The UK's innovation agency

Innovate UK

The Faraday Battery Challenge: Accelerating the UK EV Battery Industry

Anna Wise

Lithium: From Exploration to End-User

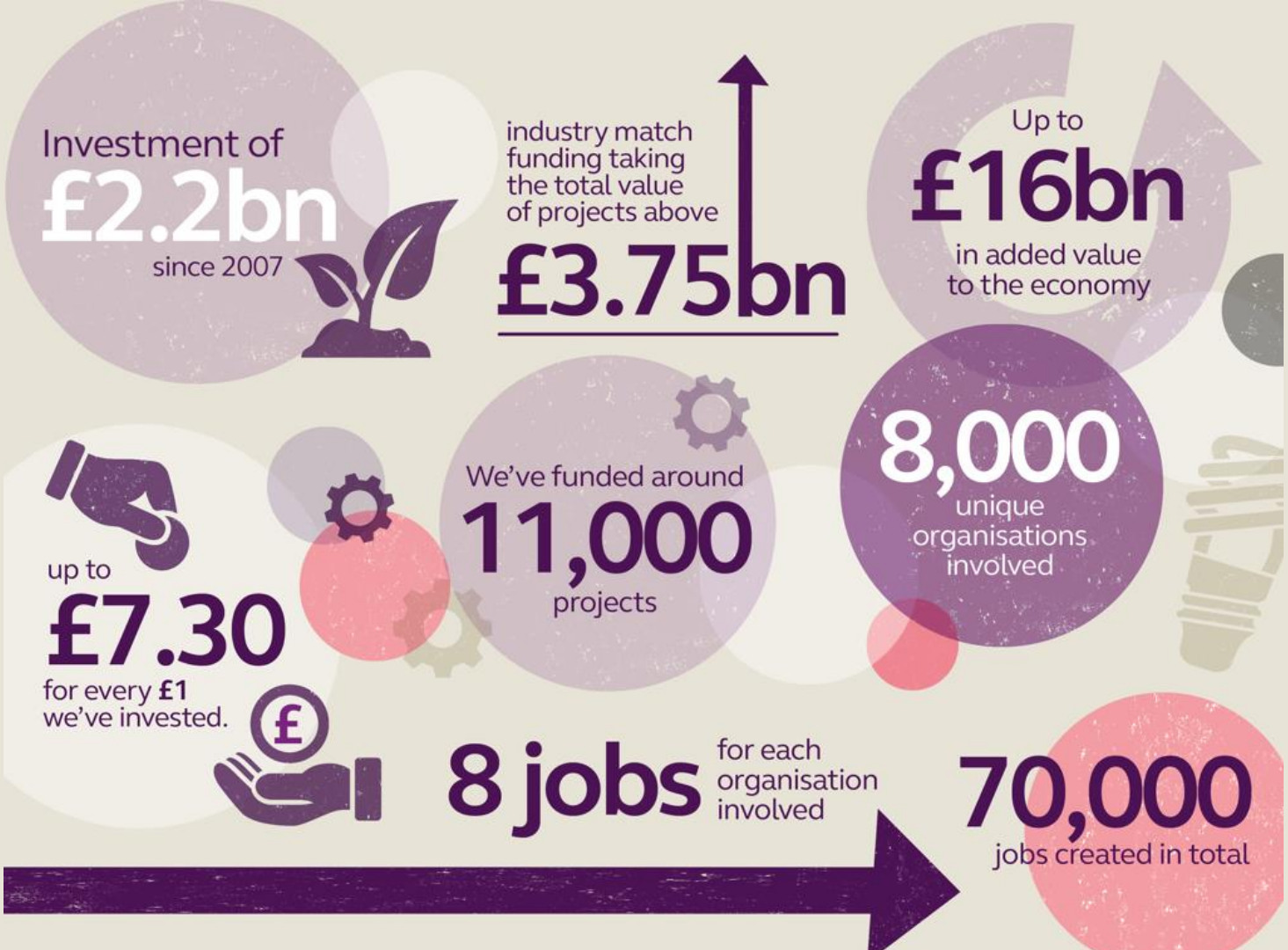
10th April 2018

Innovate UK

Innovate UK – the UK's innovation agency

We work with people, companies and partner organisations to find and drive the **science and technology innovations** that will grow the UK economy - delivering productivity, new jobs and exports.

Our aim at Innovate UK is to **keep the UK globally competitive** in the race for future prosperity.


