Department for Business & Trade

UK Battery Strategy

Contents

Foreword from the Minister

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Batteries will play an essential role in our energy transition and our ability to successfully achieve net zero by 2050. High capacity and reliable rechargeable batteries are a critical component of many devices, modes of transport, and our evolving energy generation capability.

Today we publish the UK's first battery strategy, alongside the Advanced Manufacturing Plan. This includes the Government's commitment to over £2 billion in new capital and R&D funding being made available for the automotive sector, supporting the manufacturing and development of zero emission vehicles, their batteries and supply chain for five years to 2030. This strategy represents a whole of Government effort, developed with business.

The Government's 2030 vision is for the UK to have a globally competitive battery supply chain that supports economic prosperity and the net zero transition. The UK will be a world leader in sustainable battery design and manufacture, underpinned by a thriving battery innovation ecosystem. Batteries represent one of the highest growth clean energy sectors[1] and the UK is well placed to reap the rewards thanks to its comparative advantage in research and advanced manufacturing.

Research at the University of Oxford in the 1970s made the lithium-ion battery possible. But, today, most industrial rechargeable batteries are manufactured in East Asia.[2] The UK and other industrialised countries are responding to the challenge given the importance of the growth of the sector and its critical role in ensuring our economic security.

This strategy brings together Government activity and describes our priorities. It sets out our vision for the sector, the commitments to deliver the vision, and establishes the framework and priorities for our future work with industry. The battery strategy describes how we will build on our comparative advantage, scale up our emerging supply chain, and continue to secure internationally mobile investment. Our approach sets the strategy as we further develop the regulations and support mechanisms to leverage growth in the sector, particularly to seize the

[1] McKinsey Battery Insights Team. 'Battery 2030: Resilient, Sustainable and Circular'. 2022.
[2] Nicholson J and others. 'De-bottlenecking the battery materials midstream.' 2023.

economic opportunities of increased reuse, repair, repurposing, and recycling of industrial batteries.

The scale of the opportunity for the UK economy is huge. Global demand for batteries, particularly lithium-ion ones, will accompany the growth in demand for energy-efficient products including electric vehicles (EVs). Just last year, Rolls Royce's battery-powered plane, Spirit of Aviation, was crowned the world's fastest ever all-electric vehicle.[3]

To make batteries, we need critical minerals such as lithium, cobalt, nickel, and graphite, which are being sourced or processed in the UK, from Cornwall to Lincolnshire. To strengthen our mineral supply chains, at a time of rising global demand, the UK Government has taken decisive action to accelerate domestic capabilities and expand our critical minerals partnerships, whilst drawing upon our unique strengths in critical minerals – both domestically and overseas. There are many further actions underway by Government and industry, as outlined in our Critical Minerals Strategy, which we refreshed just four months ago.[4]

For example, the UK-Australia Free Trade Agreement we have just signed reduces barriers to trade, including in the critical minerals that Australia produces such as lithium, nickel, manganese, and cobalt.[5] The UK further deepened its partnership, signing a Critical Minerals Statement of Intent.[6]

Our successful battery industry will be a significant source of jobs and regional economic growth, supporting the Government's levelling up agenda.[7] A battery industry that addresses domestic demand could employ 100,000 people by 2040, with the majority likely to be located outside of London and the South East.[8]

We are already supporting businesses to capitalise on the growth of the green economy. The new AESC Group gigafactory being built in Sunderland – AESC UK plant 2 – and Tata's announcement of the construction of a new gigafactory are jointly creating over 5,000 jobs and increasing future UK annual production capacity to an estimated 52GWh.[9] Moreover, Nissan has just announced that it is leading a further £2bn investment in Sunderland with two new EV models, building on the £1bn investment announced in 2021[10]. This represents another major vote of confidence in the UK.

The UK has set one of the most ambitious targets to reduce carbon emissions. To successfully achieve this, we will create and maintain favourable conditions for ongoing industry investment amid strong overseas competition. The UK Government is committed to continuing to invest in UK battery manufacturing.

This strategy builds on our impressive track record of targeted Government support, leading to a pipeline of investments through the battery ecosystem:

- The Advanced Propulsion Centre (APC) was launched in 2013 by Government and the Automotive Council to unlock private investment in new supply chains for low carbon

[3] Rolls Royce. 'Spirit of Innovation Stakes Claim to be the World's Fastest All-Electric Vehicle'. 2023.
[4] Department for Business and Trade. 'UK Critical Minerals Strategy.' 2023.
[5] Department for Business and Trade. 'UK-Australia Free Trade Agreement.' 2023.
[6] Australian Government Department of Industry, Science and Resources. 'Joint Statement of Intent between Australia and the United Kingdom on collaboration on critical minerals.' 2023.
[7] Department for Levelling Up, Housing and Communities. 'Levelling up the United Kingdom.' 2022.
[8] The Faraday Institution. 'UK Electric Vehicle and Battery Production Potential to 2040'. 2022.
[9] Department for Business and Trade. 'Tata Group to Invest Over £4 billion in UK gigafactory creating thousands of jobs'. 2023.
[10] BBC. 'Nissan Commits to Make New Qashqai and Juke Electric Models in Sunderland.' 2023.

vehicles. Government and industry have committed approximately £1.4 billion via the APC to accelerate the development and commercialisation of strategically important emerging vehicle technologies, including batteries.[11]

- The Faraday Battery Challenge has received £541 million funding since 2017, with the aim of making the UK a science superpower for batteries by driving innovations from laboratory to factory across the entirety of the battery supply chain.[12]
- The new AESC gigafactory now being built in Sunderland – AESC UK plant 2 – with an initial capacity of 12GWh, bringing over 1,000 new jobs, and building on almost a dozen years of UK battery production in the region.[13]
- Tata Group has also announced the construction of a new gigafactory that will produce 40GWh of batteries per year and will create up to 4,000 new jobs, as part of the electrification of the Jaguar-Land Rover brand.[14]
- Investments in cutting edge battery recycling facilities such as those in construction in London and the West Midlands.

I would like to thank the members of the UK Battery Strategy Taskforce, as they have ensured we have produced a strategy using the best knowledge and insight from industry and academia. I would also like to thank those who prepared the 84 responses to our Call for Evidence to inform our strategy.[15]

We will continue to invest in the battery sector, secure a resilient UK battery manufacturing supply chain, and remove barriers to investment.

[11] Advanced Propulsion Centre UK. '£86.9 million for scale-up and R&D of net-zero vehicle technology'. 2023.
[12] UK Research and Innovation. 'Faraday Battery Challenge'. 2023.
[13] SES Engineering Services. 'Construction Begins on Envision AESC's Second UK Gigafactory'. 2022.
[14] Tata Group. 'Tata Group to set up a Battery Gigafactory in the UK.' 2023.
[15] See Annex II

Executive Summary

Batteries are essential products in modern, industrialised economies. In recent years, they have grown in importance as they power many of the technologies that will enable the transition towards net zero. Primary uses include personal and commercial transportation and grid-scale battery energy storage systems (BESS), which allow us to use electricity more flexibly and decarbonise the energy system in a cost-effective way.[16] Batteries are also important to national security and underpin the UK's ability to develop innovative defence capabilities. As batteries become lighter, smaller, and more efficient, the aerospace, rail, and marine sectors, among others, are expected to increase their use of these technological advances.

Current battery production features complex value chains spanning multiple continents and is heavily reliant on East Asia.[17] Like most countries, the UK currently meets the bulk of its domestic demand for batteries and their components through imports.[18] Given that batteries are a vital component of many modern technologies, securing investment into the battery value chain is also important to economic security.

The global demand for batteries is expected to rise dramatically over the coming decades,[19] and the UK is uniquely positioned to seize the opportunity thanks to our key areas of comparative advantage:

- **Innovation**: The UK is playing an important global role in research and development (R&D) into battery chemistry optimisation, underpinned by the strength of our world-class research base. The UK ranks third in the world in terms of research quality into industrial batteries.[20]
- **Start-ups**: The UK has a leading electric vehicle (EV) battery start-up ecosystem, with the second highest enterprise value in Europe and fourth worldwide.[21]
- **Automotive manufacturing**: The UK's automotive manufacturing sector is the second highest by value in Europe,[22] with an annual turnover of £70 billion[23] and employing 166,000 people across the country.[24]

A successful battery industry will be an important source of jobs and regional economic growth. A battery industry that supports domestic demand for EVs could employ 100,000 people by 2040: 35,000 in cell manufacturing and 65,000 in the battery supply chain.[25] This represents an opportunity to create many highly paid, productive jobs across the country, from mining to processing and manufacturing to recycling.

