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Circular economy in energy storage from design to recycling

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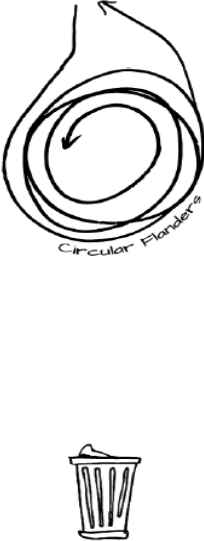


The logical transition

LINEAR ECONOMY

RECYCLING ECONOMY

CIRCULAR ECONOMY



Take-make-waste

<https://www.ellenmacarthurfoundation.org/circular-economy/what-is-the-circular-economy>

**FOUNDATION:
3 principles**

Design out waste and pollution

Keep products and materials in use

Regenerate natural systems



Everyone's involvements:
individuals, government, businesses

Li-ion batteries and applications

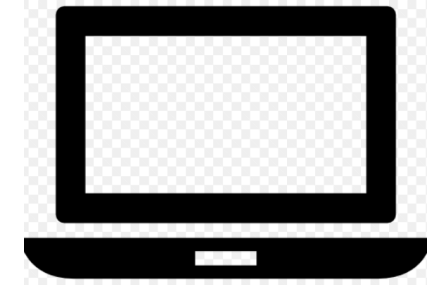
Extensively used in electronic devices and electric vehicles

Increase of 25% per annum and 60% of those corresponds to EVs

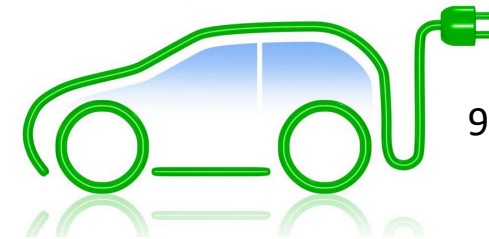
Lifetime of the battery can be limited to the application



4 years



5.5 years

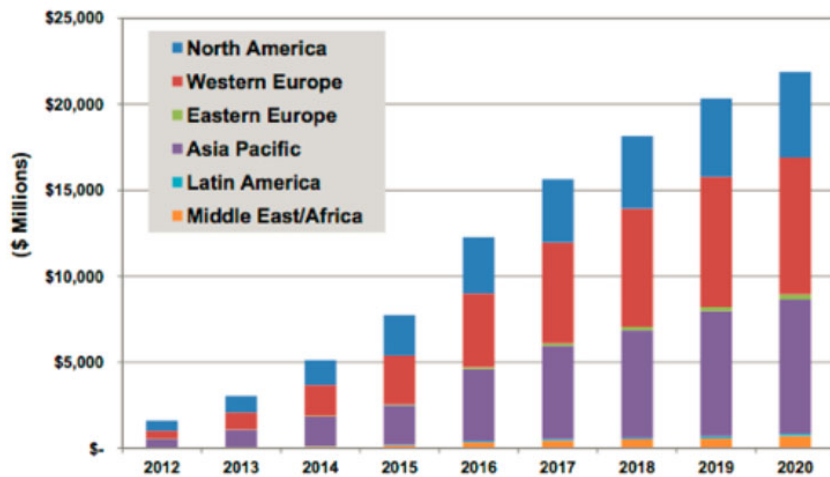


9 years

In 2020, up to **1 million** electric vehicles sales in the US and up to **6 million** globally

500 000 tonnes of spent LIB predicted in China in 2020 and 137,000 metric tons just in Australia by 2036

Chart 1.1 Total Lithium Ion Transportation Battery Revenue by Region, World Markets: 2012-2020



(Source: Pike Research)

<https://www.environmentalleader.com/2013/05/global-transportation-li-ion-battery-market-to-reach-22bn-in-2020/>

Resources, Conservation & Recycling 129 (2018) 263–277

A Review on Battery Market Trends, Second-Life Reuse, and Recycling. Sustain. Chem. 2021, 2, 167–205.

