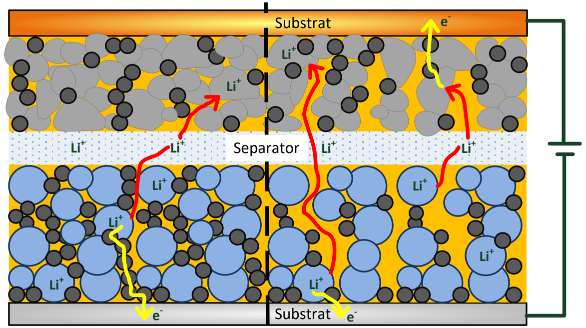
Driving electric mobility with the circular economy of traction batteries

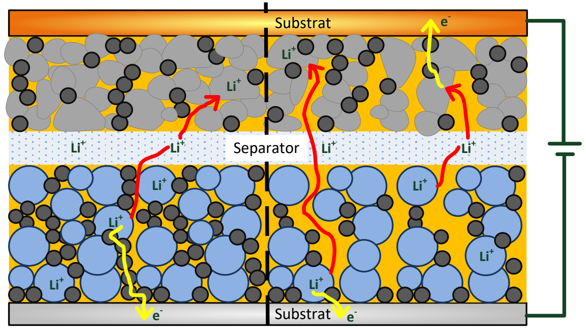
Prof. Dr.-Ing. Arno Kwade

Institute for Particle Technology & Battery LabFactory of TU Braunschweig

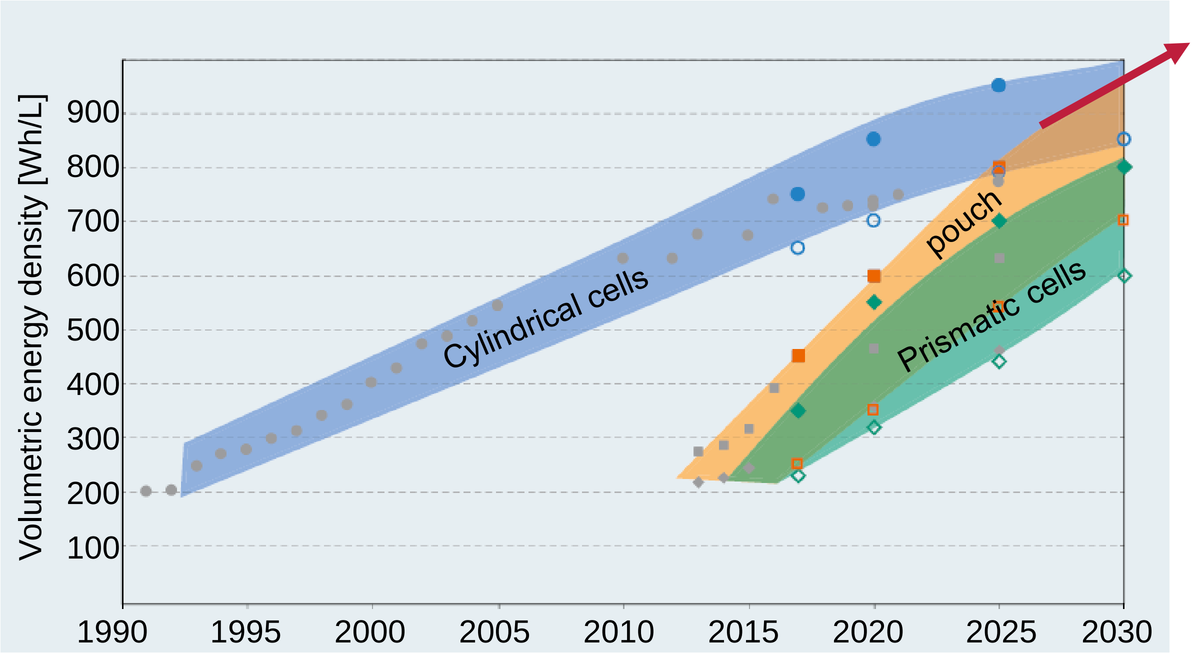
Content



Content


Substrat
e-
Li+
Li+
Li+
Li+
Separator
Li+
Li+
Li+
Li+
Li+
Li+
Li+
Li+
Substrat
e-
e-

Performance of Lithium-Ion-Batteries

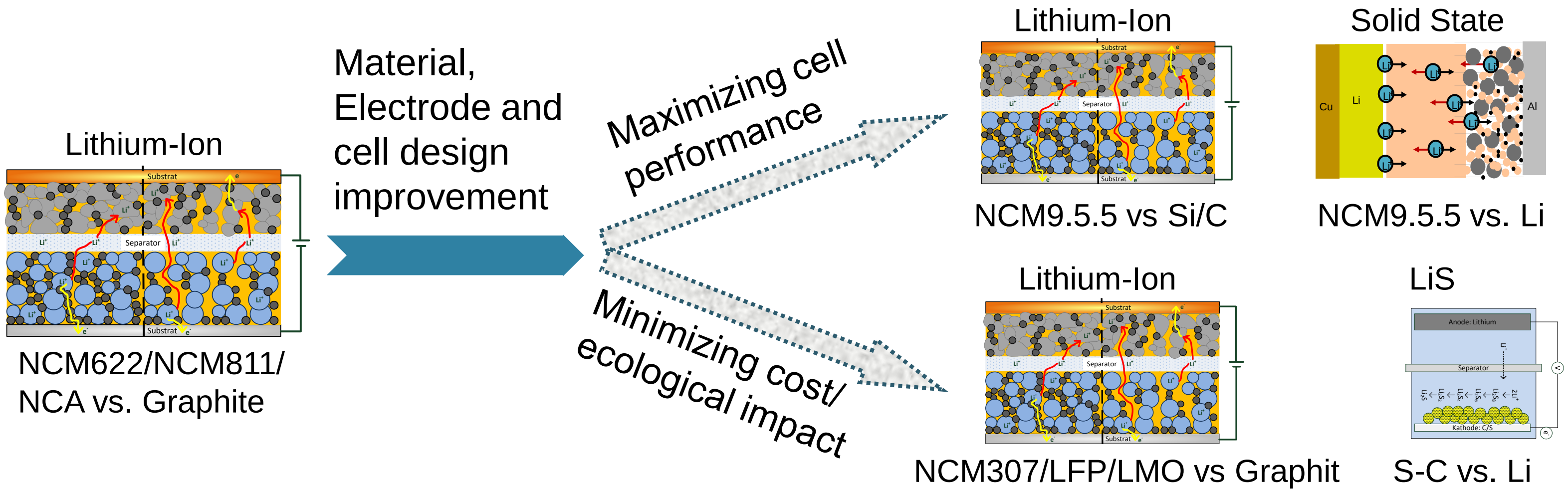


New battery types and technology

- LIB limit (pouch, prismatic, cylindrical) converges at a maximum of ~ 900 Wh/L
- Only novel battery technologies can provide higher volumetric energy densities

Source: Thielmann et al. 2017: Energy Storage Roadmap (update 2017) – High energy batteries 2030+ and prospects for future battery technologies, Fraunhofer ISI 2017.

