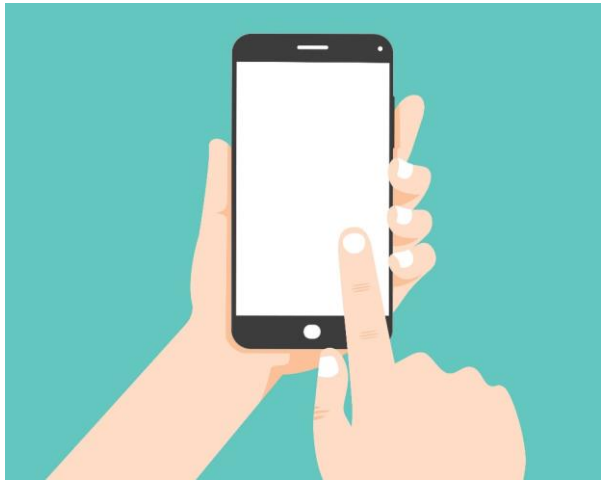
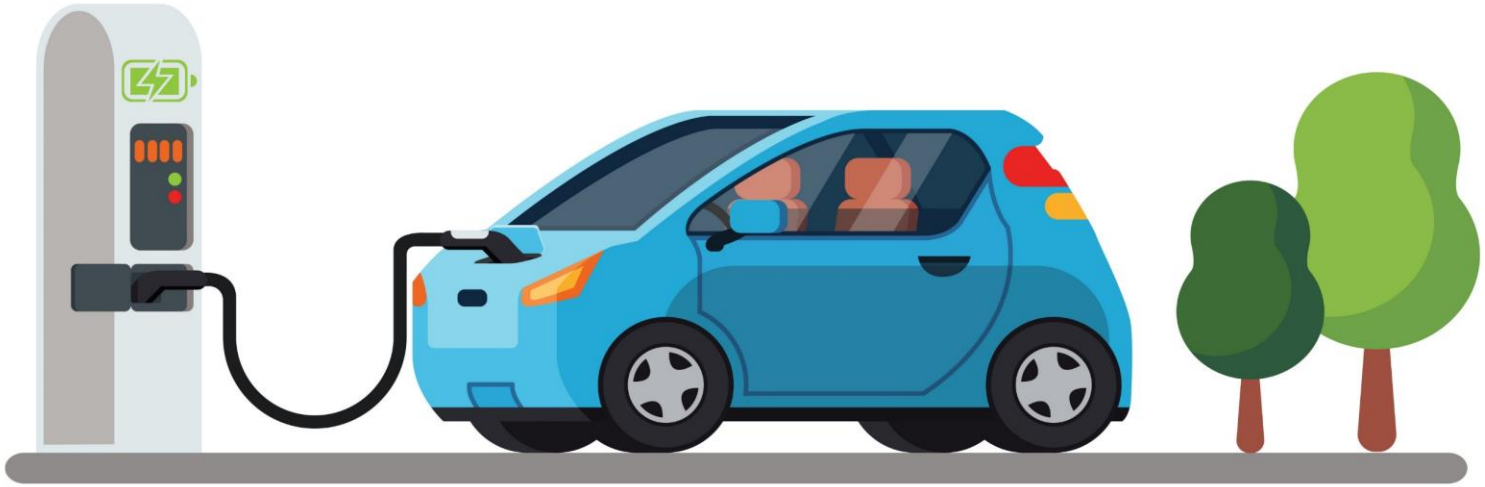
Green Kid #3
Teacher pack

Dr Lizzie Driscoll

Dr Rob McElroy

1. Li-ion batteries – where can we find them?



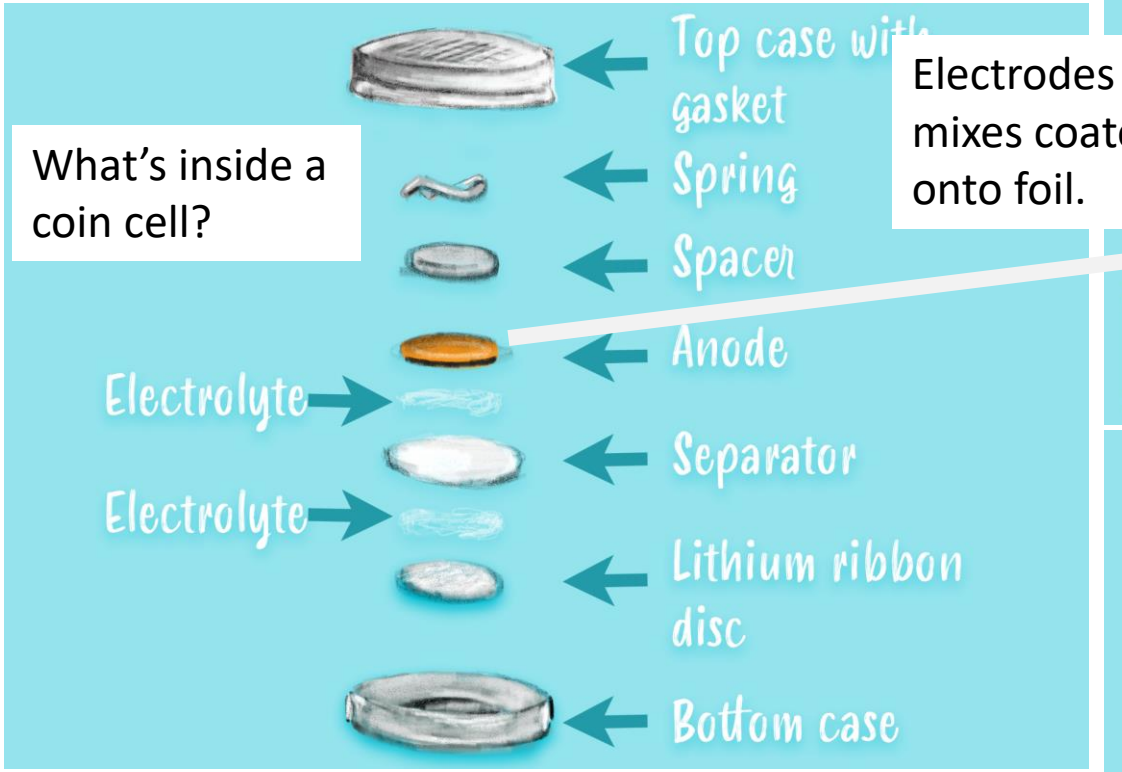


Li-ion are: light, high energy dense batteries. In these application, they're all rechargeable.

