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# Sustainable Batteries

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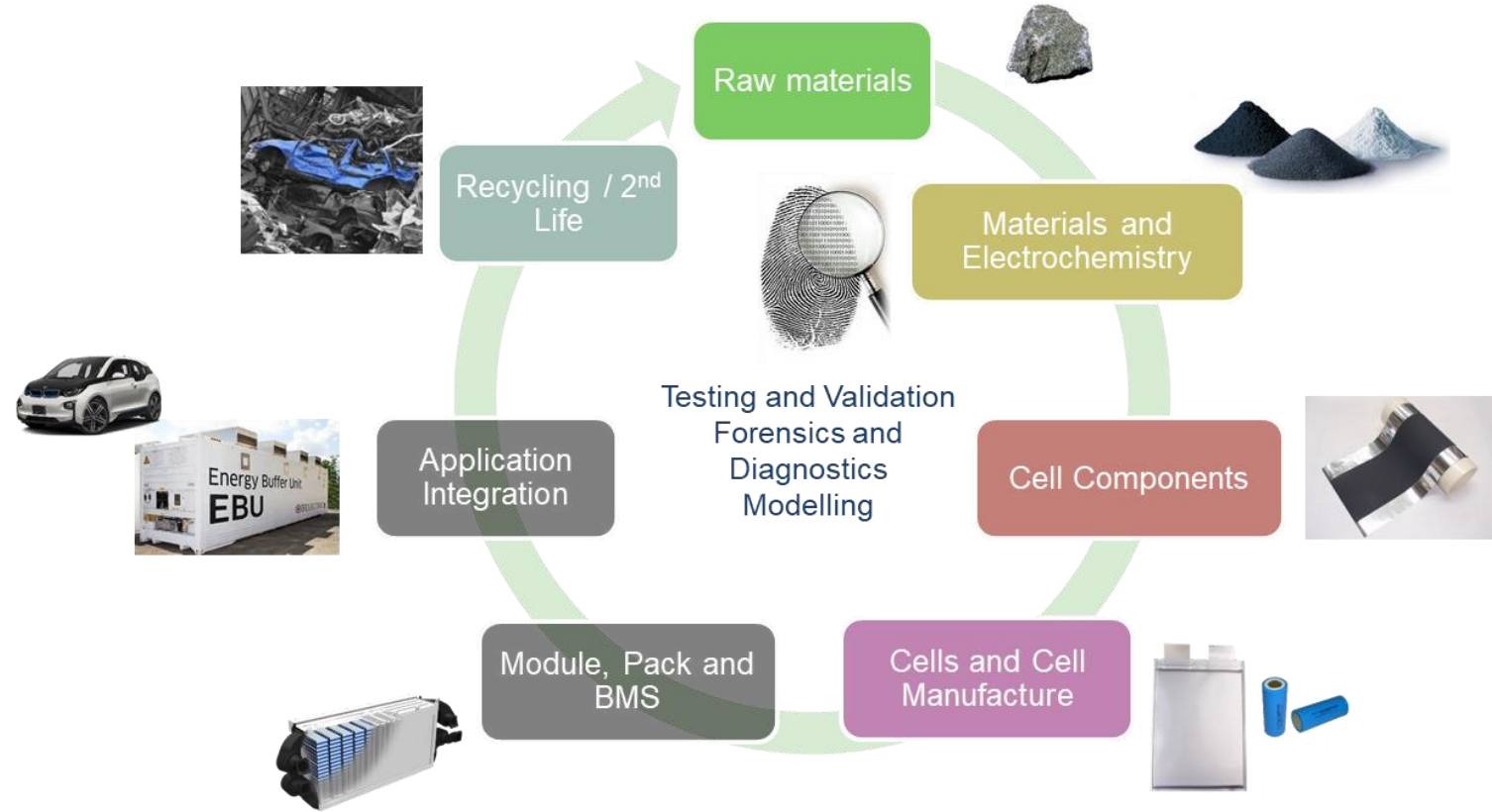
**GCRF and UPSIGN Clean and Affordable Energy and Water  
11-12 March 2020, Marriott Hotel, Islamabad, Pakistan**





