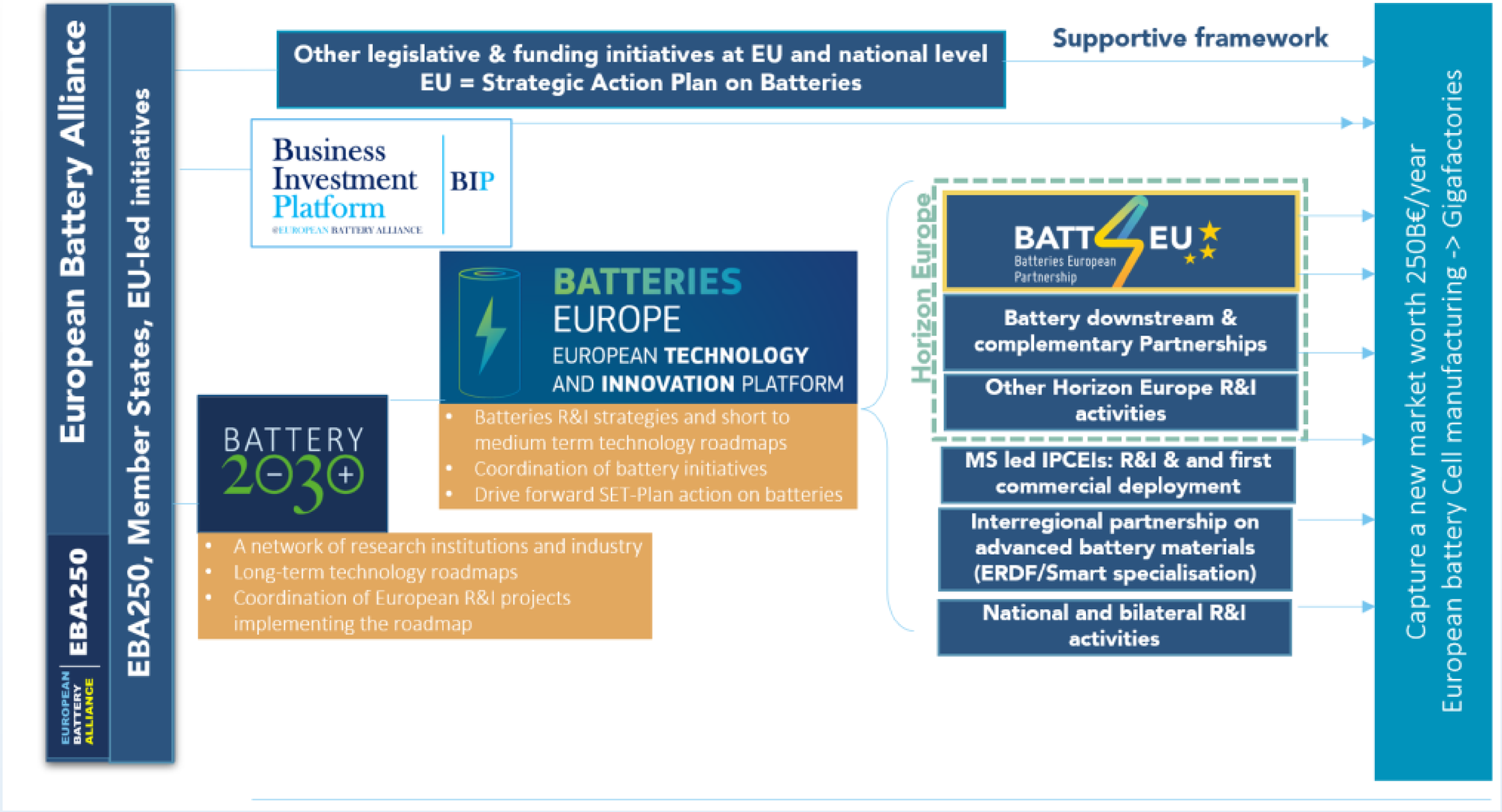
Source: www.battery-atlas.eu; abstract, no claim of completeness

Research

Industry

Build bridges

EU Battery R&I ladscape



Working Groups Chairs / BE Secretariat

Batteries Europe

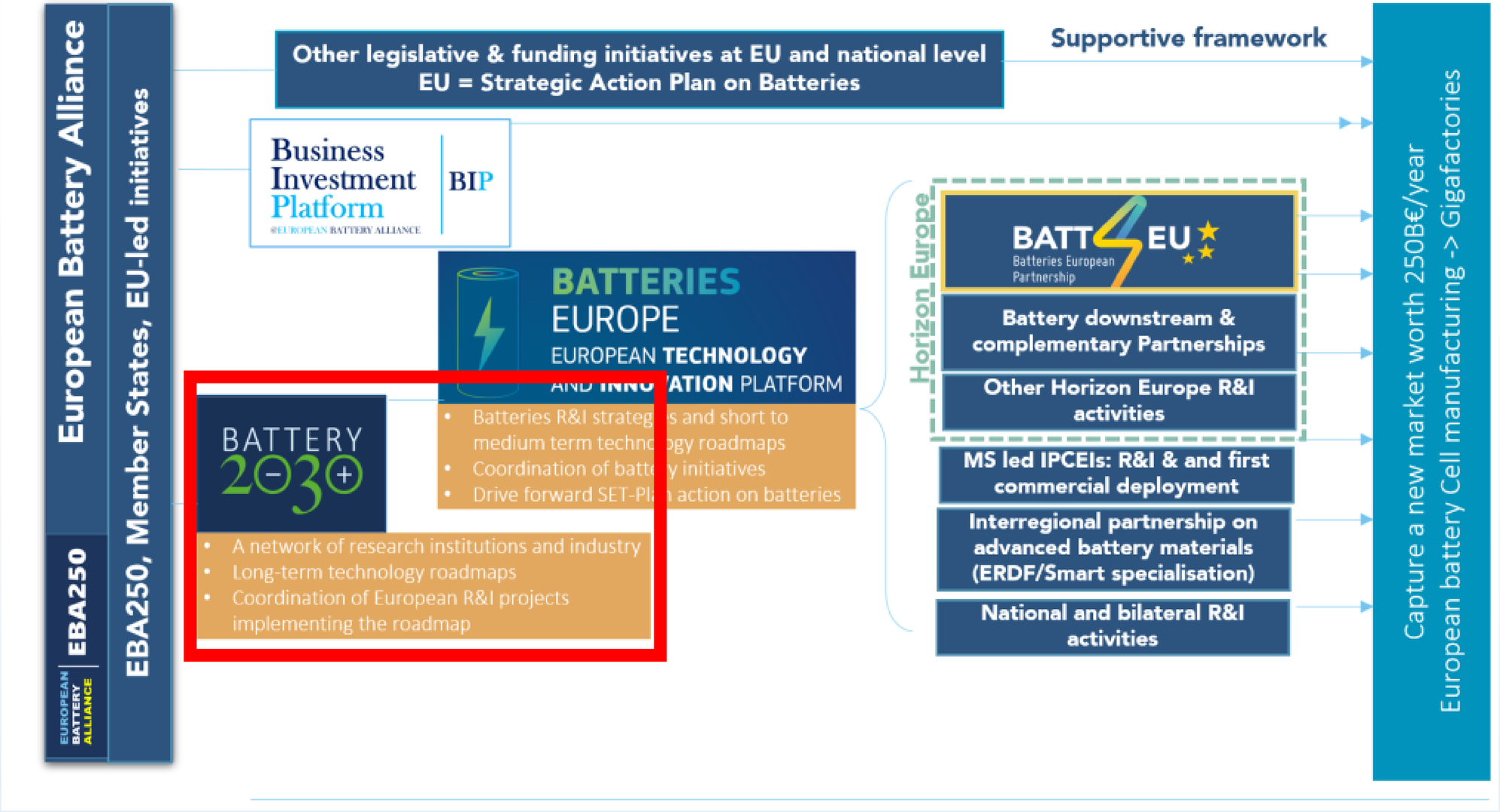
	WG1: New and Emerging Battery Technologies	WG2: Raw Materials and Recycling	WG3: Advanced Materials	WG4: Cell Design and Manufacturing	WG5: Application and Integration: Mobile	WG6: Application and Integration: Stationary
Industry Chair	Daria Hedberg, Geyser Batteries	Philippe Capron, ORANO	Fabrice Stassin, Umicore	Daniela Fontana, Comau S.p.A.; Carlo Novarese, Sunlight Group Energy Storage Systems	Franz Geyer, BMW Group	Christian Noce, Enel X
Research Chair	Kristina Edström, Uppsala University	Marja Vilkman, VTT	Silvia Bodoardo, Politecnico di Torino	Marcus Jahn, AIT	Michele de Gennaro, AIT	Javier Olarte, CIC energiGUNE
Technical Advisor	Ivana Hasa, The University of Warwick	Bart Verrecht, Umicore	Marcel Meeus, EMIRI	Arno Kwade, TU Braunschweig	Thilo Bein, Fraunhofer-Allianz Batterien	Matthias Vetter, Fraunhofer Institute for Solar Energy Systems ISE

Roadmaps
November 2021
Under the Coordination of Batteries Europe

SRIA
January 2023
Under the Coordination of BEPA

Move to future

EU Battery R&I ladscape



BATTERY 2030+

LARGE-SCALE RESEARCH INITIATIVE

BATTERY 2030PLUS CSA
UU, SWEDEN

BIG-MAP INSTABAT sensibat SPARTACUS BAT4EVER HIDDEN

Coordinator:
Kristina Edström, Uppsala University, Sweden
Deputy coordinator:
Simon Perraud, CEA, France

www.battery2030.eu
Twitter: 2030battery

Opincharge Phoenix Salamander Opera UltraBat HealingBat

Battery 2030+ annual conference

BATTERY 2030+

European batteries fit for purpose

BATTERY 2030+ roadmap:

Inventing the Batteries of the Future. Research Needs and Future Actions

Short term: Develop theoretical and experimental platforms and tools

Medium term: Integration of the different parts

Long-term: Materials accelerating platform + smart battery functionalities

Education:
WP3 New Curricula

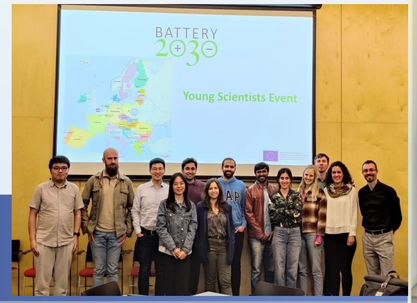
EdU Batt Network

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957213.

Young Scientists engagement

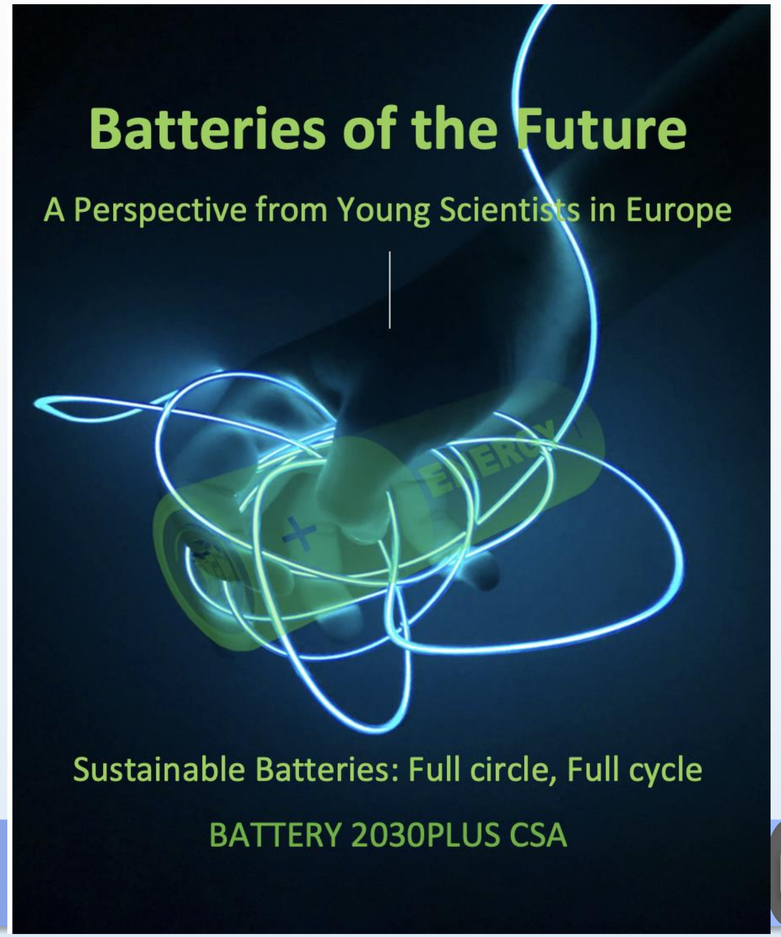
4 Universities involved and around **120 young scientists**

«Efforts made today will be the breakthroughs of the future»



Different expertise:

i.e. battery experts, engineers, chemists, physicians, economists, doctors in medicine, people with all humanistic specialisations, etc.



Inside the battery pack

Battery Pack – Module - Cells

Pack

e.g. pack for pouch cells (Nissan Leaf)

A '**pack**' is formed by connecting multiple 'modules' with sensors and a controller and then housing the unit in a case. Electric vehicles are equipped with batteries in a 'pack' state which are connected to the powertrain.

Module

e.g. module for pouch cells (Nissan Leaf)

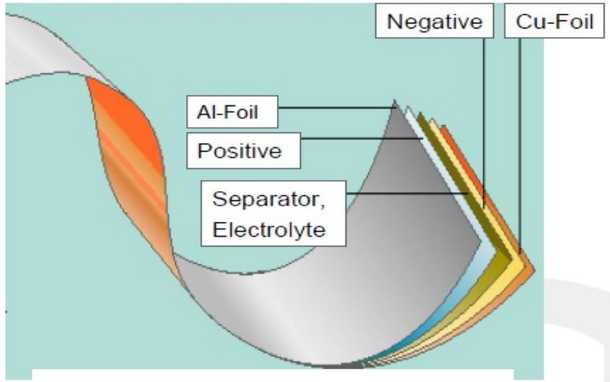
A '**module**' is formed by connecting multiple 'cells', providing them with a mechanical support structure and thermal interface and attaching terminals. Modules are designed according to cell format, target pack voltage and vehicle requirements.