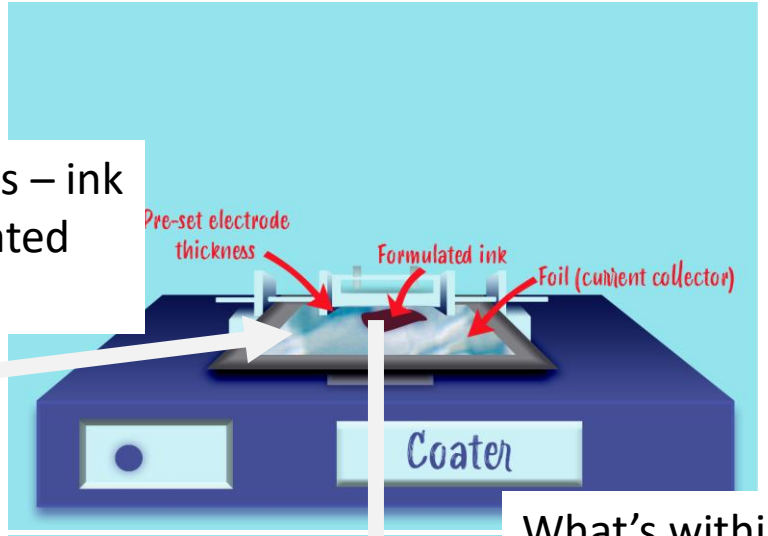
Vector images from Adobe Stock.

2. What materials currently used? Let's look inside.

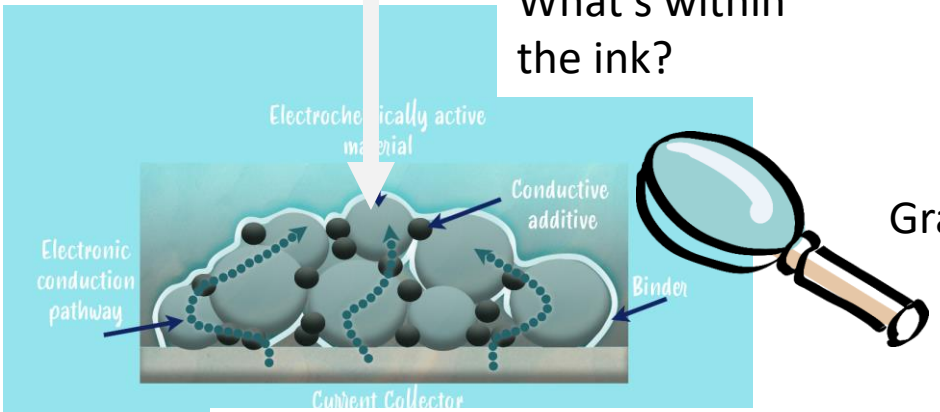
What's inside a coin cell?



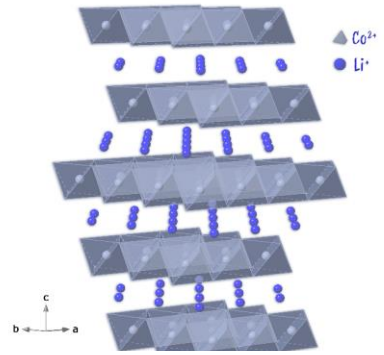
Electrodes – ink mixes coated onto foil.



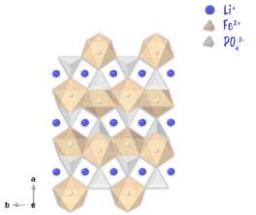
What's within the ink?



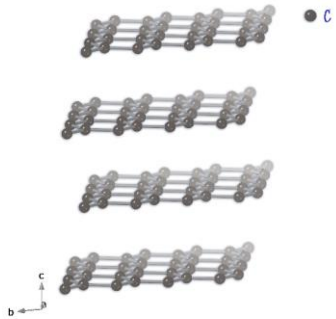
$LiCoO_2$



$LiFePO_4$



Graphite



All batteries consist of two electrodes and an electrolyte.

Using X-rays helps us understand the crystal structure (electrochemically active material).

Diagrams Lizzie Driscoll.

What the bits do

Case
- Holds the battery together and lets electrodes move out of the battery to do work

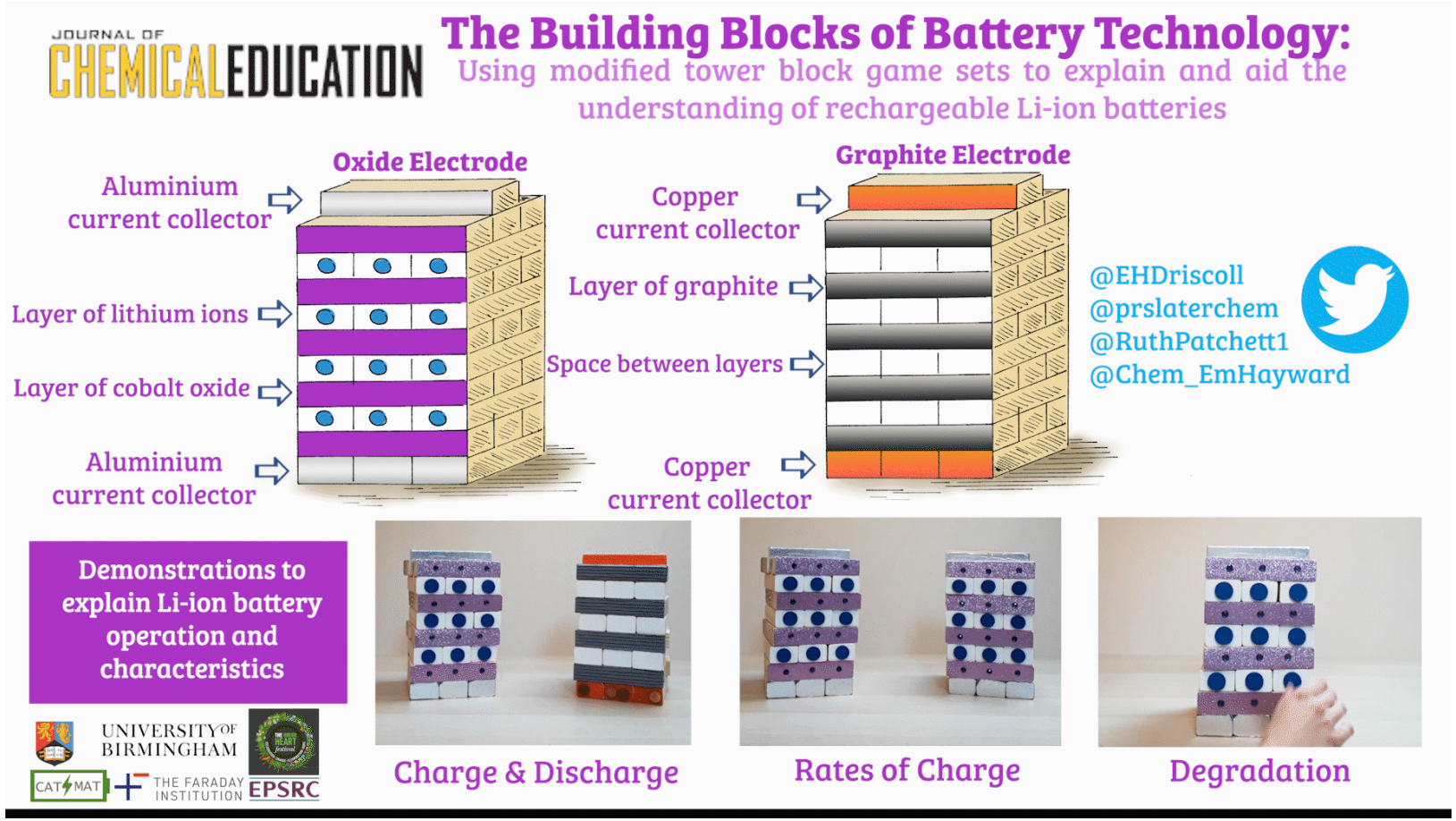
Spring and spacer
- Pushes layers together evenly