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[16] The Faraday Institution. 'UK Electric Vehicle and Battery Production Potential to 2040.' 2022.
[17] Nicholson J and others. 'De-bottlenecking the battery materials midstream.' 2023.
[18] Du J and Shepotylo O. 'Powering the Future: Unveiling Economic Policy and Global Value Chain of the UK Electric Vehicle Industry'. Centre for Business Prosperity Working Paper. Forthcoming.
[19] The Faraday Institution. 'The Gigafactory Boom.' Faraday Insights: Issue 2. 2022.
[20] Government Office for Science. 'Rapid Technology Assessment: Novel Batteries.' 2023.
[21] UK Research and Innovation and Dealroom.co. 'Electric Vehicle Battery Tech in the UK.' 2023.
[22] DBT analysis of Office for National Statistics. 'GDP output approach low-level aggregates.' 2023; Eurostat. 'National accounts aggregates by industry.' 2022.
[23] Office for National Statistics. 'Monthly Business Survey turnover in production industries.' 2022.
[24] Office for National Statistics. 'JOBS03: Employee Jobs by Industry.' 2023; Office for National Statistics. 'JOBSO4: Self-Employment Jobs by Industry.' 2023.
[25] The Faraday Institution. 'UK Electric Vehicle and Battery Production Potential to 2040.' 2022.

Businesses are already investing significantly in the UK battery supply chain. Recent examples include Tata Group's £4 billion investment to build one of Europe's largest gigafactories[26] and new investment by Nissan and AESC to create a battery and electric vehicle manufacturing hub in Sunderland.[27] Moreover, Nissan is leading a further £2bn investment in Sunderland with two new EV models. This represents another major vote of confidence in the UK, building on the £1bn investment announced in 2021.[28] We will build on these successes to put the UK at the forefront of battery development and production of the range of battery technologies that will be required, ensuring that this leads to a safe and sustainable industry.

Our Vision

This document sets out the Government's activity to support our strategic objectives and establishes the framework and priorities for our future work with industry. It was developed with the UK Battery Strategy Taskforce, drawing on the Call for Evidence[29] and engagement with businesses and stakeholders.

The Government's 2030 vision is for the UK to have a globally competitive battery supply chain that supports economic prosperity and the net zero transition. The UK will be a world leader in sustainable design, manufacture, and use, underpinned by a thriving battery innovation ecosystem.

Our Approach

To build on our strengths, the strategy is based around a DESIGN-BUILD-SUSTAIN approach:

DESIGN: Design and develop the batteries of the future that are smaller, lighter, and offer better capacity and value, building on UK world-leading research and innovation.

a. Continuing to support **innovation** across the battery value chain.
b. Exploring innovative **financing** mechanisms to support **scale-ups**.
c. Maintaining stringent battery **safety and product standards** to support growth and protect workers and consumers**.**

BUILD: Working closely with our domestic industry and international partners to secure a resilient UK battery manufacturing supply chain that supports our strong domestic growth and thriving export markets.

d. Strengthening the resilience of UK **supply chains** including through the Automotive Transformation Fund and the UK Critical Minerals Strategy.
e. Building on our extensive **international collaboration** work with our partners to open new markets.
f. Continuing to support **energy intensive industries** and speeding up **energy grid connections.**
g. Ensuring **planning and permitting** reform actions will benefit the emerging battery sector.

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[26] Department for Business and Trade. 'Tata Group to Invest Over £4 billion in UK gigafactory creating thousands of jobs.' 2023.
[27] Nissan Motor Corporation. 'Nissan Unveils EV36Z.' 2021.
[28] BBC. 'Nissan Commits to Make New Qashqai and Juke Electric Models in Sunderland.' 2023.
[29] See Annex II

SUSTAIN: Enable the development of a thriving and sustainable sector, supported by proportionate regulations that drive investment across the supply chain, from raw materials through to end of life and recycling.

h. Identifying and facilitating the **skills** needed for the battery sector.

i. Collaborating with our international partners on **green trade** to reduce barriers.

j. Exploring pro-growth regulation and industry standards to incentivise investment in the **circular economy**.

The strategy also sets out the areas of emerging growth, building on the UK's comparative advantage – our thriving auto industry, our world-class innovation base, and the recent investments by business.

How We Will Do This

This strategy will commit Government to exploring a range of policy options to deliver against our priorities. Specifically, we will:

1. Provide targeted support for zero emission vehicles, batteries, and their supply chains, including through **over £2 billion of new capital and R&D funding for five years to 2030**, building on the work of the Automotive Transformation Fund and the Advanced Propulsion Centre.
2. Provide **sustained, consistent, and targeted support** for large-scale, long-term **research and innovation activities**, from early to late stages, across applications and key areas of the battery supply chain.
3. Invest an additional **£38 million to enhance the UK Battery Industrialisation Centre development facilities**, boosting its capability for research and development in new chemistries and future technologies. This builds on our know-how in lithium-ion solutions and enables the scale-up of emerging innovations.
4. Invest **£12 million in the Advanced Materials Battery Industrialisation Centre**, a new world-class battery materials scale up facility in the West Midlands and North East to bridge the gap between laboratory research and commercial production.
5. Invest **£11 million in 20 competition winners developing technologies across the battery value chain** in areas such as artificial intelligence and digital tools to increase battery performance, future technologies such as lithium-metal anodes and sodium-ion batteries, and improved recycling technologies.
6. Explore opportunities to **promote the establishment of R&D centres** in the UK from leading battery and EV manufacturers.
7. Explore the case for new **financial mechanisms to support start-ups** in the battery sector, including through public/private equity investment with government seed funding.
8. Expand market access for the **trade of critical minerals** and promote **high international standards** in supply chains when negotiating new Free Trade Agreements.
9. Explore options for **international collaboration** on batteries through new and existing forums, and ensure that the sector develops **practical, widely adopted international standards**, and that those in existence keep up with technological developments.

10. Create an environment that is **welcoming to foreign investment** whilst protecting our national security by assessing investment into battery manufacturing and the wider energy sector under the National Security and Investment Act[30] on a case-by-case basis.
11. Work with industry, Ofgem, and the network companies to deliver the actions needed to **accelerate connection timescales**, including strategic investment, efficient and flexible management of network capacity, and a connections process that is fit for the future.
12. Ensure that **manufacturing skills training and education** is well supported by a high quality and employer led skills system. We will work closely with academia and industry, to identify areas of highest demand and promote best practice to **develop an inclusive talent pipeline**.
13. Publish a consultation and Call for Evidence through the Department for Environment, Food and Rural Affairs, in collaboration with the Devolved Administrations, as early as possible in 2024, focussing on **increasing collection rates for batteries** and **encouraging best practise in end-of-life management** of all battery types and chemistries. Defra will work with the whole supply chain to consider **regulation for the entire eco-system**.
14. **Influence and adopt international standards** for reuse, repurposing, and recycling in line with our closest trading partners, where it is in our national interest and achieves our desired policy objectives.
15. **Continue to convene a Battery Strategy Taskforce** to advise on the delivery of the strategy, emerging risks to security of supply, and opportunities for the UK Government.

[30] Cabinet Office. 'National Security and Investment Act 2021.' 2023.

Part One: Context

Why is the Battery Sector Important for the UK?

Batteries are essential products in modern, industrialised economies. In recent years, they have grown in importance as they underpin many of the technologies that will enable the transition towards net zero. They are a vital component in personal and commercial transportation, including hybrid and fully electric cars, buses, vans, and lorries. Grid-scale battery energy storage systems (BESS) enable us to use electricity more flexibly and decarbonise the energy system in a cost-effective way.[31] As the technology and innovation in battery design, manufacturing, transportation, and deployment evolves, so will the development of additional applications.

Batteries are also important to the UK's national security and underpin the UK's ability to develop innovative defence capabilities - including communication systems, fighter jets and nuclear submarines.

We already have significant battery sector capabilities, as shown in Figure 1, including a fully operational gigafactory with an output of 2GWh.[32]. Investment in UK battery manufacturing is increasing, including the new AESC Group gigafactory being built in Sunderland – AESC UK plant 2 – and Tata Group's announcement of the construction of a new gigafactory, jointly creating over 5,000 jobs and increasing UK production capacity significantly to an estimated 52GWh.[33] This follows significant UK R&D investment, including the establishment of the Advanced Propulsion Centre (APC) in 2013 – bringing together £1.4 billion in joint industry and Government R&D advanced propulsion projects[34] – and the Faraday Battery Challenge in 2017 – making £541 million of funding available to the UK Battery Industrialisation Centre (UKBIC).[35]

The UK has also seen major new commitments to electric vehicle (EV) manufacturing:

- JLR has set out £15 billion of investment over next 5 years to accelerate their path to electrification in the UK.[36]
- Nissan, in partnership with AESC, is building a new EV manufacturing hub in Sunderland.[37]
- Bentley has announced a £2.5 billion investment to produce its first EVs in Crewe by 2026.[38]
- BMW has announced a £600 million investment to produce the next all electric MINI in Cowley from 2026.[39]

[31] Government Office for Science. 'Rapid Technology Assessment: Novel Batteries.' 2023.
[32] SMMT. 'Race to Zero: Powering up Britian's EV Supply Chain.' 2023
[33] Department for Business and Trade. 'Tata Group to Invest Over £4 billion in UK gigafactory creating thousands of jobs.' 2023.
[34] Advanced Propulsion Centre UK. '£86.9 million for scale-up and R&D of net-zero vehicle technology.' 2023.
[35] UK Research and Innovation. 'Faraday Battery Challenge.' 2023.
[36] Jaguar Land Rover. 'JLR to invest £15 billion over next five years as its modern luxury electric-first future accelerates.' 2023.
[37] Nissan Motor Corporation. 'Nissan Unveils EV36Z.' 2021.
[38] Bentley Motors. 'Bentley secures UK production of first electric car.' 2022.
[39] BMW Group. 'Mini Plant Oxford Goes Electric: £600m investment for all-electric MINI production in the UK.' 2023.

