Imperial College London

The future of battery tech

Developing a UK sustainable battery industry

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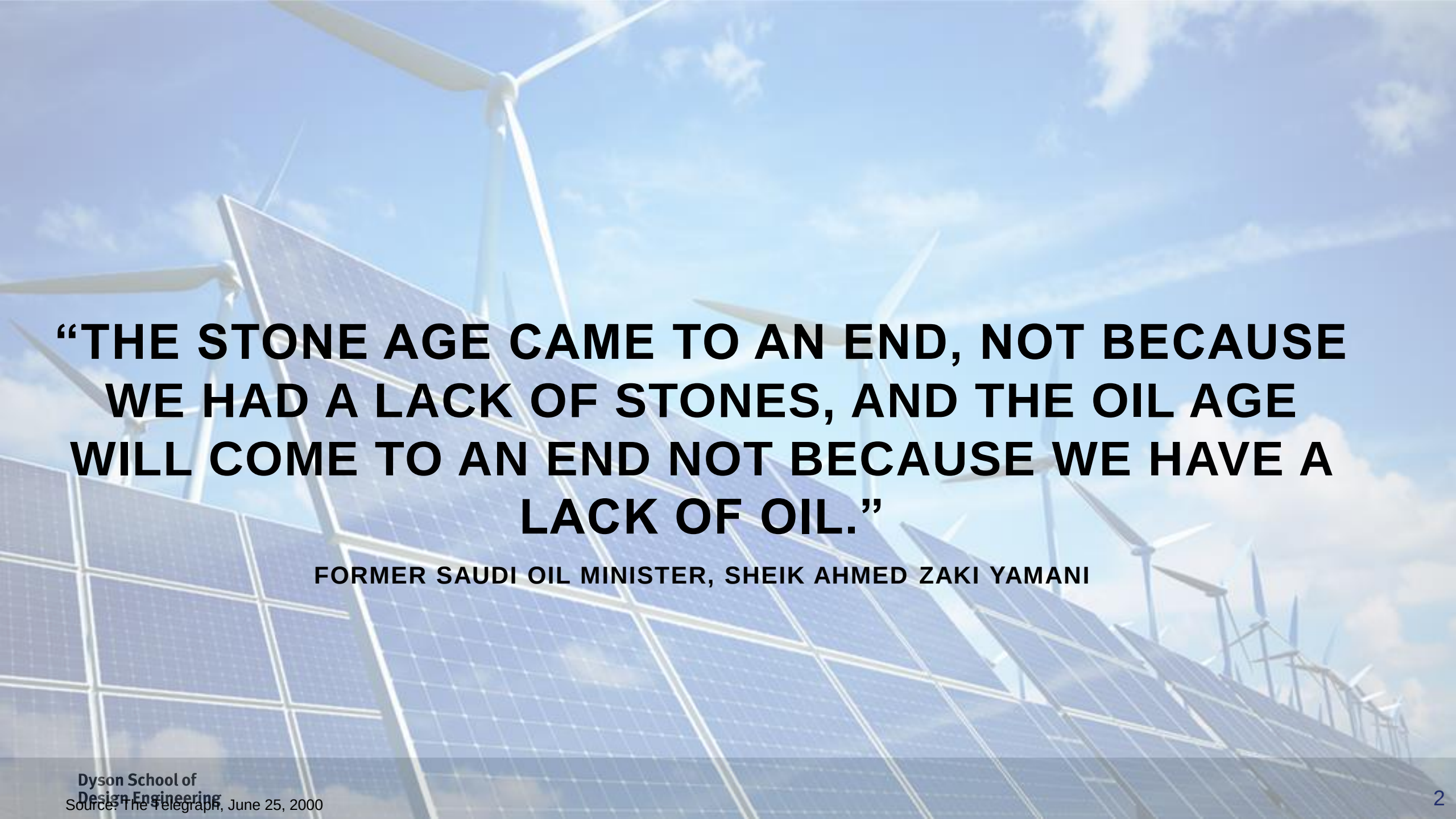


“THE STONE AGE CAME TO AN END, NOT BECAUSE WE HAD A LACK OF STONES, AND THE OIL AGE WILL COME TO AN END NOT BECAUSE WE HAVE A LACK OF OIL.”