Electrode
- Bits made of cobalt on aluminium (cathode) that hold the lithium (Li) which moves to the graphite (carbon) on copper (anode) when you charge a battery. When you use your battery, the Li goes in the other direction.

Electrolyte
- Usually a liquid that lets the Li ions (Li^+) move

Separator
- Keeps the positive and negative bit of the battery apart but lets Li ions move through it

Background: how batteries work



[link to full description and little video]

Diagrams Lizzie Driscoll.

Electrode – what is in it

- Most of the value of the battery is in the electrode
- Student's phones will be NMC electrode
  - N = Ni, nickel
  - M = Mn, manganese
  - C = Co, cobalt

#28

NICKEL

Ni

28 58.693

COOKING

Heating elements in toasters and electric ovens are made from nichrome, a nickel-chromium alloy.

MAGNETIC

Nickel is one of only four elements that's magnetic at 20 °C. The others are iron, cobalt, and gadolinium.

COINAGE

The coins used in many countries contain nickel, alloyed with other metals such as copper.

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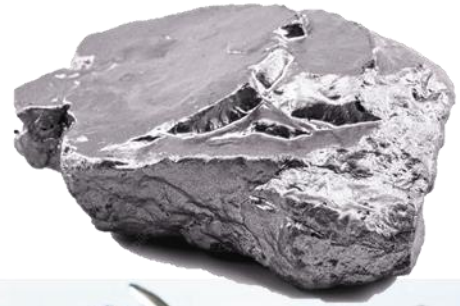

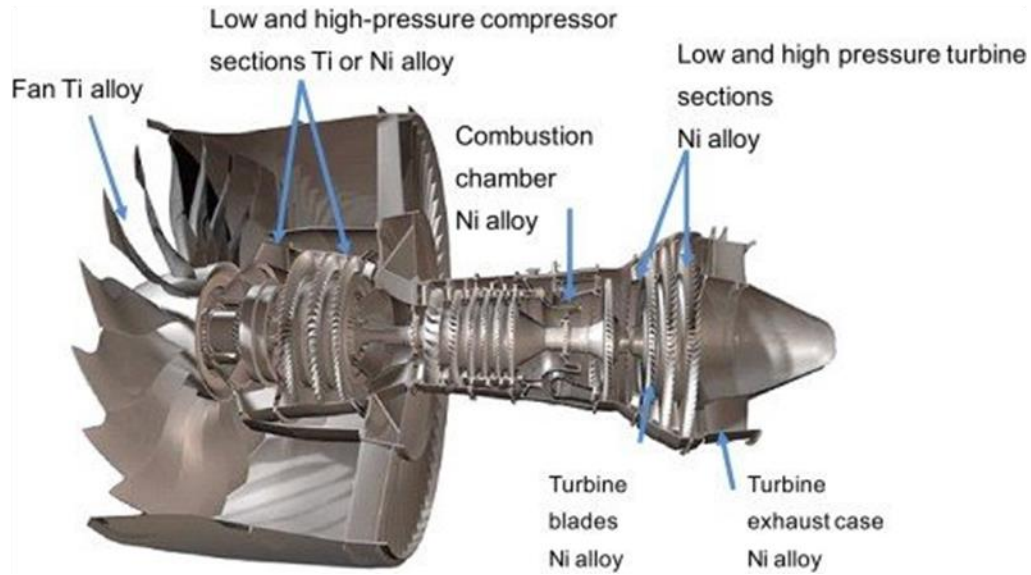

#25

MANGANESE

Mn

25 | 54.938

STRONG STEEL

Manganese steel contains ~13% manganese. It's very strong and used for railways, safes, and prison bars.

BONES & ENZYMES

Manganese is essential for organisms. It's needed for strong bones, and many enzymes also contain it.

DRINKS CANS

Drinks cans are made with an alloy of aluminium and manganese, which helps prevent corrosion.

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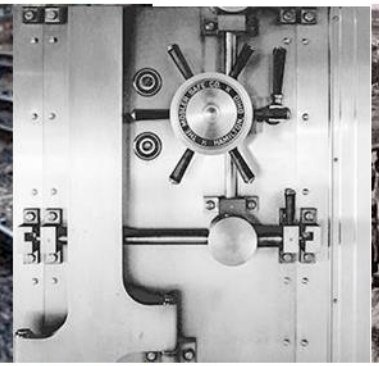

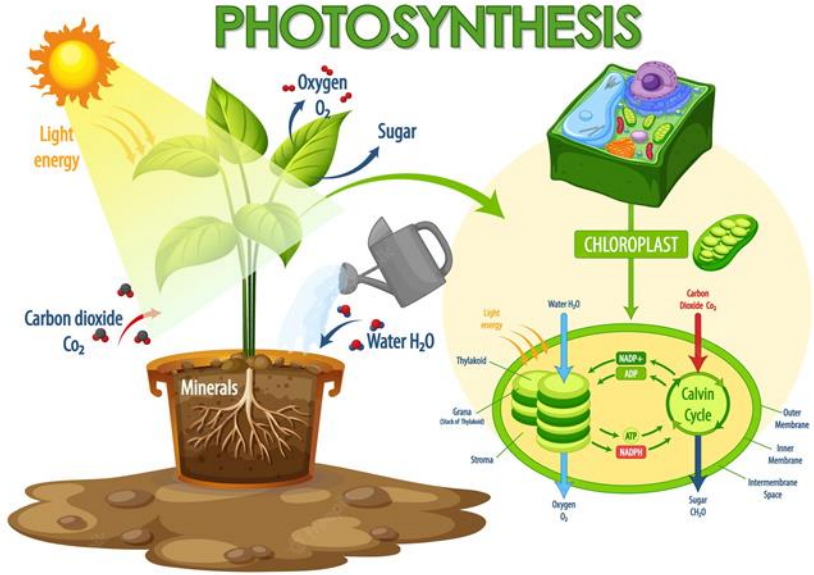

#27

COBALT

Co

27 | 58.933

PIGMENT

Cobalt blue is a blue coloured pigment, used in paints and as a colouring agent in Chinese porcelain.

