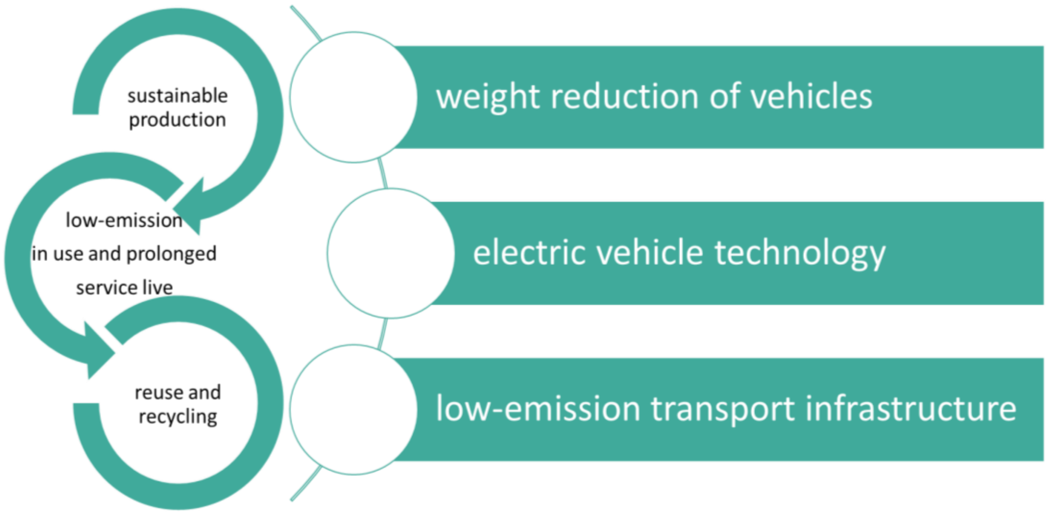
CLIMATE-FRIENDLY BATTERIES FOR TOMORROW'S MOBILITY

Energy Storage Materials & Beyond
24th November 2022

Marcus Jahn
Head of Competence Unit Battery Technologies

AUSTRIAN INSTITUTE OF TECHNOLOGY
TOMORROW TODAY

FOCUS OF THE CENTER



Overview of LET centers focus topics and addressed systems

INFLUENCING FACTORS

- **Decarbonization/Reduction of CO_2**
  - in the transportation of persons and goods
  - in the manufacturing including re-use/circular economy
  - in the construction industry including re-use/circular economy
- **Digitalization / Industry 4.0**
  - in the manufacturing
  - of infrastructure

NATIONAL/INTERNATIONAL FRAME

- **Horizon Europe**
  - Green Deal
  - Cluster 5 “Climate, Energy and Mobility”
  - Partnerships: 2zero, Clean Aviation, Batteries Europe, …
- **Strategies & Roadmaps**
  - Research, Technology and Innovation Strategy for Mobility (Federal Ministry Climate Action, Environment, Energy, Mobility, Innovation and Technology)
  - #upperVISION2030 (local government of Upper Austria)
  - Austrian long-term strategy 2050
  - Eco-Mobility 2015plus
  - Electromobility in and from Austria implementation plan

Key Figures

Competence Units

- Light Metals Technologies Ranshofen
- Battery Technologies
- Electric Vehicle Technologies
- Transportation Infrastructure Technologies

Research Fields

- Casting Processes for High-Performance Materials
- Advanced Forming Processes and Components
- Wire-Based Additive Manufacturing
- Numerical Simulation of Lightweight Components and Processes

- Battery Material Development and Characterization
- Sustainable and Smart Battery Manufacturing
- Solid State Battery

- Vehicle System Simulation
- Power Electronics
- Hybrid Electric Aircraft Technologies

- Reliable and Silent Transport Infrastructure
- Road Infrastructure Assessment, Modelling and Safety Evaluation

22 M EUR turnover

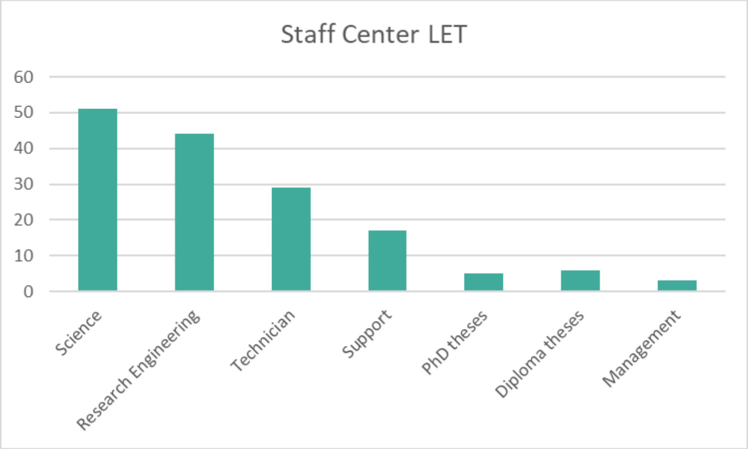
160 employees

28% Contract research
33% Cooperative research
39% Strategic research

47% European funding
53% National funding

330 Projects per year

316 Clippings per year



SMART TARGETS

	2021 - 2023
Number of projects* exceeding € 70k	**69**
Number of patents granted	**13**
Number of peer-reviewed publications (journals and conferences)	**140**
of which number of peer-reviewed journals with SCI	**74**
Number of completed co-supervised PhD theses	**16**
Rate of female project leaders**	**>1**

LABORATORIES / INFRASTRUCTURE


Battery materials research laboratory


Battery testing laboratory


Environmental testing laboratory


Drive testing laboratory

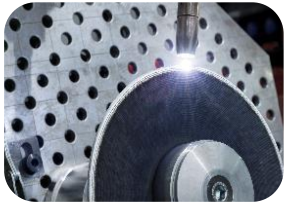

Road laboratory

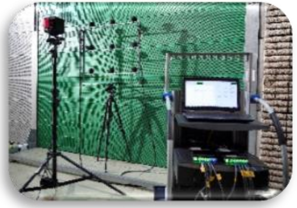

Safety observation laboratory


Material testing & characterization laboratories


Forming laboratory


Casting laboratory


Additive manufacturing laboratory

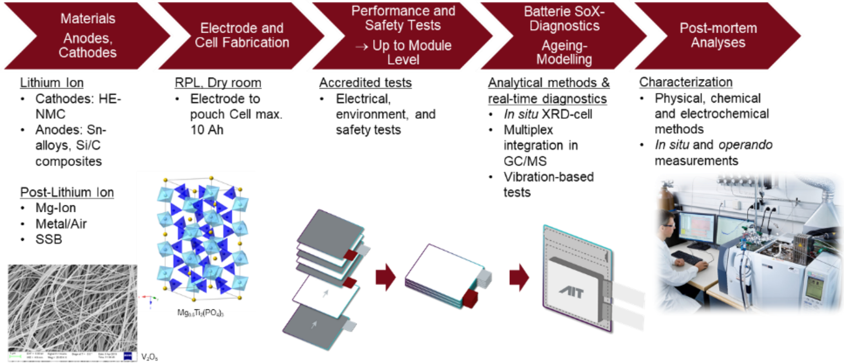

Acoustic laboratory


Mobile seismic simulator laboratory

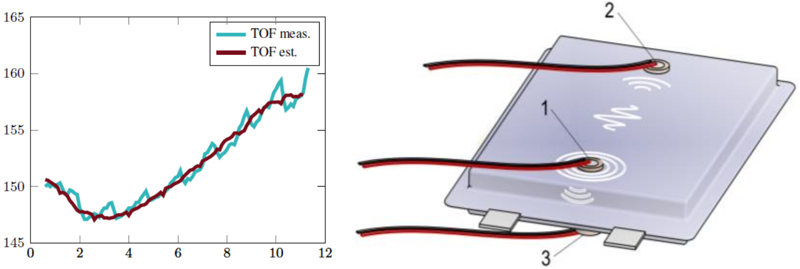
Further laboratories / infrastructure planned:

- **Solid-state battery research pilot line**
- New road laboratory RoadSTAR NEW
- Expansion of the wire-based additive manufacturing lab

