

# SIMBA-Disassembly and Recycling

Emma Kendrick, Lin Chen, Brij Kishore, Tengfei Song, Bowen Lui, Anton Zorin,  
Subha Samanta, Osaze Omoregbe, Peter Slater, Farouk Tedjar, Zijun Lu

# Contents

- +- Critical Materials and Supply Chain
- +- Routes to Recycling
- +- SIMBA reclamation routes
  - +- Base-line Cell
  - +- Solid State Cell
- +- SIMBA reuse cases
  - +- Hard Carbon,
  - +- Prussian White



# Criticality Assessment – EU 2023

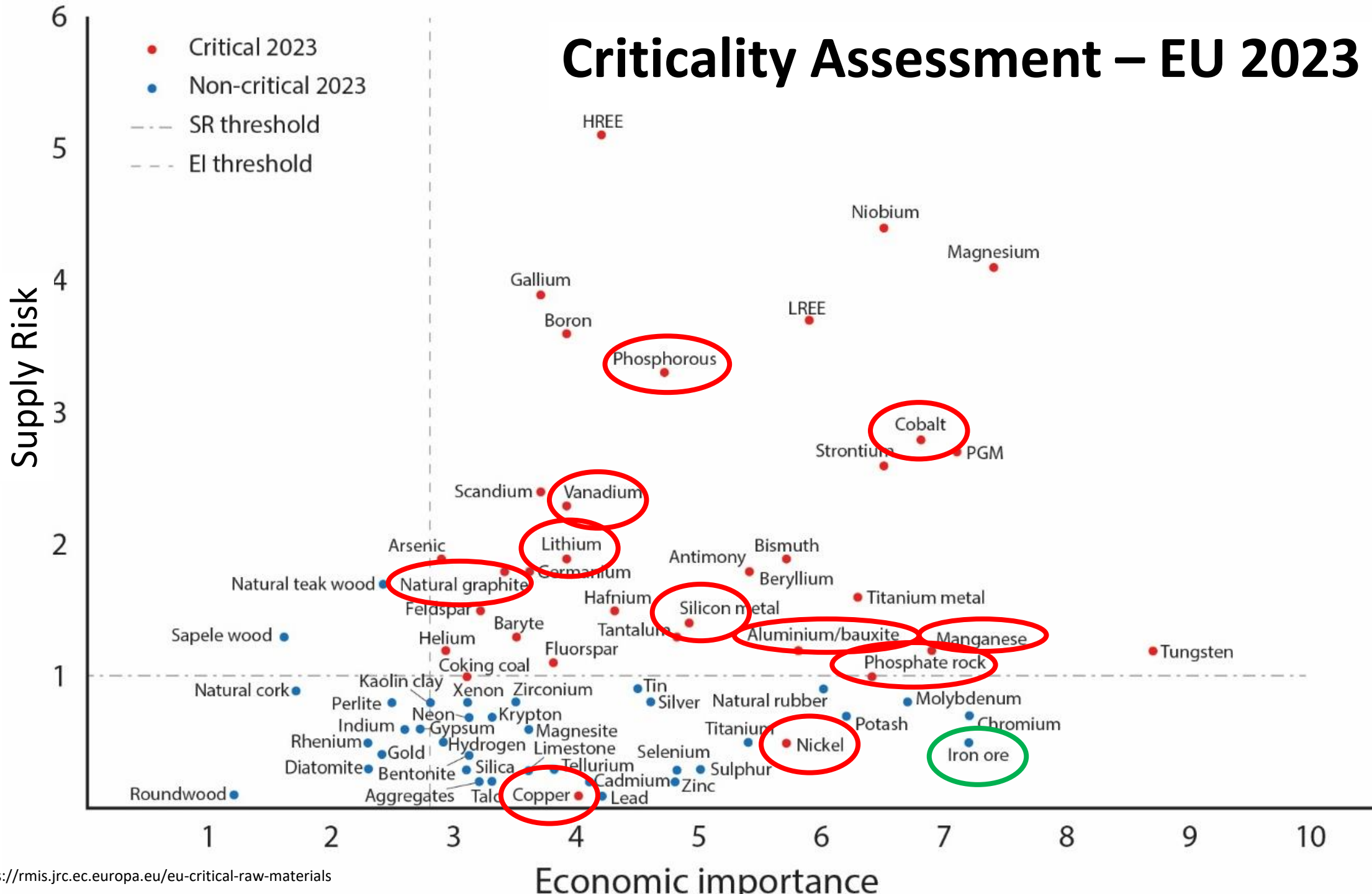


Figure 1. The Periodic Table of the Elements (Source: Science Notes and Projects)



Critical materials?

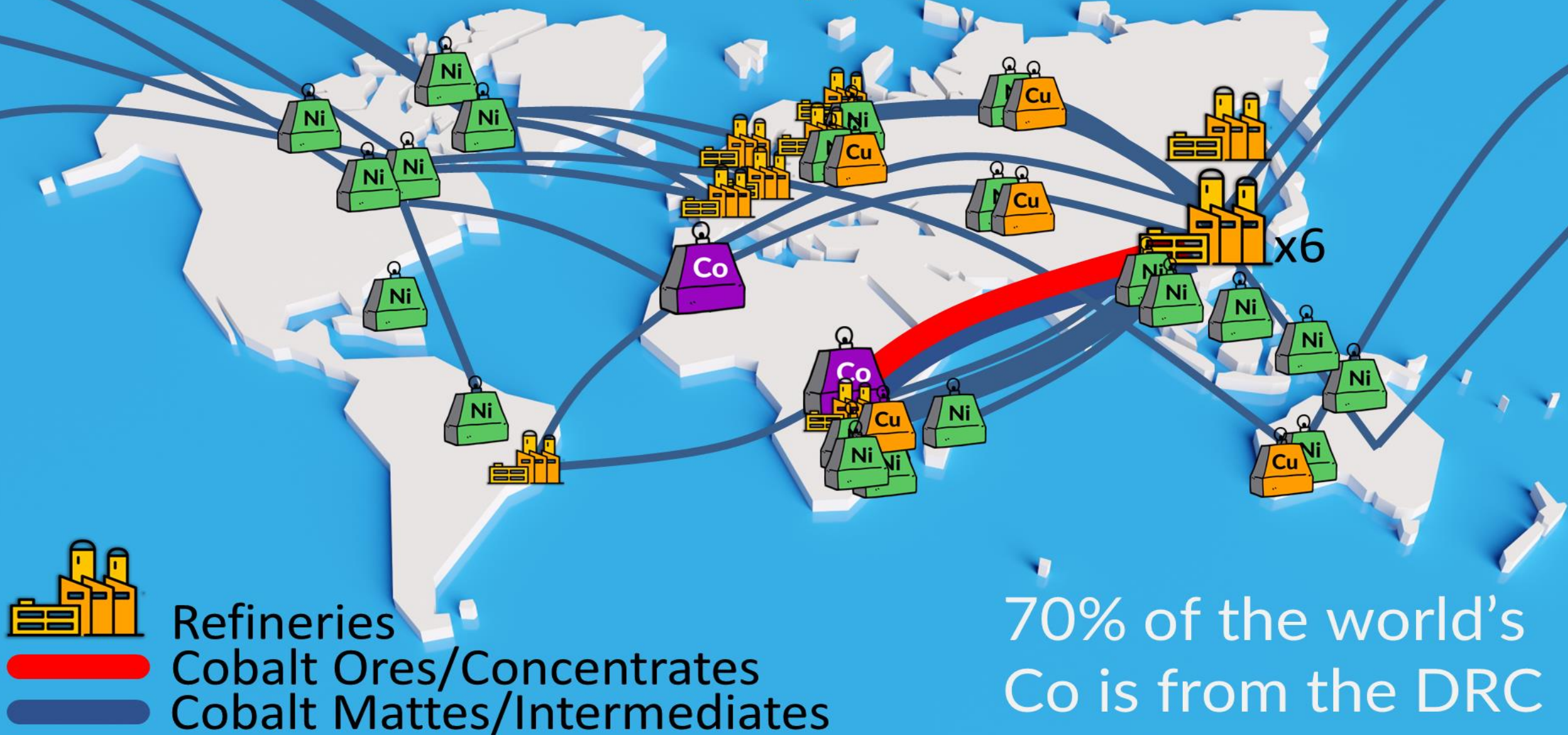
1 IA 11A 1 H Hydrogen 1.008	2 IIA 2A 4 He Helium 4.003	13 IIIA 3A 5 B Boron 10.811	14 IVA 4A 6 C Carbon 12.011	15 VA 5A 7 N Nitrogen 14.007	16 VIA 6A 8 O Oxygen 15.999	17 VIIA 7A 9 F Fluorine 18.998	18 VIIIA 8A 10 Ne Neon 20.180													
3 Li Lithium 6.941	11 Na Sodium 22.990	12 Mg Magnesium 24.305	19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.88	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.732	32 Ge Germanium 72.61	33 As Arsenic 74.922	34 Se Selenium 78.09	35 Br Bromine 79.904	36 Kr Krypton 84.80
37 Rb Rubidium 84.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.94	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.29			
55 Cs Cesium 132.905	56 Ba Barium 137.327	57-71 Lanthanide Series	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.85	75 Re Rhenium 168.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018			
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103 Actinide Series	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Fl Flerovium [289]	115 Uup Ununpentium unknown	116 Lv Livermorium [298]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown			

