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Fraunhofer Twin Transition Series

Green beginnings for End-of-Life Batteries: The potential of reuse, repair and recycling

October 24, 2022

Green beginnings for End-of-Life Batteries: The potential of reuse, repair and recycling

Fraunhofer Twin Transition Series

13:00 p.m. **Moderation by Verena Fennemann**
Head of Fraunhofer EU-Office Brussels

Welcome and introduction by Prof. Dr. rer. nat. Jens Tübke
Fraunhofer Battery Alliance

13:10 p.m. **Setting the scene by Malte Gallée**
Patron of the webinar; Member of the European Parliament

13:20 p.m. **Expert presentation I "The need for a harmonised LCA approach for the battery value chain" by Prof. Dr.-Ing. Thilo Bein**
Fraunhofer Institute for Structural Durability and System Reliability LBF

Expert presentation II "A question of sustainability and raw material independency: Technological pathways to recycle critical battery materials" by Dr.-Ing. Mareike Partsch
Fraunhofer Institute for Ceramic Technologies and Systems IKTS

13:45 p.m. **Discussion**

14:00 p.m. **End of the event**

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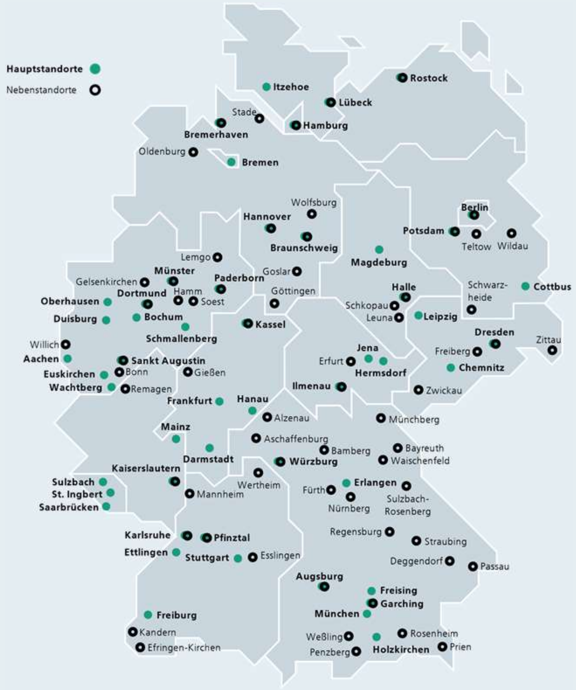
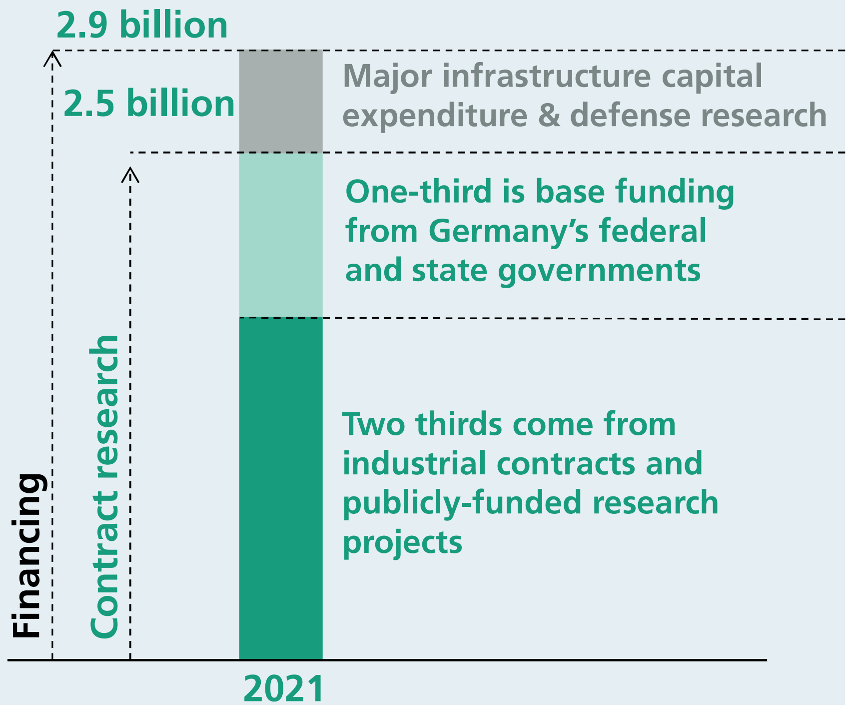
At a glance

Applied research with a focus on key future-relevant technologies and the commercialization of findings in business and industry. A trailblazer and trendsetter in innovative developments.

> 30,000 employees

76 institutes and research units





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Welcome and introduction

Prof. Dr. Jens Tübke

Fraunhofer Battery Alliance

Electrochemical Storage - Batteries

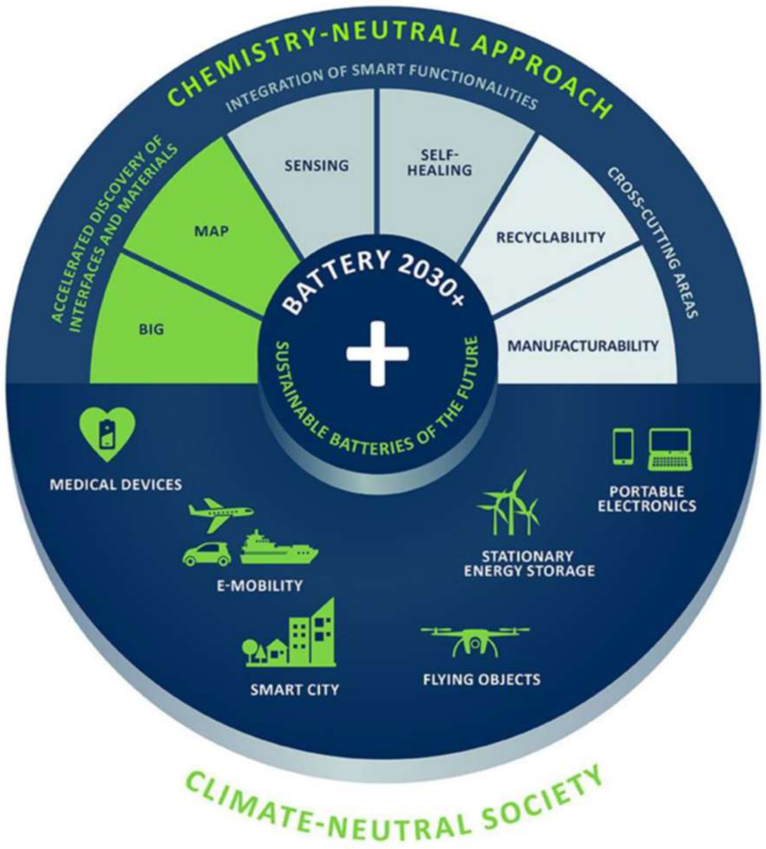
EU Battery2030+

Key facts:

If batteries can be made simultaneously more sustainable, safe, ultra high performing, and affordable, they will be true **enablers**.

Shift towards sustainable and **smart mobility**; supplying clean, affordable and secure **energy**; and mobilizing industry for a clean and circular economy.

Batteries are a key technology for battling carbon dioxide **emissions** from the transport, power, and industry sectors.