# Sustainability

1. Raw Materials
2. Manufacturing
3. Recycling





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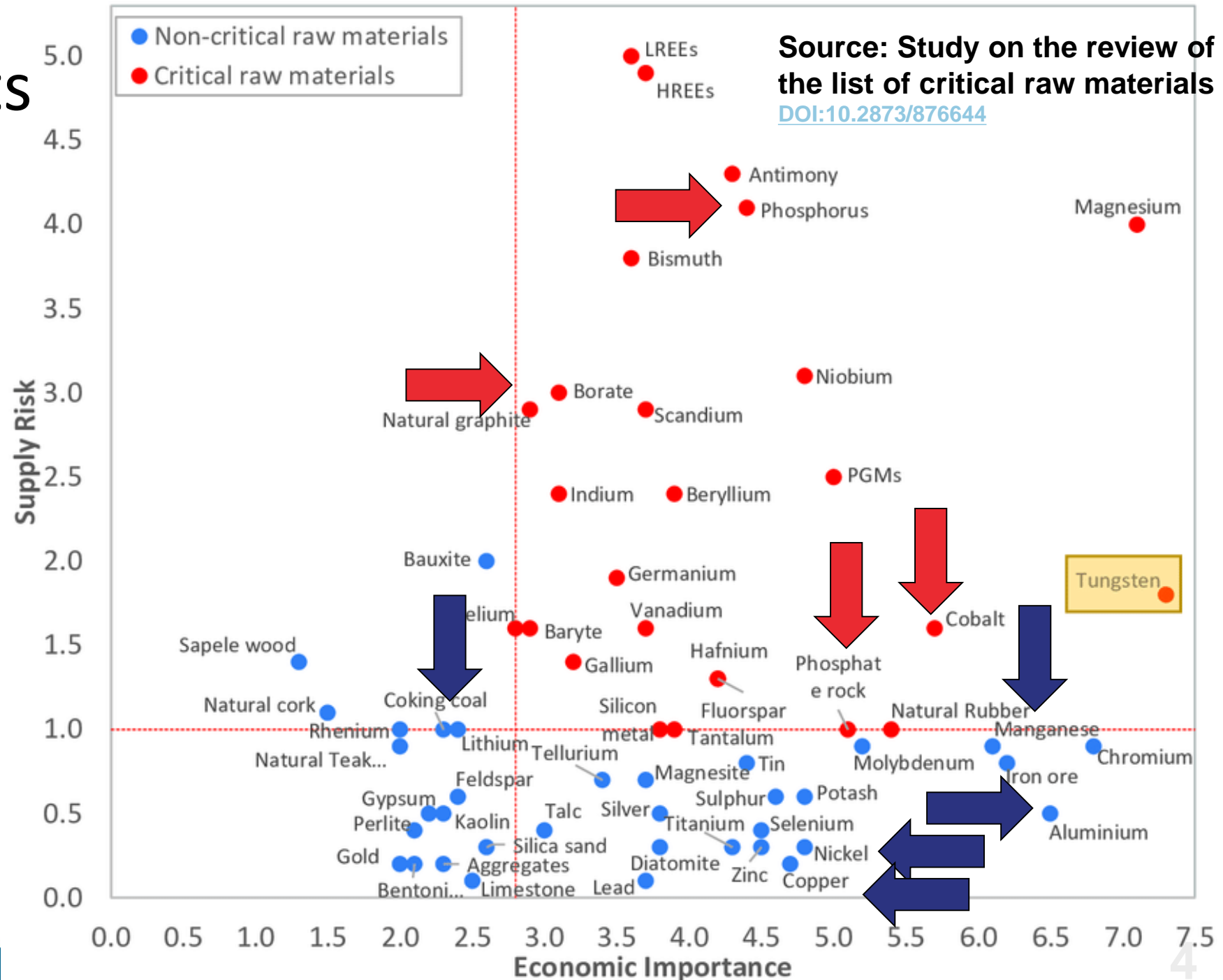
# Sustainable Materials



# Strategic Elements & Critical Materials: European Commission

- Also deemed critical by United States Geological Survey 2018:

- Lithium
- Aluminium
- Manganese





China

Data Source: [Industrial Minerals' Natural Graphite Report 2012](#)  
Picture: Simon Moores



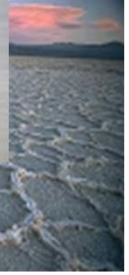
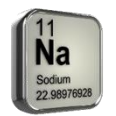
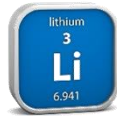
# Ethical Sourcing?