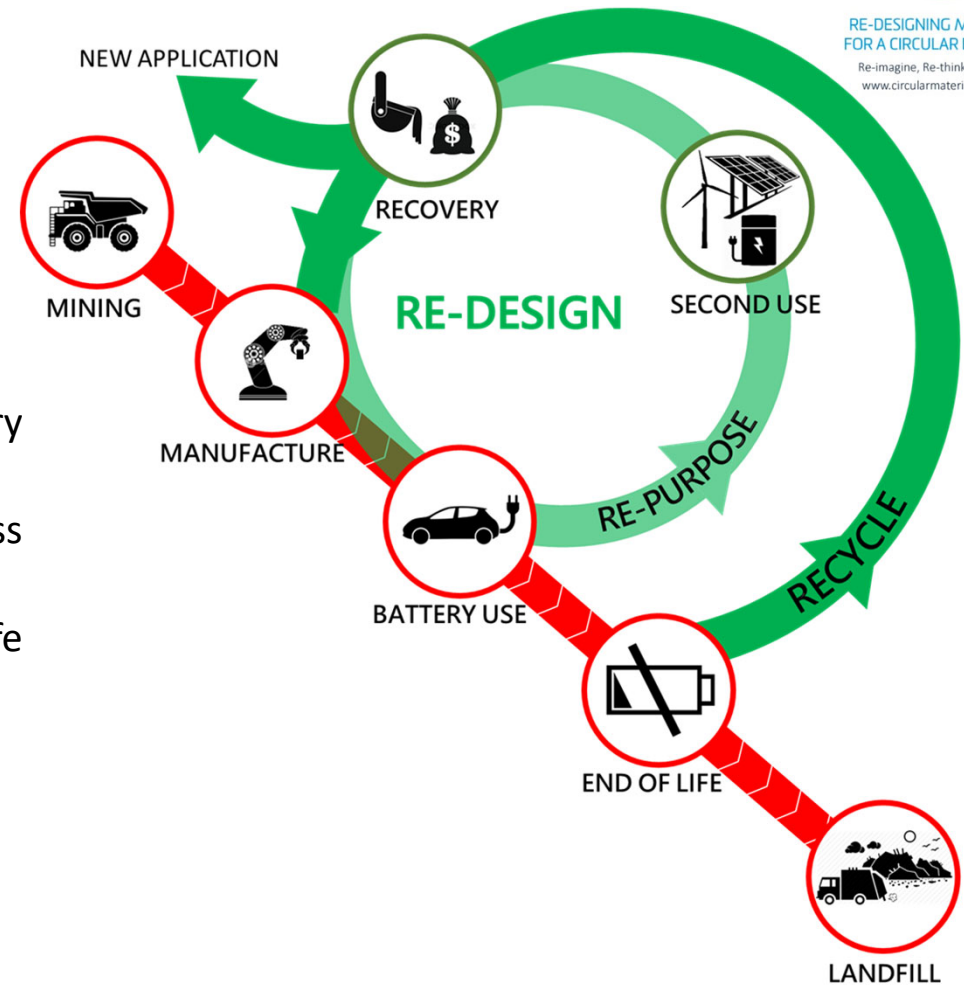
Our circular economy approach: Energy storage materials



RE-DESIGNING MATERIALS
FOR A CIRCULAR ECONOMY

Re-imagine, Re-think, Re-design
www.circularmaterials.com.au

1. **Re-design** (eco-design) of batteries to improve recovery and re-purposing.
2. **Re-purposing** of used batteries for second life and less demanding use applications.
3. **Recovery** of raw and valuable materials from end-of-life energy devices.