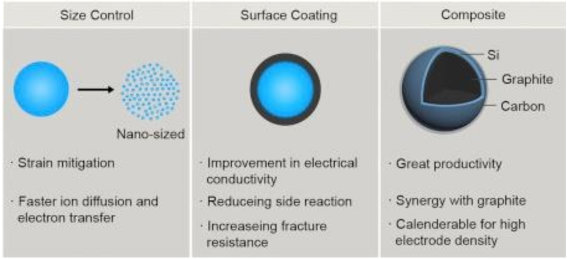
BATTERY CELL TECHNOLOGIES



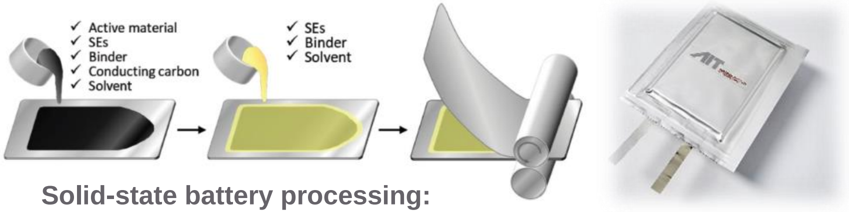
Complete research chain from materials to semi-industrial production battery cells



Advanced characterization tools, e.g. ultrasonic time-of-flight based state-of-charge estimator



Development of Lithium-ion battery **material coatings** and **interface stabilization**



Solid-state battery processing:

- electrolyte processing on hybrid-polymer electrolytes with ceramics
- Scaling laboratory processes towards industrially relevant cells

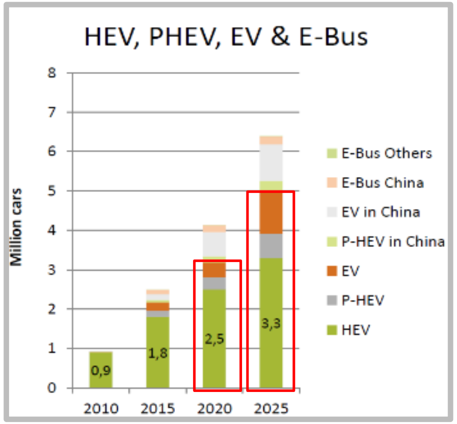
WHY THE EU WANTS CELL PRODUCTION

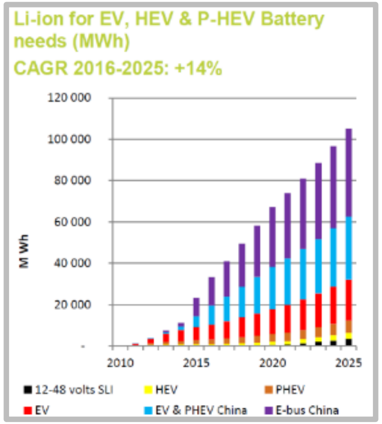
Current situation

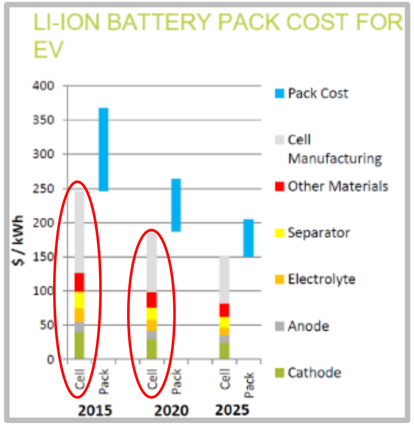
- Asian share of Li-Ion production >80%
- EU battery production for automotive sector is just a part of the value chain

Market development

- Up to 5-10% market share for electric passenger cars by 2020
- Cells account for >50% of Modul/Pack level cost







Source: Avicenne Energy 2017

FROM CONCEPT TO CELL PRODUCTION

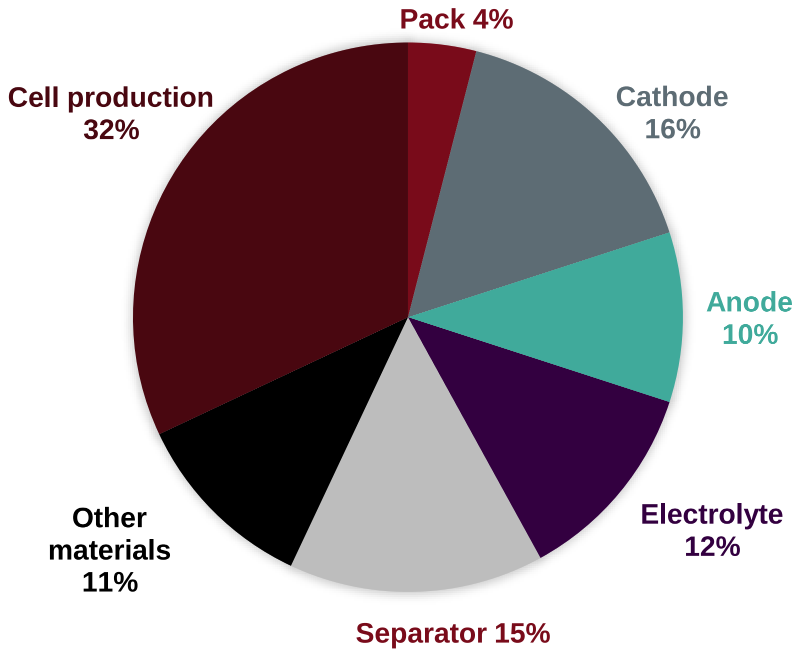
Schematic of the Overall Battery R&D Process from Conception to Production

Concept Generation → **Production**

	Concept Validation	Research	Applied Research	Development	Advanced Development
	An idea in a creative mind Limited exploratory laboratory experiments Establish repeatability of performance Is there a market?	Scale-up experiments Characterize fundamental properties of concept, chem. composition, structure, etc. Evaluate size of commercial opportunity	Lab/prototype cells Initial map of performance, rate, cycling, temperature, etc. Scale-up of material preparation Preliminary market scope	Confirm research results Establish initial product format Develop unit assembly operations Make, test, and characterize 5 to 10 cell lots of 100 cells each Construct business plan	Design initial cell product Design and construct unit operations Scale-up prototype cell fabrication Run 3 to 5 sizable pilot line-factory trials Finalize business plan Market development
Timing	One to three years	One to three years	Three to four years	Three to five years	Two to four years
Staffing	One	Two to four	Four to ten	Eight to sixteen	Twelve to thirty
Materials Batch	Grams	10 to 50 g	100 g to 1 kg	1 kg to 10 kg	10 kg to 100 kg

10-19!!!

COST BREAKDOWN
AUTOMOTIVE LI-ION BATTERIES



Cathode materials greatly influence the overall battery costs.

Why??

