Securing a sustainable supply chain

7th July 2020

LowCVP
Low Carbon Vehicle Partnership

ADVANCED PROPULSION CENTRE UK

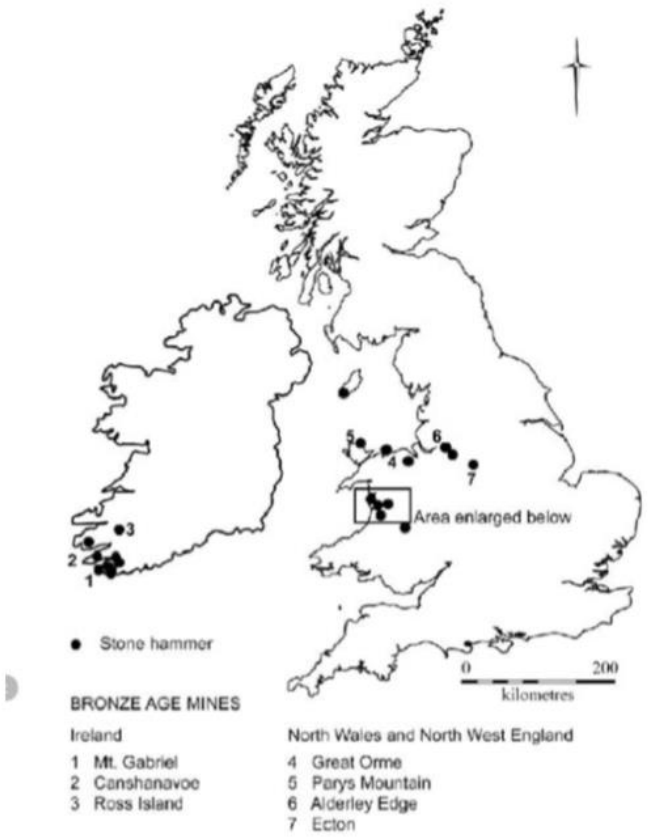
Department for International Trade

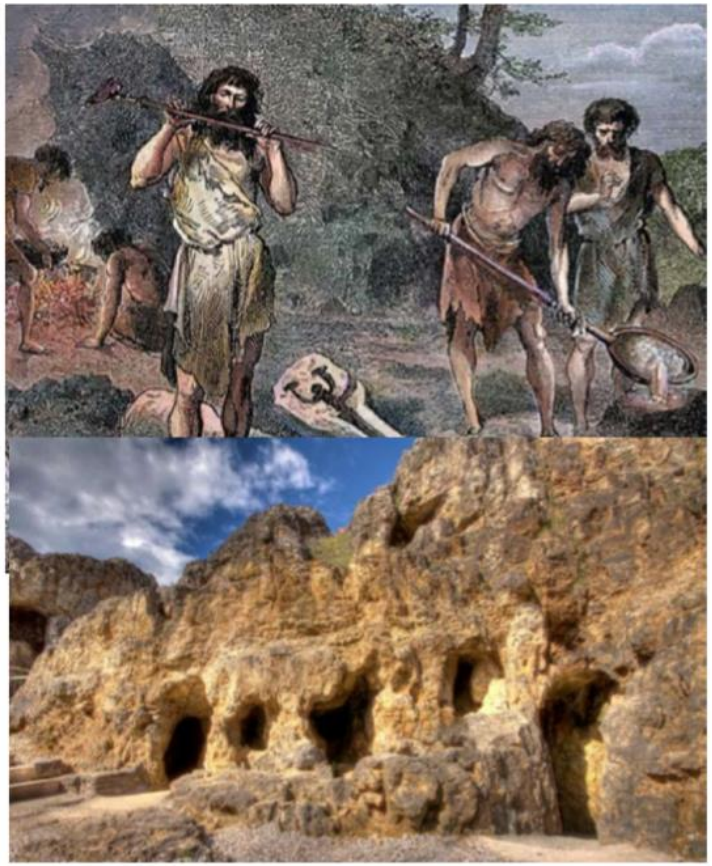
Critical Metals and Minerals

Securing the Supply Chain for Clean Growth

Darryn Quayle
July 2020

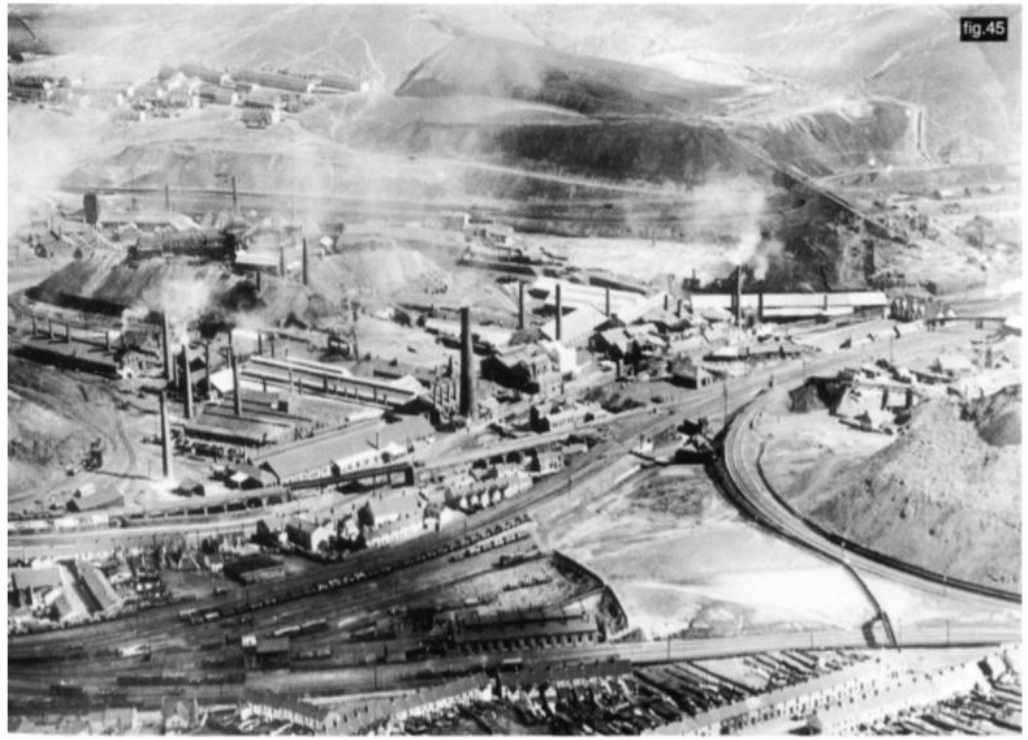
Bronze Age Mining (2,500BC)



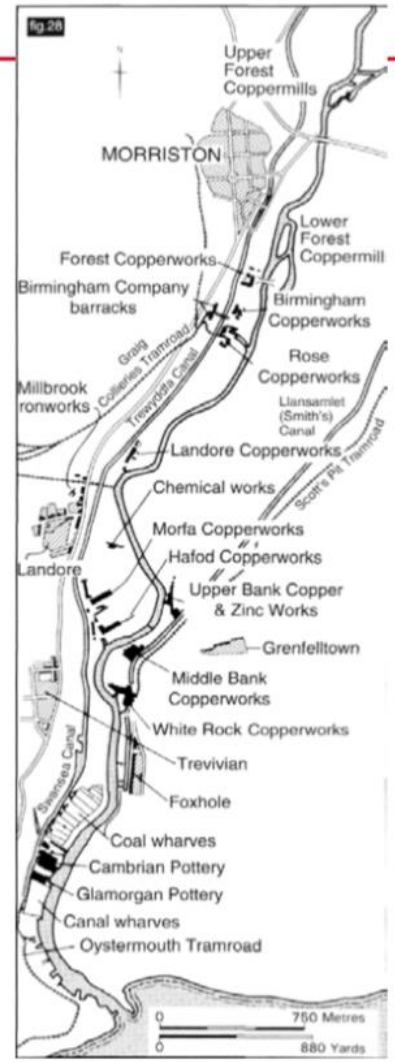


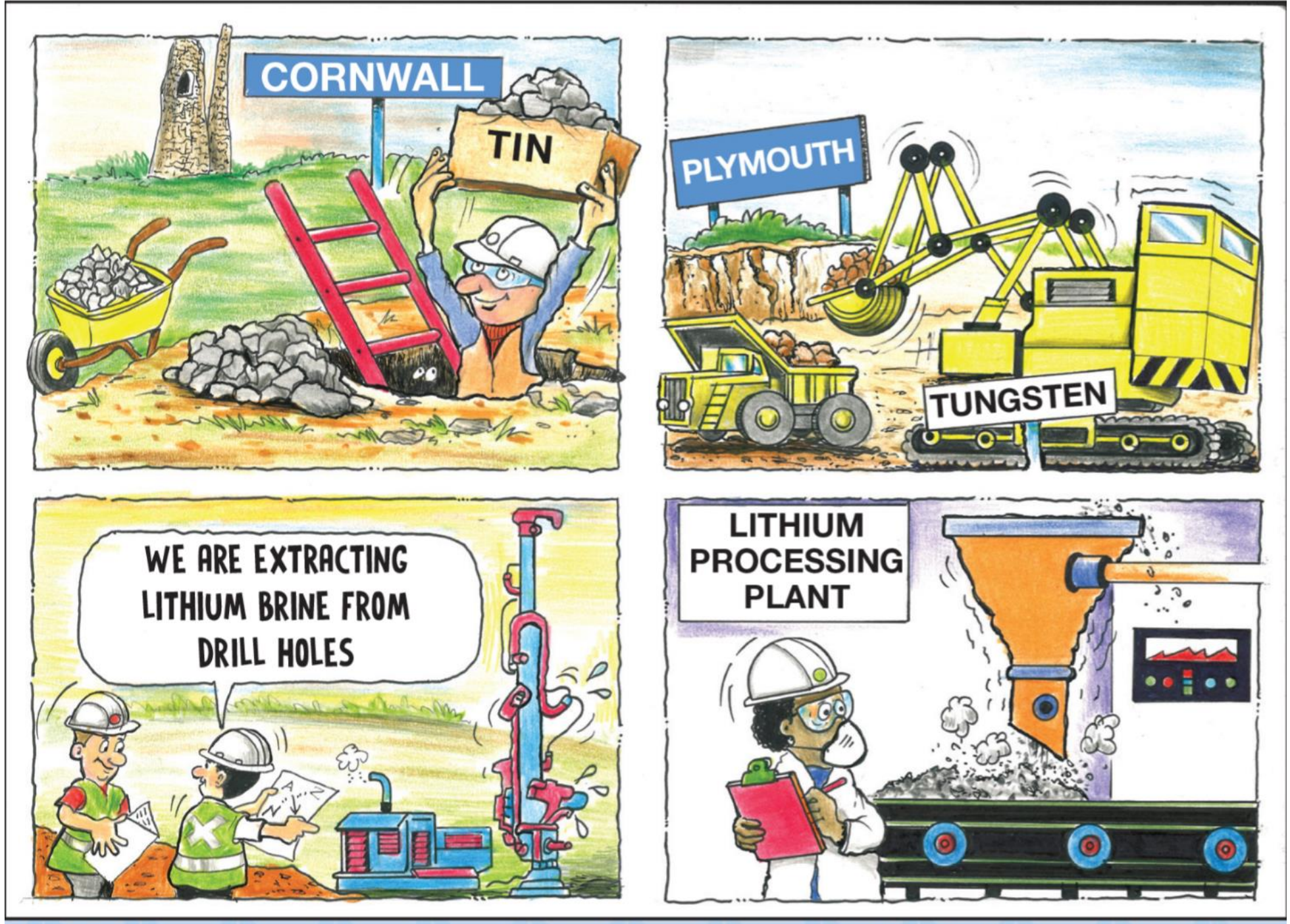
Copperopolis, Wales

- The world's first globally integrated heavy industrial complex
- For some 200 years – until the mid 19th century - Copperopolis reigned supreme over the planet's copper industry, manufacturing almost 70% of the world's copper goods