FORMER SAUDI OIL MINISTER, SHEIK AHMED ZAKI YAMANI

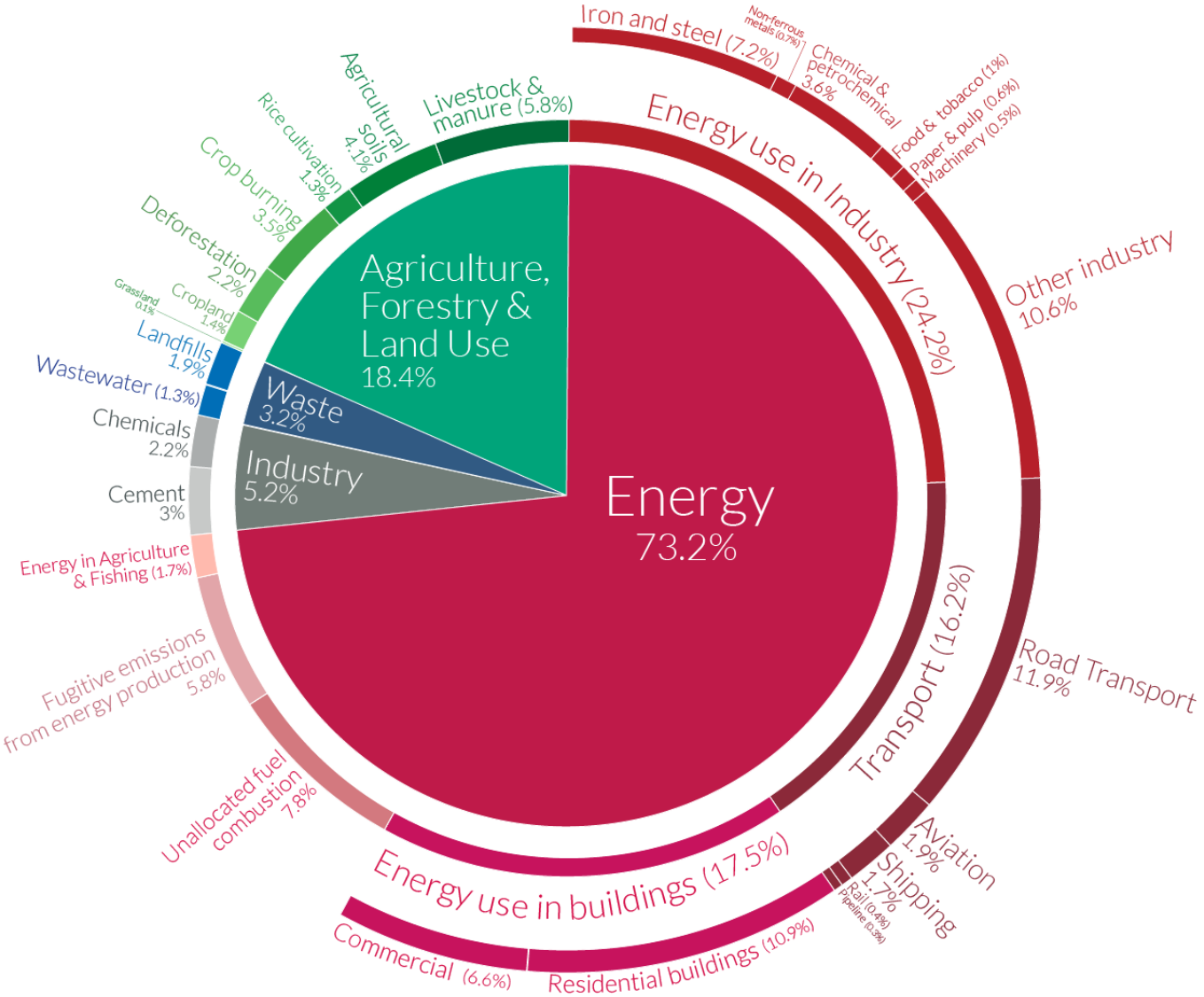
Source: The Telegraph, June 25, 2000

Electrons are the new oil

Cars

Energy storage

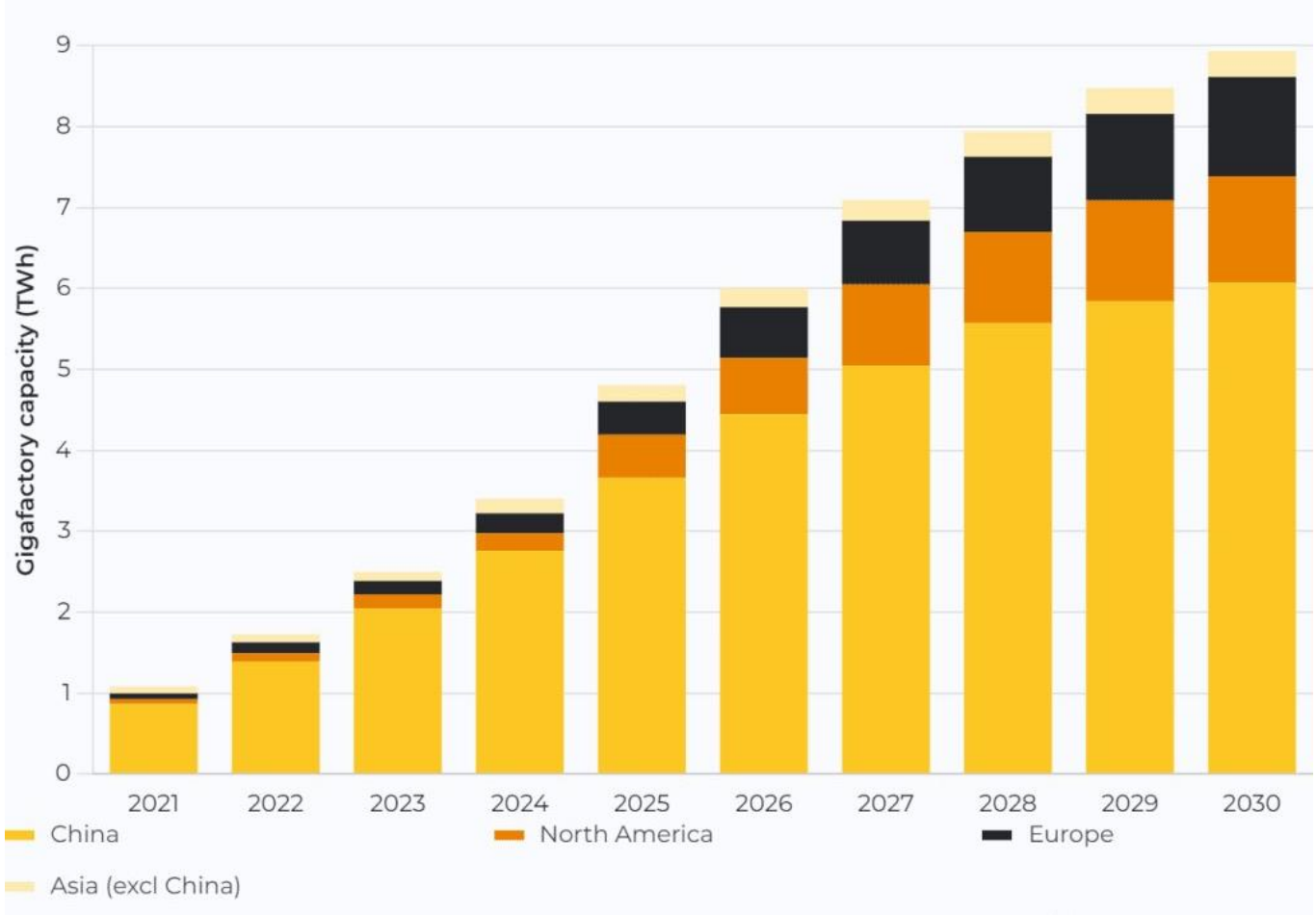
Global greenhouse gas emissions by sector
(~50 billion tonnes CO_2eq.)