Next Lithium-Ion Battery Generations – My Opinion

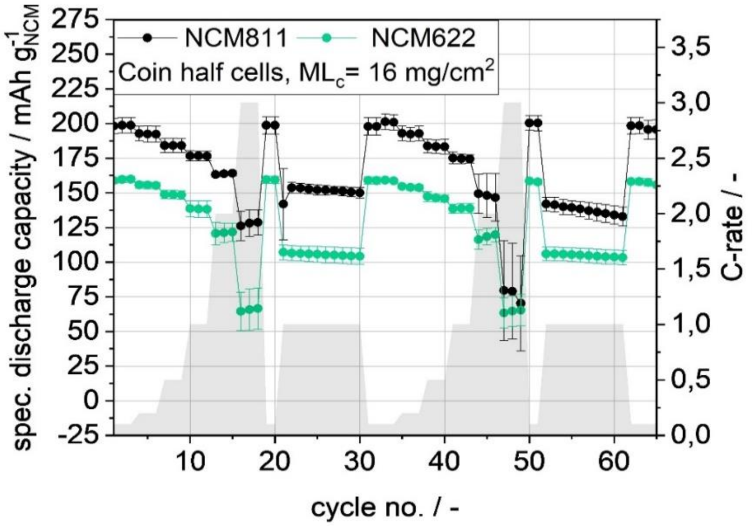


- Diversification of cell technologies, sizes and designs
- Different generations of high performance batteries will coexist
- Lower cost battery cells with better ecological footprint but lower performance will also be developed

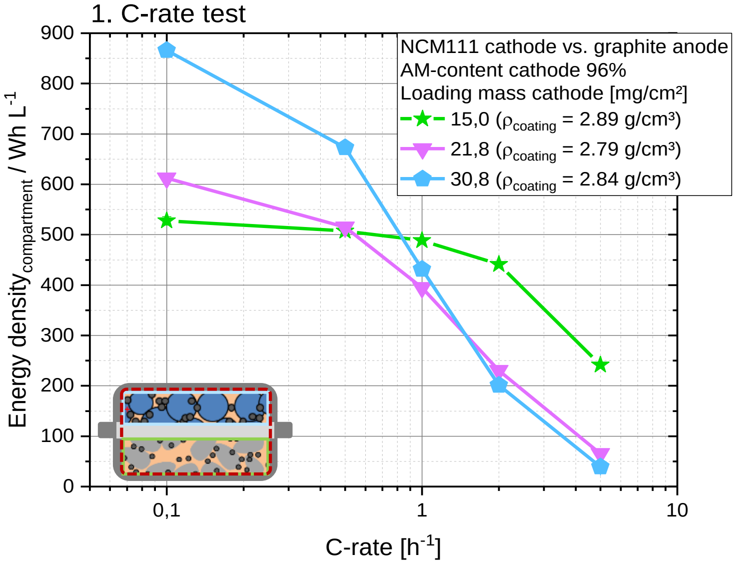
Doose, S. et al. *Metals* 2021, 11, 291. https://doi.org/10.3390/met11020291

Increasing energy density on cell level

- **Material improvement**
  e.g. use of **Nickel rich materials** like NCM811 show improved performance



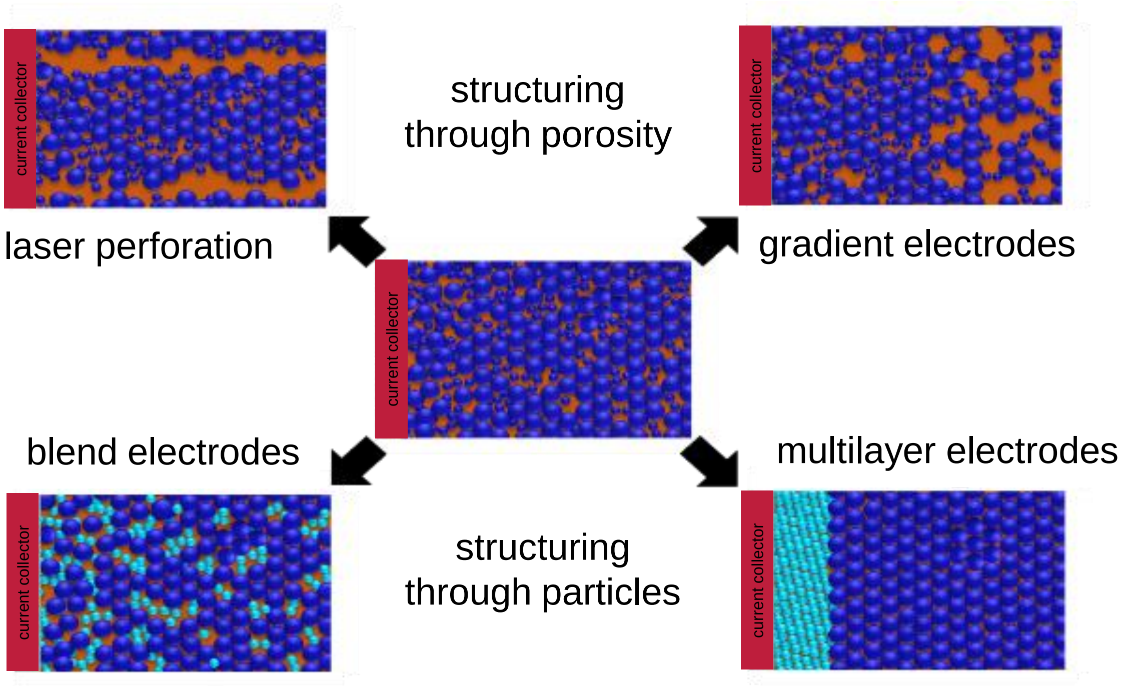
- **Electrode and cell design**
  e.g. increase of electrodes **mass loadings** can increase energy density



C. A. Heck *et al* 2020 *J. Electrochem. Soc*. https://doi.org/10.1149/1945-7111/abcd11

Structuring of thick high-energy electrodes

iPAT Institut für Partikeltechnik

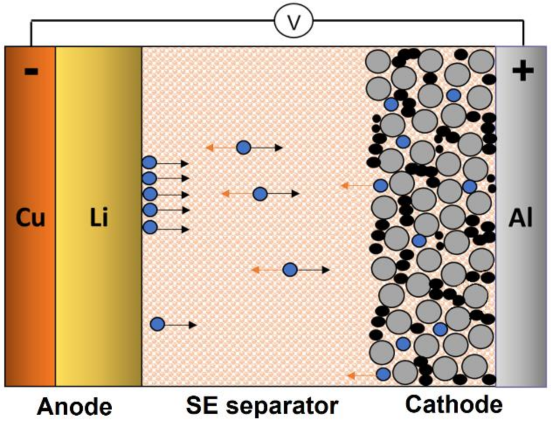


ProZell Kompetenzcluster zur Batteriezellproduktion

- By structuring fast tracks for Li ions can be created which reduce the ionic transport resistances

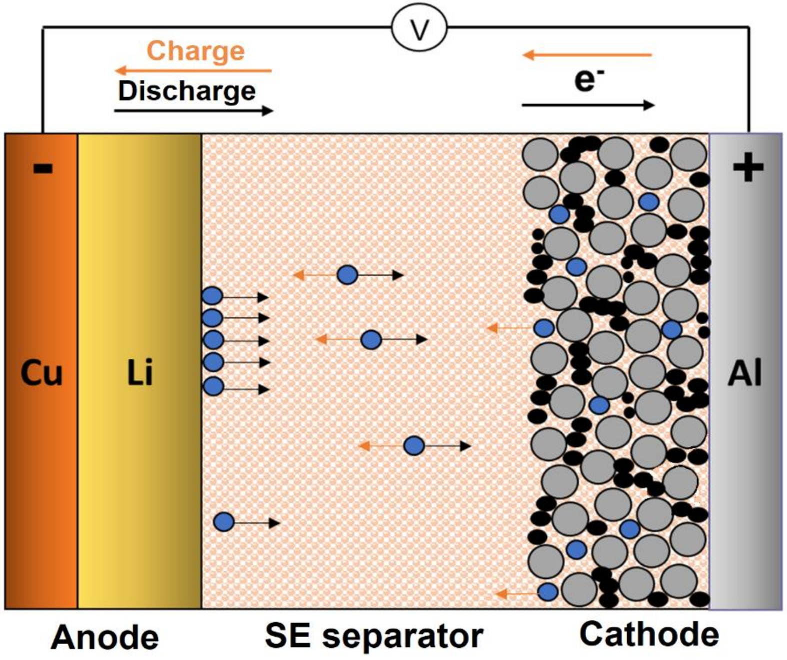
Source: BMBF project HiStructures within ProZell Cluster