- Stellantis started producing Vauxhall, Opel, Fiat, Peugeot and Citroën electric vans at their Ellesmere Port plant in September 2023, following a £100 million investment that was secured with support from Government.[40]

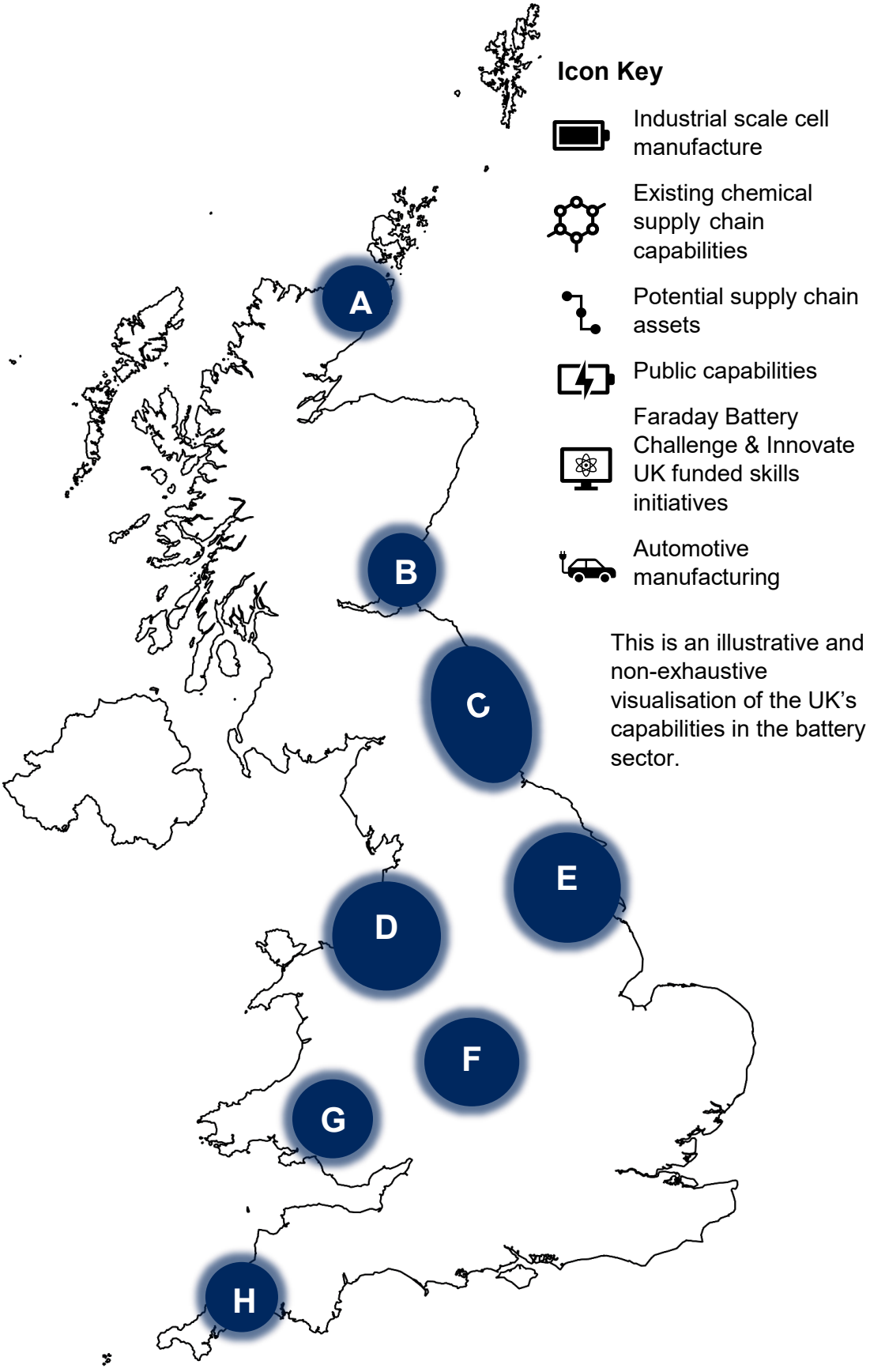
These recent announcements highlight industry's confidence in investing in the UK's battery ecosystem. But international competition is significant, particularly following the introduction of the US's Inflation Reduction Act and the EU's Green Deal Industrial Plan. This was reflected in the Call for Evidence,[41] with higher subsidies in other countries viewed by some respondents as a key barrier to UK investment.

Securing investment into the battery value chain is key to our economic security. The UK currently meets most domestic demand for batteries and their components through imports.[42] Like most countries, the UK currently relies on China as the largest import source of lithium-ion batteries for all applications.[43] In 2022, the UK imported nearly £1.8 billion worth of lithium-ion battery packs, of which around £0.9 billion came from China, £0.3 billion from Germany, and £0.1 billion from Japan.[44]

Developments will continue to be driven internationally and so our battery strategy is flexible to changing global markets and opportunities. The UK is well placed to influence standards and capture market share of growing battery demand. Our focus and objectives are centred around building on our comparative advantage, scaling up our emerging supply chain, and securing internationally mobile investment.

[40] Stellantis. 'Stellantis announces start of electric vehicle production at Ellesmere Port.' 2023.
[41] See Annex II
[42] Du J and Shepotylo O. 'Powering the Future: Unveiling Economic Policy and Global Value Chain of the UK Electric Vehicle Industry'. Centre for Business Prosperity Working Paper. Forthcoming.
[43] Energy Institute and others. 'Statistical Review of World Energy.' 72nd Edition. 2023.
[44] Trade Map. 2023.

Figure 1: Map of UK Battery Ecosystem Capabilities



A. Thurso

- AMTE Power

B. St Andrews

- Pilot Line

C. North East

- 2GWh AESC Plant 1
- 11GWh AESC Plant 2 (under construction)
- Chemical processing
- National Battery Training & Skills Academy (Newcastle University)
- Lithium exploration and refining
- Centre for Process Innovation UK
- Automotive manufacturing

D. North Wales/ North West

- Chemical processing
- Graphene Engineering Innovation Centre
- Automotive manufacturing

E. East Midlands

- Graphite processing
- Automotive Manufacturing

F. West Midlands

- UK Battery Industrialisation Centre
- Warwick Manufacturing Group Energy Innovation Centre
- The Manufacturing Technology Centre
- National Electrification Skills Framework & Forum (Coventry University)
- Electric Revolution Skills Hub (Coventry University)
- Digitally Enhanced Battery Ubiquitous Training (DEBUT) West Midlands (University College Birmingham)
- Automotive manufacturing

G. South Wales

- Nickel refining

H. South West

- Lithium processing, extraction and exploration

Location TBC

- 40GWh Tata Agratas Plant

Source: DBT mapping based on stakeholder engagement

What is the Scale of the Opportunity?

There is a significant opportunity for the UK economy as global demand continues to increase for green products and the batteries that power them.[45] In particular, the global transition to EVs will continue to drive battery demand through this decade and beyond.

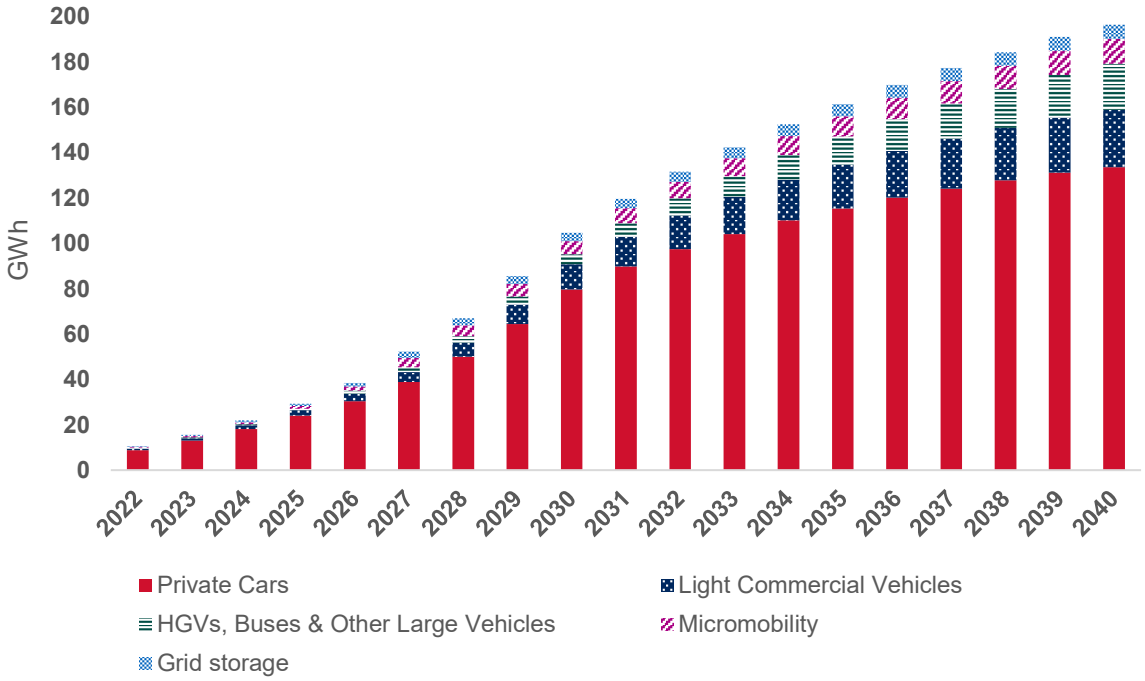
The global transition to EVs means that lithium-ion batteries are expected to dominate the rechargeable battery market for the next decade.[46] About 70% of global lithium-ion battery demand in 2030 will be from passenger EVs, with the remainder from electric buses, consumer electronics, grid stationary storage, and commercial EVs.[47] The value of lithium-ion batteries from mining through to recycling, could see global demand grow by over 30% every year, to reach a value of more than $400 billion and a market size of 4.7TWh by 2030.[48] The Government has set out regulations for all new cars to be zero emission by 2035, providing clarity to manufacturers while safeguarding UK jobs.[49]

