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Mass Energy Storage Technology Advancement – Materials and Manufacturing Implications

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Energy Storage: 1 slide overview

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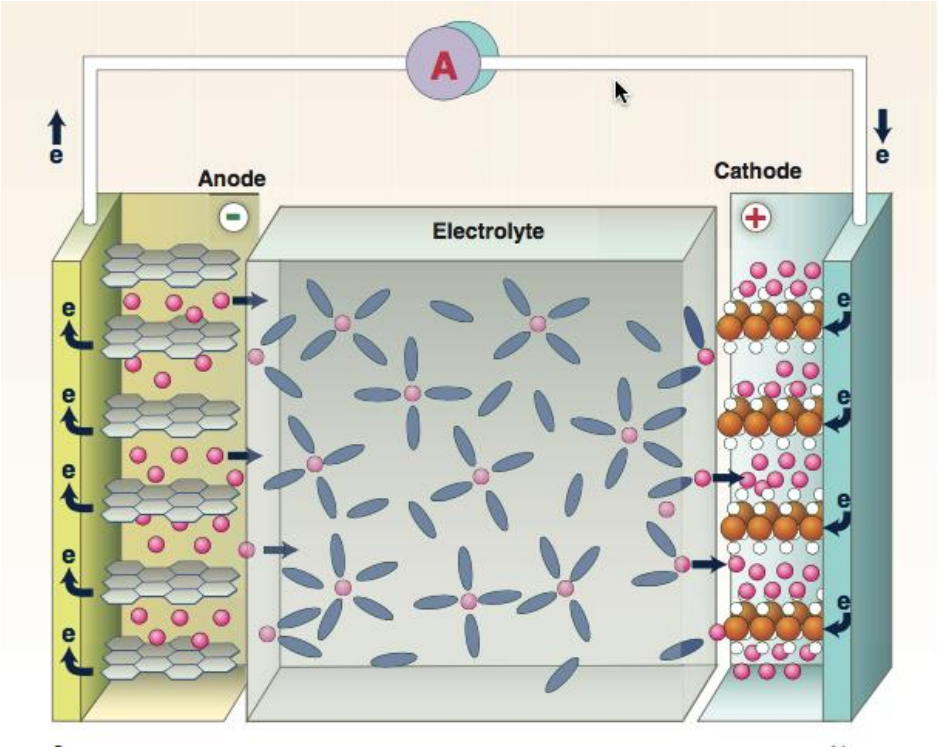

- **Focus:** electrochemical energy storage only
  - *Not* pumped hydro, chemical, thermal
  - *Not* Fuel cells (though we do consider flow batteries)
- All electrochemical storage devices have:
  - 2 electrodes made of electrochemically reversible materials
  - Electrons and ions take separate paths between the electrodes, DC electric current outside the cell performs work

Dunn et al, 18 NOVEMBER 2011 VOL 334 SCIENCE, p 92

Materials We want to use. . . .

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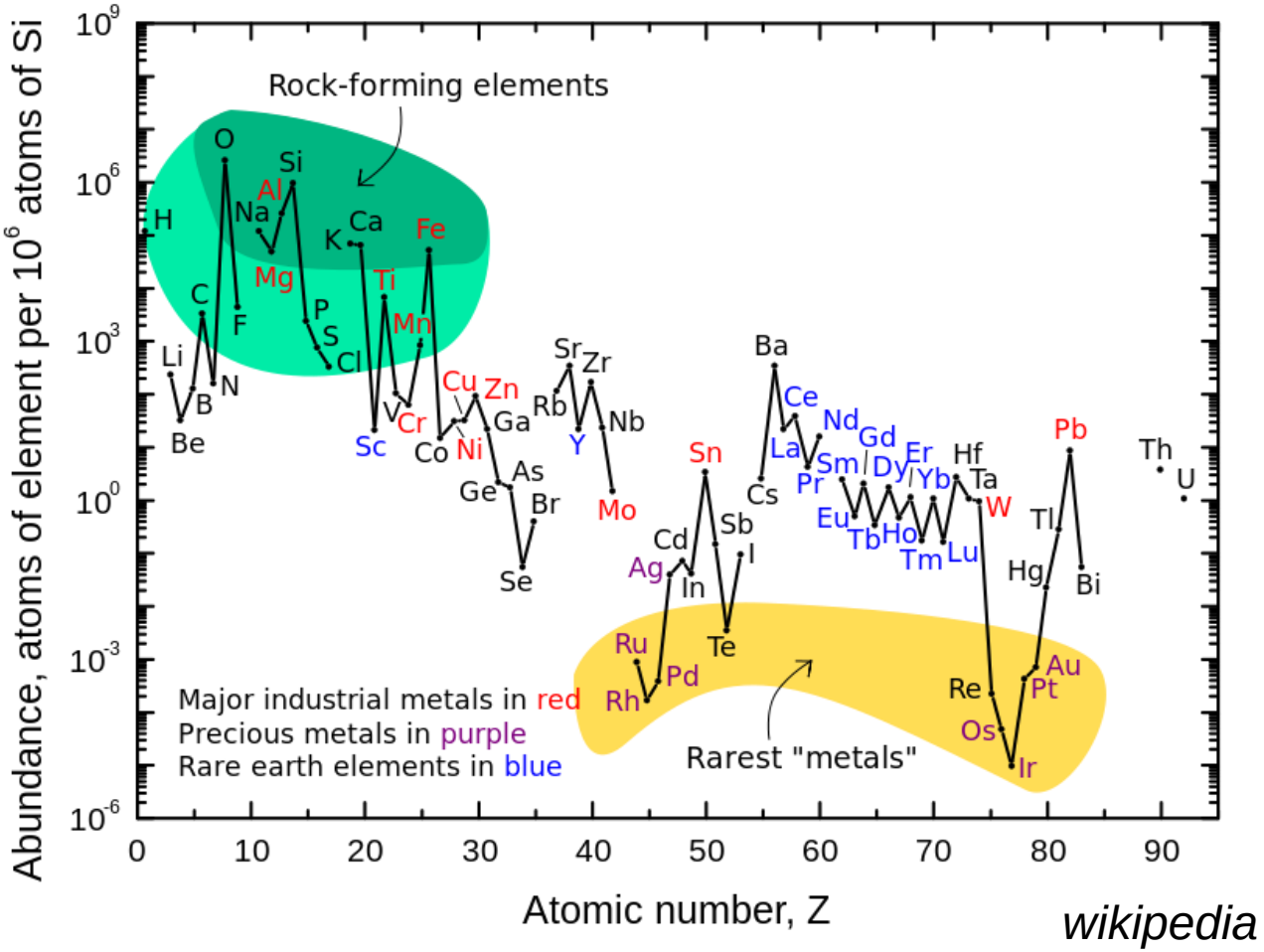

