Resource-Efficient Battery Life Cycles

Driving Electric Mobility with the Circular Economy

Circular Economy Initiative Deutschland

Executive Summary and Recommendations

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Electric mobility and the relevance of a Circular Economy

The transport sector currently accounts for around 24% of all CO_2 emissions worldwide, and 19% in Germany.[1] In order to achieve the Paris climate targets, the timely decarbonisation of the transport sector is indispensable. To this end, in addition to a general reduction in the volume of traffic and an increase in multi-modal mobility offers, the rapid scaling of the number of battery powered vehicles for individual transport is of central importance. Even under today's conditions, electric cars can have a better carbon footprint after only 50,000 to 80,000 km than vehicles with classic combustion engines. Germany's goal – in accordance with scenarios from the National Platform for Mobility – is that by 2030, there will be around seven to ten million electric vehicles in Germany. Battery-electric vehicles (i.e. vehicles with traction batteries) will probably account for most of the car fleet in the long term. It is therefore necessary to accelerate their market breakthrough and make it socially and environmentally acceptable.

Because of this expected rapid growth in the market shares of battery-powered and plug-in hybrid vehicles, the annual production of lithium-ion (traction) batteries is expected to increase considerably in the coming decade. This would multiply the annual demand for key battery materials – especially for cobalt, lithium, and nickel.

On one hand, this market expansion worldwide promises great potential for new economic value creation and increased prosperity. This could thus help to achieve the UN sustainability goals – not least in the raw material producing and manufacturing countries involved. On the other hand, the socio-economic challenges that can arise from this (e.g. environmental pollution, occupational health and safety challenges, and human rights violations) must be minimised along the entire supply chain (from the extraction of raw materials to recycling) from the onset.

It is therefore necessary to maximise the productivity of the materials used during the service life of the batteries and to guarantee safe recycling at the end of the service life. In this way, a "decoupling" of value creation from resource use, including associated environmental impacts, could be achieved.

The Circular Economy has great potential to combine socio-economic and economic effects by increasing resource productivity, minimising systemic losses, and safely reusing materials at the end of the service life.

Circular Economy for traction batteries

The *Circular Economy Initiative Deutschland* has set up a working group on traction batteries. Its 21 member organisations from science, industry and civil society have developed a common **vision for a Circular Economy for traction batteries** in **2030**. This resulted in an attractive "battery life cycle management" growth sector with potentials for entrepreneurial added value, innovation, and jobs as well as catalysts for the energy and mobility turnaround. To make this vision a reality, the working group has developed a roadmap and three topic-specific detailed considerations (**pilot profiles**), published in their results report. In doing so, the members of the working group support the 10 **guiding principles for sustainable batteries** of the Global Battery Alliance.

The key statements of the working group on traction batteries include:

- **The Circular Economy for traction batteries is crucial for achieving the desired economic, resource, and climate targets.** Circular Economy measures for drive batteries in electric cars will not only help improve the environmental performance of traction batteries (for example, in the form of up to 40 percent reduction in CO_2 emission over their service life) and contribute to resource decoupling, but also secure and accelerate the market ramp-up of electric mobility in the short and medium term. A Circular Economy can provide up to about 10% of the demand for key battery materials in 2030 (up to 40% by 2050) and reduce net costs by up to about 20% over the life cycle of the batteries. The Circular Economy will further contribute to a more resilient economy and minimise dependency on material imports, not only by tapping secondary material sources within the economy but also by supporting economic models that can be exported. This makes a Circular Economy for traction batteries highly desirable for society as a whole as well as for individual companies. The report provides specific incentives for companies to take action.
- **A Circular Economy means a fundamental transformation across the entire economy.** Current regulatory measures and existing conditions (e.g. low recovery quotas not differentiated according to materials, and unclear definitions) do not sufficiently support the effective recirculation of important battery materials and must therefore be modified. New collaborations between actors and a "business as unusual" mind-set are also required. In addition to measures to enhance productivity throughout the service life of the battery (**smart charging and vehicle-to-grid, ride pooling**), a Circular Economy for

1 | For more details on the references included in this summary, please refer to the main report.

traction batteries entails effective **collection**, prolongation of service life through **refurbishment**, and possibly a "**second life**" for materials in other, especially stationary, applications as well as high-quality recycling. The comprehensive use of **digital technologies** (battery passports, data spaces, and industrial internet of things (IIoT) enables the **transformation** from current circular waste management (low value retention through downcycling) to productive recycling management (high value retention and systemic productivity gain).