Investment of
£2.2bn
since 2007
industry match funding taking the total value of projects above
£3.75bn
Up to
£16bn
in added value to the economy
We've funded around
11,000
projects
8,000
unique organisations involved
up to
£7.30
for every £1 we've invested.
8 jobs
for each organisation involved
70,000
jobs created in total

Industrial Strategy Grand Challenges

AI and Data Economy

Healthy ageing

Clean growth

Future of mobility

Creating an economy that boosts productivity and earning power throughout the UK

UK Research and Innovation

Delivered by Innovate UK

RESEARCH COUNCILS UK

Industrial Strategy Challenge Fund

- Builds on the UK's world-class research base and delivers the science that business needs to **transform existing industries** and **create new ones**
- **Accelerates commercial exploitation** of the most exciting technologies the UK has to offer the world to ensure that scientific investment truly **delivers economic impact, jobs and growth right across the country**
- Programmes delivered by the fund will be **industry-led** and powered by **multi-disciplinary research and business-academic collaboration**
- Delivered by **Innovate UK and Research Councils UK**, and eventually **UK Research and Innovation**, the single voice for the UK's research and innovation landscape

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First Wave of ISCF

Medicines manufacturing technologies

Robots for a safer world

Batteries for clean and flexible energy storage

Self-driving vehicles

Manufacturing and materials of the future

Satellites and space technology

UK Research and Innovation

The next wave of the Challenge Fund

INDUSTRIAL STRATEGY

Transforming construction

Data to early diagnosis & precision medicine

Transforming food production

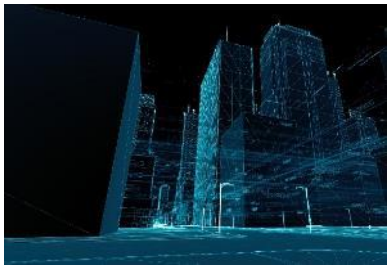
Next generation services

Energy revolution

Healthy ageing

Audience of the future

Quantum technology



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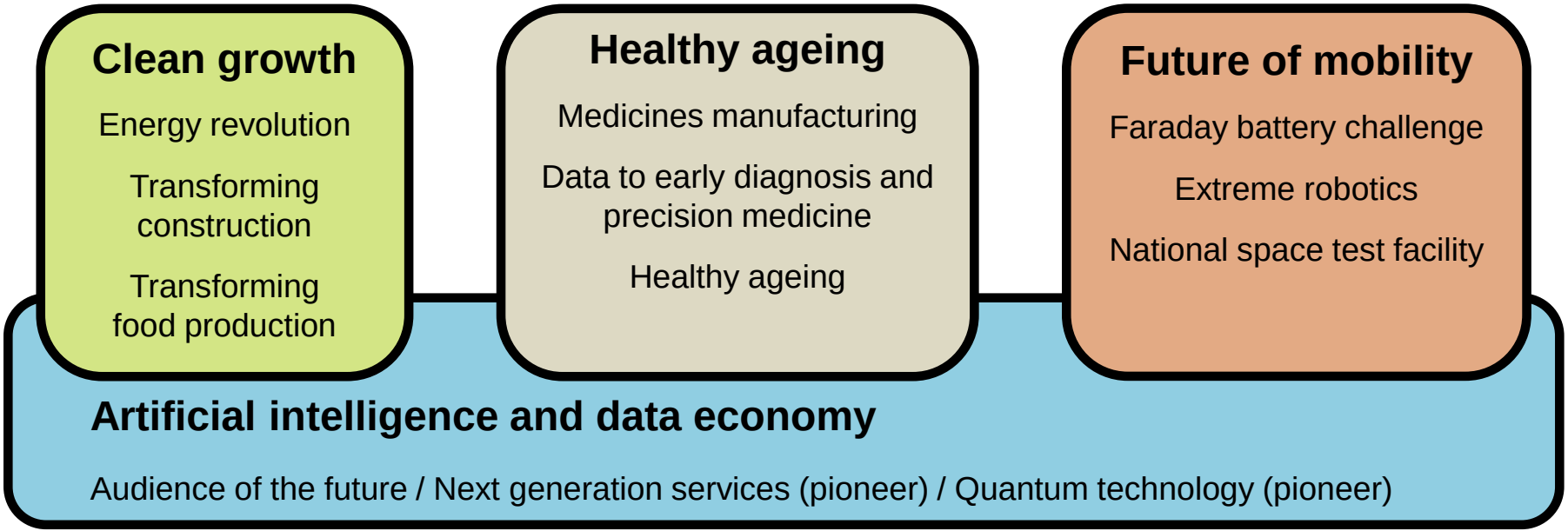
RESEARCH COUNCILS UK