wikipedia

- Mn, Zn, Ca, C, Si, Na, Fe, Al, Ti, O, N,
  - Can we use less refined natural oxides?
  - Can we avoid fossil based organics?

Types of storage, Materials in play. .

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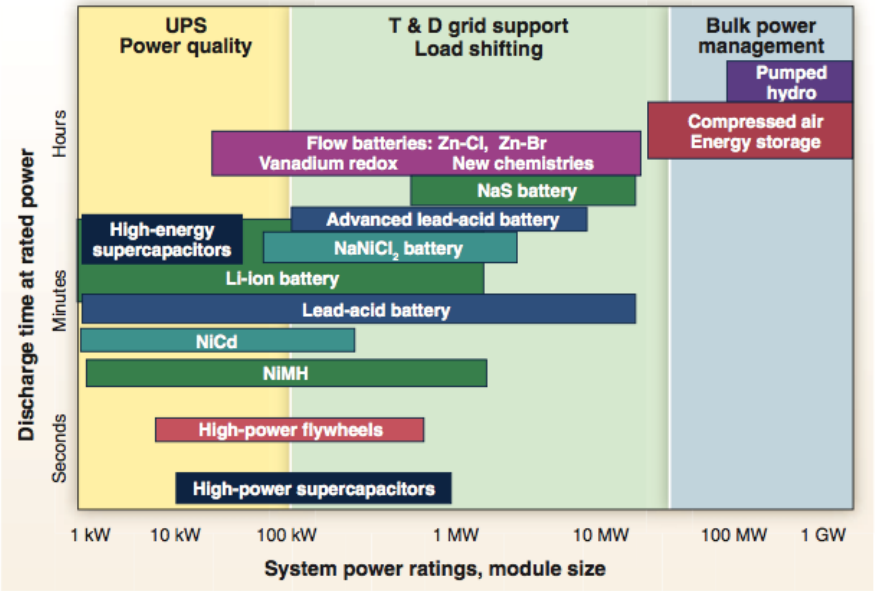


Fig. 1. Comparison of discharge time and power rating for various EES technologies. The comparisons are of a general nature because several of the technologies have broader power ratings and longer discharge times than illustrated (*1*). [Courtesy of EPRI]

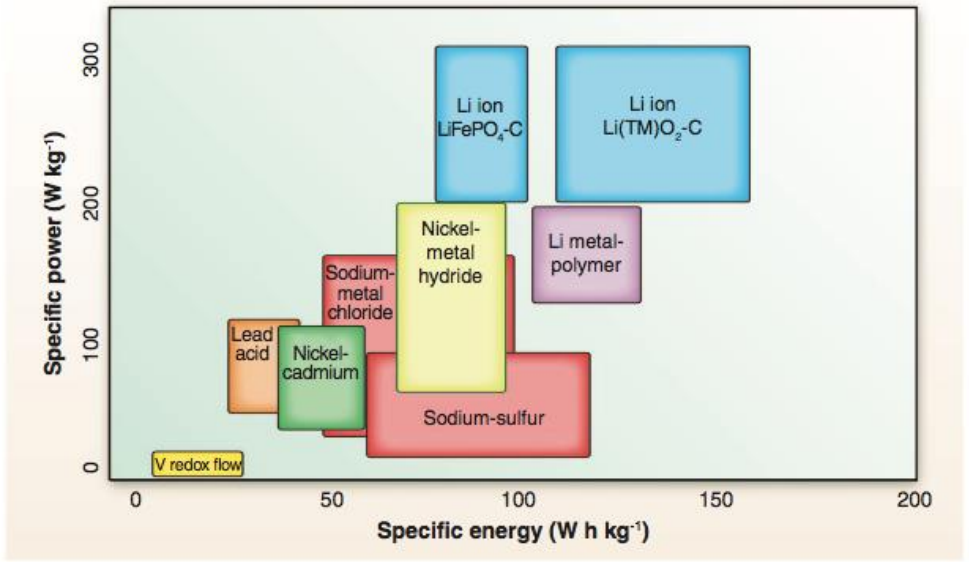
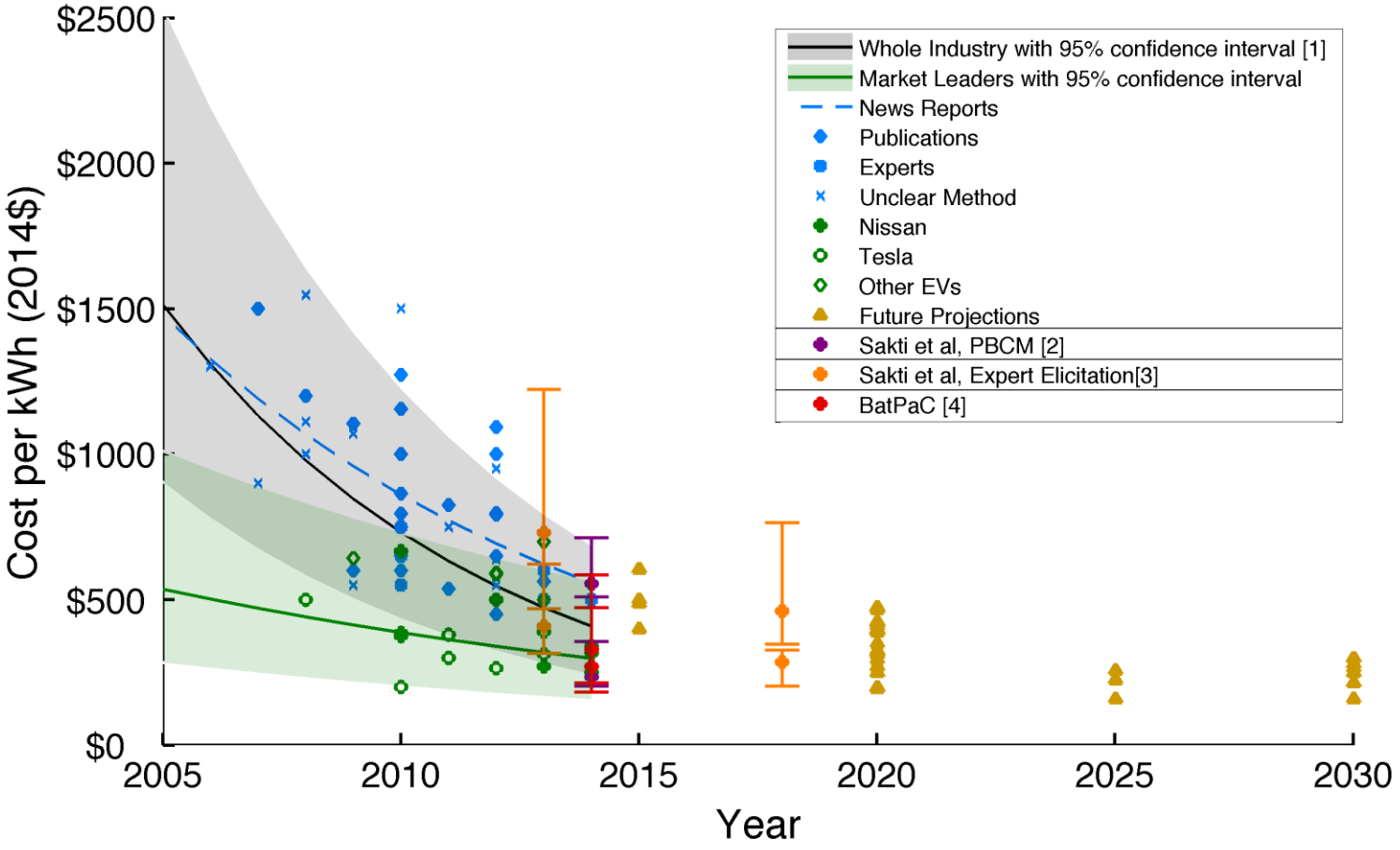