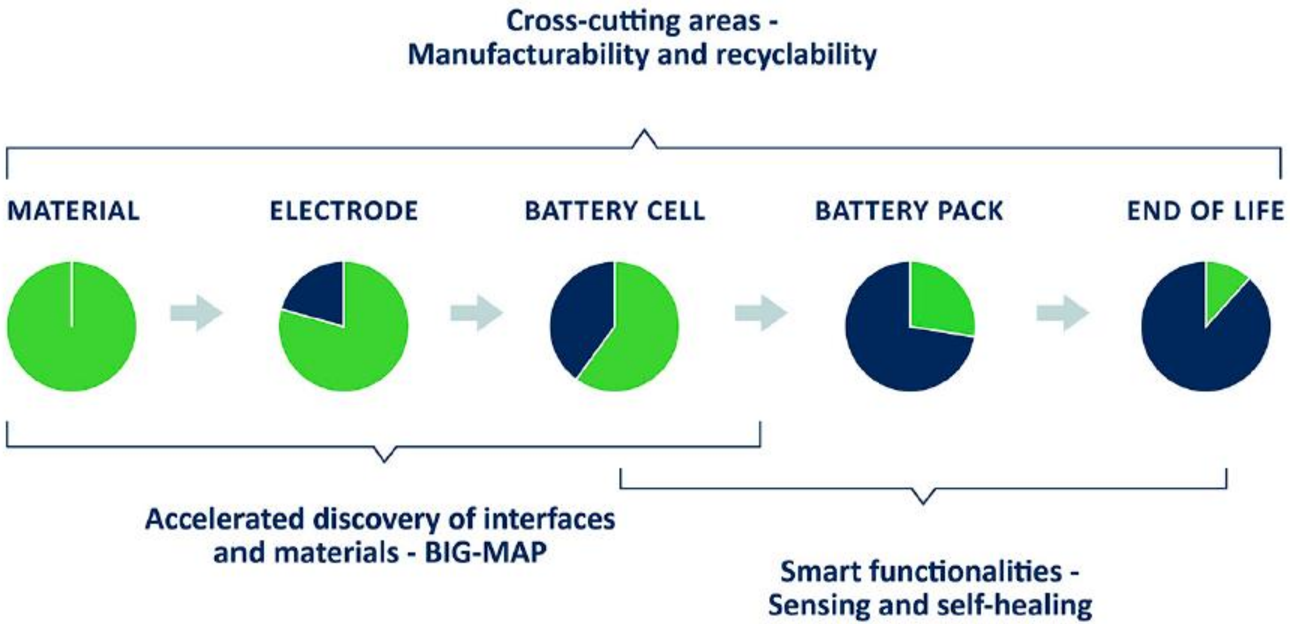
- Raw materials
- Production and mining
- Lower specific capacity compared to graphite (anode)

Cost reduction via…

- Synthesis route
- Composition
- Enlarged voltage window
- Increased specific capacity
- Long term stability

Energy density

DECREASE IN TOTAL CAPACITY AS INACTIVE MATERIAL IS ADDED



https://battery2030.eu/digitalAssets/860/c_860904-l_1-k_roadmap-27-march.pdf

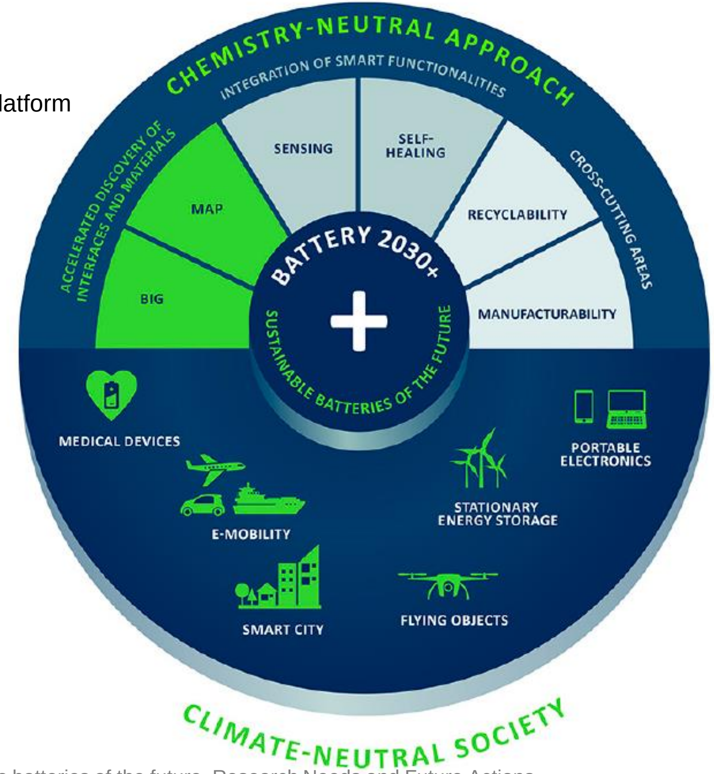
WHAT IS THE FUTURE?

To enhance the lifetime and safety of batteries

Materials **A**cceleration **P**latform

Battery **I**nterface **G**enome

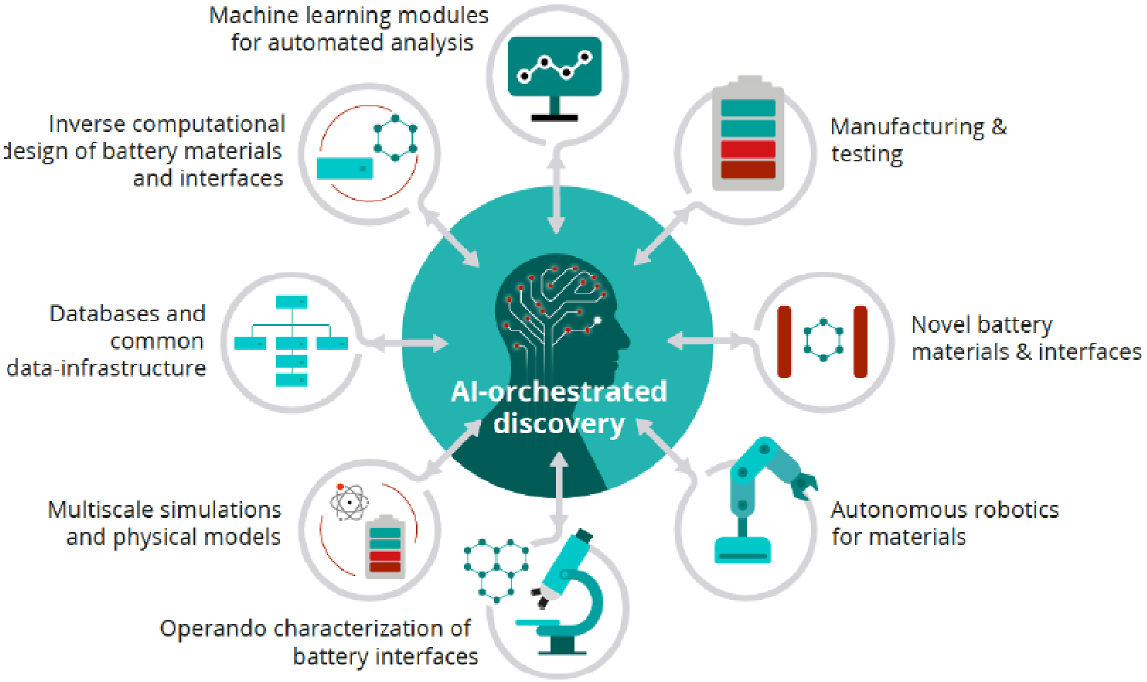
Essential to secure new sustainable materials with high energy and/or power performance and that exhibit high stability towards unwanted degradation reactions. Special attention must be paid to the complex reactions taking place at the many material interfaces within batteries



Can the new materials be upscaled in a sustainable way?
Can we recycle the new cell concepts suggested?

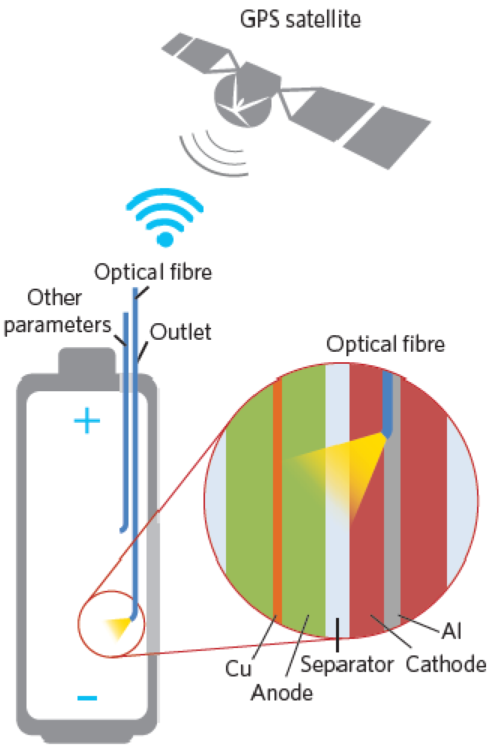
Battery 2030, Inventing the sustainable batteries of the future, Research Needs and Future Actions