Morfa Copperworks in 1920's



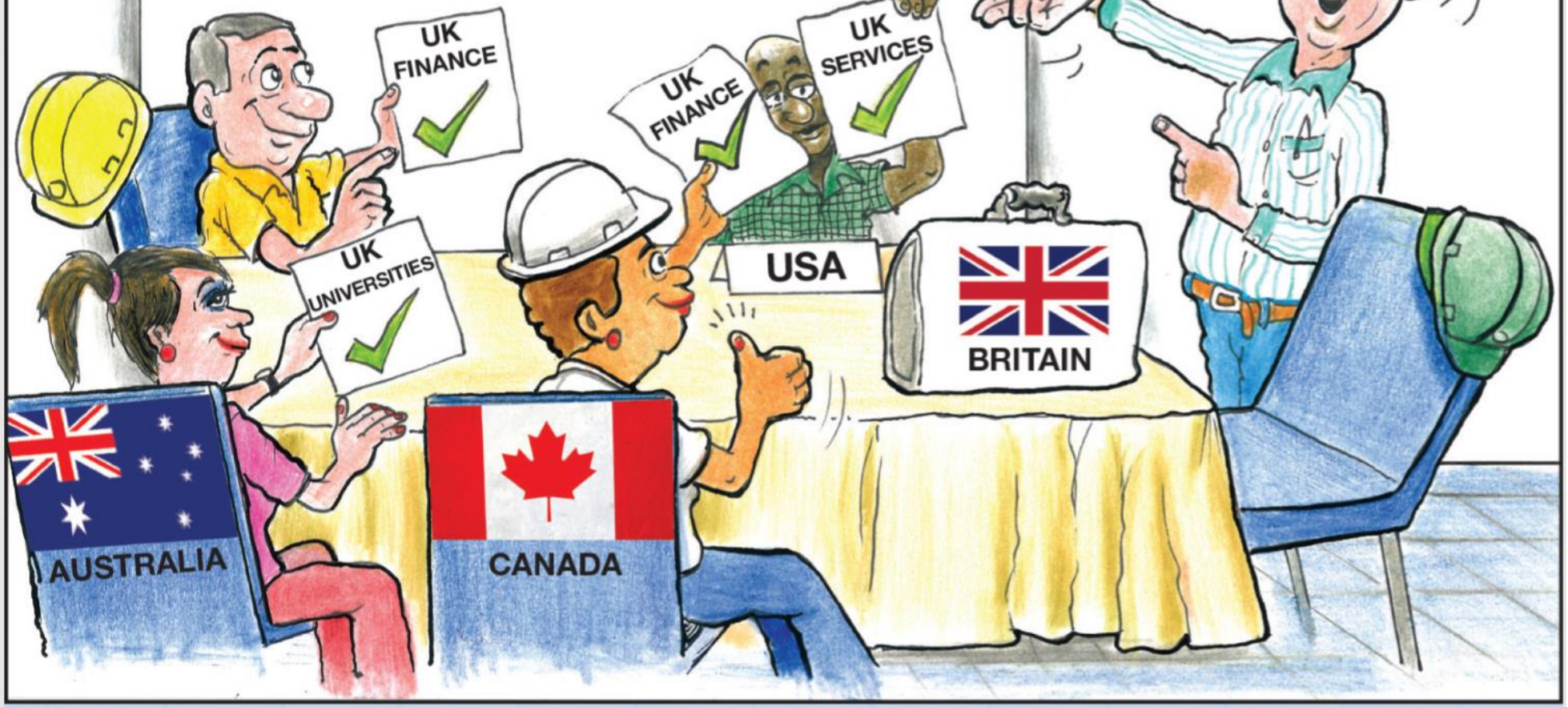


STORY 1 – 1

BRITAIN'S MINING STRENGTH

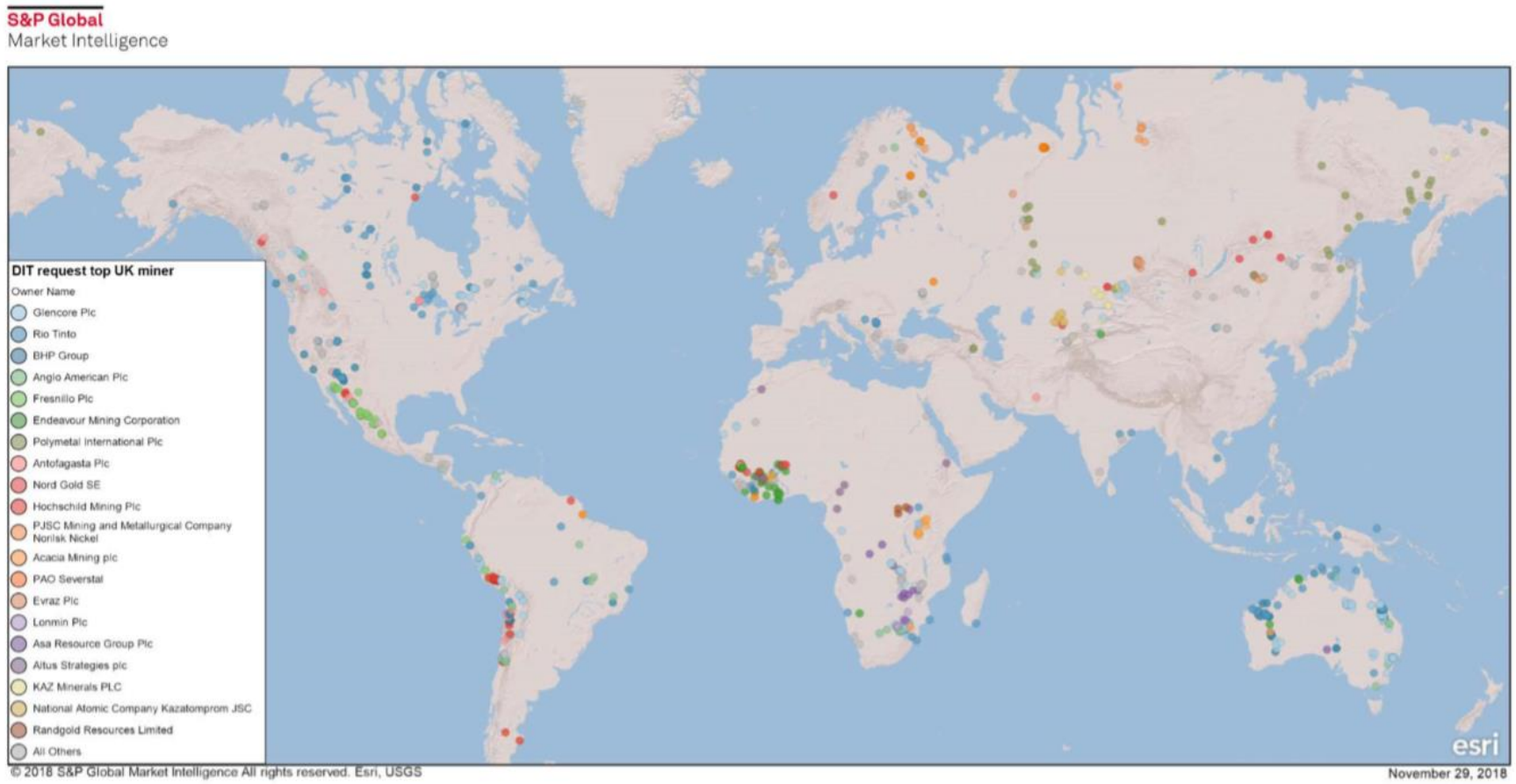
50% OF WORLD'S IRON ORE

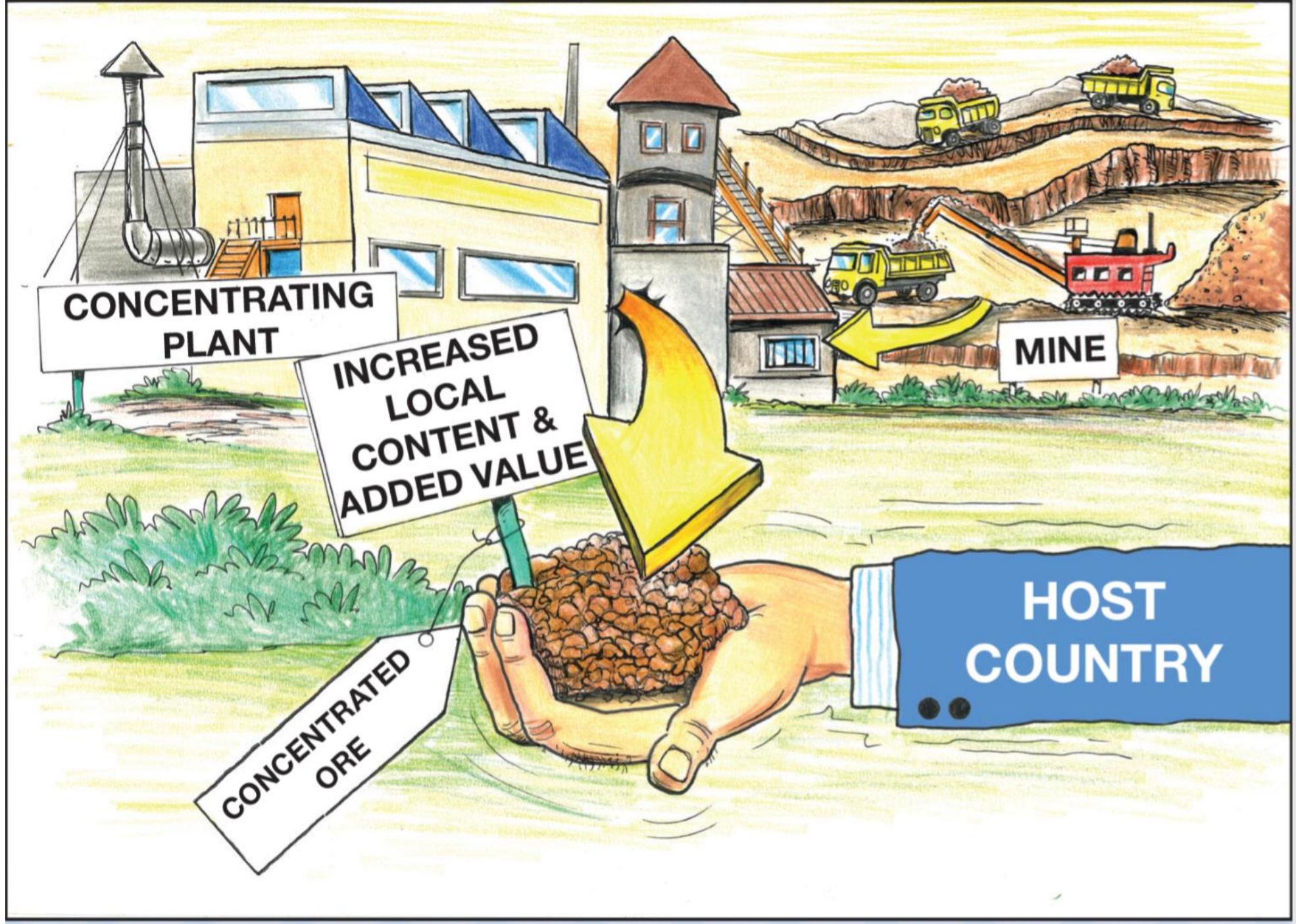
1/3 OF WORLD'S COPPER



STORY 2 – 2

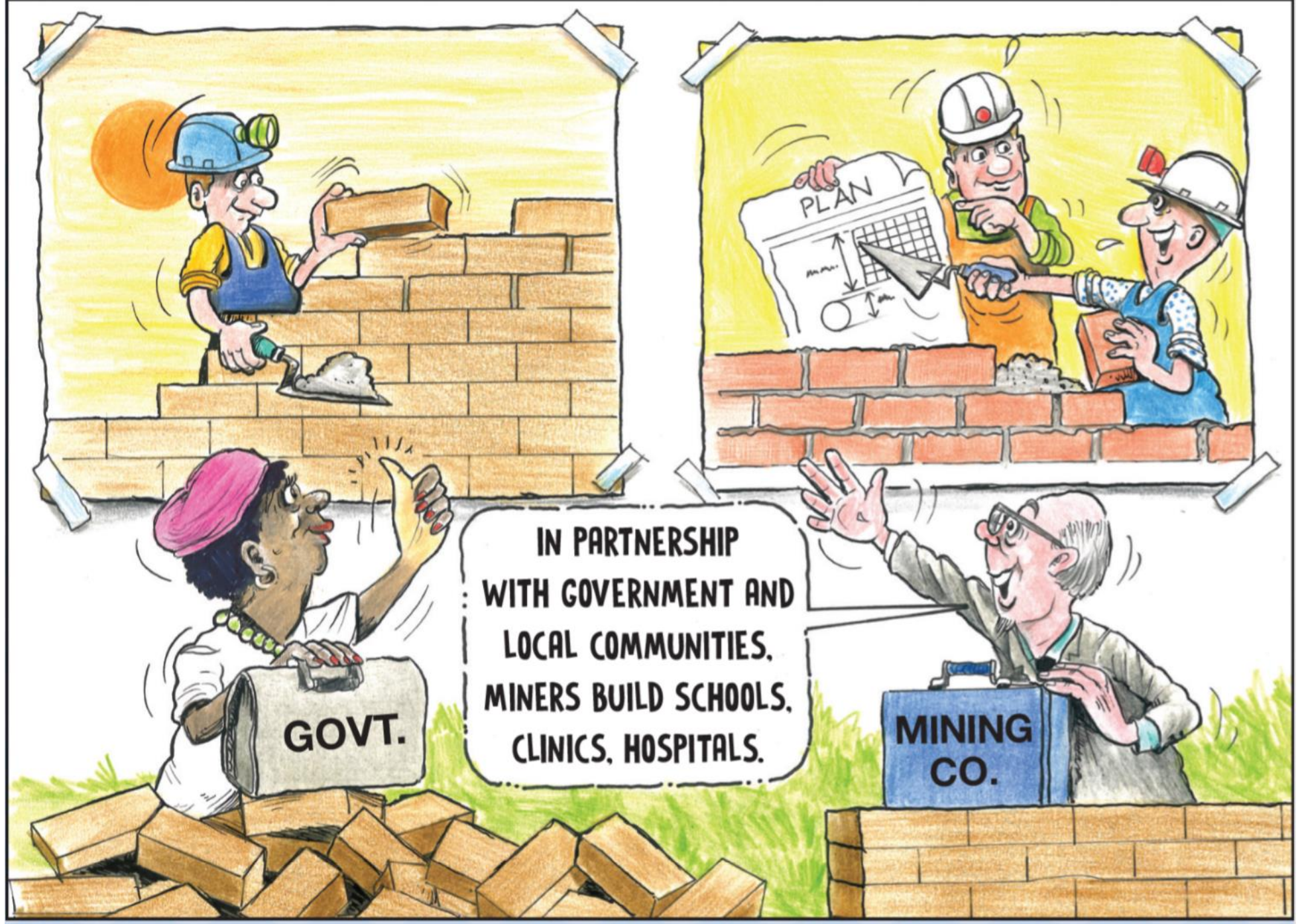