Fig. 2. Gravimetric power and energy densities for different rechargeable batteries. Most of these systems are currently being investigated for grid storage applications.

- Battery materials have nearly an order of magnitude less energy/mass or volume than combustible fuels

Dunn et al, 18 NOVEMBER 2011 VOL 334 SCIENCE, p 92

Li-ion cost projections



NOTE: capital cost per kWh is not a useful metric without much more info on use case and degradation. . .

Highly Scaled Li-Ion

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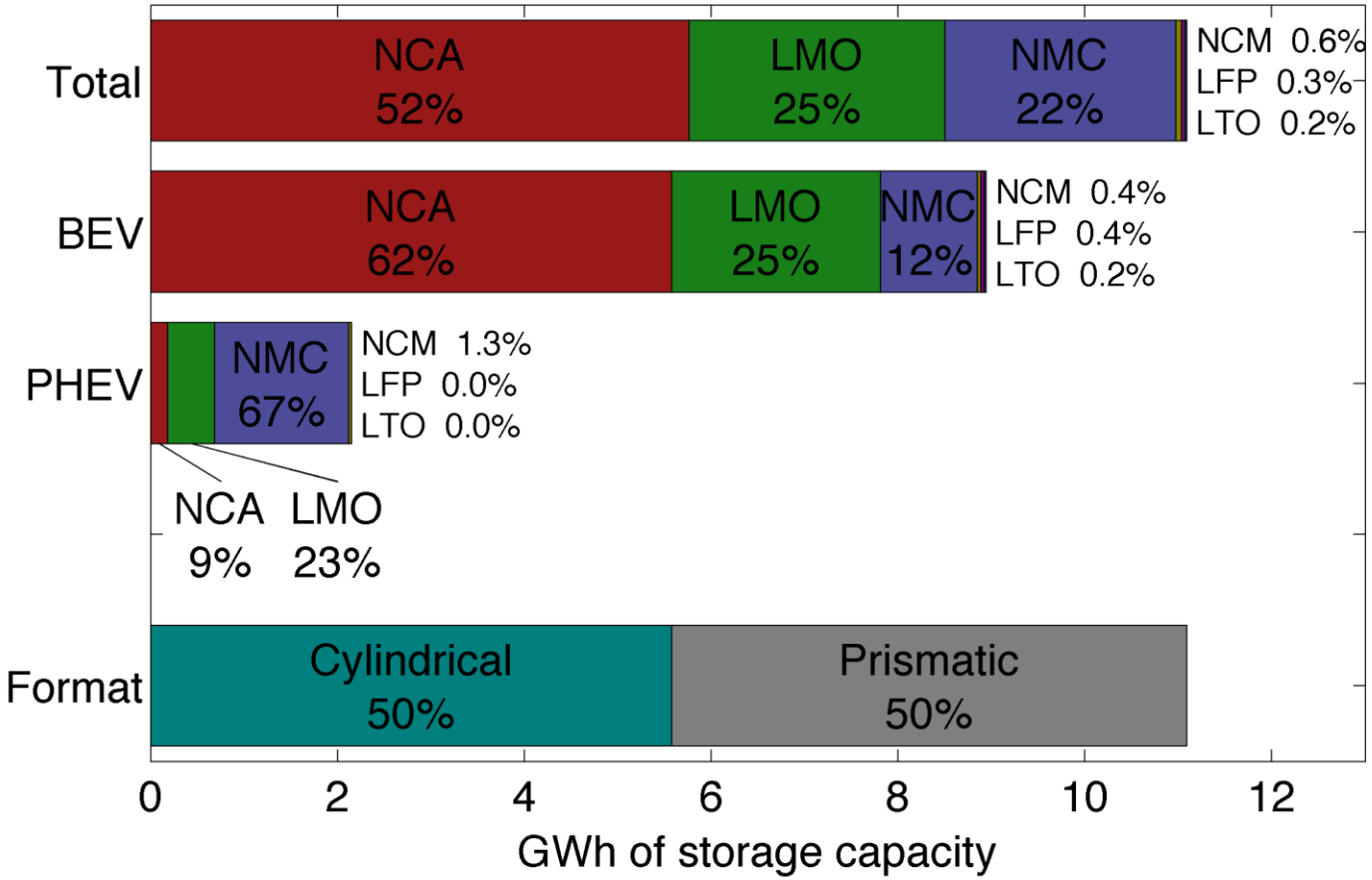