JET ENGINES

Alloys of cobalt stay strong at high temperatures and resist corrosion. They are used in jet engines.

STERILISATION

Radioactive cobalt-60 is used to sterilise medical equipment, and is also used for food irradiation.

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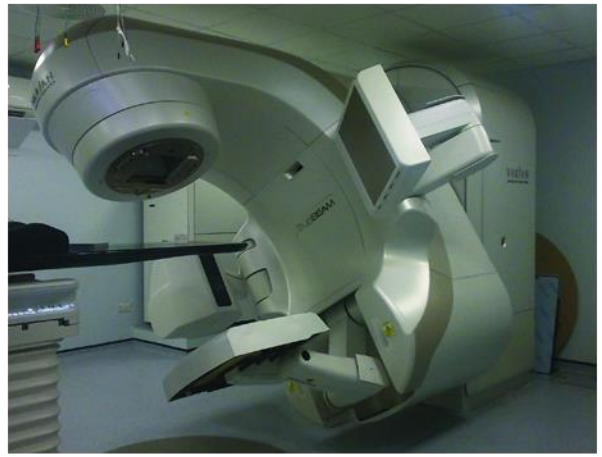
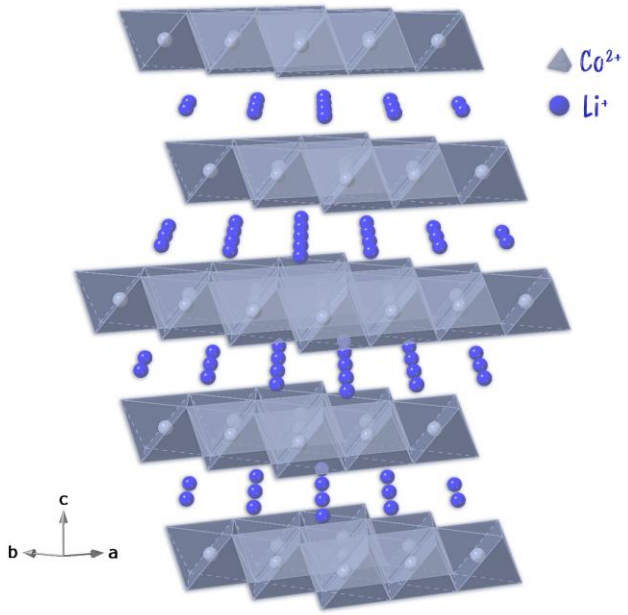


Issues with these materials…

$LiCoO_2$



For a green future, we have to mine these minerals for these materials.

The DRC is a large producer of Cobalt – serious concerns regarding child labour and modern slavery.

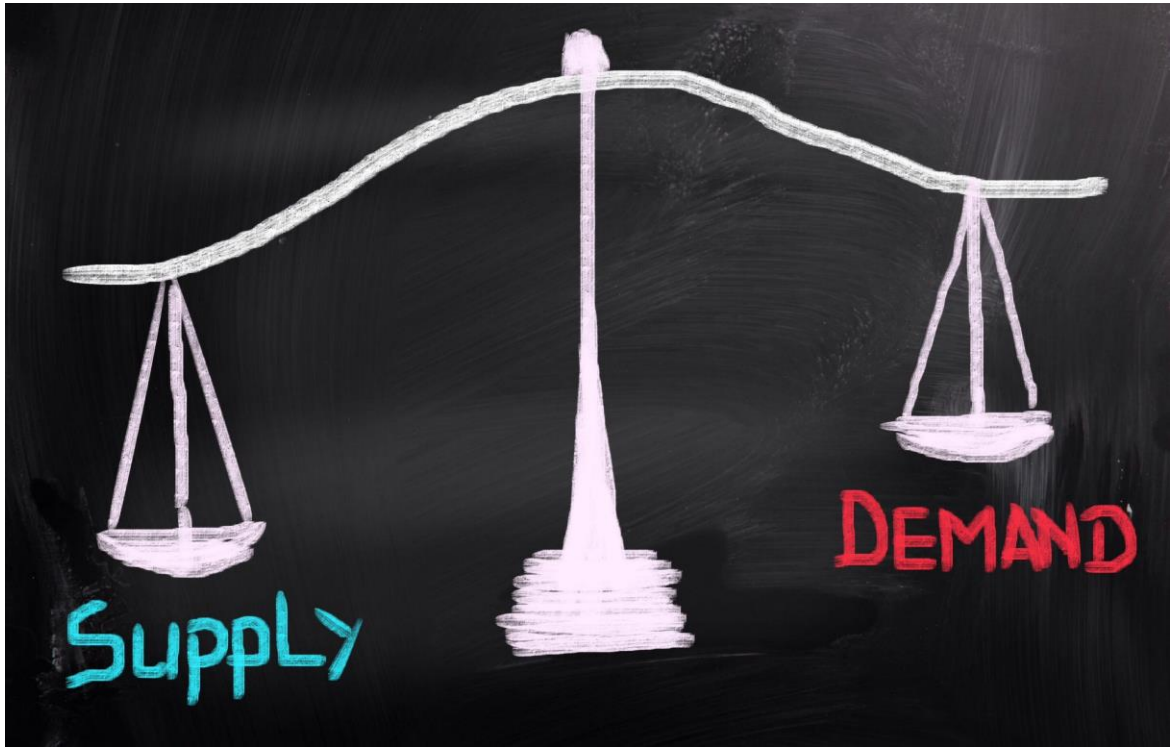
Vector images from Adobe Stock.

Issues

- $LiCoO_2$ is the archetypal material. Issues of Co mining (Child Labour). Move to NMC (using less Co, more Ni and Mn), but also $LiFePO_4$ (Fe abundant, Li and P critical).
- From an ethical standpoint, there are also serious concerns regarding the sourcing of cobalt – the Democratic Republic of Congo (DRC) being the largest producer, has received significant attention regarding child labour and modern slavery in its 'Artisanal and Small-scale Mining (ASM)' industry.
- In lieu of this, cathode chemistries have been developed which have no or limited Co use.