How the ISCF challenges fit with the Industrial Strategy Grand Challenges



UK Research and Innovation

INDUSTRIAL STRATEGY

The Faraday Battery Challenge

Part of the Industrial Strategy Challenge Fund

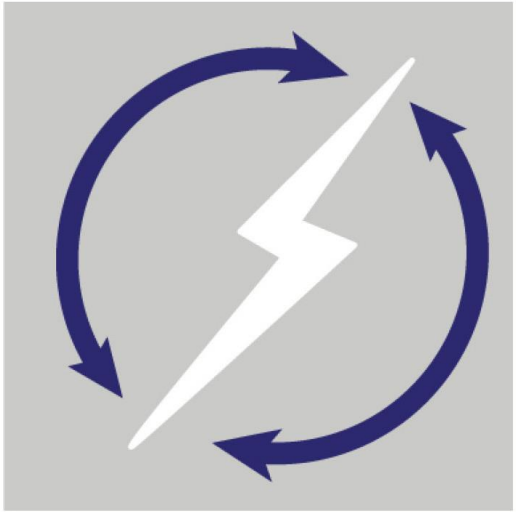
Delivered by Innovate UK

RESEARCH COUNCILS UK

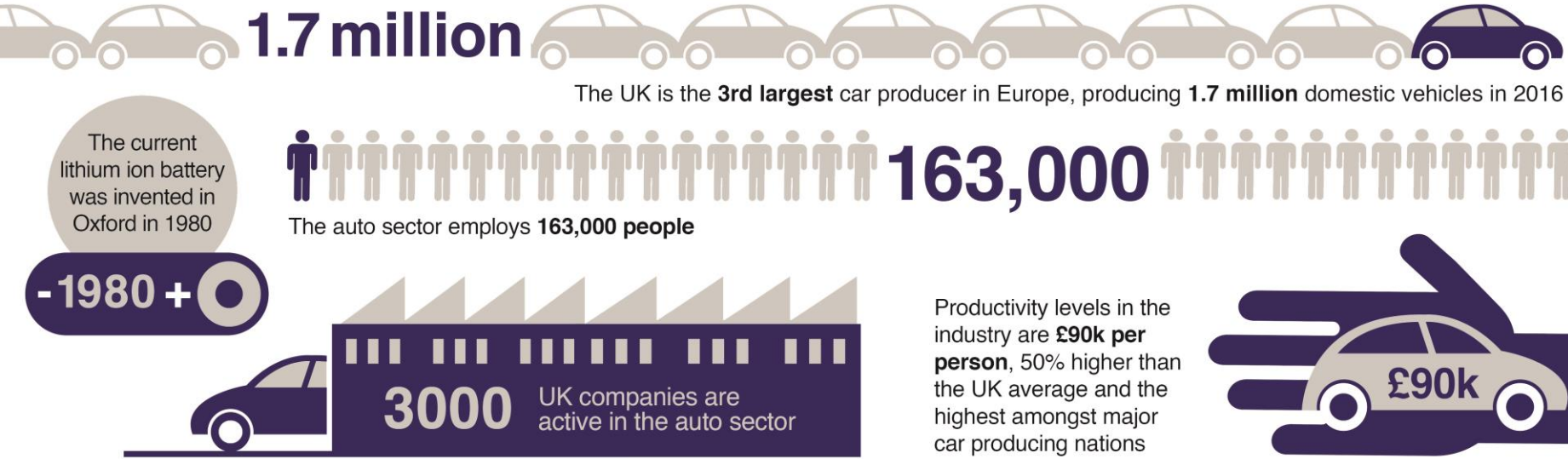
Clean and flexible energy – the Faraday Battery Challenge

The Faraday Battery Challenge, part of the Industrial Strategy Challenge Fund:

- £246 million commitment over four years to fully exploit the industrial opportunity of vehicle electrification through world-leading batteries
- Increasing multi-disciplinary application-led research in battery technologies
- Supporting UK businesses' investment capability in research, development, demonstration, testing and manufacture of battery technology

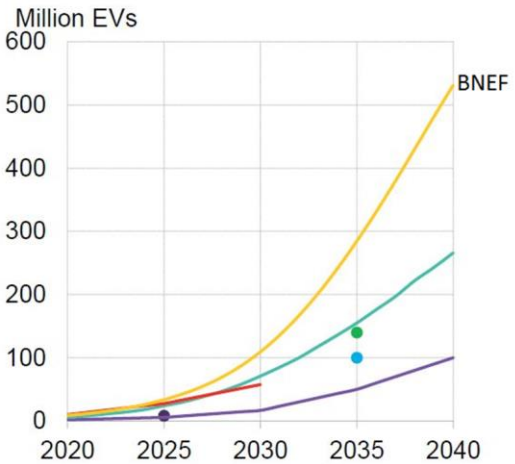


The opportunity: why does the UK want to be world-class in automotive battery technology?