The annual demand for UK battery manufacturing capacity is forecast to reach over 100GWh in 2030, predominately for private cars and light commercial vehicles (LCVs), as shown in Figure 2.[50] By 2040, nearly 200GWh of capacity will be needed in the UK to satisfy demand for batteries for private cars, commercial vehicles, HGVs (heavy goods vehicles), buses, and grid storage.[51] Figure 3 shows how global demand will also increase rapidly, to over 3,500GWh in 2030 and over 5,500GWh by 2035, also dominated by private cars[52]. Further information on the projected battery demand and the scale of opportunity in the UK is available in Annex III.

Batteries will enable us to use energy in a more flexible way that supports decarbonisation goals by helping to balance the system, maximise the usable output from renewable energy, and avoid the need for new generation capacity.[53] As batteries become lighter, smaller, and more efficient, the aerospace, rail, marine, and defence sectors are expected to increase their use of these technological advances.

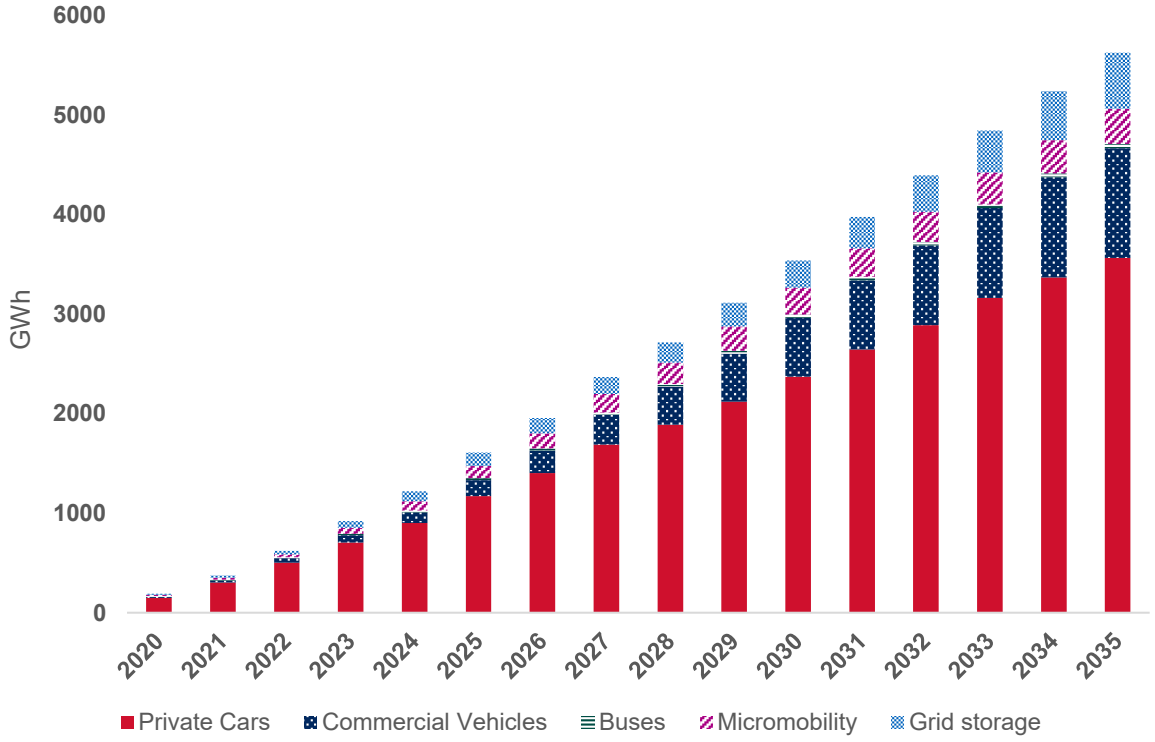
[45] McKinsey Battery Insights Team. 'Battery 2030: Resilient, Sustainable and Circular.' 2022.
[46] Government Office for Science. 'Rapid Technology Assessment: Novel Batteries.' 2023.
[47] The Faraday Institution. 'UK Electric Vehicle and Battery Production Potential to 2040.' 2022.
[48] McKinsey Battery Insights Team. 'Battery 2030: Resilient, Sustainable and Circular.' 2022.
[49] HM Government. 'Transitioning to zero emission cars and vans: 2035 delivery plan.' 2021.
[50] Advanced Propulsion Centre UK. 'Q2 2023: Automotive Industry Demand Forecast.' Quarterly Demand Reports. 2023.
[51] The Faraday Institution. 'The Gigafactory Boom.' Faraday Insights: Issue 2, 2022.
[52] See Figure 3: Future Global Demand for GWh by End Use
[53] Government Office for Science. 'Rapid Technology Assessment: Novel Batteries.' 2023.

Figure 2: Future UK Demand for GWh by End Use



Source: The Faraday Institution. 'UK Electric Vehicle and Battery Production Potential to 2040.' Faraday Report UK Gigafactory Outlook. 2022.

Figure 3: Future Global Demand for GWh by End Use

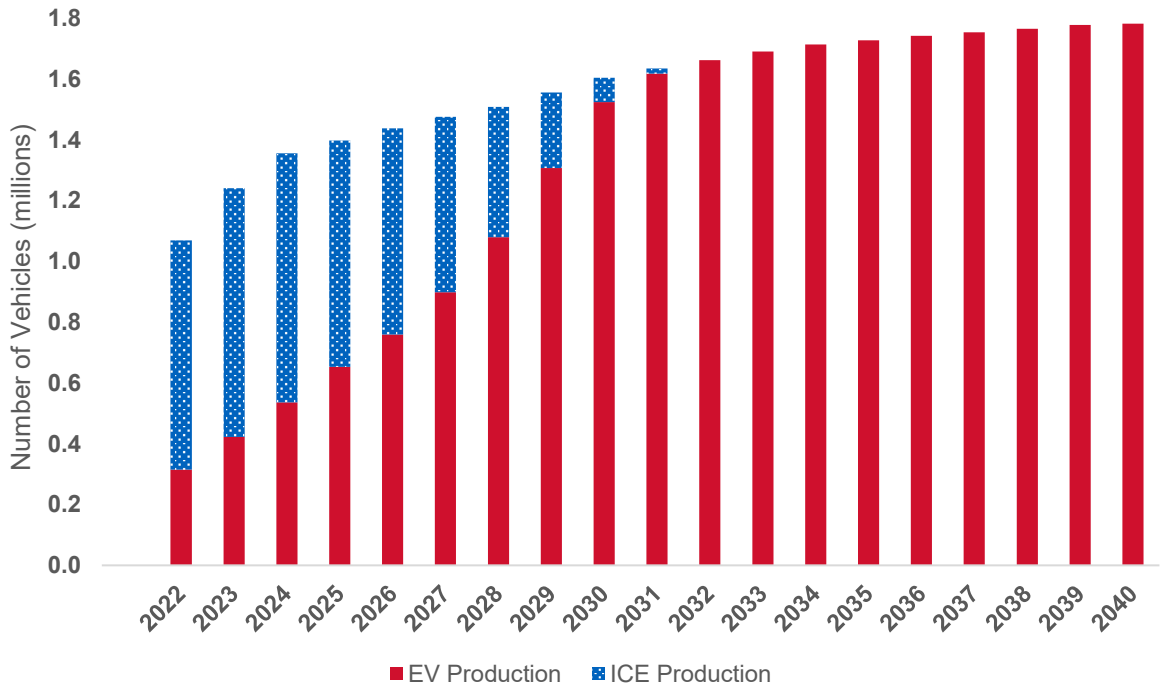


Source: BloombergNEF. 2023.