UK Mining's Global Reach



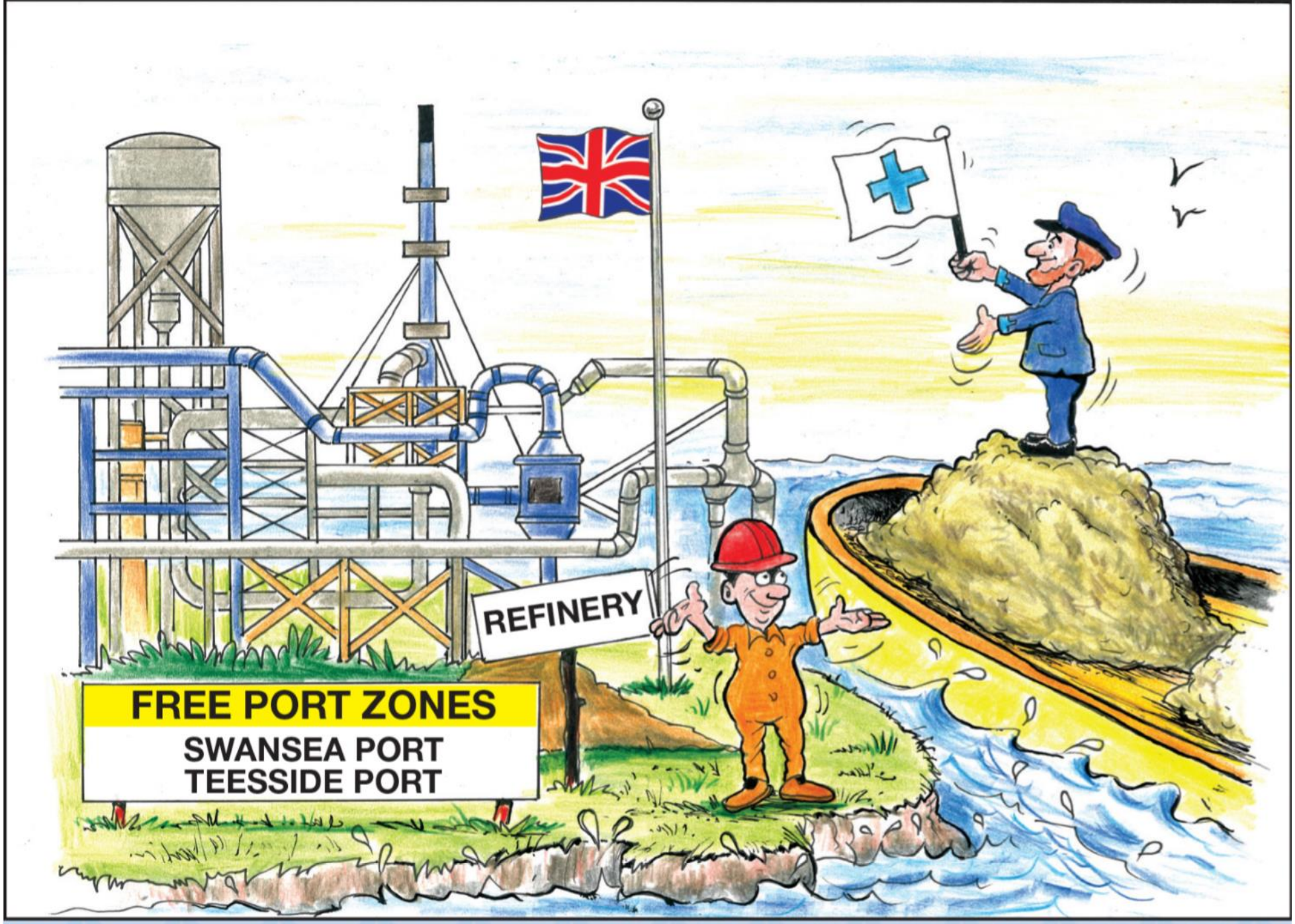


STORY 4 – 3

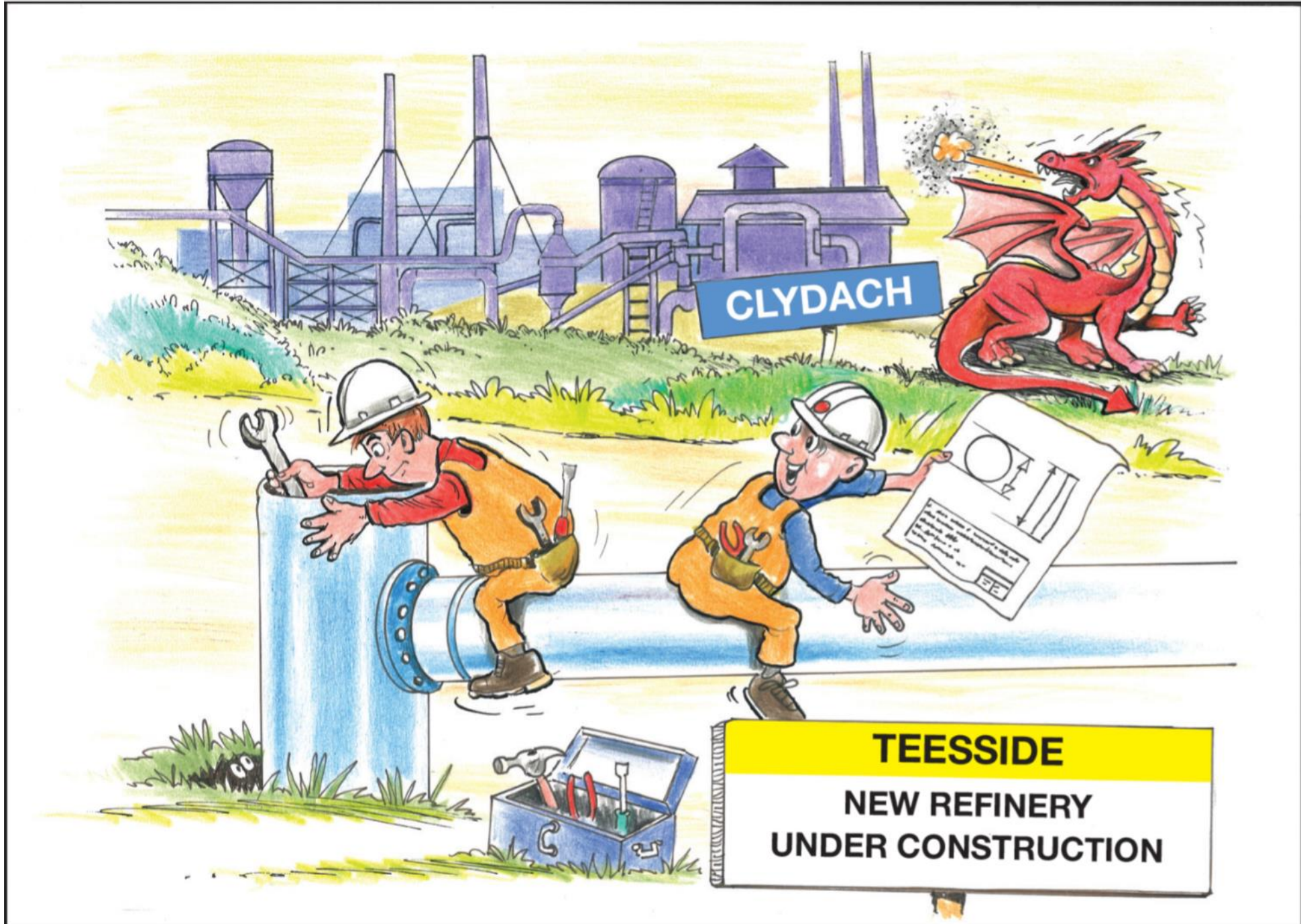
STORY 4 – 1



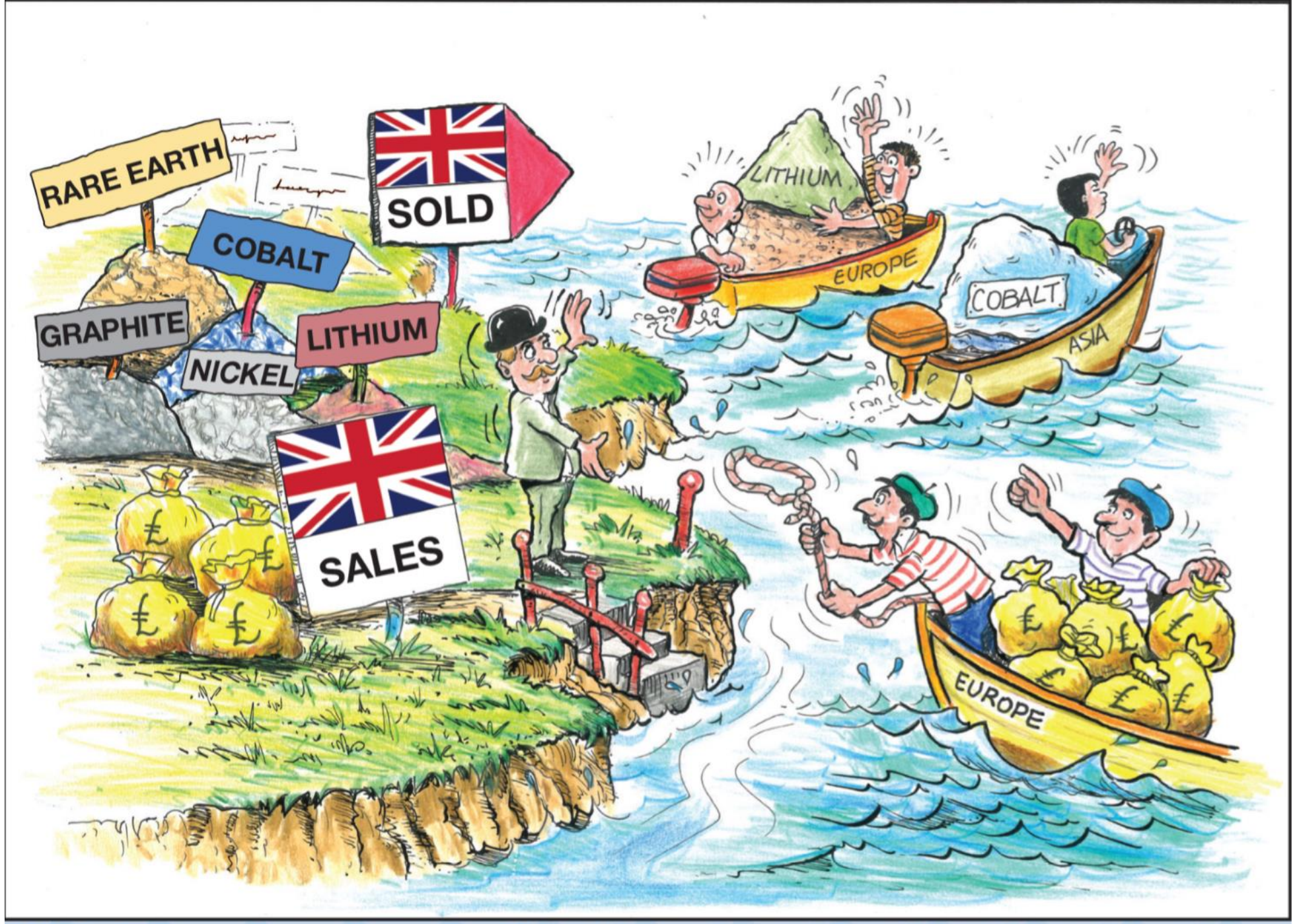
STORY 4 – 2



STORY 1 – 3



STORY 1 – 4



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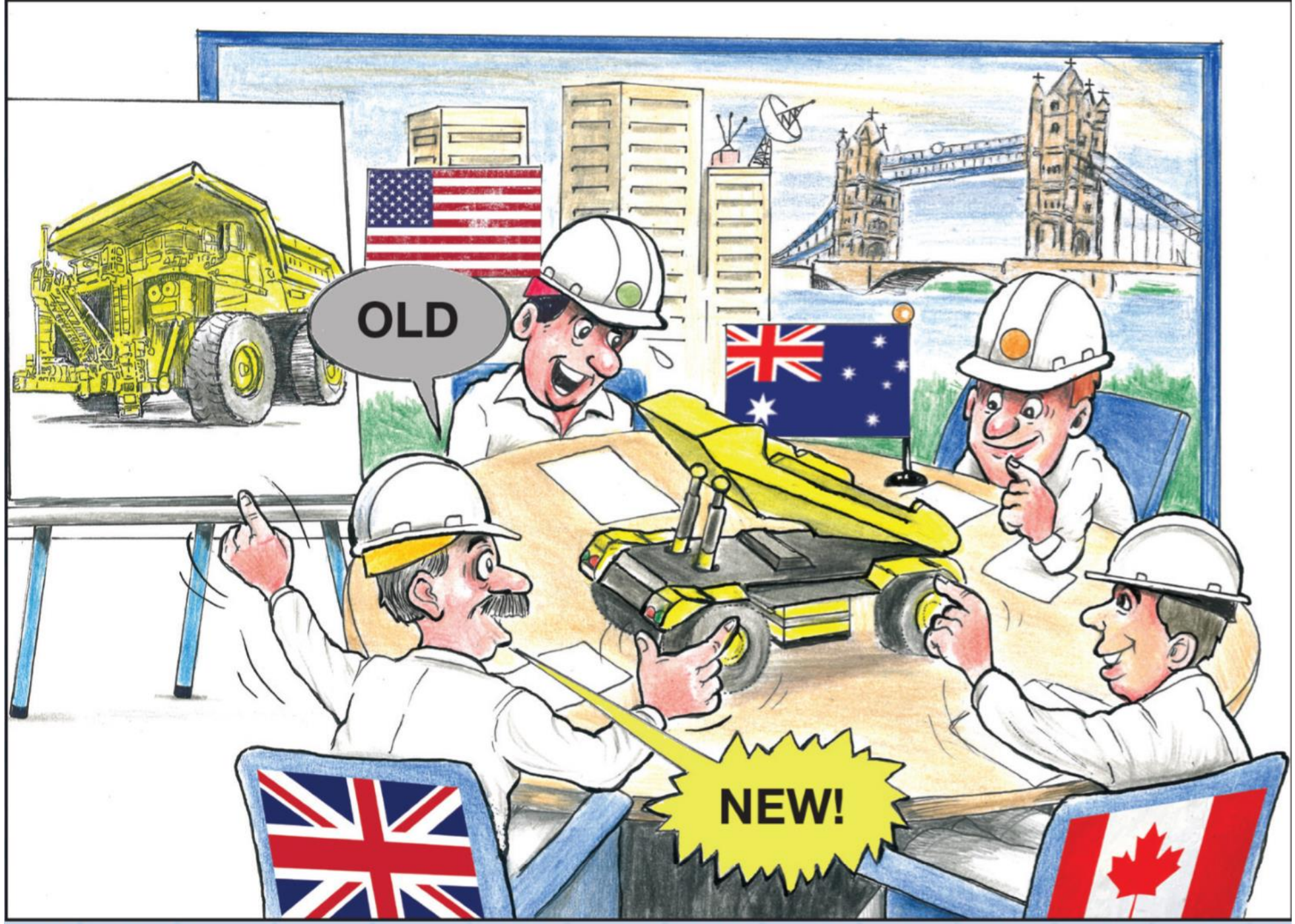