EV Market: Exponential Growth

EV fleet size



EV share of new sales

BP ExxonMobil OPEC Total SA IEA BHP Billiton Statoil Goldman Sachs BNEF

Source: Bloomberg New Energy Finance, organization websites.

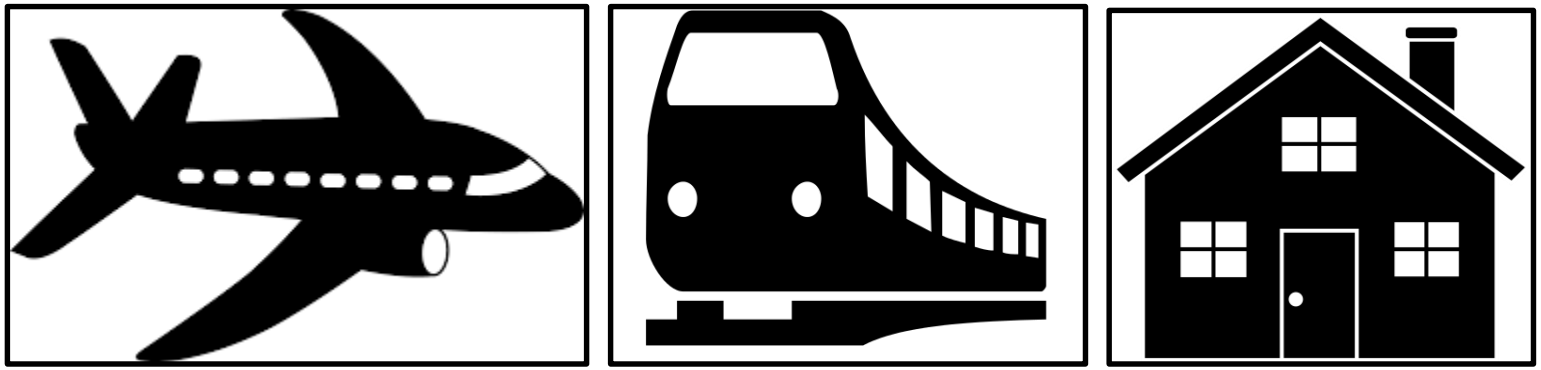
- By 2040, 53% of new car sales will be electric, with over 500m EVs on the road

  [Source: Bloomberg New Energy Finance]

- In the UK, EVs represent 1.9% of new vehicle market (135k vehicles)

  [Source: Society of Motor Manufacturers and Traders]

This is the starting point, we are looking for spill over into other sectors….



Cost

NOW $130/kWh (cell)
$280/kWh (pack)
2035 $50/kWh (cell)
$100/kWh (pack)

Energy Density

NOW 700Wh/l, 250Wh/kg (cell)
2035 1400Wh/l,
500Wh/kg(cell)

Power Density

NOW 3 kW/kg (pack)
2035 12 kW/kg (pack)

Safety

2035 Eliminate thermal runaway at pack level to reduce pack complexity

1st Life

NOW 8 years (pack)
2035 15 years (pack)

Temperature

NOW -20° to +60°C (cell)
2035 -40° to +80°C (cell)

Predictability

2035 Full predictive models for performance and aging of battery

Recyclability

NOW 10-50% (pack)
2035 95% (pack)

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Raw Materials → Materials and Electrochemistry → Electrode, electrolyte, separator, etc. → Cell Manufacture → Module, Pack and BMS → Vehicle Application → 2nd life / Recycling

UK Research and Innovation

ISCF Faraday Battery Challenge

£246 million (2017-2021)

Challenge Director, Advisory Group, Programme Board

INDUSTRIAL STRATEGY

Research: £78m

EPSRC

- ‘Application-inspired’ research programme coordinated at national scale
- Creation of the **Faraday Institution** – responsible for coordination of research and training programmes
- Four ‘fast-start’ projects announced 23rd Jan 2018 (£42m) – Battery Degradation, Multi-scale Modelling, Recycling, Solid State Batteries

