



UNIVERSITY OF  
BIRMINGHAM

# Critical Minerals and Sustainable Batteries?

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University of Birmingham



24<sup>th</sup> Feb 2025

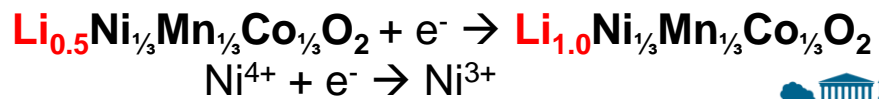
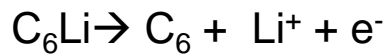
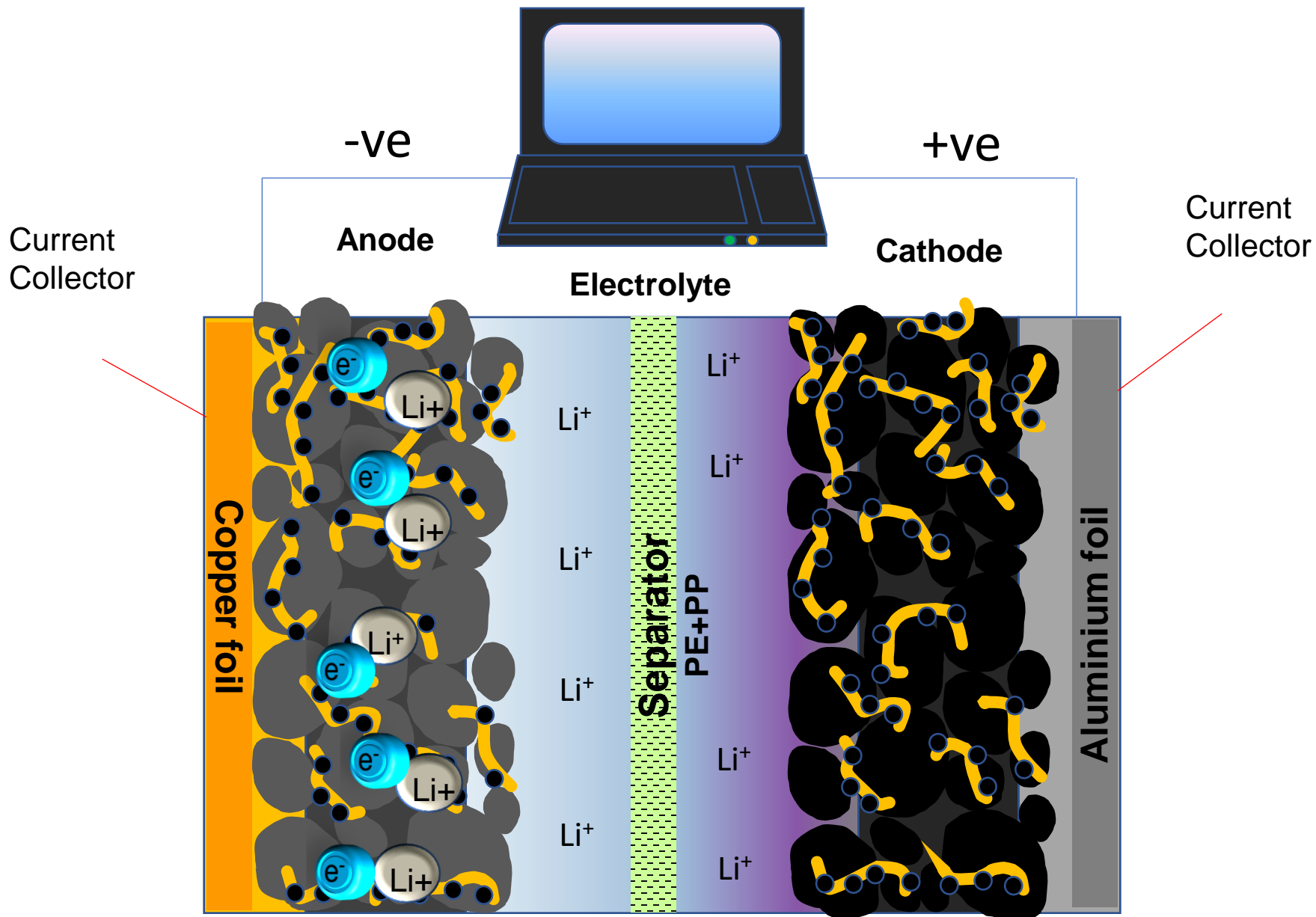


Figure 1. The Periodic Table of the Elements (Source: Science Notes and Projects)

Critical materials?