57 La Lanthanum 138.905	58 Ce Cerium 140.115	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.24	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.966	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.50	67 Ho Holmium 164.930	68 Er Erbium 167.26	69 Tm Thulium 168.934	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]

- Alkali Metal
- Alkaline Earth
- Transition Metal
- Semimetal
- Nonmetal
- Basic Metal
- Halogen
- Noble Gas
- Lanthanide
- Actinide

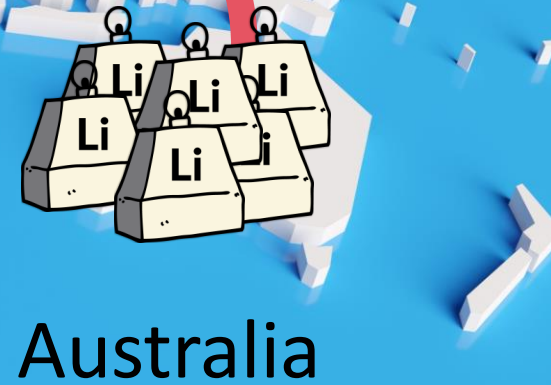


# Cobalt Supply



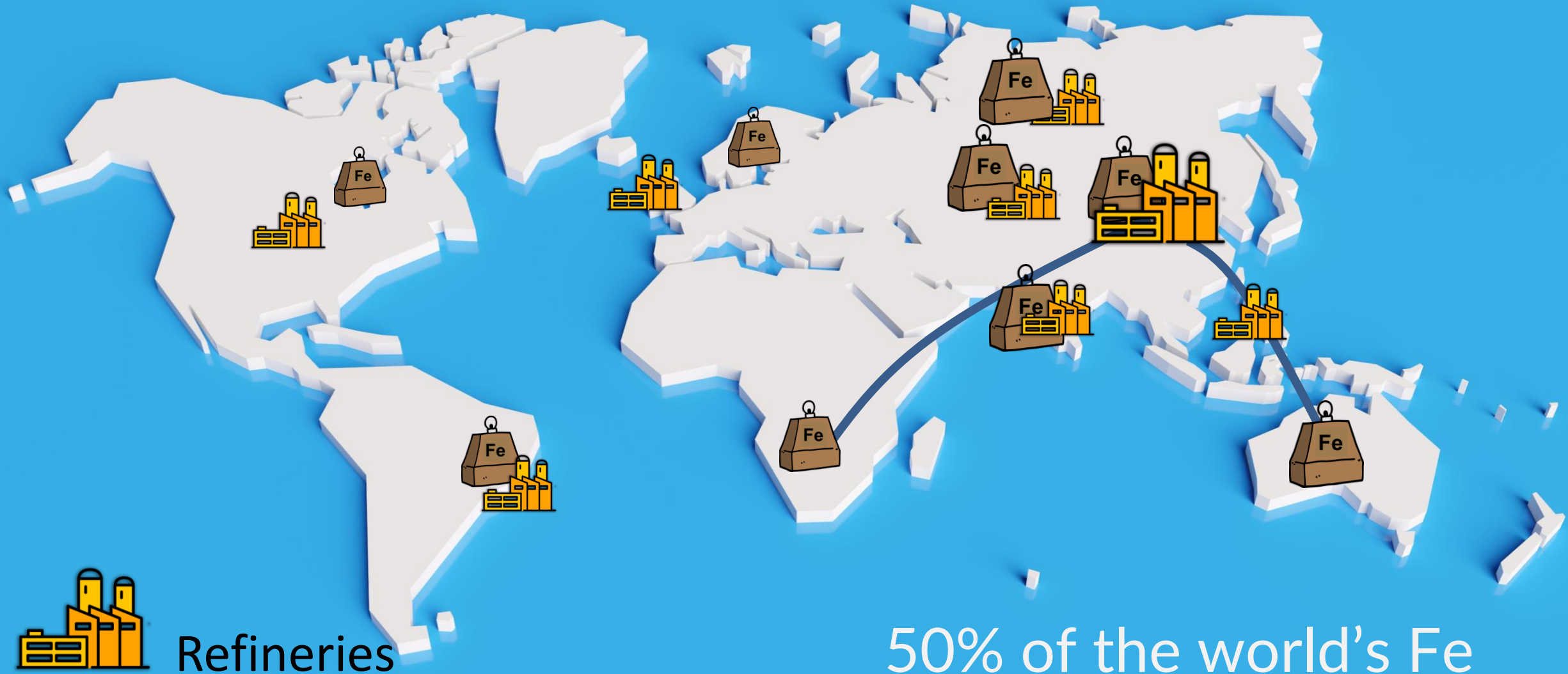


# Lithium Mining & Refining



Key  = Amount mined 10,000 tonnes

# Sodium and Iron Ore



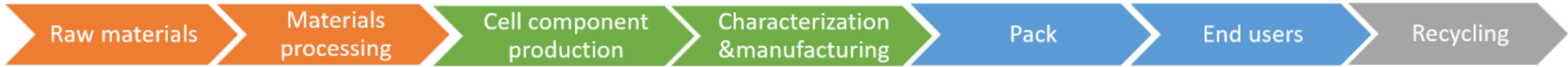
Reference: S. van den Brink *et al.*, Resource, Conservation and Recycling, 2020, 156, 10473.  
Graphics adapted from Adobe Stock.

# D1.3 SIMBA Supply Chain Dec 2022

Upstream

Midstream

Downstream



selected external vendors

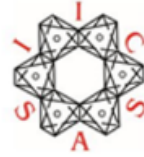
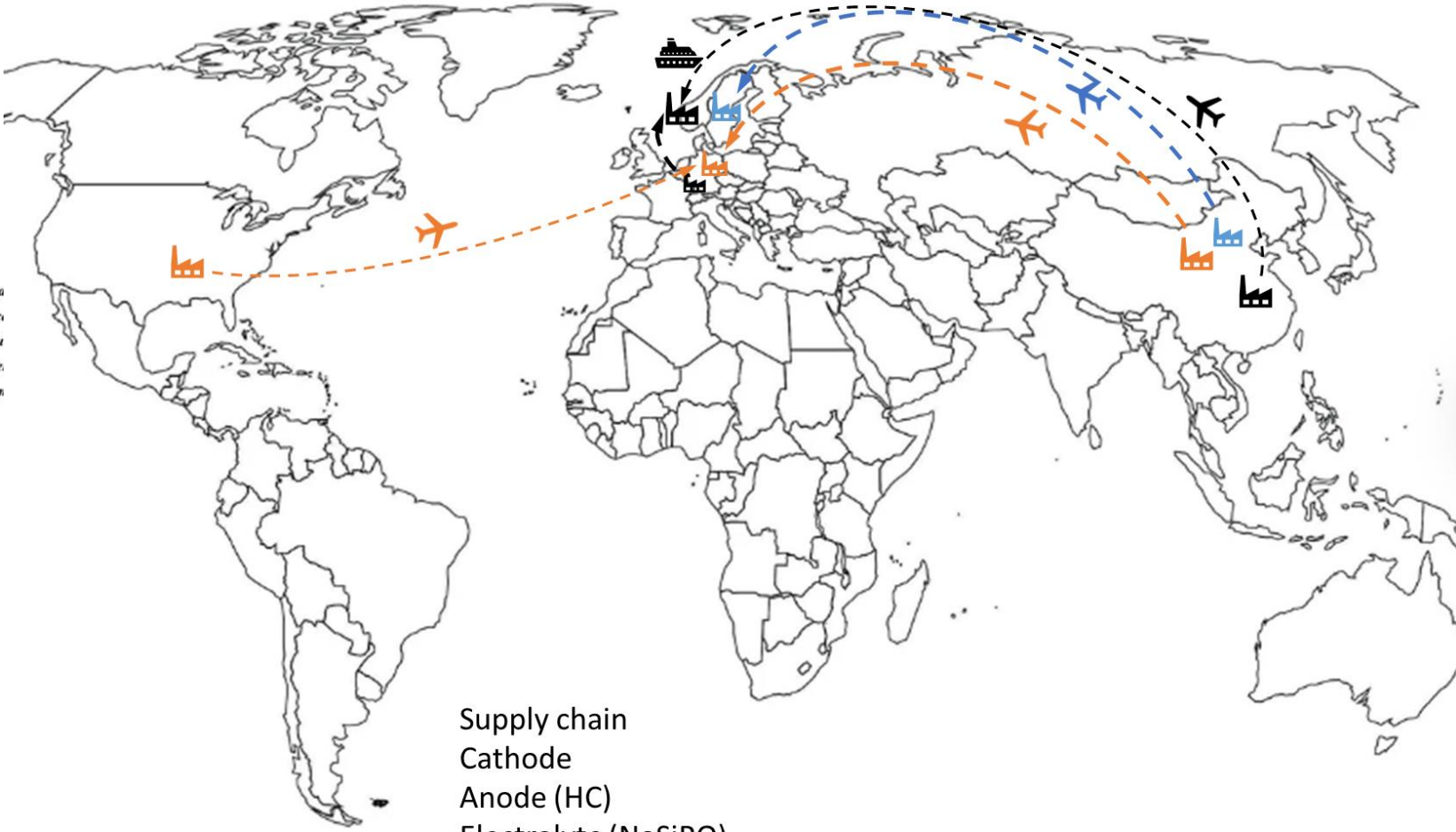
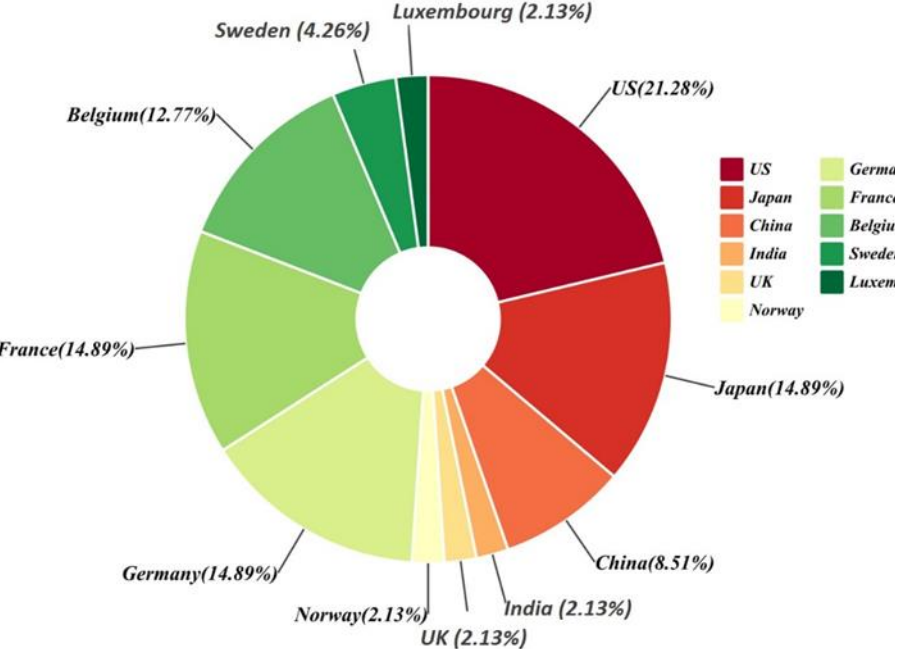