Brazil

01/14  
Picture: Simon Moores



# Lithium for Sodium for Sustainability?

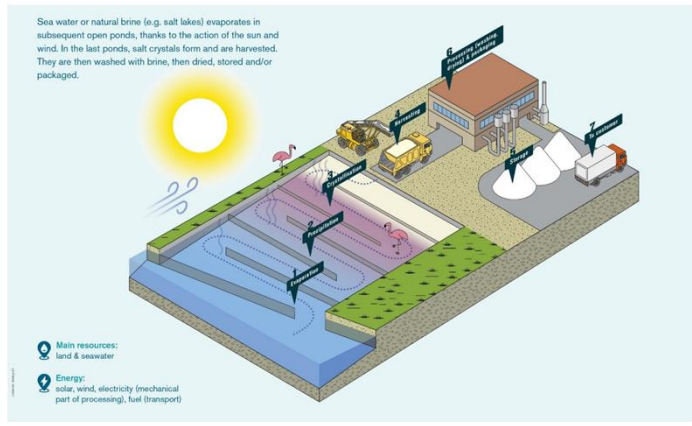


**ROCK SALT**

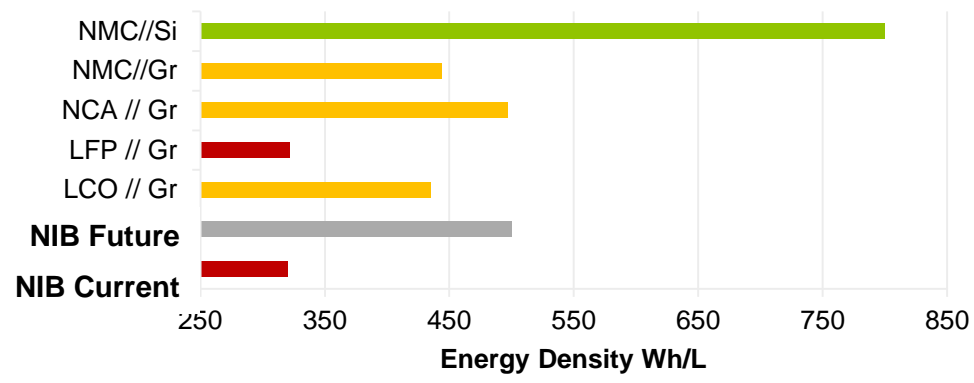
**VACUUM SALT**

**SOLAR SALT**

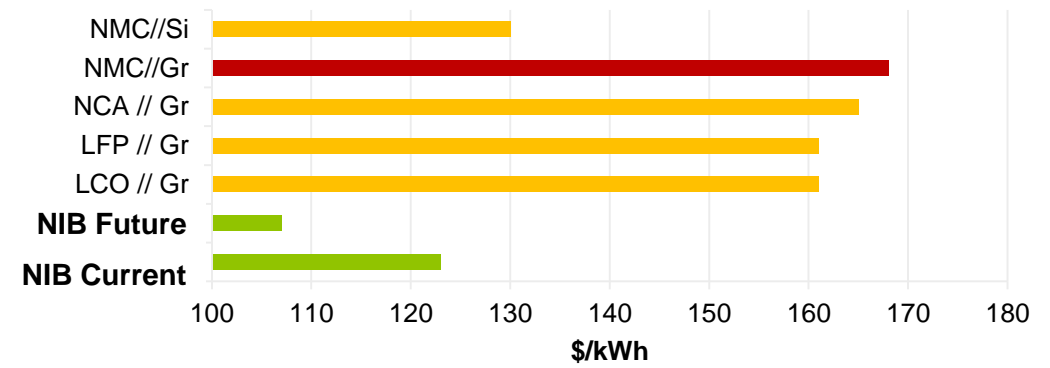
eusalt



**Energy Density (Wh/L)**



**Cost**



**High Energy NIB Target – New Anode**



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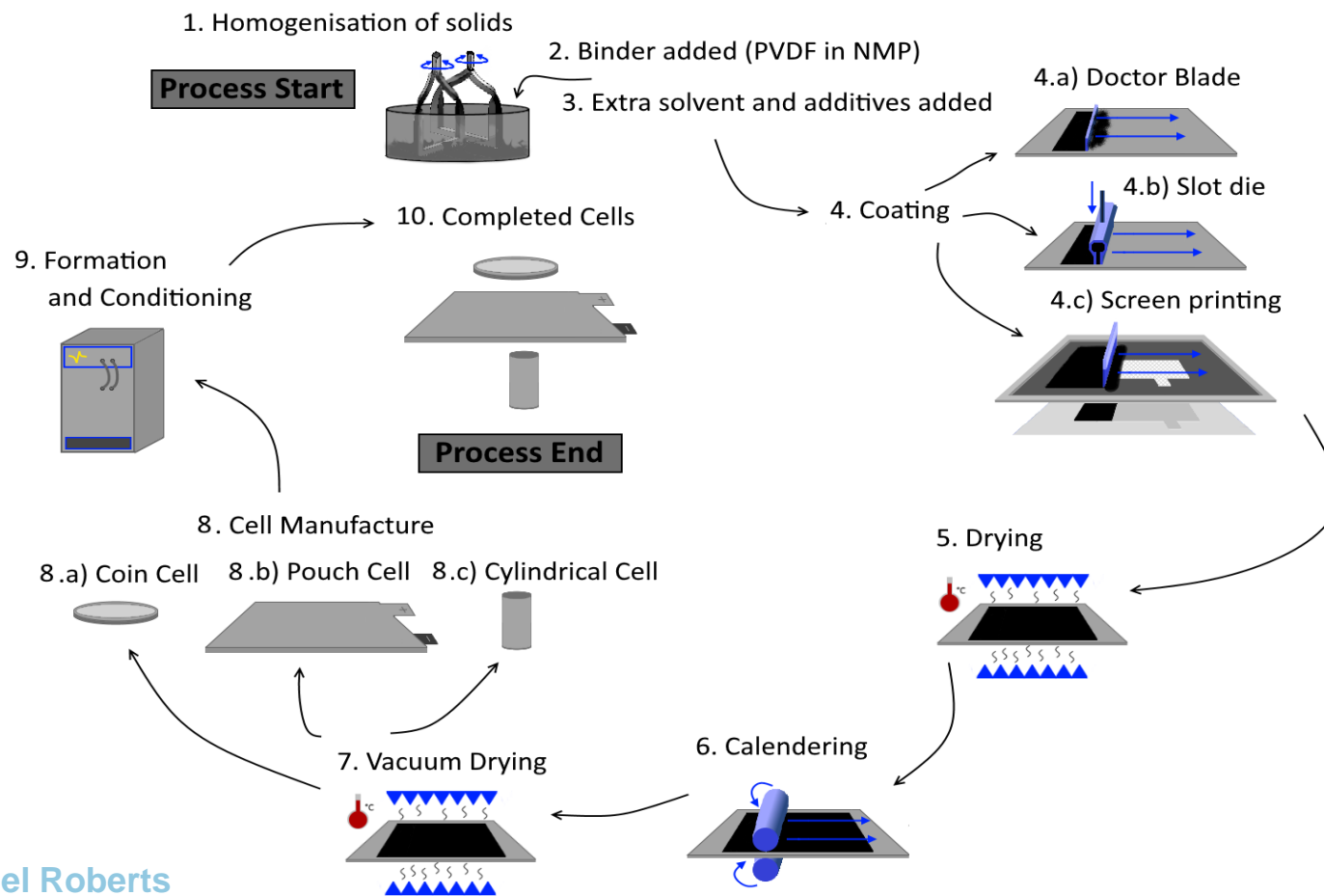
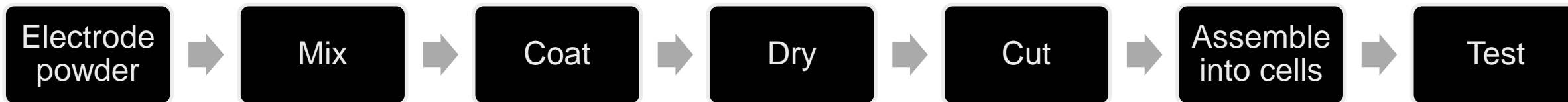




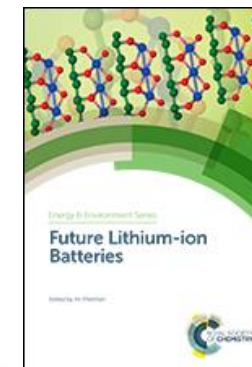
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# Sustainable Manufacturing