THE FARADAY INSTITUTION

Innovate: £88m

Innovate UK

Scale: £80m

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- Develop manufacturing tools and methods for mass production
- Demonstrate production-rate reliability and quality
- CWLEP & WMG building open-access scale up facility: **UK Battery Industrialisation Centre**

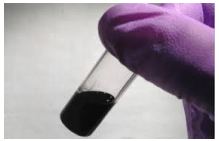
CWLEP Coventry & Warwickshire Local Enterprise Partnership

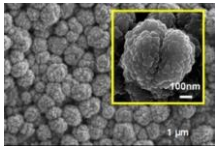
Coventry City Council

WMG THE UNIVERSITY OF WARWICK

Steps in Cell Development

Gramme Scale





Typically university scale research using small quantities of hand-made materials

Used for fundamental materials research and initial half-cell experiments at coin cell scale

Funders typically EPSRC, Faraday Institution

E.g. Oxford, UCL, Imperial, WMG

Kilogramme Scale

Typically corporate R&D lab or University / Catapult centre

Used to demonstrate scalability of materials to full size cell, and to develop electrode mixtures, deposition processes and cell formats.

Funders typically Innovate UK, EPSRC, Faraday Institution

E.g. WMG, QinetiQ

Tonne Scale

Typically full scale manufacturing facilities used at low rate. Expensive, inflexible, and impossible to access except by owner. **UKBIC provides bespoke facility for this purpose.**

Used to develop and prove materials, cell design, manufacturing processes and parameters “at-rate” prior to full plant investment

E.g. No public facility in UK or EU

Kilotonne Scale

Full scale, high volume manufacturing plant. Typically 6-50GWh/year

Used to deliver very large volumes of cells with no variation or flexibility to chemistry, format or quality. Cost/kWh and process consistency are critical

E.g. Tesla Gigafactory, LG Cheongju, Panasonic Osaka, Samsung Ulsan

UKBIC Battery Chemistries

Cathode / Anode Material	Strengths	Weaknesses
Lithium Cobalt Oxide (LCO) Cathode	• High energy • High power	• Thermally unstable • Relatively short life span • Limited load capabilities
Lithium Manganese Oxide Spinel (LMO) Cathode	• High power and thermal stability • Enhanced safety • Low cost	• Low capacity compared to other cathode materials • Limited life cycle • Need advanced thermal management
Lithium Nickel Cobalt Aluminium Oxide (NCA) Cathode	• High specific energy • Good specific power • Long life cycle	• Safety issues • Cost
Lithium Nickel Manganese Cobalt Oxide (NMC) Cathode	• Ni has high specific energy; Mg adds low internal resistance • Can be tailored to offer high specific energy or power	• Nickel has low stability • Manganese offers low specific energy
Lithium Iron Phosphate (LFP) Cathode	• Inherently safe; tolerant to abuse • Acceptable thermal stability • High current rating • Long cycle life	• Lower energy density due to low operating voltage and capacity
Graphite / carbon-based Anode	• Good mechanical stability • Good conductivity and Li-ion transport • Good gravimetric capacity	• Low volumetric capacity
Lithium Titanate (LTO) Anode	• Withstands fast charge / discharge rates • Inherently safe • Long cycle life	• Lower energy density compared to graphitic anodes • Cost
Silicon alloy (Si) Anode	• High gravimetric / volumetric capacity • Low cost • Chemical stability	• High degree of mechanical expansion on charging

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UKBIC will be specified and equipped to handle all lithium-ion anode and cathode materials being volume manufactured today

UKBIC will be specified and equipped or protected for promising next generation chemistries within reasonable investment considerations

Chemistry*	Properties / Benefits	Research Challenges
Solid State Batteries	• Solid electrolyte and separator components; no concerns over 'leakage' • Improved safety due to lack of liquid electrolyte • High operating voltages increase potential energy density • Lighter and more space efficient; less need for cooling	• Improving poor conductivity • High volume manufacturing at acceptable cost
Metal Air Batteries e.g. Li, Al, Zn, Na	• Pure metal anode and ambient air/O_2 cathode • Very high theoretical capacity • Increased safety vs Li-ion • No use of heavy metals	• Short life cycle • Issues with practical rechargeability • Air handling • Energy density reduces at high power
Lithium Sulphur (Li-S)	• High theoretical gravimetric energy density • Sulphur is a low cost, abundant material • Improved safety	• Poor volumetric energy density • Issues with power density and discharge rate • Issues with cycle life stability
Sodium-ion (Na-ion)	• Sodium is a low cost, abundant material • Improved safety for battery transportation	• Issues of volumetric/gravimetric energy density compared to Li-ion
Silicon-Based Electrodes (Si)	• Si has ~x10 gravimetric capacity compared to graphite • Could be lighter and / or store more energy	• Do not offer long cycle life • Practical application constraints