Figure 1 - Micro supply chains within the SIMBA project Dec 2022

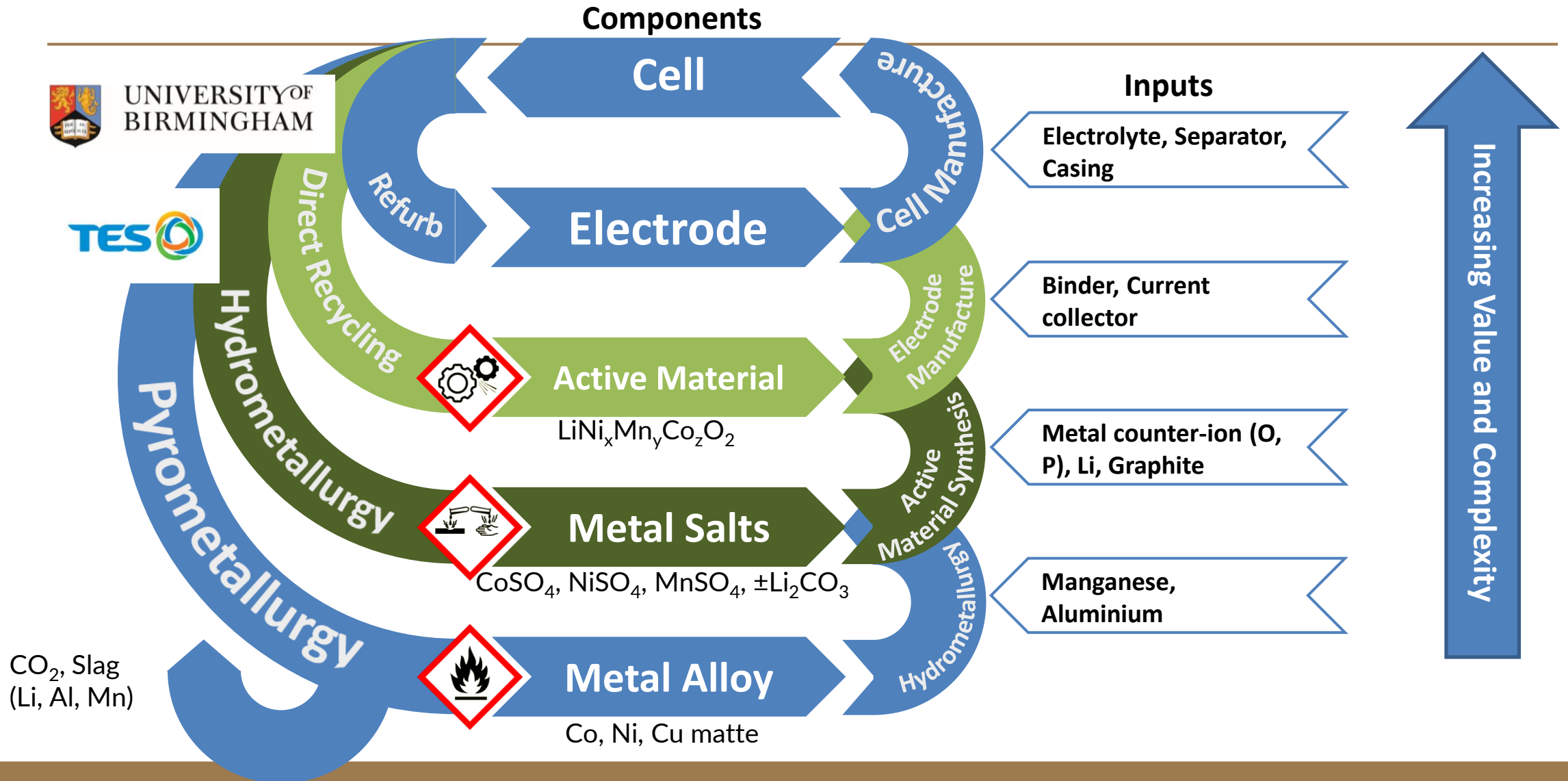


# D1.3 SIMBA Supply Chain Dec 2022

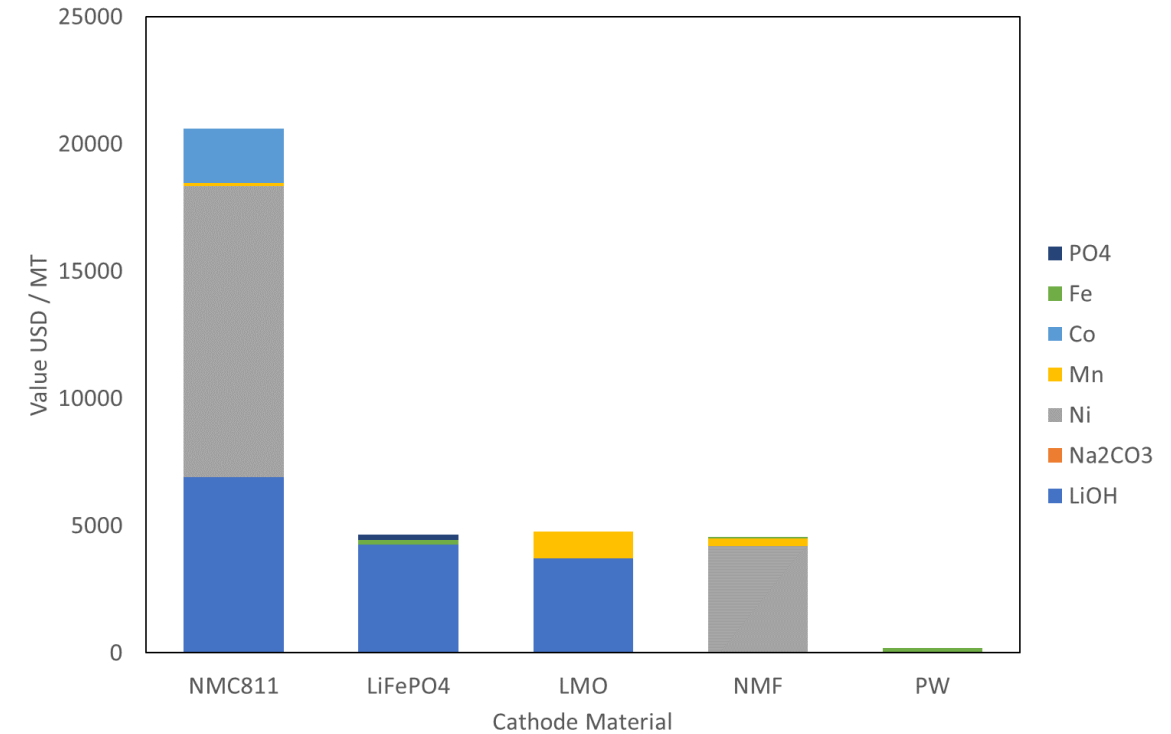
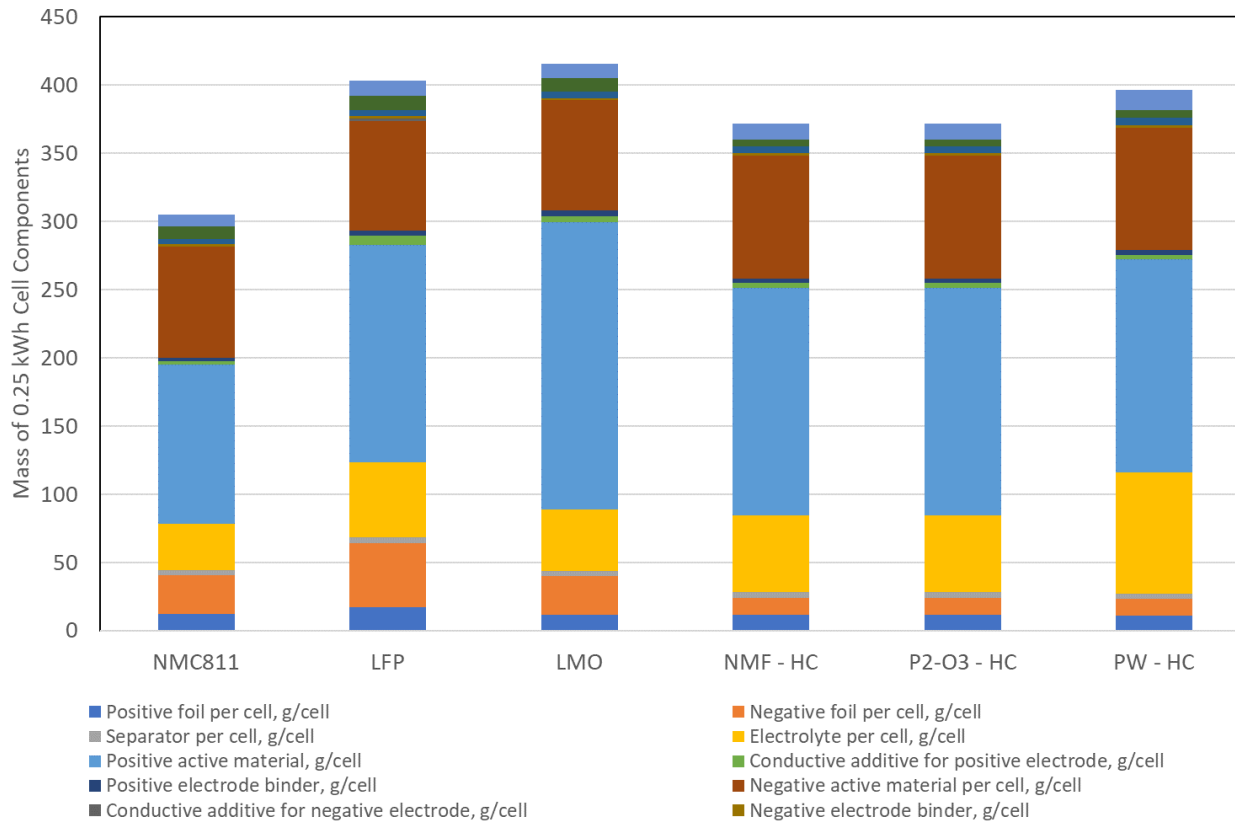


Supply chain  
 Cathode  
 Anode (HC)  
 Electrolyte (NaSiPO)