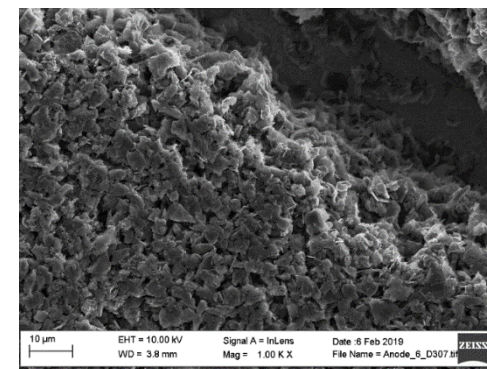
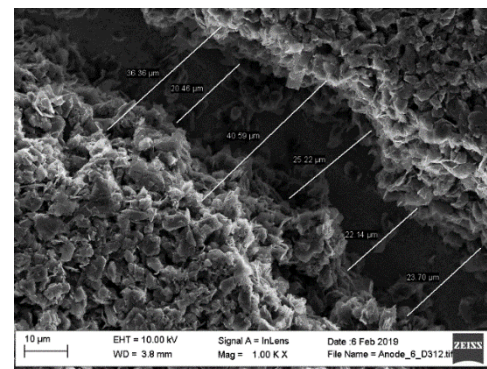
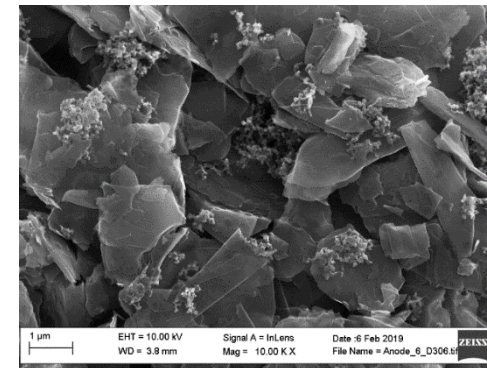
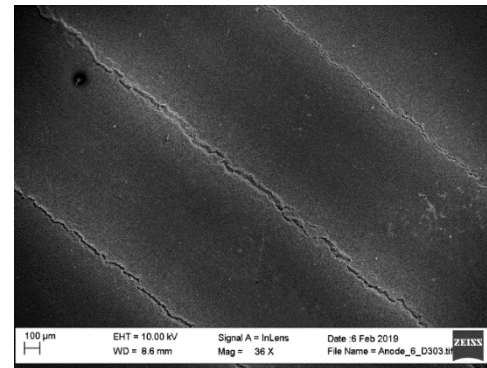
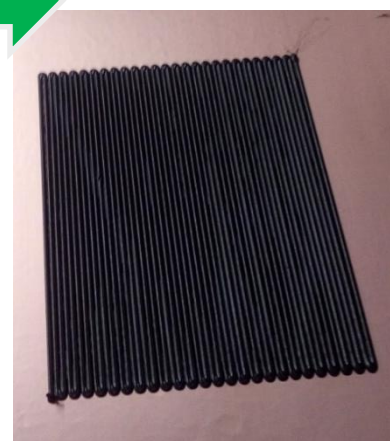
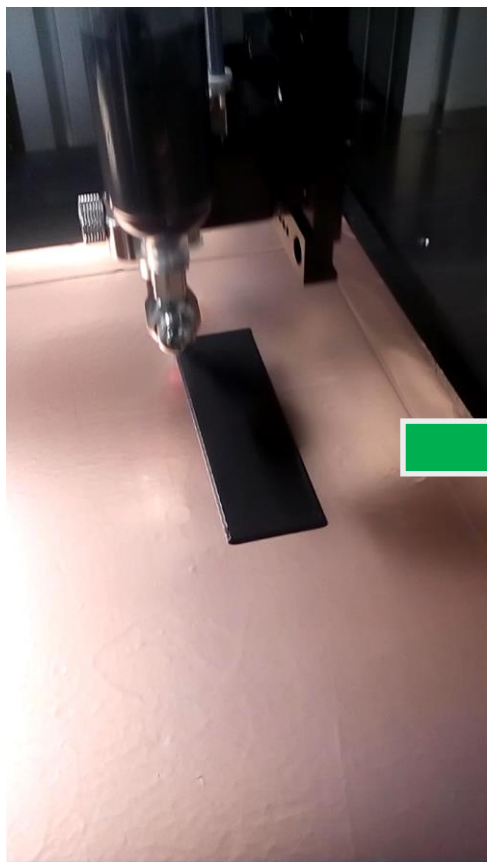
Credit – Samuel Roberts