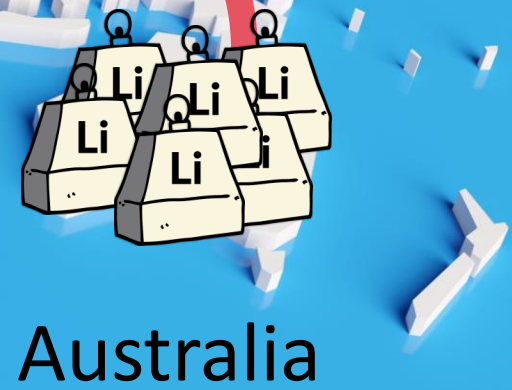
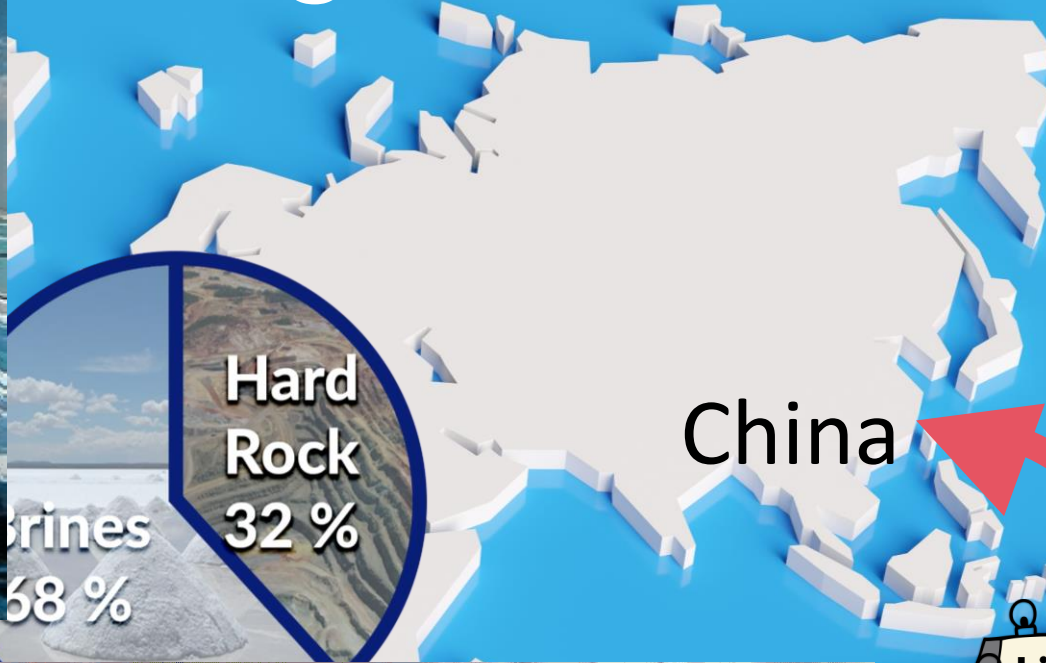
1 IA 11A	2 IIA 2A											13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A		
1 H 1.008												5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180		
3 Li 6.941	4 Be 9.012											11 IB 1B	12 IIB 2B	13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.066	17 Cl 35.453	18 Ar 39.948
19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.88	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.693	29 Cu 63.546	30 Zn 65.39	31 Ga 69.732	32 Ge 72.61	33 As 74.922	34 Se 78.09	35 Br 79.904	36 Kr 84.80		
37 Rb 84.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.94	43 Tc 98.907	44 Ru 101.07	45 Rh 102.906	46 Pd 106.42	47 Ag 107.868	48 Cd 112.411	49 In 114.818	50 Sn 118.71	51 Sb 121.760	52 Te 127.6	53 I 126.904	54 Xe 131.29		
55 Cs 132.905	56 Ba 137.327	57-71	72 Hf 178.49	73 Ta 180.948	74 W 183.85	75 Re 168.207	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.967	80 Hg 200.59	81 Tl 204.383	82 Pb 207.2	83 Bi 208.980	84 Po [208.982]	85 At 209.987	86 Rn 222.018		
87 Fr 223.020	88 Ra 226.025	89-103	104 Rf [261]	105 Db [262]	106 Sg [266]	107 Bh [264]	108 Hs [269]	109 Mt [268]	110 Ds [269]	111 Rg [272]	112 Cn [277]	113 Uut unknown	114 Fl [289]	115 Uup unknown	116 Lv [298]	117 Uus unknown	118 Uuo unknown		

Lanthanide Series	57 La Lanthanum 138.906	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
Actinide Series	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