# Recycling Routes

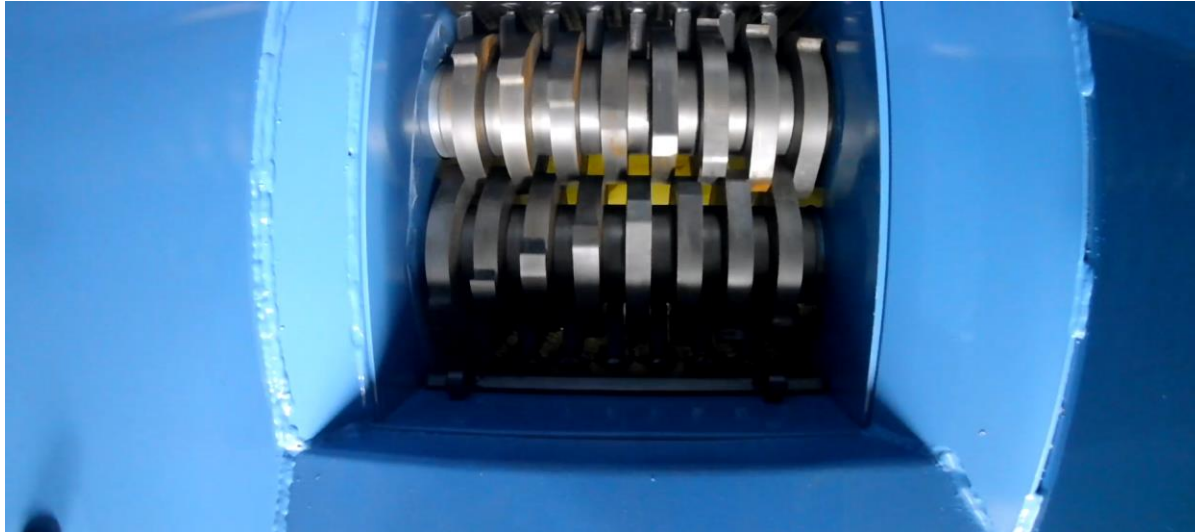


# Cathode Content and Value



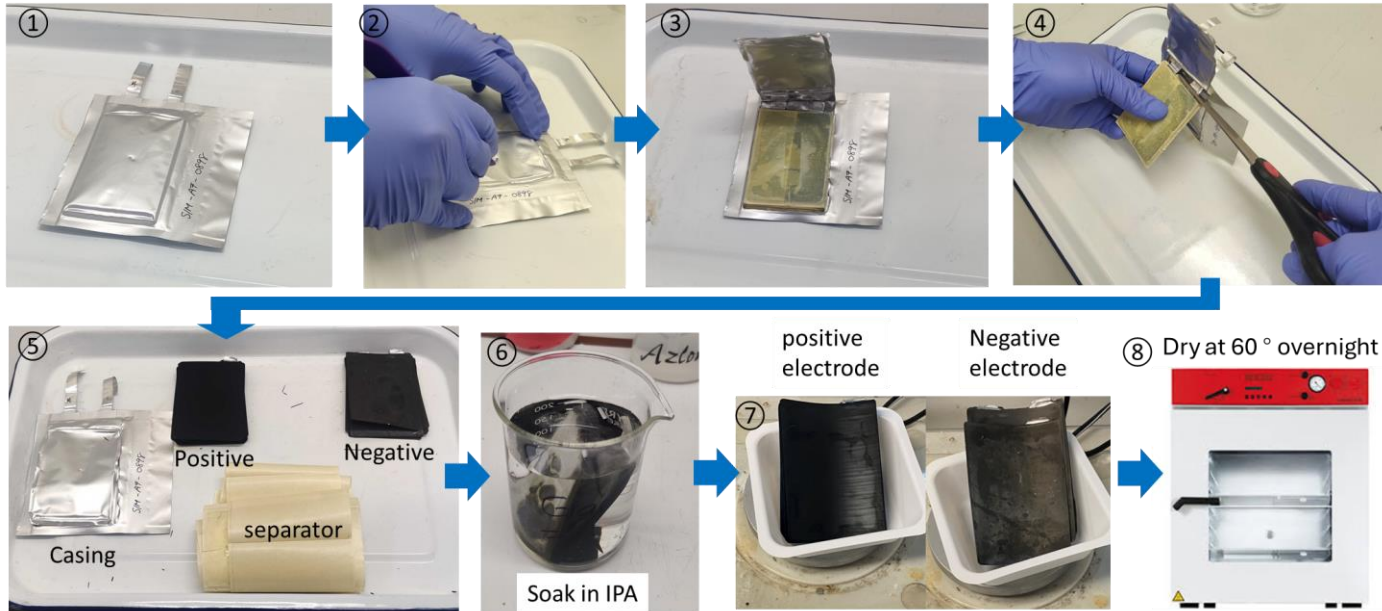


# Shredding vs Disassembly

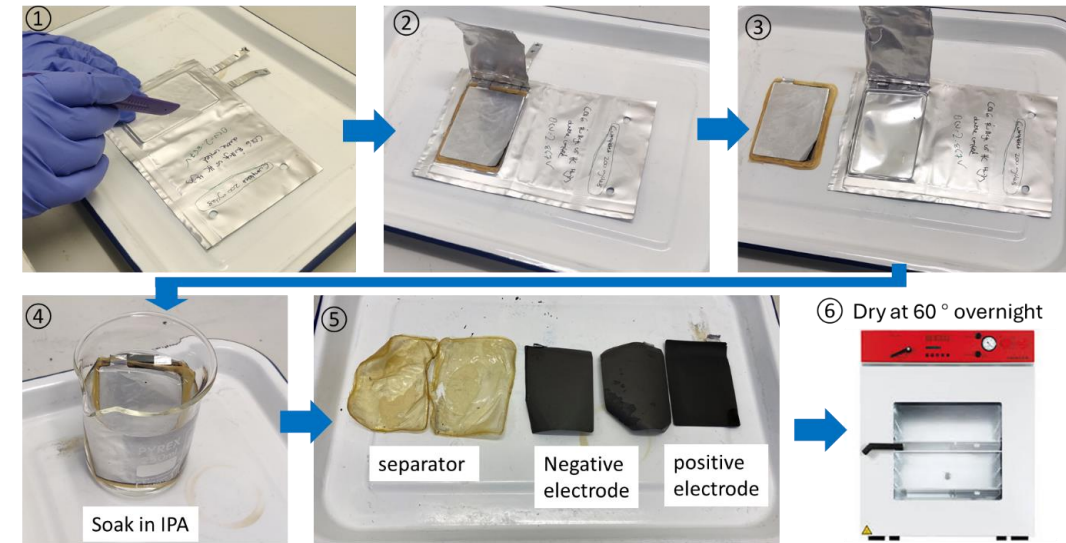


# Disassembling

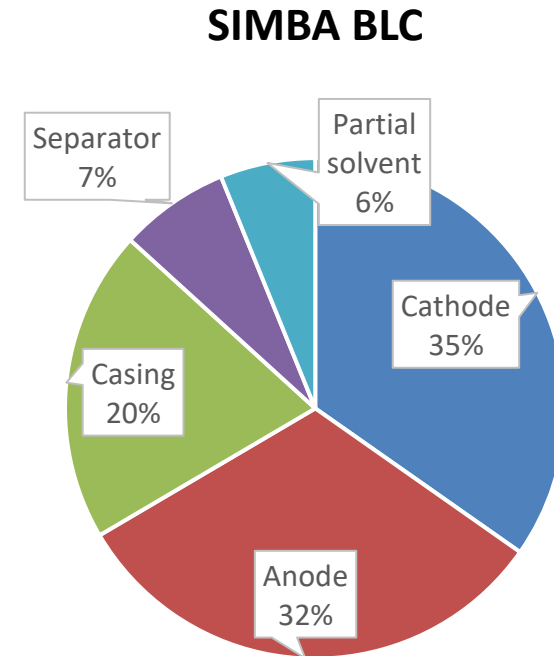
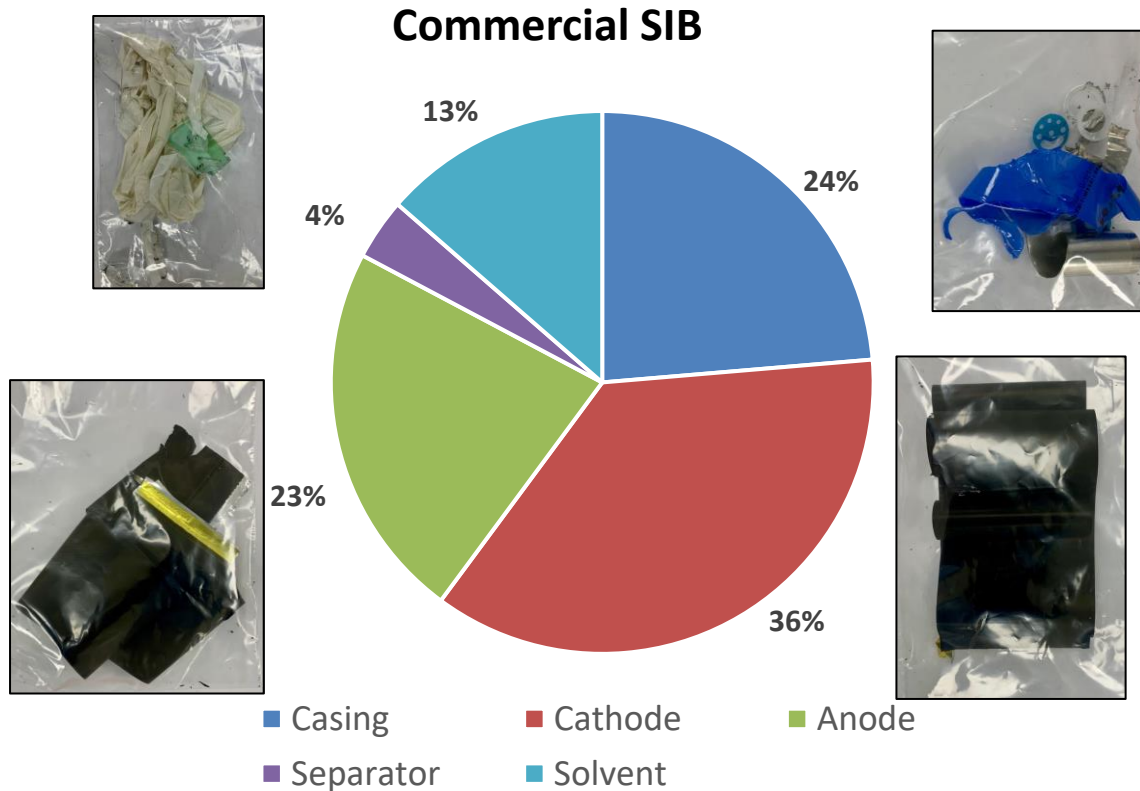
Baseline cell



Sodium-ion solid-state battery