# Spraycoat – Digital Electrode Deposition

## Controlled Deposition of Electrodes



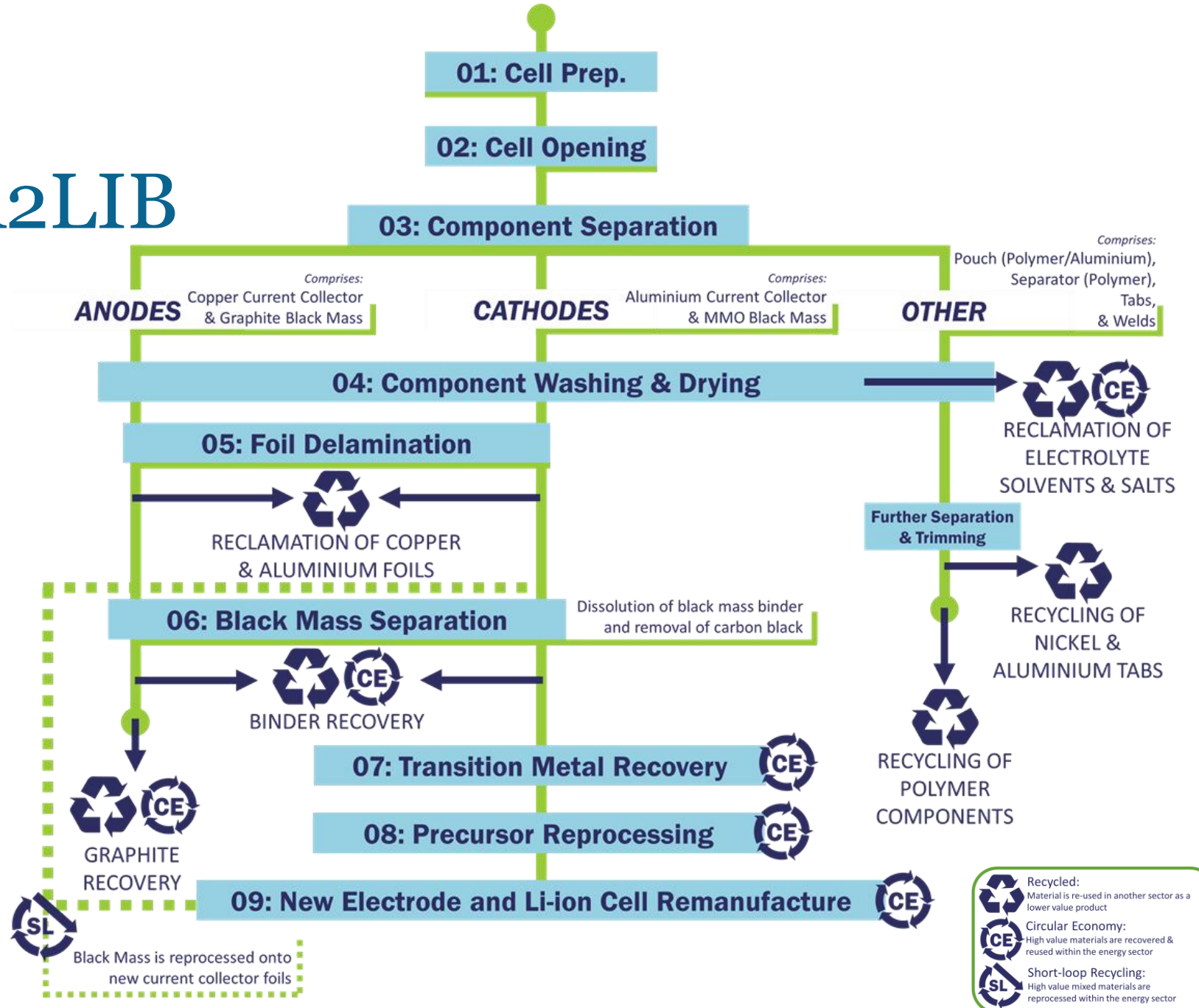


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# Reuse and Remanufacture



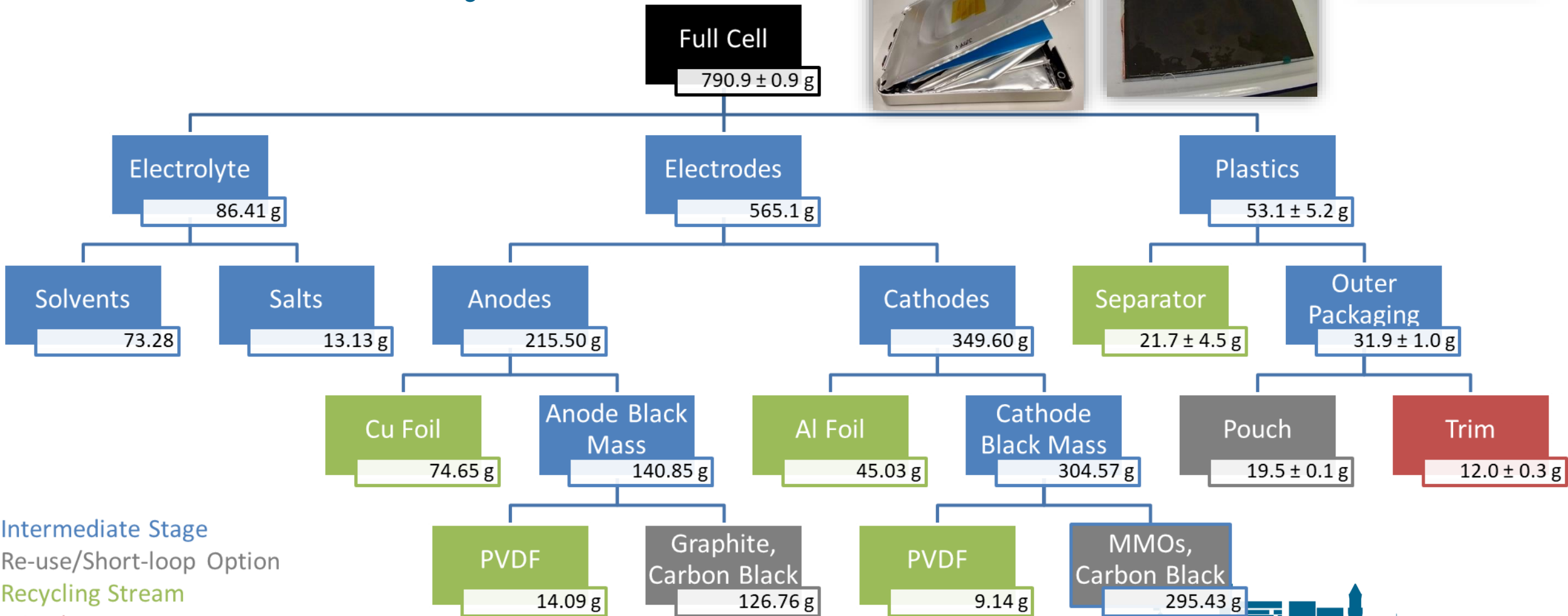
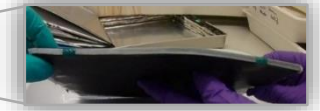
# Reclamation IUK Project R2LIB



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# Teardown (Manufacturing Scrap)

## Full Cell Analysis



Intermediate Stage  
 Re-use/Short-loop Option  
 Recycling Stream  
 Mixed Waste





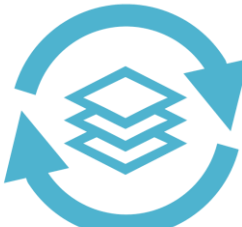
# R2LiB: From manually opened, QC failed cells...