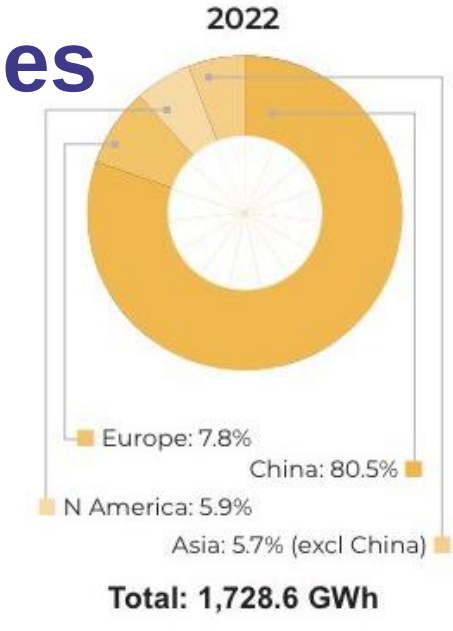


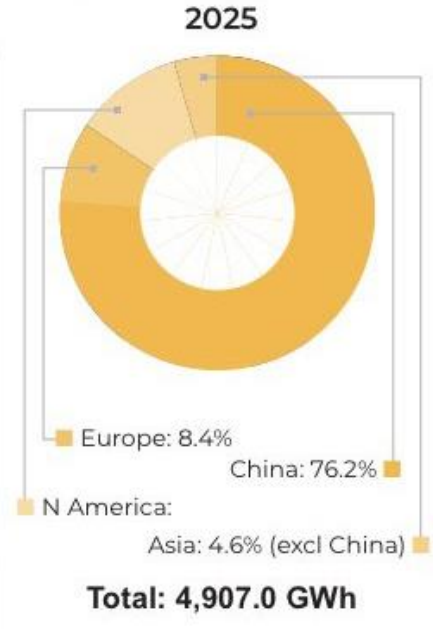
https://unsplash.com/photos/2--Gg0gpWIA
https://unsplash.com/photos/white-and-black-solar-panels-under-white-clouds-and-blue-sky-during-daytime-itv-MC5S6cU
https://ourworldindata.org/emissions-by-sector - 2016 data