STORY 3 – 1

Benchmark Mineral Intelligence: Sustainable Supply Chains

Andrew Leyland, Head of Strategic Advisory

LowCVP
Low Carbon Vehicle Partnership

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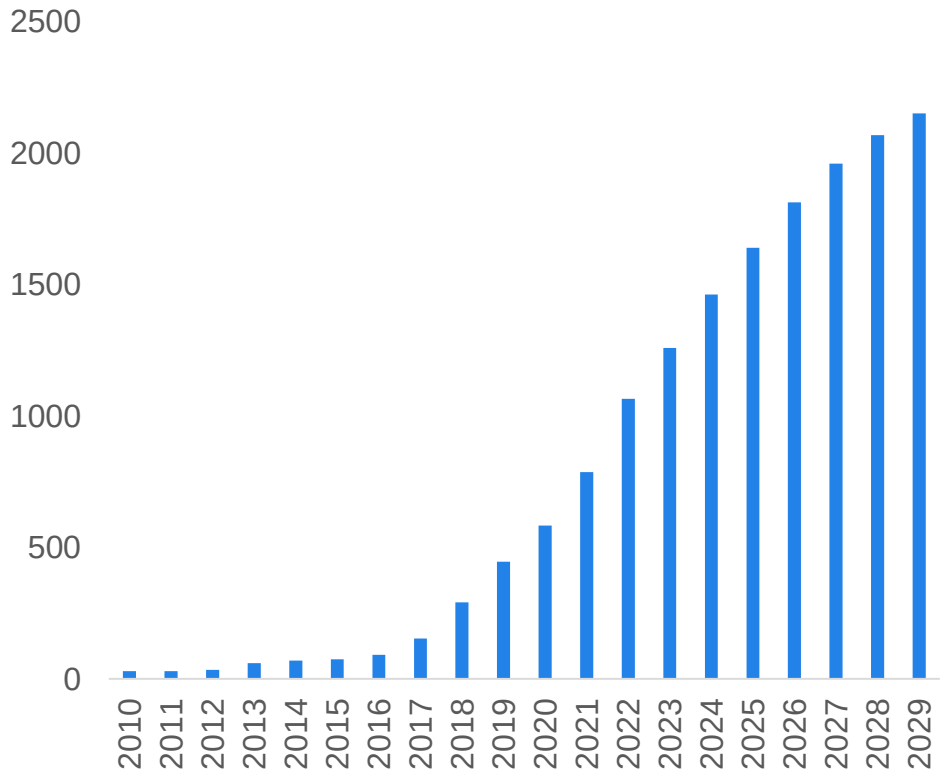
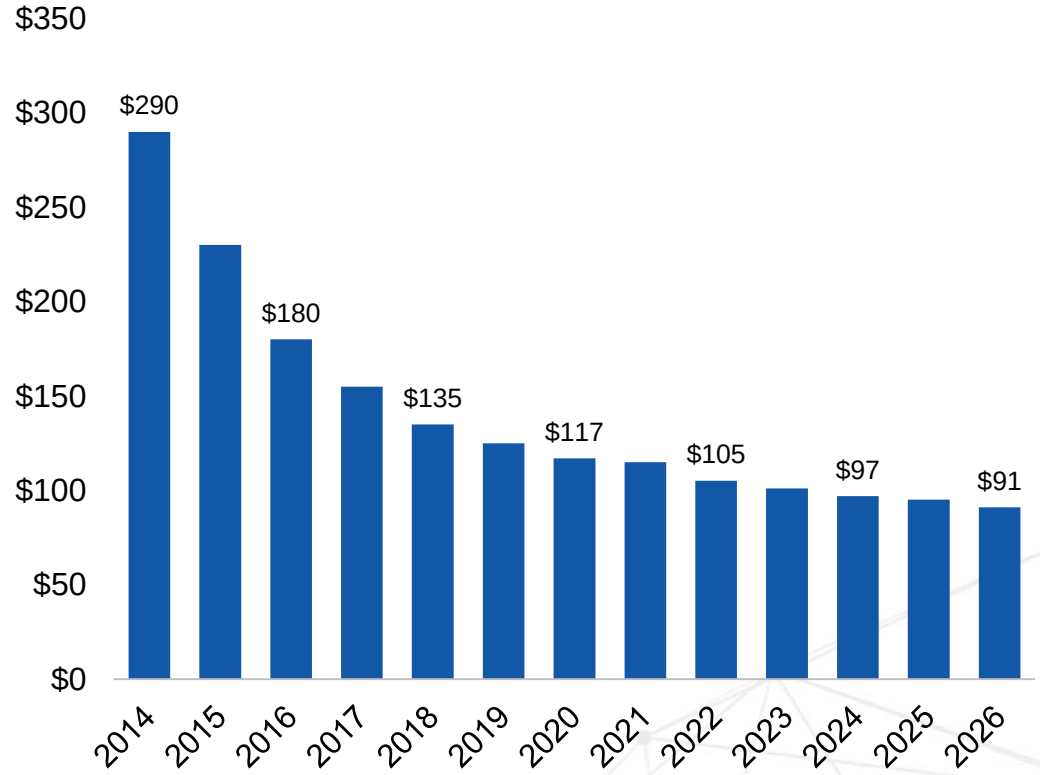
Green New Deal: Increasing scale and new technologies in the anode and cathode are seeing average EV cell costs fall to below $100/KWh in 2023-2024

Megafactory Capacity (GWh)



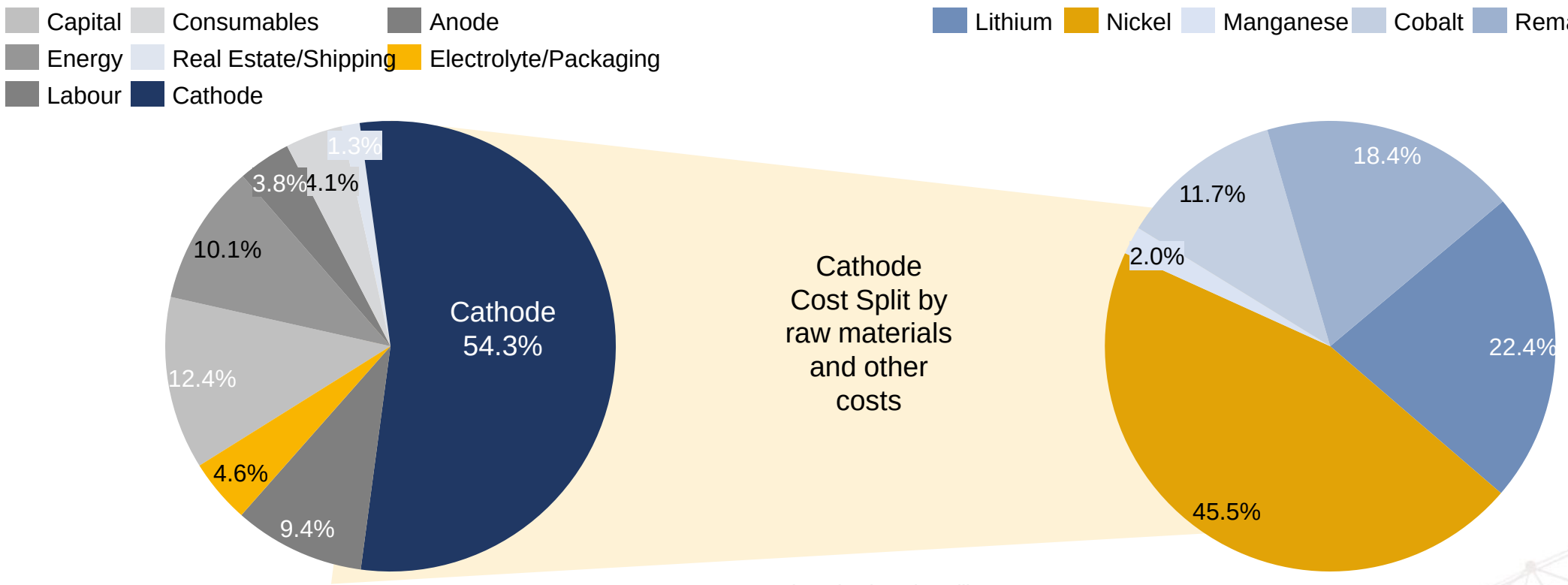
Lithium ion battery cell cost fall $/kWh*
(average NCM cell cost including cathode evolution)



*Assuming flat future raw material prices, excludes margin, module and pack costs, figure account for top 80% of producers by scale only.

Low Cost EV's = Low Cost Batteries = Controlling Your Supply Chain

811 battery cell cost estimate; RHS chart is the cathode split out by its components

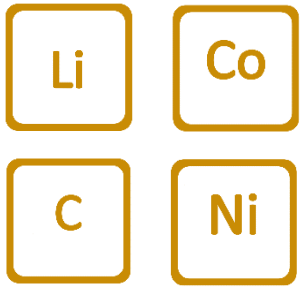
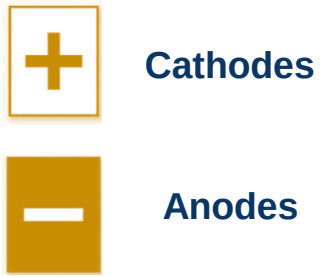


Source: Benchmark Mineral Intelligence

BENCHMARK MINERAL INTELLIGENCE

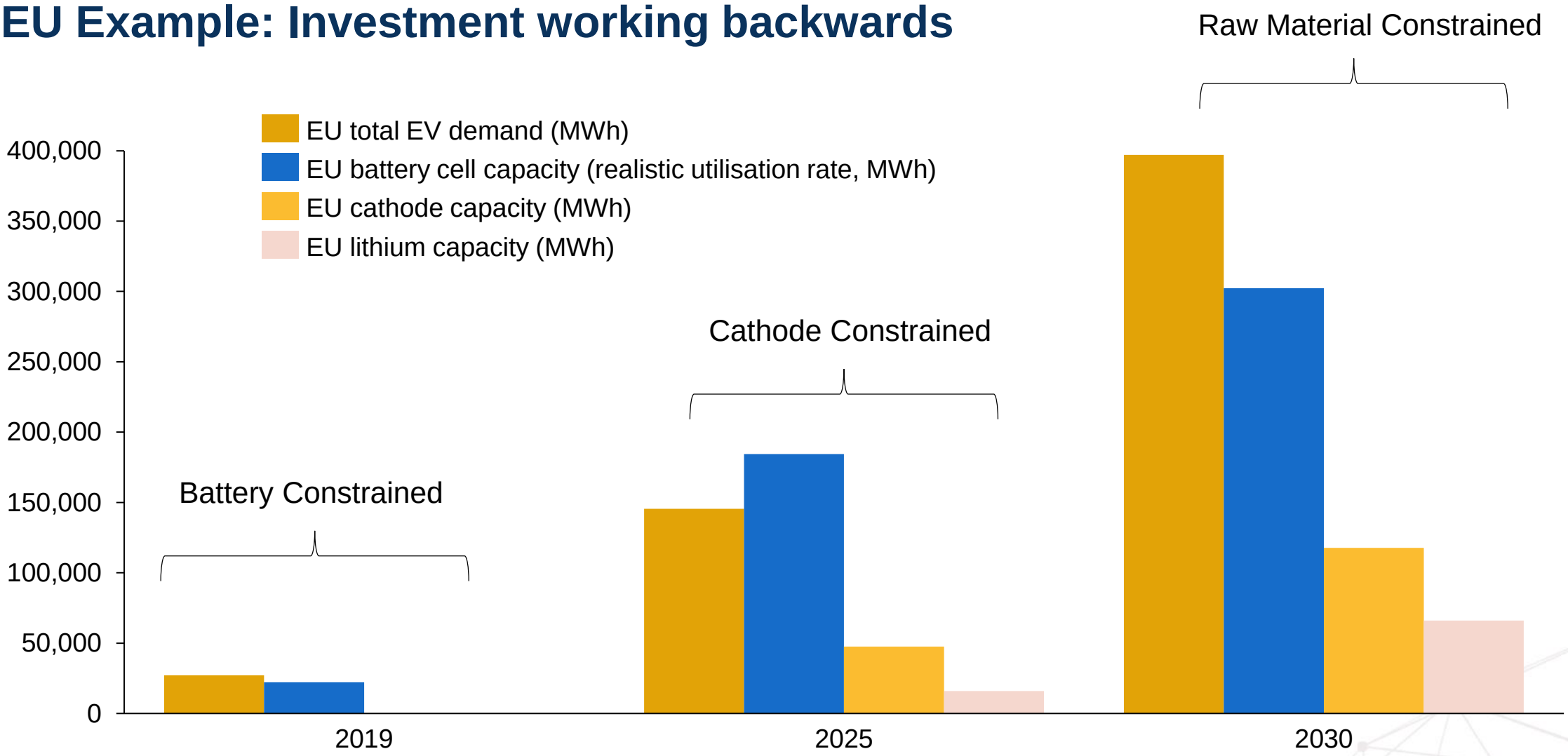
Green New Deal: Li-ion Supply Chains aren't just minerals and cells