...445 g of black mass has been reclaimed per cell



...86 g of electrolyte has been reclaimed per cell



...120 g of metal foils have been reclaimed per cell



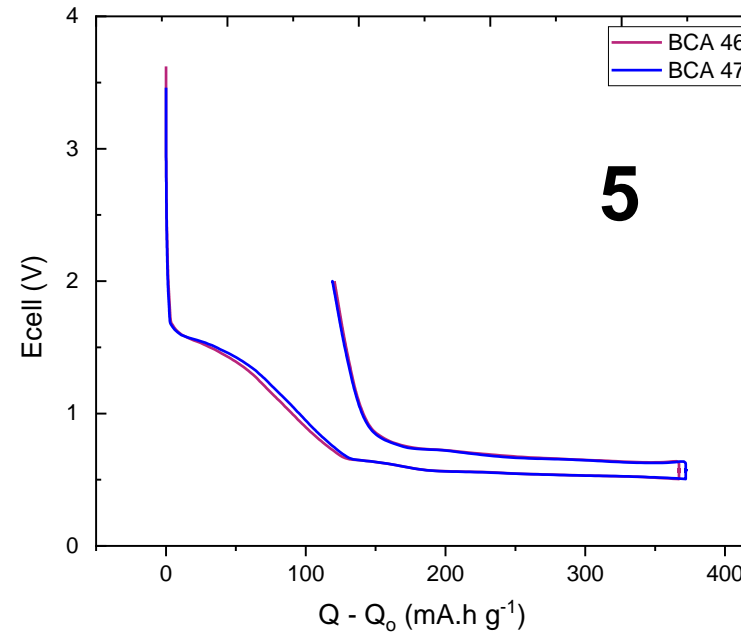
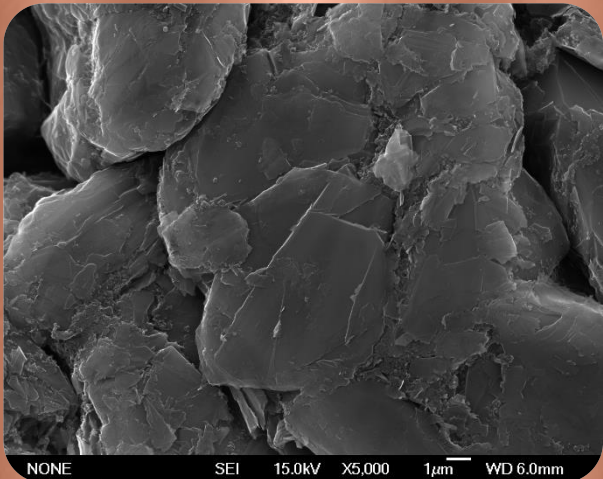
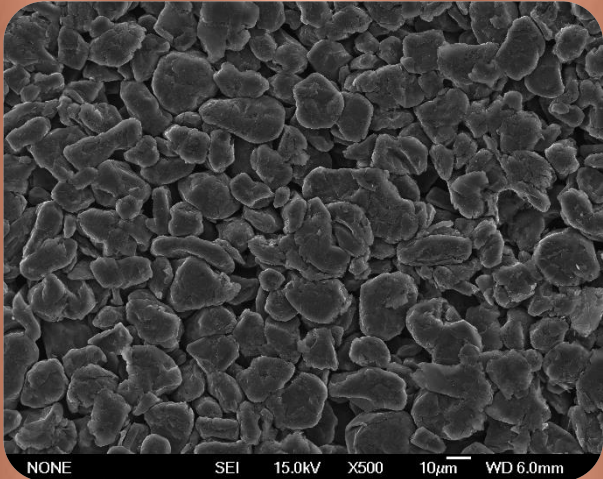
...41 g of plastic films have been reclaimed per cell