- Graphite anode
- NCA = LiNi**Co**AlO_2, LMO = $LiMn_2O_4$, NMC = LiNiMn**Co**O2
- ~74,000,000 kgs of processed battery materials on road today
- Gigafactory production is stated to be ***35 GWh/year by 2022. . .***

Li-ion Bill of Materials

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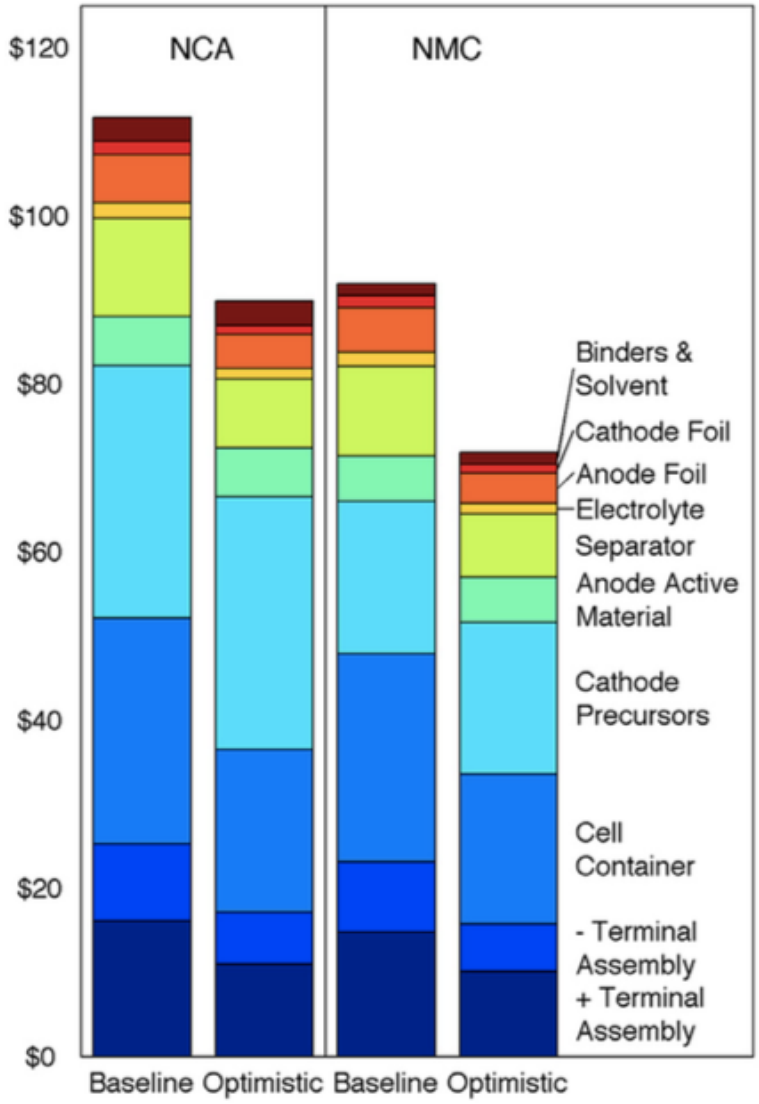

- Li – salt flats in South America
- Co, Ni, Mn, Cu, Al – various mines
- Fossil organic systems
  - Polymer separator
  - Polymer binder
  - Organic solvent electrolyte