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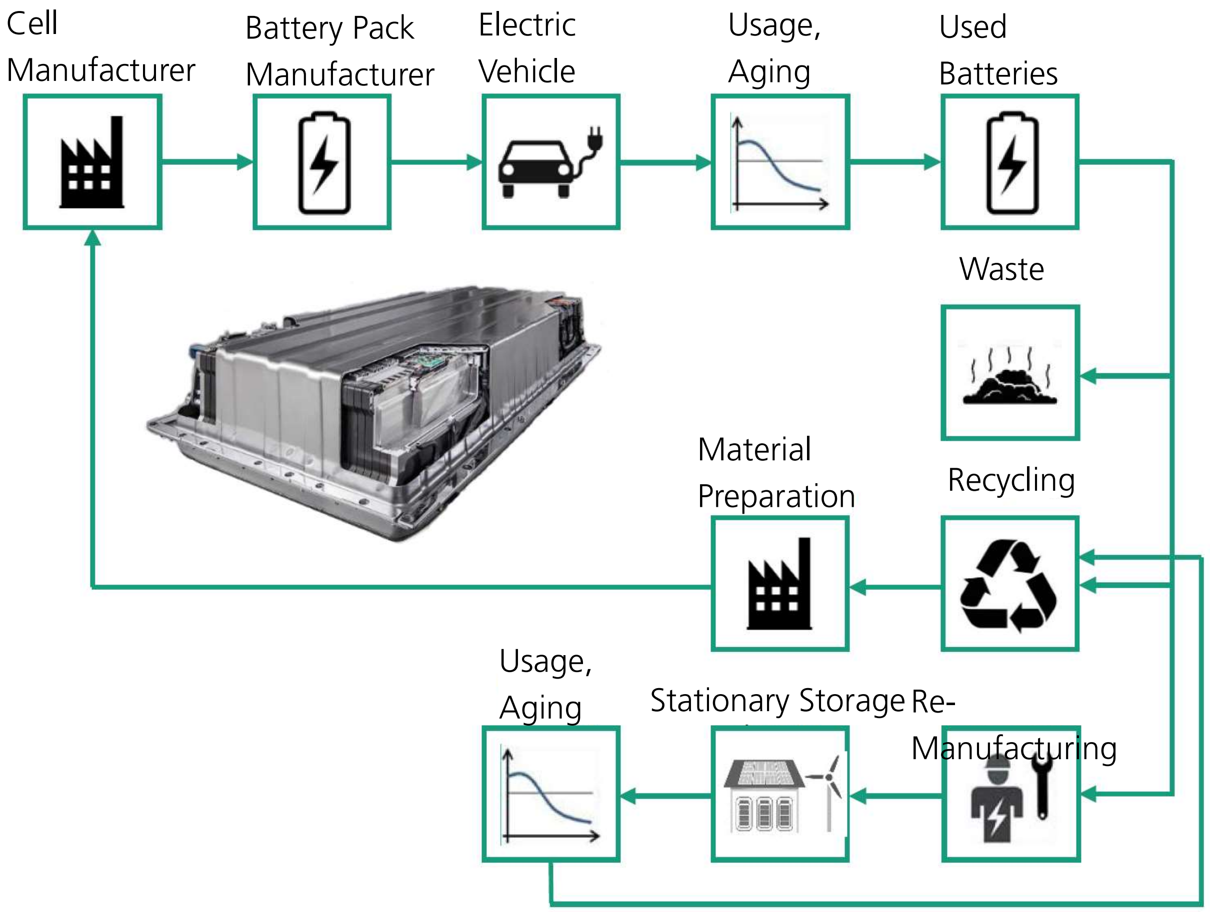
Fraunhofer Battery Research

Reuse– Repair – Recycling?

But

To meet the expectations placed on batteries in terms of climate protection and resource conservation, circular value creation is required, from the raw materials to the cell, battery, usage phase and recycled materials.



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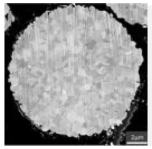
Lithium ion batteries State of the art

Development strategies from the perspective of automotive engineering

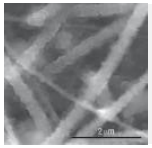
- **Low cost**
- **High energy density**
- **Fast charging capability**
- **Lifetime**
- **Environmentally friendly**
- **Safety**

Innovation technologies



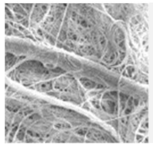
High nickel-rich cathodes

- Particle doping/coating



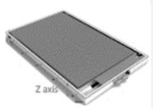
Silicon based anodes

- Advanced materials and specific compositions



Advanced inactive materials

- CNTs, Ultra Thin Separators & Electrolyte Formulations



Cell design

- C2P, Lightweight & Safety Materials

Solid-state technology

- Solid state or hybrid methods with polymer, sulfide or oxide electrolytes

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Fraunhofer Battery Research

Battery Alliance

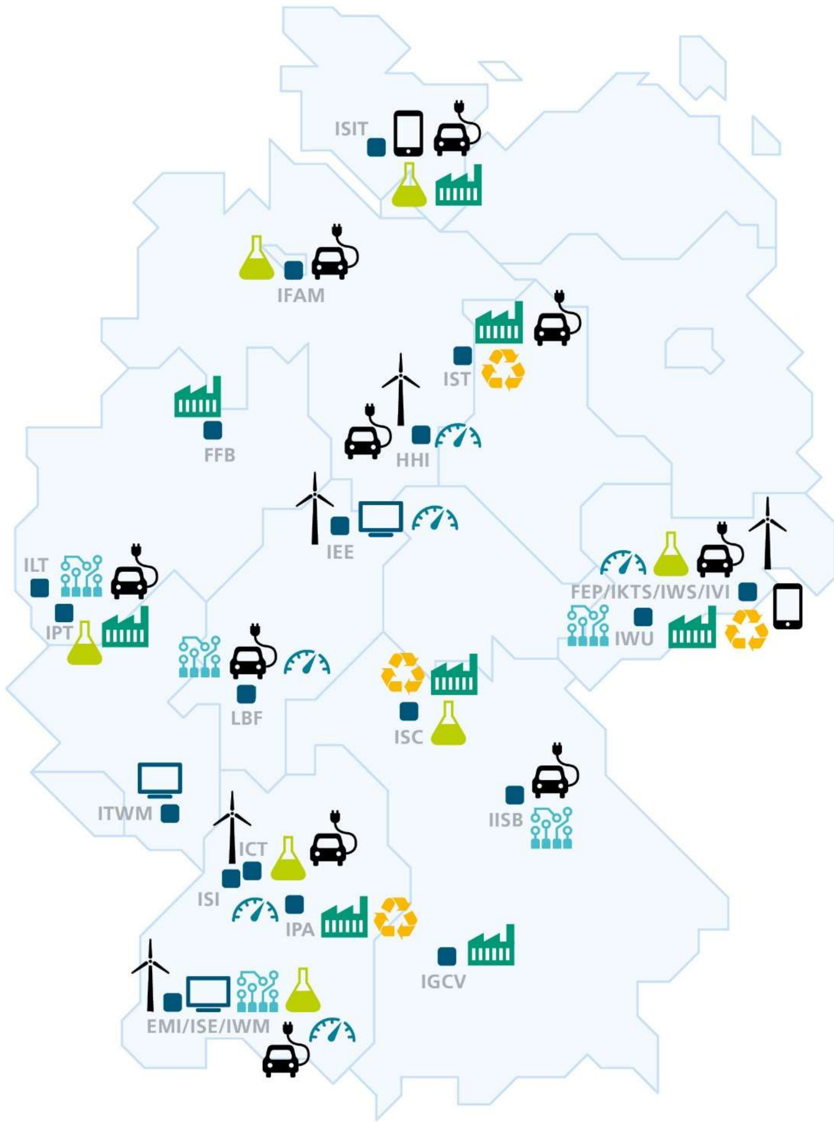
Competence map of Alliance Batteries

Competencies of the 24 member institutes along the entire value chain

- Material & Cell
- Cell production
- System & Integration
- Test & Evaluation
- Simulation
- Recycling & LCA

Markets addressed

- **Mobile storage** (**Electromobility**, Heavy Duty, Rail, Aviation)
- Stationary storage
- Powertools/ Consumer