UK automotive manufacturers are responding to the growing demand for electric vehicles. There were there were 265,000 new EV registrations in 2022 and registrations were 20% higher in October 2023 compared to October 2022.[54]

UK production of electric vehicles as a proportion of total automotive production has increased from 3.4% in 2019 to 9.5% in 2022[55]. The Society of Motor Manufacturers & Traders (SMMT) predicts UK automotive sector could see a ten-fold increase from 74,000 to over 750,000 annual electric cars and vans produced, worth £106 billion in 2030, with further growth opportunities in supply-chain, aftermarket and heavy-duty vehicles.[56] Other predictions go further, with The Faraday Institution's 2022 forecast suggesting EV production could be over 1.4 million by 2030 and up to nearly 1.8 million by 2040,[57] as shown in Figure 4. There is also a large export potential. Currently, 78% of UK finished vehicle production is exported.[58]

Figure 4: Forecasted UK Vehicle Manufacturing to 2040: Electric Vehicle (EV) and Internal Combustion Engine (ICE) Production



Source: The Faraday Institution. 'UK Electric Vehicle and Battery Production Potential to 2040.' Faraday Institution UK Gigafactory Outlook. 2022.

A successful battery industry could be a significant source of jobs and regional economic growth. The current automotive sector is 27% more productive than the economy as a whole and 14% more productive than wider UK manufacturing in terms of output per hour,[59] and attracts a wage premium of around £4,500 compared to the whole economy.[60] Moreover, in 2021, 89% of automotive jobs were based outside of London and the South East.[61] A battery

[54] Society of Motor Manufacturers and Traders. 'SMMT Data: Car Registrations.' 2023.
[55] Society of Motor Manufacturers and Traders. 'SMMT Motor Industry Facts.' 2023
[56] Society of Motor Manufacturers and Traders. 'Manifesto 2030: Automotive Growth for a zero-emission future.' 2023.
[57] The Faraday Institution. 'UK Electric Vehicle and Battery Production Potential to 2040.' 2022.
[58] Society of Motor Manufacturers and Traders. '2019 UK Automotive Trade Report.' 2019.
[59] Office for National Statistics. 'Output Per Hour Worked, UK.' 2023.
[60] Office for National Statistics. 'Earnings and Hours Worked, Industry by four-digit SIC.' 2023.
[61] Office for National Statistics. 'Business Register and Employment Survey.' 2022.

industry that supports domestic demand for EVs could employ 100,000 people by 2040 (35,000 in cell manufacturing and 65,000 in the battery supply chain), in highly paid, productive jobs across the country.[62]

Through the Automotive Transformation Fund (ATF), the Government is helping UK businesses to capitalise on the opportunities provided by the expansion of this industry.[63] The ATF provides support to unlock large-scale industrialisation projects that speed up the development of an electrified automotive supply chain in the UK. The ATF engages with companies at all stages of the supply chain, including activities such as lithium extraction, chemical refining, anode and cathode material manufacturing, and cell production. At Autumn Statement, the Government announced over £2 billion of capital and R&D funding for five years to 2030 for zero emission vehicle manufacturing, including gigafactories and their supply chains. This is helping to support the automotive industry in its transition to net zero whilst safeguarding existing jobs and delivering new ones throughout the sector.

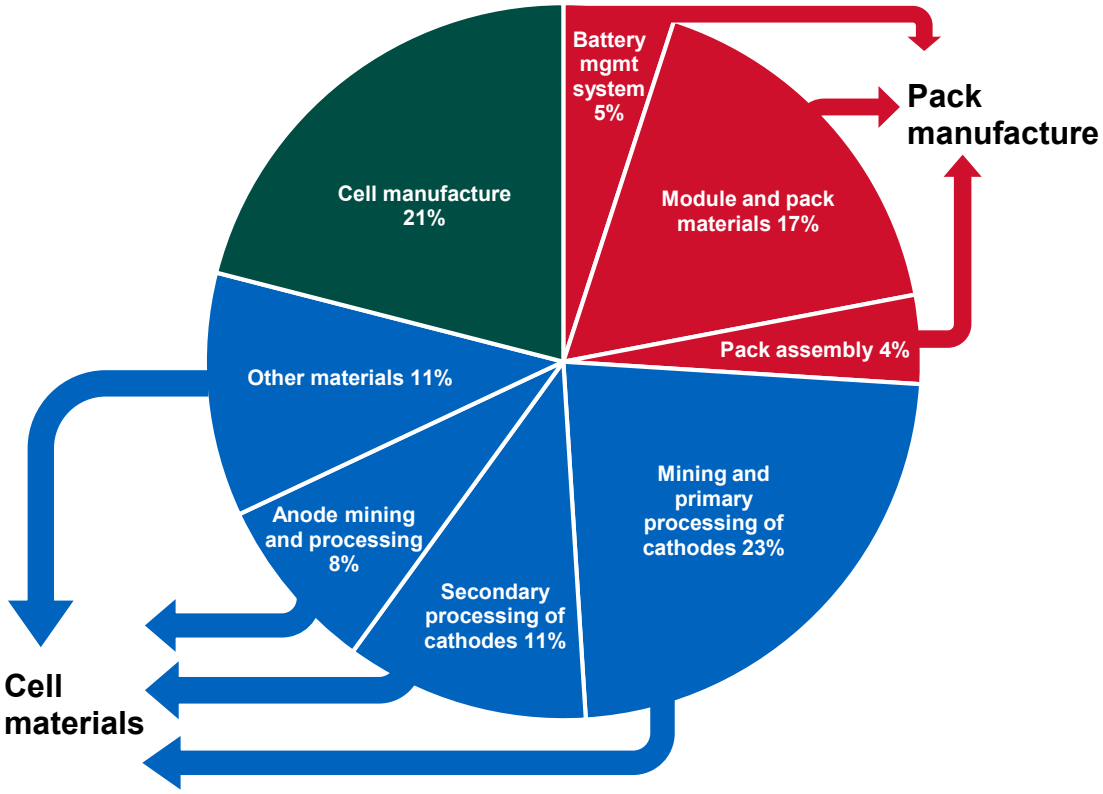
Unlocking these investments will also enable UK EV manufacturers to meet the Rules of Origin (RoO) requirements set out in the UK-EU Trade and Cooperation Agreement (TCA).[64] The automotive industry is trade-intensive, with 78% of domestic production exported.[65] Meeting these requirements and avoiding tariffs with our largest export market is vital for the health of the industry. We expect future investment for many components, both for the battery and the wider EV supply chain, will be regionalised to Europe in order to support these targets.

The importance of investment in the production of high value-add battery supply chain elements such as cathode precursors and active materials is reflected in RoO requirements in our Free Trade Agreements.[66] These are specialised chemical businesses and key midstream steps, where critical minerals are prepared for the cell manufacturing process. The cathode makes up over 40% of the value of a cell,[67] so establishing production capacity would help ensure that UK-made batteries and EVs can meet RoO requirements. In addition, cathode production can open opportunities for the circular economy, with refiners sustaining the hydrometallurgical battery recycling business model by buying the critical minerals recovered.

Figure 5 shows the approximate value of the different components of a lithium-ion battery pack. Most of the value comes from mining and processing critical minerals to produce the electrodes. Primary cathode processing refers to the formation of mixed-metal salts, typically from commodity materials, and secondary processing refers to the production of cathode active material.

[62] The Faraday Institution. 'UK Electric Vehicle and Battery Production Potential to 2040.' 2022.
[63] Advanced Propulsion Centre UK. 'Automotive Transformation Fund.' 2023.
[64] European Commission. 'The EU-UK Trade and Cooperation Agreement.' 2021.
[65] Society of Motor Manufacturers and Traders. 'Driving Global Britain.' 2021.
[66] Make UK. 'EU Trade Hub: The Rules of Origin.' 2023.
[67] Benchmark Mineral Intelligence. 'Battery Cathode Prices Rise for First Time This Year as Lithium Costs Increase.' 2023.

Figure 5: Approximate Value of Lithium-ion Battery Pack Components



Source: Roland Berger. 'The Lithium-Ion (EV) Battery Market and Supply Chain.' 2021.

How Could Technological Innovation and the Market Evolve?

Like other net zero enablers, batteries are a rapidly developing technology and the source of much research. The battery sector has the potential to become highly diverse, with different battery types used for different applications based on their key characteristics – including size (volumetric energy density), weight (gravimetric energy density), use-cycle and life-cycle longevity, and power performance. As highlighted in the Call for Evidence responses,[68] the trajectory that technological advances will take and the way the market will evolve are uncertain.

Most electric vehicles today use lithium-ion batteries containing one of two main chemical formulations in the cathode.[69] Lithium iron phosphate (LFP) batteries are cheaper but heavier and are better suited to recharging between short trips, so they are mostly found in shorter-range, lower-priced electric vehicles.[70] Most LFP batteries are made in China,[71] where research has focused on improving their performance. Lithium-ion batteries with a nickel manganese cobalt (NMC) formulation are more expensive but are smaller, lighter, and offer a

[68] See Annex II
[69] S&P Global. 'The Future of Battery Technology.' 2023.
[70] Government Office for Science. 'Rapid Technology Assessment: Novel Batteries.' 2023.
[71] Fraunhofer Institute for Systems and Innovation Research. 'Analysis of Global Battery Production.' 2023.

longer range.[72] These are mostly found in higher-performing vehicles, with manufacturing capacity rising across the US and Europe.[73] Researchers are exploring ways to reduce the cobalt content in the cathode, mainly due to rising costs and supply chain security concerns.