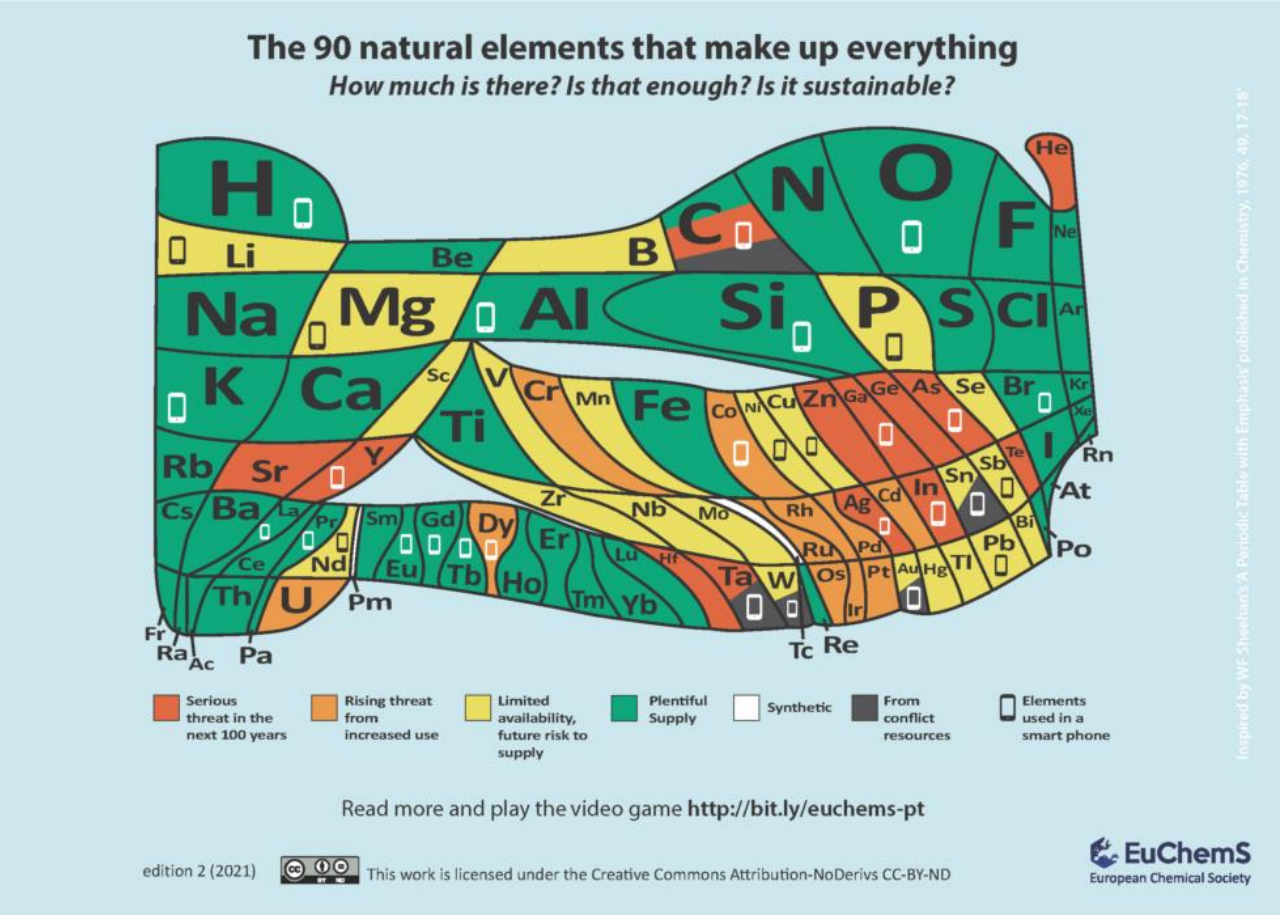
Critical Materials

Li, Co, P, graphite – all critical elements and are used in Li-ion batteries.



Vector images from Adobe Stock.

This the periodic table but with size and colour showing how much and how critical elements are



Critical elements means any one of the following;

- We don't have many known reserves – resource criticality
- We don't have ways of recycling efficiently – resource criticality
- What the world has is controlled by only a few countries – political criticality
- Buying these elements can lead to support of conflicts – human rights issues

https://www.euchems.eu/euchems-periodic-table/

3. Ultimately batteries performance fade over time. What happens to them?

Potentially second-use, but ultimately they will reach the end of their life. Landfill most likely.

Vector images from Adobe Stock.

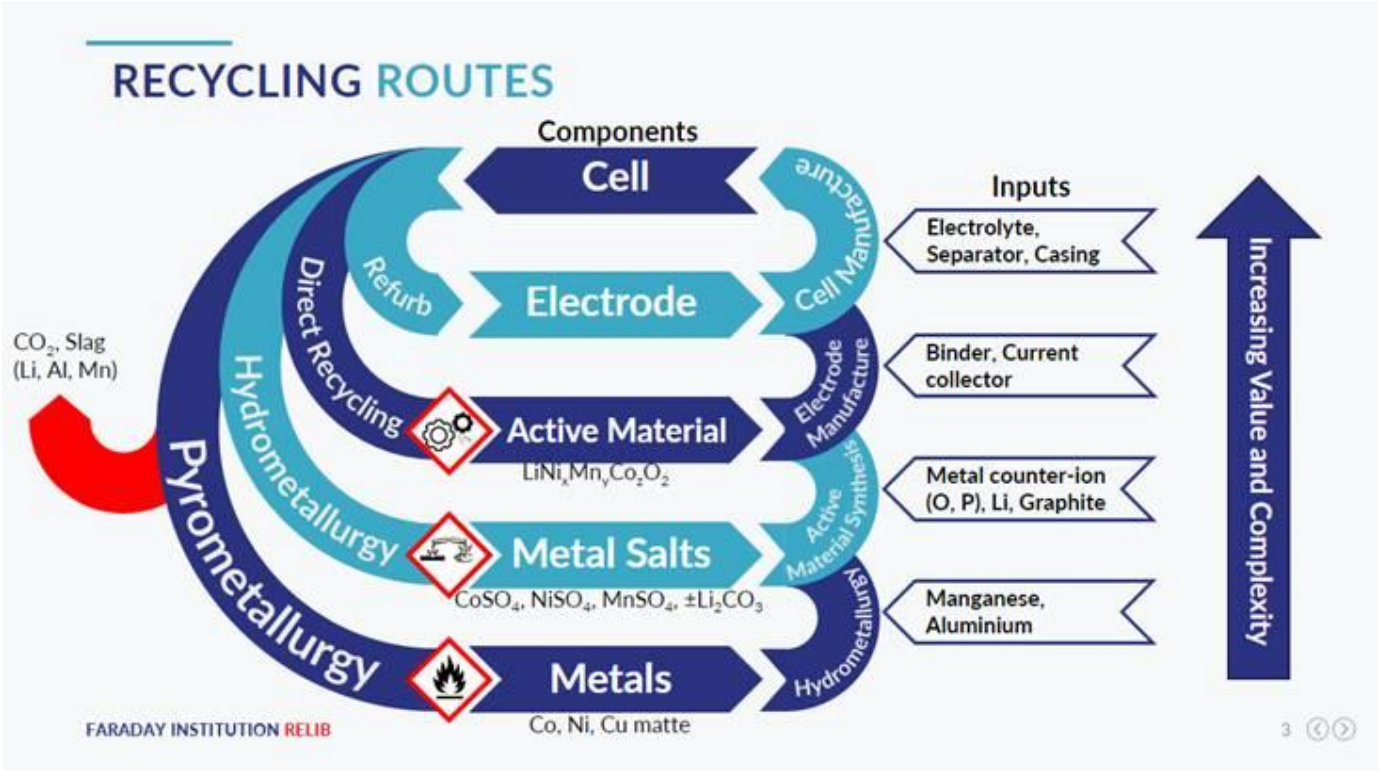
4. Can we recycle them?