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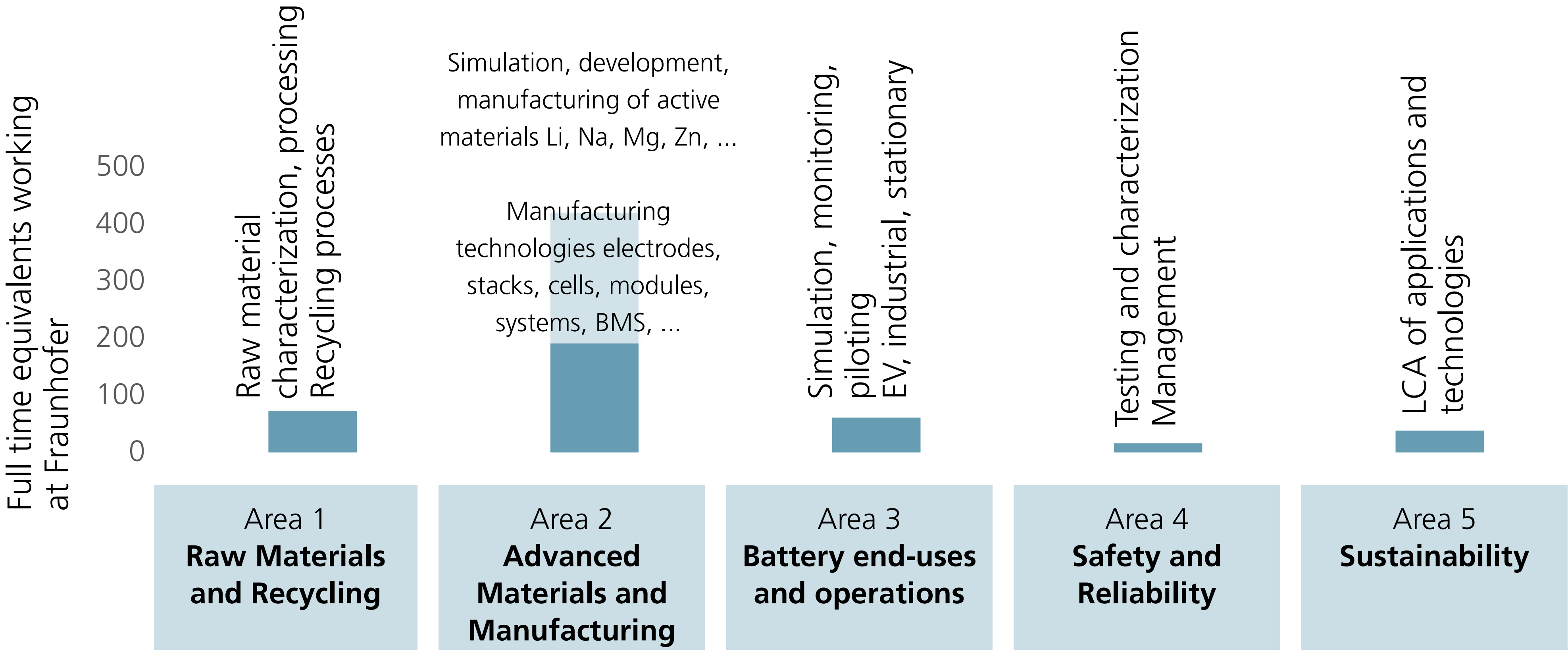
Fraunhofer Battery Research

Mapping of Fraunhofer battery competencies within the R&I areas in the SRIA

Total of 600 FTE at Fraunhofer working on battery technology development in all SRIA R&I areas



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Research management and foresight

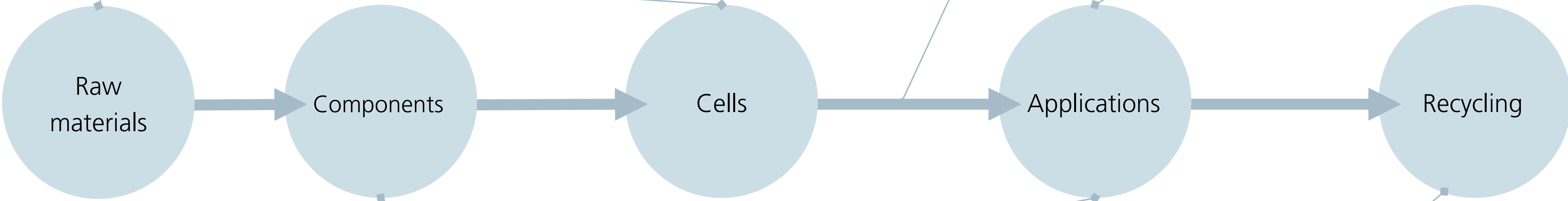
Battery Technology Roadmapping at Fraunhofer

- More efficient extraction processes for raw materials
- New ways to extract lithium (e.g. from sea water)

- Novel cell designs: solid-state batteries (SSB)
- Novel chemistries: Na-ion batteries, Zn batteries, etc.
- Improved production technologies (e.g. wet processing with green solvents, dry processing)

- Improvements in packaging design and technologies (e.g. Cell2Pack)
- Improved battery management systems (BMS)

- Emerging business cases for 2nd life applications
- Battery Passport



- Novel chemistries for LIB:
  - Anodes: Si-rich anodes; Li metal anodes
  - Cathodes: NMCs with higher Ni and Mn contents; NMCAs; LMFPs; sulphur (long term)
  - Solid electrolytes -> solid-state batteries
- Components for novel battery chemistries: Na-ion batteries, Zn batteries, etc.

- Strongly increasing demand from BEV and EES
- Electrification of further applications, such as trucks (also long haul), short distance planes, ships, etc.

- Improvement and scale-up of existing recycling processes (hydrometallurgical / pyrometallurgical)
- novel recycling processes, e.g. "direct recycling"
- Battery Passport

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Setting the Scene

Malte Gallée

Member of the European Parliament

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The need for a harmonised LCA approach for the battery value chain

Expert Presentation I

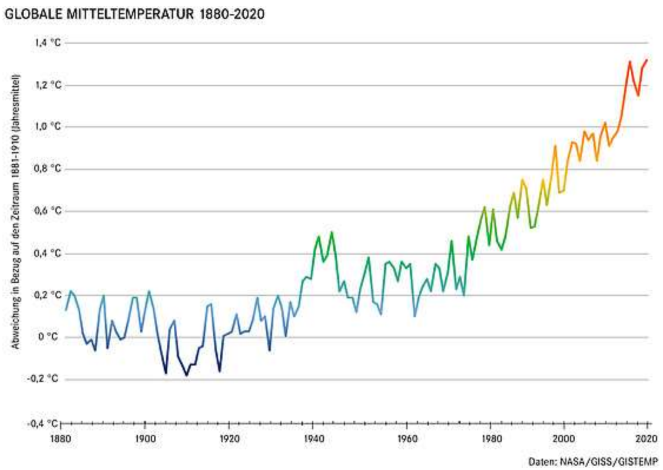
Prof. Dr.-Ing. Thilo Bein

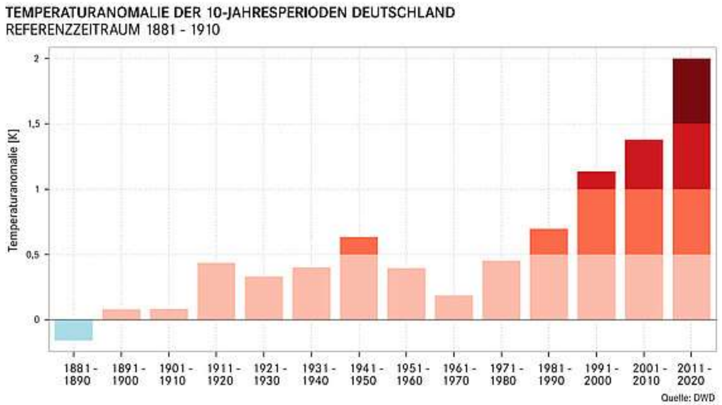
Fraunhofer Institute for Structural Durability and System Reliability LBF

Climate Change

We have to act now

- **Global warming**
  - Limiting global temperature rise < 2,0 °C is a global challenge
- **More and more weather extremes**
  - Heavy rain and floods
  - droughts
  - Storms
  - fires