- **Regulatory and incentivising measures** initiated by the German government and institutions of the European Union, and **transnational corporate collaborations** as well as **active promotion of scientific research** are essential for creating an effective market for the Circular Economy of traction batteries.
- A **systemic and European integration** of the Circular Economy transformation is important for dealing with future issues such as the ambitious expansion of **renewable energies**, the harmonisation of European **electricity markets**, and the development of **multi-modal electromobility.**
- A **fundamental revolution** in the design, use, and recycling of batteries coupled with regulatory measures and business models that facilitate a systemic shift towards a physical Circular Economy is essential. **The mandate goes to all involved actors in politics, business and science** to immediately start developing and **implementing the options for action outlined here**.
- **Without the establishment of a circular model, the battery and thus electromobility will not be able to meet high expectations of society.** There is a danger that certain groups will voice their reservations – with damaging consequences for the mobility- and energy turnaround. On the other hand, the introduction of circularity will increase the economic and environmental benefits. This essentially involves the rapid construction of a product-service system integrated across the entire life cycle of the product, which provides an example for other systems.

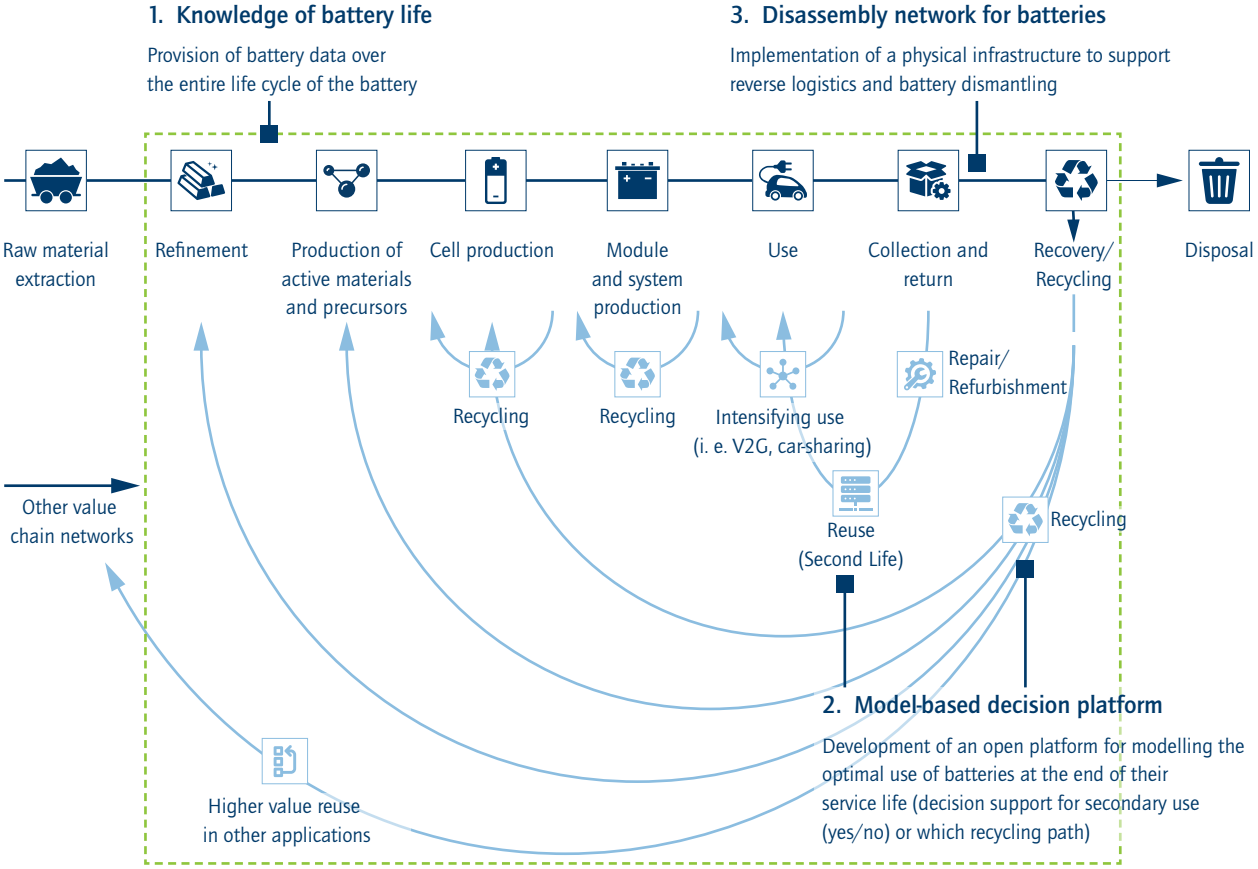

Illustration of the Circular Economy for traction batteries and scope of the Traction Batteries working group. Items 1 through 3 locate* the pilot topics along the value chain (source: own figure, based on the illustration from the World Economic Forum 2019).

Aim and vision of the Circular Economy for traction batteries

Traction batteries represent a great opportunity for decarbonisation. However, they must be managed in terms of a smart Circular Economy. By 2030, traction batteries must be:

- designed for a Circular Economy
- used highly productively
- used as long as possible
- collected in their entirety
- recycled in high quality

This way, in the long term, they can be a central element of a largely circular and thus resource-productive, decarbonised economy with minimum system losses and maximum raw material productivity. The recommendations presented here, including a roadmap, outline a path towards this vision. In order to make this a reality, decision-makers from politics, business, and science must implement measures in the short, medium, and long term.

The pilot topic at a glance

By working on the **three pilot profiles** of potential relevant projects, the "Traction Batteries" working group has identified topics of central importance and outlined specific possible implementation steps in order to accelerate the transition.

- **Pilot profile 1 "Understanding of battery life"**: In principle, a considerable amount of data on the condition of a battery exists. However, in most cases, this is not available to relevant actors. Therefore, there is a need for increased incentives for vehicle manufacturers and users or owners to provide operating data, especially through battery passports. In doing so, data protection must be taken into account.