Cobalt

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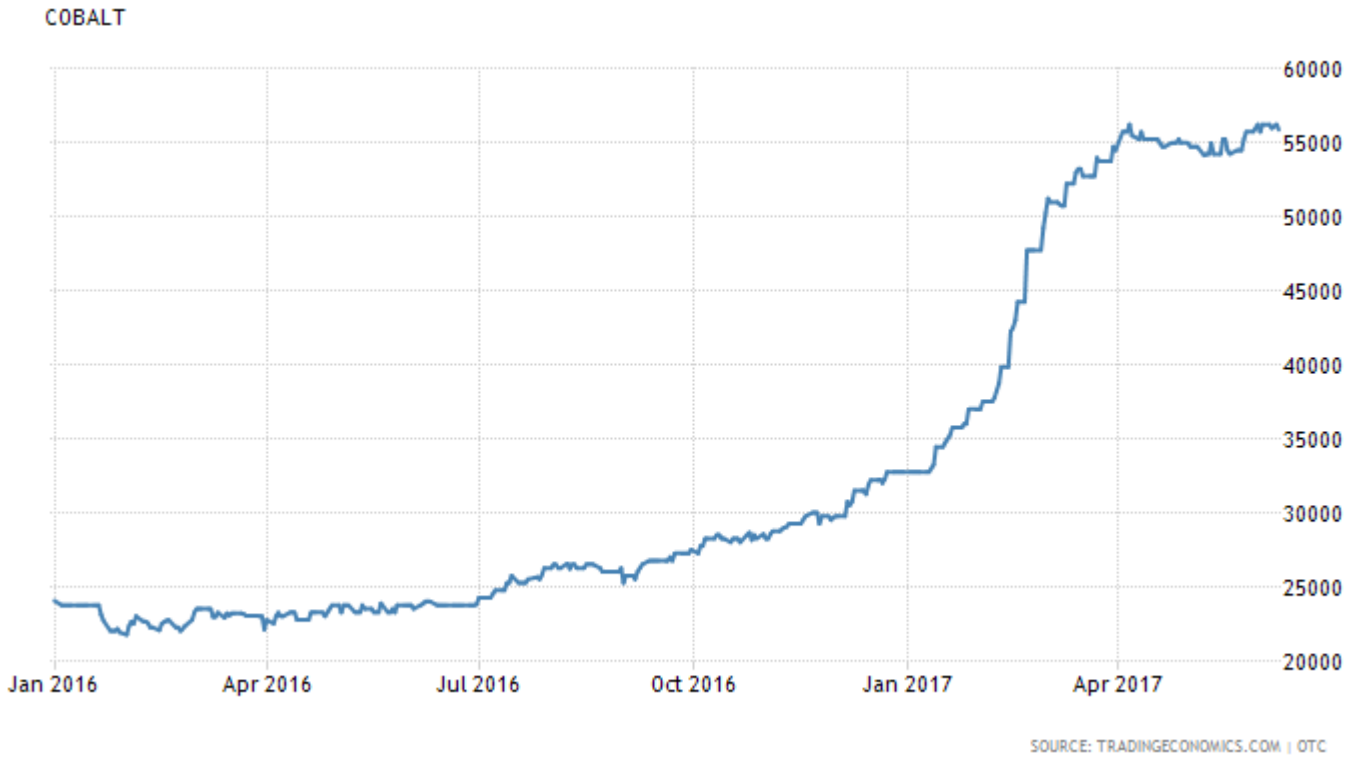

- Co price has more than doubled in past year. . .
- Other Issues with Co
- Finding; the most scaled energy storage materials systems are not materials optimized

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Implications for extraction

Other experts in room. .

Manufacturing

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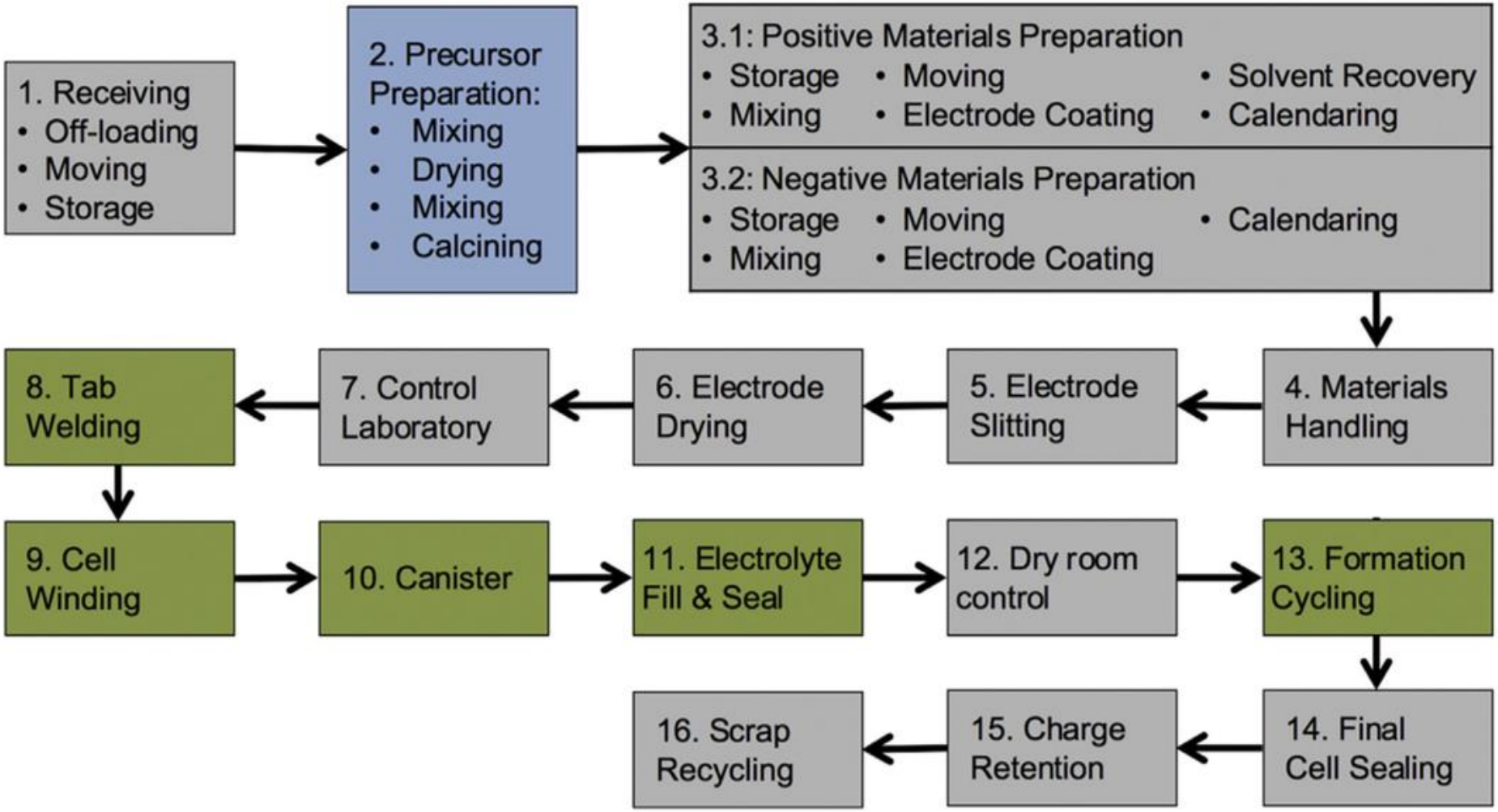