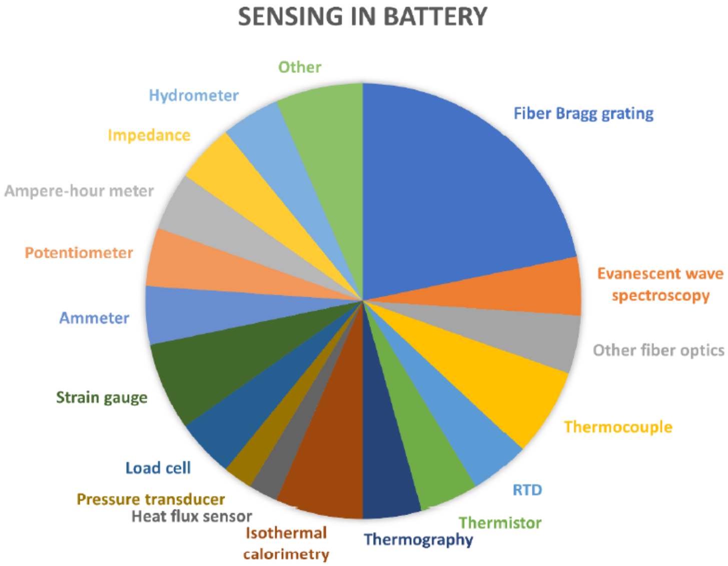
KEY COMPONENTS OF ESTABLISHING A BATTERY MAP



https://battery2030.eu/digitalAssets/860/c_860904-l_1-k_roadmap-27-march.pdf

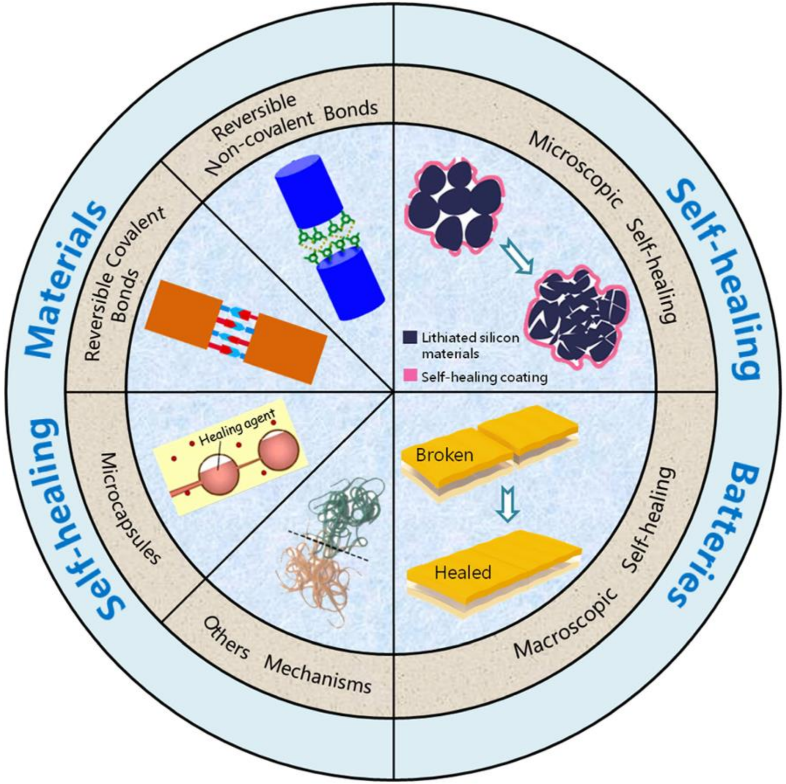
BATTERY SENSORS





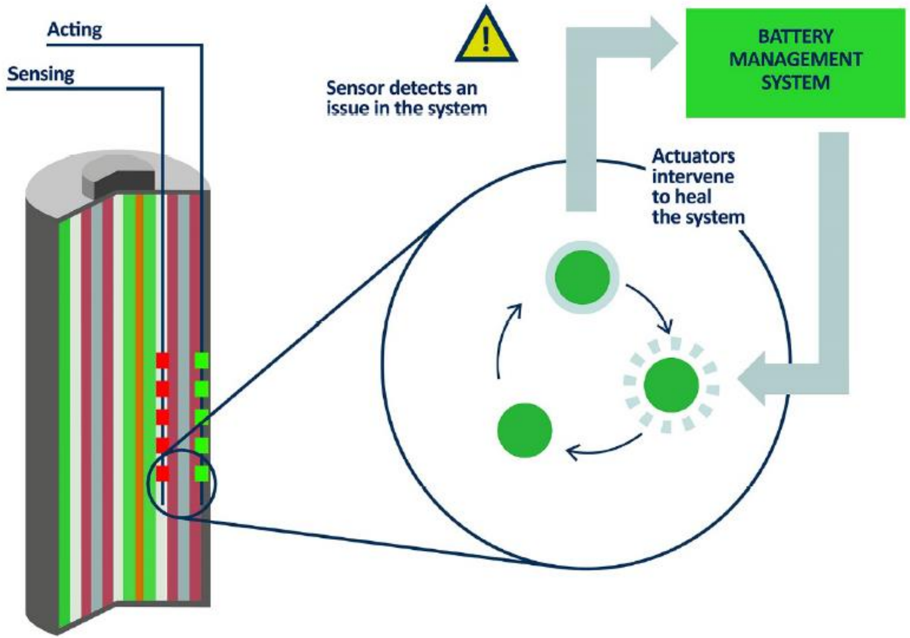
https://battery2030.eu/digitalAssets/860/c_860904-l_1-k_roadmap-27-march.pdf

SELF HEALING MATERIALS



Wang et al., “Recent advances on self-healing materials and batteries”, Chem. Electro. Chem., 6, (2019), 1605 - 1622

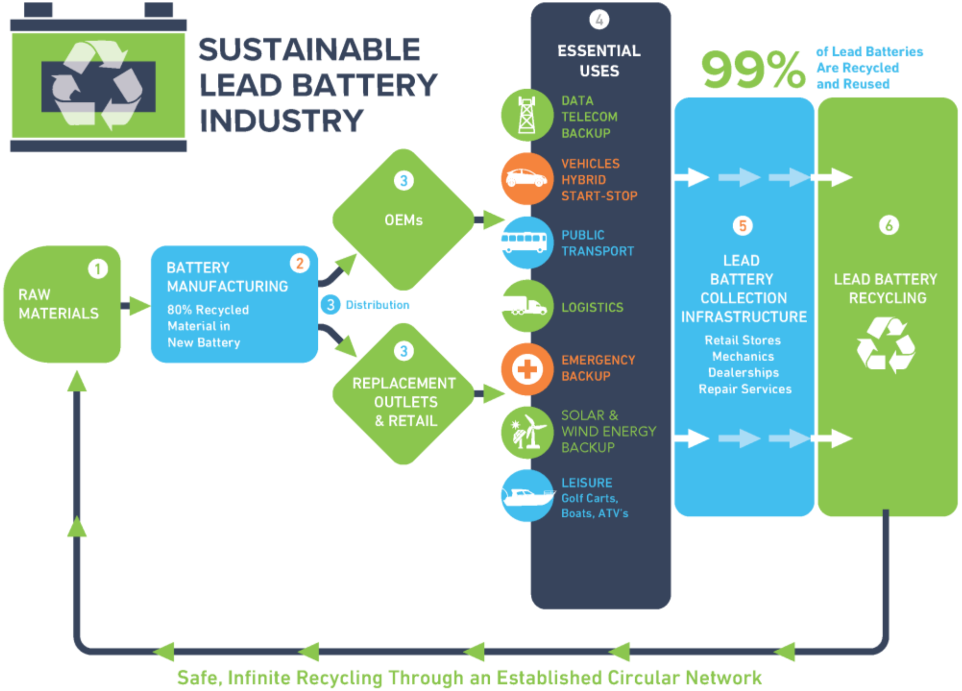
SYNERGY BETWEEN BATTERY SENSING AND HEALING



https://battery2030.eu/digitalAssets/860/c_860904-l_1-k_roadmap-27-march.pdf

RECYCLING AND 2ND LIFE

» *Potential circular economy model for lithium batteries.*



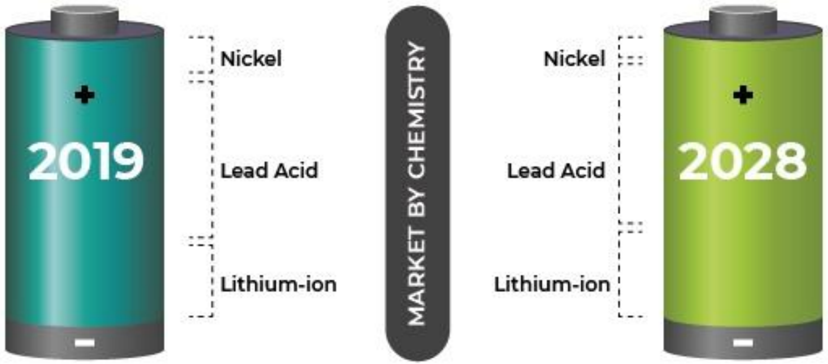
Essentialenergyeveryday.eu, 2019

Vpsolar.com, 2019

GLOBAL BATTERY RECYCLING MARKET FORECAST 2020-2028

Regionally, Europe accounted for ***largest revenue share*** of battery recycling market in 2019.