Advances in both lithium-ion batteries and their alternatives are creating opportunities to electrify other applications and sectors. However, there are competing forces that will affect how the market evolves:

1. **Consolidation:** Lithium-ion batteries are likely to undergo further improvements that extend their prevalence into the near future. This may lead to battery market consolidation, with only a small number of applications deviating from the trend.
2. **Specialisation:** As the current generation of lithium-ion batteries approaches its maximum technical limits, some commentators expect more radical change and argue that next-generation technologies could create opportunities for specialisation, with a larger number of battery technologies servicing niche segments across and within sectors.

Some examples of next-generation batteries include:[74]

- **Sodium-ion batteries**, which use a similar manufacturing process to current lithium-ion batteries, but do not require lithium. Sodium-ion batteries have the potential to be cheaper than lithium-ion batteries – and have a separate supply chain – due to the abundance of sodium as a raw material, resulting in a more resilient and price-stable technology. Respondents to the Call for Evidence singled out sodium-ion batteries as one of the most promising battery technologies, particularly for non-transport applications.[75] Over the next ten years, the technology is likely to be employed in stationary applications, such as residential and grid storage, given their lower energy density than lithium-ion batteries. However, they will need to compete with cost reductions in LFP-based lithium-ion technology, as well as establish a supply chain at scale.
- **Lithium-sulphur batteries,** which use a conversion-type chemistry and operate differently than lithium-ion or sodium-ion batteries. These replace metal-rich cathodes with cheaper sulphur cathodes, and graphite anodes with lithium metal, and can offer greater energy density than current lithium-ion batteries. Research is underway to improve their longevity and power, with a view to using them in drones, short-range aircraft, and satellites.
- **Solid-state batteries**, which replace the liquid electrolyte and plastic separators in cells with a solid-like material and could offer a step-change in energy density, faster charging rates, and safety. The technology could lead to breakthrough advances in anode and cathode chemistries and more efficient battery pack designs. This is seen as critical to the future development of automotive and aerospace applications. Solid-state batteries have shown exceptional performance at small scales, but further work is needed to manufacture at an industrial scale in a cost-competitive way.
- **Metal-air batteries,** which use oxygen from the air as the active cathode material and a reactive metal – such as lithium – as the anode. They have a high theoretical energy

[72] Government Office for Science. 'Rapid Technology Assessment: Novel Batteries.' 2023.
[73] Government Office for Science. 'Rapid Technology Assessment: Novel Batteries.' 2023.
[74] Government Office for Science. 'Rapid Technology Assessment: Novel Batteries.' 2023.
[75] See Annex II

density and could be high-performance lightweight batteries, but significant research challenges remain.

What is the Role of Critical Minerals?

A robust domestic industrial base for battery manufacturing requires secure, resilient, and diversified supply chains for key inputs. To make batteries we need lithium, cobalt, nickel, and graphite, among other critical minerals. However, supply chains are not only strained by rapidly increasing demand, but also take time and investment to build, as do the associated skills and know-how. Moreover, these supply chains are complex and opaque, often concentrated in specific countries. Markets are volatile, distorted, and fraught with environmental, social and governance issues. We cannot rely on mineral supply chains vulnerable to market shocks, geopolitical events, and logistical disruptions, at a time when global demand is rising faster than ever.

This is why the Government has taken decisive action to accelerate domestic capabilities, collaborate with international partners, and enhance international markets:

- The **Critical Minerals Strategy**, published in July 2022, sets out an approach to improve the resilience of critical mineral supply chains to safeguard British industries now and in the future, deliver our clean energy transition, and protect national security and defence capability. [76]
- The **Critical Minerals Refresh**, published in March 2023, sets out a refreshed approach to delivering resilient critical mineral supply chains and demonstrates Government's sustained commitment to securing the long-term supply of critical minerals for UK industry. [77]

Additionally, the forthcoming UK Critical Imports and Supply Chains Strategy will set out the Government's plans to bolster supply chain resilience across critical sectors.

The Government seeks to encourage sustainable UK critical mineral production and processing. The UK has unique strengths in critical minerals – both domestically and overseas – including mineral and mining expertise, R&D, finance, and standards, and it is a home to global mining majors. Leveraging its diplomatic, trading and development relationships, the UK is participating in building new resilient global supply chains for critical minerals, including those used to make batteries.

The more challenging it becomes to source and extract critical minerals from the ground, the more important it will be to make the best use of those already in circulation. As batteries reach the end of their economic life, there will be an opportunity and necessity to repair, repurpose, reuse, and recycle them. The chemicals sector will play an important role in recycling and recovering valuable materials, enhancing environmental sustainability, and alleviating pressure on primary supply.

[76] Department for Business and Trade. 'Resilience for the Future: The UK's Critical Minerals Strategy.' 2023.
[77] Department for Business and Trade. 'Critical Minerals Refresh: Delivering Resilience in a Changing Global Environment.' 2023.

Part Two: The UK's Approach

The UK's Vision and Objectives

The Government's 2030 vision is for the UK to have a globally competitive battery supply chain that supports economic prosperity and the net zero transition. The UK will be a world leader in sustainable design, manufacture, and use of batteries, underpinned by a thriving battery innovation ecosystem.

The strategy was developed with the UK Battery Strategy Taskforce, drawing on the Call for Evidence[78] and engagement with businesses and stakeholders. The strategy sets out the Government's activity to support our objectives and sets a framework for our future work with industry to support the sector.

Given the high forecast demand for batteries over the coming years, businesses are investing significantly in the UK battery supply chain. In 2023, we have already secured 52GWh in planned capacity for the UK – over halfway to meeting 2030 demand. Recent public-private investments include both Tata Group's £4 billion investment to build one of Europe's largest gigafactories[79] and new investment by Nissan and AESC to create an electric vehicle manufacturing hub in Sunderland.[80] The UK is well placed to build on these investments and our comparative advantages, including:

1. **Our battery research expertise**, where the UK ranks third in the world in terms of research quality, and leading work on sodium-ion batteries.[81]
2. **Our leading EV battery start up ecosystem**, with the second highest enterprise value in Europe and fourth worldwide.[82]
3. **Our automotive manufacturing sector**, the second highest by value in Europe,[83] with an annual turnover of £70 billion[84] and 166,000 employees across the country.[85]

To build on these strengths, our strategy is based around a DESIGN-BUILD-SUSTAIN approach:

DESIGN: Design and develop the batteries of the future that are smaller, lighter, and offer better capacity and value, building on UK world-leading research and innovation.

a. Continuing to support **innovation** across the battery value chain.

b. Exploring innovative **financing** mechanisms to support **scale-ups**.

c. Maintaining stringent battery **safety and product standards** to support growth and protect workers and consumers**.**

BUILD: Working closely with our domestic industry and international partners to secure a resilient UK battery manufacturing supply chain that supports our strong domestic growth and thriving export markets.

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[78] See Annex II
[79] Department for Business and Trade. 'Tata Group to Invest Over £4 billion in UK gigafactory creating thousands of jobs.' 2023.
[80] Nissan Motor Corporation. 'Nissan Unveils EV36Z.' 2021.
[81] The Faraday Institution. Sodium-ion Batteries: Inexpensive and Sustainable Energy Storage.' Faraday Insights: Issue 11. 2021.
[82] UK Research and Innovation and Dealroom.co. 'Electric Vehicle Battery Tech in the UK'. 2023.
[83] Internal DBT analysis of Office for National Statistics. 'GDP output approach low-level aggregates.' 2023; Eurostat. ' National accounts aggregates by industry.' 2022.
[84] Office for National Statistics. 'Monthly Business Survey turnover in production industries.' 2022
[85] Office for National Statistics. 'JOBS03: Employee Jobs by Industry.' 2023; Office for National Statistics. 'JOBSO4: Self-Employment Jobs by Industry.' 2023.

d. Strengthening the resilience of UK **supply chains** including through the Automotive Transformation Fund and the UK Critical Minerals Strategy.

e. Building on our extensive **international collaboration** work with our partners to open new markets.

f. Continuing to support **energy intensive industries** and speeding up **energy grid connections.**

g. Ensuring **planning and permitting** reform actions will benefit the emerging battery sector.

SUSTAIN: Enable the development of a thriving and sustainable sector, supported by proportionate regulations that drive investment across the supply chain, from raw materials through to end of life and recycling.

h. Identifying and facilitating the **skills** needed for the battery sector.

i. Collaborating with our international partners on **green trade** to reduce barriers.

j. Exploring pro-growth regulation and industry standards to incentivise investment in the **circular economy**.

Design

The UK has a long history of world-leading and world-changing innovation. From the steam engine and the telephone to the World Wide Web and the Oxford AstraZeneca vaccine, the UK's rich heritage of innovation has shaped the modern world. The driver behind many of these innovations is the strength of the UK's research base, which is consistently ranked as best in class across a wide range of areas.[86] Indeed, research at the University of Oxford in the 1970s made the lithium-ion battery possible.