Energy Embodied vs Functional Energy

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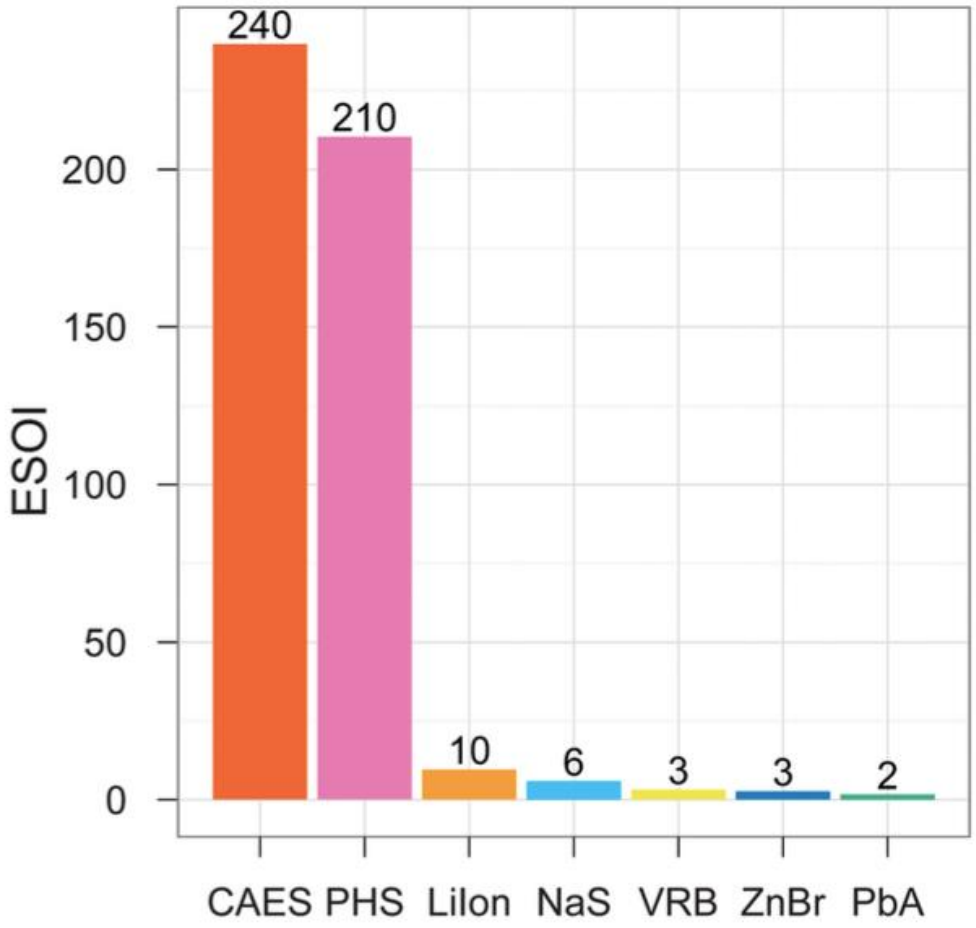

Fig. 2 A bar plot showing ESOI, the ratio of total electrical energy stored over the life of a storage technology to its embodied primary energy. Higher values are less energy intensive.

Besnon et al., Energy Environ. Sci., 2013, 6, 1083–1092 |

Recycling methods

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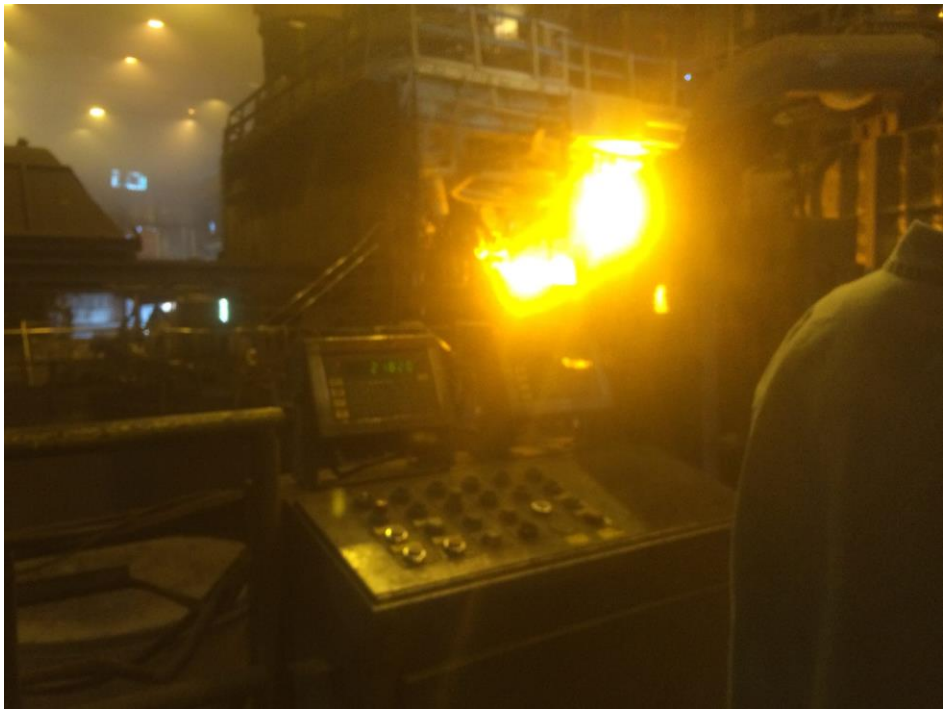