# T1.4 | Composition breakdown





# T6.2 | Results and outcome M25-M30

## + Ice stripping-modified

$$\text{Coating Separation Efficiency } CSE_{A/\text{coating}} = \frac{\text{mass of separated A/coating}}{\text{initial mass of A/coating}}$$

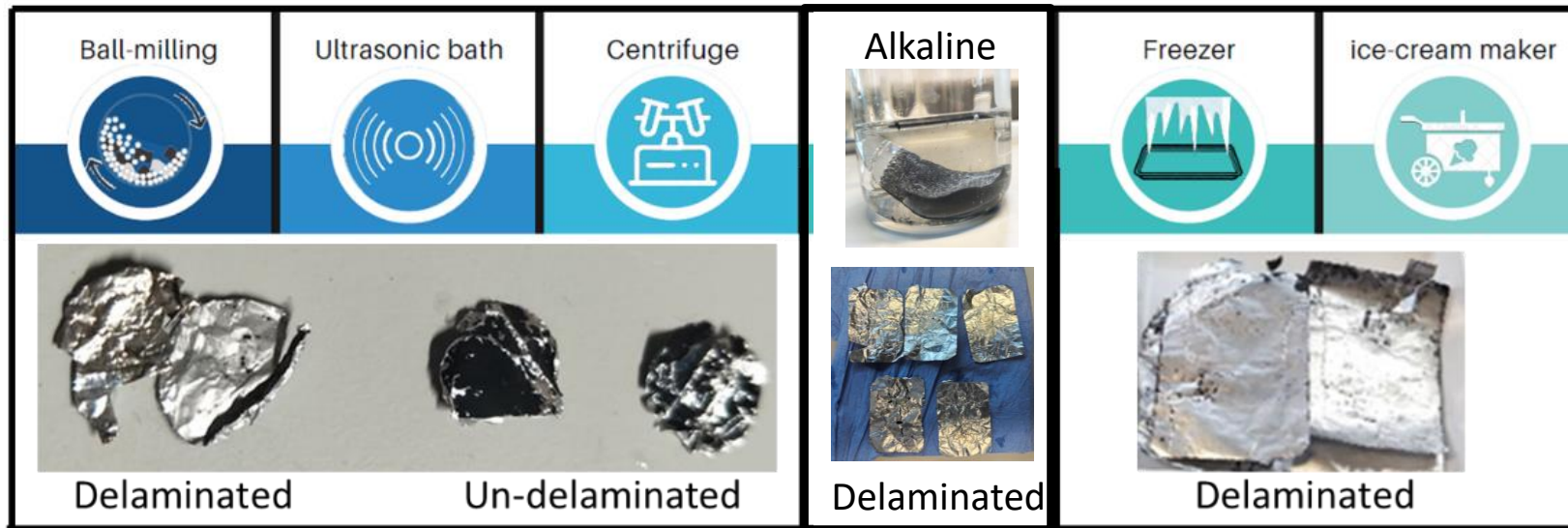
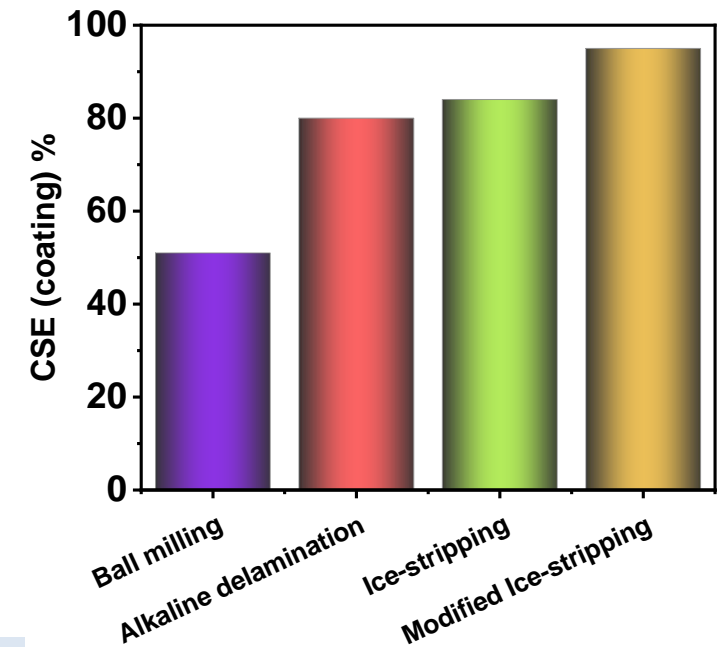