Yes! But we need to be safe and sustainable.

Additional challenges of the Li-ion batteries consisting of different chemistries and architecture.

Vector images from Adobe Stock.

5. How do we recycle?



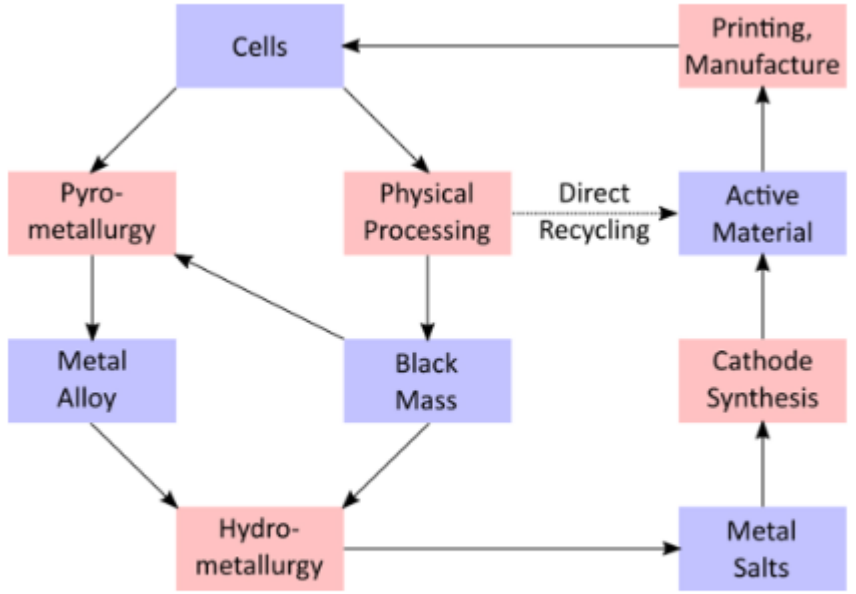


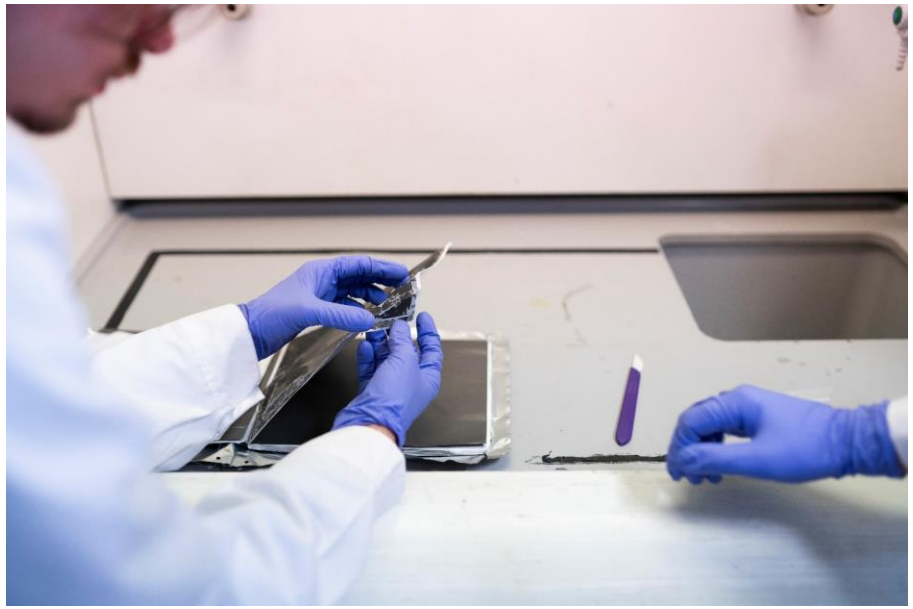
Fig. 2. Generalised Recycling loop, showing processes in red, and intermediate products in blue.

Vector images from Adobe Stock. Graphic from Rob Sommerville.