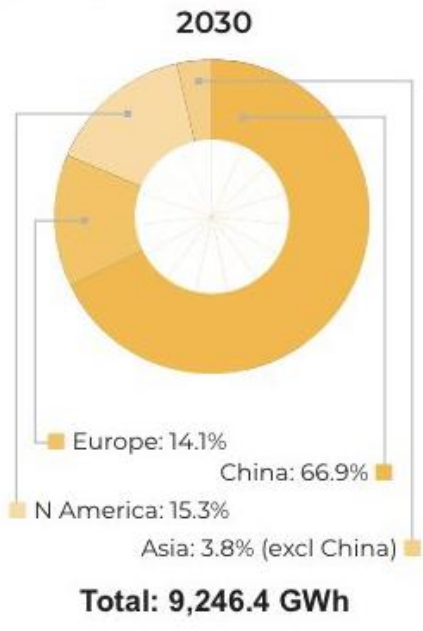
The world will need A LOT of batteries

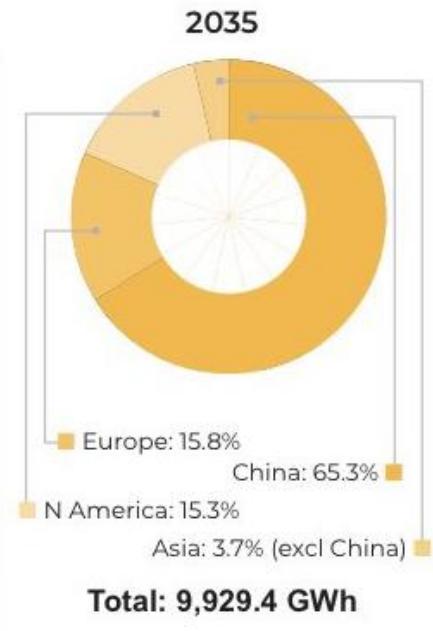
>400 battery gigafactories in the 2030 pipeline
Two thirds of the ~9 TWh capacity from China