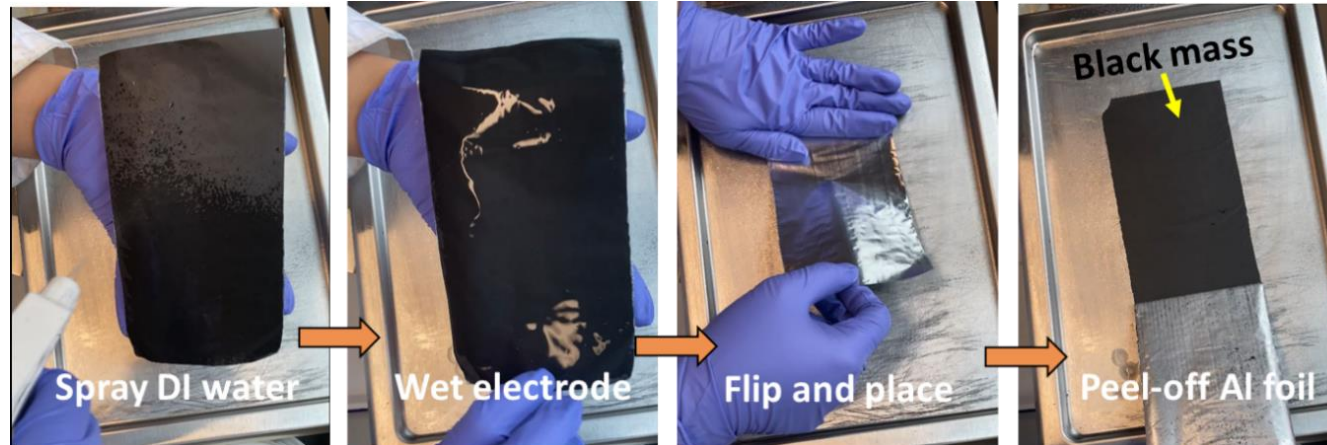
Figure. Comparison of separation efficiency with different delamination techniques.



The advantages of the modified ice stripping method were :

- + Reduction in amount of water required for the delamination;
- + Reduced the process time (freezing time);
- + Easier to handle and potential to be scale-up and industrialized.

# Ice-stripping

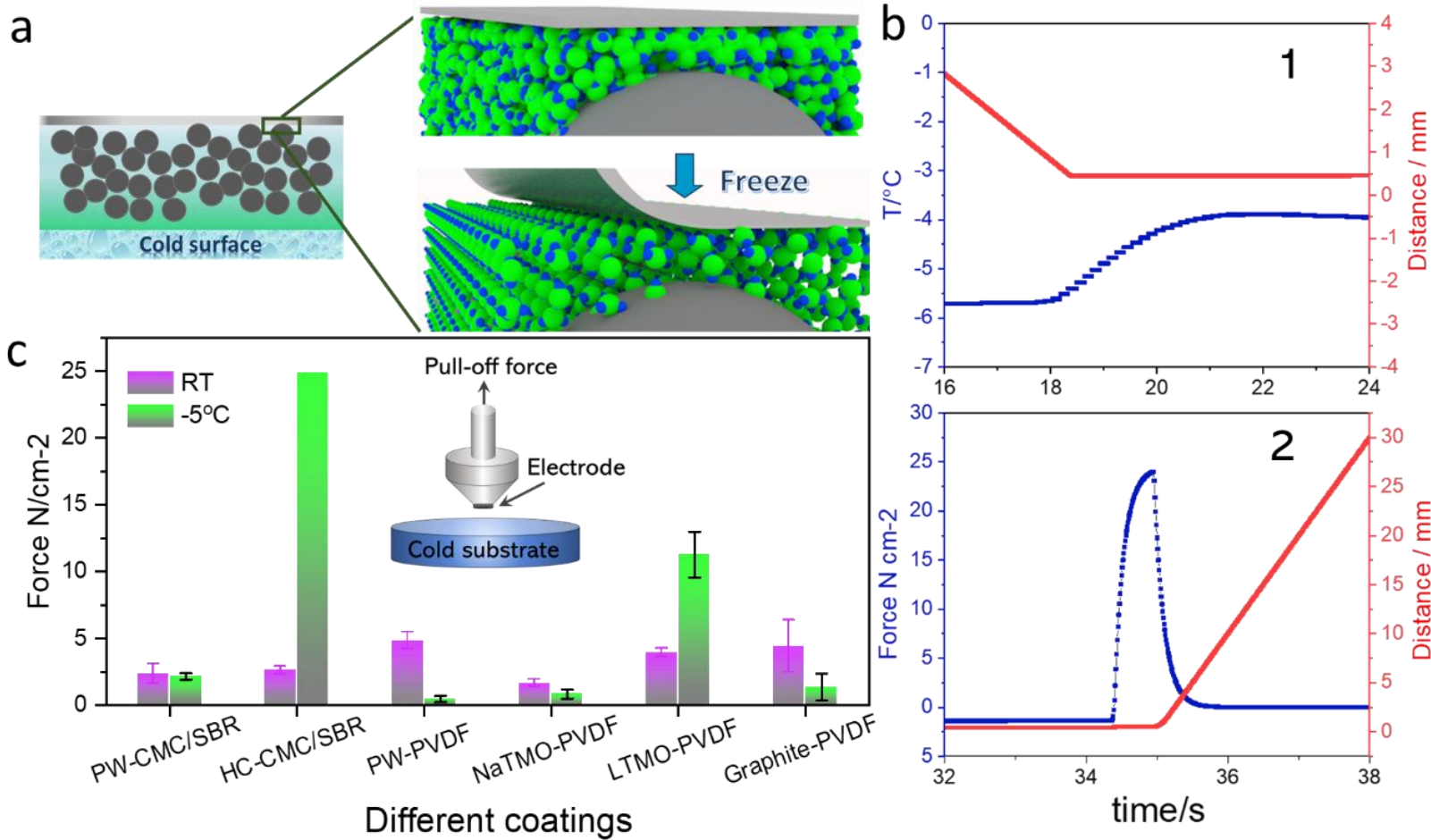


- Zero waste procedure: 0.02mL DI water per cm<sup>2</sup>
- Highly efficient process
- Fast procedure time ~10s



A 'cool' route to electrode recovery L. Chen *et al.* <https://doi.org/10.21203/rs.3.rs-4504057/v1>