Content

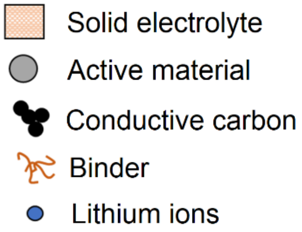


Lithium-ion based all-solid-state-battery - basics

iPAT Institut für Partikeltechnik



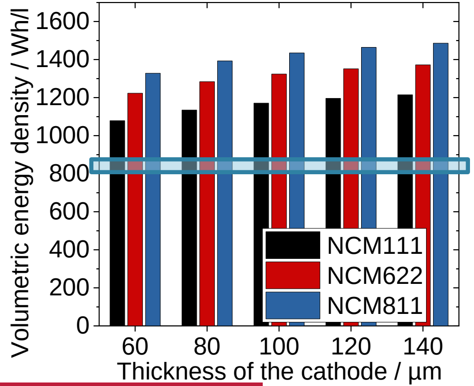
- Liquid electrolyte and porous separator are replaced by a solid electrolyte
- Main theoretical advantages:
  - Broader temperature window
  - Higher energy density (Wh/L)
  - Potential of higher ionic conductivity for fast-charging capability
  - Increased safety

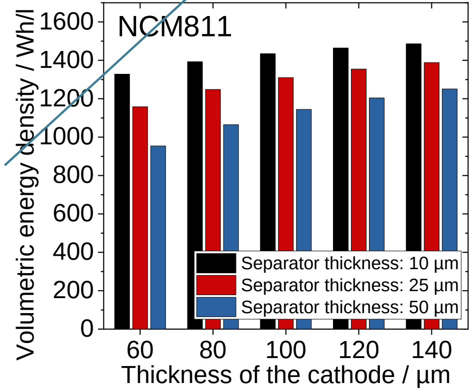


All Solid State Batteries
Performance and challenges

Calculation values		
Cathode	Active material	65.0 %
	Solid electrolyte	30.0 %
	Binder	2.0 %
	Conductive agent	3.0 %
	Al current collector (half thickness)	5 µm
Anode	Anode to cathode capacity ratio	130 %
	Cu current collector (half thickness)	4 µm

Liquid electrolyte target





Remaining challenges:

- Interfacial stabilities
- Scalability of production routes
- Ideal fabrication and operating pressures
- Requirements to production atmosphere

Availability on the market:

Polymers:

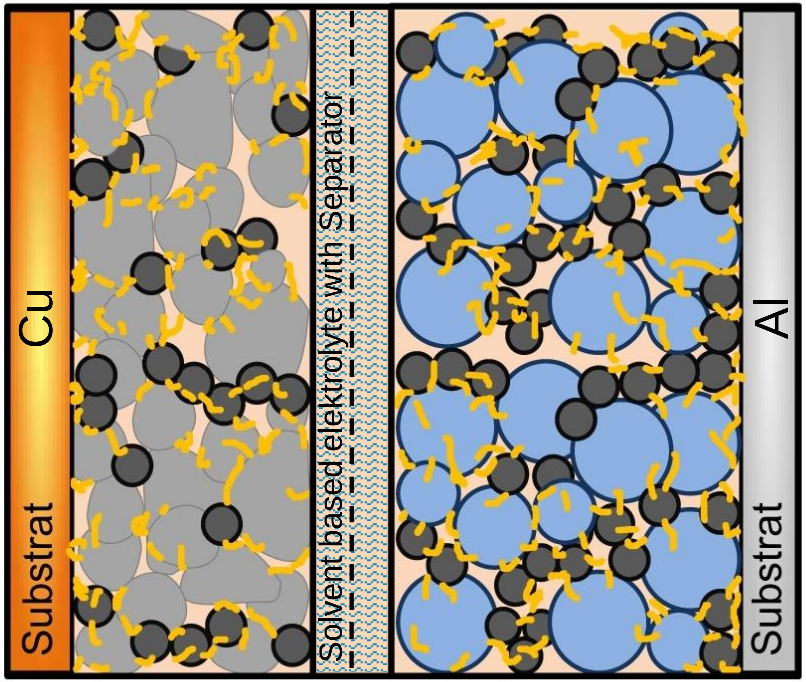
→ already available, but operation at 80 °C

Sulfides, oxides, halides:

→ 5-10 years

Content

Activities to increase sustainability

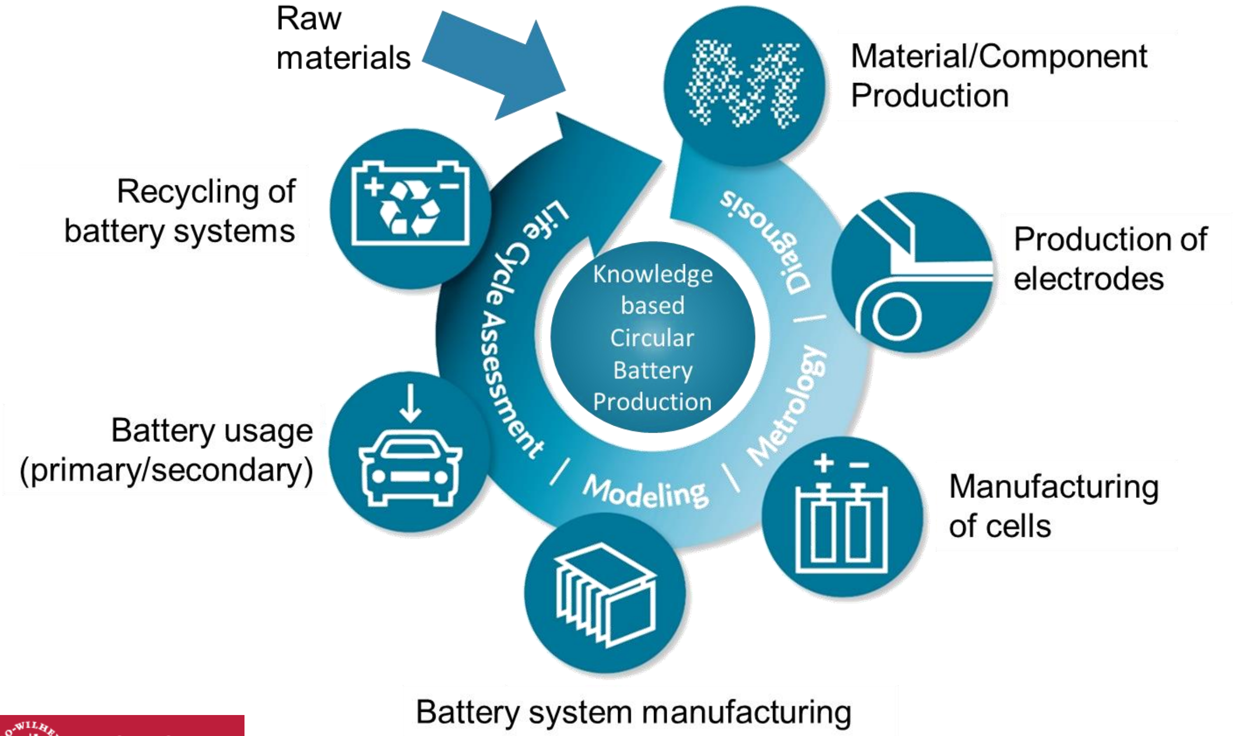


Anode Cathode

Decrease of CO_2**-footprint** under the one of today combustion cars:

- Water based binder or even better **dry processing of electrodes**
- Cathode materials without or **minimum amount of cobalt and nickel**
- **Thick electrodes** to reduce relative content of aluminium and cupper
- **Closed material cycles**

Circular Battery Production – main future goal of BLB



- Cycle materials and keep them in country
- less CO_2 footprint
- less negative social impact
- reduced costs

Overview Circular Economy Initiative Deutschland and the Working Group Traction Batteries

Circular Economy Initiative Deutschland

Politics

Bundesministerium für Bildung und Forschung
Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit
Bundesministerium für Wirtschaft und Energie

Coordination

Industry

Science

Civil Society & further Institutions

Working Committee

Working Group Business Models

Working Group Traction Batteries

Working Group Packaging

Working Group Traction Batteries

Coordination

Industry: Dr. Hagelüken, Umicore
Science: Prof. Kwade, TU Braunschweig

Members

Industry

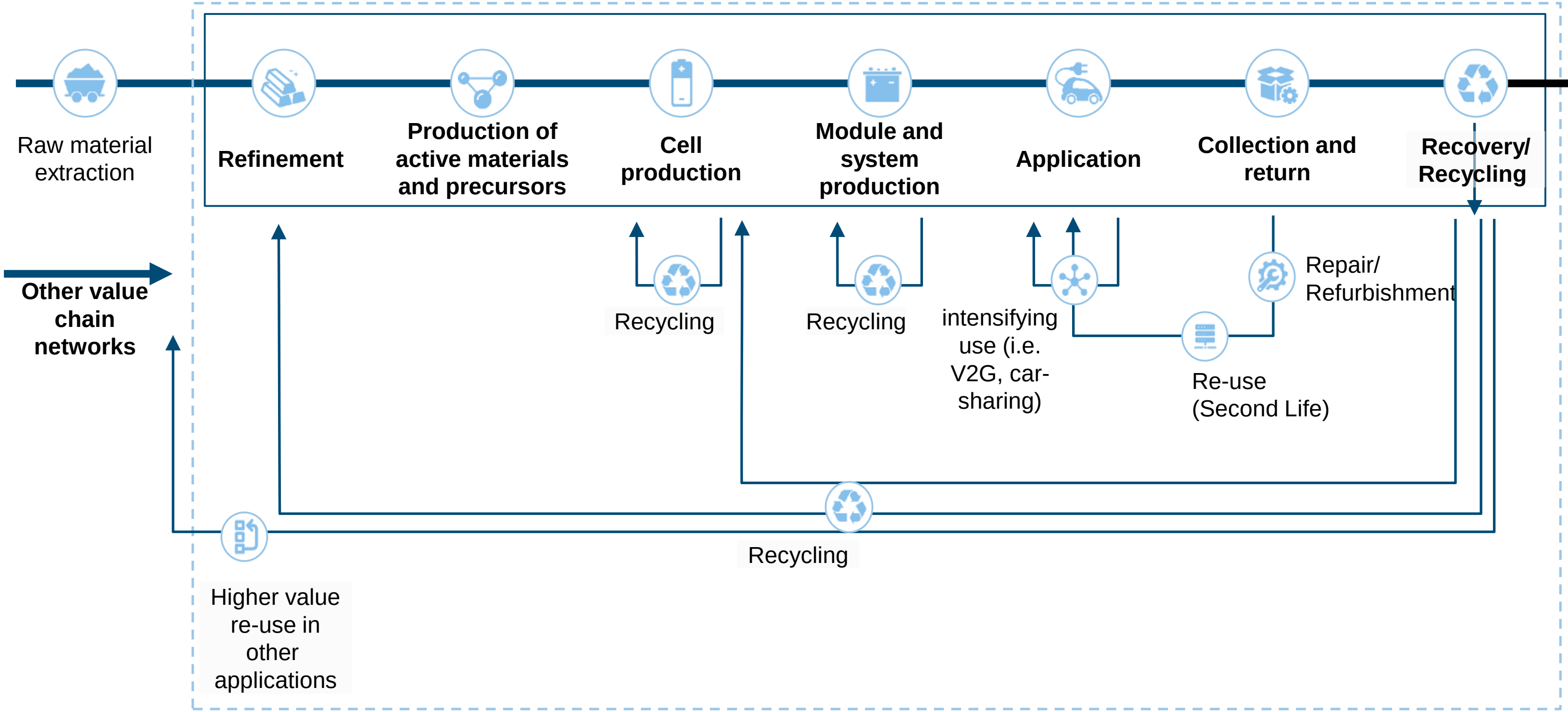
Science

Civil Society & further Institutions

Source: Circular Economy Initiative Deutschland; based on World Economic Forum 2019

www.circular-economy-initiative.de

CEID Working Group Traction Batteries: Focus



Source: Circular Economy Initiative Deutschland; based on World Economic Forum 2019

www.circular-economy-initiative.de

Overview of the results of the WG Traction Batteries

Circular Economy Initiative Deutschland

1 Report (GER & ENG)

Quantification of the Wuppertal Institute

1 Vision
across 5 dimensions as a collective orientation for the transition

5 Excursions
for central topics: covid-19, definitions, recycling, second life, deposit system

3 Pilot Profiles
to support the implementation

- "Knowledge of battery life"
- "Model-based decision platform"
- "Disassembly network for batteries"