Asia pacific is anticipated to be the ***fastest growing regional*** market over the forecast years.



MARKET BY APPLICATIONS

TRANSPORTATION

Transportation

Growing automotive sector creates high demand for batteries which further drive the demand for recycled batteries over the forecast period.

CONSUMER ELECTRONICS

Consumer Electronics

Growing consumer electronic sector in emerging economies is expected to drive demand for battery recycling in this sector.

INDUSTRIAL

Industrial

Growth of the global energy storage systems market is estimated to increase the recycling of industrial batteries over the coming years.

Research pilot line in a nutshell…

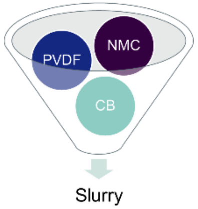
R&D on **energy storage** technologies:

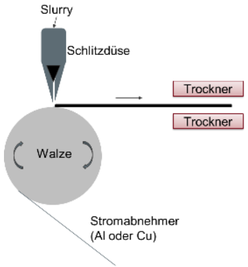
From **cell manufacturing** and prototyping, through **material & component screening**, simulation to **cell testing.**

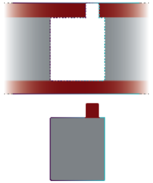
Pouch cell production facilities for small series up to **10 Ah/cell** in Austria‘s only dry room

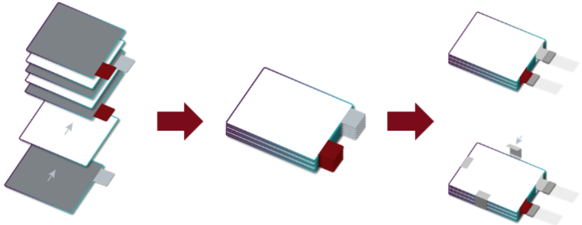
POUCH CELL PRODUCTION

Slurry mixing → Coating → Calendering → Electrode cutting → Stacking

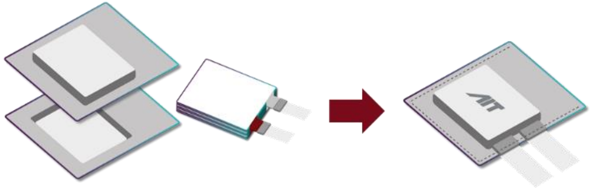


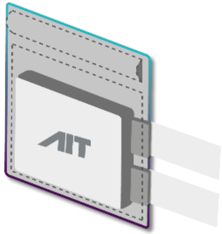






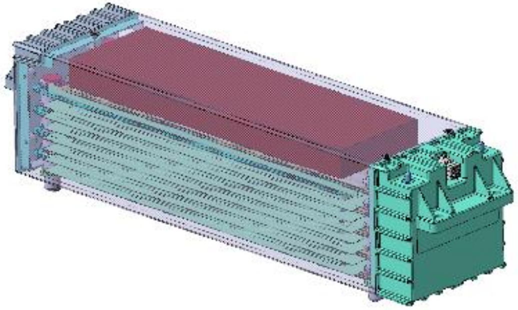
Sealing (Blister forming) → Electrolyte filling → Formation → Degassing → **POUCH CELL**






Our mission:
Sustainable electrification of the
automotive sector…

3BELIEVE AS EXAMPLE PROJECT



(1) secure access to raw materials from outside the EU, accessing secondary raw materials through recycling;

(2) support European battery cells manufacturing at scale and a full competitive value chain in Europe: bringing key industry players Member States and the European Investment Bank together;

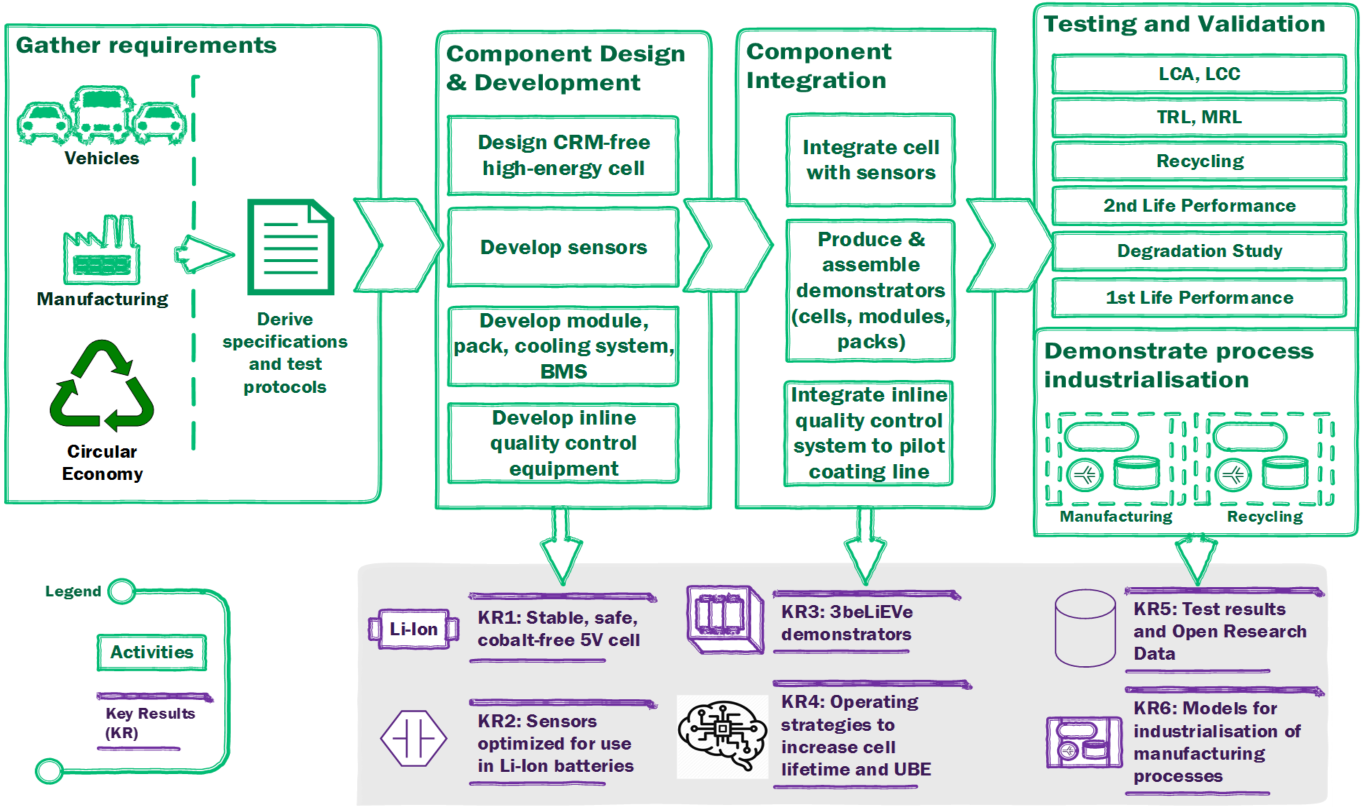
(3) strengthen industrial leadership through stepped-up EU research and innovation support to advanced (Li-ion) and disruptive (e.g. solid state) technologies;