# Ice-stripping Mechanism



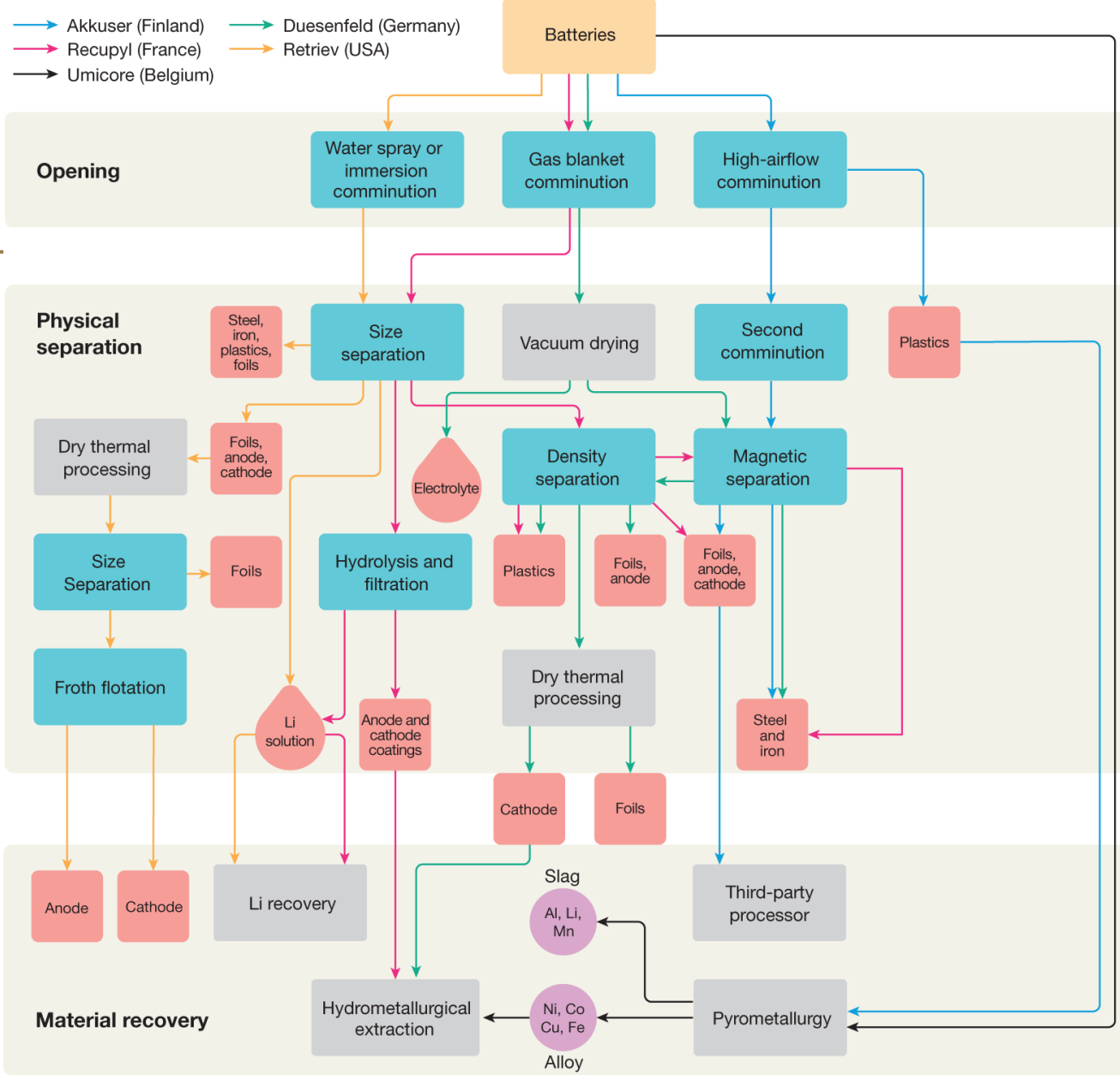
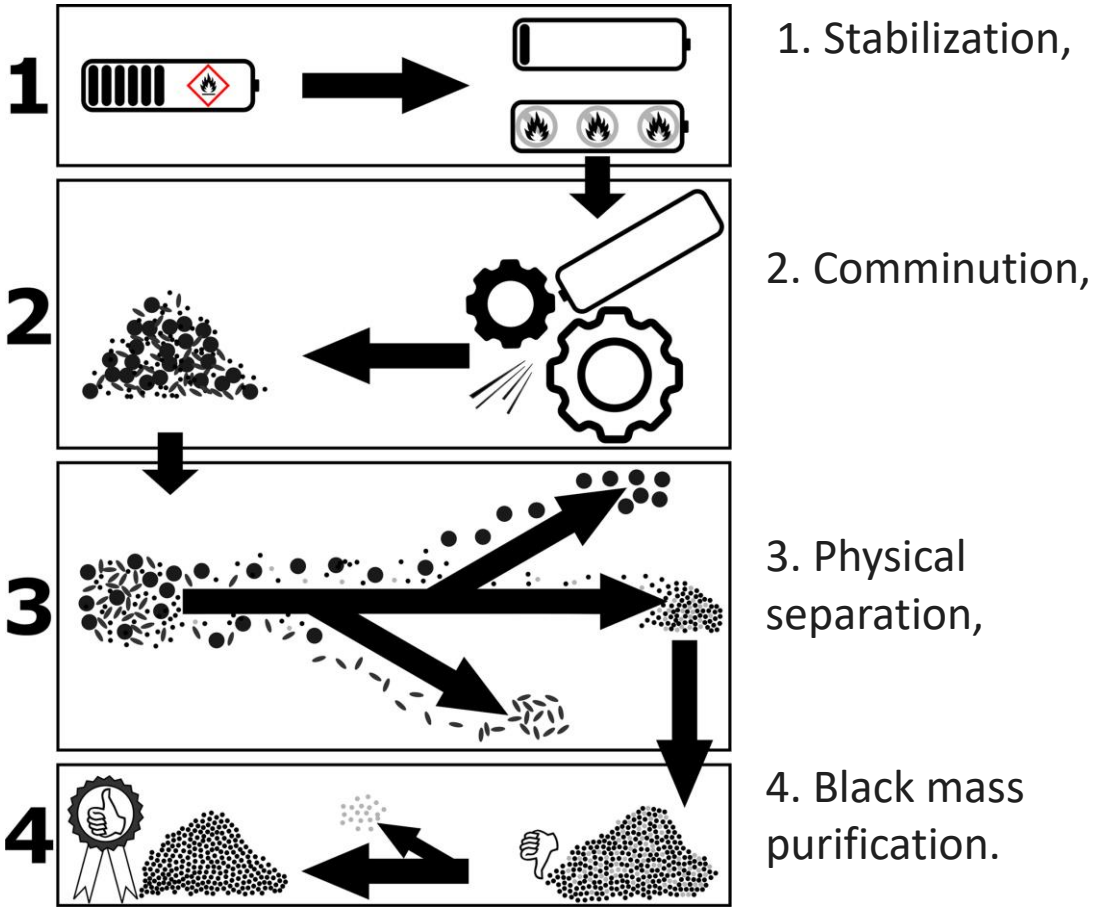
Water was frozen in 5 s

Lowering temperatures to sub-zero levels to harness ice's cohesive strength over the electrode adhesion to delaminate electrode coatings.

A 'cool' route to electrode recovery L. Chen *et al.* <https://doi.org/10.21203/rs.3.rs-4504057/v1>



# Mechanical Sorting



R. Sommerville, J. Shaw-Stewart, E. Kendrick *et al*, A review of physical processes used in the safe recycling of lithium ion batteries, *Sustainable Materials and Technologies*, 25, 2020, <https://doi.org/10.1016/j.susmat.2020.e00197>.

Harper, G., Sommerville, R., Kendrick, E. *et al*. Recycling lithium-ion batteries from electric vehicles. *Nature* **575**, 75–86 (2019). <https://doi.org/10.1038/s41586-019-1682-5>