Source: www.deutsches-klima-konsortium.de

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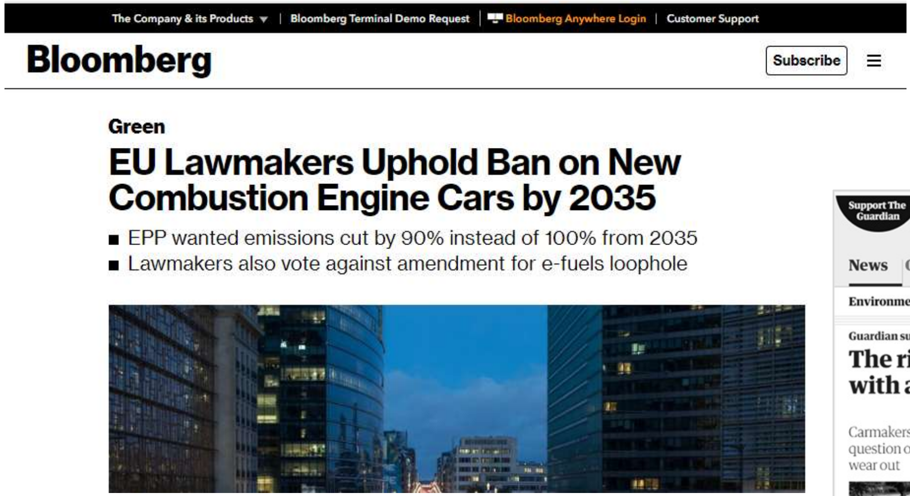
Challenge of future vehicles and systems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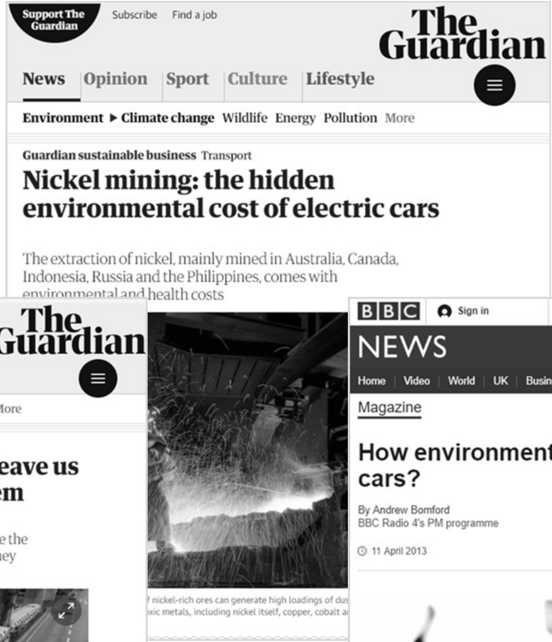
Green

EU Lawmakers Uphold Ban on New Combustion Engine Cars by 2035

- EPP wanted emissions cut by 90% instead of 100% from 2035
- Lawmakers also vote against amendment for e-fuels loophole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Nickel mining: the hidden environmental cost of electric cars

The extraction of nickel, mainly mined in Australia, Canada, Indonesia, Russia and the Philippines, comes with environmental and health costs


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Guardian sustainable business Rethinking business

The rise of electric cars could leave us with a big battery waste problem

Carmakers, recyclers and tech startups are working to solve the question of how to deal with lithium-ion batteries when they wear out

▲ New electric vehicles parked in a parking lot under a viaduct in Wuhan, central China's Hubei province. The number of electric cars globally has just passed 2m. Photograph: STR/AFP/Getty Images


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Magazine

How environmentally friendly are electric cars?

By Andrew Bomford
BBC Radio 4's PM programme

11 April 2013

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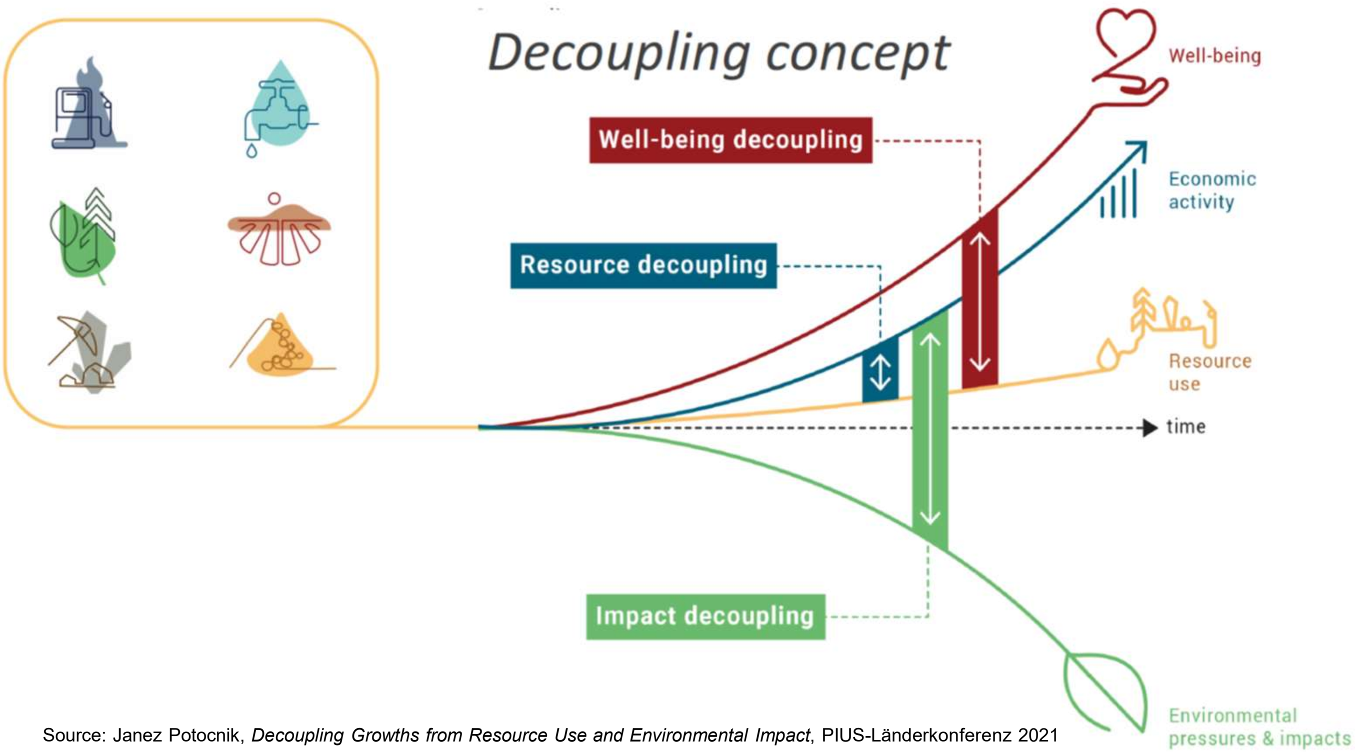
Transforming the European Road Transport System

The Decoupling Concept

- Global resource use has more than tripled since 1970
- Global material demand per capita grew from 7.4 tons in 1970 to 12.2 tons per capita in 2017
- Material productivity started to decline around 2000 and has stagnated in the recent years



Source: Janez Potocnik, *Decoupling Growths from Resource Use and Environmental Impact*, PIUS-Länderkonferenz 2021

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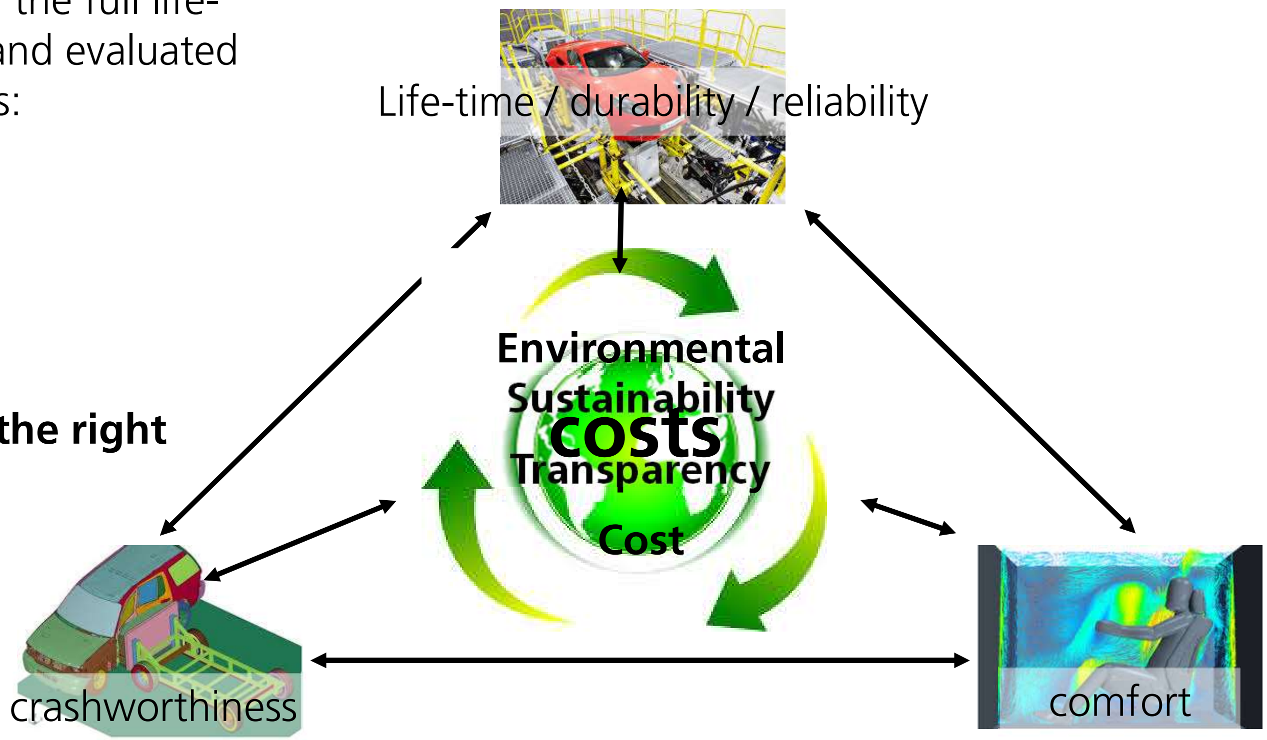
Challenge of future vehicles and systems (e. g. battery)