23 Recommendations for Action
for politics, industry, and sciences

1 Roadmap
for short-, medium-, and long term planning

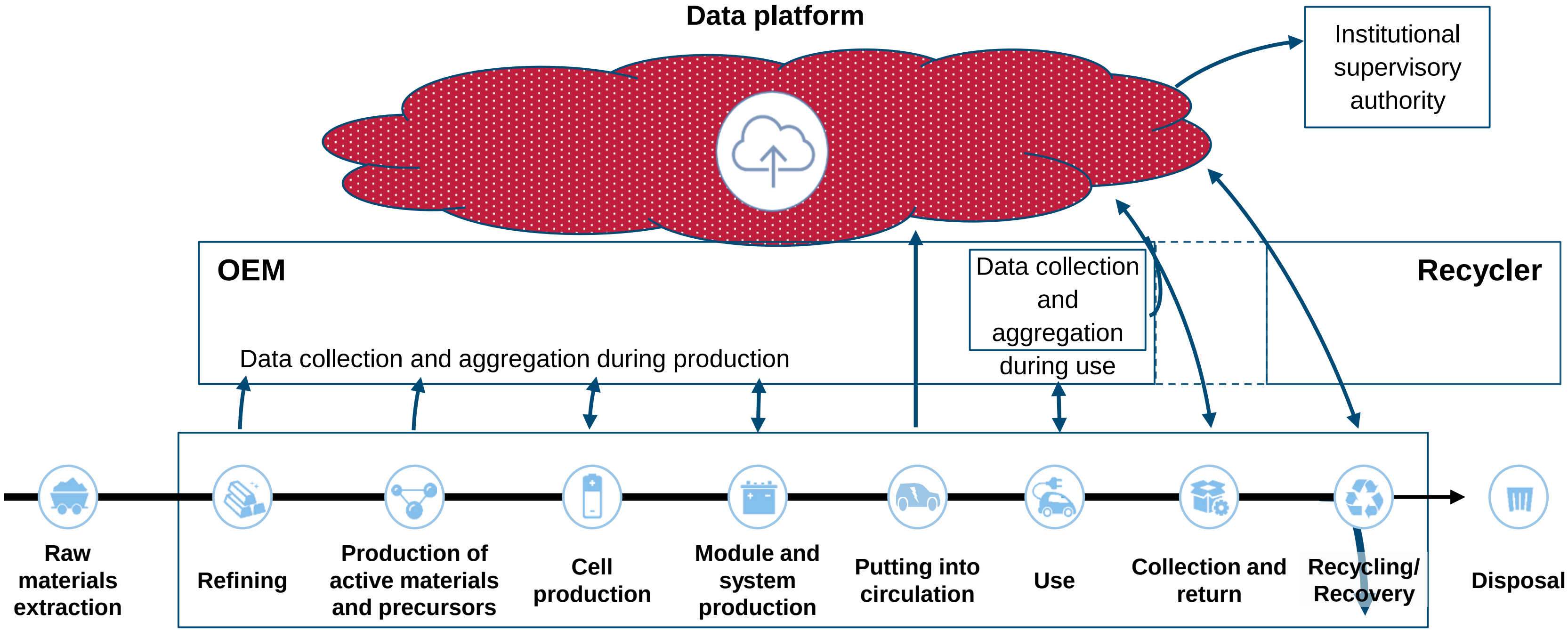
Executive Summary (GER & ENG)

Communication Package

Source: Circular Economy Initiative Deutschland; based on World Economic Forum 2019

www.circular-economy-initiative.de

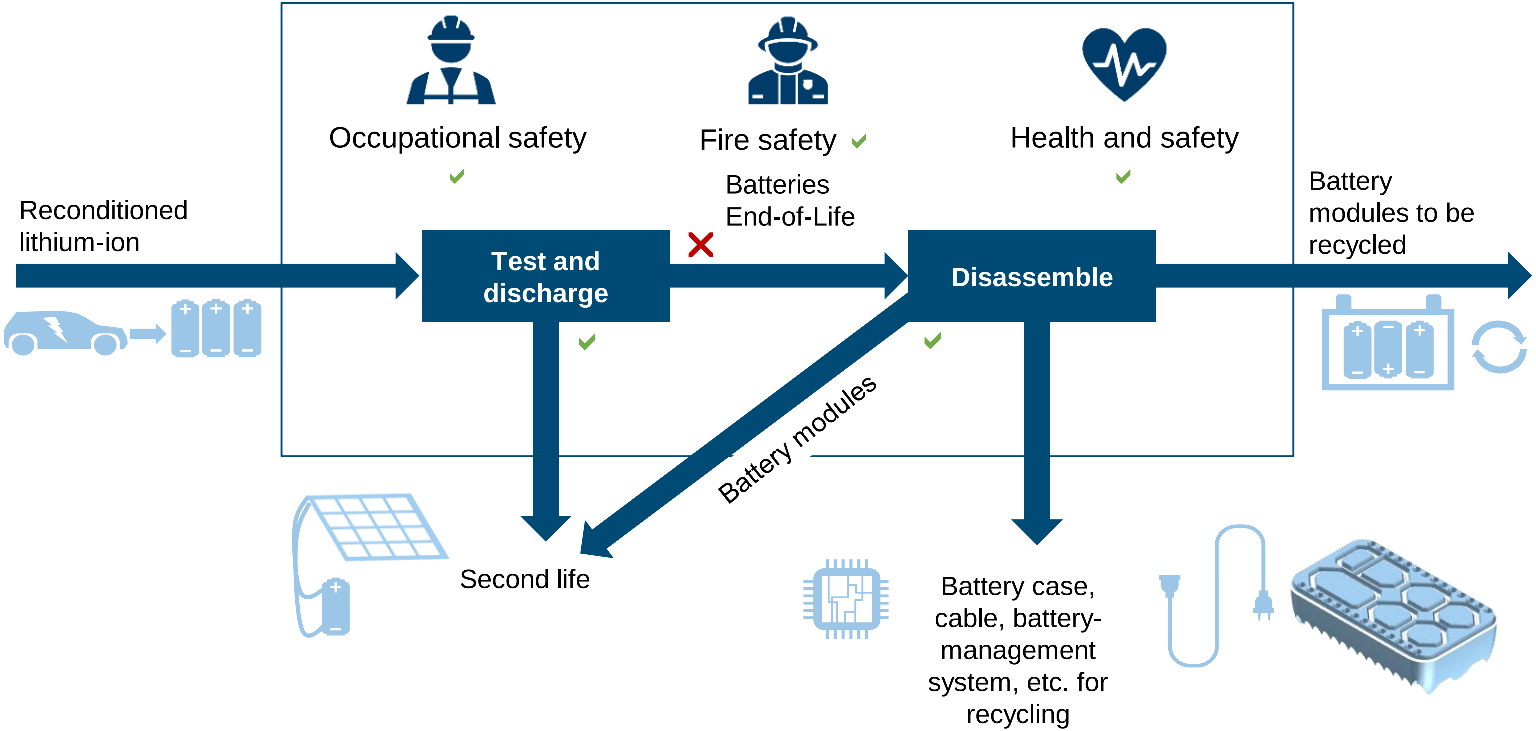
Pilot Profile I:
„Knowledge of battery life“



Information flows to promote the recycling of lithium-ion batteries

Source: Circular Economy Initiative Deutschland; based on World Economic Forum 2019

Pilot Profile III: „Disassembly network“



Source: Circular Economy Initiative Deutschland; based on World Economic Forum 2019