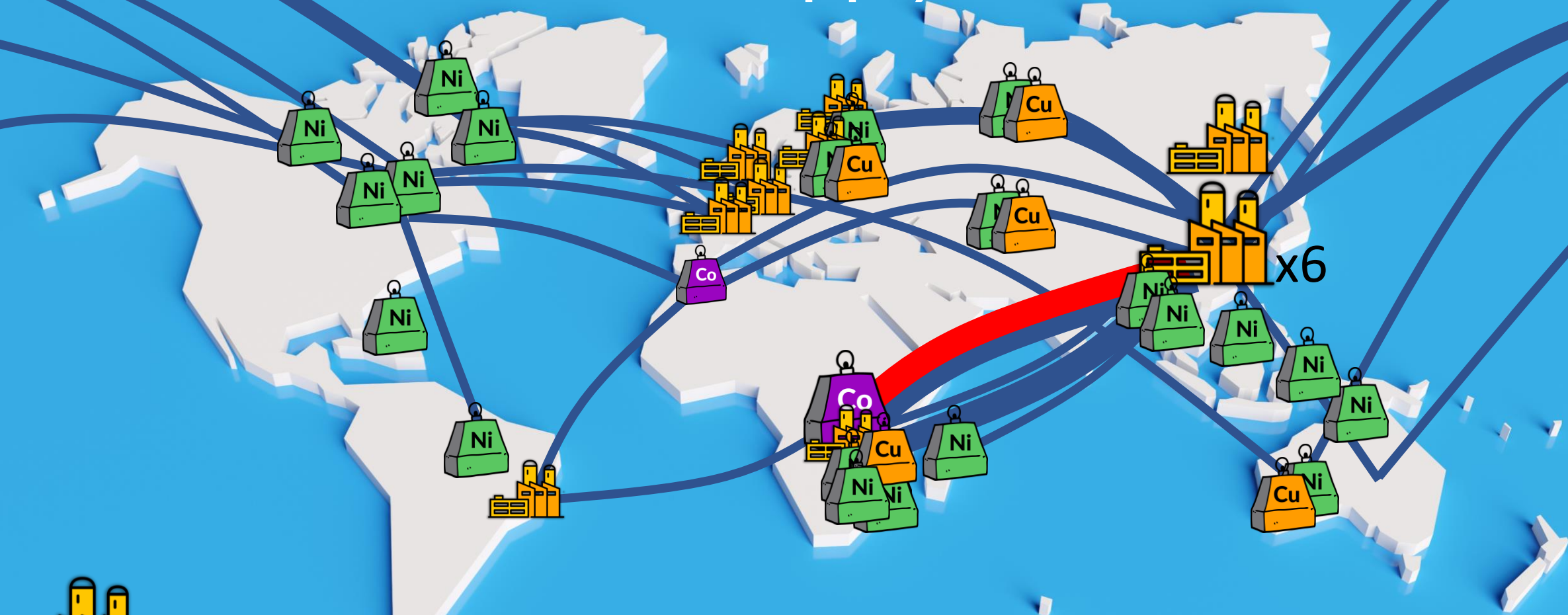


# Lithium Mining & Refining



Key  = Amount mined 10,000 tonnes

# Cobalt Supply



Refineries



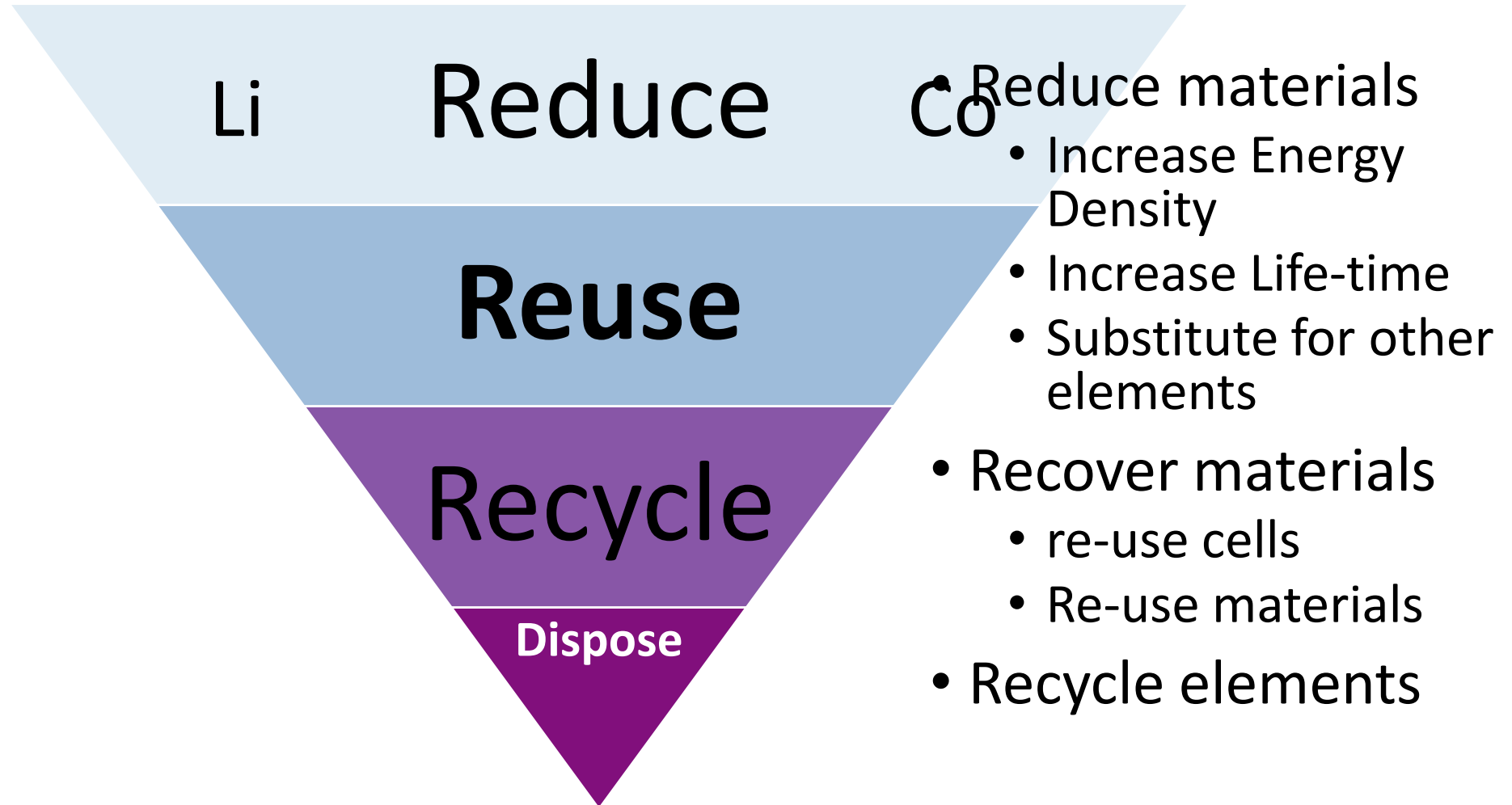
Cobalt Ores/Concentrates




Cobalt Mattes/Intermediates


70% of the world's  
Co is from the DRC

# Waste Hierarchy – Towards Sustainability



# Reduce - Substitution

Li  3  
Lithium



6.9  
Batteries




elements.wlonk.com




 VACUUM SALT  ROCK SALT

 SOLAR SALT





Na    11  
Sodium

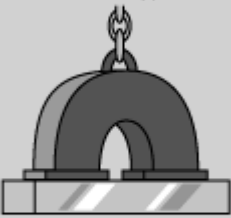


Salt 23

elements.wlonk.com




	Li	Na
Size: Pauling ionic radii	65	95
Weight : Atomic weight	6.941	22.99
Voltage vs SHE (V)	-3.04	-2.71
Volumetric capacity (mAh/cm <sup>3</sup> )	2066	1128
Gravimetric capacity (mAh/g)	3861	1165
Melting point (°C)	180.5	97.7
Compound	Li <sub>2</sub> CO <sub>3</sub>	Na <sub>2</sub> CO <sub>3</sub>