(4) develop and strengthen a highly skilled workforce in all parts of the battery value chain;

(5) support the sustainability of EU battery cell manufacturing industry with the lowest environmental footprint possible, (e.g. renewable energy in the production);

(6) ensure consistency with the broader enabling and regulatory framework;

3BELIEVE AS EXAMPLE PROJECT

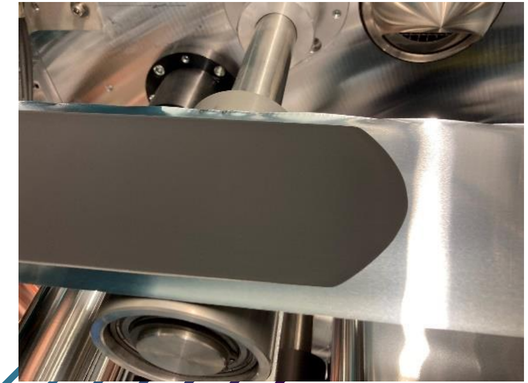


ELECTRODE AND CELL PRODUCTION - CATHODE

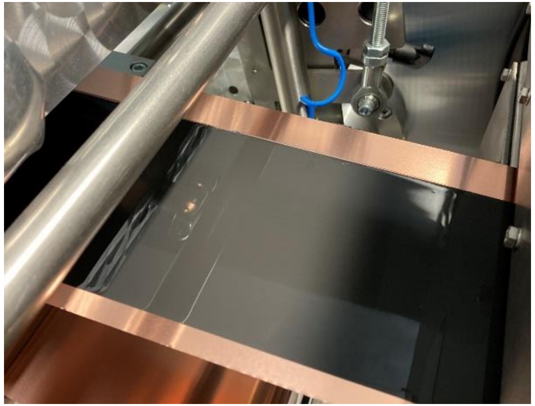
- 65-70 wt% dry content
- NMP based

Material	wt%
LNMO	>92
Super C65	<5
PVDF (HSV-900)	<4

- Coating speed: 0.5 $mmin^{-1}$
- Uniform double-sided coatings of ~2.5 $mAhcm^{-2}$, 200 µm
- Compacted to 2.6 gcm^{-3} (R2R @ 85 °C)



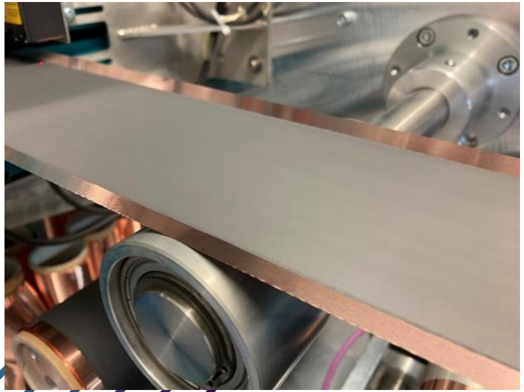
ELECTRODE AND CELL PRODUCTION - ANODE



- 40-48 wt% dry content
- Water based

Material	wt%
SiC	>93
Super C65	<2
CMC (Walocel)	<2
SBR (Zeon)	<2

- Uniform double-sided coatings of 2.33 mAhcm-2 (4.38 mgcm-2), 130 µm
- Compacted to 1.1 gcm^{-3} (R2R @ 80 °C)



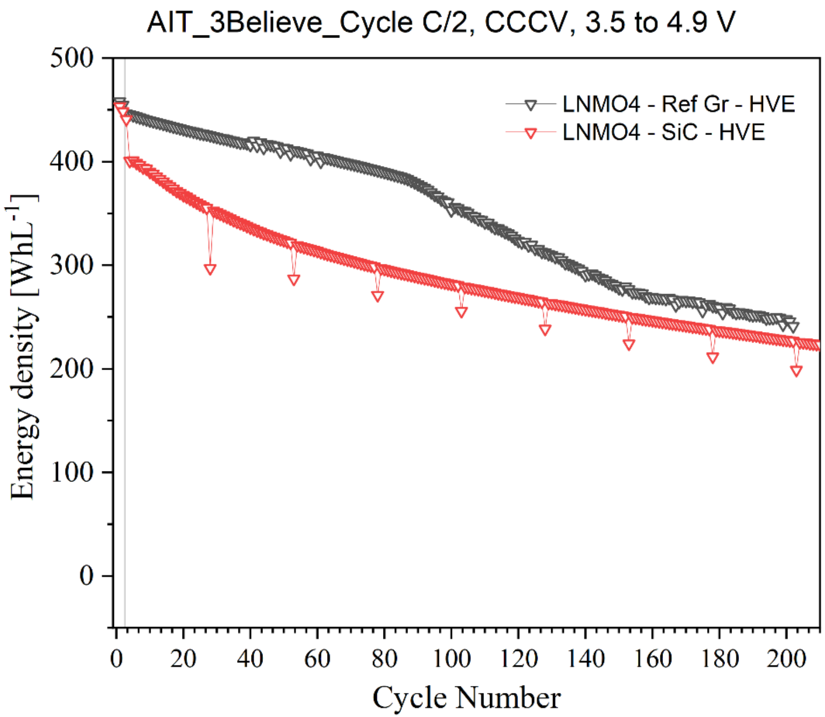
POUCH CELLS

- 3, 5 and 7 layer pouch cells tested
- Capacity of ~0.5 to 1 Ah per cell
- Interaction of all materials in full cell & reproducibility
- Integration of optical sensors
- Achieving 450 Wh/L at prototype, but challenges in cycle life

ANODE COMPARISON

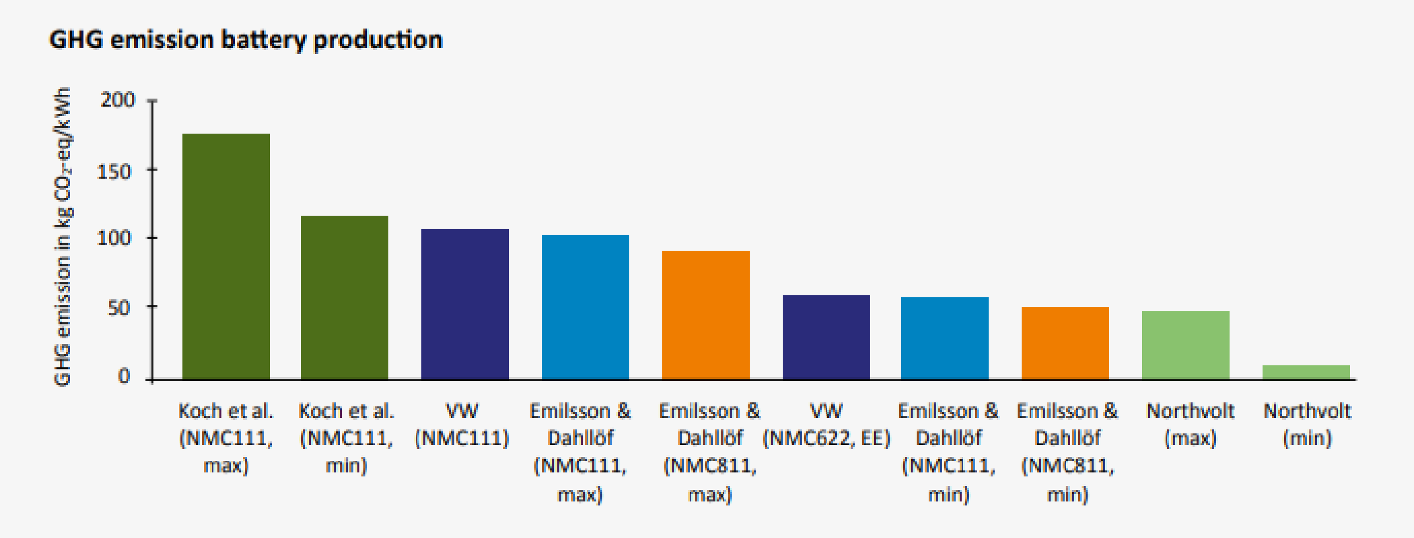
- Nominal 4.7V, stack energy density

- Similar initial energy density @C/10
- Energy density of LMNO//Gr higher @C/2, especially until cycle 100
- After cycle 150 energy density is on the same level
- Optimised electrolyte for the LMNO//SiC system