www.circular-economy-initiative.de

Source: Circular Economy Initiative Deutschland

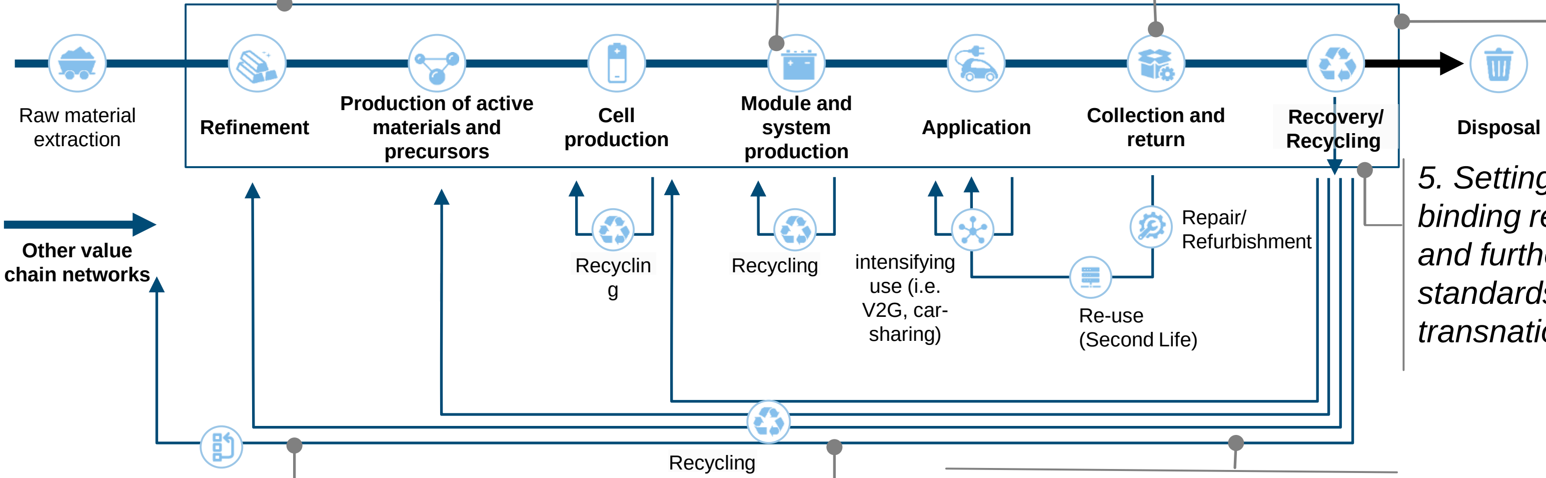
Central recommendations for action

1. Provision of battery data over the entire life cycle of the battery ("battery passport")

2. Design for circularity including modularity, better recyclability and reuse

3. Building physical infratructure – network reverse logistics and disassembly of batteries.

4. Strengthening trans-/ interdisciplinary education, training, and research for Circular Economy



5. Setting ambitious, binding recycling quotas and further definitions and standards in the context of transnational regulation

8. Developing relevant metrics, measurement methods and tools for systemic evaluation of optimal CE.

7. Developing effective incentive systems to ensure transformation

6. *Development of digital tools to support optimal end-of-life battery applications (decision support for second use*)**.**

www.circular-economy-initiative.de

Source: Circular Economy Initiative Deutschland; based on World Economic Forum 2019

Recommendation of recovery rates

Circular Economy Initiative Deutschland

EU directive (proposal)

Material	Recommended Recovery rates*		EU directive (proposal)	
	2025 – binding	2030 – to be aspired to***, ****	2025	2030
Total battery**	60 %	70 %	65 %	70%
Lithium	50 %	85 %	35 %	70 %
Cobalt	85 %	90 %	90 %	95 %
Nickel	85 %	90 %	90 %	95 %
Copper	85 %	90 %	90 %	95 %
Steel	90 %	95 %	-	-
Aluminum (without Al foil)	90 %	95 %	-	-

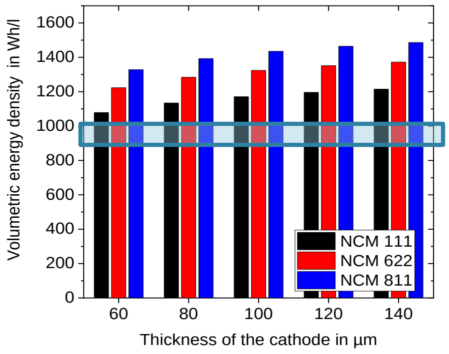
Source: Circular Economy Initiative Deutschland; based on World Economic Forum 2019

www.circular-economy-initiative.de

Content

Conclusions and outlook

- New cell generations enable an potential energy density of greater than 900 Wh/L with graphite/Si – anode and greater than 1200 Wh/L for all solid state with Li-anode



- Sustainability of batteries will be very important in the future, especially within the EU

- Closed material cycle and, thus, circular economy is very important for securing secondary material resources, redusing CO2 footprint, negative social impact and costs

Circular Economy Initiative Deutschland

Acknowledgement

iPAT Institut für Partikeltechnik

Federal Ministry
for Economic Affairs
and Energy

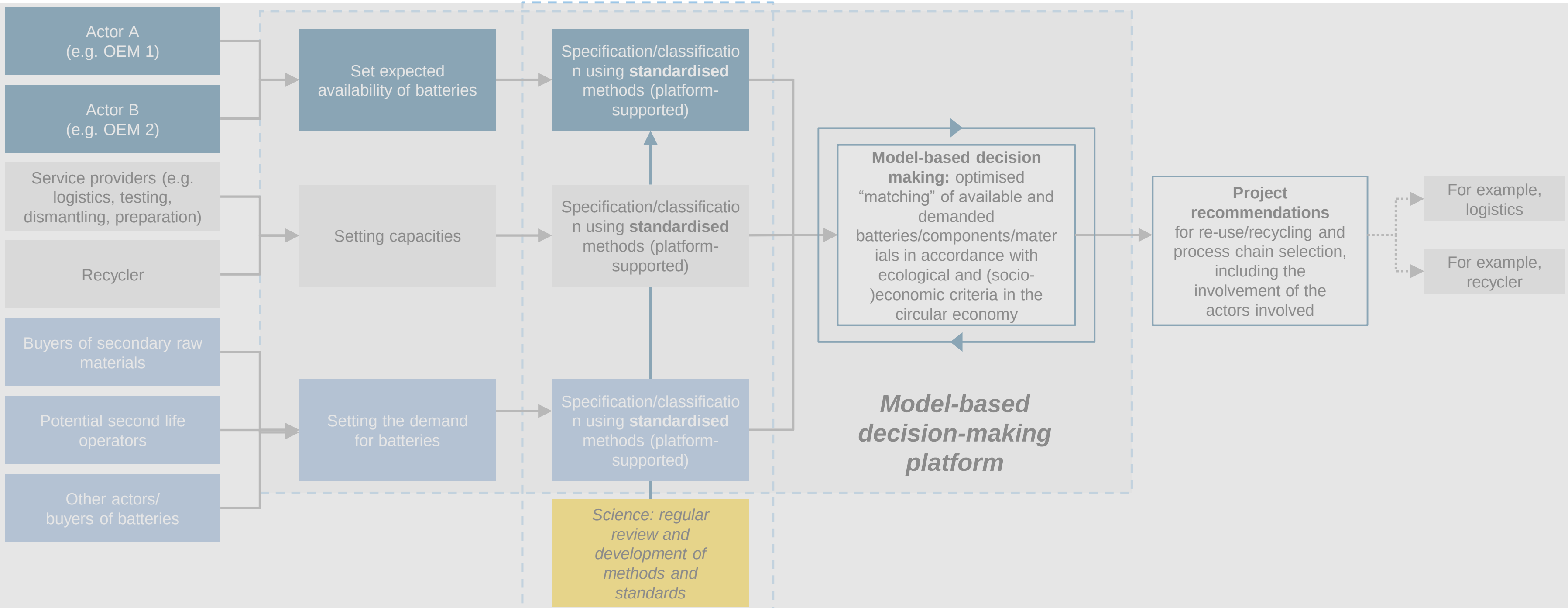
Federal Ministry
for the Environment, Nature Conservation
and Nuclear Safety

Federal Ministry
of Education
and Research

Battery LabFactory Braunschweig

Special thank to Laura Jess, Kevin Voges, Laura Gottschalk, Alexander Diener, Axel Thielmann for the help in preparing the slides

Pilot Profile II:
„Model-based decision platform“



Schematic representation of the integration of a platform into the business processes of the circular economy