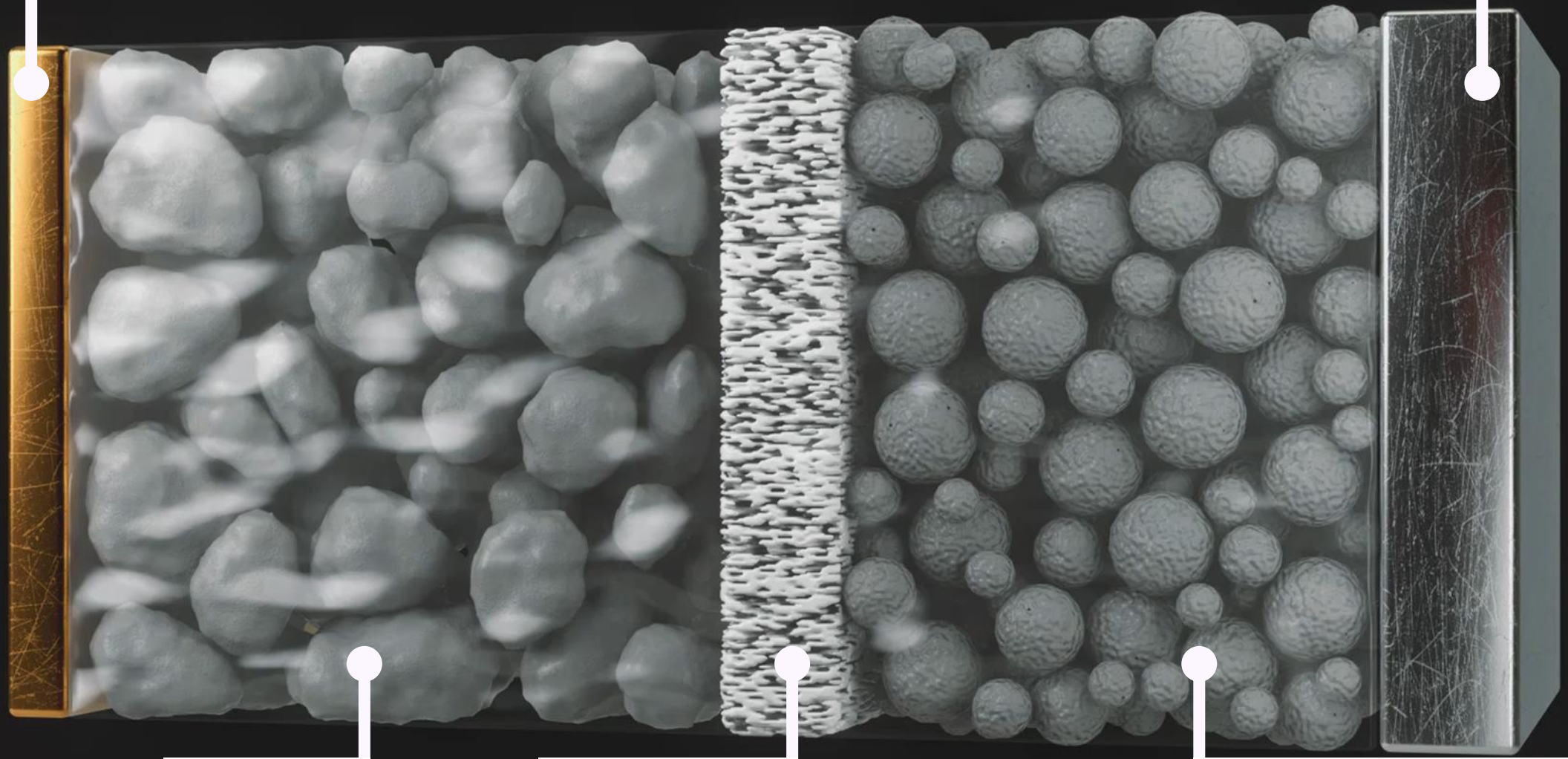






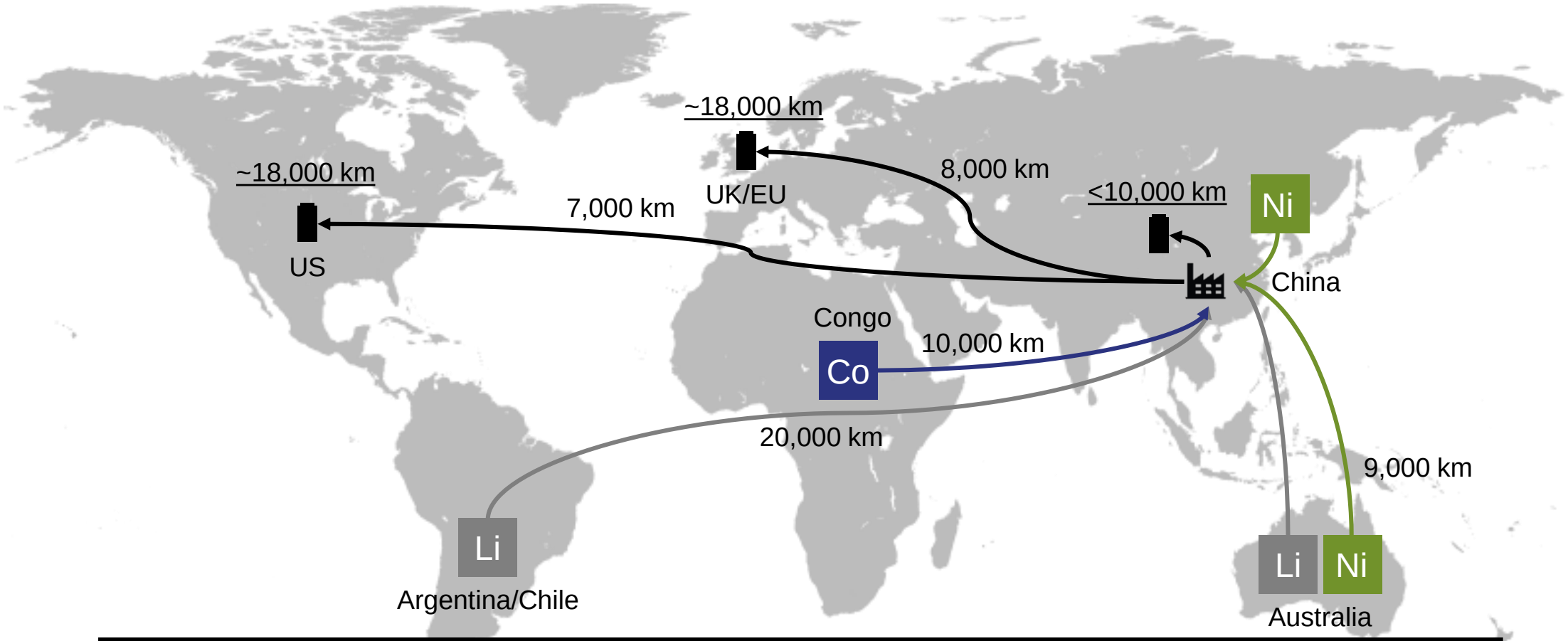
Benchmark mineral intelligence. 2023

What are the critical elements?



Special thanks to @TheLimitingFactor

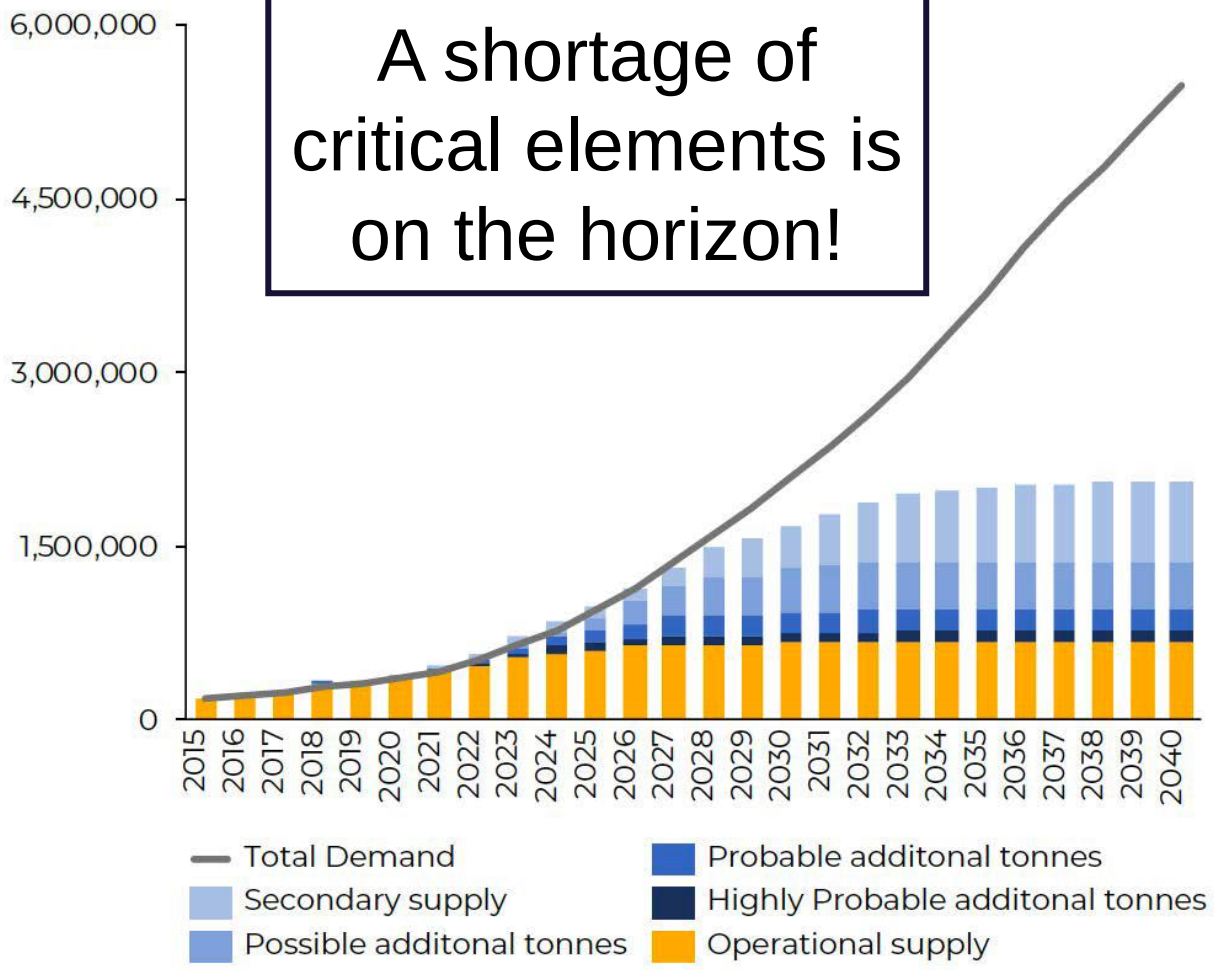
We will need a lot of critical materials