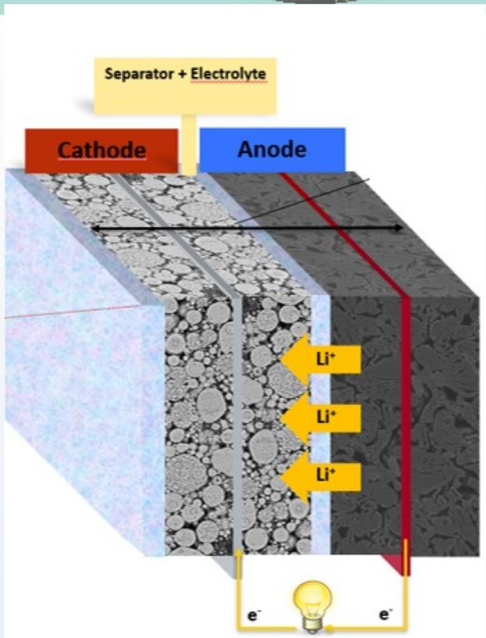
Lithium-ion cell

e.g. pouch or cylindrical cell

As a single unit, a '**cell**' performs the primary functions of a rechargeable 'battery'. Cells come in varied formats:

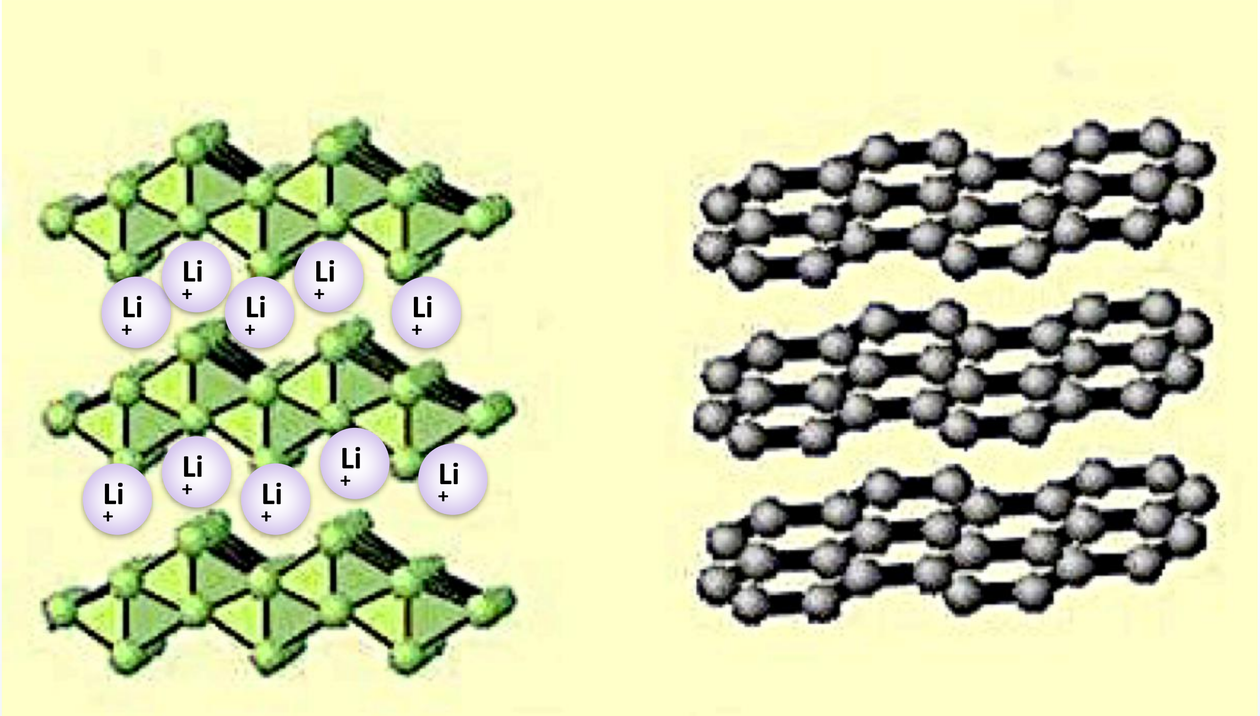
- Cylindrical Cells
- Pouch Cells
- Prismatic Cells





https://warwick.ac.uk/fac/sci/wmg/business/automotive_batteries_101_wmg-apc.pdf

Lithium ion cell reaction



Cathode : $LiMn_2O_4$ spinel
$LiCoO_2$ cobaltite

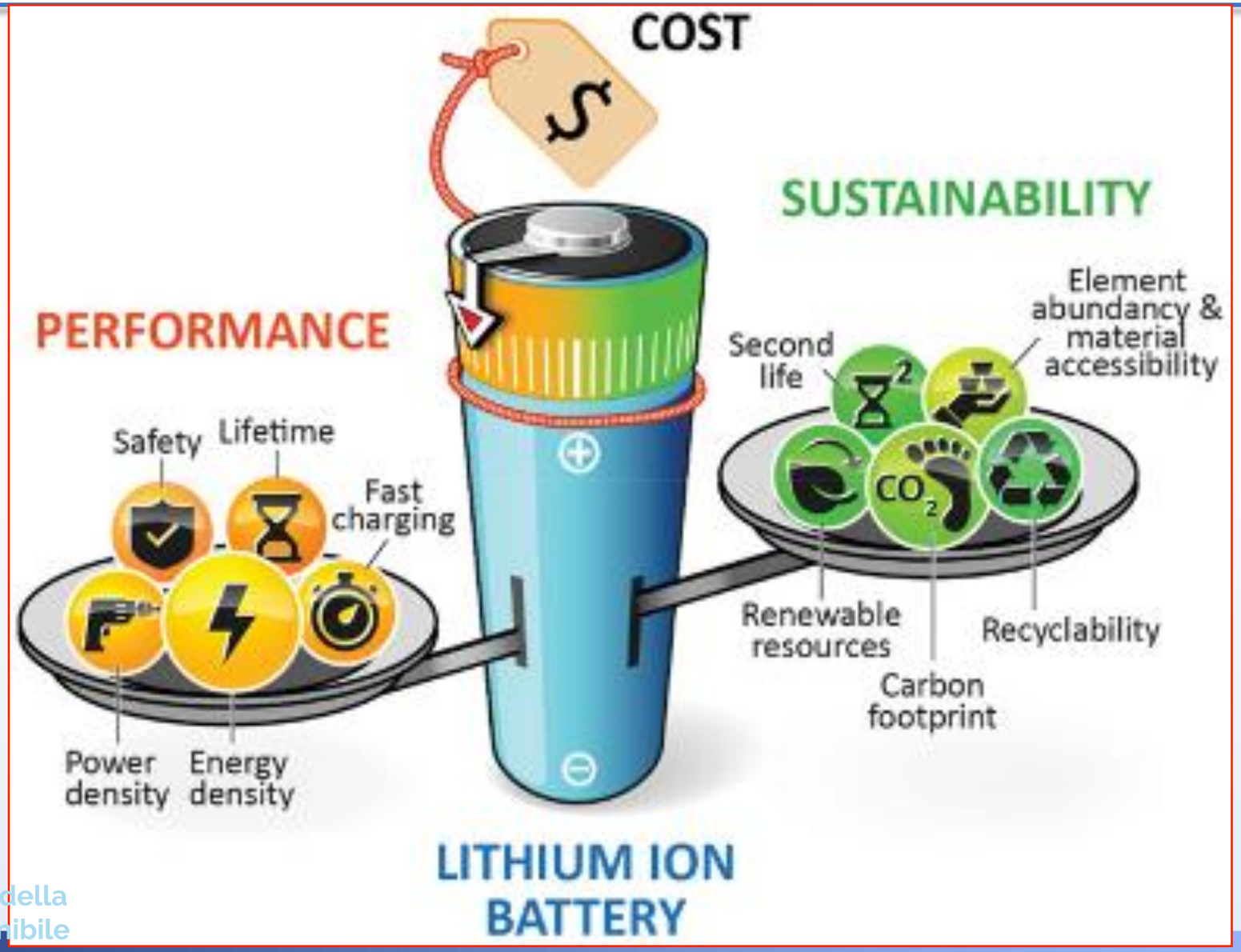
Anode : metallic Li foil
graphite
intercalation compounds

$$LiM^{+n}O_x \xrightarrow{\text{charge}} M^{+(n+1)}O_x + Li^+ + e$$

Metal oxidation

How should be the Battery for future

MATERIALS



Small Methods, Volume: 4, Issue: 7, First published: 06 April 2020, DOI: (10.1002/smtd.202000039)

Chemical cell composition tailored on the applications

Lithium – Cobalt –Oxide
($LiCoO_2$)

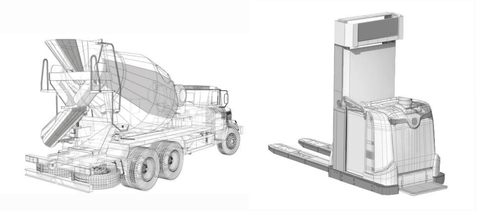
- Rated voltage: 3.6 V
- Gravimetric density: 200 Wh/Kg
- Energy density: 400 Wh/l
- Complete life cycles: 500 – 1,000
- Discharge rate: 1C

Advantage: high specific energy, fast charge.

Lithium – Manganese – Oxide
($LiMn_2O_4$)

- Rated voltage: 3.7 V
- Specific energy: 150 Wh/Kg
- Energy density: 350 Wh/l
- Complete life cycles: 300 – 700
- Discharge rate: 1C, 10 C

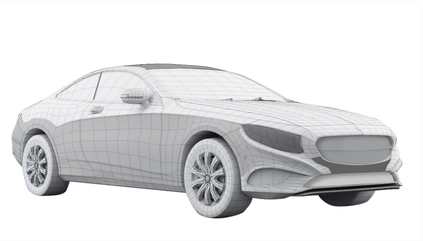
Advantage: high thermal stability



Lithium – Iron – Phosphate
(LiFePO4)

- Rated voltage: 3.2 V
- Gravimetric density: 170 Wh/Kg
- Energy density: 350 Wh/l
- Complete life cycles: > 4000
- Discharge rate: 1C/3C

Advantage: high thermal stability, long cycling, fast charge, no cobalt



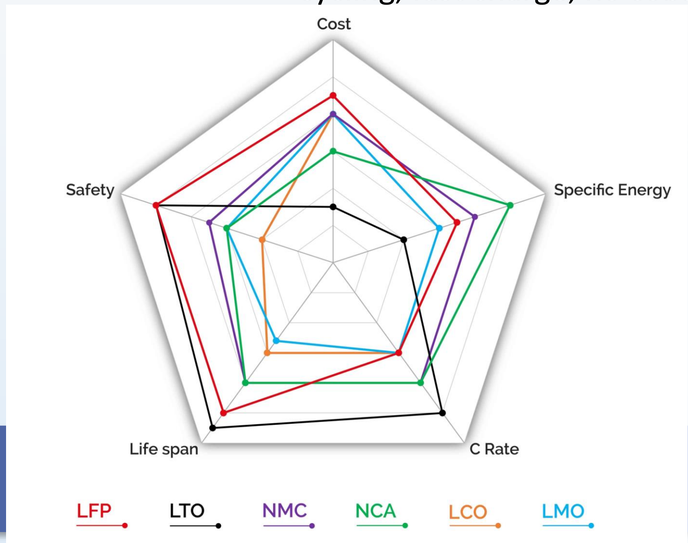
Nickel – Manganese – Cobalt
(LiNixMnyCozO2)

- Voltage rating 3.6 V
- Gravimetric density: 220 Wh/Kg
- Energy density: 500 Wh/l
- Complete life cycles: 2000
- Discharge rate: 2C/3C

Advantage: very high specific energy

Lithium – Iron – Phosphate
(LiFePO4)

Next future **Na-ion**

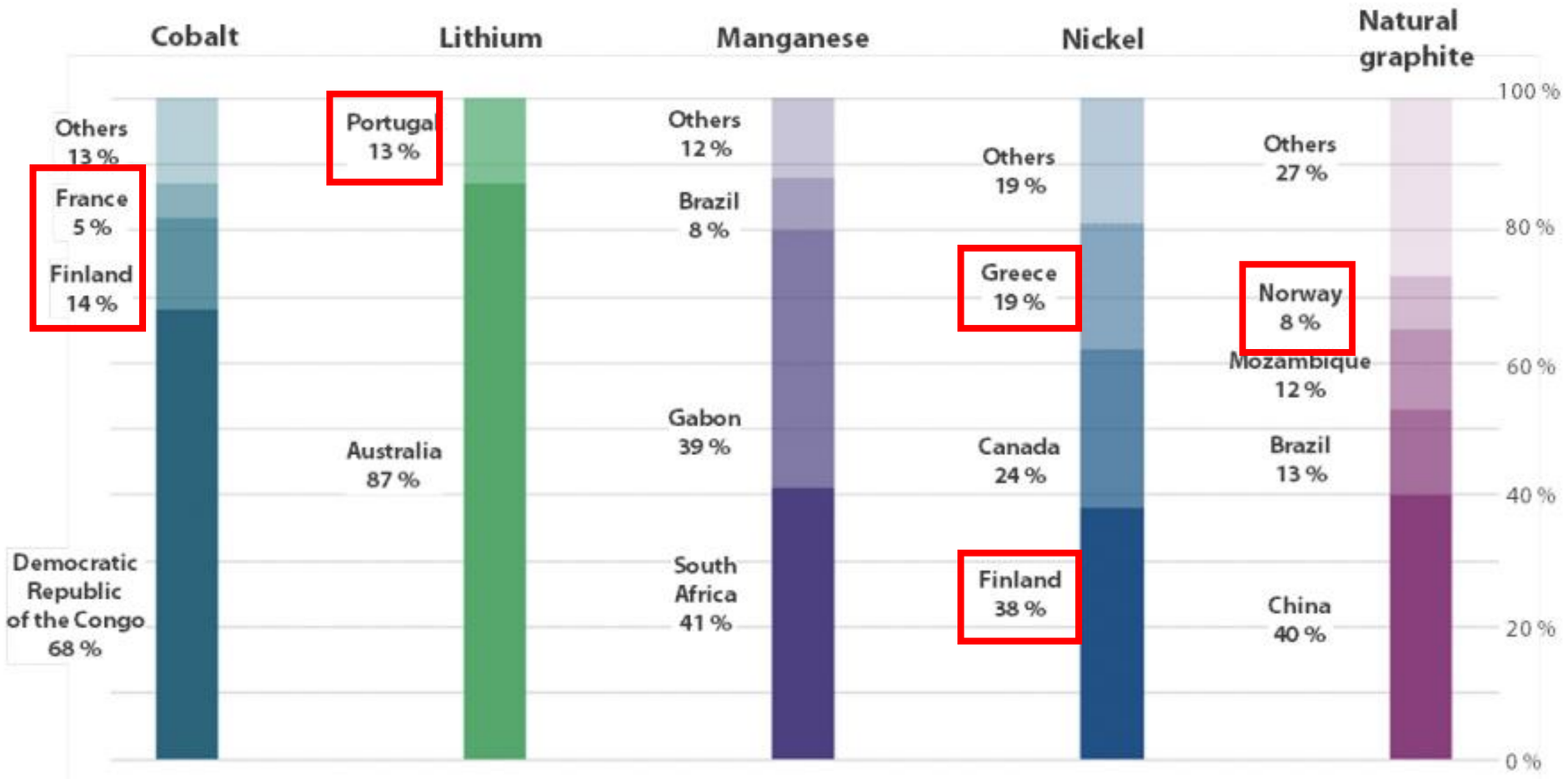


Lithium – Iron – Phosphate
(LiFePO4)

https://www.flashbattery.tech/en/types-of-lithium-batteries-which-chemistry-use/

Raw materials

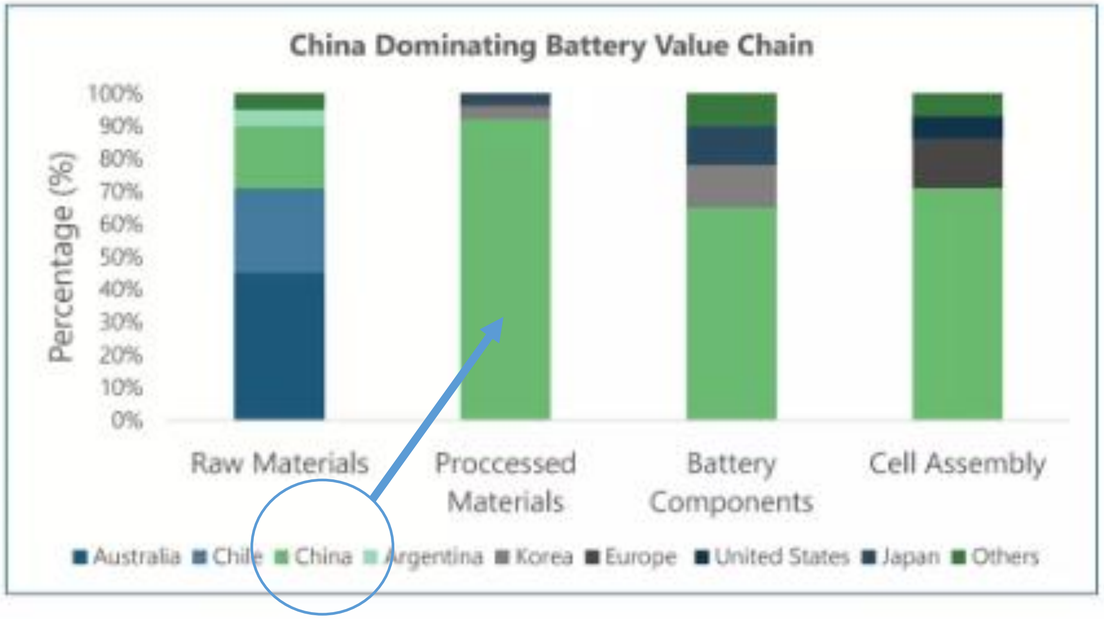
EU supply sources of raw materials for batteries



Source: Data for raw manganese, nickel and natural graphite sourced from the 2023 Study on the Critical Raw Materials for the EU (referenced to the 2016-2020 period). Data for raw cobalt and lithium is not available in the 2023 study and was instead retrieved from the Raw Materials Information System (referenced to the 2012-2016 period and sourced from the 2020 Critical Raw Materials assessment).