ENERGY CONSUMPTION OF CELL PRODUCTION

Source: VDI/VDE, study 2021



Energy consumption of cell production based on NMC cathode materials

Depends on many factors

- Factory scale
- Region and climate
- Cell size and format

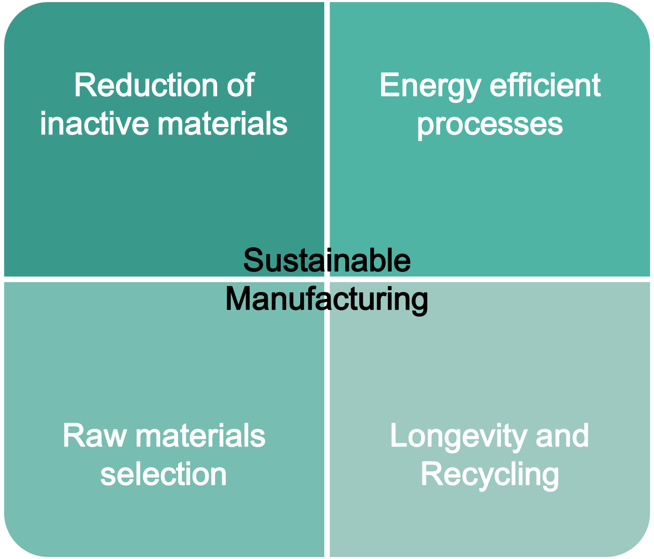
HOW TO ACHIEVE GREEN CELL PRODUCTION?

Reduction of **inactive materials**
- Increased energy density

Energy efficient processes
- Solvent free or reduced processing
- Dry room environment reduction

Raw materials
- CRM-free cell chemistries

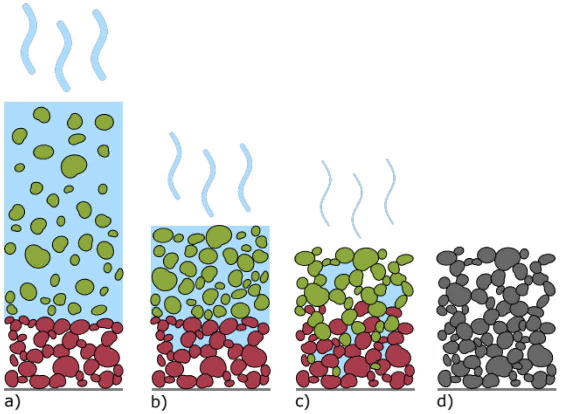
Longevity and Recycling
- Smart Cells and Cell Design



REDUCTION OF INACTIVE MATERIALS

Challenges of **thick electrodes**

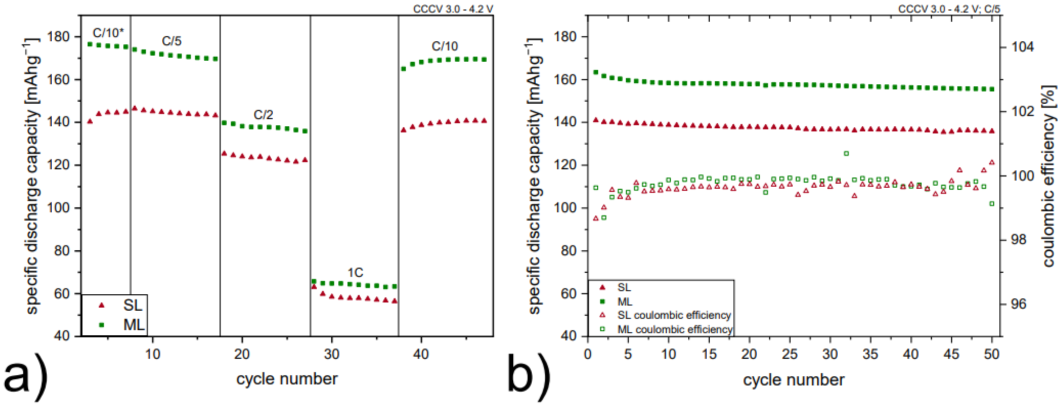
- Delamination
- Binder migration
- Residual solvents
- High resistance
- Poor electrochemical performance



Multilayer approach

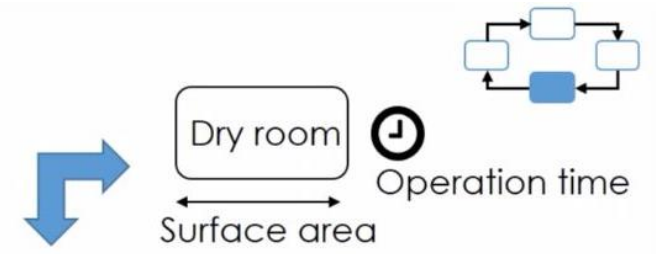
Variation of:

Active materials
Porosities
Binder content
etc. …



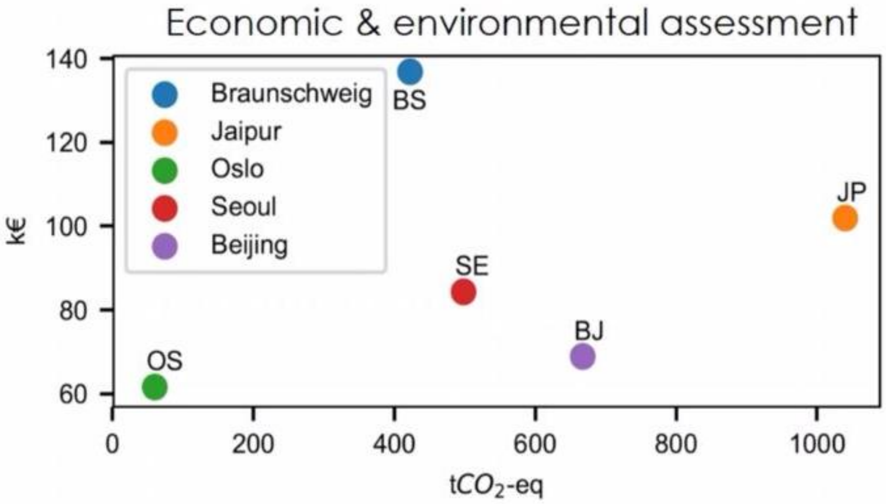
Neidhart et al., Nanomaterials 2022, 12/3, 317.

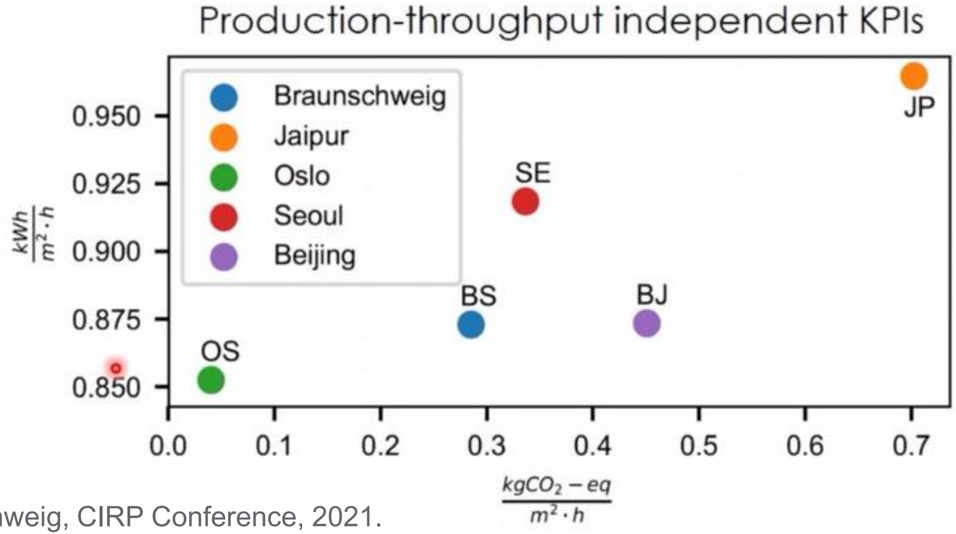
DRY ROOM OPERATION ENERGY CONSUMPTION



Dry room usage is highly energy consuming

Energy can be reduced by strategic planning
- Place (e.g. Oslo)
- Positioning of the equipment