Investment in clean tech can also include processing, components, R&D and new technologies

Extraction	Chemical Processing	Cathode/ Anode Production	Cell Manufacturing	Application
		 Cathodes Anodes		
$50-70bn required (split across lithium, cobalt, nickel, manganese)	$15bn required	$40bn required	$130bn planned	>$300bn committed
Lithium (spodumene/ brine producers): 26 producers (up from 16 in 2026*) 48 new projects in pipeline	**Nickel Sulphate:** 36 producers 13 expansion projects **Lithium Chemical Plants:** 69 producers (up from 25 in 2016*) Increasing to 114	**Cathodes:** 73 producers 11 new producers 49 expansion projects **Anodes:** 49 producers 54 expansion projects	**Cell MegaFactories:** 88 producers (up from 28 in 2016) 29 new plants 72 expansion projects	**Full BEV light vehicle producers:** 54 producers, up from 31 in 2015 and a quadrupling of production

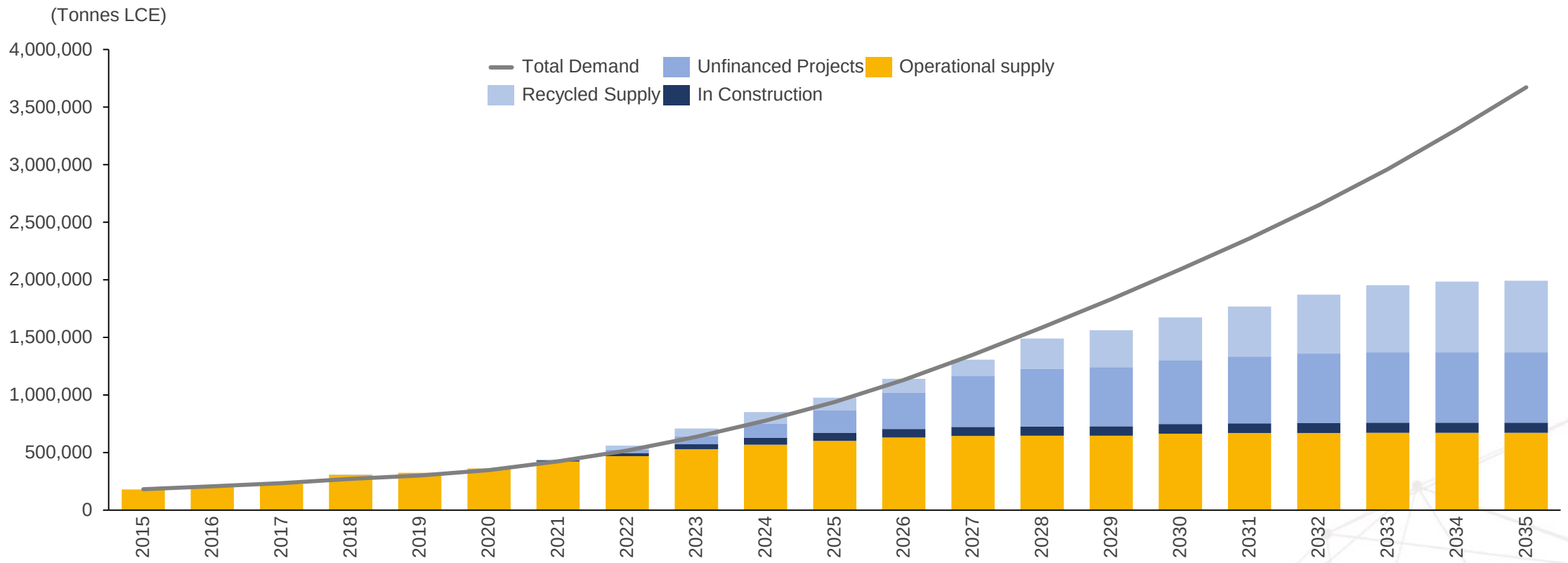
*excludes some small-scale Chinese producers
Source: Benchmark Mineral Intelligence and RHO Motion

EU Example: Investment working backwards



All major battery raw materials face impending shortages due to drastically increasing demand, and industry is looking for new material sources

Lithium Demand Vs Financed and Unfinanced Supply (MT LCE)



Source: Benchmark Mineral Intelligence, Bolivian estimate

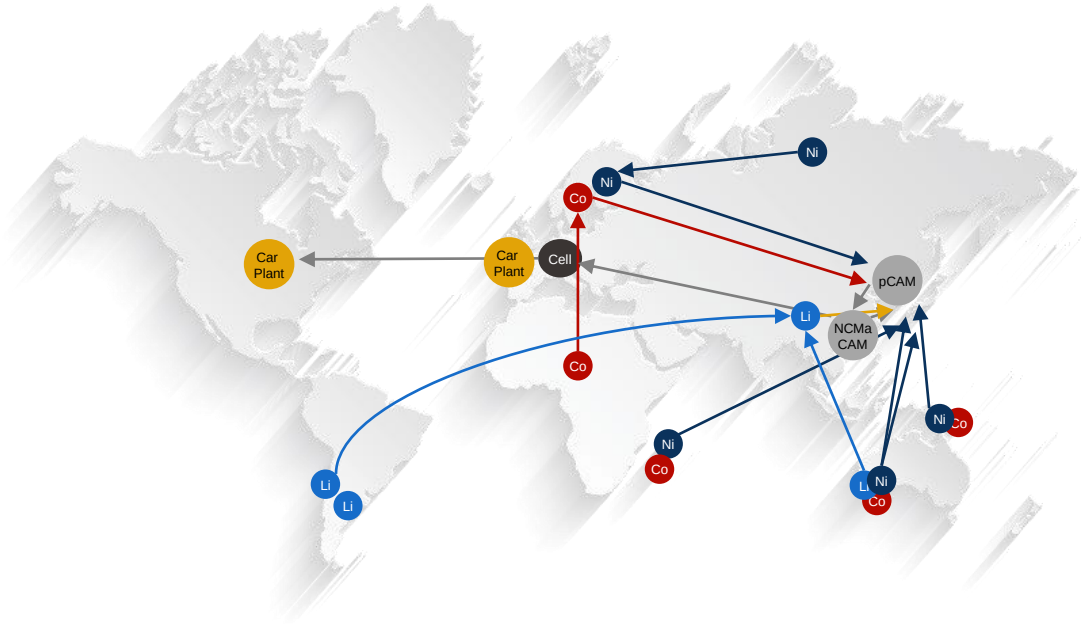
Supply Chain Nationalism Growing in EV and ESS space

Huge pressure to build out European and North American Supply Chain to reduce costs and create jobs. Many governments and commercial banks are directing funding to this sector while reducing hydrocarbon investments.

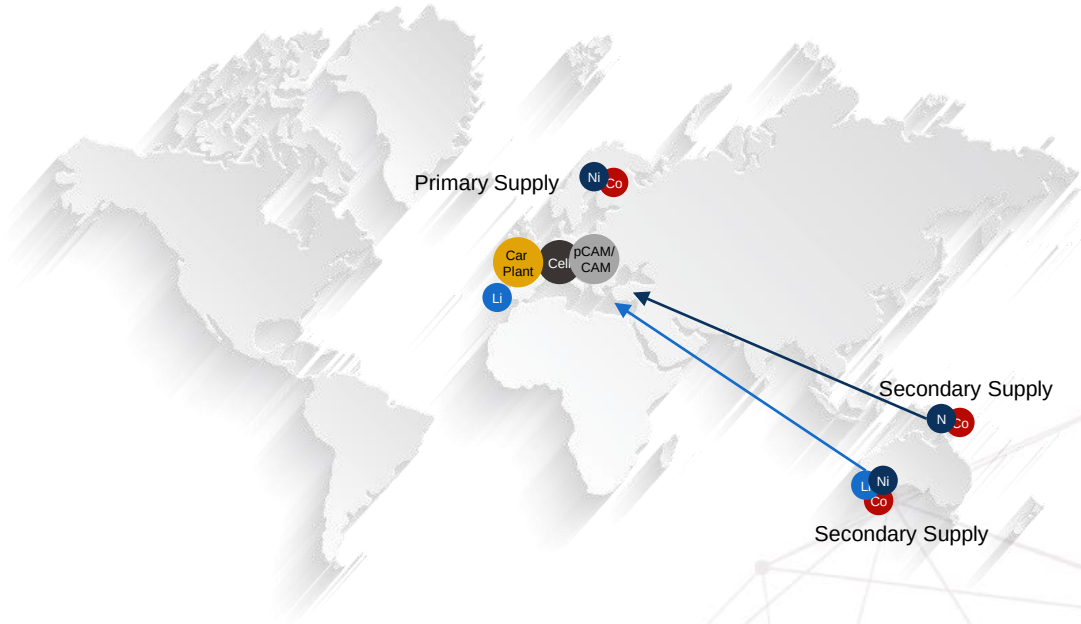
Current Supply Chains for Europe and North America focus on Global Mining and Asian Refining

Growing demand allows future sourcing to optimized, creating local jobs while reducing political risk

Current



Future



BENCHMARK MINERAL INTELLIGENCE

Source: Benchmark Mineral Intelligence

Sustainability is not just related to environmental impact. EV and ESS supply chains need to provide low prices and consistent materials for mass adoption

Considering the necessity of continuously reducing $/kWh costs for lithium-ion batteries, these risks for battery materials are ultimately borne by the automotive OEM and they must address them

Factors Impacting Adoption

Price

Illiquid markets, opaque pricing, oligopolistic behavior could all impact mass EV adoption

Capacity

Mining and chemicals industries notorious for CAPEX overruns and delays, long timeline to production, specialized skillsets needed to commission new projects

Supply & Localisation

Guaranteeing quality, consistency, and reliability of material at exponentially increasing volumes

CAN THE UK BUILD A SUSTAINABLE SUPPLY CHAIN FOR ELECTRIFIED VEHICLES?

Jon Regnart

LowCVP
Low Carbon Vehicle Partnership

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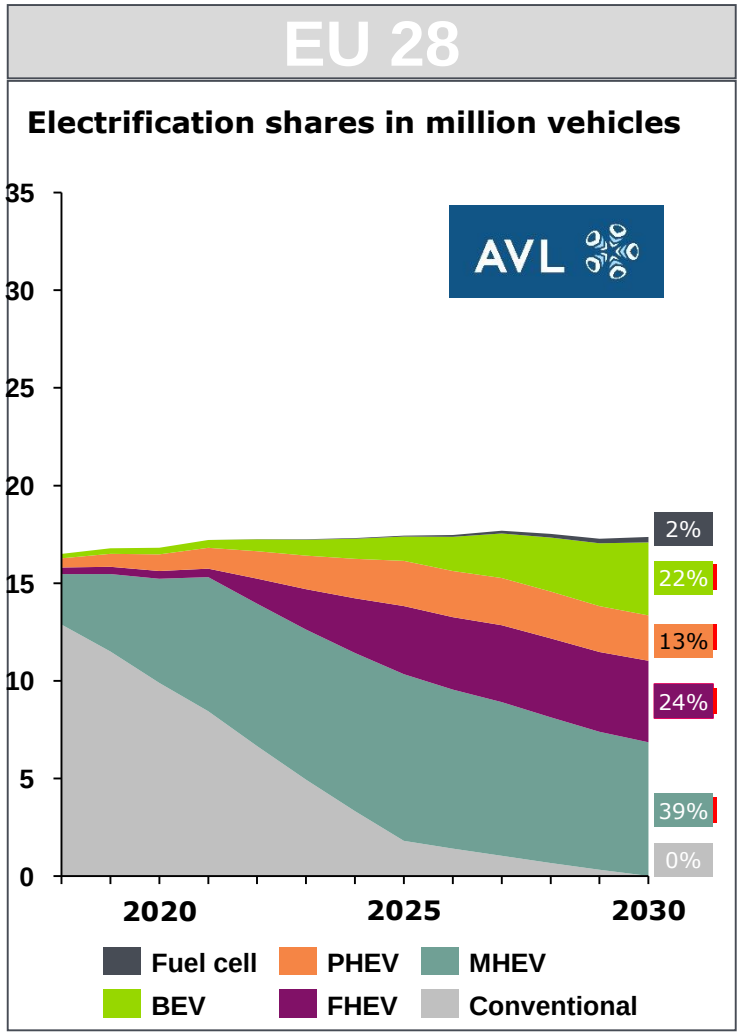
THE NUMBER OF ELECTRIFIED VEHICLES IS EXPECTED TO INCREASE RAPIDLY WHICH WILL PRECIPITATE A RAMP UP IN THE SUPPLY CHAIN