- **Pilot profile 2 "Model-based decision-making platform"**: Focus of this project is to model the optimal use of batteries at the end of their service life. This model-based decision support must be based on real, validated data and take into account exergy losses and achievable output qualities in the various options for managing traction batteries at the end of their first life in a vehicle.
- **Pilot profile 3 ("Dismantling network for traction batteries"**: A critical success factor for implementing a disassembly network is to make well-founded investment decisions for new disassembly facilities in order to develop and improve the recycling infrastructure in line with market developments. Important factors for planning of new plants include the selection of the time and the plant location within the European Union, the dimensioning of the plant size, and the substantiation of the plant equipment (e.g. degree of automation).

Overview of the recommendations for action of the "Traction Batteries" working group

With the aim of realising their vision and facilitating the transformation to a Circular Economy, the members of the "Traction Batteries" working group developed recommendations for action for politics, business, and science. The recommendations for action for politics focus on the dimension of "regulations". They also strengthen the possibility of collaborative action between actors (value networks) by creating harmonized conditions for competition (level playing fields) and offering planning security for the initiation and implementation of new business models. The recommendations for action for business focus on bringing Circular Economy technologies and business models to the market and scaling them within collaborative value networks. The recommendations for action for science aim to apply sound scientific expertise to politics and business and help the relevant actors make objective decisions based on the latest technical advancements.

For politics:

To be designed at EU level in cooperation with the member states and supported and implemented by the respective national legislator:

1. **Establishing clear definitions** (e.g. legal definitions of automotive batteries, recycling targets, and recovery rates for each major battery material) and **setting standards** for calculating carbon footprints for recyclates, primary materials, and battery systems.
2. **Developing incentives for return and high-quality reuse** (keyword: "Second Life") **or the recycling of** traction batteries: These should apply to all participants in the market – **regardless of their origin** – in order to promote fair business conditions (level playing field).
3. Developing regulatory **requirements to ensure that relevant information is provided throughout the life cycle** (e.g. on origin, recyclate content, carbon footprint, and battery condition) – for example, through battery passports and data spaces – as well as appropriate incentives for relevant actors to disclose such information.
4. Harmonisation of the national implementations of relevant transnational (EU) regulations so that consistent interpretations and implementations are possible in the EU internal market.