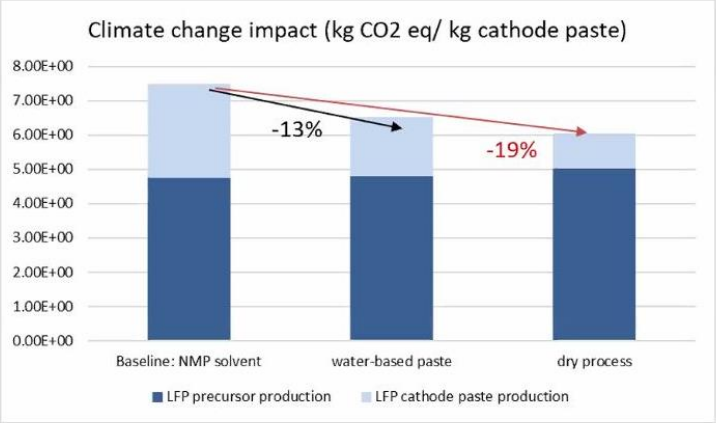


Source: Vogt, TU Braunschweig, CIRP Conference, 2021.

IMPACT OF ENERGY OPTIMISED PROCESSES

Potential energy and cost reduction from sustainable Li-ion cell production.

Conventional production process	Proposed new process/concept	Potential energy reduction	Potential cost reduction
NMP-based slurry preparation	Solvent-reduced H_2O based slurries	0.4%	4-6%
Conventional electrode thicknesses	Thick electrodes with high areal capacity > 4 $mAhcm^{-2}$	25-30%	20-25%
Electrode coating with following drying unit and compacting	Single-unit approach of drying and compacting electrodes	2%	4%
Mechanical electrode cutting	Laser-cutting of electrodes	3-4%	2-3%
Dry room for slitting, stacking, electrolyte filling production steps	Energy-efficient drying unit and direct transfer to electrolyte filler	15-20%	10-12%
Electrolyte filling in several steps and under vacuum	One-step filling with less electrolyte amount	0.2%	5-10%
Conventional formation and ageing	Improved energy and time efficient formation and ageing procedures	1-2%	8-10%
Conventional scrap rate of 5%	Reduced scrap rates of maximum 1%	n.a.	1-3%



Source: EMPA, Green Batteries Conference 2021.

RECENT TRENDS

Extrusion

UV curable binder

Scrap rate minimisation

ALD

Protective Coatings

Laser processing

Freestanding electrodes

3D Printing

Lamination

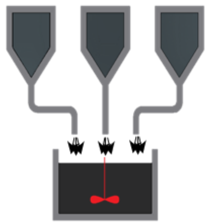
Spray deposition

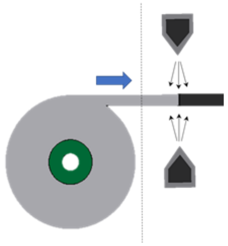
Solvent-free electrode manufacturing

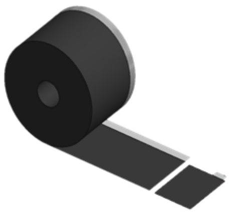
Design 4 Manufacturing

Design 4 Recycling

EXAMPLE #2 BATWOMAN PROJECT

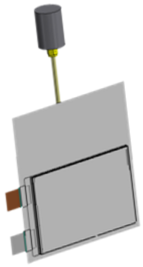


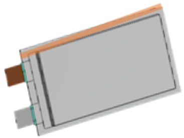




Raw materials	Sustainable materials‘ supply chain Reduction of electrolyte, solvents and other inactive materials
Slurry mixing	Water-based slurry processing Increase of dry mass content
Coating	Processing of highly viscous slurries for anode and cathode
Compacting	Compacting and electrode drying in a combined unit
Electrode cutting	Laser-cutting to increase cell performance and efficiency

EXAMPLE #2 BATWOMAN PROJECT





Electrode drying	Development of energy efficient drying concepts in stack configuration
Cell stacking	Combined cell stacking and electrolyte filling
Electrolyte filling	Improved wettability and accelerated filling process through 3D patterned electrodes
Formation & ageing	Digitally-driven improvement of cell formation & ageing procedure
Degassing & sealing	Safer, sustainable BatWoMan cell with increased lifetime

COLLABORATIVE NETWORK – CURRENT EUROPEAN PROJECTS

3BELIEVE

LIPLANET

SENSE

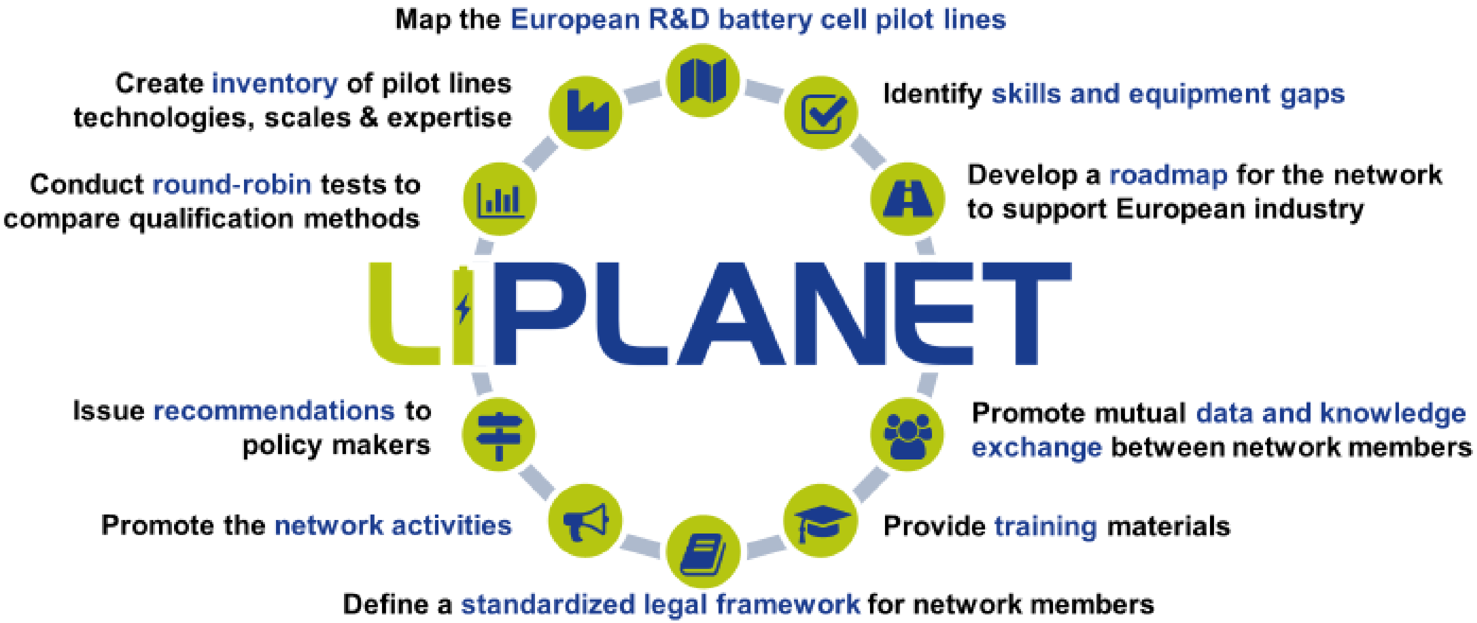
sense-battery.eu

sensibat

BATTERY 2030+

NETWORKING ACROSS EU

The objective of the LiPLANET Network of research pilot lines for lithium battery cells is to create a European innovation and production ecosystem



LET Employees

THANK YOU!

Marcus Jahn

Battery Technologies, Center for Low-Emission Transport

Marcus.jahn@ait.ac.at

+436648251081