Co   27  
Cobalt



Magnets

elements.wlonk.com

Fe    26  
Iron




Steel Structures

elements.wlonk.com



# Reduce - Substitution


Li  3  
Lithium




6.9  
Batteries

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	Co	Fe
Geographical availability	DR Congo	AU / Brazil / China / India
Extraction and Refining	China	Global
Earth Crust Abundance (ppm)	25	56300
Voltage vs SHE (V) $M^{3+} + e^- \rightarrow M^{2+}$	+1.92	+0.77
Atomic Weight	58.9	55.8
Ore	2° from Ni/Cu	Iron oxides
\$/mt	51,500	106

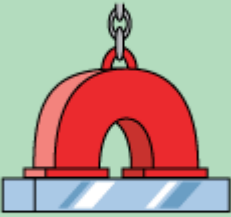
Na  11  
Sodium



Salt 23


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Co  27  
Cobalt



Magnets

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Fe  26  
Iron

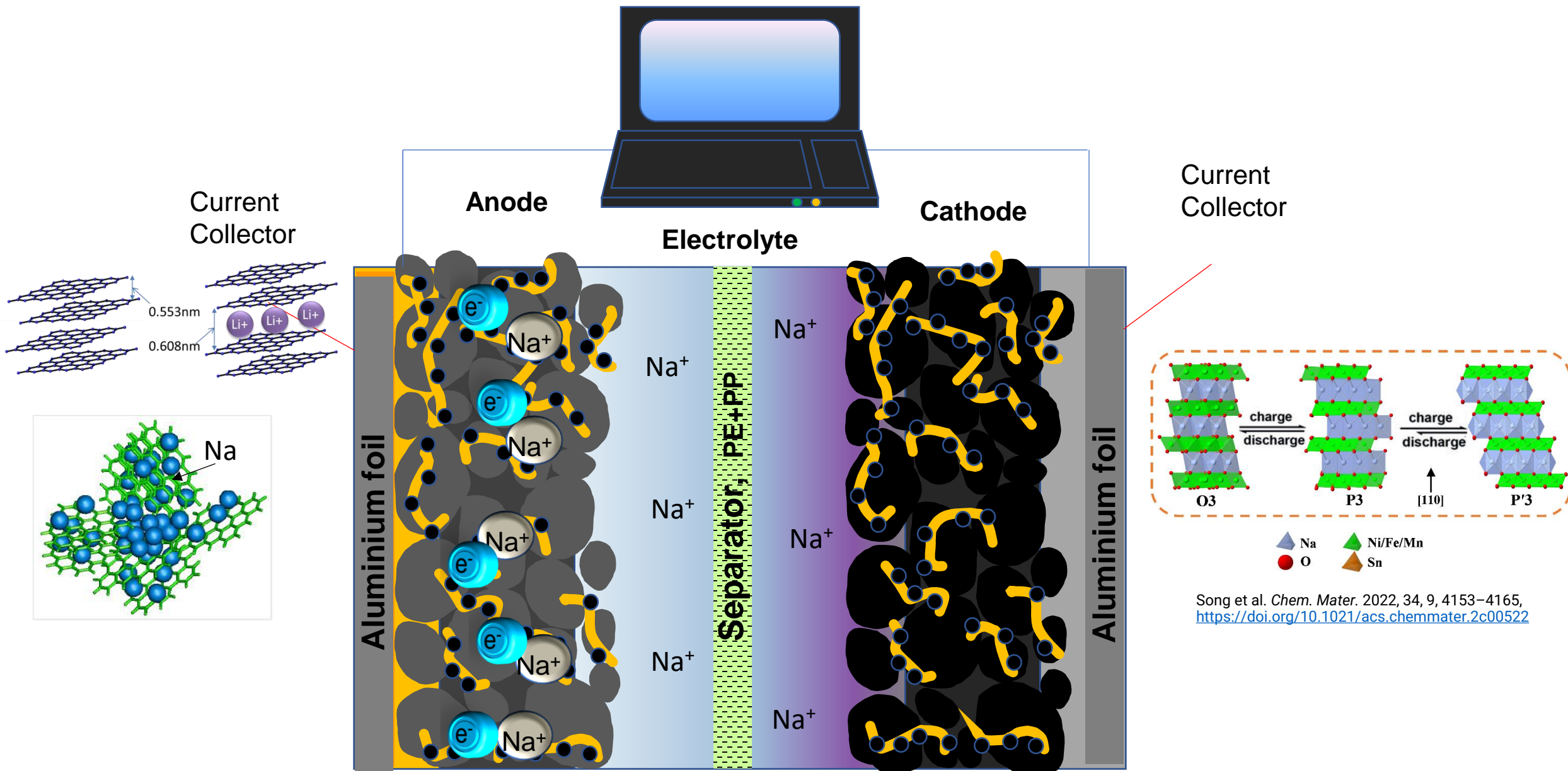


Steel Structures

elements.wlonk.com



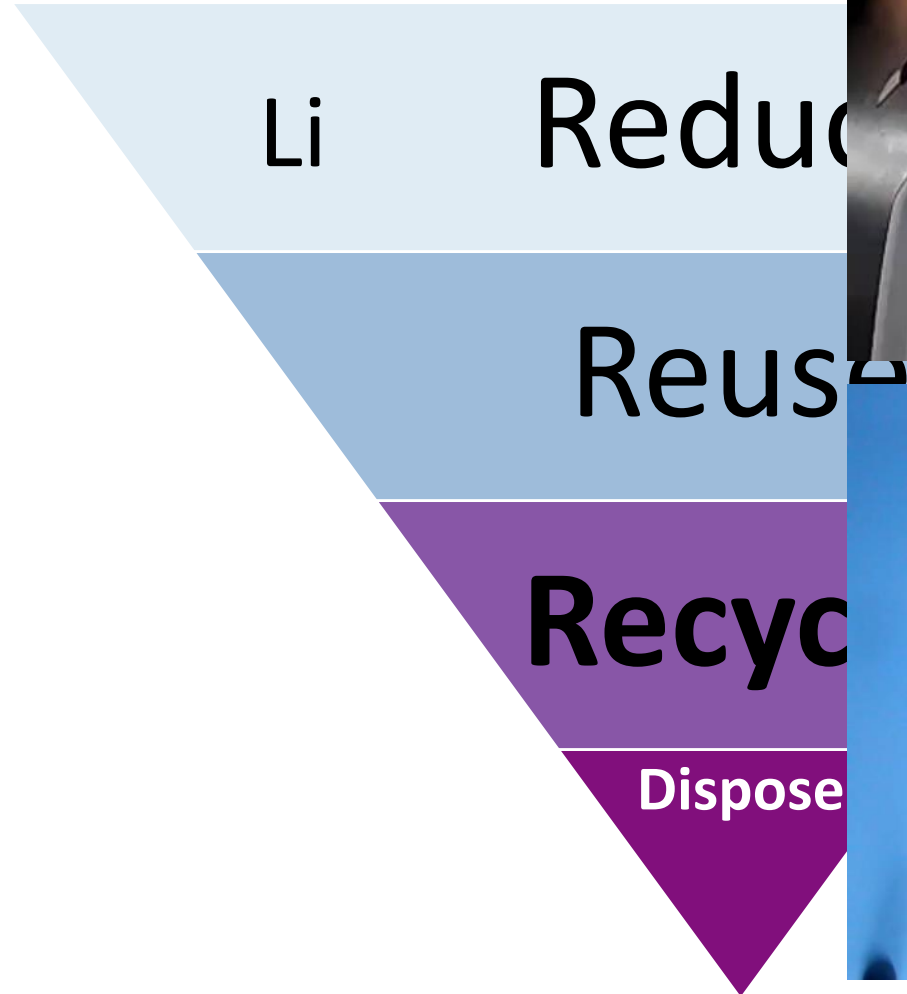