Redesign for sustainable energy storage technologies

Chemistry: High energy density, cyclability, efficiency

Active materials: abundant, price, ethical extraction, equally distributed, toxicity

Electrolytes: volatility, flammability

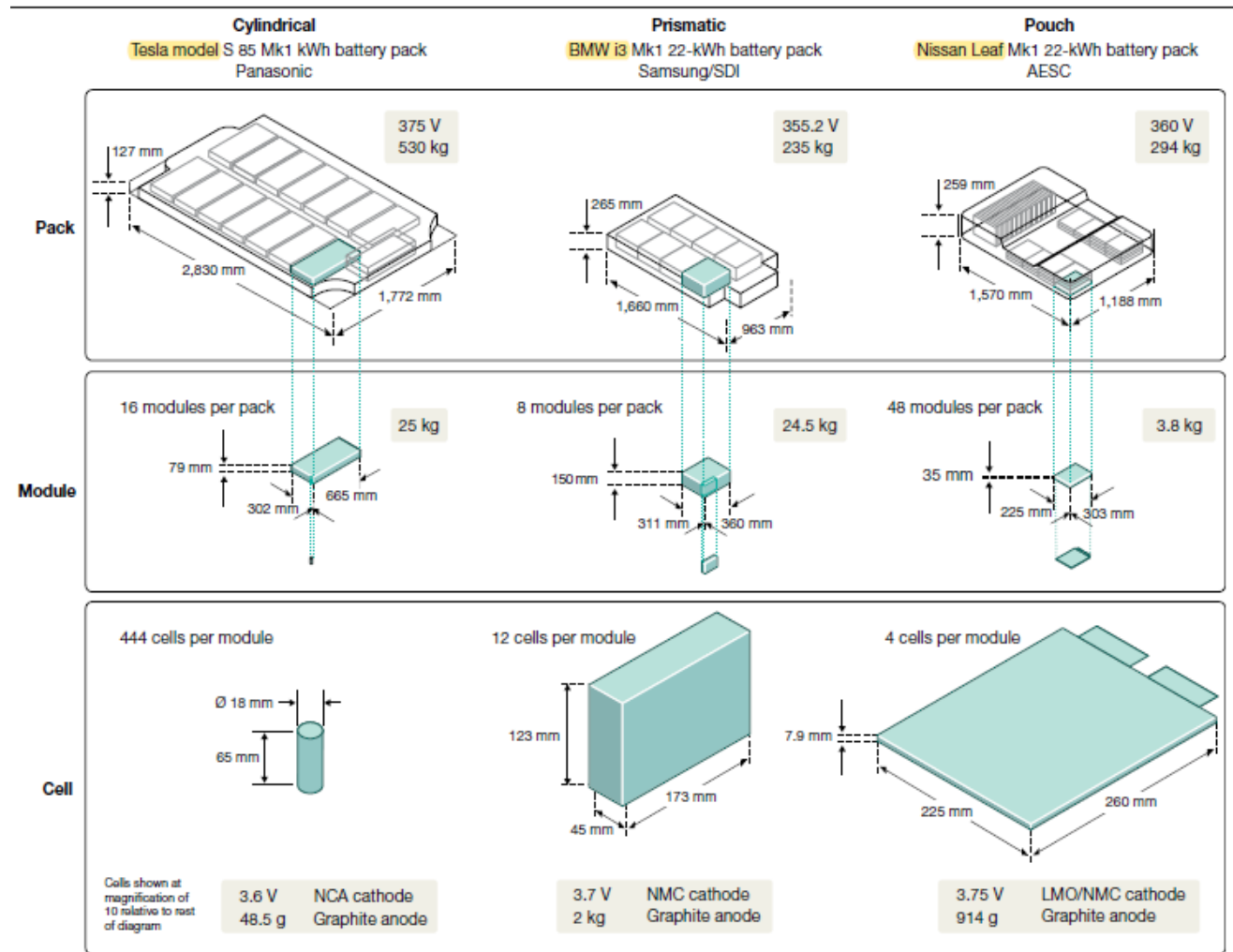
Binders: road block in the recycling steps

Cell design: facile disassemble towards repurpose or recycling, standardisation (automating battery disassemble)

Design out waste and pollution

Keep materials and products in use

Examples of battery pack designs in electric vehicles



Re-purpose: Use a battery in a less energetically demanding application

Batteries from EVs to stationary storage

Major barriers to overcome

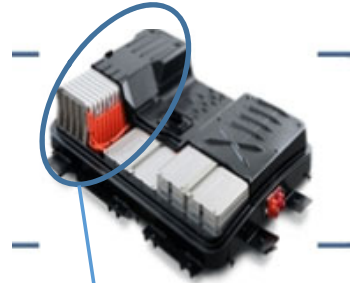
Collection and transport due to the large dimensions and safety risks