Manually Disassembly

Labour intensive

Higher Purity



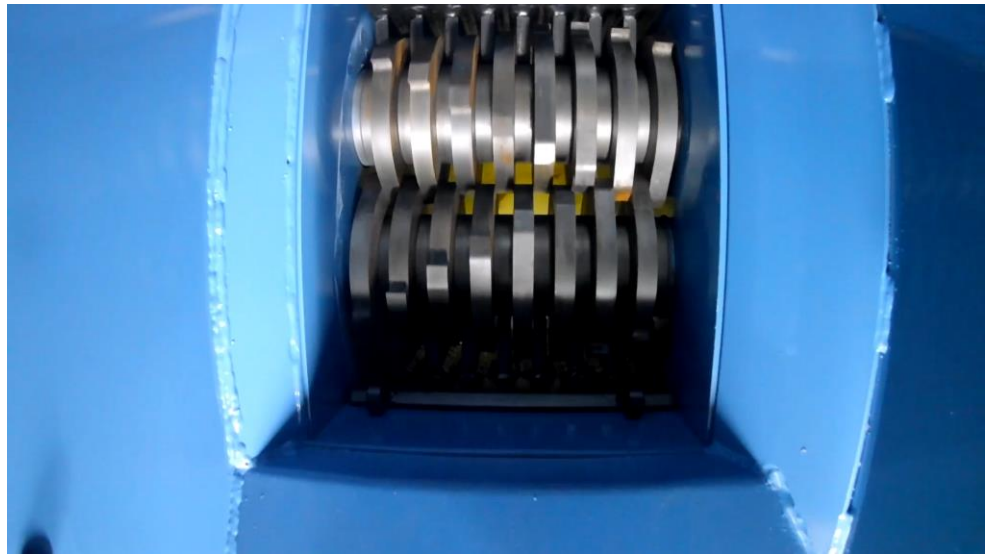
Vs

Shredding

Well established

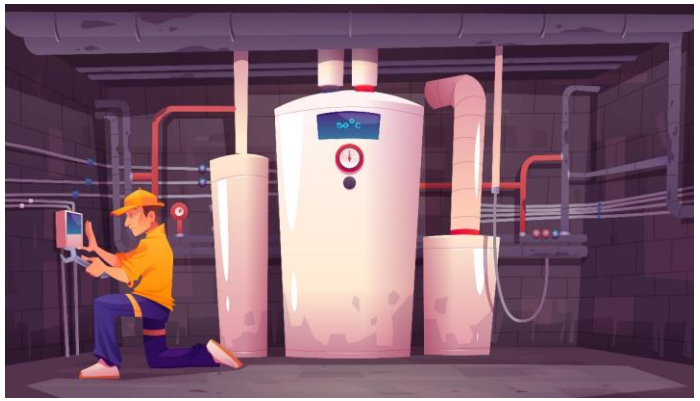
Quick

Lower Purity



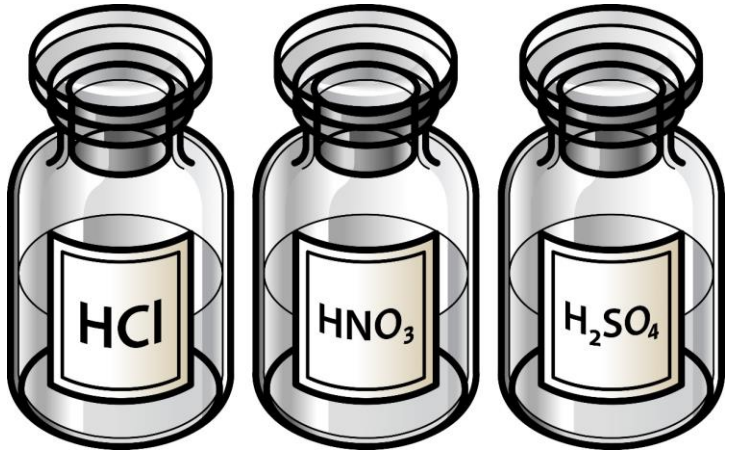
Photos – ReLiB Faraday Institution.
Video – Rob Sommerville.

One option -
Pyrometallurgy



Disassemble to shoebox or small, then pyrometallurgy to get a copper/cobalt/nickel (with/without Fe), alloy.

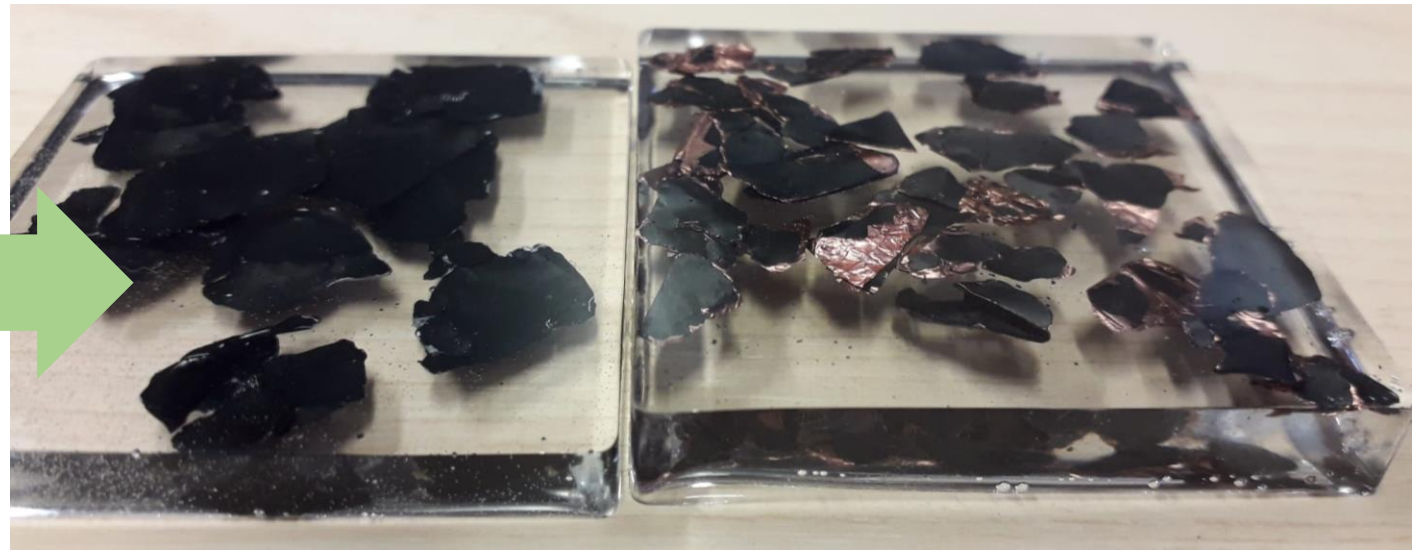
Second option -
hydrometallurgy



Dissolve in acid, and separate the dissolved ions to get high purity.

The Results of Physical Processing Techniques on Shredded Material

Shredded material
(sealed in epoxy resin)



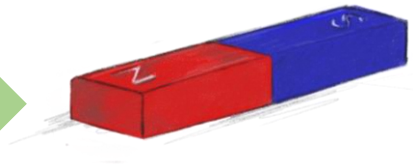
Cathode

Anode

Photos – Lizzie Driscoll.