= Successful reclamation of **87%** of a cells mass

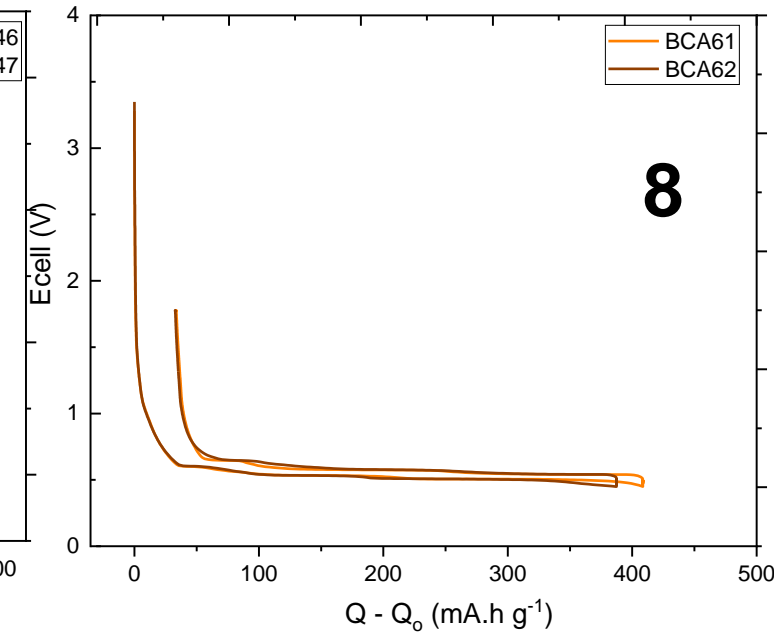


# End of Life Re-Use? Short Loop Recycling - Graphite

End of life cell



Not Washed and  
Heat Treated



Washed, separated  
and heat treated



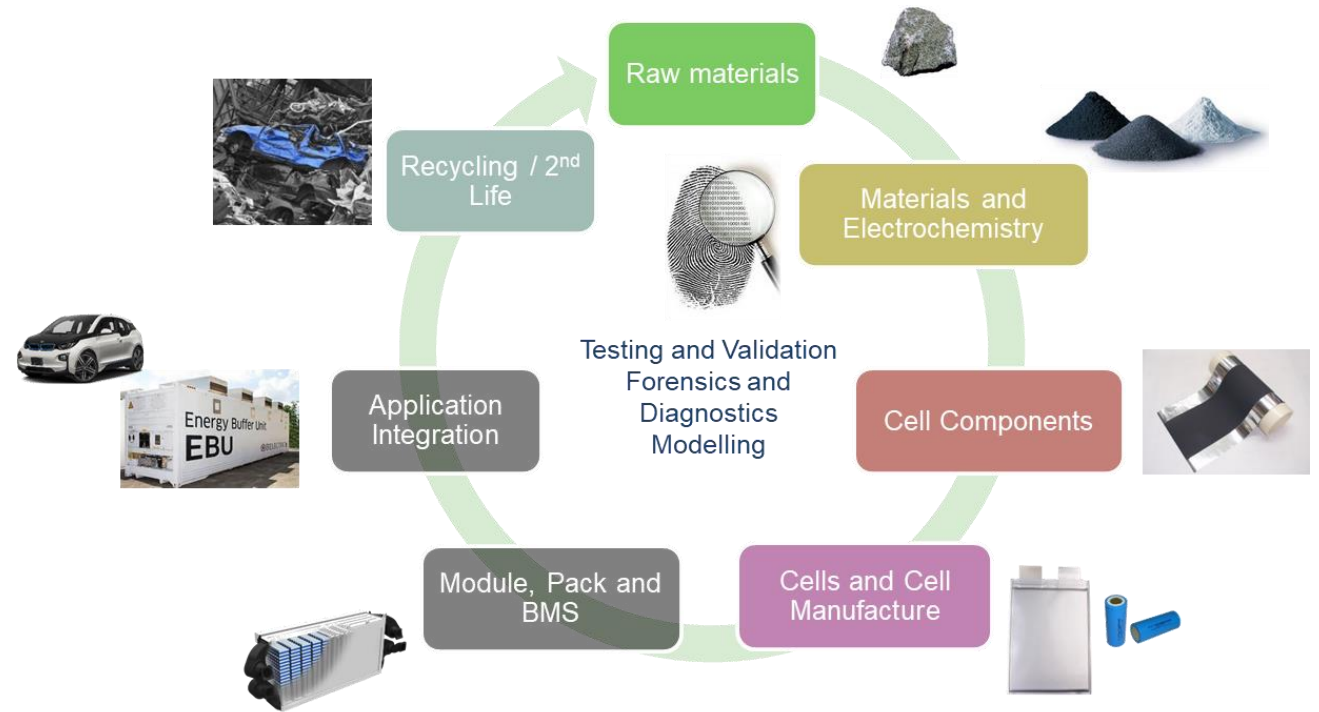


# Sustainability

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2. Manufacturing

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# Acknowledgements

Recycling Work: Birmingham: **Dominika Gastol, Rob Sommerville, Ben Pye**

WMG: Vanessa Goodship, Beth Middleton, Jean Marshall

Sodium-ion Work: **Lin Chen, Brij Kishore,**  
UCL: Daniela Ledwoch, Dan Brett, Paul Shearing, James Robinson