Manufactures pack (different chemistries and design)

Faulty cell detection and removal (increase price)

Guarantee of a lifetime (safety, performance certainty)

Pack



Module



Cell



Battery recycling: Industrial approach

Mostly used: Hydrometallurgy and pyrometallurgy

Other: Direct recycling, bioleaching

Major barriers to overcome

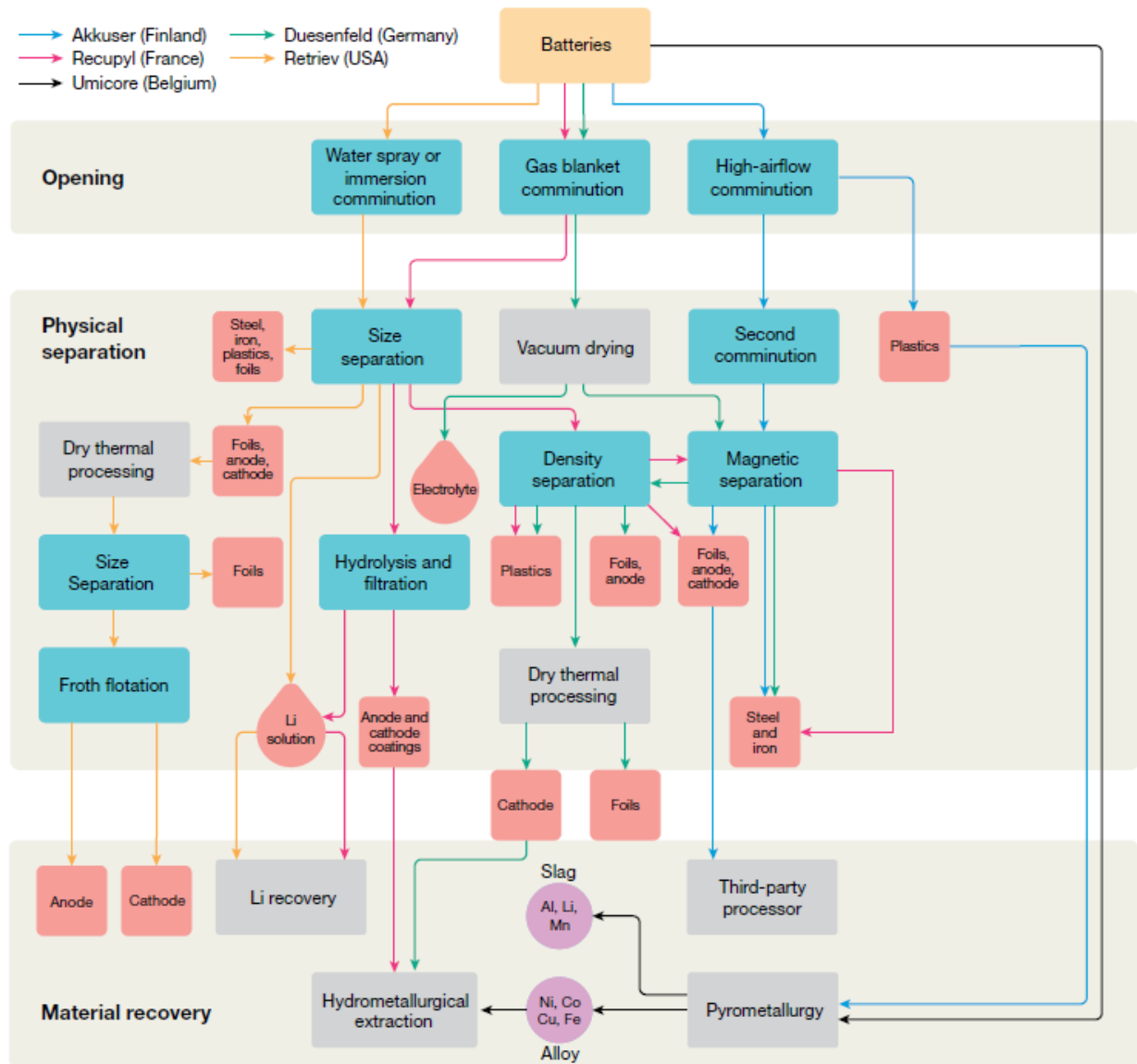
Large number of steps

Combination of several methodologies

Different chemistries

High temperatures

Secondary waste streams



Harper et al, Nature, 575, 2019,75-86

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Li-ion battery waste

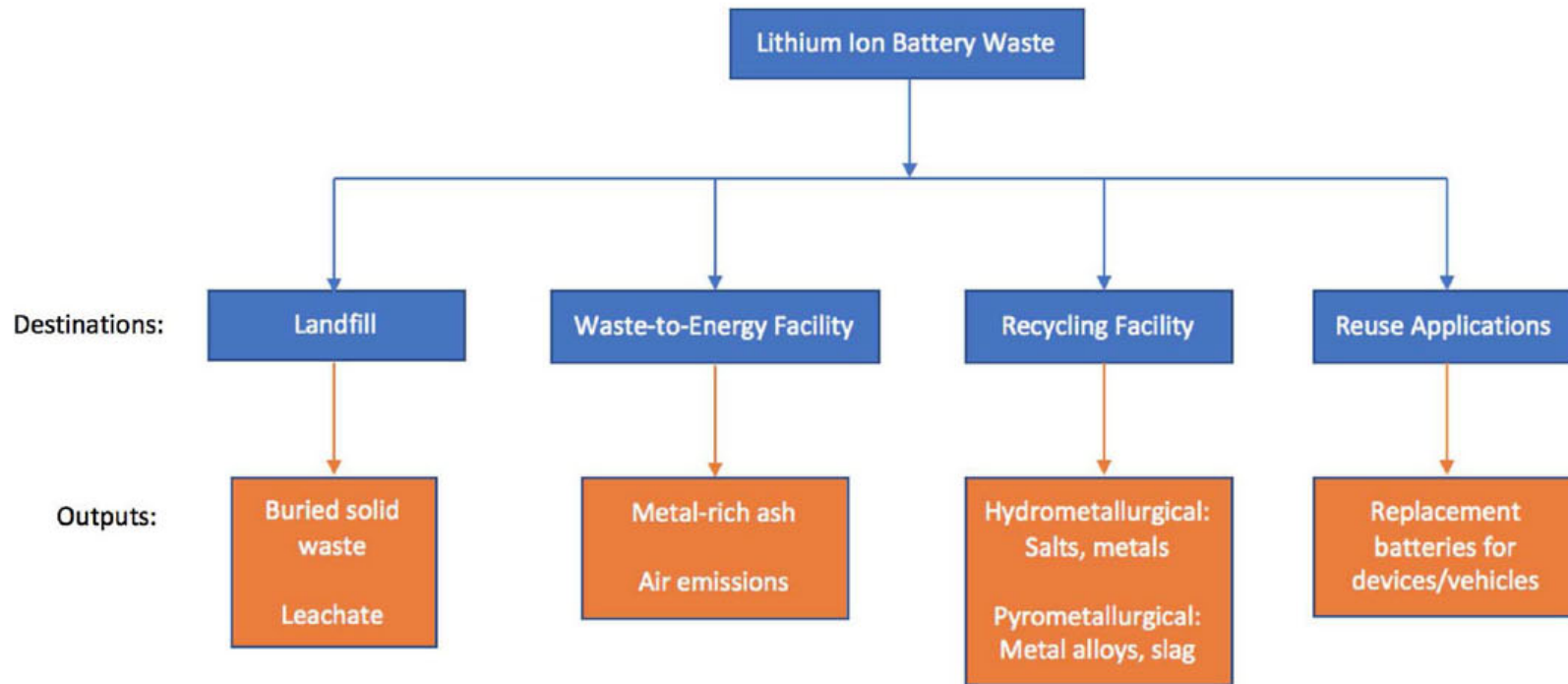


Fig. 1. Possible Destinations and Outcomes for LIB Waste.