Source: Circular Economy Initiative Deutschland

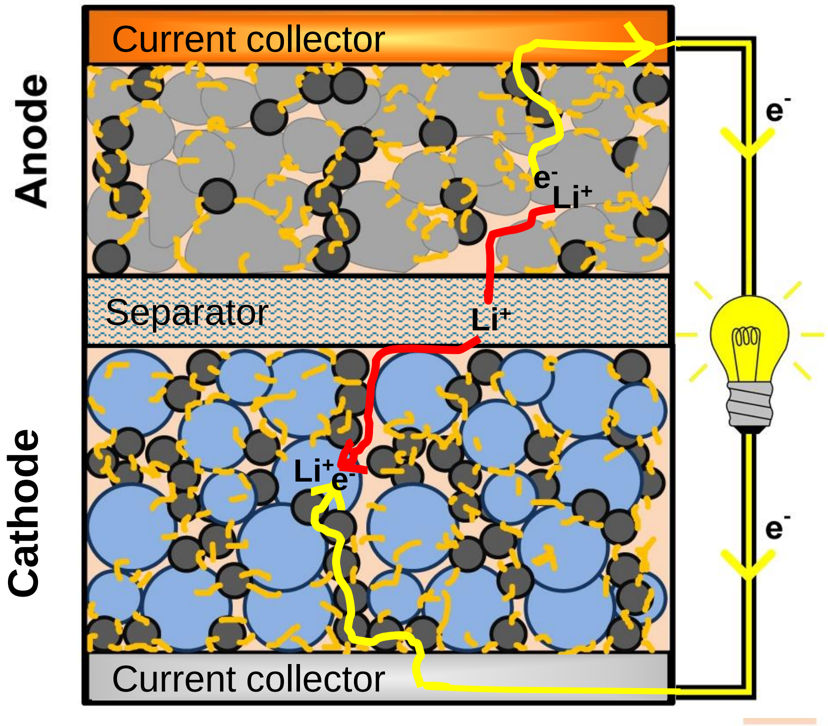
Some highlights of the vision

Circular Economy Initiative Deutschland

Regulatory framework	Material Flows	Technological development	Value networks	In-house implementation
EU-wide **harmonised regulatory framework**, including **incentives** for responsible sourcing, high value re-use, and responsible recycling	Development of **tools** for tracking and eco-social decision making (e.g. battery passports, data spaces, LCA simulations)	Increasing **automation** of maintenance and dismantling resulting in cost savings and safety	**Value creation** increasingly collaborative and **across (several) life cycles** of the battery	**Application of new B2B/ B2C business models** for EoL management for circular product management

Source: Circular Economy Initiative Deutschland

Basics of Lithium-Ion Batteries



Electrode compartment of Lithium-Ion-Batteries consists of

- Graphite Anode (may be some silicon)
- Lithium-metal oxide Cathode
- Liquid electrolyte

Carbon black

Graphite

Active material

Binder

Electrolyte

Some Highlights of the recommendations for action

Circular Economy Initiative Deutschland

Pilot projects	2021–2024: Short-term, "lay the foundation"	By 2027: Medium-term "establish a structure"	By 2030: Long term „breakthrough"

Public Policy

- Clear and mandatory **definitions and standards** (minimum recovery rates, CO2 disclosure etc.) (S)
- Maximizing **systemic potentials** of traction batteries for the energy turnaround (L)

Business

- Scaling of **investments** for the circular economy (M)
- Europe-wide **infrastructure for the disassembly** and recycling of EoL traction batteries (L)

management for traction batteries

and management of EoL batteries and digital

Science

- **Basic and applied research** focusing on **energy and materials flows and overall systemic effects** (S)
- Establishment of overall accepted **key values and measuring quantities** (S)

10. Provision of **academic training** for the circular economy

Source: Circular Economy Initiative Deutschland

Thank You

Tilmann Vahle (tilmann.vahle@systemiq.earth)

Dr. Reinhard von Wittken (wittken@acatech.de)

Prof. Dr. Arno Kwade (a.kwade@tu-braunschweig.de)

Dr. Christian Hagelüken (christian.hagelueken@eu.umicore.com)

Dr. Susanne Kadner (kadner@acatech.de)

www.circular-economy-initiative.de

For further information, please see CEID website and social media presences

Technische Universität Braunschweig

BATTERY LABFACTORY BRAUNSCHWEIG

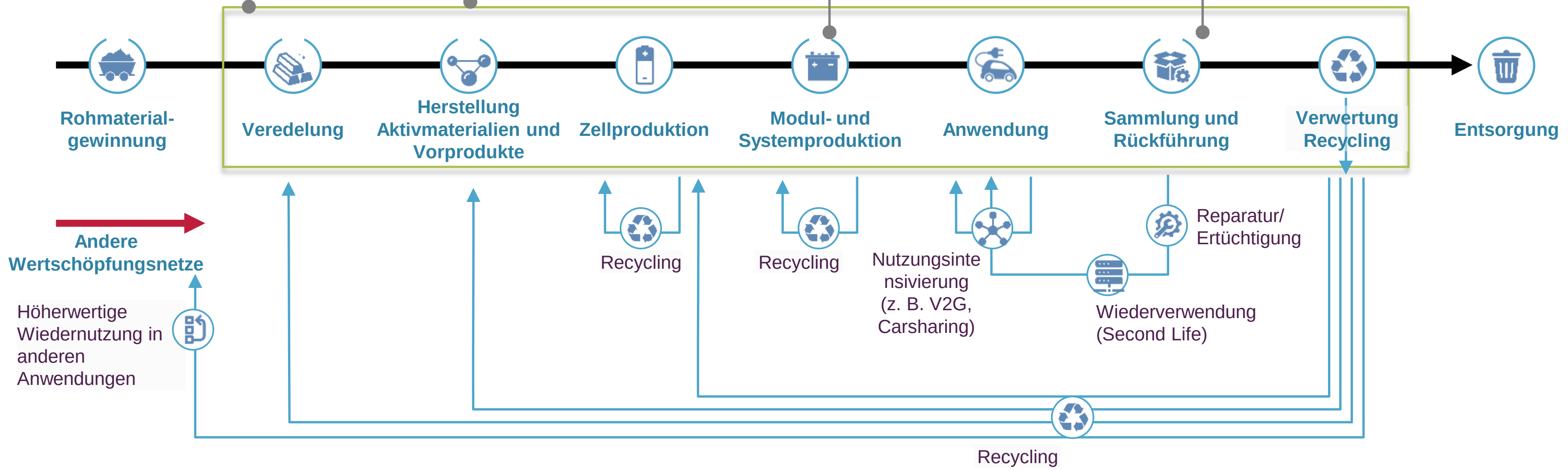
Zentrale Handlungsempfehlungen AG Traktionsbatterien*

1. **Bereitstellung von Batteriedaten über den gesamten Lebenszyklus der Batterie („Batteriepass“)**

2. **Stärkung der trans-/ interdisziplinären Bildung, Ausbildung, und Forschung für Circular Economy**

