

## Towards a circular economy for lithium-ion batteries: Repurpose or recycle end-of-(first)-life materials?

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**Abstract:** Large volumes of electric vehicles (EVs) will reach the end of their first life in the process of the mobility transition. While EV and battery producers may face supply chain issues due to lacking raw materials or high prices, the residual value of EV batteries remains untapped. This study focuses on repurposing and recycling of EV batteries as central pathways of a circular economy. We investigate the decision factors to transition from the current linear system to a circular economy in Switzerland. A System Dynamics approach is presented that captures the interconnection of significant drivers and barriers for establishing circular battery solutions. The model will serve to assess the impact of the newly introduced EU Battery Directive and test path dominance for repurposing and recycling strategies. Expected results will indicate the effects of the new EU Battery Directive, allowing policy recommendations to balance incentives for promoting recycling while not hampering repurposing opportunities. Especially, consumer preferences and novel business models are expected to have high relevance in the transition.

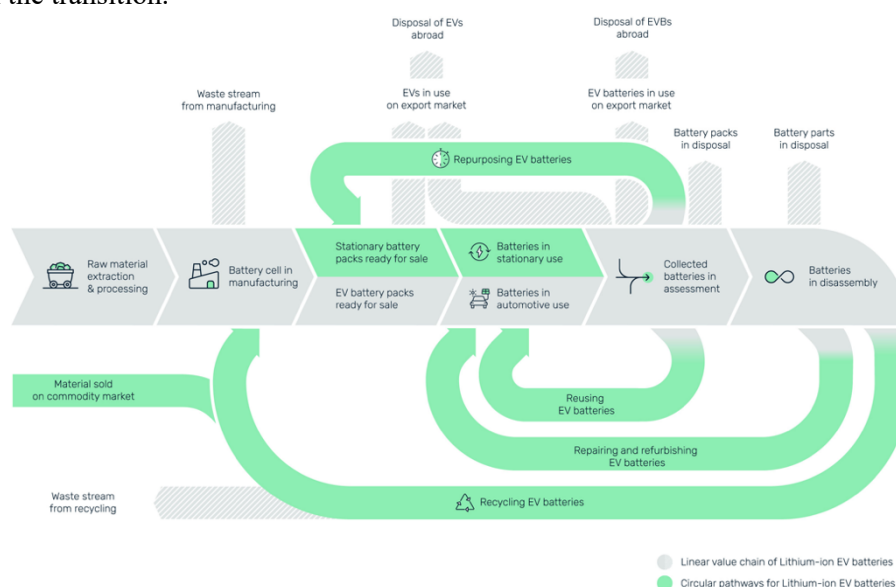
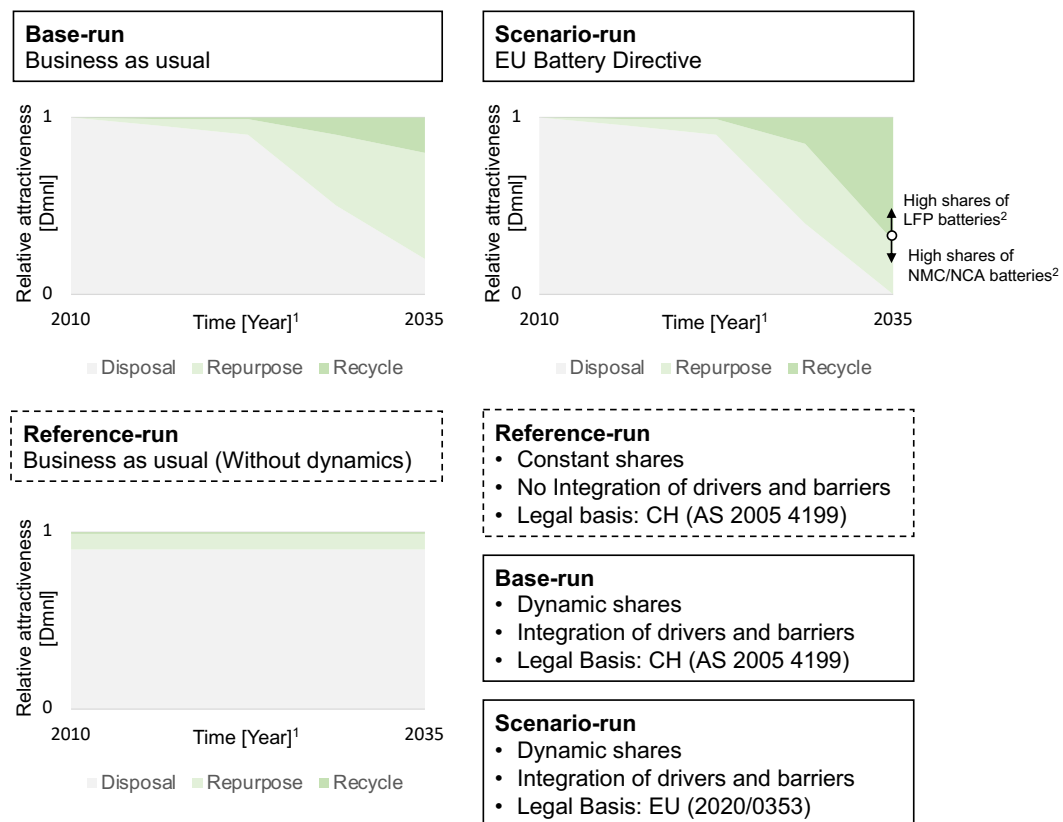


Figure 1: Conceptual structure of System Dynamics model (Source: CircuBAT project, Deliverable 7.1.; Work conducted by Kubli, Crenna, Seika & Hischier (2023)).

**Methodology:** The System Dynamics Model focuses on the decision of whether to repurpose or recycle collected end-of-(first)-life materials. It integrates the economic values for each pathway and considers technology learning effects. Thus, increasing the recycled and repurposed volumes is expected to reduce operational costs. In addition, the model integrates compliance utilities to measure the impact of the EU Battery Directive. It follows the assumption that with rising policy pressure - in particular, mandatory recycling shares for new EV production - the recycling utility compared to repurposing values increases. Although the System Dynamics model is still in the developing stage, hypotheses are being formulated and represented in Figure 2. Here, two exemplary simulation runs are being assessed based on fictitious data: the Base- and Scenario-run. In the former, the current legal framework for managing waste in Switzerland will be applied, representing the business-as-usual case. On the other hand, the Scenario-run will consider outcome changes resulting from a potential Swiss adoption of the EU battery directive.



1: Since relevant measures (e.g. minimum shares of recycled contents) in the EU Battery Directive are planned until 2031, the period until 2035 was chosen for this first analysis.

2: NMC/NCA batteries require Cobalt for production. As Cobalt is characterized as a critical raw material, supply risks can increase the market price and consequently incentivize recycling.

Figure 2: Methodological approach and hypothesis (Source: Own illustration).

**Contributions:** Our paper presents several contributions. Firstly, we estimate the end-of-life volumes of electric vehicle (EV) batteries in Switzerland for the period between 2010 and 2035. Secondly, we plan to create subsequent versions of the model to identify leverage points for developing circular value chains for end-of-life EV batteries. This will help assess the success of the EU battery regulation and provide guidelines for its possible implementation in Switzerland. Lastly, we will measure the impact of the EU battery regulation quantitatively, recognize profitable future markets, and estimate future trends and market potentials to avoid potential malinvestments for investors. This will enable business owners to align their existing business models and create new market opportunities.