The **ecological footprint** of a product over the full life-cycle (cradle to cradle) must be considered and evaluated already in the product development process:

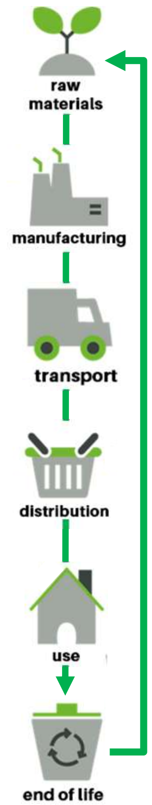
- energy- and GWP-balance
- EoL-strategies (recycling, re-use,…)
- costs (Total Cost of Ownership)

and must be the basis for the **selection of the right technology.**



Challenges for a harmonized assessment of the ecological footprint

- **Standardised and comparable (real) data are missing.**
- **Harmonised methods and tools for affordable (in terms of cost and time) and easy-to-handle assessment of the ecological footprint are needed.**
- **Strategies and definitions** for consistent circular economy approaches (e.g. categories like share of recovered materials, energy efficiency of recycling process …) are missing.
- **Knowledge and skills** for LCA and CE are lacking.
- **LCA- and circular economy-based solutions are not implemented** on a wide scale.
- **Communication and acceptance** of LCA- and circular economy-based solutions.



Source: 2ZERO SRIA, Cluster 4

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Research needs for the battery value chain

Data for comparable and reliable assessments

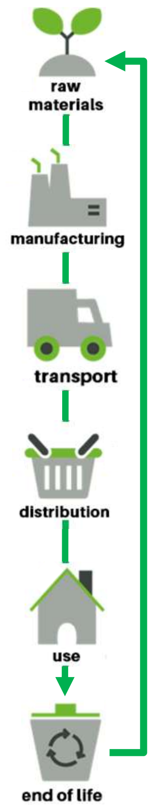
- Life-cycle inventory (LCI) data base beyond the batterie pass
- Monitoring of the ecological footprint over lifetime

Methods and Tools

- Methods and tools for LCSA tailored to the battery value chain
- Social LCA for the battery value chain
- Methods, tools and processes for circular economy approach for the battery value chain → Recycling, Re-Use and Repair
- Development of approaches/methods and tools for system-wide life-cycle and CE strategy modelling

Assessment and demonstration

- Assessment of application scenarios
- Development and demonstration of CE strategies for battery value chain



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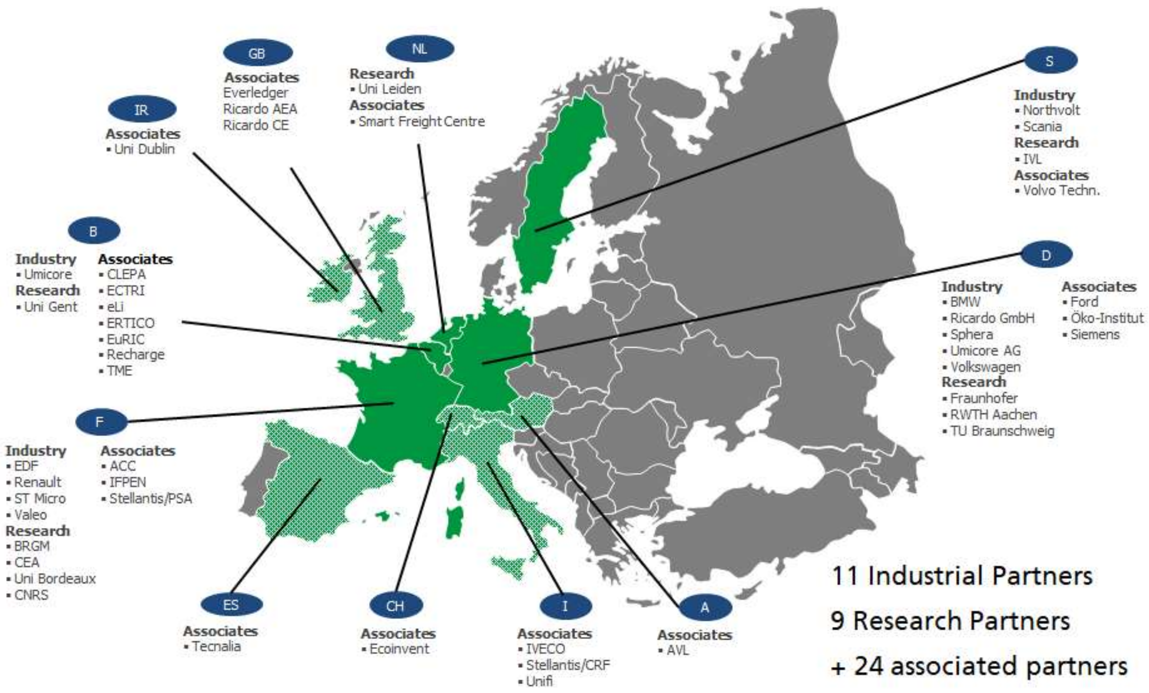
The Coordinated and Support Action (CSA) TranSensus LCA