Raw Material Supply Chain Disruptions

Challenges in Raw Material Supply Chain Hindering the Outlook for Smooth Energy Transition



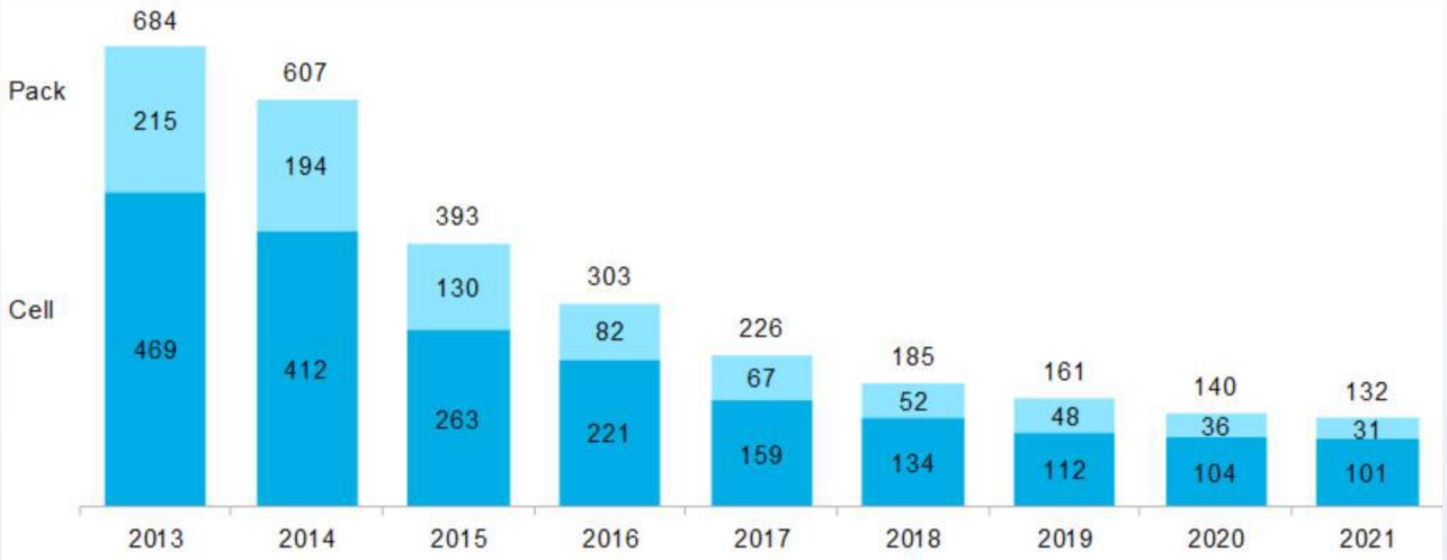
Causes of Supply Chain Disruptions

- Rate of EV production vs rate of mining of raw materials.
- Biggest Market of EV i.e., Europe dependent on other regions for raw material sourcing/Raw material sourcing by European EV manufacturers
- Ukraine-Russia crisis
- Covid-19 Pandemic Effect

Battery price

In 2021, average global battery prices fell by 6% to around **116 EUR/kWh** (in EU market - around 150 EUR/kWh) continuing a long-term trend.
The system cost of grid scale Li-ion applications was around EUR 350/kWh in 2021 and, for home storage systems, roughly twice that.

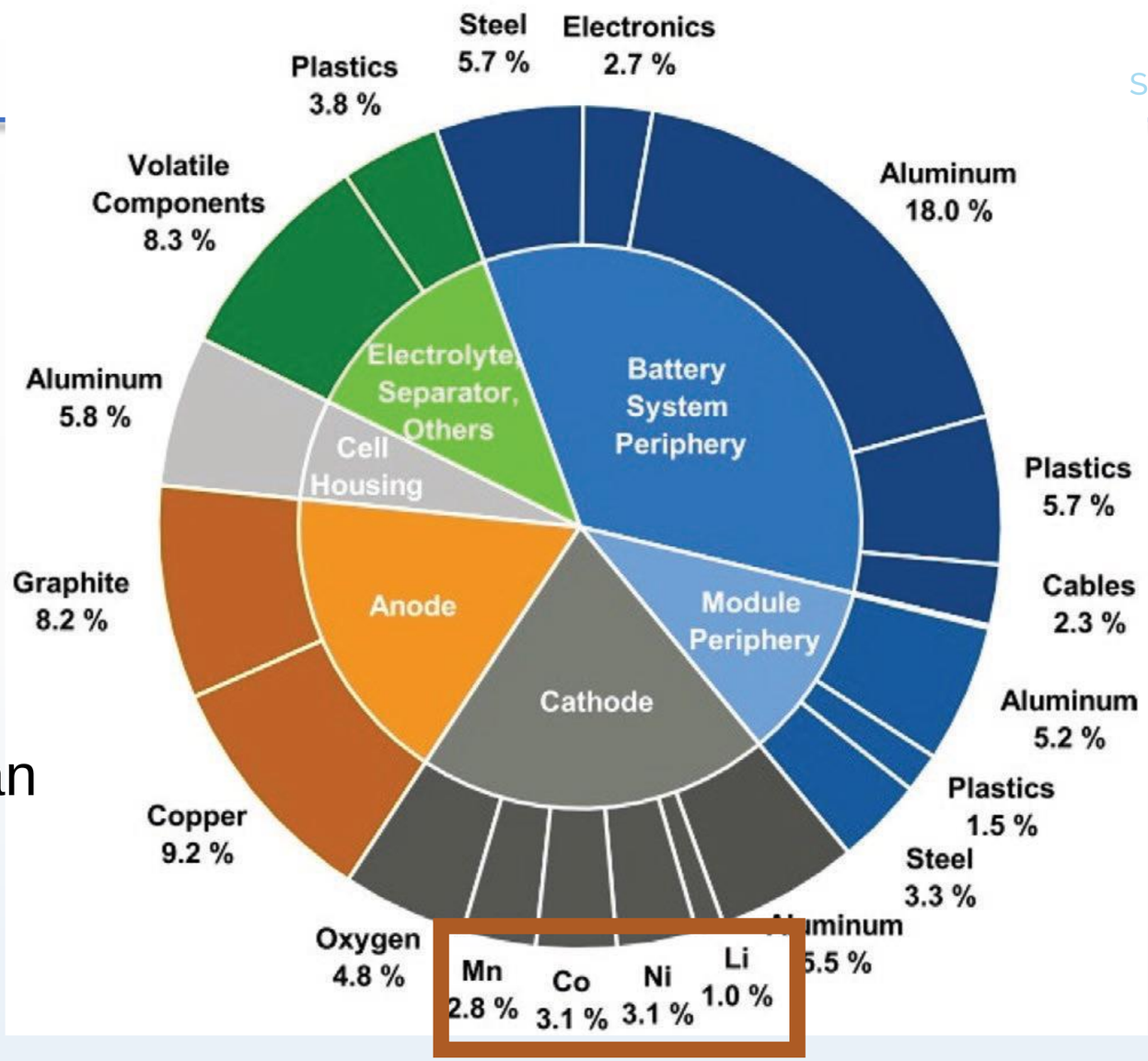
CATL announcement **56** €/kWh/cell



Volume weighted average pack and cell price split (real 2021 USD/kWh).

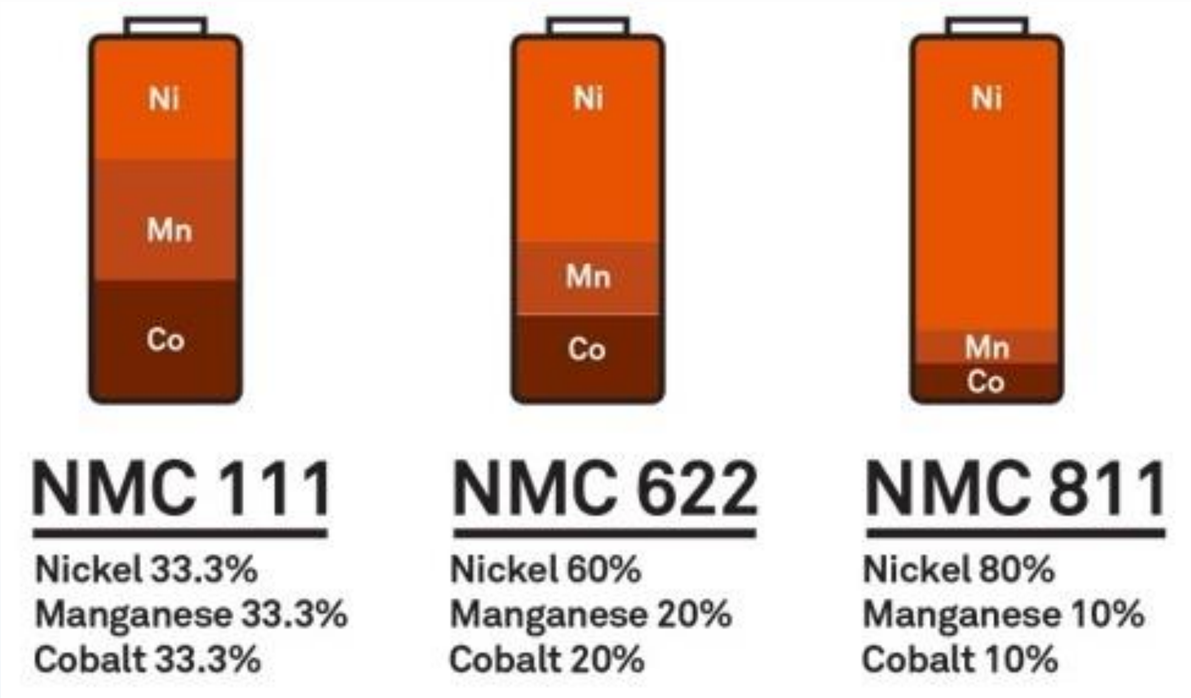
Source: BloombergNEF, Nov 2021

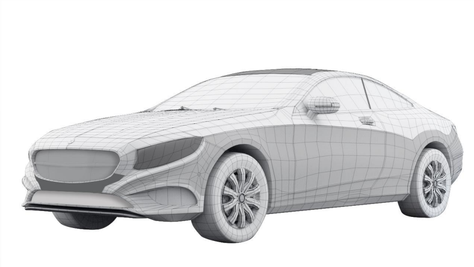
Mass fractions of components in an electric vehicle battery system.



Towards more sustainable cells.. Co reduction

Nickel – Manganese – Cobalt
(LiNixMnyCozO2)



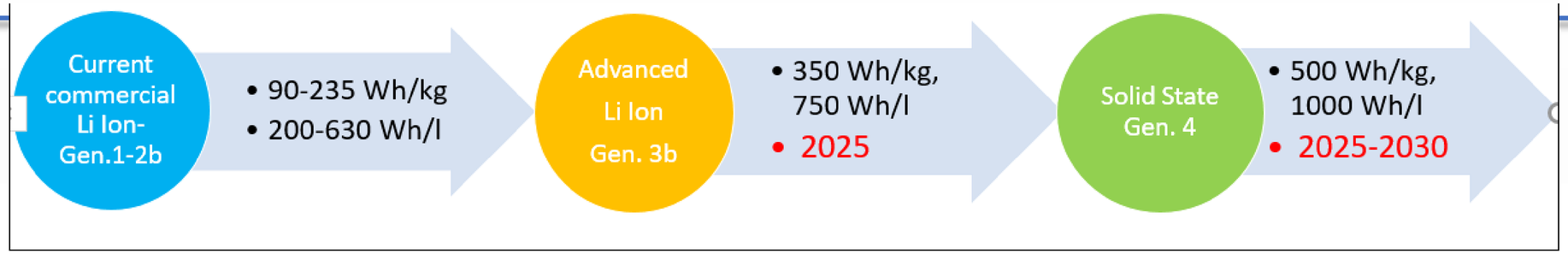


Lithium – Iron – Phosphate (LiFePO4)

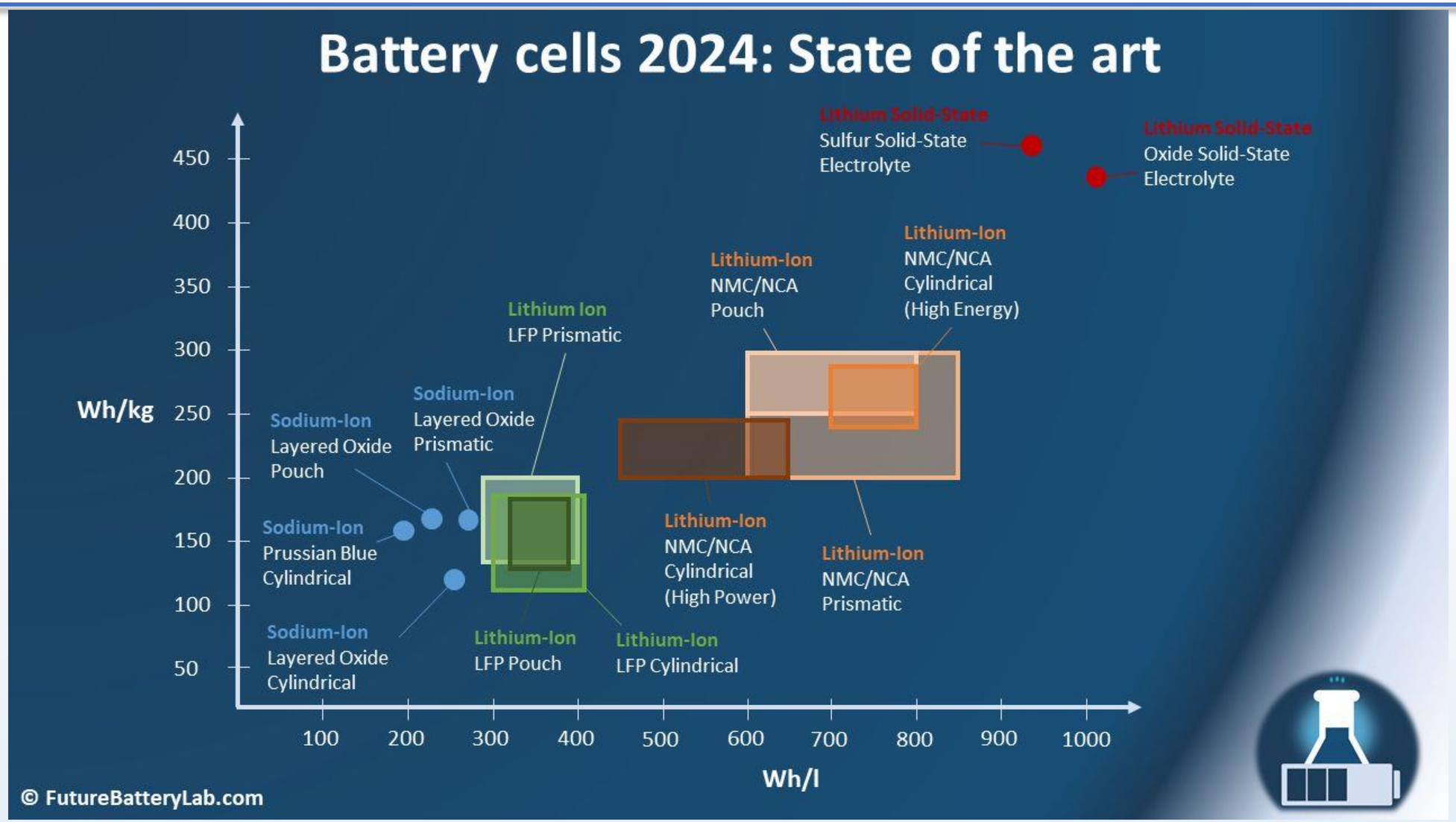
https://www.flashbattery.tech/en/types-of-lithium-batteries-which-chemistry-use/

Work on materials?