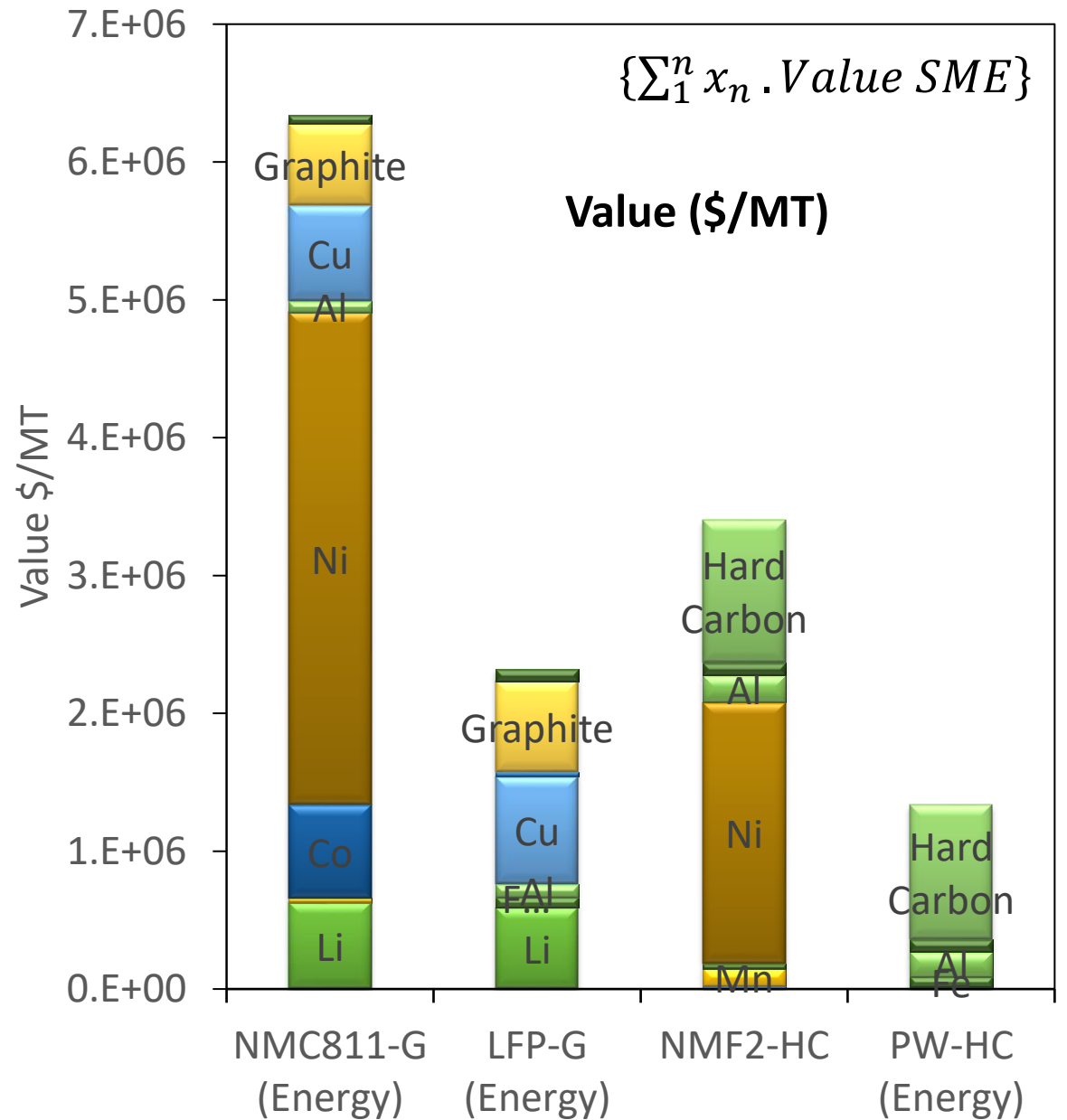
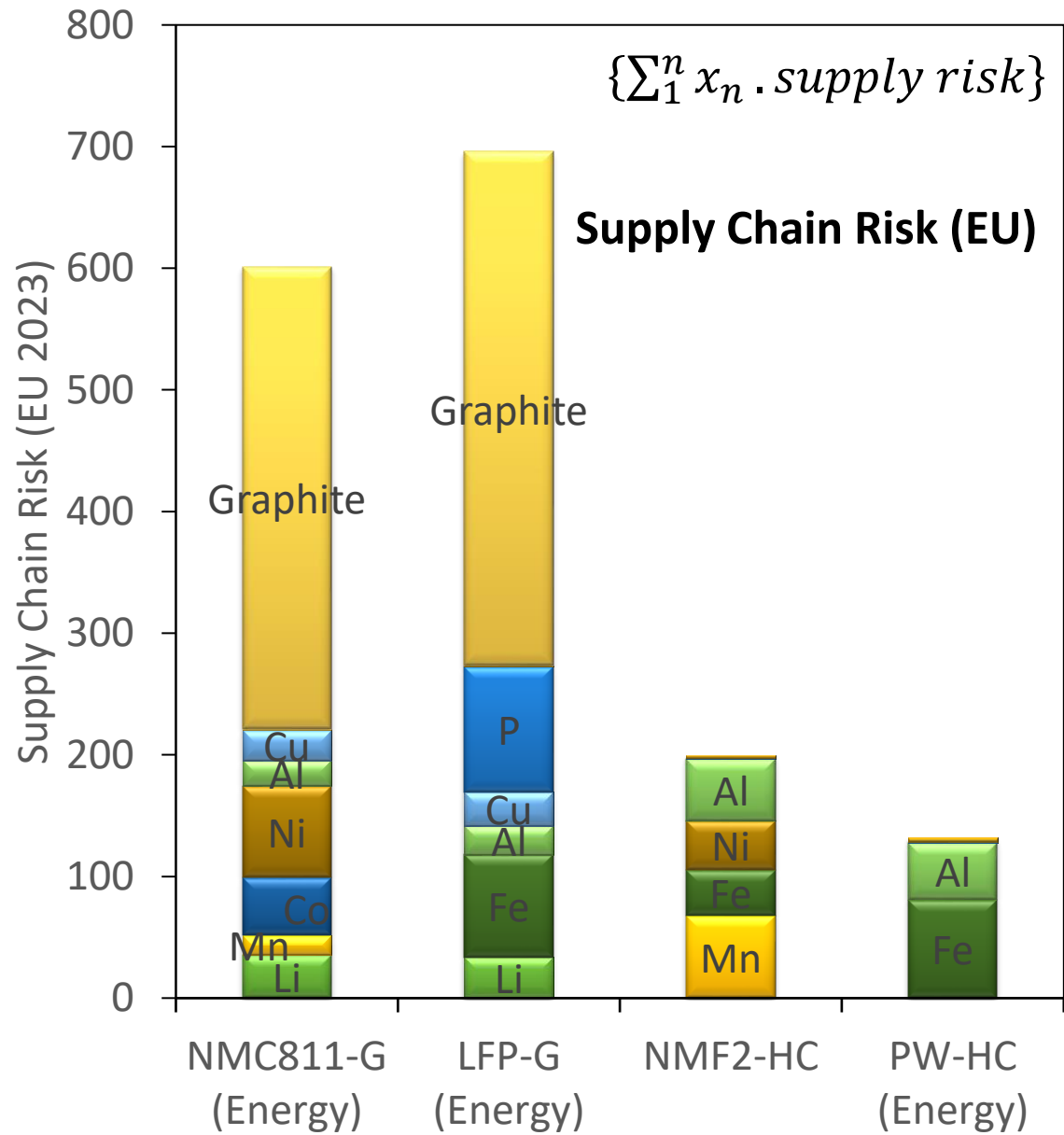


Song et al. *Chem. Mater.* 2022, 34, 9, 4153–4165, <https://doi.org/10.1021/acs.chemmater.2c00522>



# Waste Hierarchy





# Energy Materials Group



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birmingham-energy-materials-group



This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101137585.