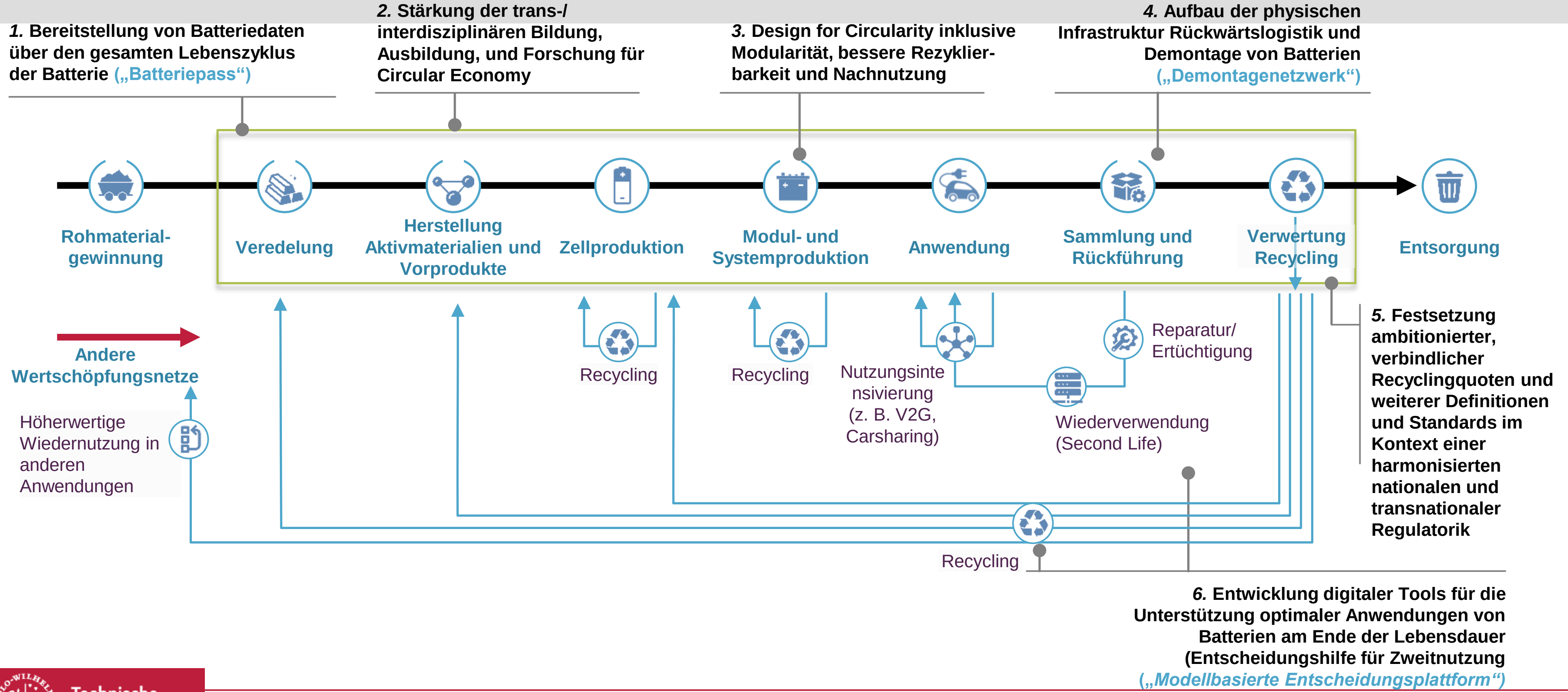
3. **Design for Circularity inklusive Modularität, bessere Rezyklier-barkeit und Nachnutzung**

4. **Aufbau der physischen Infrastruktur Rückwärtslogistik und Demontage von Batterien („Demontagenetzwerk“)**



*Auswahl von Handlungsempfehlungen an Politik, Wirtschaft, Wissenschaft | Quelle: eigene Darstellung, angelehnt an Darstellung des World Economic Forum 2019

Zentrale Handlungsempfehlungen AG Traktionsbatterien*



*Auswahl von Handlungsempfehlungen an Politik, Wirtschaft, Wissenschaft | Quelle: eigene Darstellung, angelehnt an Darstellung des World Economic Forum 2019

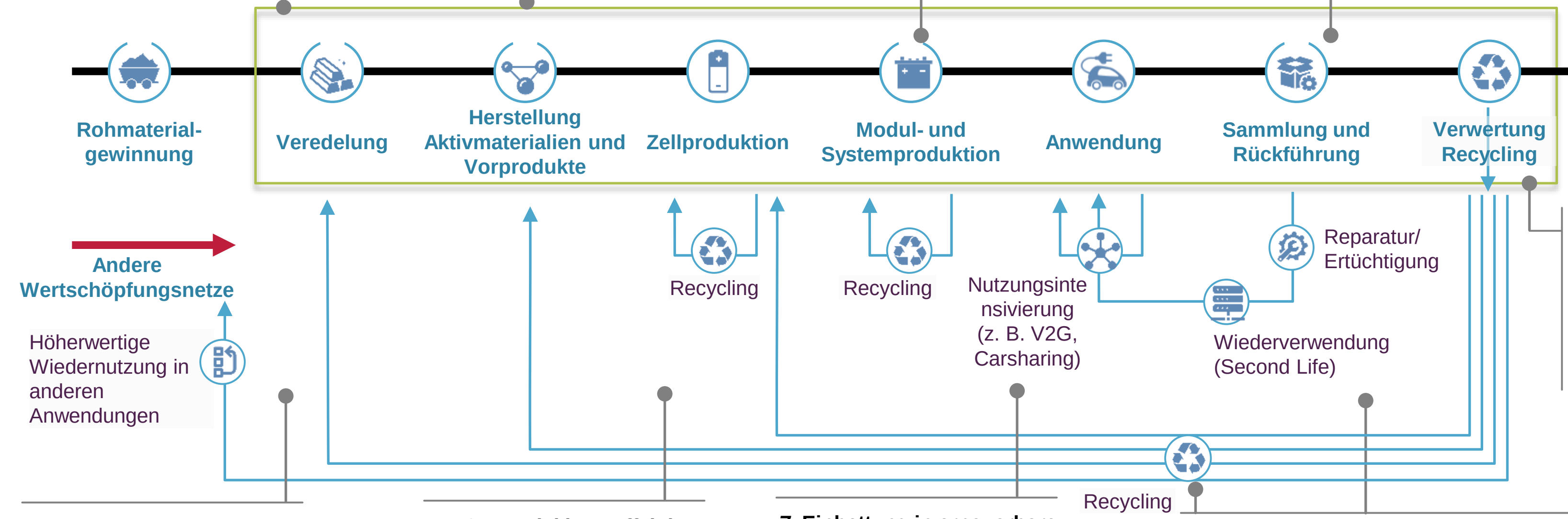
Zentrale Handlungsempfehlungen AG Traktionsbatterien*

1. **Bereitstellung von Batteriedaten über den gesamten Lebenszyklus der Batterie („Batteriepass“)**

2. **Stärkung der trans-/interdisziplinären Bildung, Ausbildung, und Forschung für Circular Economy**

3. **Design for Circularity inklusive Modularität, bessere Rezyklierbarkeit und Nachnutzung**

4. **Aufbau der physischen Infrastruktur Rückwärtslogistik und Demontage von Batterien („Demontagenetzwerk“)**



5. **Festsetzung ambitionierter, verbindlicher Recyclingquoten und weiterer Definitionen und Standards im Kontext einer harmonisierten nationalen und transnationaler Regulatorik**

9. **Entwicklung relevanter Metriken, Messmethoden und –Tools für die systemische Bewertung optimaler CE**

8. **Entwicklung effektiver Anreizsysteme zur Sicherstellung der Transformation**

7. **Einbettung in erneuerbare Energiesysteme und Mehrfachnutzung (Sharing-Konzepte)**

6. **Entwicklung digitaler Tools für die Unterstützung optimaler Anwendungen von Batterien am Ende der Lebensdauer (Entscheidungshilfe für Zweitnutzung** ***(„Modellbasierte Entscheidungsplattform“)***

*Auswahl von Handlungsempfehlungen an Politik, Wirtschaft, Wissenschaft | Quelle: eigene Darstellung, angelehnt an Darstellung des World Economic Forum 2019