Cell Generations



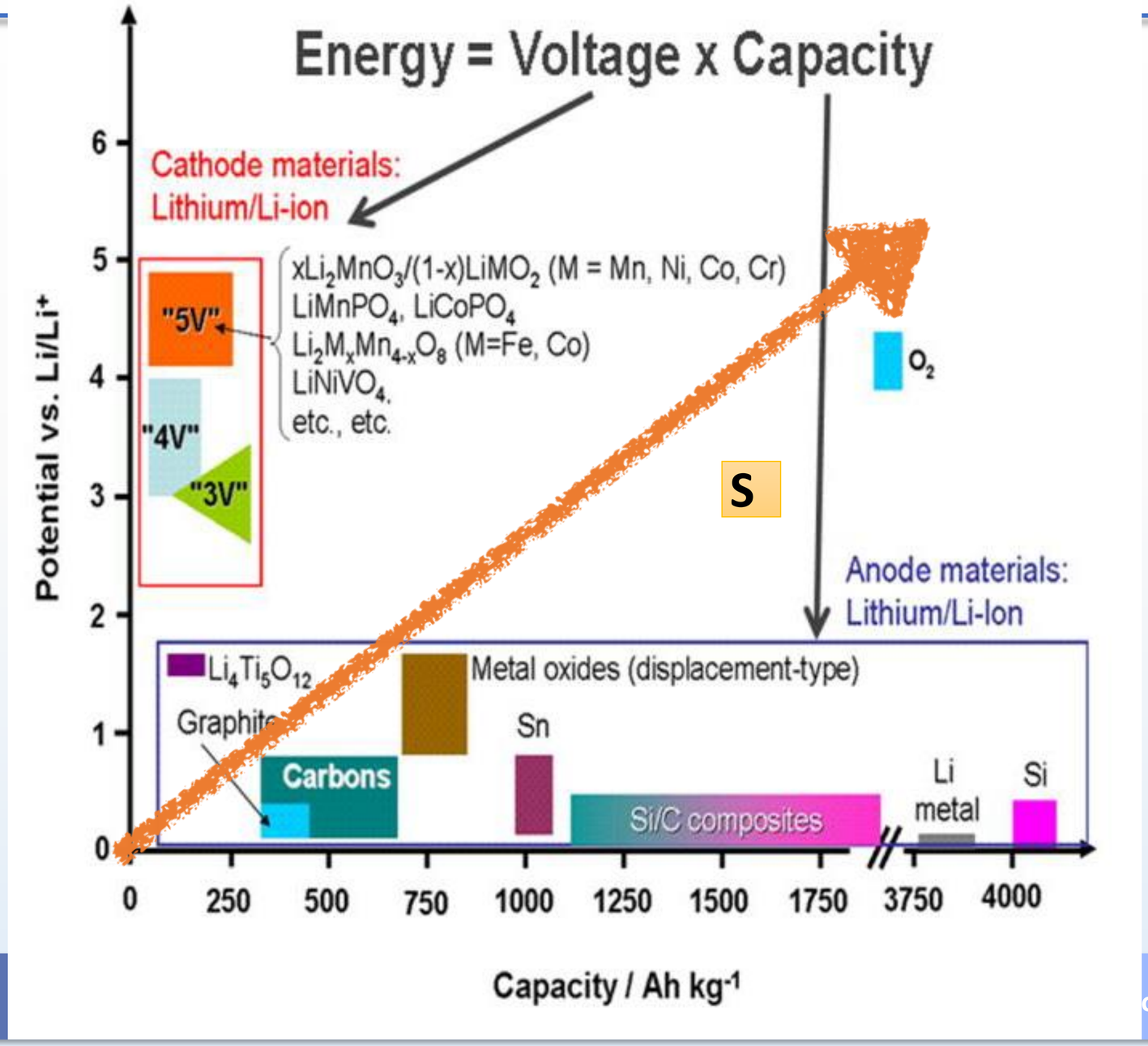
Generation	1	2		3		4			5
		2a	2b	3a	3b	4a	4b	4c	
Type	Current	Current	State-of-the-Art	Advanced Li-ion HC	Advanced Li-ion HV	Solid State			Beyond Li-ion
Expected Commercialisation	Commercialised	Commercialised		2020	2025	>2025			
Cathode	• NMC/NCA • LFP • LMO	• NMC111	• NMC424 • NMC523	• NMC622 • NMC811 • NMC910	• HE NMC • Li-rich NMC • HVS	• NMC	• NMC	• HE NMC	• O_2 • S
Anode	• Modified Graphite • $Li_4Ti_5O_{12}$	Modified Graphite	Modified Graphite	Carbon (Graphite)+Si (5-10%)	Silicon/Carbon (C/Si)	Silicon/Carbon (C/Si)	Li metal		Li metal
Electrolyte	• Organic • $LiPF_6$ salts				• Organic+ Additives	• Solid electrolyte – Polymer (+Additives) – Inorganic – Hybrid			Post Li-ion: K-ion, Mg-ion, Al-ion, Ca-ion …
Separator	Porous Polymer Membranes								

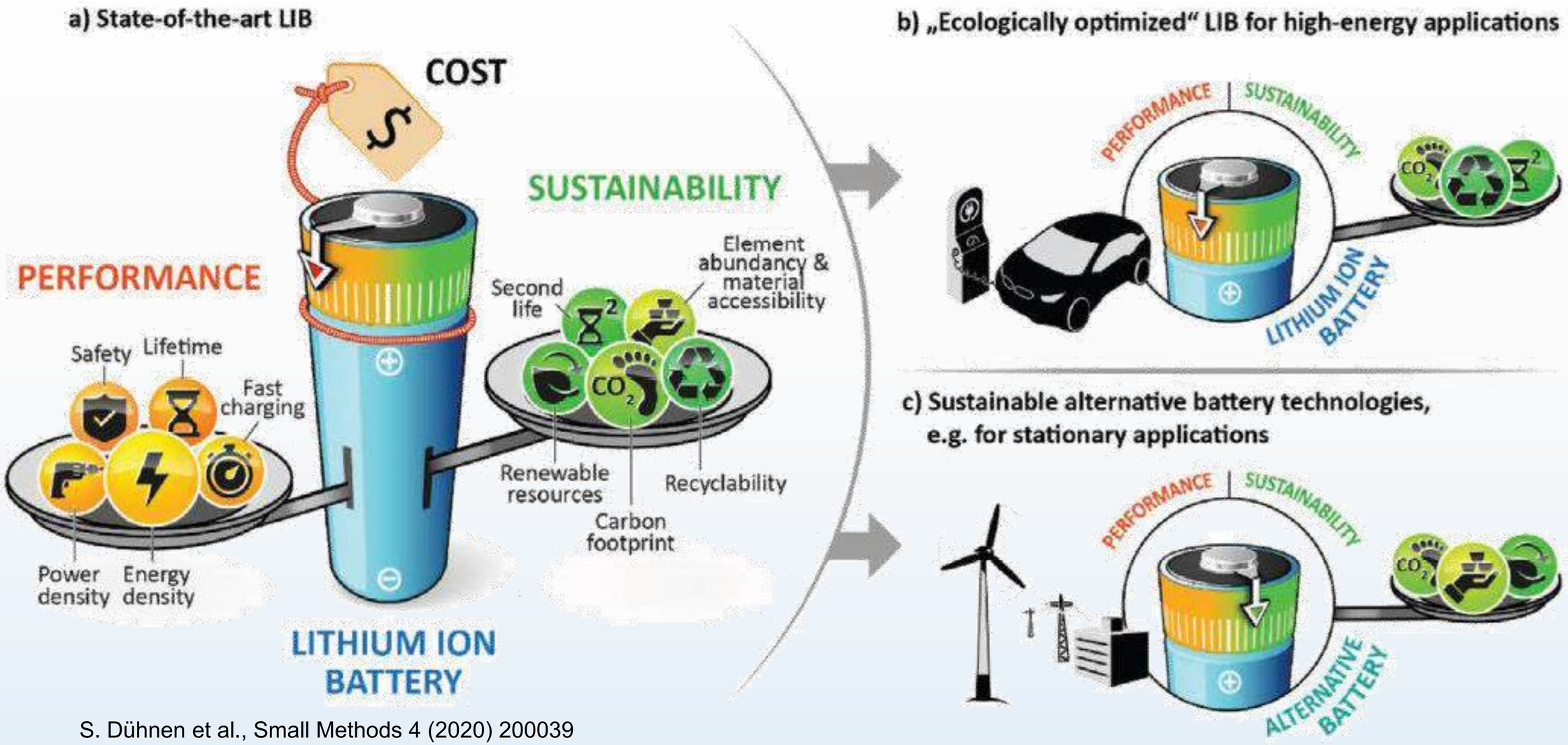

Battery cells 2024: State of the art
Lithium Solid-State
Sulfur Solid-State Electrolyte
Lithium Solid-State
Oxide Solid-State Electrolyte
Lithium-Ion
NMC/NCA
Cylindrical
(High Energy)
Lithium-Ion
NMC/NCA
Pouch
Lithium Ion
LFP Prismatic
Sodium-Ion
Layered Oxide
Prismatic
Sodium-Ion
Layered Oxide
Pouch
Sodium-Ion
Prussian Blue
Cylindrical
Sodium-Ion
Layered Oxide
Cylindrical
Lithium-Ion
NMC/NCA
Cylindrical
(High Power)
Lithium-Ion
NMC/NCA
Prismatic
Lithium-Ion
LFP Pouch
Lithium-Ion
LFP Cylindrical
Wh/kg
450
400
350
300
250
200
150
100
50
100
200
300
400
500
600
700
800
900
1000
Wh/l
© FutureBatteryLab.com

Key parameters

key parameters:

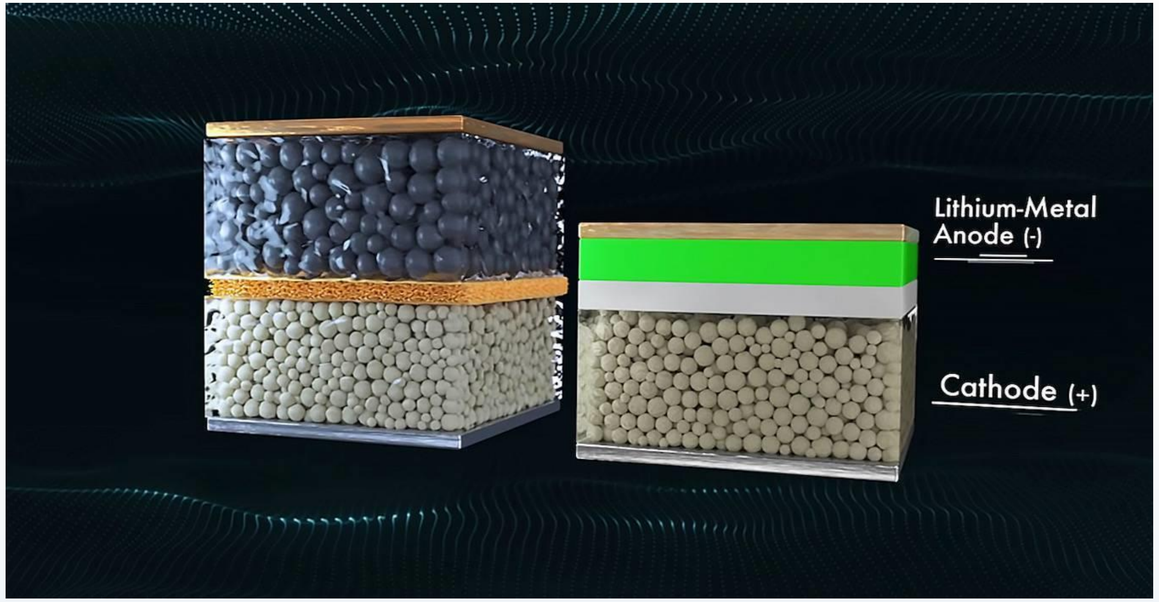
- **energy density**
- **power safety**
- charging rate
- cost
- temperature and chemical stability
- manufacturability
- sustainability
- recyclability

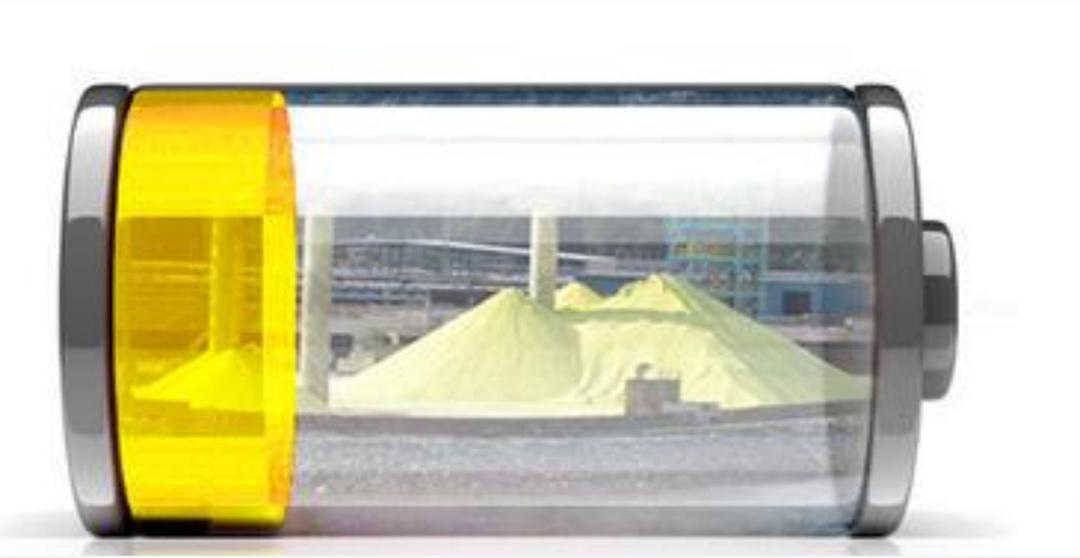




S. Dühnen et al., Small Methods 4 (2020) 200039

Increase the energy density:
Solid State cells and conversion systems





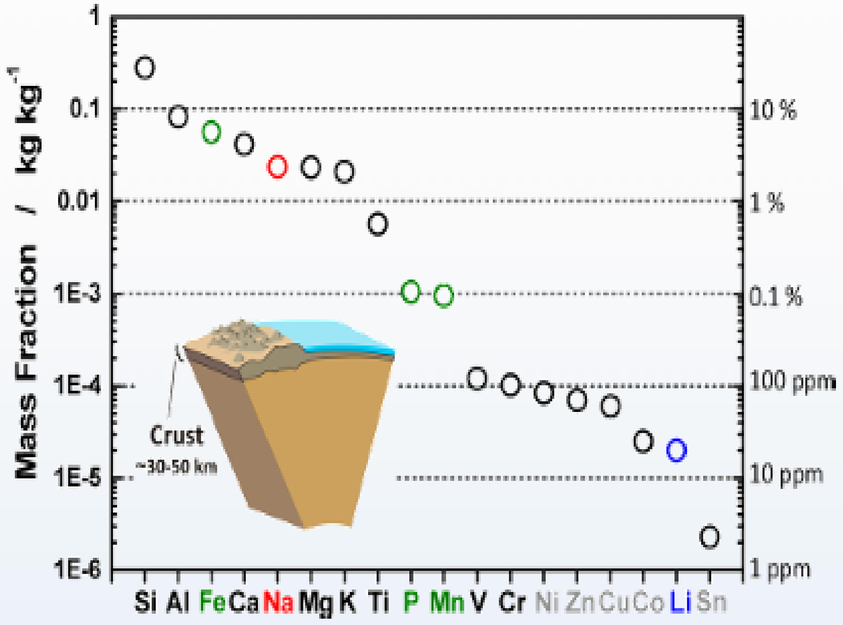
Higher energy density
Smaller volume

Theoretical energy density
5 times higher than Li-ion

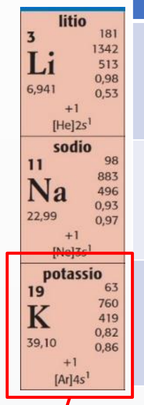
Na-ion

A Sodium-Ion (Na-Ion) Battery System is an energy storage system based on electrochemical charge/discharge reactions that occur between a positive electrode (cathode) composed of sodium-containing layered materials, and a negative electrode (anode) that is typically made of hard carbons or intercalation compounds. The electrodes are separated by some porous material which allow ionic flow between them and are immersed in an electrolyte that can be made up of either aqueous solution (such as Na2SO4 solution) or non-aqueous solution (e.g. salts in propylene carbonate).

