

Environmental and Economic Life-Cycle Assessment of Battery Technologies for Electricity Storage.

Conrad Bielitz

This study assesses three different battery technologies with regard to their environmental and economic life cycle performance when used as large-scale storage systems for renewable energy. The analyzed technologies include the lead-acid (PbA) battery, the lithium-titanate-oxide (LTO) battery and the vanadium-redox-flow battery (VRFB). The evaluation is based on Life Cycle Assessment (LCA) with ILCD 2011+ midpoints and Life Cycle Costing (LCC) for the environmental and economic part respectively. Primary data from industry partners is used for the LTO and VRFB system, while the PbA battery is modeled based on literature review. Besides taking a cradle-to-gate approach in the environmental assessment, several use cases are examined that consider the operation of the batteries during a 20-year time horizon with varying cycles per day, depth-of-discharges and discharge rates. Potential environmental benefits are also examined by modeling the storage and dispatch of wind or solar energy and thus averting electricity from the average production mix in Switzerland and Germany. The economic evaluation considers Total Life Cycle Cost (TLCC) data from the literature and simulates revenue generation through the projected spread between wholesale and retail electricity prices in Switzerland.

Lead-acid, the most conventional technology, is outperformed in the studied scenarios by its counterparts in every respect. The lithium-titanate-oxide and the vanadium-redox-flow battery are more evenly matched and the advantage of one over the other is highly dependent on the use case. While the VRFB is the best performer in the studied scenarios both economically and environmentally, the advantage over the LTO system diminishes with increasing discharge rate and cycle frequency. The results also show that even in the idealized case of replacing 'dirty' energy from the production mix with 'clean' energy stored in the battery, an overall positive ecological balance is only obtained in the German market.