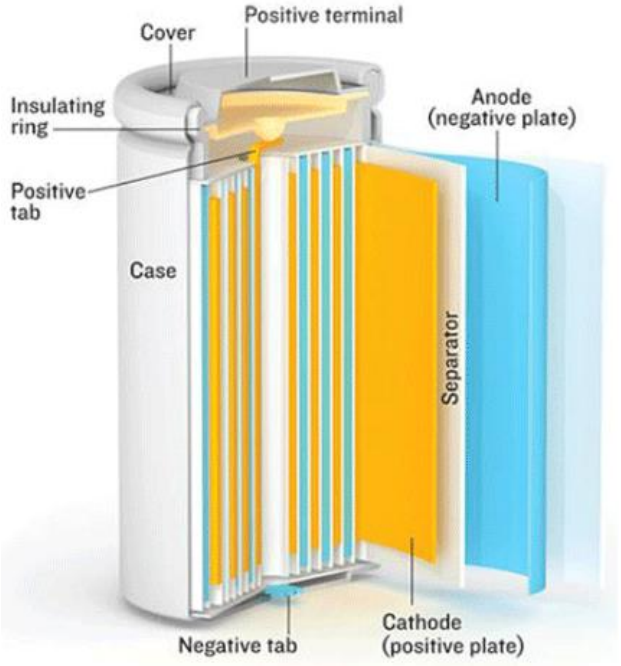

Wikipedia

- Goal: Recover constituent materials
- In practice – downcycling for other industries

Recycling methods

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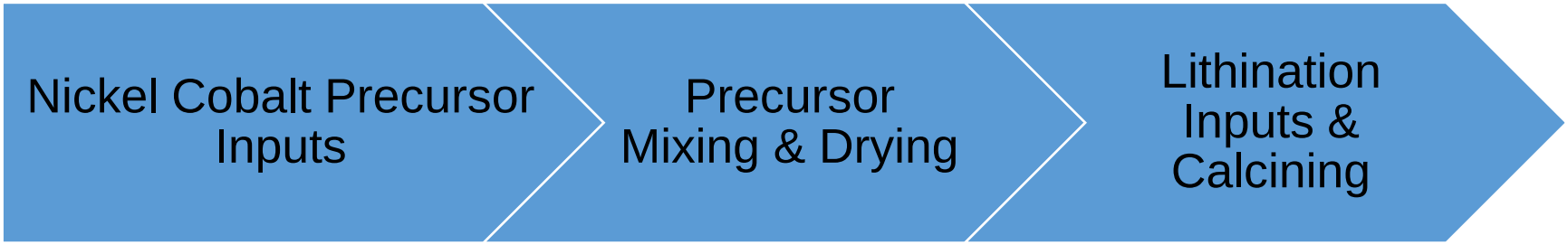
- Total
- Recover constituent materials
- In practice – downcycling for other industries

Direct

- Cathode materials are collected & reprocessed



- Use GREET to model emissions and energy consumption for cathode materials (2 types of precursors, 1 recycled)

Recycling methods

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Potential emissions & energy savings from using recycled NCA, robust even at low recovery rates

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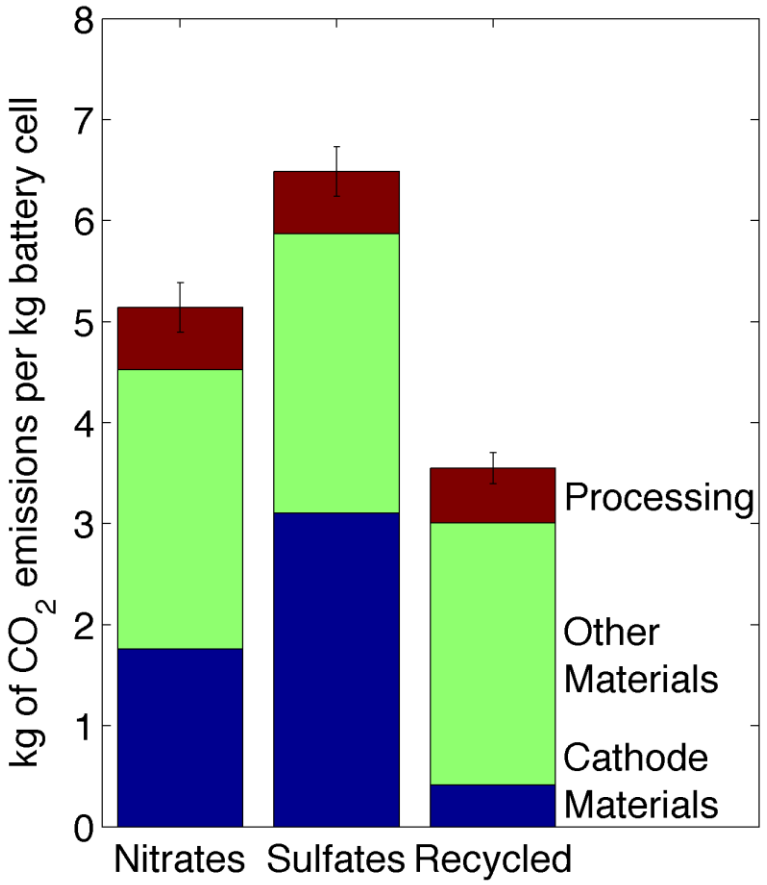