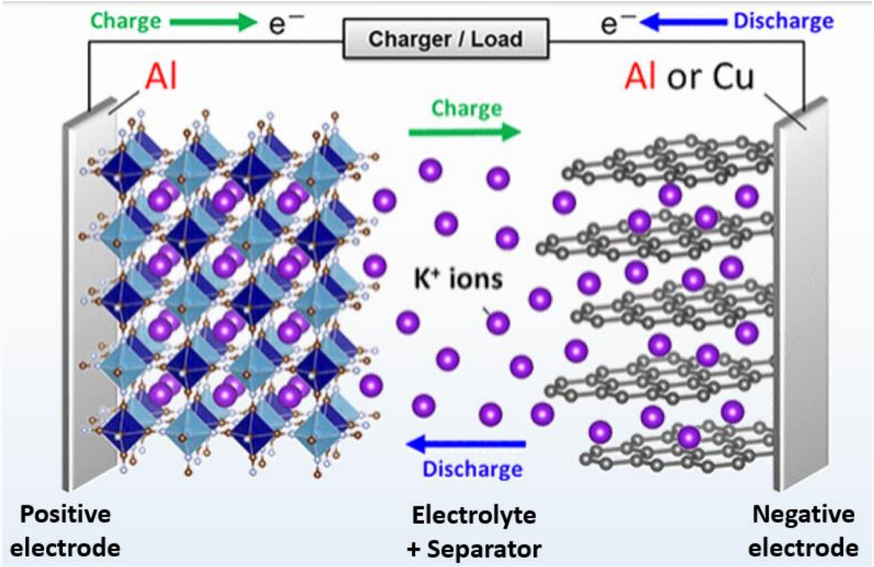
https://ease-storage.eu/wp-content/uploads/2016/07/EASE_TD_Electrochemical_Nalon.pdf



Potassium as an emerging post-Li choice



Abundance in Earth crust [%]	Cost [$ ton^{-1}]	Potential [V *vs* SHE]	Ionic radius [Å]	Stoke's radius in PC [Å]
0.0017	100 000	–3.04	0.76	4.8
2.3	3 000	–2.71	1.02	4.6
1.5	10 000	–2.93	1.38	3.6



- **Available** worldwide
- Forms **graphite** intercalation compounds
- Does not alloy with **Al**.
- Less ordered solvation structure → the lowest desolvation energy in EC → faster **K⁺ diffusion**.

Min et al., *Energy Environ. Sci.* **14** (2021) 2186

1.8 *M*-EUR project just granted

GREEN 2 MOVE

Green potassium batteries manufacturing processes: towards sustainable gigafactories (FISA)

ZEBRA batteries (batterie al sale….)

High temperature battery → Stationary applications

C.-H. Dustmann / Journal of Power Sources 127 (2004) 85–92

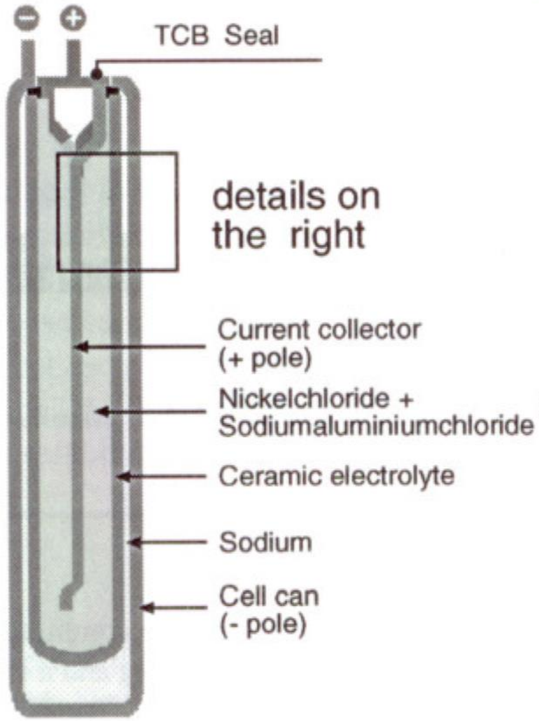
OCV 2.58 at 300°C,

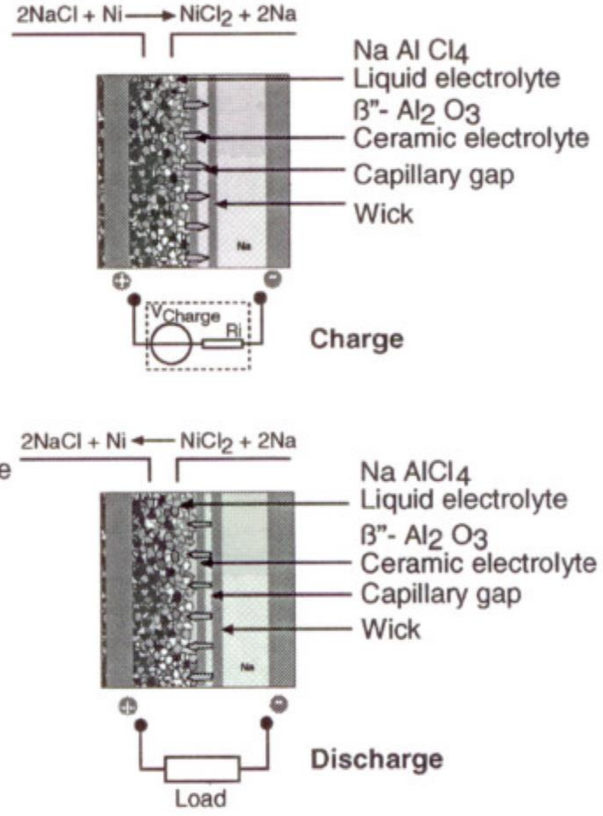
Operating range

270°C to 350°C,

Typical capacity 32Ah

100% Ah-efficiency

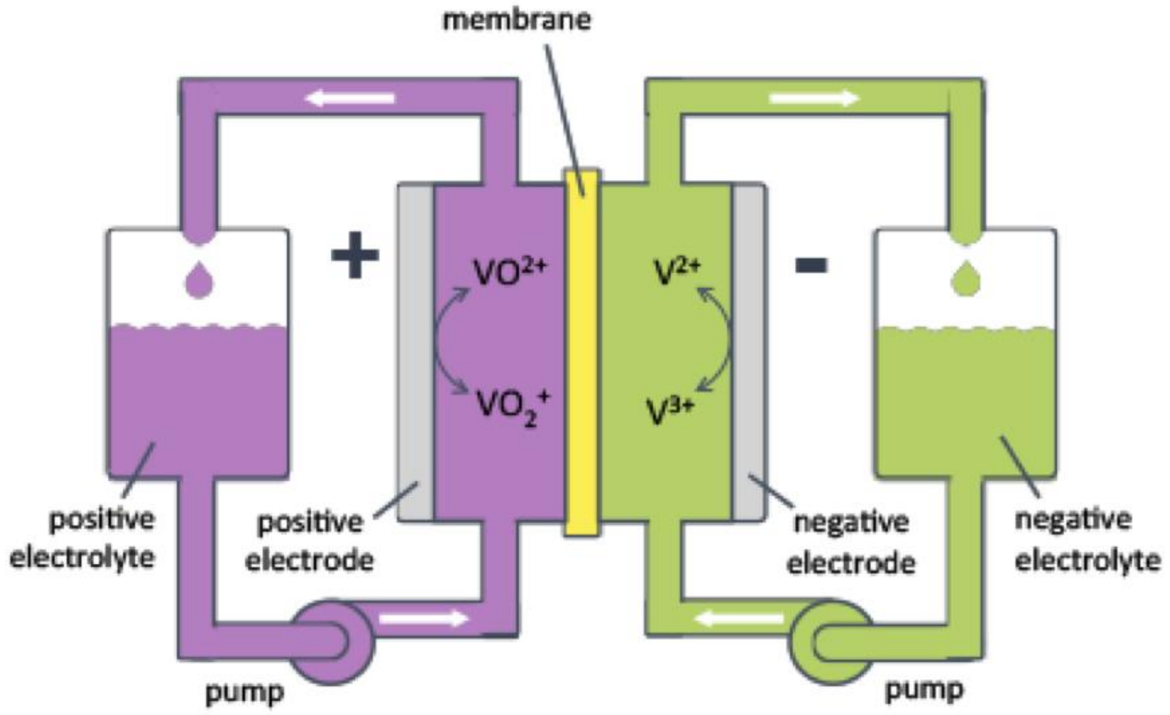




$$2\,NaCl + Ni \underset{discharge}{\overset{charge}{\rightleftharpoons}} NiCl_2 + 2\,Na$$

Fig. 1. Basic cell reactions.

Vanadium Flow Batteries

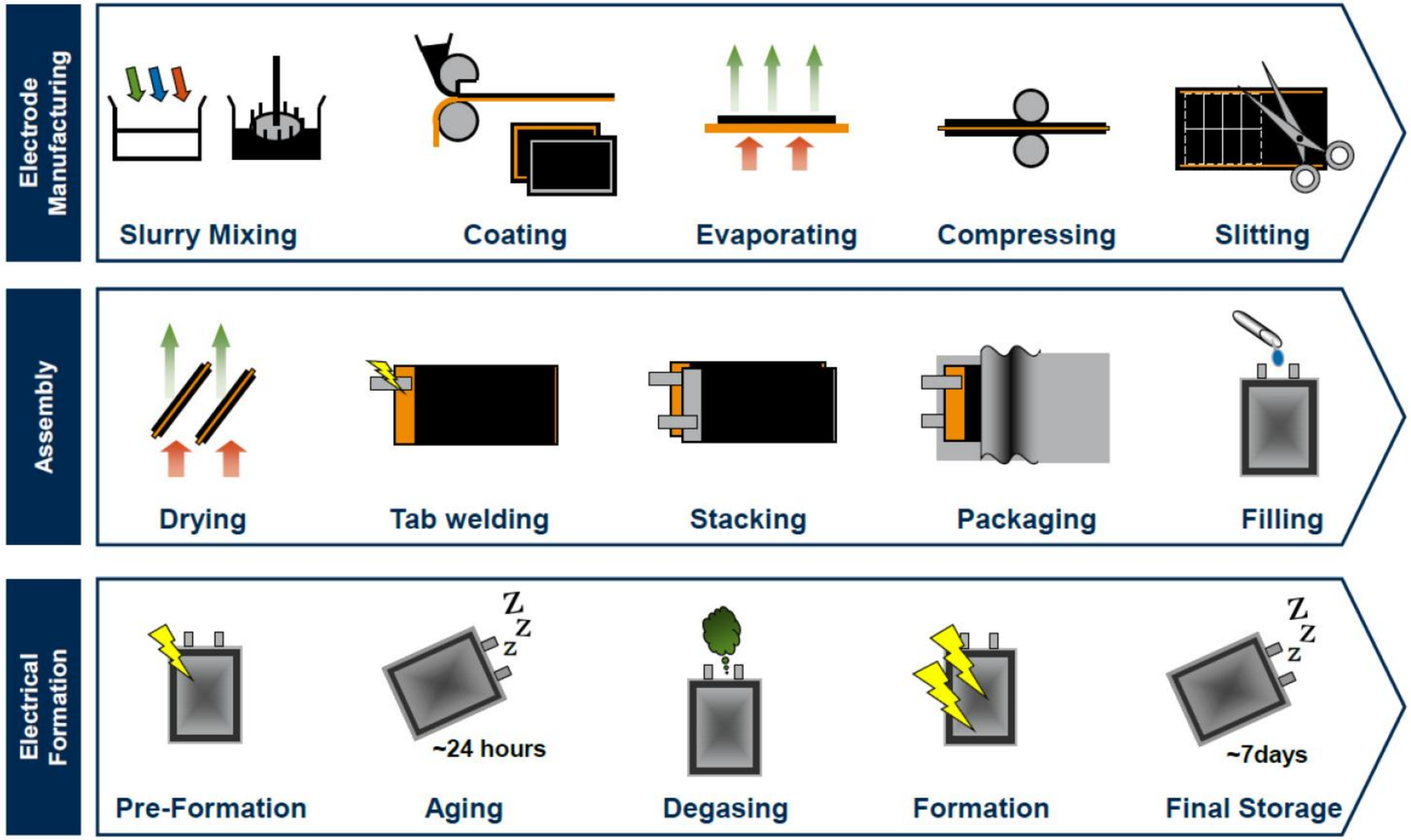


Source: www.echemion.com

Time to invest in Cell Manufacturing and EDUCATION

GIGAGREEN Design to Manufacture Giga-Factory concept

Production



Fuente: M+W Group 2013

Cell Manufacturing

GIGAGREEN Design to Manufacture Giga-Factory concept

SAFER
- NMP-free
- SOPs for safety handling and automation

CHEAPER
- Reduced energy and material consumption, economy of scale
- Cell manufacturing cost reduced by 20%

GREENER
- Reduced energy and material consumption
- Energy consumption of cell manufacturing reduced by 25%

FLEXIBLE
- Digitalisation processes allowing to quicker specification change
- Affordable scalable process

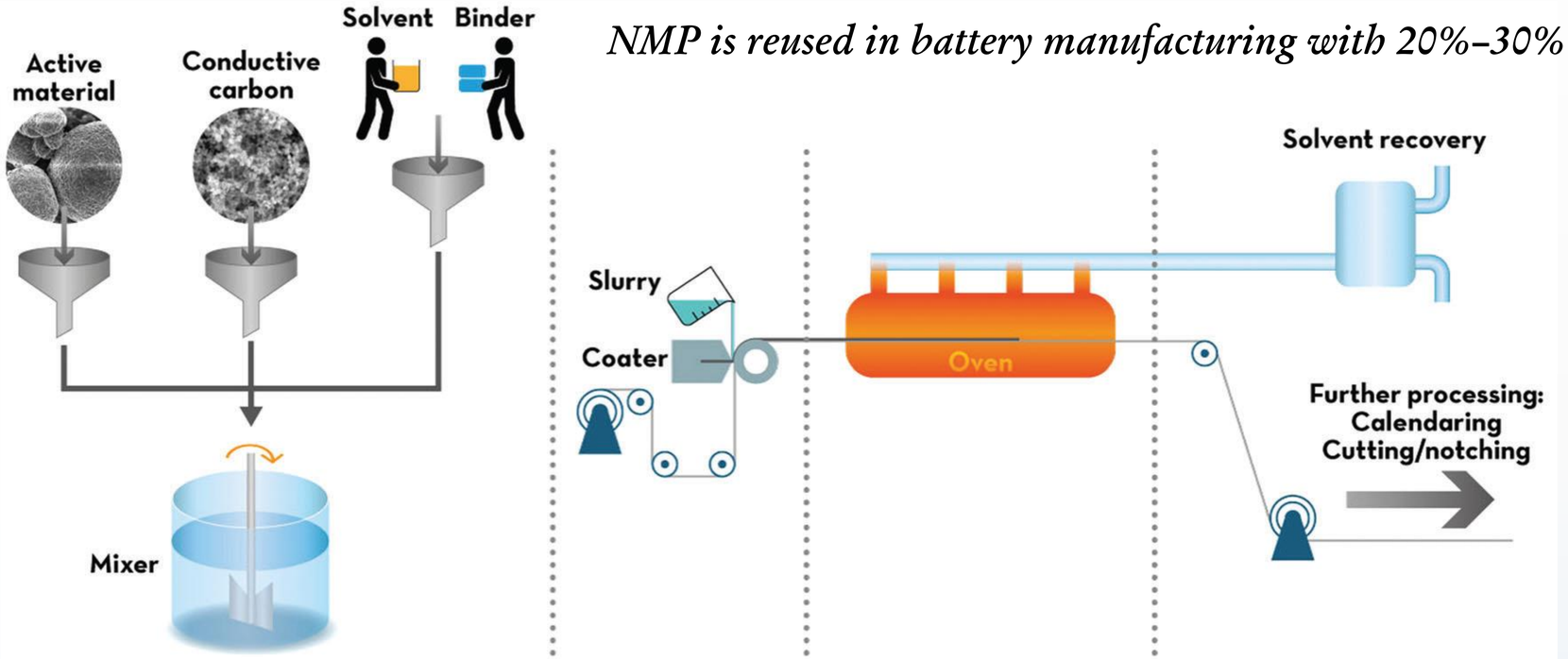
BETTER
- High performance LNMO/SiC
- Data-driven process and product quality control