Urgent need to localise/secure supply chains and establish recycling capability to create robust sovereign capability

Will we have enough?

A shortage of critical elements is on the horizon!



What about recycling?

Collection and sorting

Shredding

Pyrometallurgical processes = Heat!
Lower recovery rate but cheaper

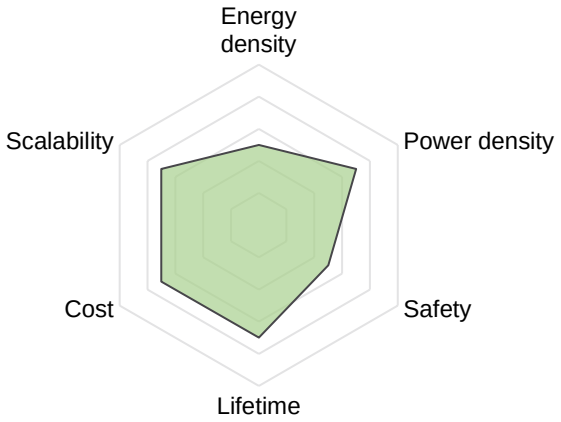
Hydrometallurgical processes = Chemicals!
Higher recovery rate but more expensive

Need more efficient and cheaper recycling with more infrastructure and policies!

Benchmark mineral intelligence 2020
@yasinb3da - https://unsplash.com/photos/zHK__gTTTds | @alexkondratiev - https://unsplash.com/photos/H9t723yPjYI | @david_Gabriel - https://unsplash.com/photos/rzrfWXiEWVc
https://www.eurekalert.org/multimedia/602025 | https://www.forbes.com/sites/jimvinoski/2021/08/09/li-cycle-aims-to-change-the-game-for-recycling-lithium-ion-batteries/?sh=64d2910244f4
https://group.mercedes-benz.com/company/news/recycling-factory-kuppenheim.html

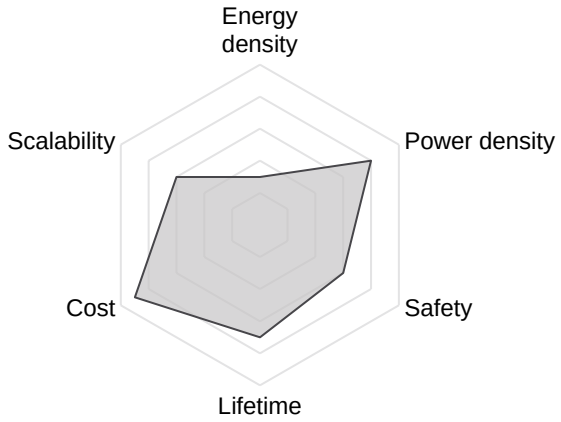
The winners will use new battery tech!