105GWh of battery cells

17 million electric motors & inverters

3.5 million on-board chargers

Jaguar Land Rover to invest £1bn to build electric cars in Britain

VW invests €900 million for 20% stake in Northvolt

13 June 2019

BMW Group investing €400M in Plant Dingolfing for production of BMW iNEXT EV

03 December 2019

Tesla factory outside Berlin to cost €4 billion

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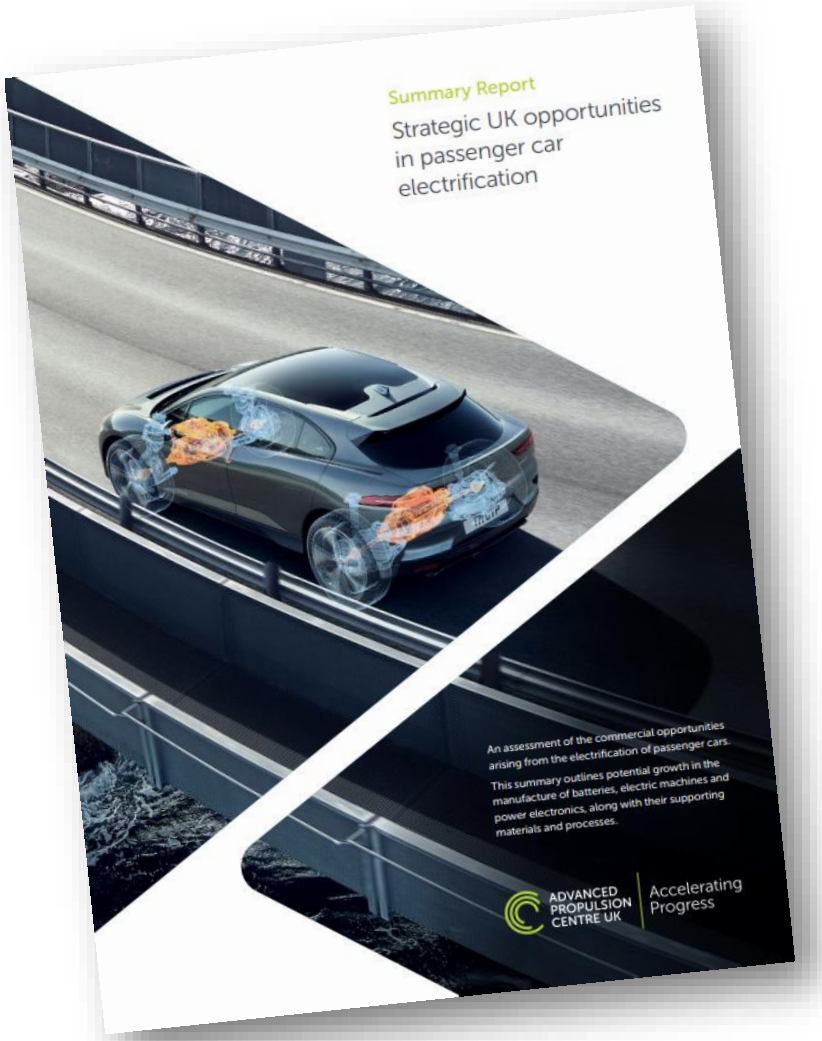
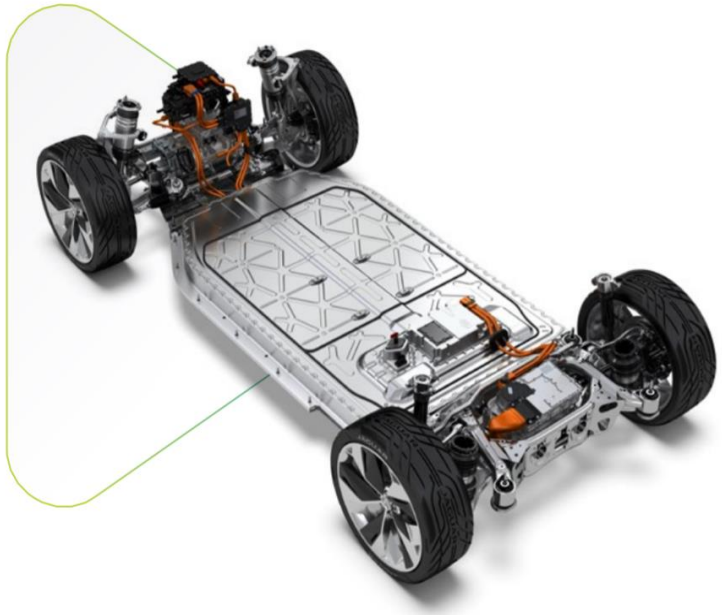
THE PASSENGER CAR ELECTRIFICATION REPORT IDENTIFIED 12 OPPORTUNITIES FOR THE UK SUPPLY CHAIN REPRESENTING A POTENTIAL VALUE OF £24 BILLION





Area of focus	UK opportunity for the electrification of passenger cars
Report timeframe	5 years
Value of opportunity	£24bn

£24 billion represents the serviceable available market across 12 opportunities considering geographic access for UK-based manufacturers.

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12 SPECIFIC OPPORTUNITIES WERE HIGHLIGHTED ACROSS THE BATTERY, ELECTRICAL MACHINES AND POWER ELECTRONICS SUPPLY CHAINS

Batteries - £12bn
Cathode materials refining
Cathode active materials manufacturing
Anode materials (synthetic and natural graphite)
Electrolyte mixing
Cell manufacturing and assembly
Battery pack components (BMS, busbars, cooling plates)

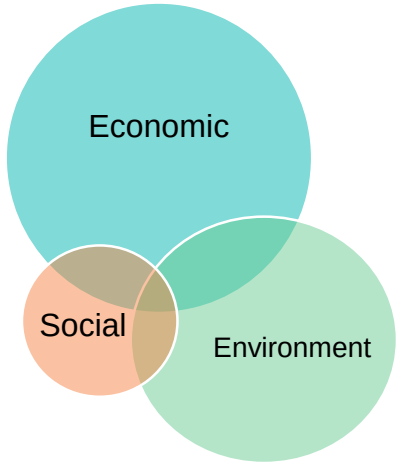
Electrical Machines - £2bn
Magnet manufacturing
Electrical steel
Electrical machine assembly (inc. stator winding)

Power Electronics - £10bn
Wide band gap semiconductors
Sensors
High performance passive components

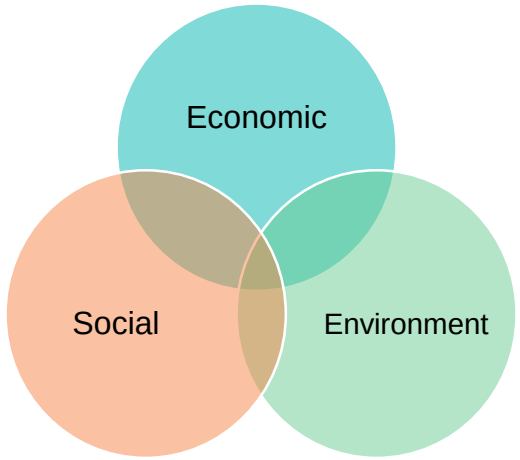
SUSTAINABLE DEVELOPMENT REQUIRES TAKING A MORE HOLISTIC VIEW OF TECHNOLOGY DEVELOPMENT AND UNDERSTANDING THE TRADE-OFFS

John Elkington described **sustainable development** (and by extension life cycle analysis) as a **three-legged stool**. If you remove one of the legs the concept falls over!

Current State



Ideal State



What this means for LCA?

Resource Extraction
(Ni, Co, Cu, Nd, Dy, Ga)

Refined Material
(Sulphates, oxides, WBG ingots)

High Value Component
(Cathode, magnet, chip)

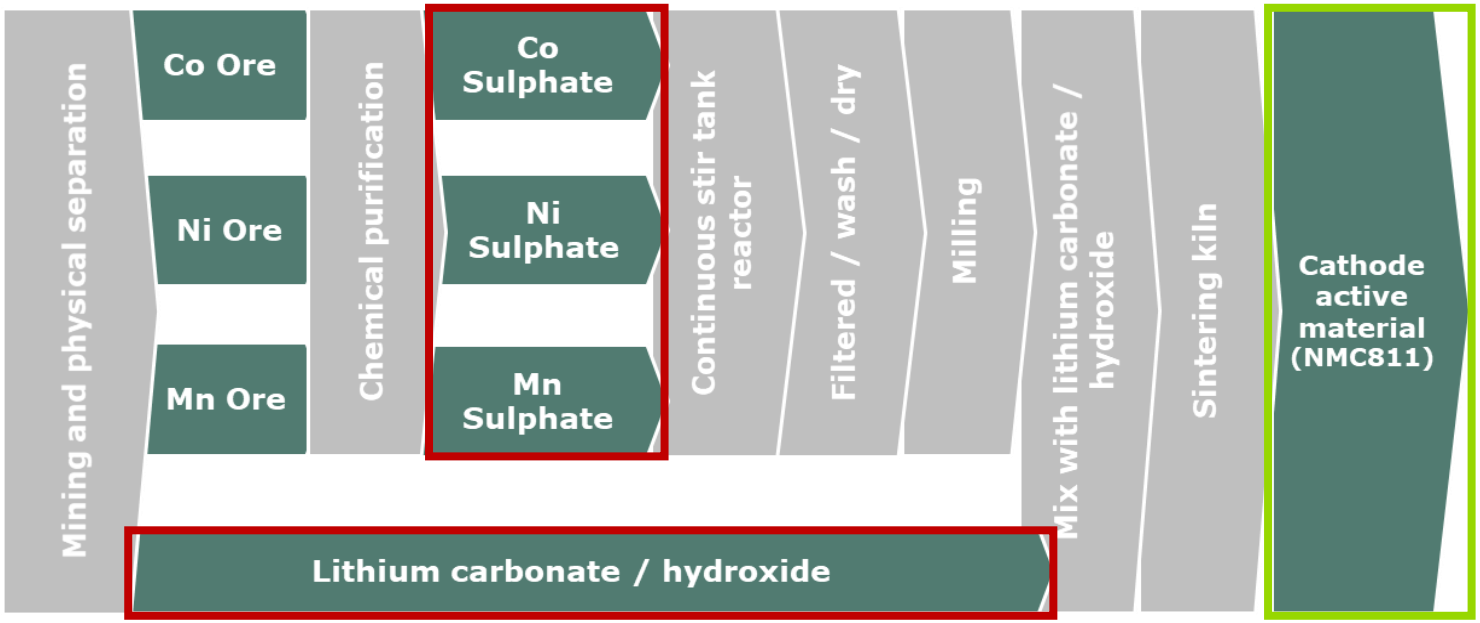
Sub-System
(Battery, Motor, Inverters)

Vehicle
(Passenger car, bus, truck)

Disposal
(Recycling / Reuse)

EXAMPLE OPPORTUNITY - CATHODE ACTIVE MATERIALS MANUFACTURING

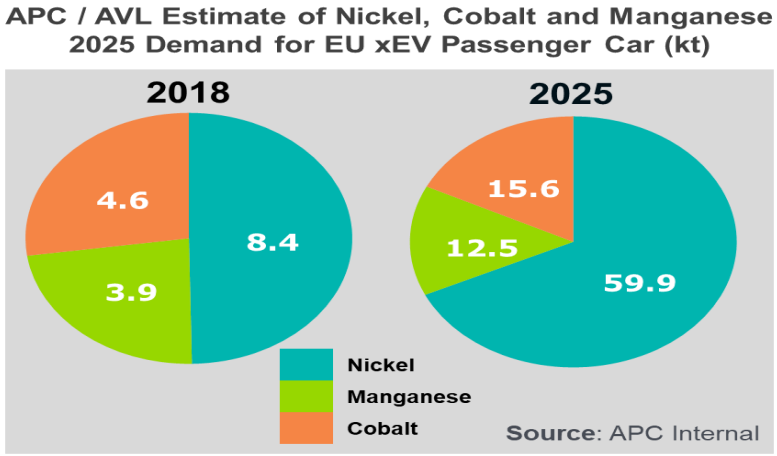
Cathodes represent ~£4bn of the £12bn battery opportunity



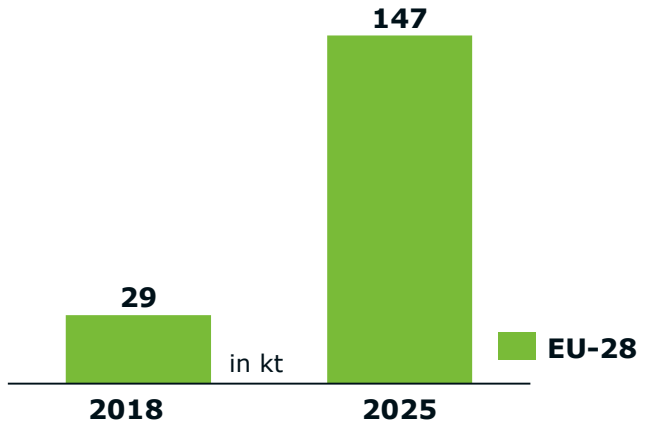
Semi-finished product

Manufacturing processes

Cathode materials refining



Cathode active materials manufacturing



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COULD THE UK ATTRACT A CATHODE MANUFACTURER?

UK STRENGTHS

Cathode manufacturers tend to set up near their supply chain. The UK has good capability in nickel refining and lithium hydroxide / carbonate

Strong domestic vehicle manufacturing and battery pack assembly which creates a market pull for cell assembly

Good R&D landscape and access to skills through excellent universities and scale up facilities like UKBIC

CHALLENGES FOR THE UK

Europe also has access to nickel refineries via Umicore and Nornickel which have already committed sums of money to satisfy EU demand.

A critical mass of giga factories is amassing in Europe around vehicle plants. This may make it more attractive for cathode manufacturers.

Cathode manufacturing is extremely energy intensive and requires low cost energy to be cost competitive.

CATHODE ACTIVE MATERIALS MANUFACTURING – WHAT ARE THE KEY SUSTAINABILITY CHALLENGES THAT LIFE CYCLE ANALYSIS WILL BRING INTO SHARPER FOCUS?