The UK also has one of the world's most innovative and open financial services sectors, with London ranking first in the Global Green Finance Index.[87] The London Stock Exchange is one of the world's most international capital markets and the destination of choice for both international firms and international investors.[88]

We will leverage these strengths to design and develop the batteries of the future by:

a. Continuing to support **innovation** across the battery value chain.

b. Exploring innovative **financing** mechanisms to support **scale-ups**.

c. Maintaining stringent battery **safety and product standards** to support growth and protect workers and consumers**.**

Innovation

Innovation has been a fundamental feature of the rapidly evolving battery ecosystem, with technological advances over the last decade making it possible to hit the necessary cost and performance requirements for widespread adoption. A recent study by the Government Office for Science found that the UK is playing an important global role in investment, patent, and

[86] Government Office for Science. 'Rapid Technology Assessment: Novel Batteries.' 2023.
[87] Long Finance. 'The Global Green Finance Index 12.' 2023.
[88] Department for Business and Trade. 'Financial Services.' 2023.

research activity into battery chemistry optimisation, and is among the top 5 global leaders in terms of research and patent output.[89] Experts highlighted solid state, and cathode research as particular UK strengths, alongside a growing number of start-ups and a relatively strong position in equity investment, especially in next-generation anodes.[90] The UK also has a significant comparative advantage in sodium-ion batteries for stationary storage applications, with the potential to take a leading role in their commercialisation and industrialisation.

The Government is driving innovation to support both current applications and the development of future battery technologies through a range of programmes. These include:

1. The Faraday Battery Challenge (FBC), which aims to make the UK a science superpower for batteries. It has received £541 million in funding since 2017 to drive innovations from lab to factory across the entirety of the supply chain.[91] The Faraday Battery Challenge is a UKRI (UK Research and Innovation) Challenge Fund programme that was created and is now supported by two key delivery partners:
    a. The Faraday Institution leads on delivering application-inspired research programmes. It brings together 27 UK universities, 85 industry partners and over 500 researchers across 10 major projects covering current and next-generation battery technologies.[92]
    b. UK Battery Industrialisation Centre (UKBIC) is our national manufacturing development centre, providing open-access infrastructure as well as manufacturing and scale-up skills in its 20,000m^2 world-renowned facility. UKBIC plays a key role in supporting technology development and de-risking commercialisation pathways for UK battery technologies, helping to remove barriers to firm scale-up and investment.
2. The Advanced Propulsion Centre (APC), formed in 2013, which has seen over £1.4 billion of industry investment and Government grant funding to help the automotive industry meet the challenges of decarbonisation identified by the Government and the Automotive Council.[93] Funded by the Department for Business and Trade, the APC works with the automotive industry and academia on late-stage collaboration R&D projects to accelerate the industrialisation of technologies. The APC recently announced £86.9 million of Government and industry funding to develop cutting-edge electric vehicle technology, including projects on luxury EV platforms, lithium refining, and solid-state battery manufacturing.[94]
3. The Automotive Transformation Fund (ATF), first announced in 2020, has enabled the UK to secure a number of significant Original Equipment Manufacturers (OEM) and supply chain investments. This has accelerated the UK's journey towards electrification, with industry setting itself ambitious goals in terms of inward investment. ATF funding supports companies across the electric vehicle supply chain, including batteries, electric drive units, and fuel cell systems, amongst other technologies.
4. The Energy Innovation Centre at Warwick Manufacturing Group (WMG) and The Centre for Process Innovation are part of the High-Value Manufacturing (HVM)

[89] Government Office for Science. 'Rapid Technology Assessment: Novel Batteries.' 2023.
[90] Government Office for Science. 'Rapid Technology Assessment: Novel Batteries.' 2023.
[91] UK Research and Innovation. 'Faraday Battery Challenge.' 2023.
[92] The Faraday Institution. 'About the Faraday Institution.' 2023.
[93] Advanced Propulsion Centre UK. '£86.9 million for scale-up and R&D of net-zero vehicle technology'. 2023.
[94] Advanced Propulsion Centre UK. '£86.9 million for scale-up and R&D of net-zero vehicle technology'. 2023.

Catapult, which respectively provide a national facility for research across the R&D process and battery material development, scale-up, and recycling support. These two centres have recently received £12 million of funding for an Advanced Battery Materials Innovation Facility, which will allow for the synthesis, scale-up, formulation, and validation of novel active materials and solid-state electrolytes.[95]

Other examples of Government support for the manufacturing sector across the UK, more generally, include R&D tax credits worth £1.7 billion in 2021-22, contributing to over £11 billion in R&D expenditure by over 20,000 firms.[96] The UK has one of the world's leading EV battery start-up ecosystems, with the second highest enterprise value in Europe.[97] The Government has provided longstanding support to the automotive sector and has built a globally recognised 'research to manufacture' capability that provides funding from early-stage research, through mid-level development, to late-stage R&D as a launchpad to commercialisation.

The Government is committed to internationally competitive R&D tax reliefs. Following consultation, the current R&D Expenditure Credit (RDEC) and SME (small and medium sized enterprise) schemes will be merged from April 2024 onwards, simplifying the system and providing greater support for UK companies to drive innovation. Furthermore, the rate at which loss-making companies are taxed within the merged scheme will be reduced. The Government is also making changes to the additional support for R&D intensive SMEs. The intensity threshold will be reduced from 40% to 30% for accounting periods that start on or after 1 April 2024, allowing around 5,000 extra SMEs to qualify for an enhanced rate of relief, and a one-year grace period will be introduced to provide certainty for companies that dip under the 30% intensity threshold that they will continue to receive relief'. Taken together, changes announced at Autumn Statement 2023 will provide £280 million of additional relief per year by 2028-29 to help drive innovation in the UK.

University spin-outs are some of our most innovative companies and play a hugely important role for the UK economy. To capitalise on this strength, the Government is accepting all the recommendations of the Independent Review of Spin-outs and setting out how it will deliver them. Several universities and investors have already endorsed the recommendations of the review, and the Government will provide £20 million for a new cross-disciplinary proof-of-concept research funding scheme to help prospective company founders in our universities demonstrate the commercial potential of their research.

Key to the UK's success in automotive R&D and innovation is the certainty of funding, providing industry partners with the confidence that they will receive support throughout the product development cycle, from the drawing board to market. This coordinated and targeted approach has helped position the UK at the vanguard of the development of next-generation zero-emission vehicle technologies and future mobility solutions, providing a pathway to a future net zero automotive industry. Vehicle makers and major suppliers are leading collaborative R&D projects, supported by expertise from SME technology developers and academics from our global leading universities and research organisations.

At Autumn Statement 2023, the Government announced over £2 billion of new capital and R&D funding for five years to 2030, building on the work of the Automotive Transformation Fund and the Advanced Propulsion Centre R&D programmes. This will unlock investment in zero emission vehicle manufacturing, including gigafactories and the wider supply chain. It will

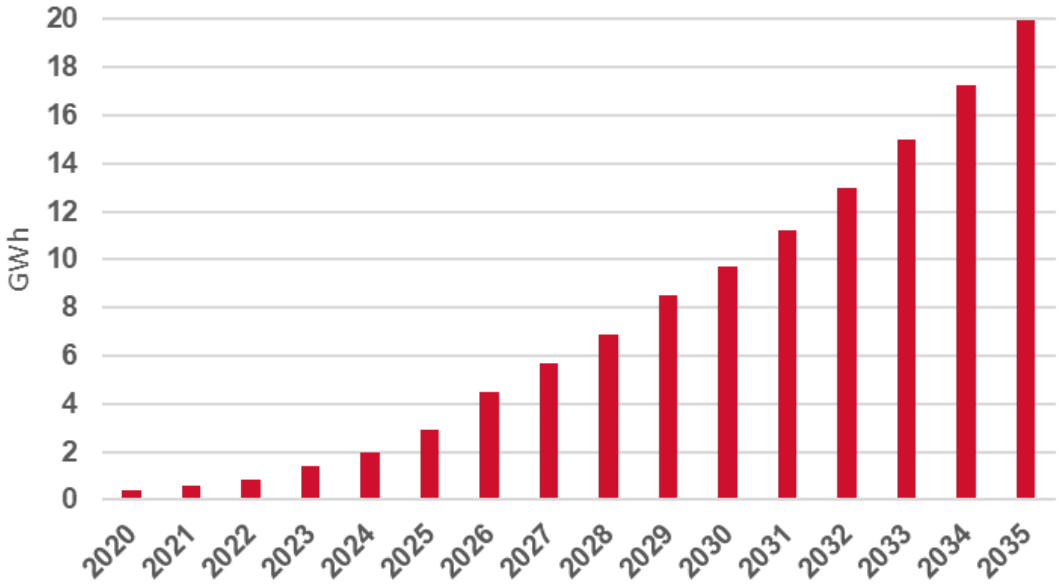
[95] Warwick Manufacturing Group. 'WMG in landmark battery development partnership'. 2023.
[96] HM Revenue and Customs. 'Research and Development Tax Credit Statistics.' 2023.
[95] UK Research and Innovation and Dealroom.co. 'Electric Vehicle Battery Tech in the UK'. 2023.

support R&D and the commercial scale up of strategically important zero emission vehicle technologies.