Traditional lithium-ion



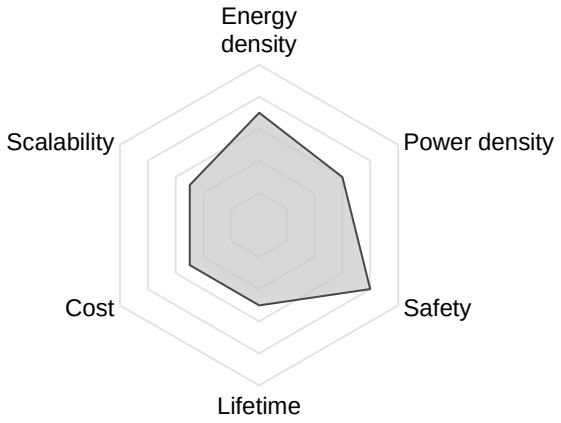
All rounder but issues with safety

Sodium-ion



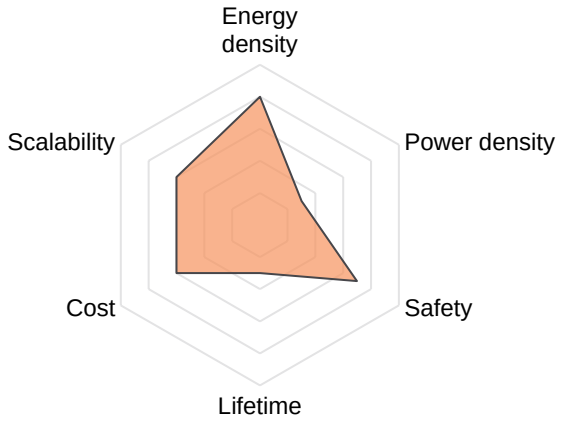
Cheap but low energy density

Solid-state



High energy density but issues with scalability

Lithium-sulphur



High energy density but low power and lifetime

Professor John Goodenough

Winner of the 2019 Nobel Prize in Chemistry for work on lithium cobalt oxide at the University of Oxford in the 1980s

Invented in the UK, commercialised in Asia

Faradion

Global technology leader in sodium-ion batteries based in Sheffield (NEXGENNA partner @ Faraday Institution)

The Faraday Institution

Flagship UK battery research programme

27 universities | 120+ businesses | 500 researchers

Research and development powerhouse has been established!

Time to reap the rewards

Large industry inertia, we can't lose momentum






Raw materials	Precursors	Electrodes + components	Cells	Modules + packs	Vehicle applications	2nd life + recycling
Lithium, nickel, cobalt, manganese, copper, aluminium, graphite Supply chain, price volatility Purity Ethics	Lithium carbonate vs hydroxide Cobalt, nickel and manganese sulphates Processing, single crystal vs polycrystalline Chemicals	Active material, conductive additives, binders Mixing, coating, drying, calendaring Separators, current collectors, electrolytes	Cylindrical, pouch, prismatic Size, capacity Electrolyte filling Formation Lifetime Consistency	Pack design Thermal management system Battery management system Lifetime	Load profile Environmental conditions Servicing Residual value Real world performance	Residual capacity Safety Logistics Residual value Policy Economics