Physical Processing Techniques

Separate the different size fractions initially

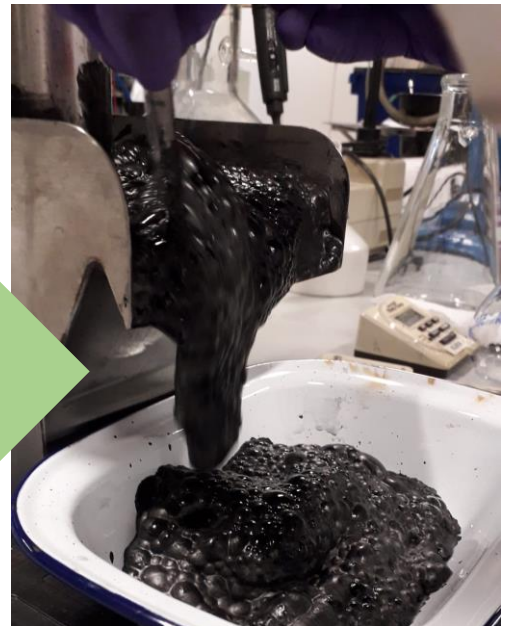


Magnetic separation to remove the steel casings

Density separation

Electrostatic separation

Remove plastics/polymers



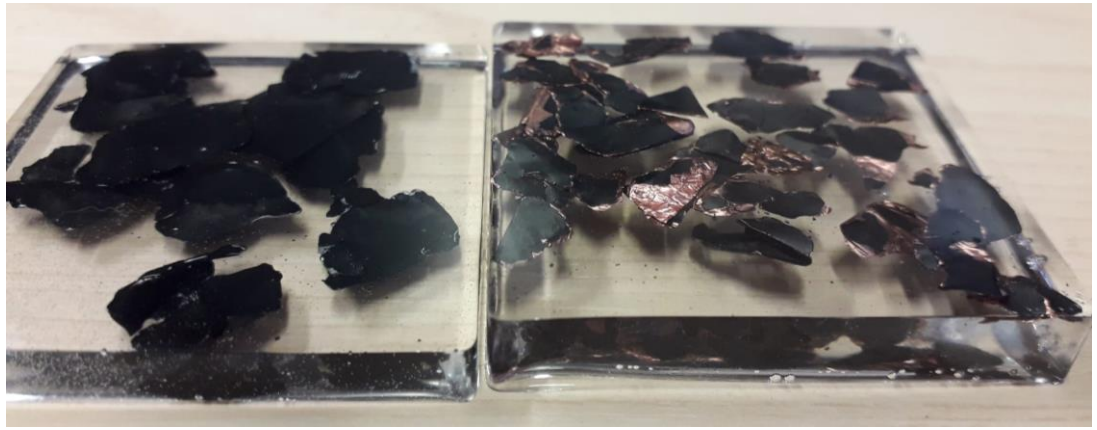
Froth Flotation

To remove carbon additives

If we picked it out by hand, it would take a long time + human error

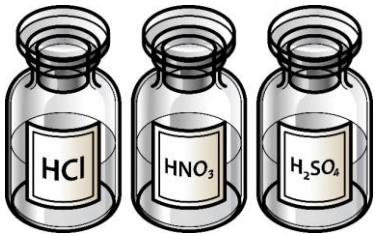
Photos & drawings – Lizzie Driscoll.

Green Solvents: Getting the Active Material back



Option one

Can use a solvent called NMP – it's very nasty. This is to get the active material which can be used in the hydrometallurgy process.



Option two

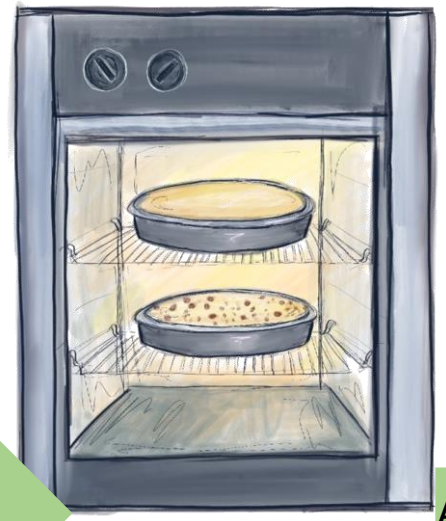
Use NMP, get the active material and then direct recycle this.

Option three

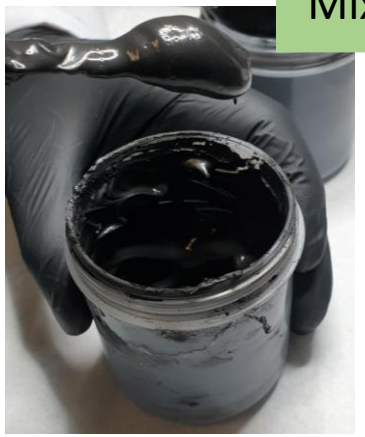
Use a green solvent in place of NMP, get the active material and then direct recycle this. (see Green Kid issue 1)

Remanufacture

(Re)manufacture – we typically link back to cake.

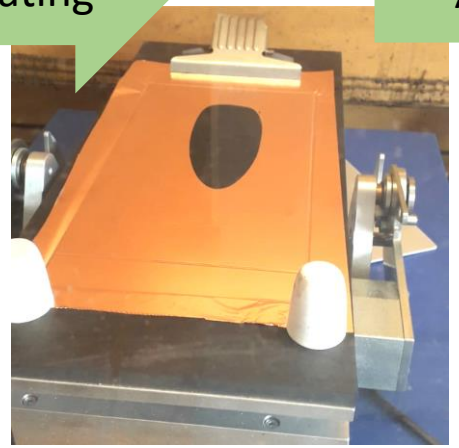


Mixing

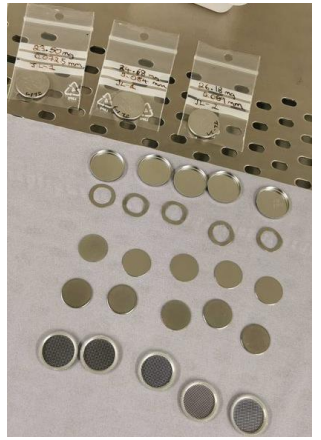


Coating

Drying

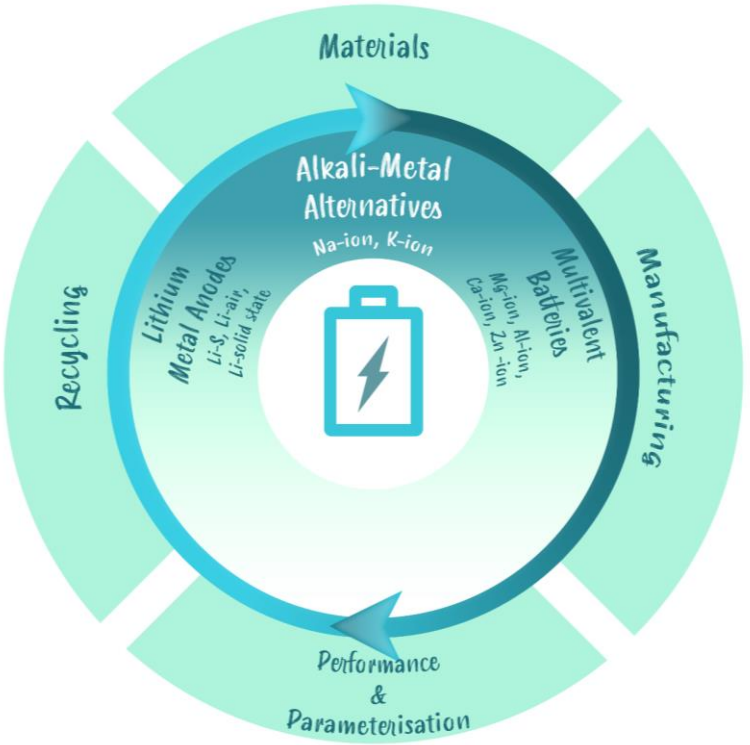


Assembly



Drawings by Sophia Constantinou – NEXTRODE FUSE Intern 2020.

Batteries then ready to use



Cell tester

Photo – ReLiB Faraday Institution.
Schematic – Lizzie Drisocll & Emma Kendrick.

Questions?

- Please contact;

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