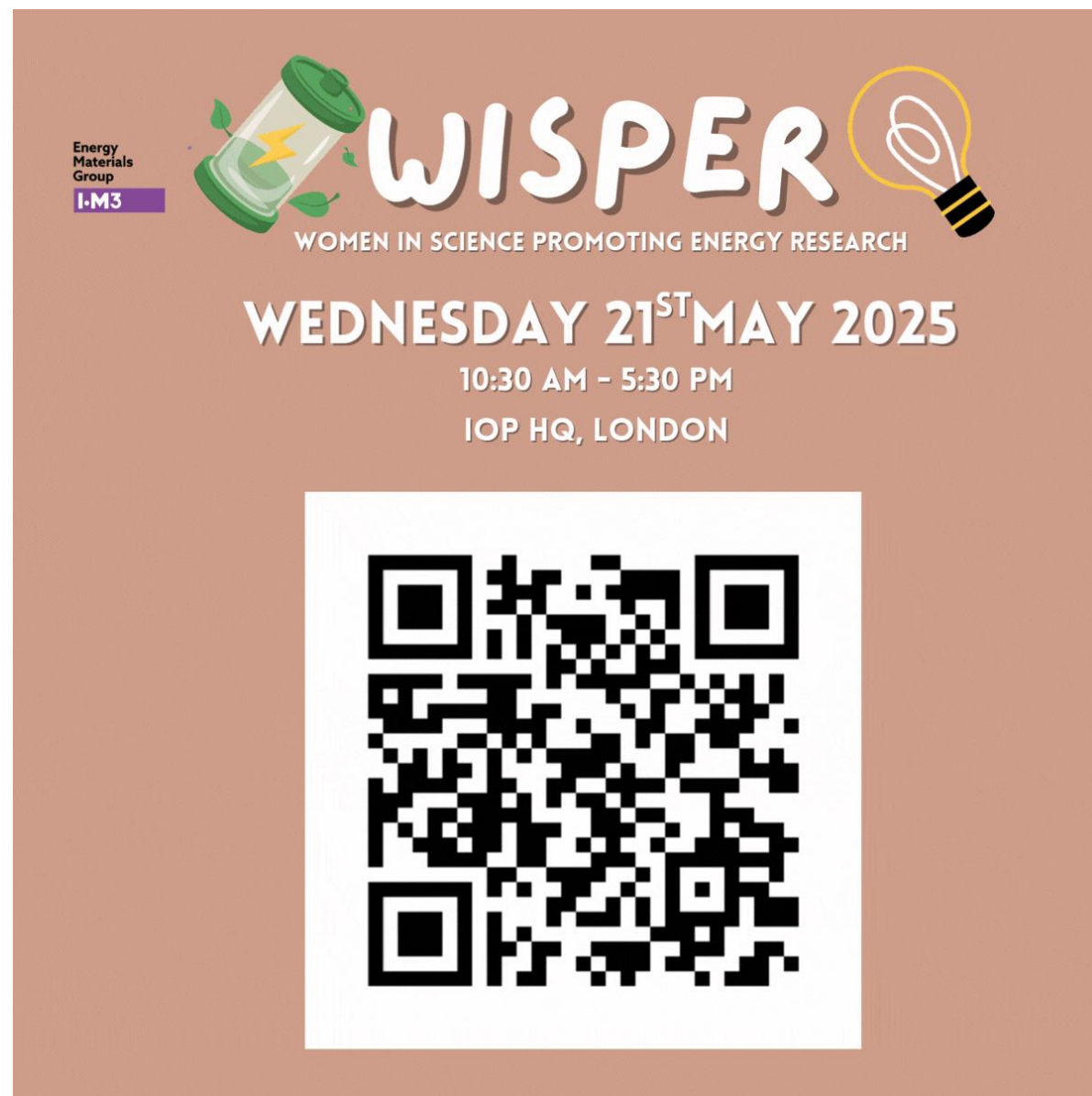
This project has received funding from the European Commission under grant agreement No 963542



# WISPER 2025

- Free event (but spaces limited to 100!)
- One day workshop for women in science working in energy research
- Open to all, but early career women are particularly encouraged to attend/participate.
- Combination of invited talks, contributed, round-table session and a poster session.
- Full details at:  
<https://wisper2025.my.canva.site/>