Overarching approach

- Industry actors from all value chain
- Pathway 1 – wet (NMP-free) processing
- Open Access ensured
- Pathway 2 – dry processing
- LNMO/Si-C chemistry
- Time to impact: immediate

Water-based slurries

Solvent recovery process is necessary for the cathode production during drying and the recovered NMP is reused in battery manufacturing with 20%–30% loss



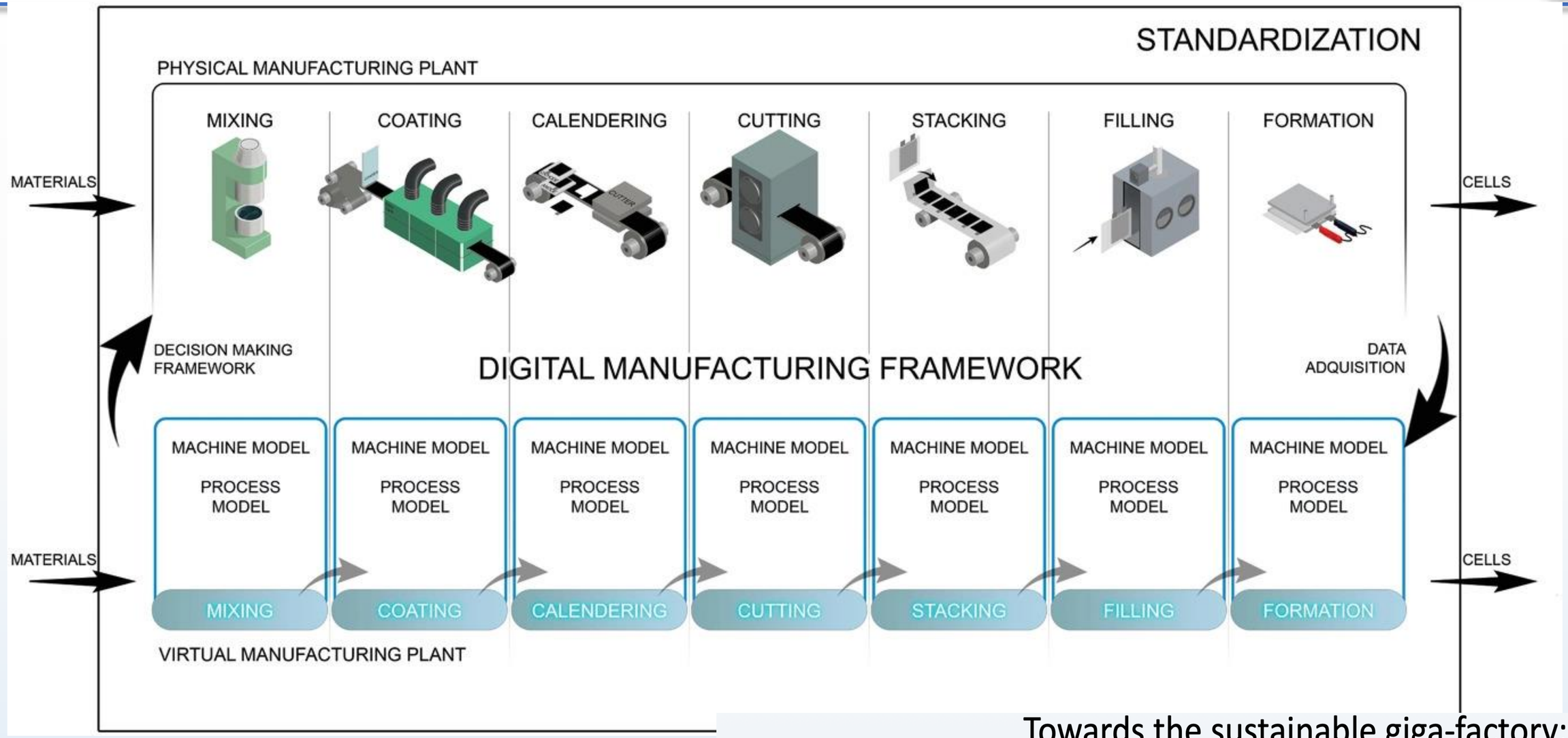
Solvent	Mixing	Coating	Drying	Recovery
NMP	Hazardous handling requires ventilation system and PSE	Controlled enviroment needed	Solvent vapours need to be collected to avoiding dispersion in the atmosphere	Recovery system required to recycle the expensive solvent
Water	PSE only required for handling of powders	Can be performed in air	No recovery necessary	Not needed

The changeover from an NMP-based to an aqueous electrode production process could not only reduce the energy consumption tremendously due to a simplified process without the otherwise mandatory solvent recovery procedure for NMP.

The switch to an aqueous processing route could also lead to cost reduction of over 90%.

Ecological and cost optimization of the electrode coating process is directly connected with the drying step.

Cell Production: Digital twins

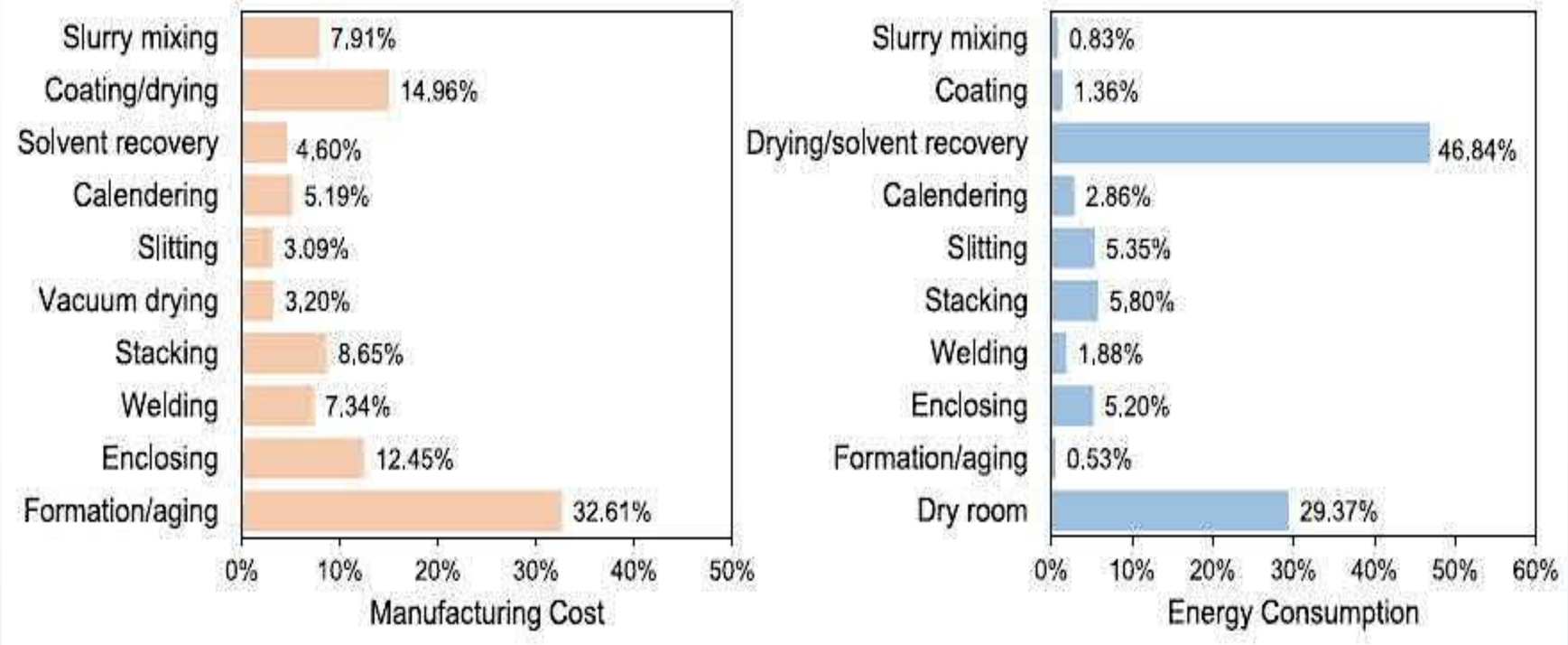


https://onlinelibrary.wiley.com/doi/10.1002/aenm.202102696

GIGAGREEN

Towards the sustainable giga-factory: developing green cell manufacturing processes (HORIZON-CL5-2021-D2-01-04)

Cost and Energy consumption breakdown for Li-ion cell manufacturing



The estimation is based on a 67 Ah NMC622/graphite cell

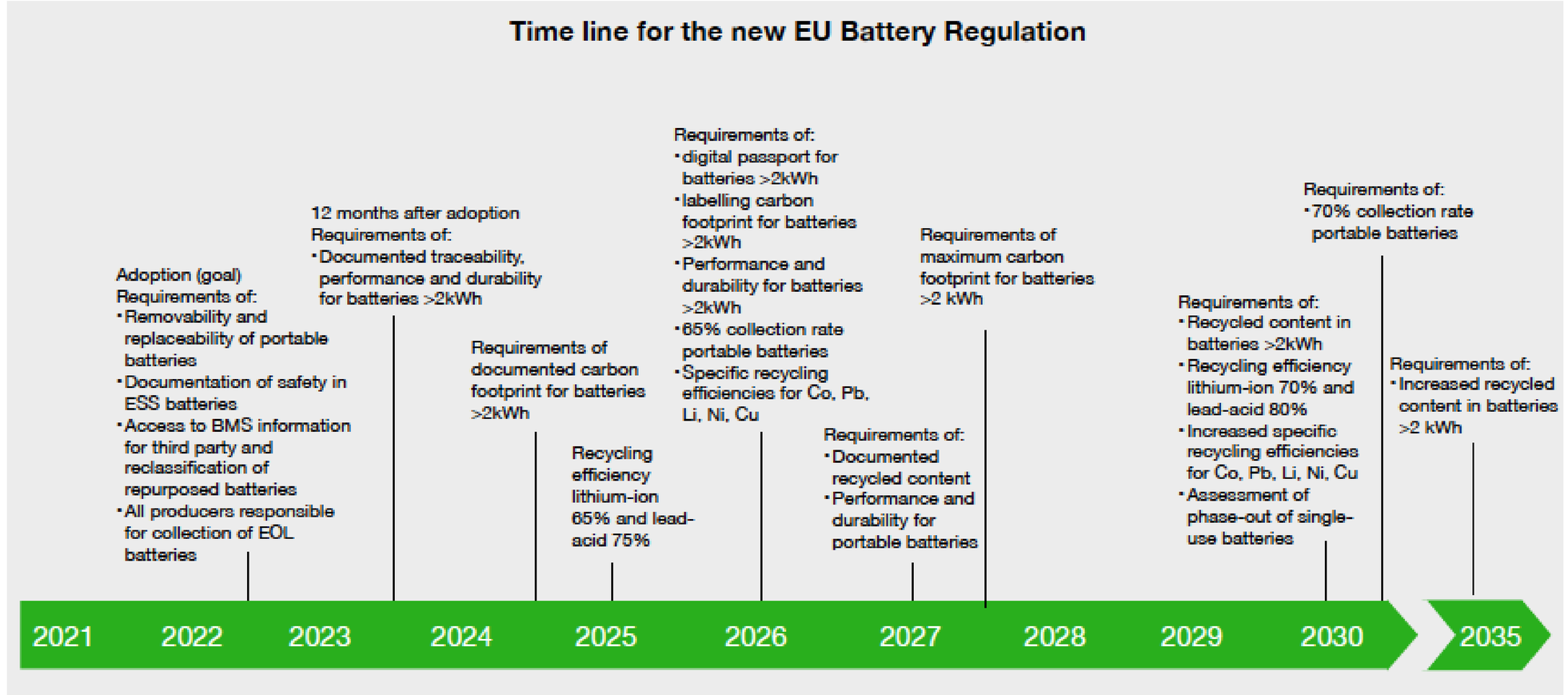
The electrode coating, drying, cel formation and aging contribute to 48% of the entire manufacturing cost !

y. Liu et al., iScience 24, 102332, April 23, 2021

RE DUCE
USE
CYCLE

Collecting exhausted batteries is mandatory

new EU regulation on Recycling ready!



Increase of percentage of recycled materials

https://eur-lex.europa.eu/legal-content/IT/TXT/HTML/?uri=CELEX:52020PC0798&from=EN

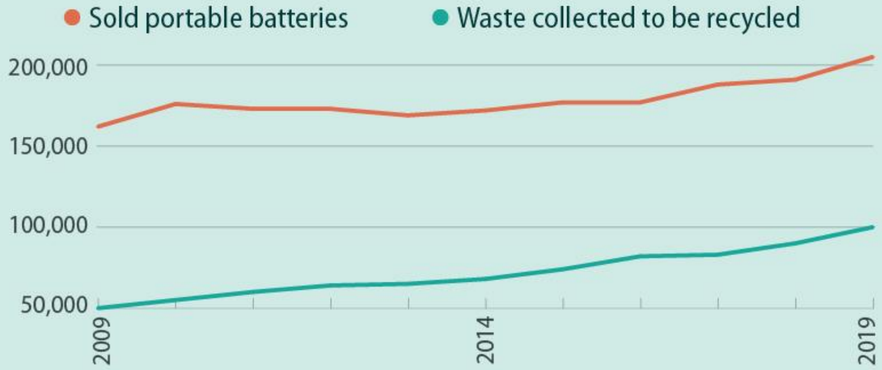
Battery Identity Global Passport

. Bai, N. Muralidharan, Y.-K. Sun, S. Passerini, M. S. Whittingham, I. Belharouak, Mater. Today 41 (2020) 304
ew EU regulatory framework for batteries Setting sustainability requirements. PE 689.337 – March 2022
roposal for a Regulation of the European Parliament and the Council concerning batteries and waste batteries, repealing Directive 2006/66/EC and amending Regulation (EU) No 2019/1020

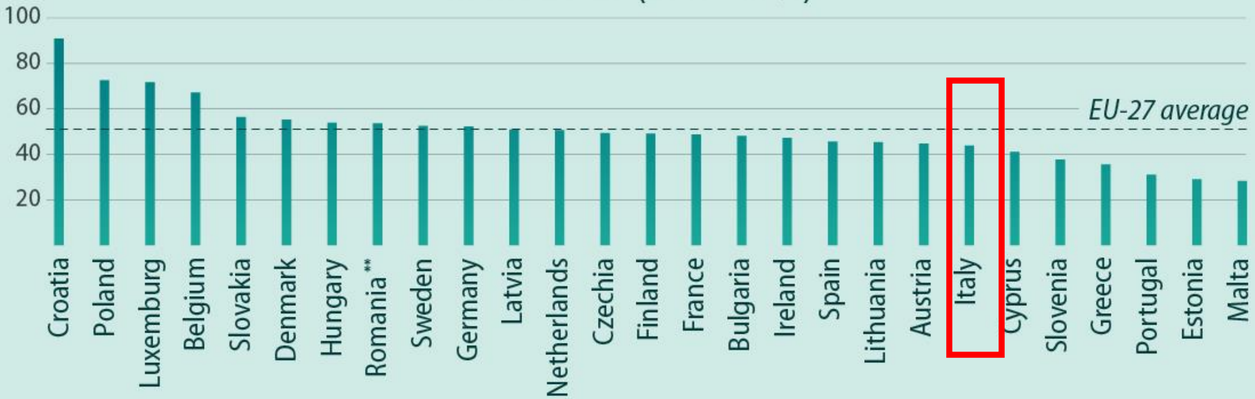
RECYCLING OF BATTERIES IN THE EU

of portable batteries sold in the EU were collected for recycling in 2019

Sales and collection of portable batteries and accumulators in the EU-27 (tonnes)*



Portable batteries and accumulators collected for recycling in the EU-27 (2019 - in %)



** Data estimated by Eurostat from 2009 to 2014, and 2019*

*** Data from 2018*

Source: Eurostat (2021), online data code: ENV_WASPB

Time to invest in Recycling!!