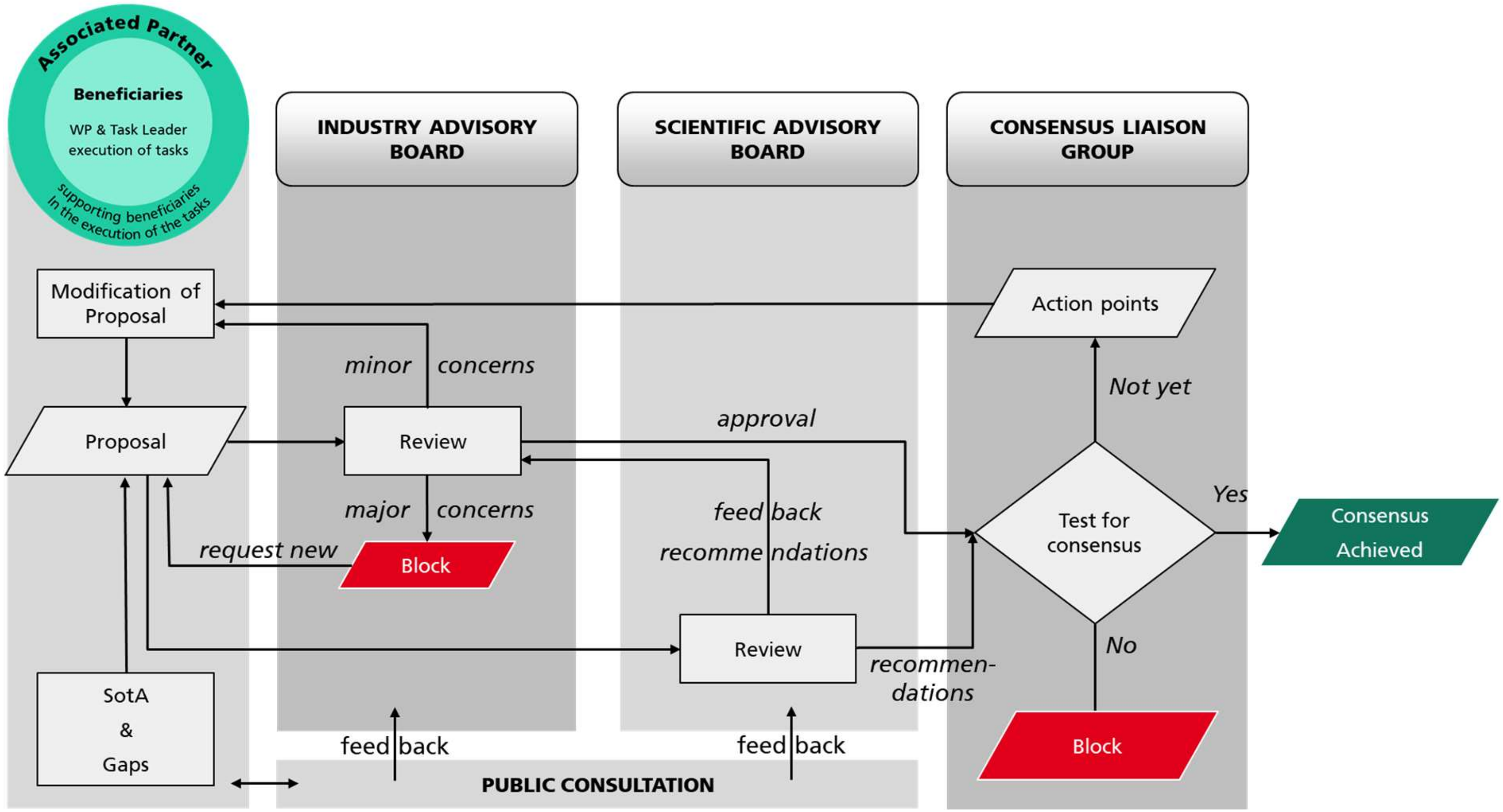
Commonly accepted and applied single LCA approach for zero-emission road transport and the battery value chain

- Conceptualize and demonstrate a single, European-wide real-data LCA approach for zero-emission road transport
- Harmonization of methodologies, tools and datasets
- Elaborate an ontology and framework for a European-wide LCI database
- Conceptualize LCI data management and update along the life cycle and along the supply chain
- Upcoming technologies and demands.
- Paving the way for LCA-based product and business development



TranSensus LCA
Fraunhofer

Decision Making Process



A question of sustainability and raw material independency: Technological pathways to recycle critical battery materials

Dr.-Ing. Mareike Partsch

Fraunhofer Institute for Ceramic Technologies and Systems IKTS

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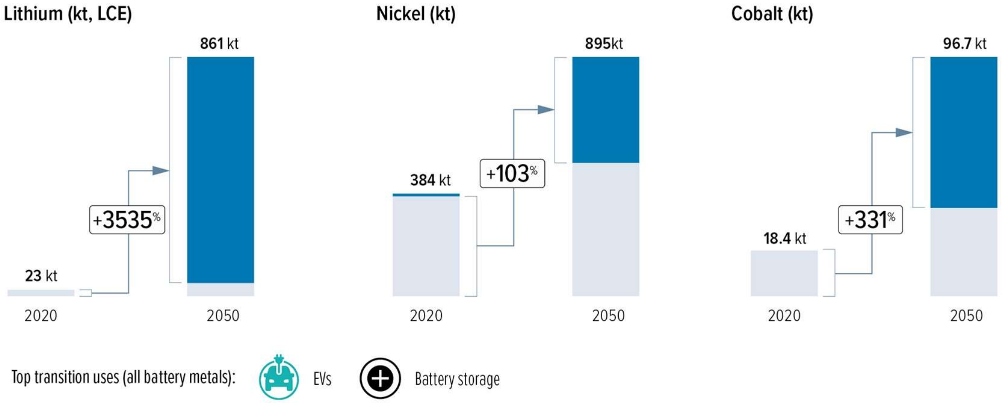
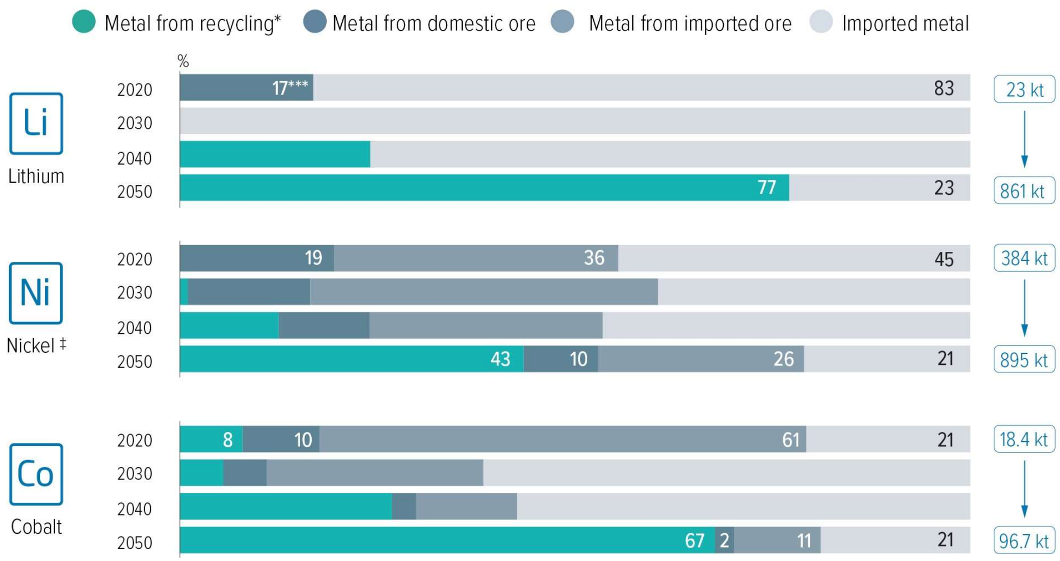
Critical battery materials

Increasing demand and ways to cover that

Significant supplies of nickel, lithium, and cobalt required to cover future scenarios -> Europe will need to develop new recycling capacity

The first generation for electric vehicle batteries will start reaching end-of-life in significant volumes after 2035.
By 2050, recycling can give Europe a major supply source if batteries reach EU recyclers and new recovery technologies are commercialized.
(https://www.eurometaux.eu/metals-clean-energy/)





*** This does not represent battery grade lithium, but spodumene destined for the ceramics market
‡ Today nickel is recycled as part of stainless steel but not as pure nickel