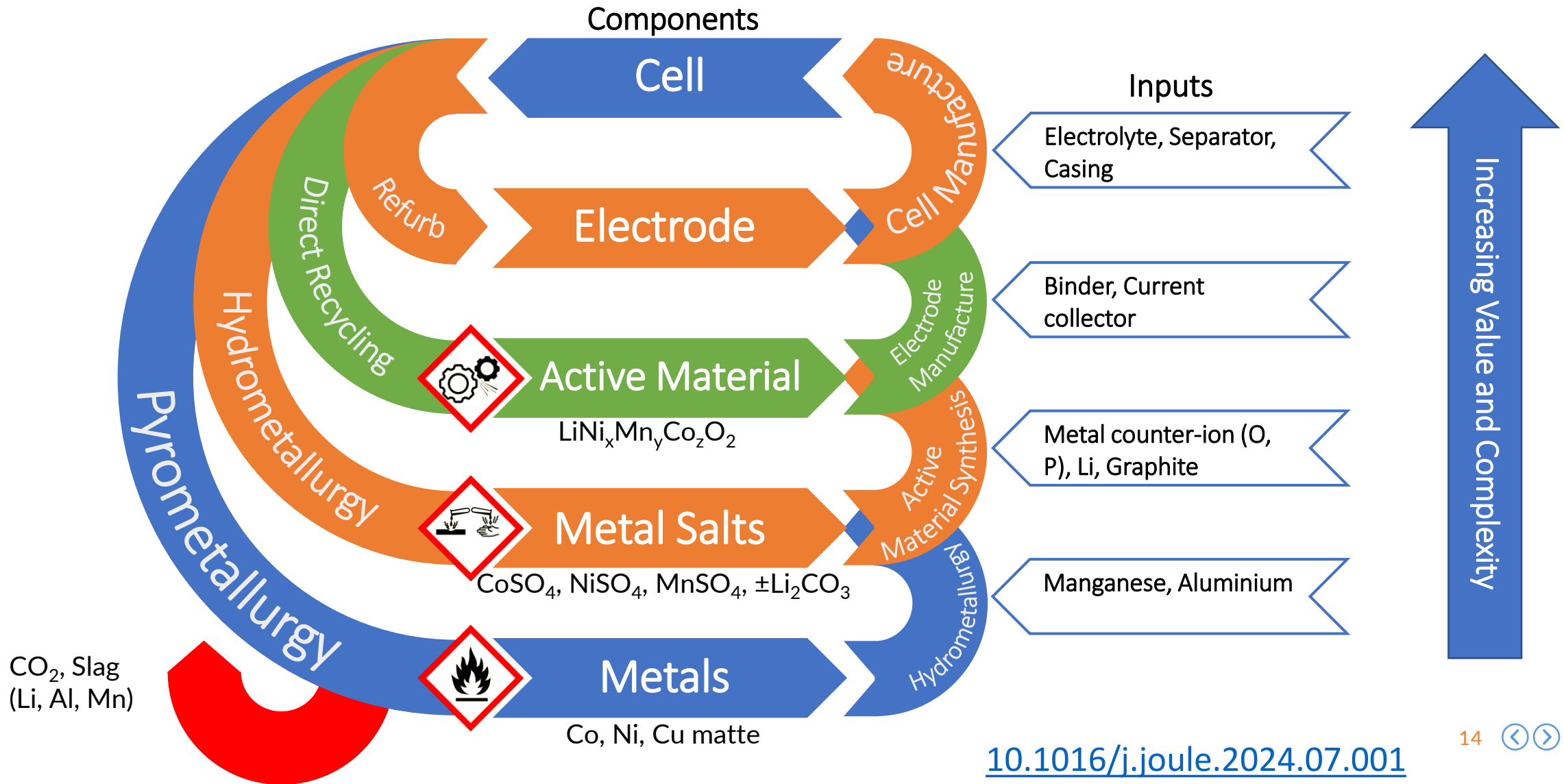
LinkedIn: IOM3 Energy Materials Group



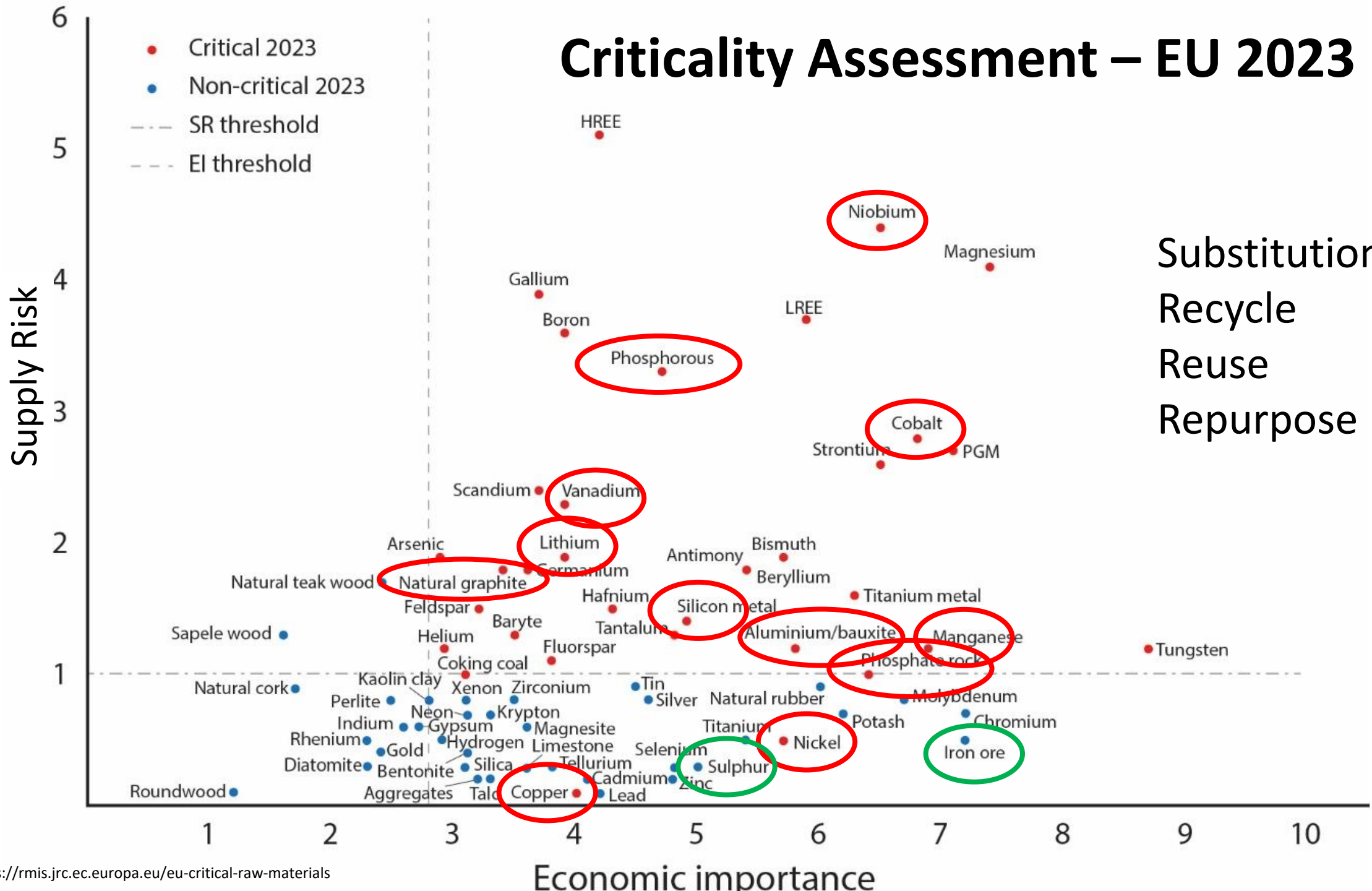
The poster features the Energy Materials Group I-M3 logo on the left. The word 'WISPER' is written in large, white, rounded letters, with a lightbulb icon to its right. Below 'WISPER' is the text 'WOMEN IN SCIENCE PROMOTING ENERGY RESEARCH'. The date 'WEDNESDAY 21<sup>ST</sup> MAY 2025' is prominently displayed in white, followed by the time '10:30 AM - 5:30 PM' and the location 'IOP HQ, LONDON'. A large QR code is centered in the lower half of the poster.



# RECYCLING ROUTES



# Criticality Assessment – EU 2023



Substitution  
 Recycle  
 Reuse  
 Repurpose



# Sustainable Batteries