ENVIRONMENTAL SUSTAINABILITY

BASF further invests in Europe to strengthen global leadership position for battery materials for electric vehicles

- BASF announces Schwarzheide, Germany, as location for cathode active material production in Europe
- Battery materials plants in Germany and Finland will utilize an industry leading energy mix lowering CO_2 emissions across the value chain

Christiaan Hetzner
@christiaanhtznr

.@UmicoreGroup CEO Marc Grynberg tells @CARSymposium his new Polish production plant for cathode active material will run solely on renewable energy, leading to a 10% reduction of the total #CarbonFootprint of an electric vehicle. #Sustainability #ResponsibleSourcing #SupplyChain

2:52 PM · Feb 12, 2020 · Twitter Web App

Making lithium-ion batteries more environmentally friendly

New process uses water-soluble binders to avoid the need for organic solvents in manufacturing and recycling

by ***Mitch Jacoby***

APRIL 30, 2020 | APPEARED IN **VOLUME 98, ISSUE 17**

SOCIAL SUSTAINABILITY

RSBN
RESPONSIBLE SOURCING BLOCKCHAIN NETWORK

CO-FOUNDED AND ASSURED BY RCS GLOBAL GROUP

RCS | GLOBAL GROUP

Powered by IBM blockchain

SUSTAINABLE BUSINESS FEBRUARY 10, 2020 / 3:06 AM / 5 MONTHS AGO

Exclusive: Top lithium miner seeks to monitor water scarcity in parched Chile salt flat

"What we're seeing is a scrutiny of how lithium is being produced, and particularly, in the Salar de Atacama," Ellen Lenny-Pessagno, Albemarle's Chile manager, told Reuters in an interview in capital city Santiago. "They want data."

EXAMPLE OPPORTUNITY – SECURING A MAGNET SUPPLY CHAIN

25-40% of Electric Motor Cost

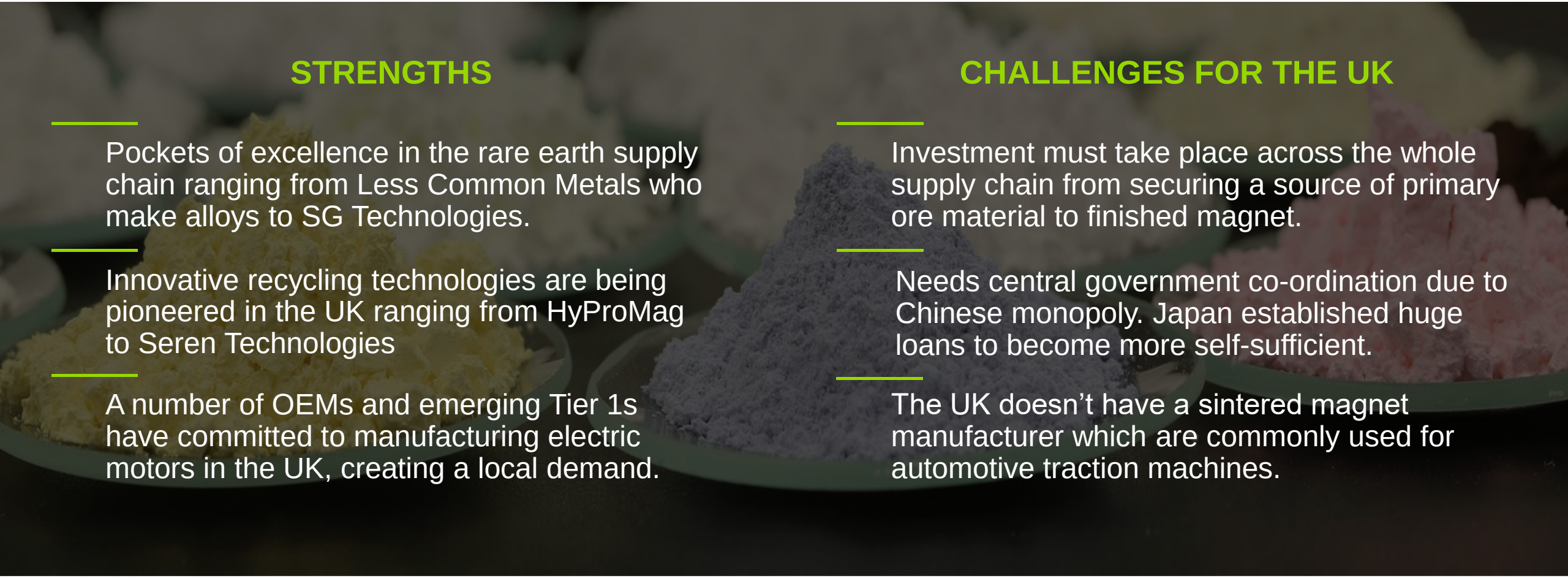
China dominate this supply chain

€0.8bn*

€3.4bn*

*Assuming all xEV passenger cars produced in the EU27 and UK in 2025 have NdFeB magnets

COULD THE UK BUILD A COMPETITIVE MAGNET SUPPLY CHAIN?



STRENGTHS

- Pockets of excellence in the rare earth supply chain ranging from Less Common Metals who make alloys to SG Technologies.
- Innovative recycling technologies are being pioneered in the UK ranging from HyProMag to Seren Technologies
- A number of OEMs and emerging Tier 1s have committed to manufacturing electric motors in the UK, creating a local demand.

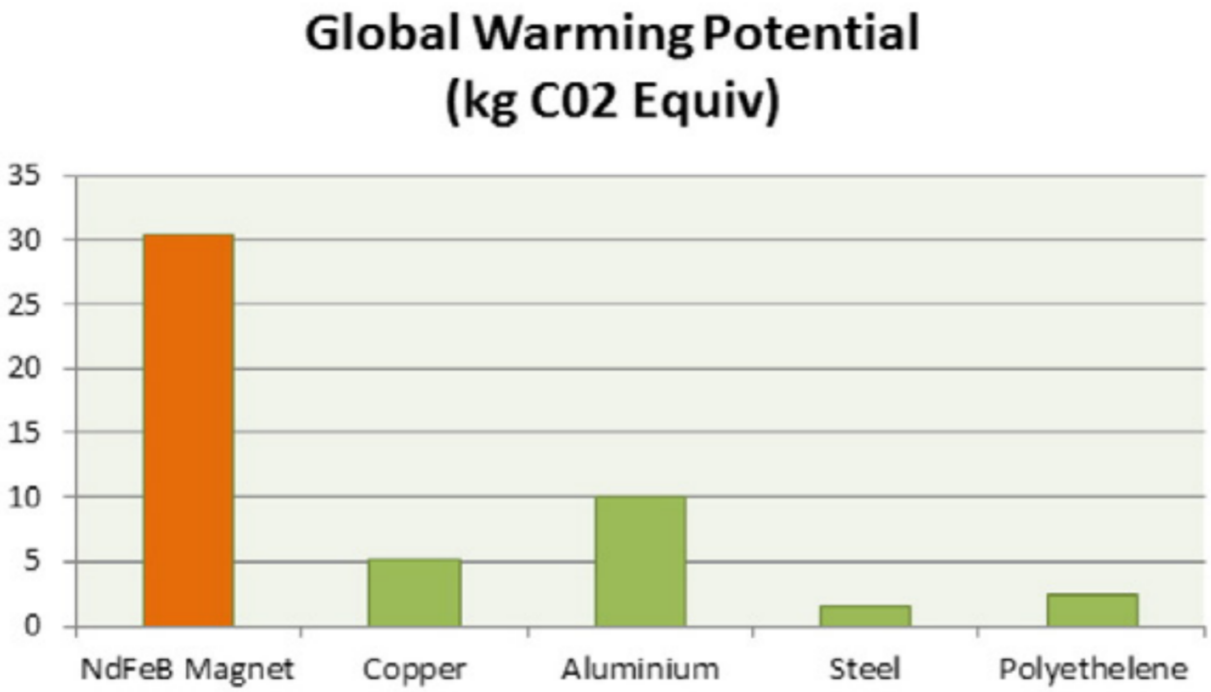
CHALLENGES FOR THE UK

- Investment must take place across the whole supply chain from securing a source of primary ore material to finished magnet.
- Needs central government co-ordination due to Chinese monopoly. Japan established huge loans to become more self-sufficient.
- The UK doesn’t have a sintered magnet manufacturer which are commonly used for automotive traction machines.

MAGNET MANUFACTURING– WHAT ARE THE KEY SUSTAINABILITY CHALLENGES THAT LIFE CYCLE ANALYSIS WILL BRING INTO SHARPER FOCUS?

ENVIRONMENTAL SUSTAINABILITY

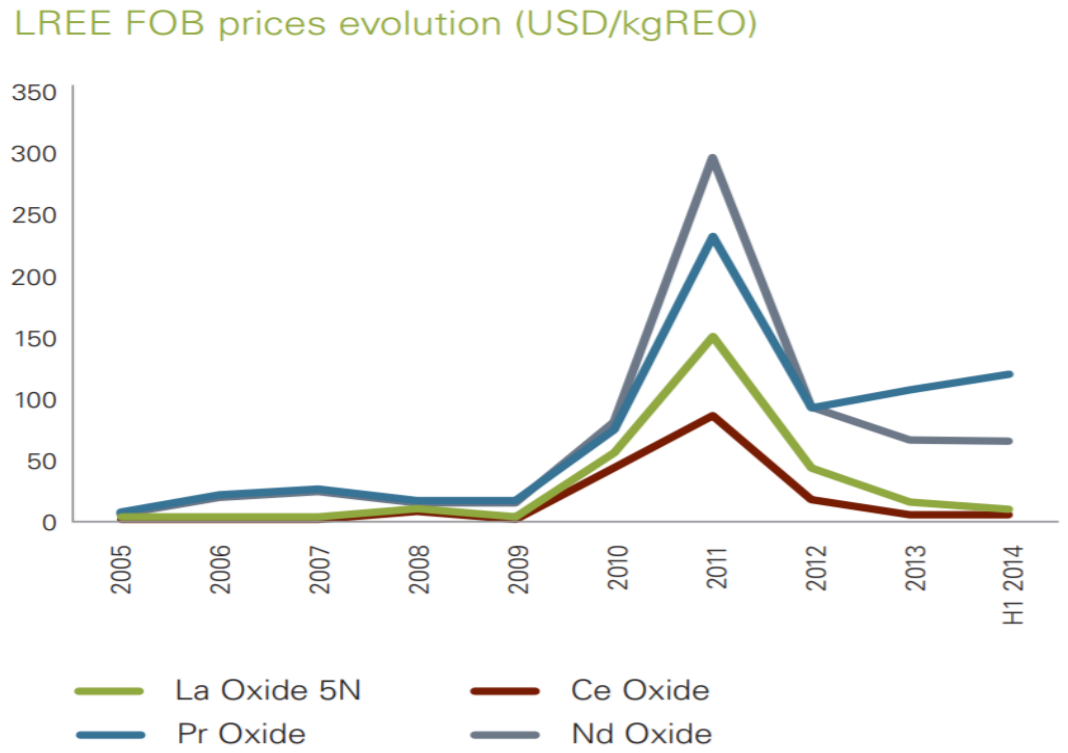
Producing magnets from **primary rare earth oxides** has a large global warming potential compared to other materials in an electrical machine.



Source: Widmer JD, Martin R, Kimiabeigi M. Electric vehicle traction motors without rare earth magnets. Sustainable Materials and Technologies 2015, 3, 7-13.

ECONOMIC SUSTAINABILITY

Not creating an alternative supply chain could leave the UK open to price spikes like in 2011.



Source: ERECON (2014) Strengthening the European rare earths supply chain: Challenges and policy options. Kooroshy, J., G. Tiess, A. Tukker, and A. Walton.

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THANK YOU FOR LISTENING!

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FOR MORE INFORMATION PLEASE CONTACT:

JON.REGNART@APCUK.CO.UK

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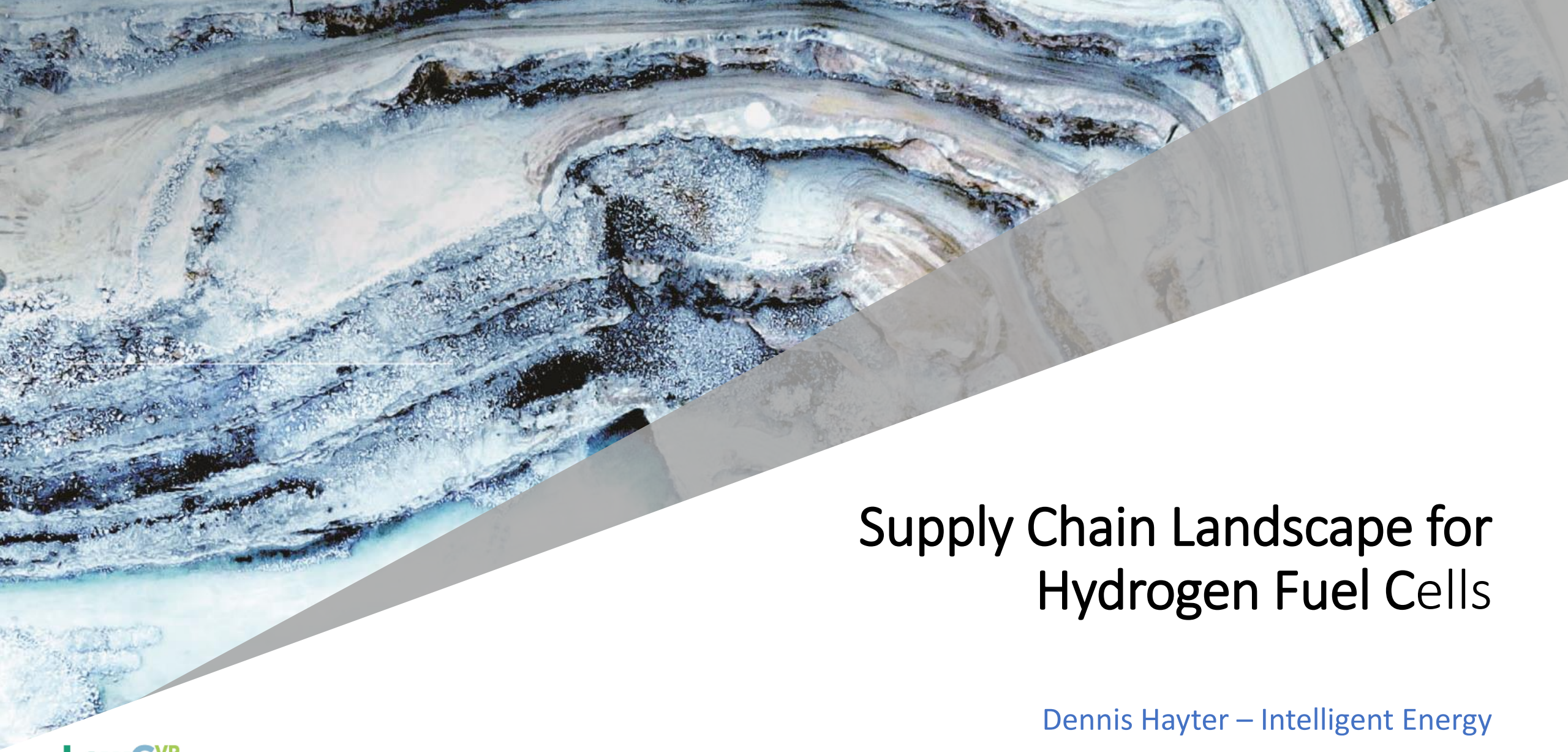