New approaches to recovery criticAl MEtals from spent LIthium-ions batteries (AMELIE)

MICS
Made in Italy
Circolare e Sostenibile

Waste streams

3a Selection of batteries from general waste

4b Biocarbon from waste

4a Mechanical pre-treatments

5 Microwave applications (*)

6 Solvometallurgy approach

Hydrometallurgy applications 7

TRL 1 - 3

8 Synthesis and testing of new cells with recycled anodic and cathodic materials

New batteries

AMELIE supports companies to meet EU Batteries Regulation

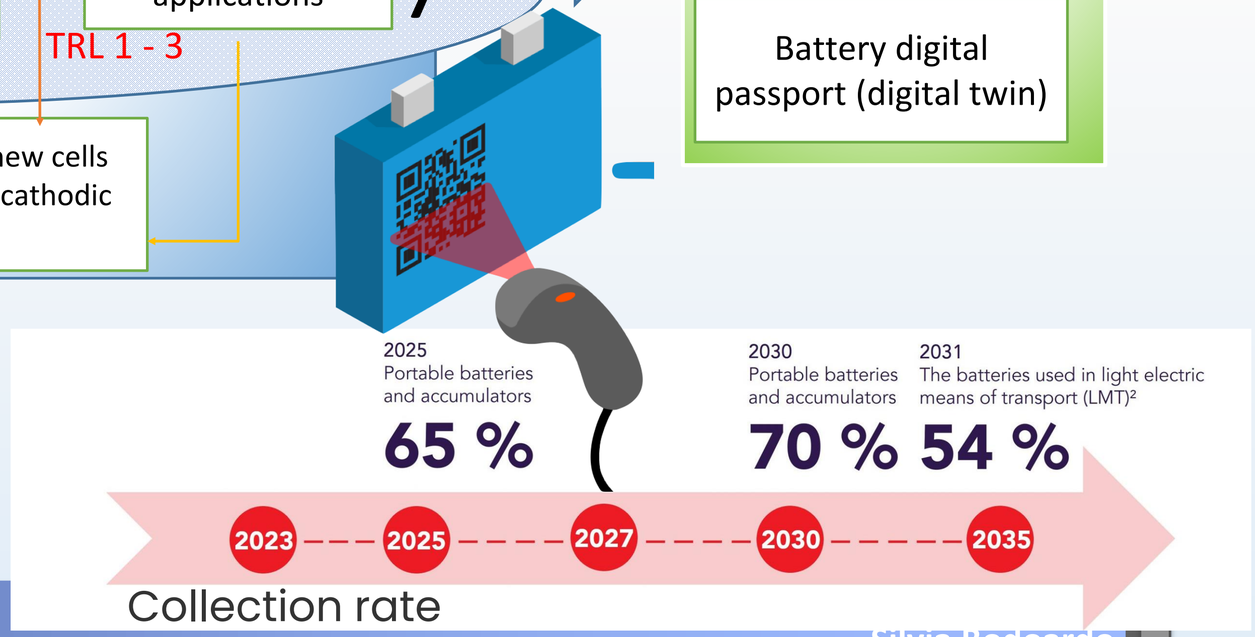
9 Modelling and optimization of the manufacturing and de-manufacturing process

10 Sustainability analysis of the proposed technologies

11 Battery digital passport (digital twin)

1 Waste batteries recovery supply chain

2 Human-centric solutions for the waste batteries recovery context



Smart
Functionalities

Smart Batteries @Electrochemistry Group

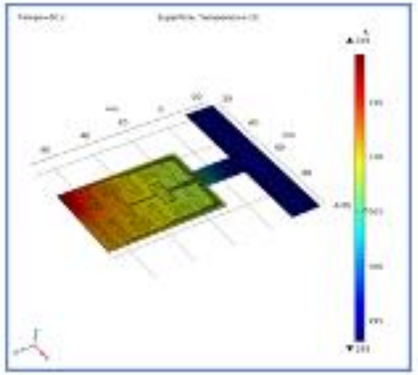
SENSORS

sensibat

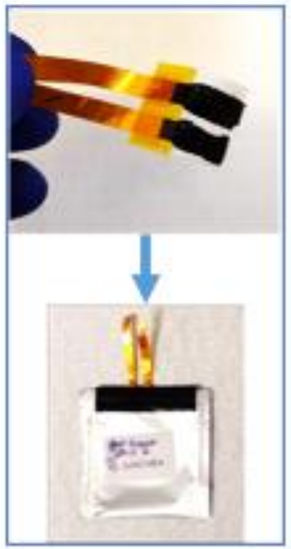
(EU PROJECT LCBAT13 2020-2023)

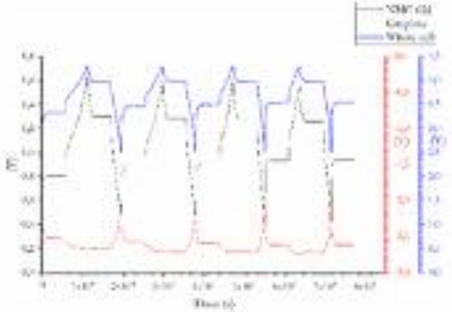
- ✓ Temperature has a strong effect on ageing and materials degradation
- ✓ Sensing temperature, pressure, cell resistance is important to increase the battery life & safety

- ✓ **New Thermal arrays prototypes for sensing directly integrated inside the cell** (developed by ANDREA MARCHISIO-PhD research work)



- ✓ **Printed electrodes directly integrated in small pouch cells for in situ & in operando Electrochemical Impedance Spectroscopy (EIS)**



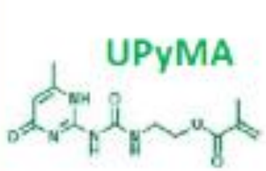


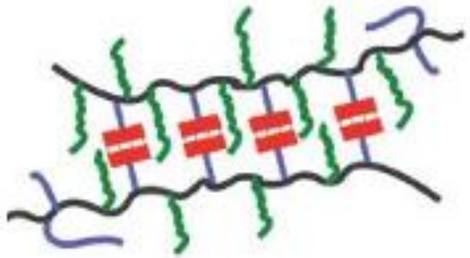
voltage of NMC622 vs Graphite and full cell. Working and Counter vs LFP. Plateau after every half-cycle is due to EIS analysis at constant OCV voltage.

SELF-HEALING MATERIALS

- ✓ New self-repairing polymer electrolytes for smart batteries (developed by SIMONE SICCARDI-PhD research work)

- ✓ **Development of UV cured polymer electrolytes with UpyMA (methacrylated ureidopyrimidinone) functionalities with self-healing properties through H-H bonding**





Ongoing grants funded by the European Commission

SUBLIME — Solid state sulfide based Li-metal batteries for EV applications (H2020)

HYDRA — Hybrid power-energy electrodes for next generation lithium-ion batteries (H2020)

sensibat — Cell-integrated sensing functionalities for smart battery systems with improved performance and safety (H2020)

BIG MAP — Battery interface genome – Materials acceleration platform (H2020)

BATTERY 2030+ — BATTERY 2030+ large-scale research initiative: at the heart of a connected green society (H2020)

SEA BAT — Next generation battery system concepts for marine application (H2020)

MSCA GREENER — Electrolyte optimization for enhancing GREEN ammonia production from nitrogen ElectroReduction (MSCA)

erc SuN2rise — Solar driven electrochemical nitrogen fixation for ammonia refinery (ERC-StG)

erc JANUS BI — All-liquid phase JANUS BIdimensional materials for functional nano-architectures and assemblies (ERC-StG)

SYNERGY — Symbiosis for energy harversting concepts for smart platforms on foils (H2020)

GIGAGREEN — Towards the sustainable giga-factory: developing green cell manufacturing processes (HE)

ADVAGEN — Development of advanced next generation solid-state batteries for electromobility applications (HE)

NEXTCELL — Towards the next generation of high performance li-ion battery cells (HE)

DigiCell — Towards the next generation of high performance li-ion battery cells (HE)

National ongoing grants

HYDREAM — Tailoring the HYDrophilic-hydrophobic Reaction zone for the Electrochemical nitrogen reduction reaction to AMmonia (PRIN)

BIONIC — Binders with high iONIc Conductivity for fully sustainable Li-ion cells (PRIN)

PINPOINT — Perovskite-Inspired materials-based iNdoor PhotovOltaics for powering the Internet of Things (PRIN)

PoLiBatt — Next-Generation Redox Polymers for Lithium and Post-Lithium Organic Batteries (PRIN)

LOTUS — Lithium protection for robust and Safe batteries (FARE)

GREEN 2 MOVE — Green potassium batteries manufacturing processes: towards sustainable gigafactories (FISA)

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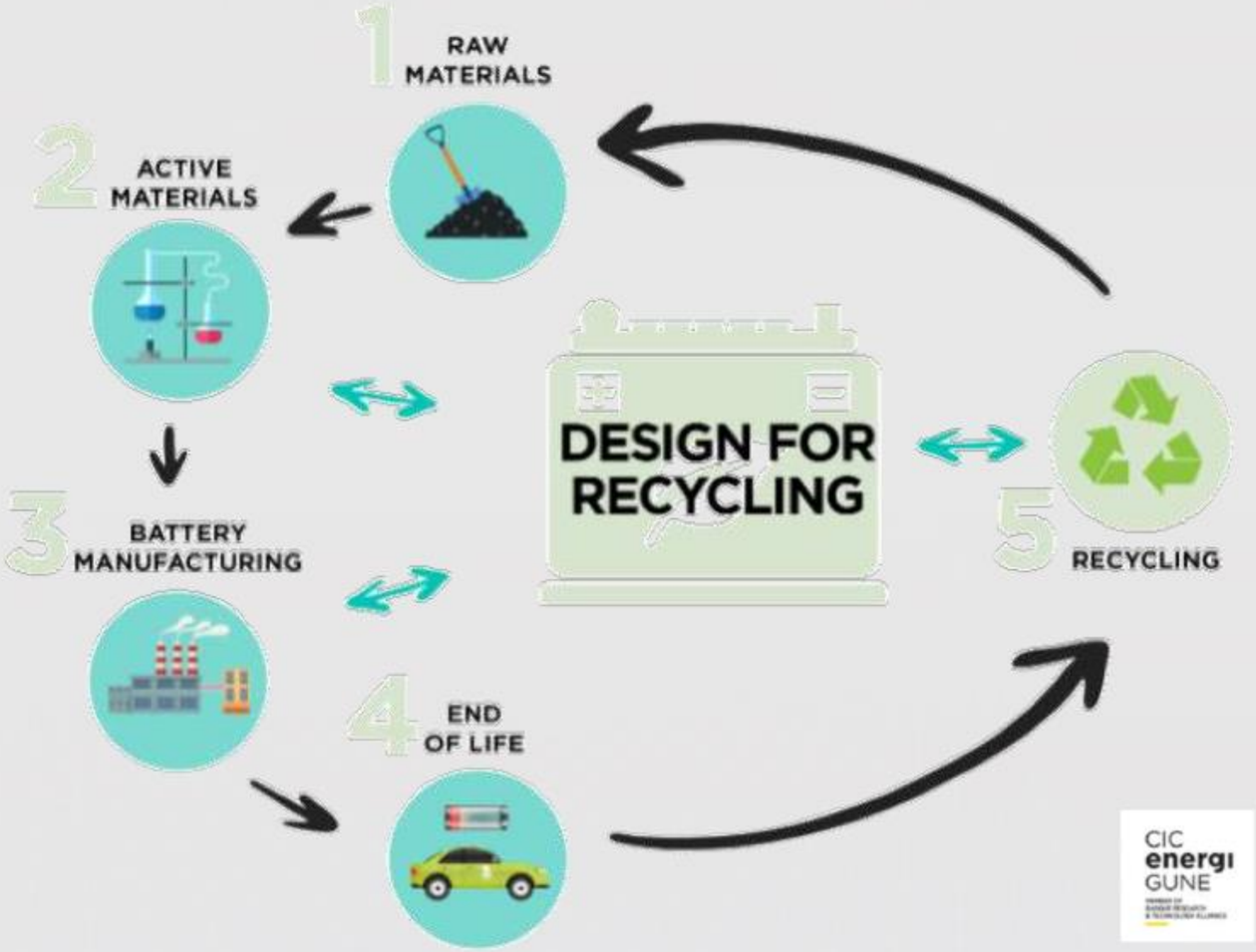
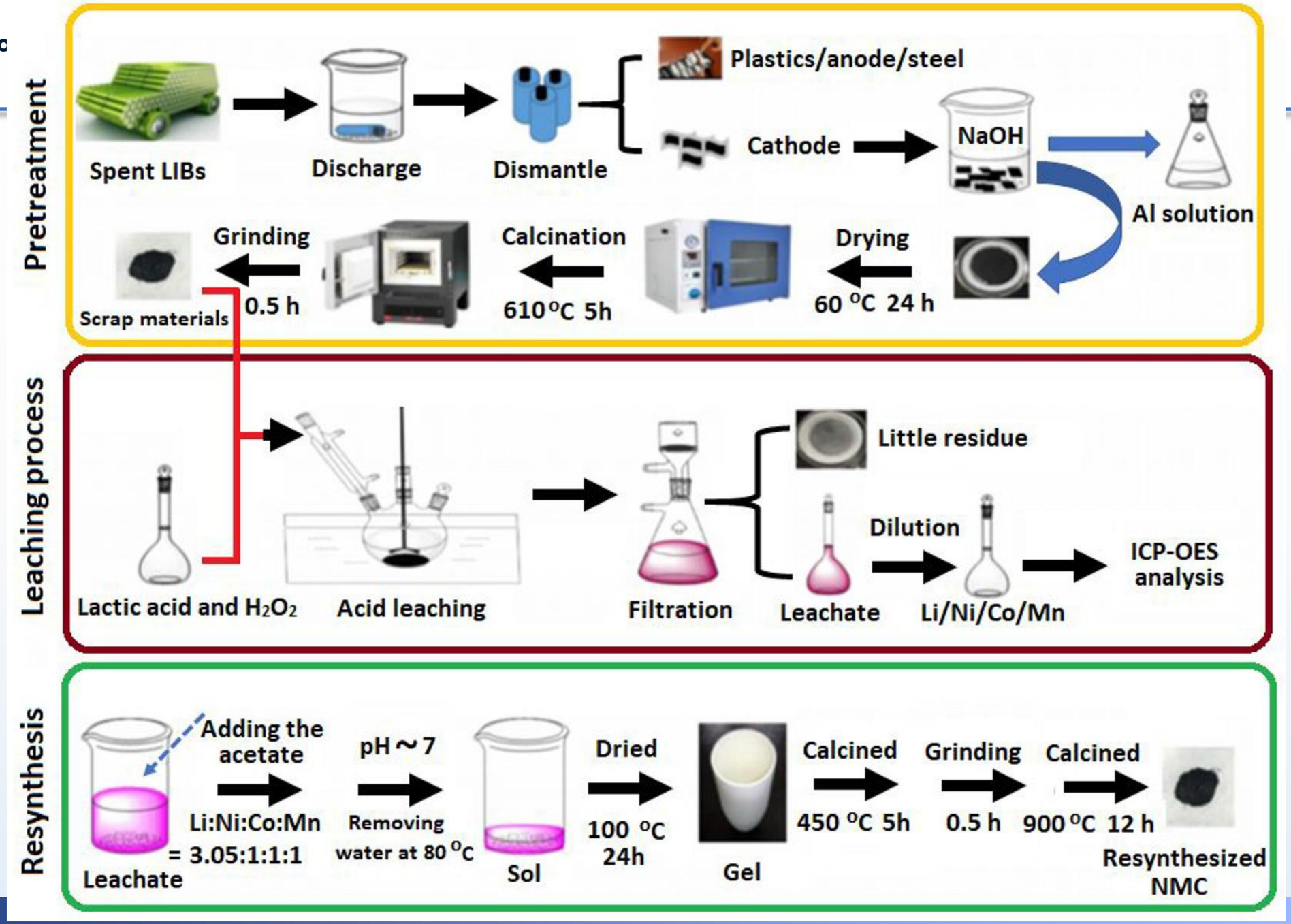
SECOND-LIFE & RECYCLING

by 2030: **140 million Evs** are predicted to be **on the road worldwide** and **11 million metric tons of end-of-life LIBs** are expected to be generated cumulatively

by 2040: the **annual waste flows** of **EV batteries** will reach as high as **340,000 metric tons**



CIC EnergiGUNE
Y. Bai, N. Muralidharan, Y.-K. Sun, S. Passerini, M. S. Whittingham, I. Belharouak, Mater. Today 41 (2020) 304



