Circular Battery Design: Investing in Sustainability and Profitability

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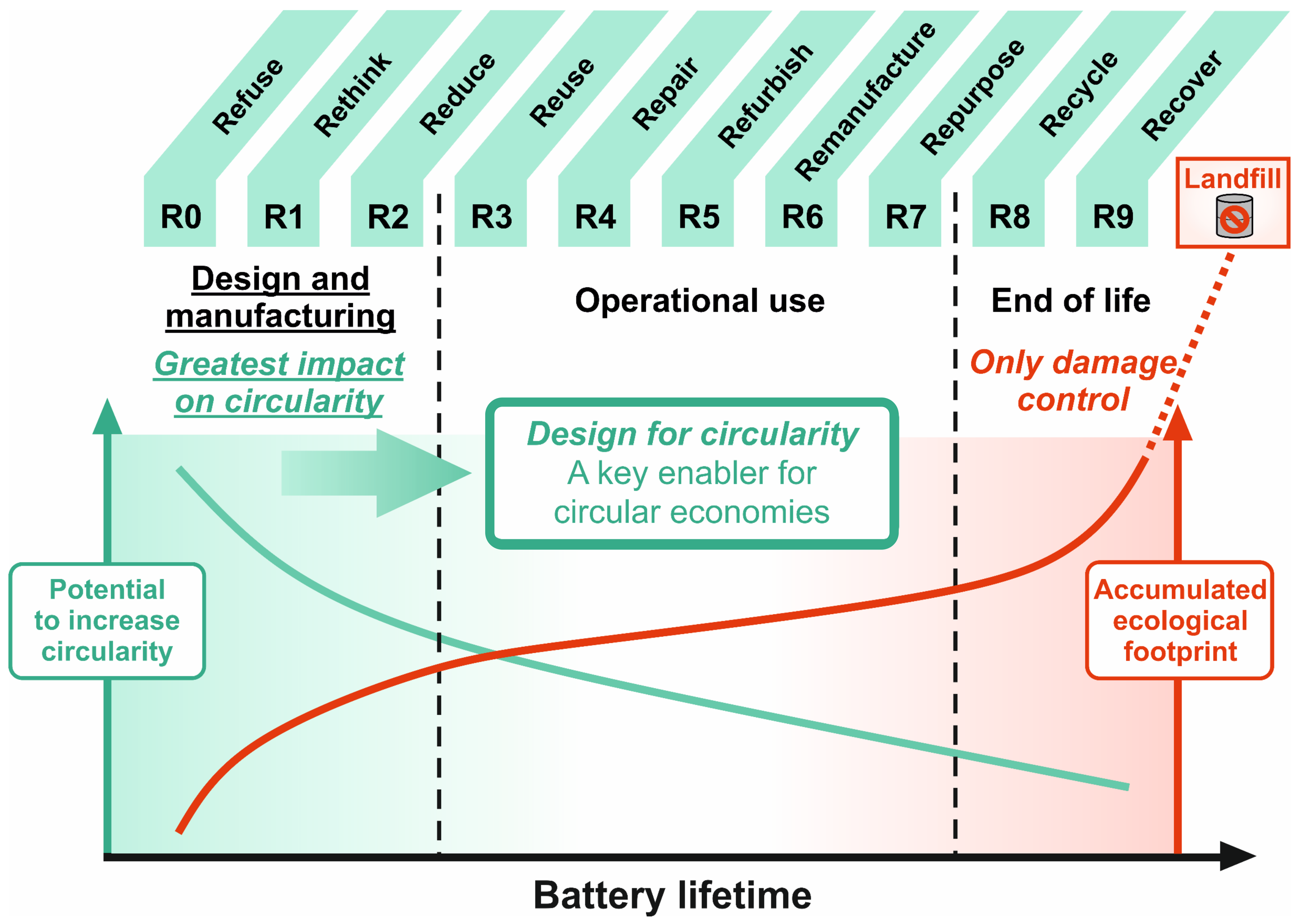
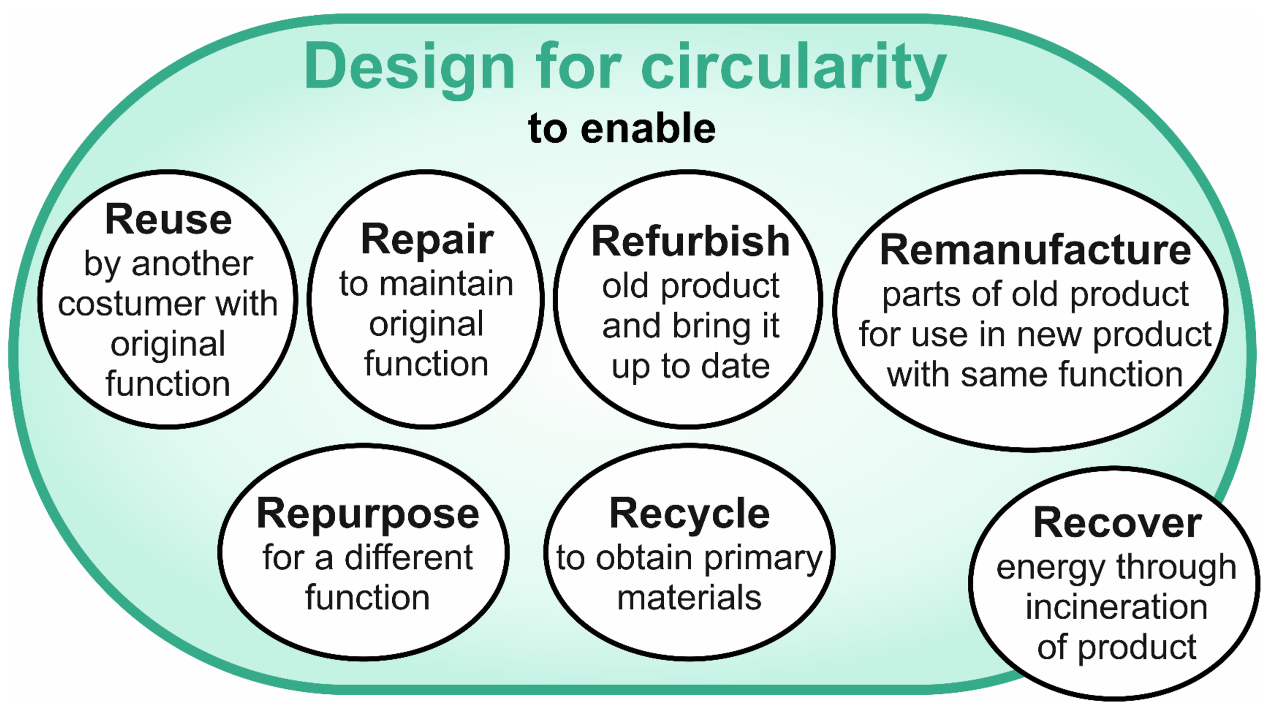
INTRODUCTION