Energy Materials Group  
University of Birmingham

 @EnergyMatBham



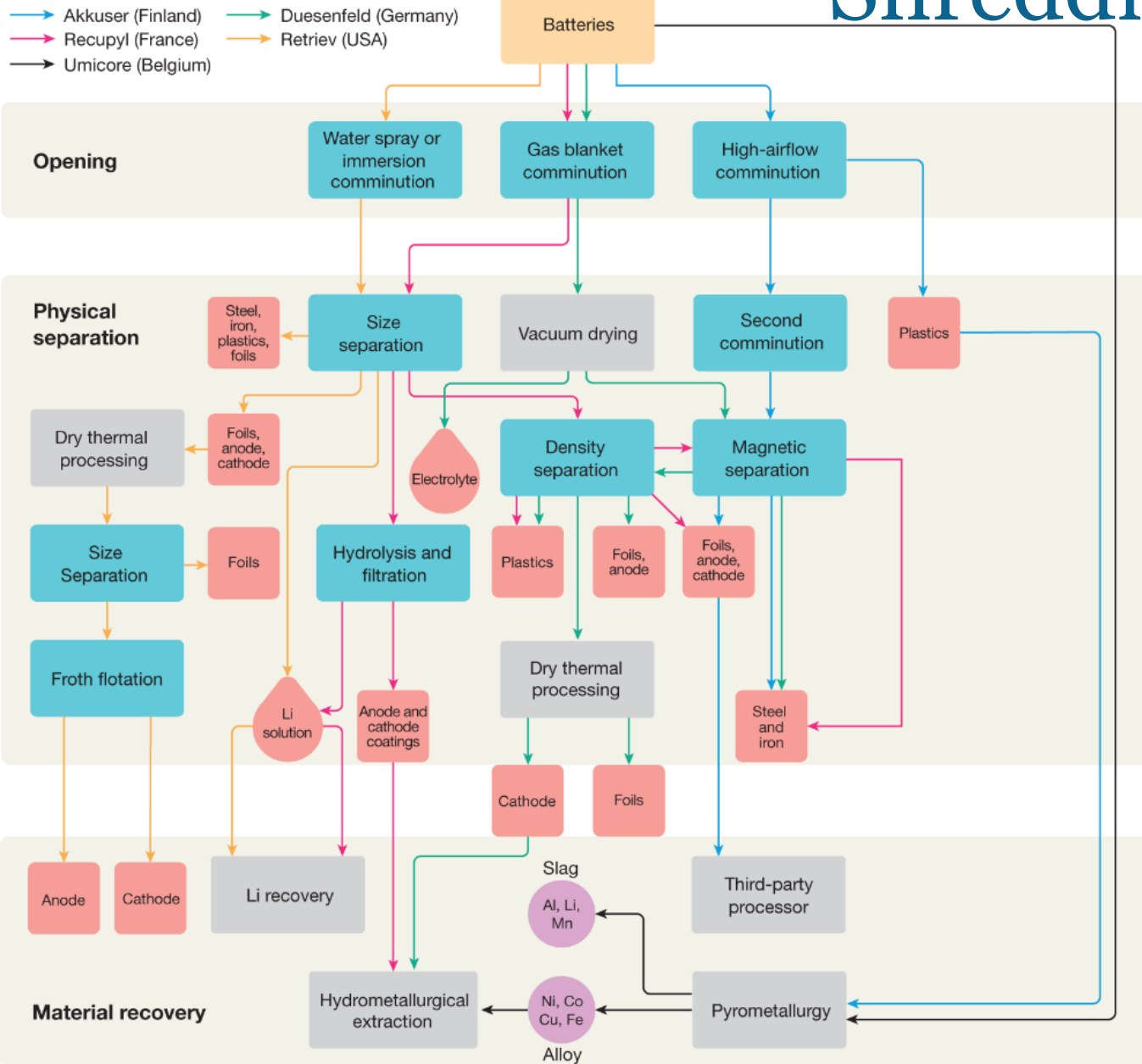
## Energy Materials Group

Lin Chen, Brij Kishore, Tengfei Song, Yongxiu Chen, Julian Key, Dave Burnett, Scott Gorman, Tanveer Pathan, Anton Zorin, Zahira Latif, Ben Pye, Yazid Lakhdar, Samuel Roberts, Kieran O'Regan, Matthew Lloyd, Chris Constable, Keiron Knoble-Vickrage, Dominika Gastol, Rob Sommerville,





# Shredding?



## Review

# Recycling lithium-ion batteries from electric vehicles

<https://doi.org/10.1038/s41586-019-1682-5>

Received: 14 January 2019

Accepted: 23 July 2019

Gavin Harper<sup>1,2,3\*</sup>, Roberto Somerville<sup>1,2,4</sup>, Emma Kendrick<sup>1,2,3</sup>, Laura Driscoll<sup>1,2,5</sup>, Peter Slater<sup>1,2,5</sup>, Rustam Stolkin<sup>1,2,3,6</sup>, Allan Walton<sup>1,2,3</sup>, Paul Christensen<sup>1,7</sup>, Oliver Heidrich<sup>1,2,8</sup>, Simon Lambert<sup>1,7</sup>, Andrew Abbott<sup>1,9</sup>, Karl Ryder<sup>1,9</sup>, Linda Gaines<sup>10</sup> & Paul Anderson<sup>1,2,5\*</sup>



Anniversary collection:  
go.nature.com/nature150



Material discovery



Material manufacture



Electrode development

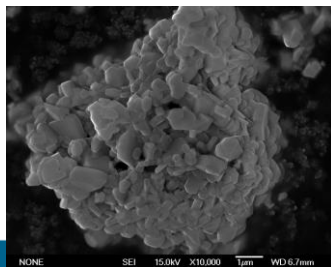
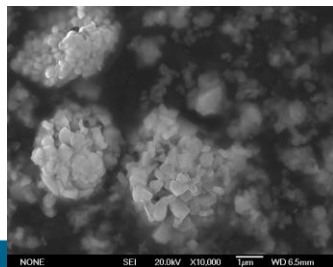
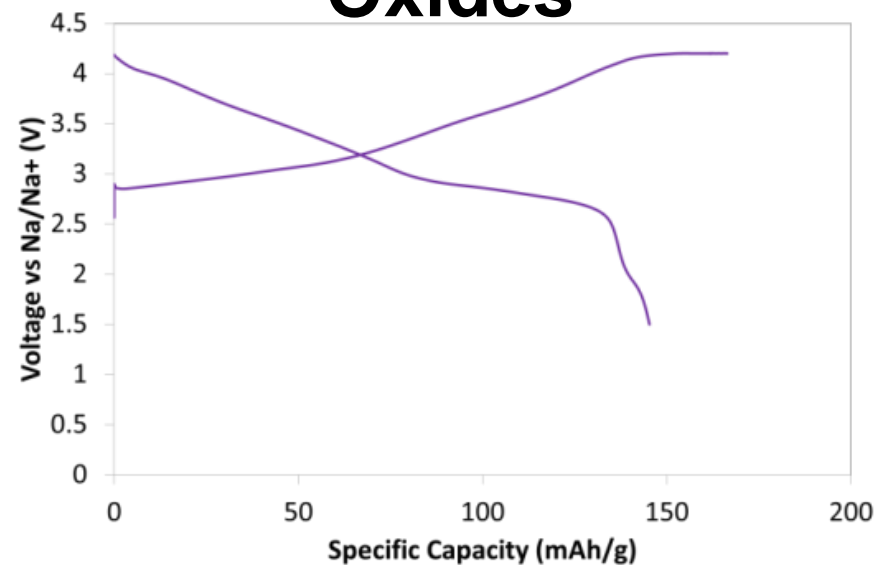


Cell development

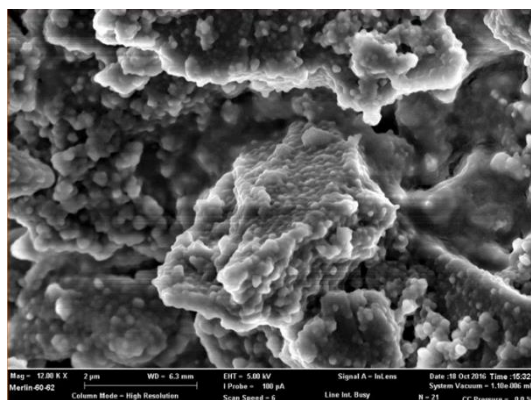
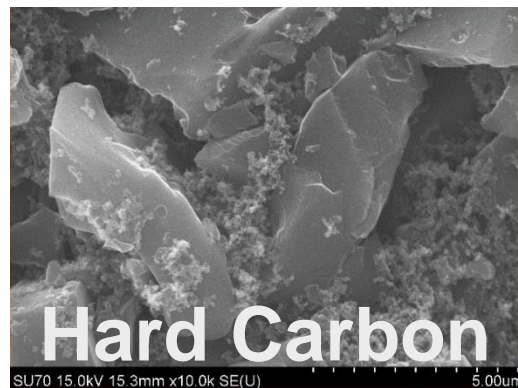


Cell demonstrator

## O3-type Layered Oxides



## SEI Optimisation Additives, Solvents



## Formation Studies