Both at the level of the European Union and by national legislators (federal and state):

5. **Incorporation of the traction batteries into the resource-productive ecosystem** (including sector coupling, carpooling, high percentage of renewable energies) during use.
6. Promotion of **the necessary training** for the Circular Economy, especially in relevant technical **skilled professions** (e.g. for the safe handling of high-voltage systems) as well as **economic and academic education** (e.g. through separate **courses of study focusing on the Circular Economy and in-depth studies**).
7. Strengthening **research and development** (through anchoring in research framework plans, funding for Circular Economy, and joint project funding), establishing Circular Economy related professorships and junior research groups, and expanding the necessary research infrastructure.
8. Establishment of a **central institutional body with competencies (such as monitoring and tracking) that still need to be defined and which is** responsible for safeguarding the transformation.

As a central actor, the German legislator is called upon to provide momentum for ambitious action in the European process. In both the European and national context, the range of resource policy instruments (i.e. economic, regulatory, and informational as well as education and research) should be used to accelerate the transformation towards a Circular Economy.

The members of the Traction Batteries working group and the office of the *Circular Economy Initiative Deutschland* offer to support this process with their expertise.

For business:

1. Establishment of **industry-wide agreements** governing aspects such as indicators for **measuring circularity** and **(minimum) standards** for process chain and system design in the sense of systemic **design for circularity.**
2. Provision of **relevant information** and data among relevant actors through **digital technologies** and product passports.
3. Development of **circular business models** – that go beyond the recycling of used batteries to increase productivity – and the scaling of **investments** for a Circular Economy.
4. Establishment of a Europe-wide **infrastructure for the dismantling and recycling** of traction batteries that have come to the end of their service life.
5. **Training** of specialists for the end-of-life management of traction batteries (e.g. by offering specialist training in recycling and waste management and opening up other training occupations such as production technology).
6. **Planning taking into account systemic resource and energy efficiency** measured across the value chain (long-term: based on the thermodynamically sound measurement of the effect of measures on systemic entropy or exergy) as a measure of circularity.

For science:

1. Establishment of scientifically sound and generally accepted **indicators, measurement parameters, and**

methods for determining circularity and the carbon footprint as well as material and energy efficiency.

1. Development of technical and transdisciplinary **basic research**, in particular to support the optimisation of overall systemic effects.
2. Establishment of **professorships and junior research groups** related to the Circular Economy as well as the inclusion of subject-related lectures and in-depth studies on the Circular Economy in technical, scientific, and economic study programmes.
3. **Strengthening of application-relevant interdisciplinary research and development** for the Circular Economy – for example, with respect to **extending the service life of batteries, designing battery systems suitable for dismantling and integrating them into the vehicle, designing possible stationary applications after the first use phase**, introducing **new battery and production technologies, and optimising of material compositions.**
4. Provision of **methods and tools** (that can also be used without technical expertise) for the analysis of energy and material flows and their effects as well as the assessment of business models.
5. Development and monitoring of the **industrial implementation of integrated process chains**, taking into consideration technological developments as well as economic and ecological factors.

Analysis and procedure

Between October 2019 and May 2020, the "Traction Batteries" working group of the *Circular Economy Initiative Deutschland* devised a roadmap for establishing a Circular Economy for traction batteries. **The members of the working group are representatives from leading academic institutions, German companies, and associations with proven expertise on traction batteries** and thus covering the entire value chain of traction batteries: from production (battery material, production equipment, batteries, and vehicles) and logistics to recycling and metallurgy to software applications and systemic integration. This ensures that the topic is viewed as holistically as possible.

The report is the main product of the work done by the "Traction Batteries" working group. It includes the discussion of the **potentials, obstacles, and possible conflicting goals** of a Circular Economy for traction batteries, the outlining of a **vision**, the development of **three pilot profiles of projects** to accelerate the transformation, and the derivation of **recommendations for action** for the central actors. This summary provides an overview of the most important background, measures, and impulses for a Roadmap 2030.

Circular Economy Initiative Deutschland

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* Members of the Working Group other than AK, CH, HK, MB and CH are listed alphabetically.

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