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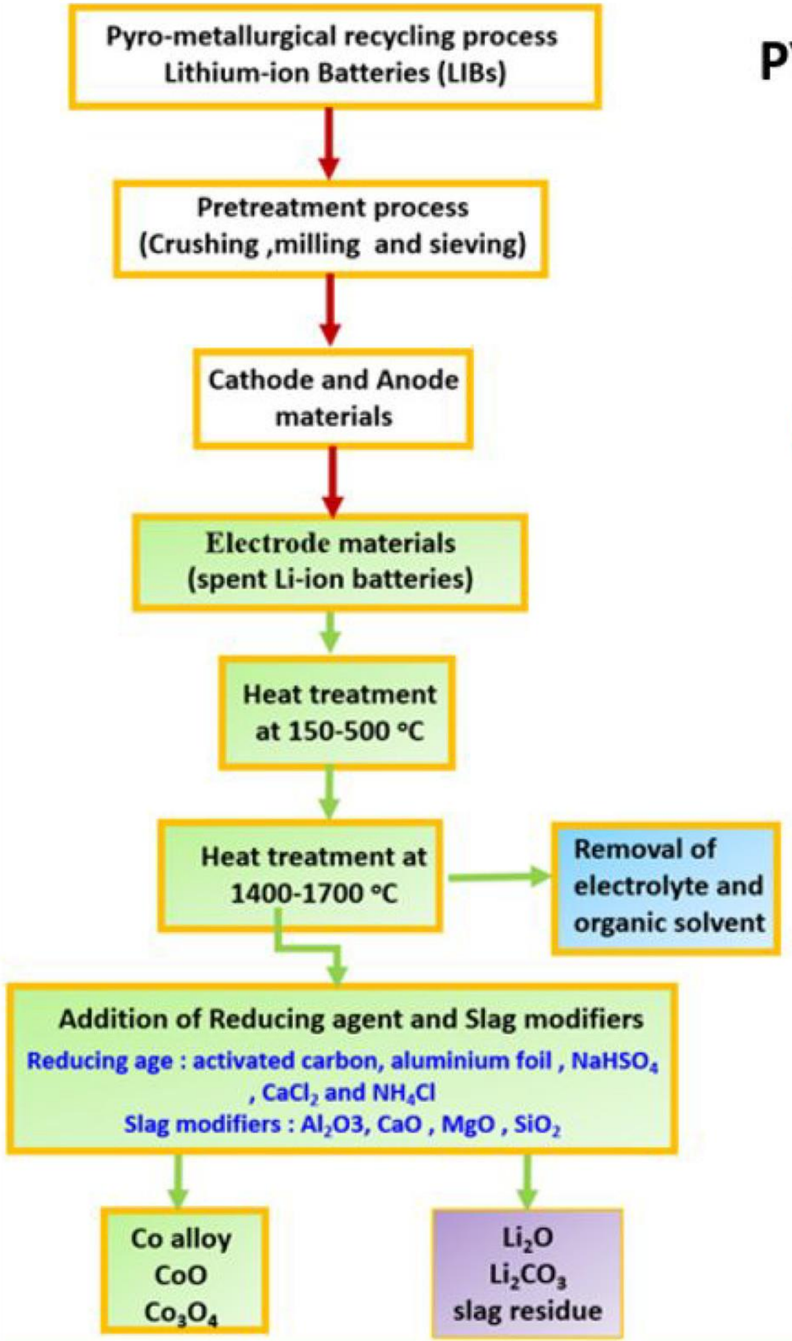
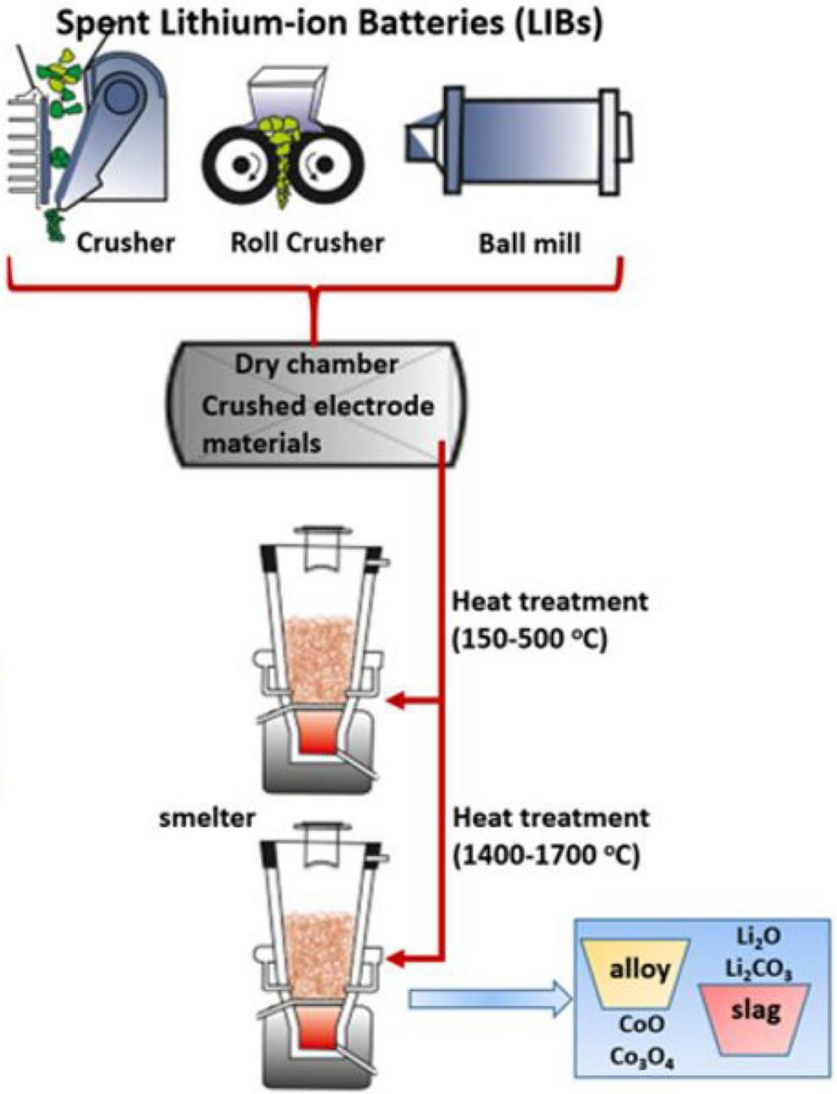
PYRO-METALLURGICAL PROCESSES





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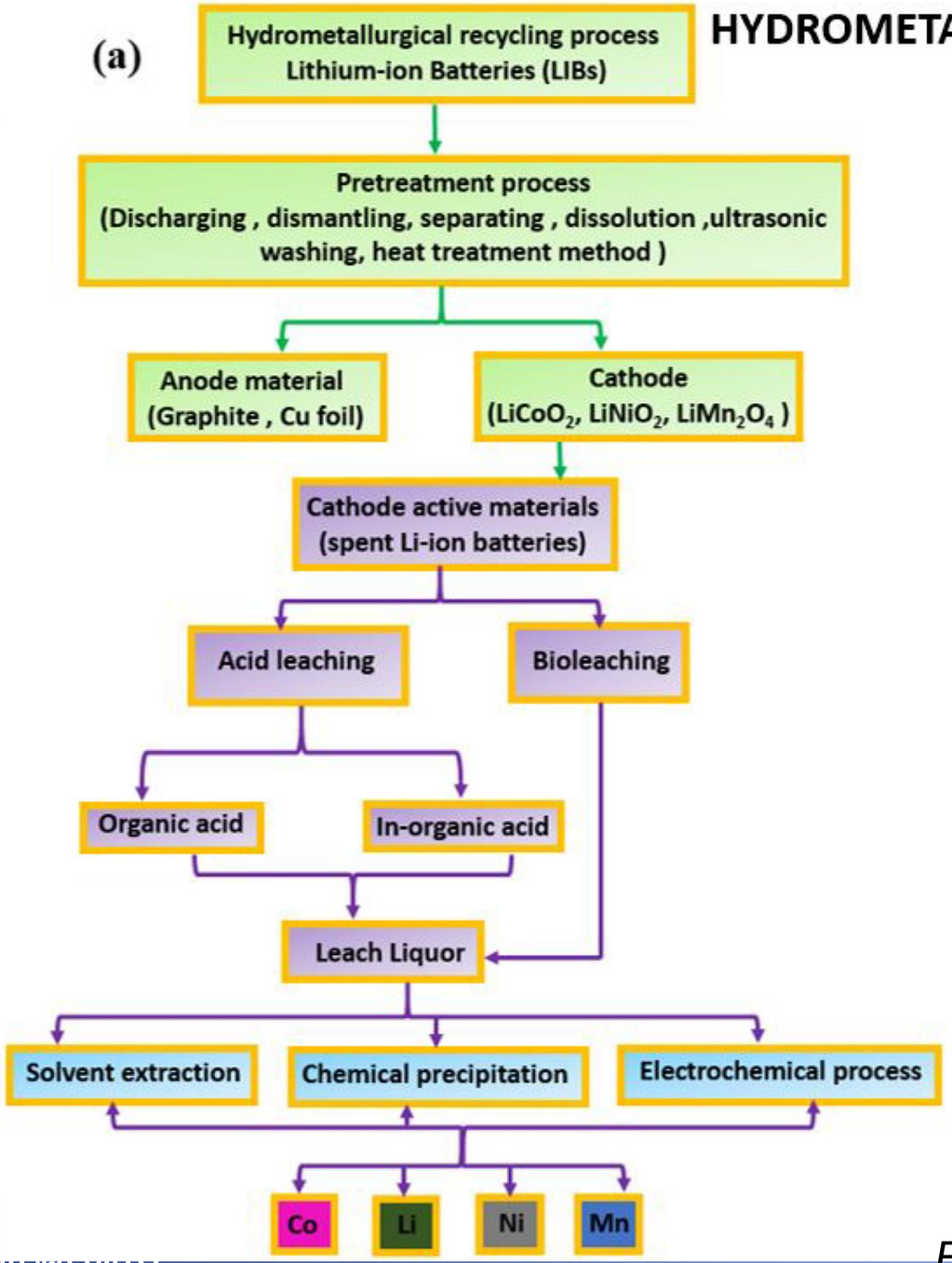
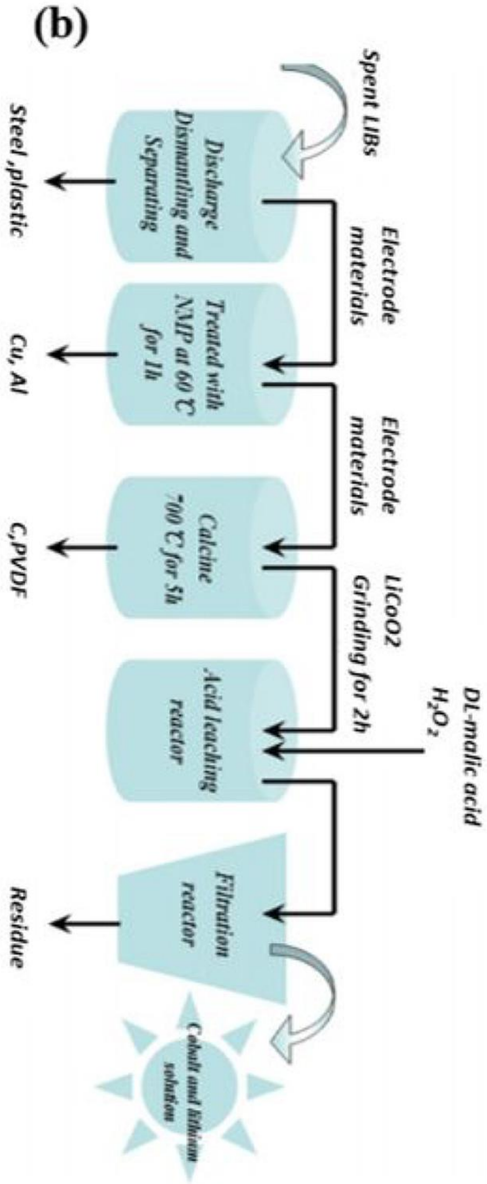
HYDROMETALLURGICAL PROCESSES





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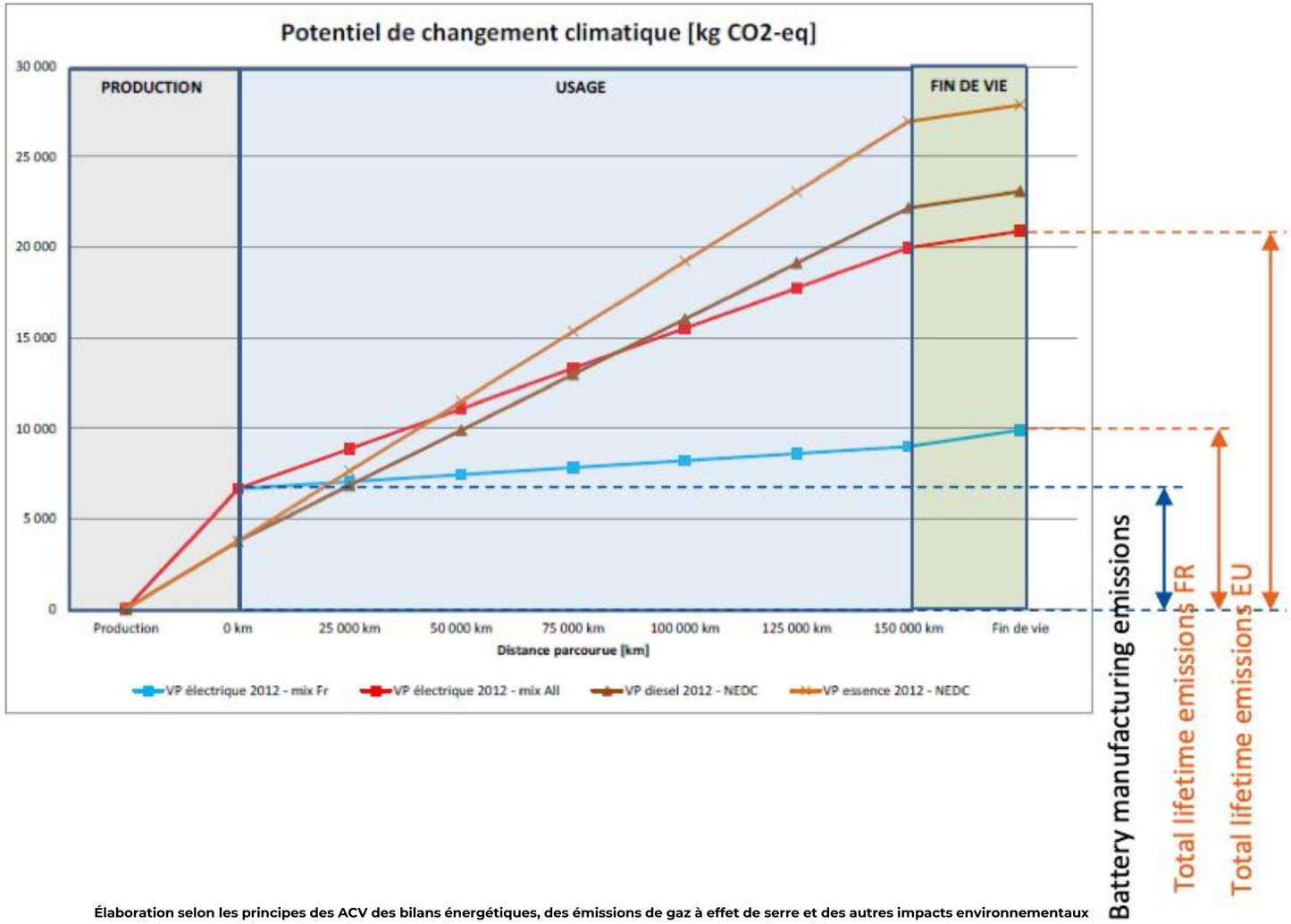

Élaboration selon les principes des ACV des bilans énergétiques, des émissions de gaz à effet de serre et des autres impacts environnementaux
Induits par l'ensemble des filières de véhicules électriques et de véhicules thermiques , VP de segment B (citadine polyvalente) et VUL à l'horizon 2012 et 2020

Battery manufacturing can account from 30% to 65% of total CO2 emissions depending on the emergy mix

Increase prooduction efficiency
Reduce critical materials also in production
Extend battery life