# T1.4 | Mechanical-sorting process

## + Sorting results of commercial SIB



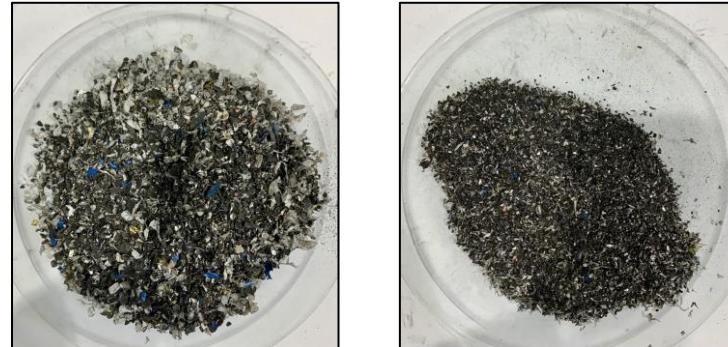
> 4 mm



Aluminium and separator

30.6 % vs 28.9 % of SIMBA BLC

0.355 - 4mm



Fine Al foil + electrode not fully delaminated

40.3 %

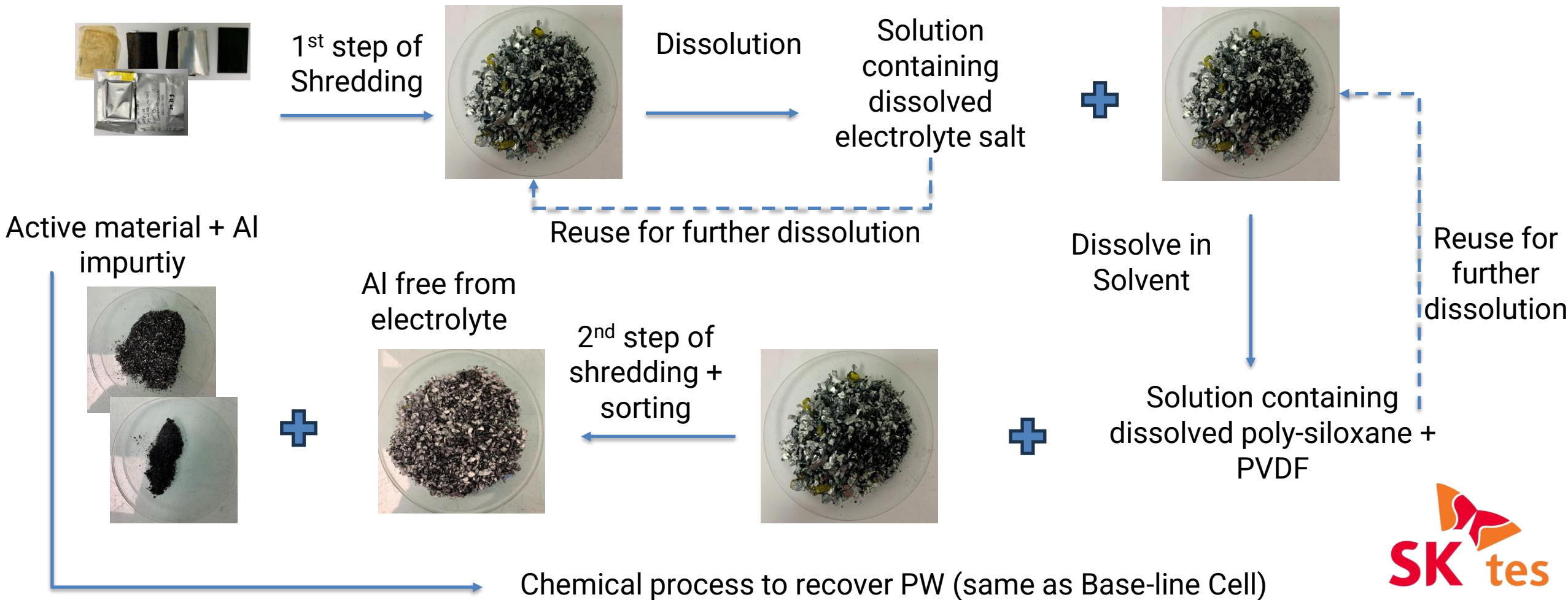
<0.355 mm



Active materials

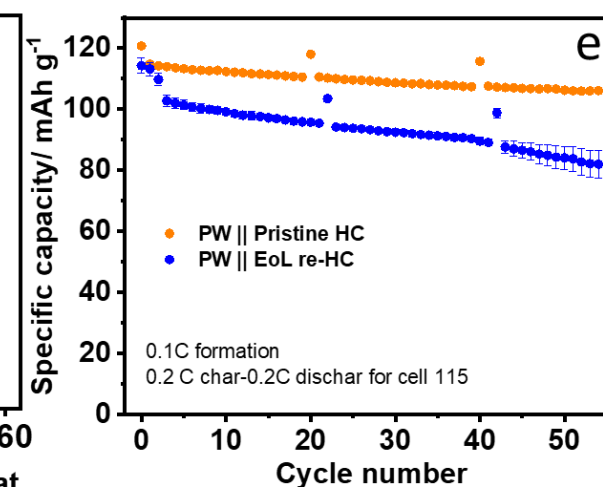
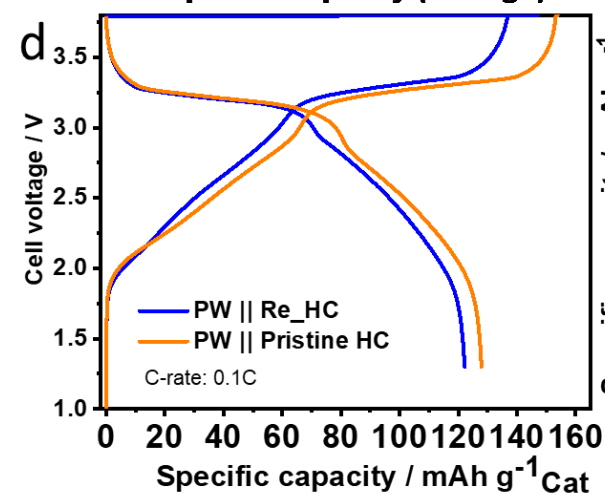
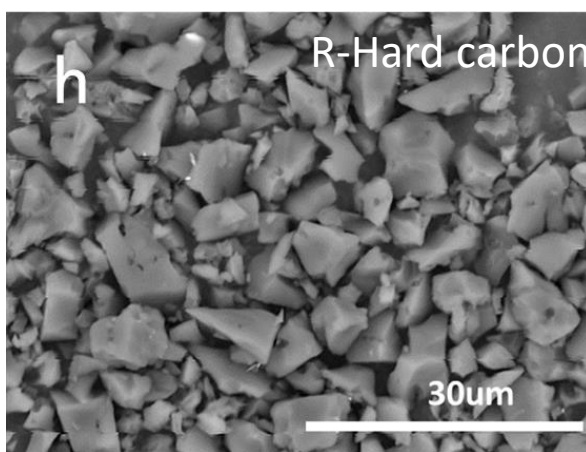
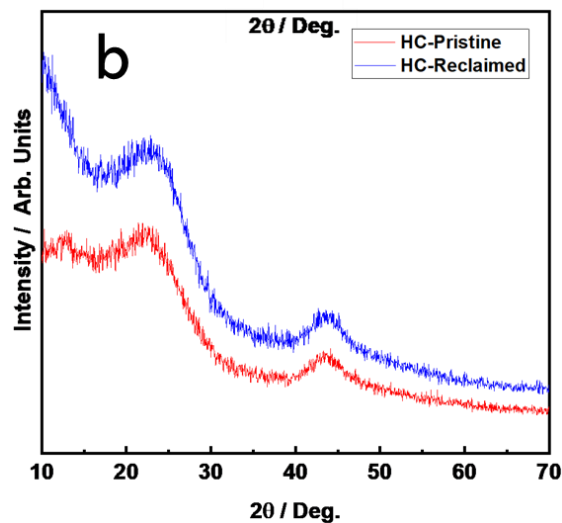
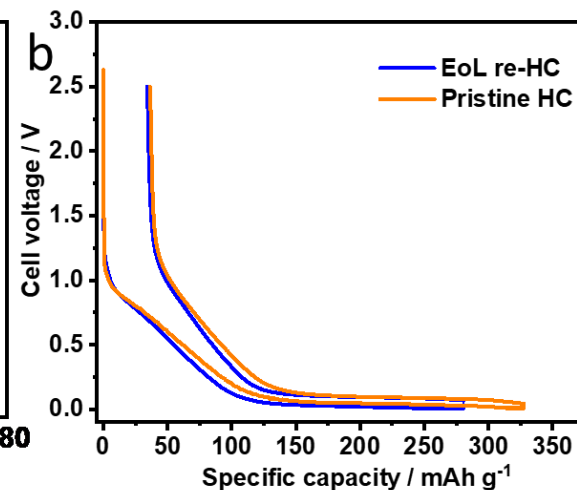
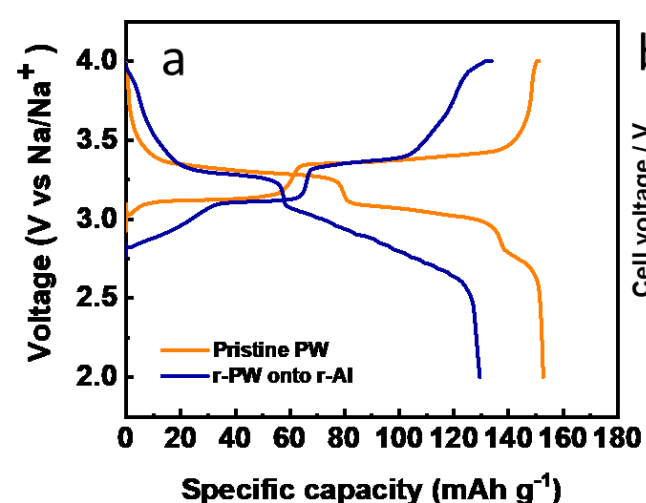
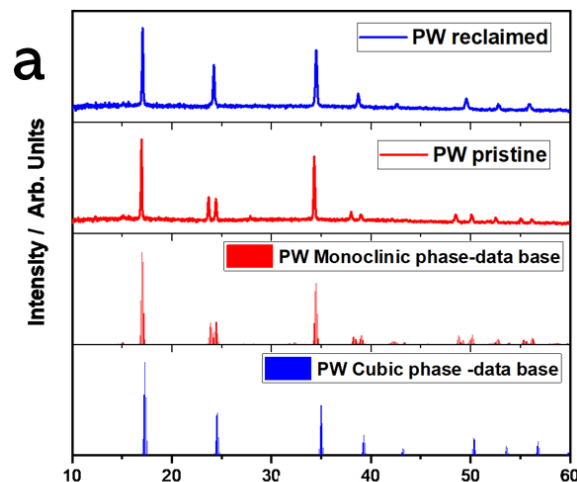
29.1 % vs 58.8 % of SIMBA BLC

# WP6 | Potential process for SIMBA solid-state Sodium-ion Battery





# Reclaimed and Directly reused PW and HC



# Summary

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- + Critical Materials and Supply Chain
- + Low-value materials – need to retain added value during reclamation processes
- + Direct and Short Loop Recycling for Scrap and End of Life
- + Ice Stripping delamination retains morphology of components
- + Direct Recycling for Hard Carbon Demonstrated

# Thank you!

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