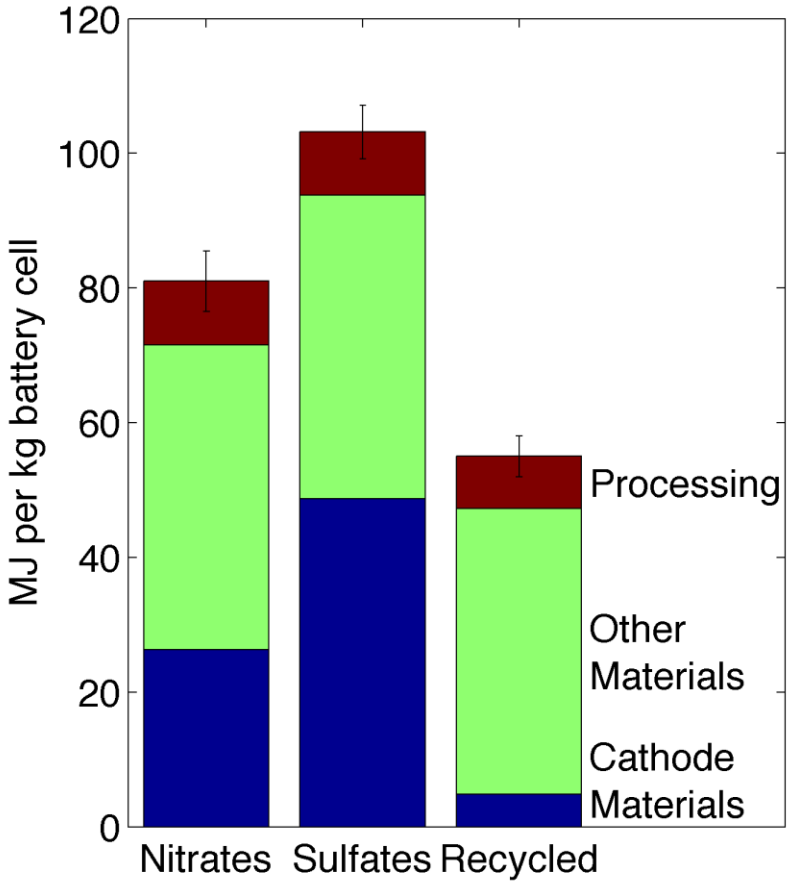

Potential emissions & energy savings from using recycled NCA, robust even at low recovery rates

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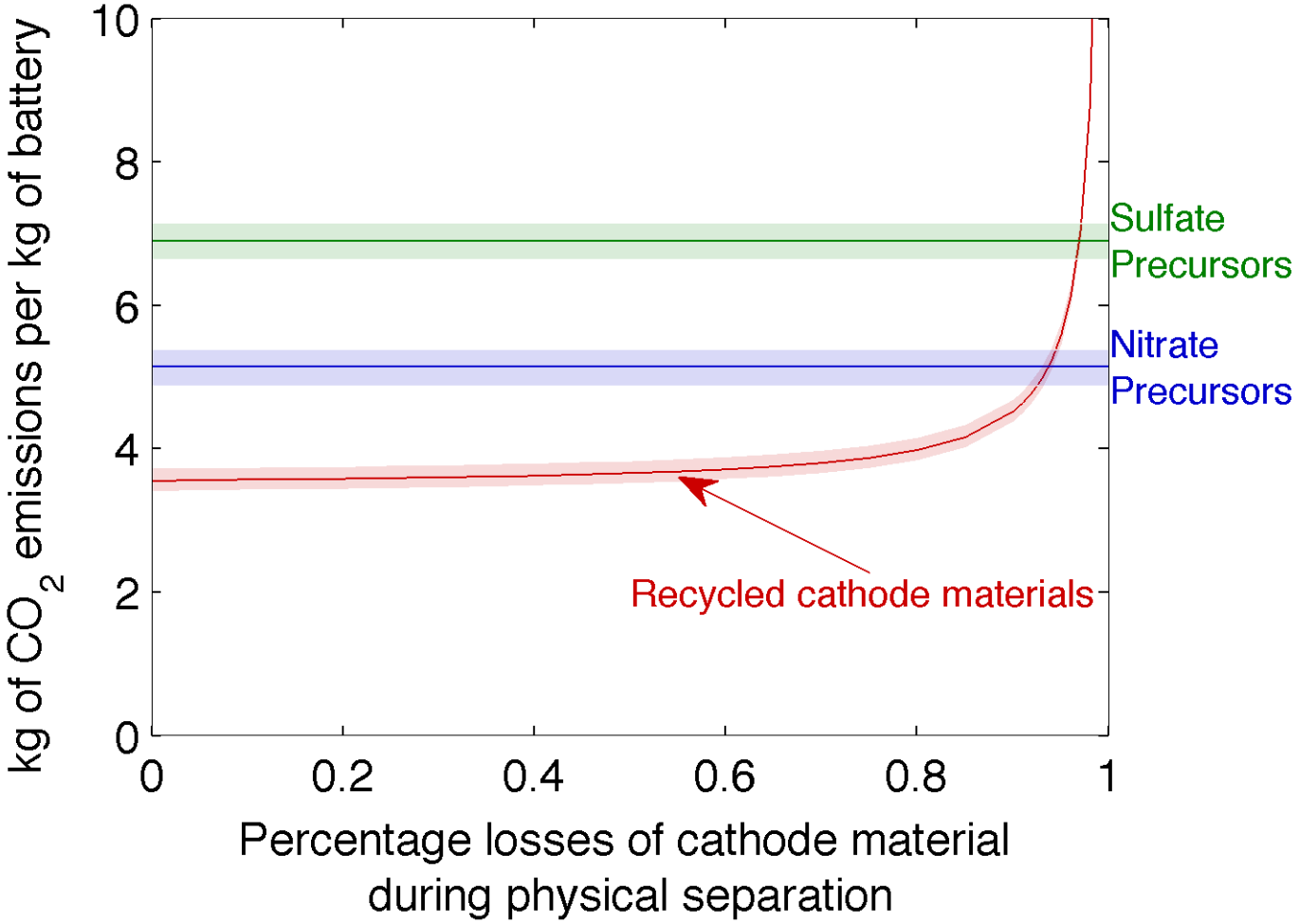

What would a more sustainable energy storage look like?

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- Less processing of materials before insertion
- Aqueous based electrolytes
  - More feasible for stationary systems based on energy density
- High tolerance to lower purities
- Very long lifetime/cycles
  - Levelized assessment needed to make cost/materials/use trades

Example: AQUION ENERGY

cradle to cradle

- Spun out of CMU in 2009
- Simple materials (MnO_2, TiO_2 inputs), less complex manufacturing, ”cradle to cradle” certified
- Pathway to $100/kWh with 3000 cycles (current about 2.5 x this)
- ~$200 M raised, 150 jobs, domestic manufacturing, ~40 MWh shipped
- Undergoing restructuring – 120 Laid off - acquisition to complete on 21 June
- Scaling a stand-alone new energy company *extremely* difficult. . .