☑ ☒ ? ☑ ☑

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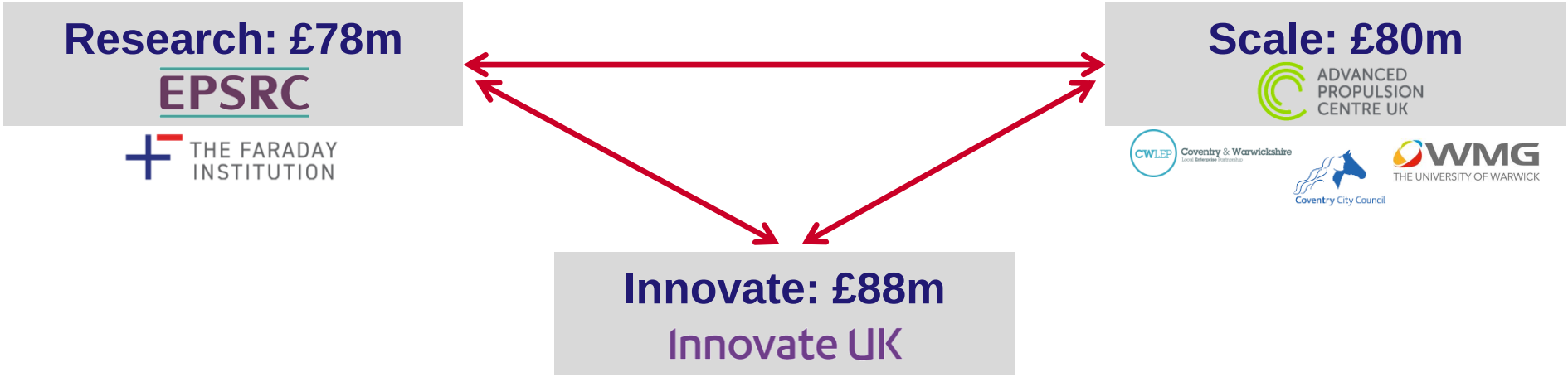
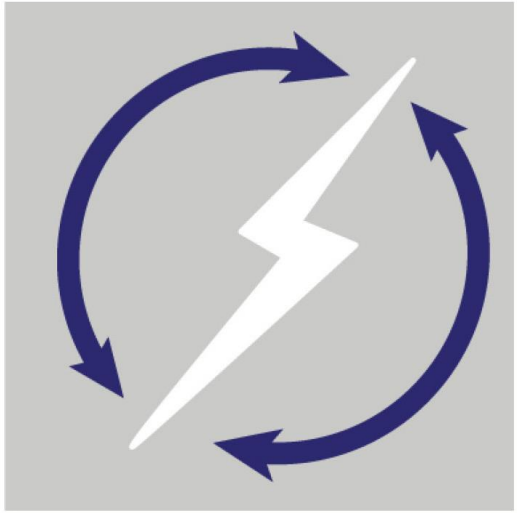


- Three elements spanning all TRLs interact to support the development of future technologies and to accelerate path to market for more mature technology
- Skills → critical to establish a workforce to support this industry
  - Programme being developed across the Faraday Battery Challenge to support skills training at all levels

Creating a UK Vehicle Battery Industry

- Phase 1 in process to fully exploit the industrial opportunity of vehicle electrification
- World-leading batteries developed, designed and manufactured in the UK
  - Establish UK battery supply chain
  - Enabling the UK to transition from internal combustion engines to EV
- Realistic - needs sustained investment, coordination and collaboration
- Faraday Institution – seeking industry input on future calls for research projects – www.faraday.ac.uk
- Innovation & Scale: Building UK supply chains, UK Battery Industrialisation Centre – open-access facility operational 2020



- UK Chemical Supply Chain for Battery Manufacture – 19th April, Darlington
- anna.wise@innovateuk.gov.uk

Thank You

Innovate UK

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