Key considerations

Industrial chemists

Mining and refining

Material suppliers

Cell suppliers

Tier 1

Low volume OEM

2nd user

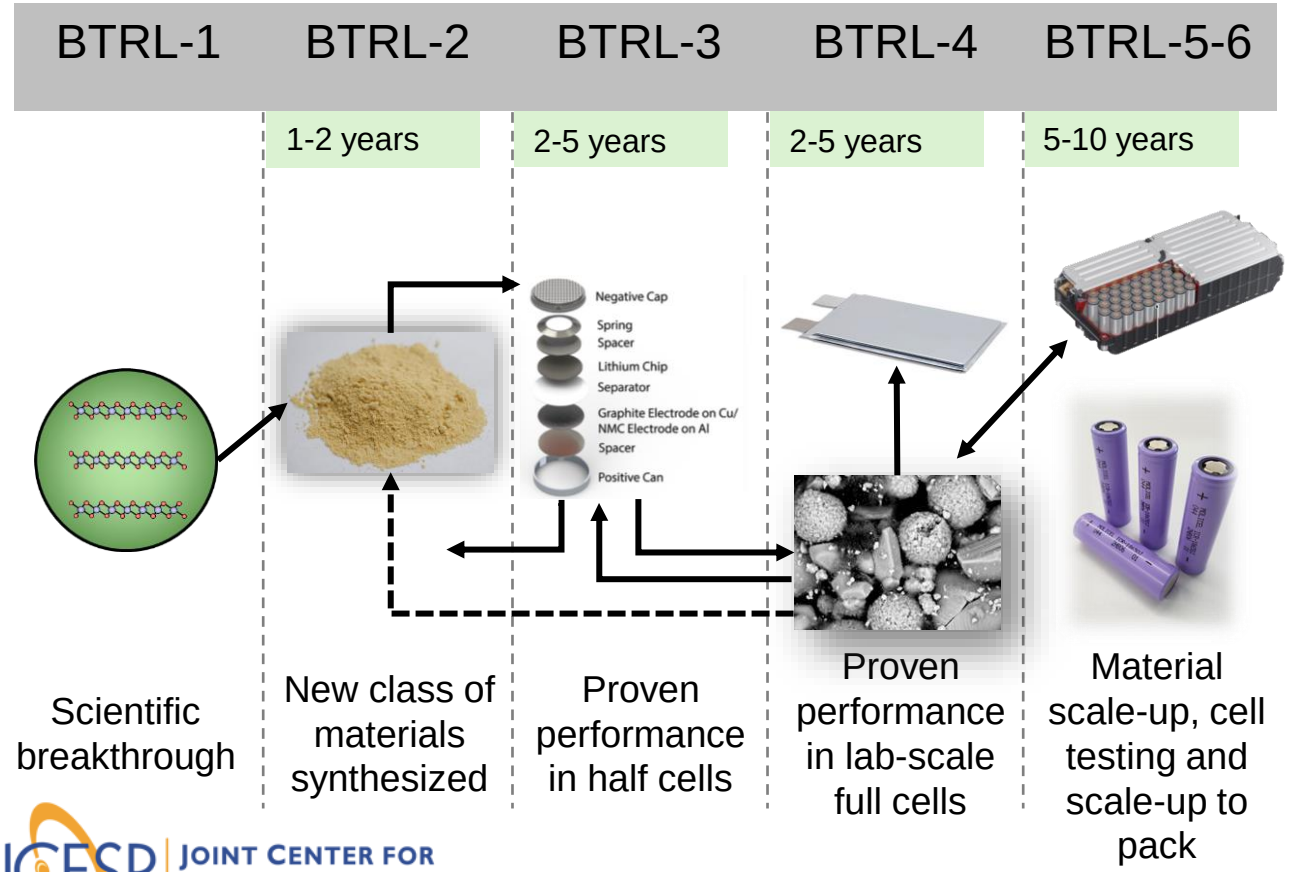
High volume OEM

Recycler

Adapted from content from Professor Dave Greenwood at Warwick Manufacturing Group
https://unsplash.com/photos/F_EooJ3-uTs

Long-term research is key to sovereign capabilities

Battery Technology Readiness Level (BTRL)



JCESR | JOINT CENTER FOR ENERGY STORAGE RESEARCH

Pace of action needs to increase to maximise economic once in a generation opportunity

The UK is well placed to have a leading position in next generation batteries

EV production could reach 1.6 million by 2030 but essential for batteries to be made in the UK

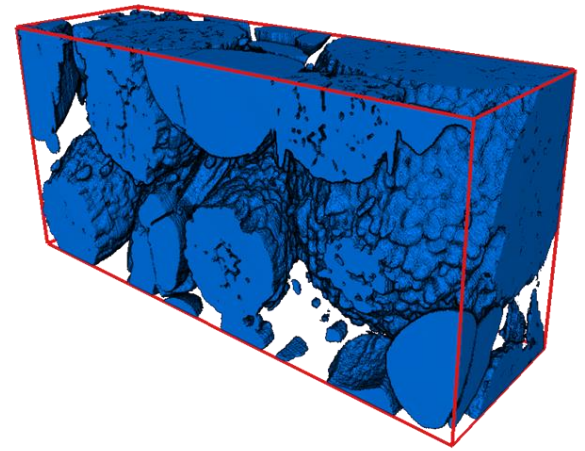
By 2040 a successful battery industry could employ 270,000 people in EV manufacturing

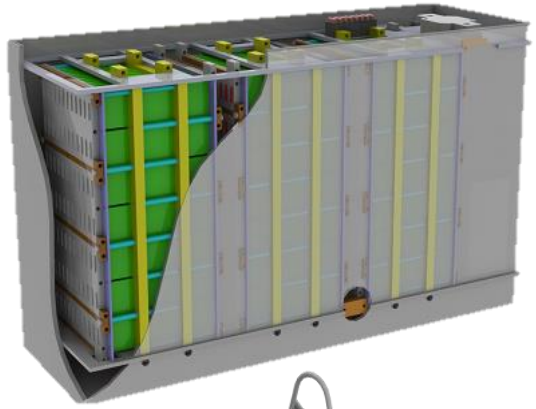
Highly skilled jobs and researchers (PhDs) will be the innovation engine for export opportunities

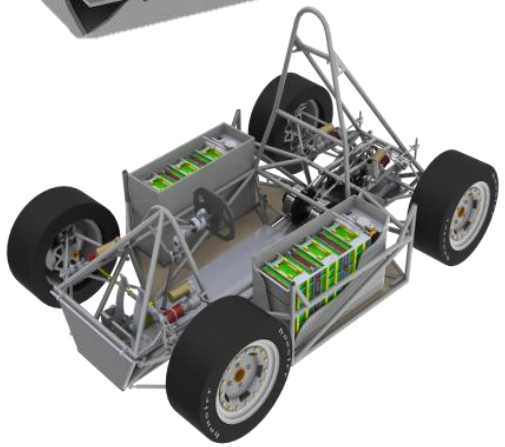
Adapted from: The joint centre for energy storage research: A new paradigm for battery research and development. Crabtree. AIP Conference Proceedings. 2015.
UK electric vehicle and battery production potential to 2040. The Faraday Institution. 2022

Take away messages

- **Electrons will be the new oil**
  - Once in a generation technology/energy transition
- **Batteries will be the enabler and we will need A LOT of them**
  - >400 gigafactories already in the global pipeline (2/3rd from China)
- **Everyone will want the critical materials**
  - Lithium shortages on the horizon
- **The winners will innovate**
  - Huge potential to capitalise on the UK intellectual powerhouse in next gen battery technologies
  - If not in the race, you will be left behind
- **The seeds have been planted, now its time to harvest the rewards**
  - Goodenough battery invented in the UK, commericalised in Asia
  - Lessons must be learnt
- **Long-term research is key to sovereign capabilities**
  - Huge inertia, but momentum built which we can't lose
- **Huge benefits if achieved**
  - 1.6 million UK EVs by 2030 | 270,000 highly skilled jobs | Export potential







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The race is on!

Thank you for listening

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