Supply Chain Landscape for Hydrogen Fuel Cells

Dennis Hayter – Intelligent Energy

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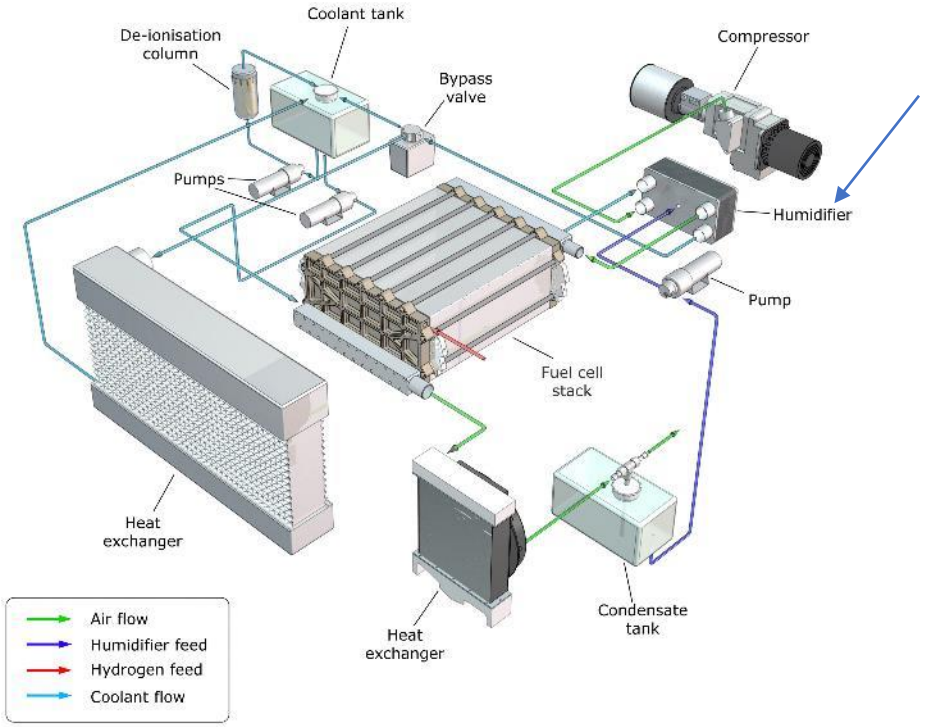
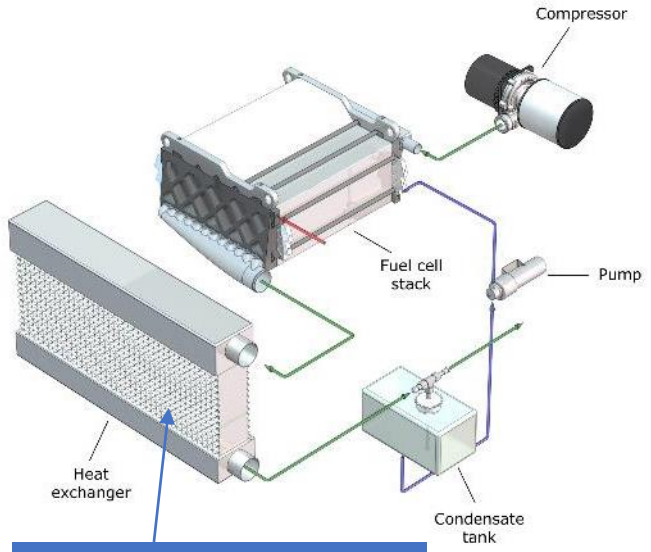
Intelligent Energy

Hydrogen fuel cell stacks – open & closed cathode

Liquid or evaporatively cooled stacks



Liquid Cooled)



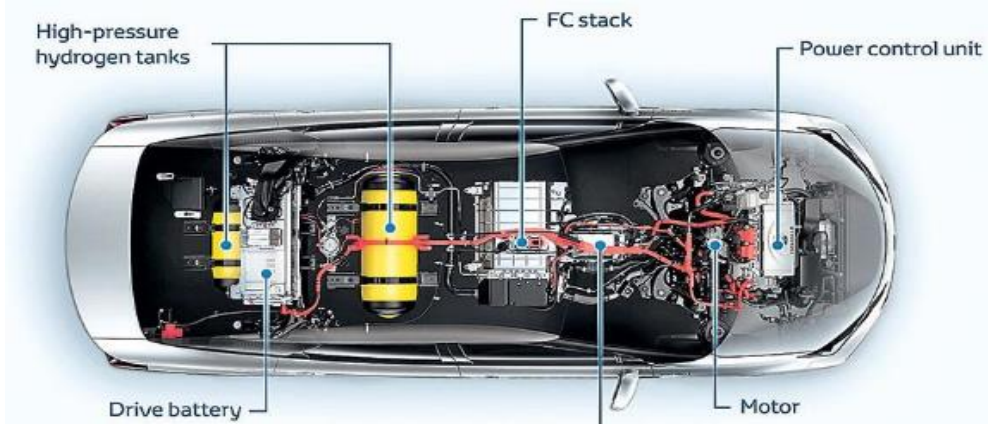
20% smaller heat exchange than LC

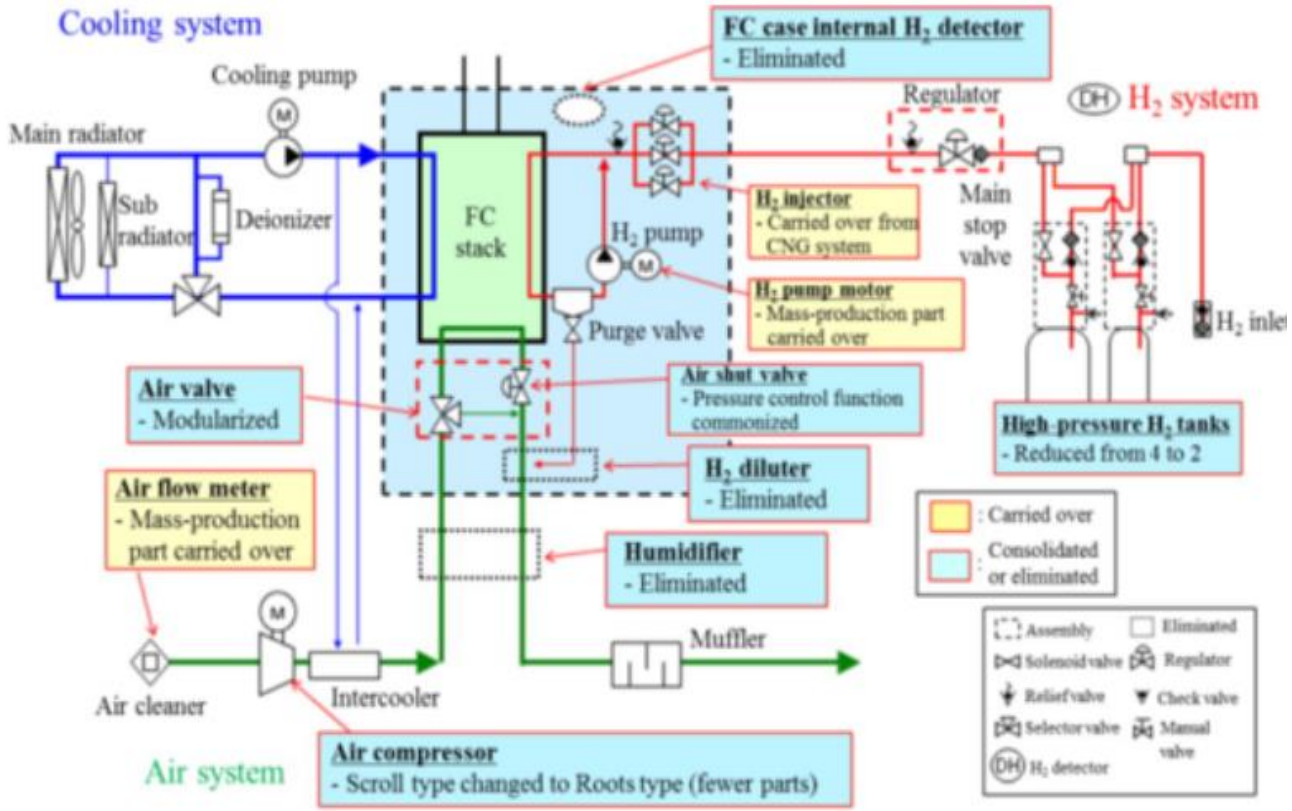
Evaporatively Cooled (IE)

Features	LC	EC
Stack cooling plate	✓	-
Humidifier	✓	-
Heat Exchanger	✓	✓
Coolant Pump	✓	✓
Air Compressor	✓	✓
Coolant Storage	✓	✓

Benefits	EC
High power density	✓
Lower component count	✓
High reliability	✓
Lower cost at volume	✓
Rapid sub-zero start-up	✓

Complete fuel cell systems – multiple modules





Toyota Mirai example

Fuel cell system – supply chain & availability

- Stacks:
  - MEA, catalyst, GDL, bipolar plate, coatings, gasket, seals
  - Around 50% UK source: 50% Europe
- System component (BoP)
  - Air module, H2 module, thermal, coolant, HV
  - By value it's predominantly UK sourced (70% - 80%)
  - Europe the secondary source point
  - RoW around 6-7%

Fuel cell stack– resource issues

- Stack
  - MEA – PGMs (Platinum group metals)
    - Recyclable – Pt does not lose chemical or physical properties in the recycling process and can be recycled ’an infinite number of times’
    - Similar quantity of Pt in exhaust catalyst; 95%+ Pt recovery rate via highly selective metal separation achieved in Molecular Recognition Technology systems
    - PGM loadings are falling
  - Plate
    - Metallic plate and end plates / tie bars are readily recoverable; carbon resin plate lower recyclability
    - Coatings – variable (gold ok – similar to PGMs – graphene inks less so)

Fuel cell systems – resource issues

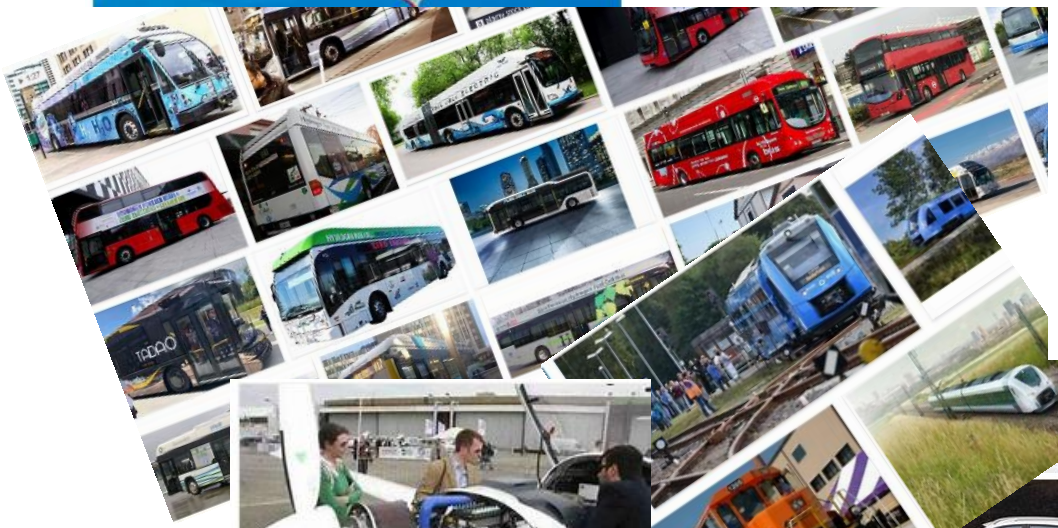
- Systems
  - Component dependent
    - Metals – HEX, casings, etc: typically recyclable
    - Electronics – copper cable recoverable; sub-components less so

- The recovery of materials and components from Hydrogen Fuel Cell systems is currently feasible and increasingly necessary; EoL technology depends both on innovation and regulatory frameworks

Growing range of HFC applications

Japan reveals tantalising zero-emissions ship details

Hydrogen-based fuels could be a step in the right direction for an industry responsible for 2.5% of global greenhouse gas emissions ...



Seoul aims to commercialise urban air taxis by 2025

The government is working with Hyundai to roll out urban air mobility services as it strives to tackle worsening traffic congestion ...

Trains, boats, trucks, planes - new announcements daily

All images for illustrative purpose only

Intelligent Energy

- Privately-owned
- Focused only on PEM fuel cell technology
- 15 years automotive experience
- Product range 650W to 120kW (2 types of cooling)
- Headquartered in the UK
- 200 employees
- International commercial presence

Commercial offices

Loughborough, UK
HQ, main facility

Japan, Tokyo
Commercial Office

Regional representation

USA, Korea and China

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