Sustainability is a much talked about goal in battery production but currently comes third in importance to cost and performance. Historically, improved sustainability comes with a penalty in terms of cost and performance. This interplay will certainly evolve in the coming years. Ecological and social aspects driven by legislative frameworks guarantee recycling of lithium-ion batteries (LIBs) to prevent hazardous waste in landfills. The trend in the electric vehicle (EV) sector towards low-cost chemistries like lithium iron phosphate (LFP) represents a double-edged sword, as the recycling profitability of such materials is extremely low for the established recycling methods.[1,2] The direct recycling approach, where anode and cathode materials maintain their structure and functionality, holds the potential to make recycling profitable also for low-cost chemistries.[3,4] However, direct recycling, which faces major processing challenges, necessitates a shift in LIB design priorities. This work highlights ***design for circularity*** as an enabler for direct recycling and a key tipping element for reducing cost and increasing sustainability in LIB production and disposal concurrently.

THE MEANING AND POSSIBLE IMPACT OF *DESIGN FOR CIRCULARITY*





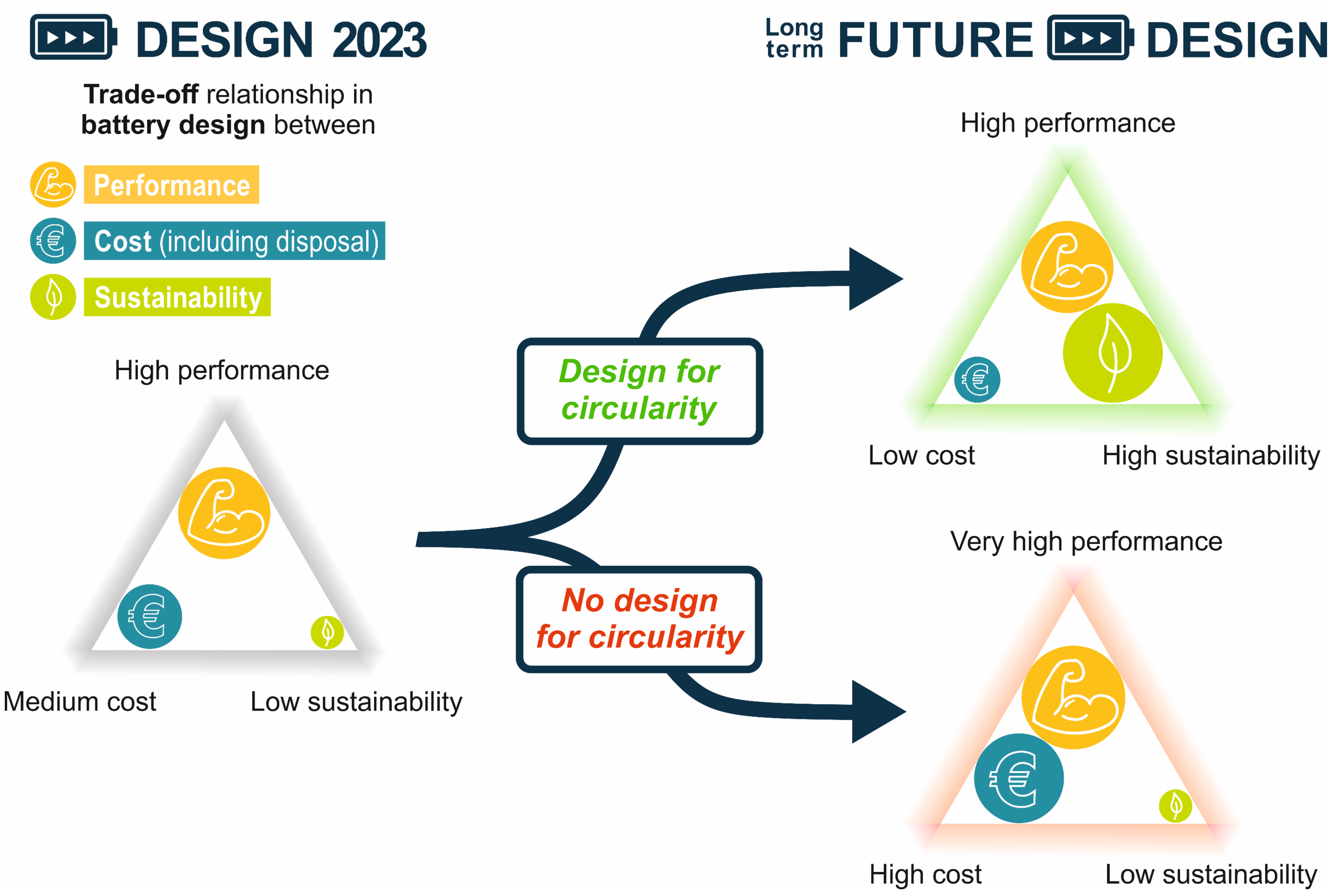
- The R9 framework for circular economies provides ten (R0 – R9) strategies to increase the circularity of a product (here, batteries).[5]
- R8 (Recycle) and R9 (Recover) are necessary to avoid hazardous waste, but have less impact on circularity than earlier implemented R-strategies (R0 – R7)
- It is the design and manufacturing phase of a battery (R0 – R2), which determines how effectively further R-strategies (R3 – R9) can be implemented.

➡ **The consideration of recycling after the market launch of a battery, which has been optimized only with regard to cost and performance, contradicts the concept of circular economies to a large extent and is seen as "only damage control".**

THE CHANGING INTERPLAY BETWEEN COST, PERFORMANCE AND SUSTAINABILITY

- Regulatory frameworks demand ambitious recycling rates and will cause increasing costs resulting from battery disposal.
- A continuing focus only on optimizing cost and performance will lead to higher disposal costs and less profitable recycling.
- Direct recycling, including the implementation of R-strategies during operational life (R3 – R7), lowers the dependency towards raw material processing and thereby leads to a strengthened European LIB ecosystem, especially for low-cost chemistries.

➡ **Design for circularity is the key enabler to increase sustainability and lower costs in the long term**



CONCLUSION

- Regulatory frameworks are required to overcome some of the facets of linear economies, in which generation of waste is tolerated, since sustainability places third, far behind cost and performance.
- Only by implementing *design for circularity* strategies can the recycling of low-cost chemistry batteries (LFP and sodium ion batteries) turned into a profitable endeavor.
- All stakeholders along the value chain have to elaborate battery design standards

➡ **The battery sector could be a role-model for other industries to gradually from a linear to a (more) circular economy**

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