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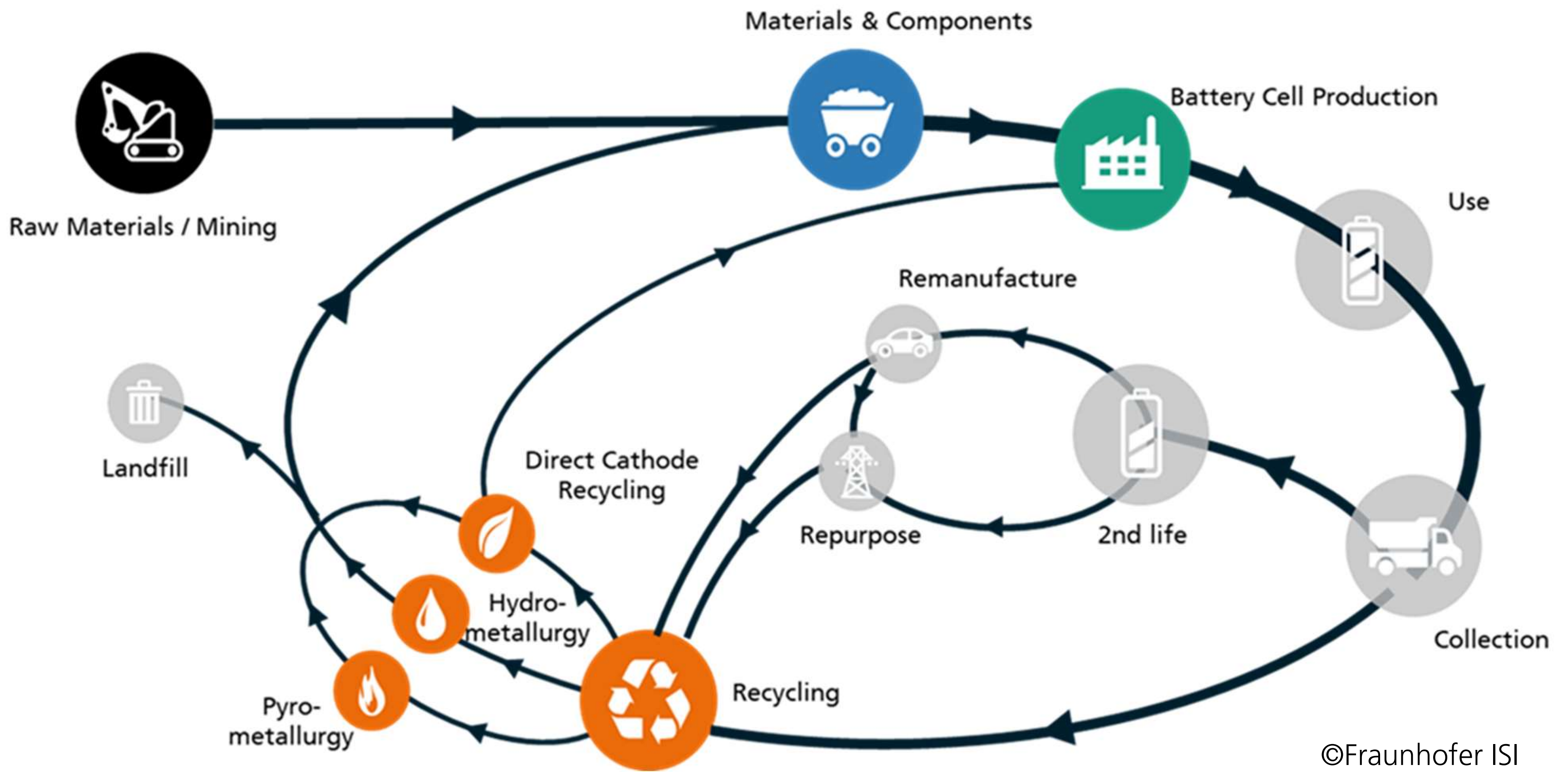
Eficient use of raw material along the whole value chain

Rethink, Reuse, Repair, Recycle



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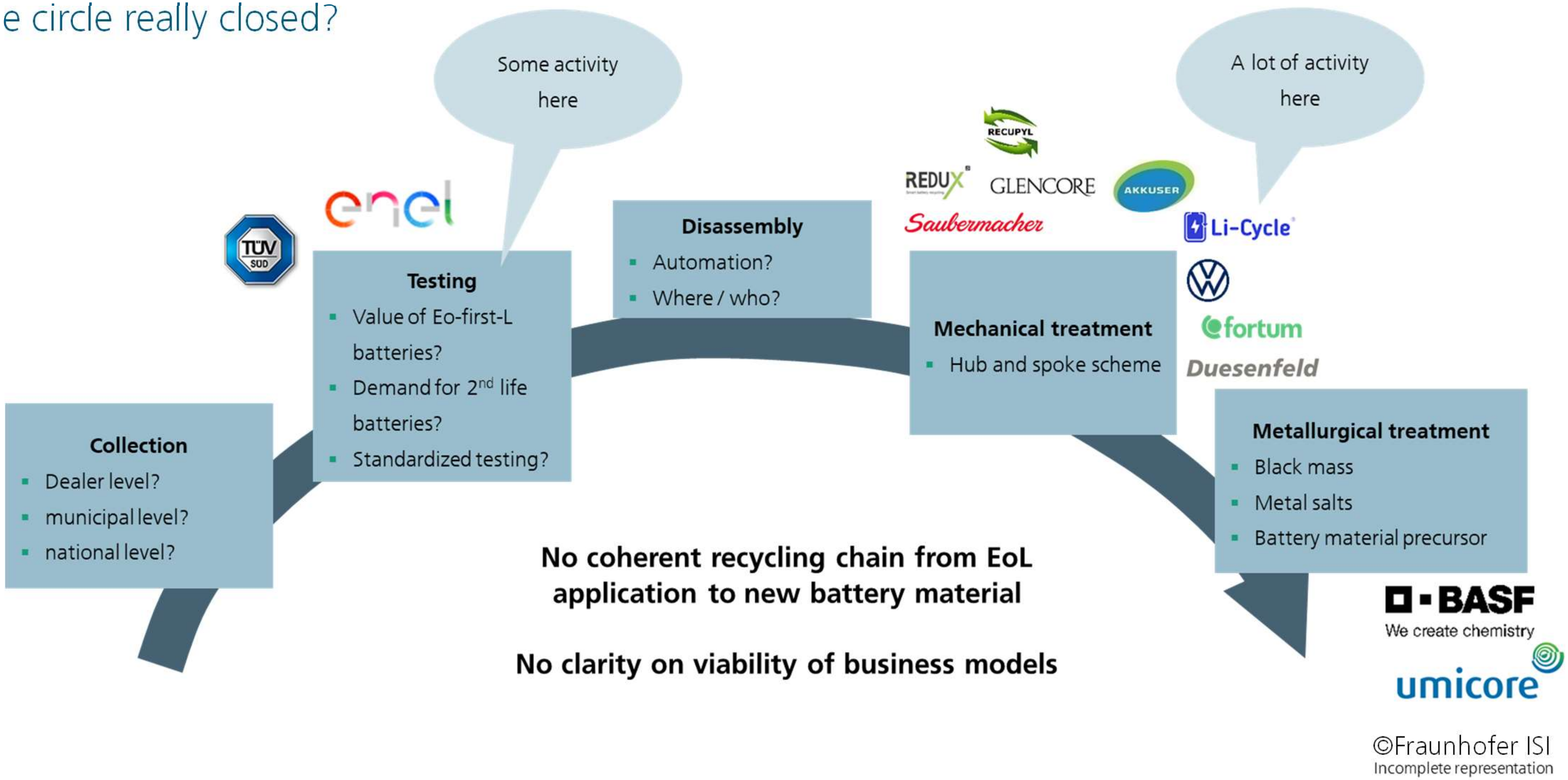
Battery recycling

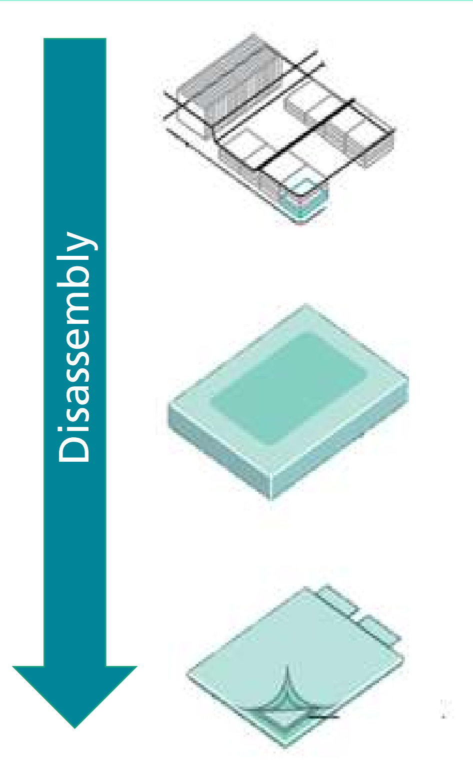
Is the circle really closed?



Disassembly at pack, module and cell level

Key process to efficient recycling

Grant: 03XP0318B



Recovered parts	Challenges
• Electronics • Cables • Modules	• Connector removal • No data about battery condition • residual charge → safety issues • Fire hazard
• Housing • Terminals • Cell	• Removal of adhesive between cells • solder joints • Module SoC sometimes unknown
Li 3 Lithium 6.941; Ni 28 Nickel 58.69; Mn 25 Manganese 54.94; Co 27 Cobalt 58.93; Cu 29 Copper 63.55; Al 13 Aluminium 26.98; C 6 Carbon 12.01 PP PVDF Electrolyte	• Good separation of anode and cathode • Contamination and mixing of polymer components • Gas generation HF (from conducting salt) • Changing compositions and materials

Harper, Gavin; Sommerville, Roberto; Kendrick, Emma; Driscoll, Laura; Slater, Peter; Stolkin, Rustam et al. (2019): Recycling lithium-ion batteries from electric vehicles. In Nature 575 (7781), pp. 75–86. DOI: 10.1038/s41586-019-1682-5.

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RecyLIB

Direct recycling of lithium-ion batteries

RecyLIB aims to establish sustainable, low-energy and higly efficient manufacturing and recycling chains for lithium-ion batteries

Six partners from 3 countries:
Fraunhofer ISC, ImpulsTec GmbH
Hutchinson, Ghent University, CEPA, BayFOR

Fraunhofer's contribution

- Cell assembly and testing
- Deagglomeration of black mass
- Material selective separation of black mass
- Regeneration of aged cathode materials

read more:

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fwo Opening new horizons

ADEME Agence de l'Environnement et de la Maîtrise de l'Energie

ERA-MIN has received funding from the European Union's Horizon 2020 Research and Innovation Programme (Grant agreement No. 101003575 ERA-MIN3)

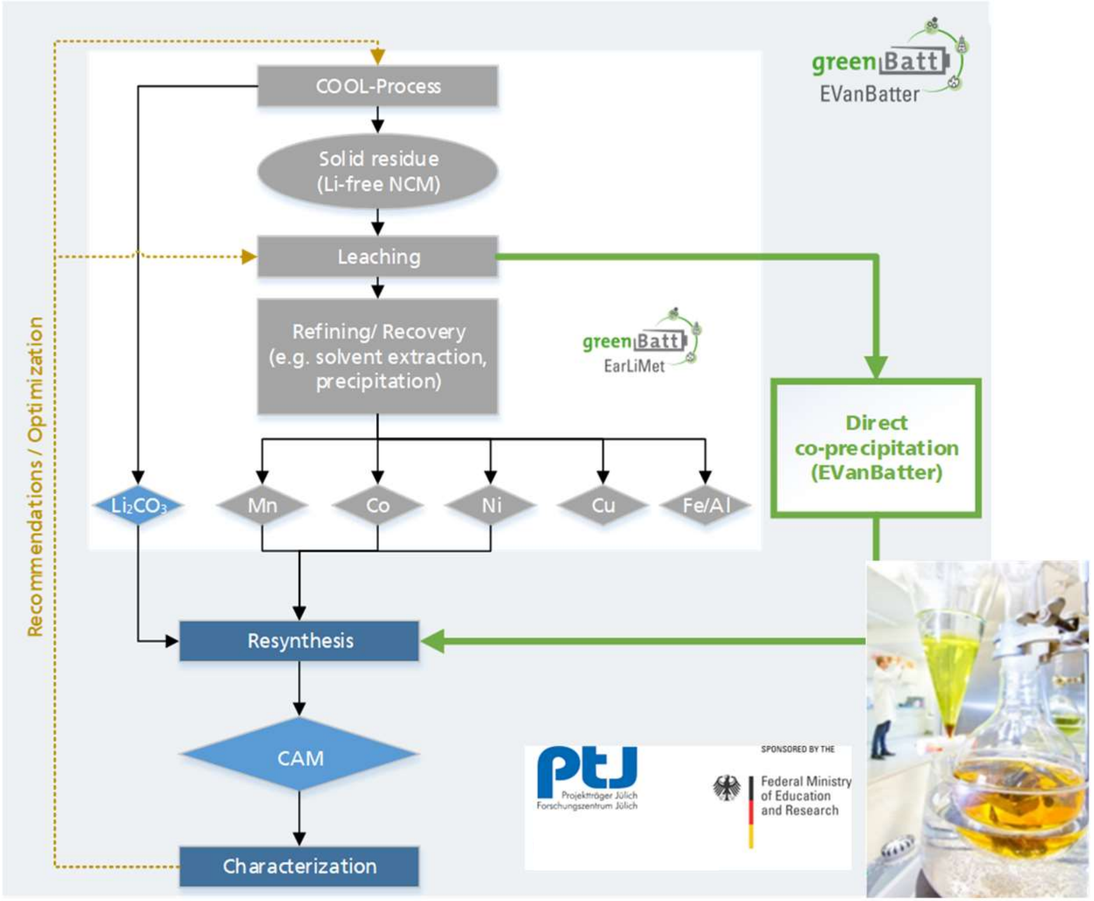
RecyLIB

Recycling and Resynthesis of Cathode Materials

How to bring critical raw materials back into the cycle

Fraunhofer's contribution

- Further development and adaptation of hydrometallurgical processes for optimized and cost-efficient recovery of Co, Mn, Ni and Li as priority valuable metals
- Recovery of components such as phosphorus, fluorine, etc.
- Use of membrane separation processes, electrochemical processes, leaching, precipitation, selective adsorption and liquid-liquid extraction,
- Purification and recycling of leaching and other chemicals (leaching chemicals, extraction agents, diluents, precipitants), process water and waste water produced
- Complete material balancing across all scale-up capable sub-processes and cost evaluation
- Investigations on masking/complexation or removal of impurities (Cu, Al, and Fe)



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Synopsis

Challenges and policy recommendation

Lithium-ion battery storage is an essential component of a future energy economy

From production to use and recycling: innovative solutions are still needed to save resources and costs --> further need to strengthen research for EoL scenarios of batteries

Circular economy will need legislative as well as political support, motivation and guideline, e.g.

- Implementation of new Battery Directive
- Establish a harmonized standard for LCA and the supporting data
- Provide legal framework that material flows can be retained in Europe

We need to be fast! Recycling is one crucial part for ensuring material basis for future battery manufacturing!

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Discussion

Verena Fennemann

Head of Fraunhofer EU Office

Pose your questions either directly to the speakers or write them in the chat – we will then ask the question for you!

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European Learning Lab Battery Cells by Fraunhofer FFB

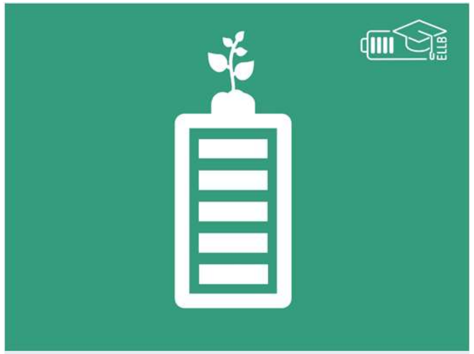
Webinar series for the battery sector

1. European battery eco-system

Nov 2, 2022 - 3pm

- European battery eco-system
- Pricing
- Key players & resources along the value chain

Registration open!

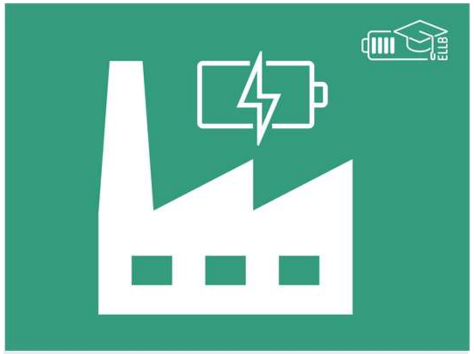


2. Material Cycle of LIB

Nov28, 2022 - 1pm

- Material cycle of LIB
- Challenges in the production process
- Recycled materials

Registration open!

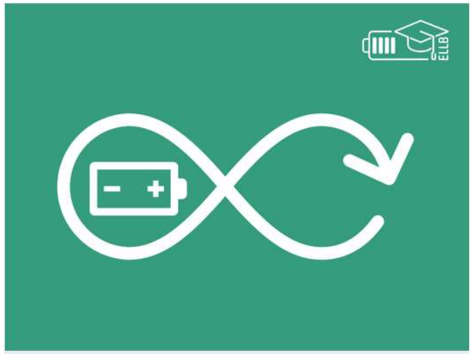


3. Sustainable battery cell production & Digital twin

Jan 3, 2023 - 1pm

- Sustainability
- Innovation
- Problems of classic LIB production
- Use of digital twins

Pre-Registration open!



4. Forecast of the battery value chain

Mar 27, 2023 - 1pm

- Employment effects
- Challenges
- Political, strategic, economic and social future perspective

Pre-Registration open!

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Fraunhofer Technology Experience

Register now!

For more information and registration: s.fhg.de/techx

Contact information

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For more information on the Fraunhofer Twin Transition Series:
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