The UK automotive sector continues to invest heavily in R&D as it transitions to a zero-emission future. In 2020, the automotive sector invested £2.9 billion into R&D – 6.6% of total UK business R&D spend that year.[98] Leading vehicle makers including Ford, JLR and Nissan have substantial R&D centres and operations established in the UK. Newer market entrants, such as Polestar, have also set up and expanded their R&D operations to take advantage of the UK's world-renowned automotive engineering expertise.[99]

Beyond electric vehicles, the energy storage sector for grid balancing is showing increasing demand projections globally[100] and domestically.[101] As shown in Figure 6, demand is due to rise to nearly 10GWh by 2030, and double to 20GWh by 2035. The Government has supported the development of BESS through innovation competitions such as the recent longer duration energy storage demonstration (LODES), which made £69 million of capital funding available to start-ups and was open to novel battery technologies.[102]

Figure 6: UK Annual Demand Forecast for Stationary Storage (GWh by Year)



Source: BloombergNEF. 2023.

[98] Office for National Statistics. 'Business Enterprise Research and Development.' 2021.
[99] Polestar. Polestar accelerates global engineering capability as it doubles UK Research & Development team. 2021
[100] Wood Mackenzie. 'Global Energy Outlook.' 2023. .
[101] Rystad Energy. 'Charging Up: UK utility-scale battery storage to surge by 2030.' 2023.
[102] Department for Energy Security and Net Zero. 'Longer Duration Energy Storage Demonstration (LODES).' 2021.

Case Studies 1 and 2: Examples of longer duration energy storage demonstration (LODES) competition winners

Invinity Energy Systems

Invinity Energy Systems has been awarded £11 million for the VFB LEAD project to build a longer duration, large-scale vanadium flow battery (VFB) that will be deployed at a key node on the National Grid.[103] The battery will be the largest ever manufactured in the UK and will perform a broad range of grid balancing services, providing vital flexibility to the electricity network, and supporting the buildout of renewables. Invinity will manufacture the VFB at the company's factory in West Lothian, Scotland and the project is expected to go live in early 2025.

StorTera

StorTera has developed a sustainable, highly efficient, and highly energy dense lithium sulphur based single liquid flow battery (SLIQ) technology. In Phase 2 of LODES, StorTera will manufacture a prototype SLIQ that utilises a novel cylindrical cell architecture in a modular format to optimise the manufacture, installation, and maintenance of the system. With a focus on sustainability, and circularity, the SLIQ has been designed as a modular system that enables recovery and reuse of components at end of life. Towards the end of Phase 2, 8 SLIQ units will be combined to build a 200kW/1.6MWh first-of-a-kind demonstrator that will be installed at Midlothian Innovation Centre outside Edinburgh.[104]

The UK is also leading the way in the development of batteries for aerospace applications. The Aerospace Technology Institute (ATI) leads a £3.58 billion programme to 2025 jointly funded by the Government and industry that supports world-class R&D into sustainable flight innovations.[105] The ATI works closely with businesses and academia to develop technology roadmaps and strategies to accelerate aerospace electrification and keep the UK competitive in the global aerospace market. At Autumn Statement 2023, the Government announced £975 million is being made available for the aerospace sector[106], as part of our £4.5 billion manufacturing funding package[107], securing the UK's role as a global hub for aerospace production.

In March 2023, Vertical Aerospace was awarded £14 million in funding from the ATI to develop frontier battery technologies at its dedicated battery R&D facility, the Vertical Energy Centre. The project will increase the core capability of Vertical's battery system, improve recycling efficiency, and increase the scope of its use in additional markets.[108] In addition, in 2021 Rolls-Royce's 'Spirit of Innovation' aircraft achieved a new world record for an all-electric flight of 345.4mph.[109] The £6.9 million project, co-funded with £3.4 million from the ATI,[110] designed, built and flight-tested a high-performance electric powertrain featuring 6,000 battery cells.[111]

Cross-sector battery innovation is necessary to create the critical mass of research and supply chain development required to support the UK's battery industry, driving technical leadership in emerging areas where there is a compelling economic or strategic case.

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[103] Invinity. 'Invinity to Build Largest Grid-Scale Battery Ever Manufactured in the UK.' 2023.
[104] The Faraday Institution. 'Going with the Flow Could Help Energy Access in Emerging Economies.' 2023.
[105] Aerospace Technology Institute. 'Transforming aerospace through technology and innovation.' 2023.
[106] Aerospace Technology Institute. 'Government announces ATI Programme funding up to 2030'. 2023.
[107] GOV.UK. 'Billions of investment for British manufacturing to boost economic growth'. 2023.
[108] Vertical Aerospace. 'Vertical Announces the Opening of the Vertical Energy Centre.' 2023.
[109] Rolls Royce. 'Spirit of Innovation Stakes Claim to be the World's Fastest All-Electric Vehicle'. 2023.
[110] Rolls Royce. 'Rolls-Royce's all-electric Spirit of Innovation takes to the skies for the first time'. 2021.
[111] Rolls Royce. 'Spirit of Innovation: Electrifying Flight'. 2023.

We will continue providing sustained, consistent, and targeted support for large-scale, long-term research and innovation activities, from early to late stage, across applications and key areas of the battery supply chain to ensure that the UK's battery ecosystem continues to thrive. This includes £2 billion of new capital and R&D funding for zero emission vehicles, batteries, and their supply chains for five years to 2030.

We will invest £50 million in developing the UK's battery world-class capabilities, from R&D to industrialisation. We will enhance the UKBIC development facilities, boosting its capability for research and development in new chemistries and future technologies, building on our know-how in lithium-ion solutions and enabling the scale-up of emerging innovations. We will also invest in an Advanced Materials Battery Industrialisation Centre, a new world-class battery materials scale up facility in the West Midlands and North East to bridge the gap between laboratory research and commercial production.

We will invest £11 million in 20 competition winners developing technologies across the battery value chain in areas such as artificial intelligence and digital tools to increase battery performance, future technologies such as lithium-metal anodes and sodium-ion batteries, and improved recycling technologies. This brings the overall budget of the Faraday Battery Challenge to £610 million since 2017.

We will explore opportunities to promote the establishment of R&D centres in the UK by leading battery and EV manufacturers. These centres hold a significant role in regional and global product development and in providing collaboration and market opportunities for scaling businesses. The Government is committed to building a pipeline of technology that will enable the UK to remain competitive and future-proof our manufacturing industry.

Access to Scale-Up Finance

With over half of the value of our start-up ecosystem concentrated in companies founded since 2015,[112] there is a significant opportunity to scale up these technology start-ups in the UK. Businesses and the Taskforce both highlighted UK strengths in obtaining funding for early-stage research and prototype development, but difficulty in obtaining follow-on finance to de-risk and grow these innovative firms from pre-revenue to manufacture. The importance of having a suite of innovative financing options, including cornerstone investment and guarantees for established and growing firms was also underlined.

Government-backed finance options are available through the British Business Bank (BBB), UK Infrastructure Bank (UKIB) and UK Export Finance (UKEF) to help UK companies develop and scale their business.

[112] UK Research and Innovation and Dealroom.co. 'Electric Vehicle Battery Tech in the UK'. 2023.

The British Business Bank works with, and through, the market to provide smaller businesses with access to finance and information. They gather market insight and use evidence to identify market gaps and act in a commercially minded way to address them. In doing so, they seek to leverage private sector capital alongside Government money to increase the impact they can deliver for smaller businesses. The BBB delivers a wide range of finance programmes, each designed to address a specific market failure while helping to improve access to finance for smaller businesses. Several BBB schemes are helping to build up the battery supply chain in the UK, supporting firms like battery designer and manufacturer Alexander Technologies.[113]

The UK Infrastructure Bank invests in projects that generate a financial return, crowd-in significant private capital over time, and deliver against one or both of its strategic objectives of tackling climate change and promoting regional and local economic growth. It offers project and corporate finance and can invest across the capital structure, including debt, debt guarantee and equity products. In September, UKIB published a strategy update setting out its offer for short duration BESS, which includes a mezzanine loan product that aims to increase the pool of banks willing to lend to these projects.[114] UKIB also aims to support the development of markets for long duration storage, including by taking greater risk than private investors, to help ensure first-of-a-kind projects are delivered. Additionally, UKIB invests in projects in cell manufacturing and the critical minerals supply chain. For example, in August 2023, UKIB announced a £24 million equity investment in Cornish Lithium.[115]

UKIB has announced a £60 million loan to support Pacific Green to develop a new 249MW/374MWh electricity storage park which, once completed, will be one of the largest standalone battery storage projects in the country.[116]

UK Export Finance, the UK's export credit agency, offer loans, guarantees and insurance to help grow UK exports. To date, UKEF's working capital loan guarantees have been utilised by UK automotive companies including JLR[117] and Ford[118] to help finance their transition to EV manufacturing. UKEF's guarantees can help other parts of the automotive supply chain to access finance in order to stimulate existing and future UK exports. UKEF also supports SMEs with working capital facilities to help them grow their business and secure new export contracts.

Case Study 3: AceOn battery energy storage system exports

UKEF recently announced £300,000 of support for Telford-based battery manufacturer AceOn.[119] UKEF's support, offered through a guarantee to non-bank lender Newable, was crucial in them securing a new export contract to supply batteries to a Portuguese manufacturer of solar energy and energy storage technologies. UKEF's General Export Facility Scheme was their most used product in 2022-23 and unlocked over £325 million in working capital loans for UK exporters last year.[120]

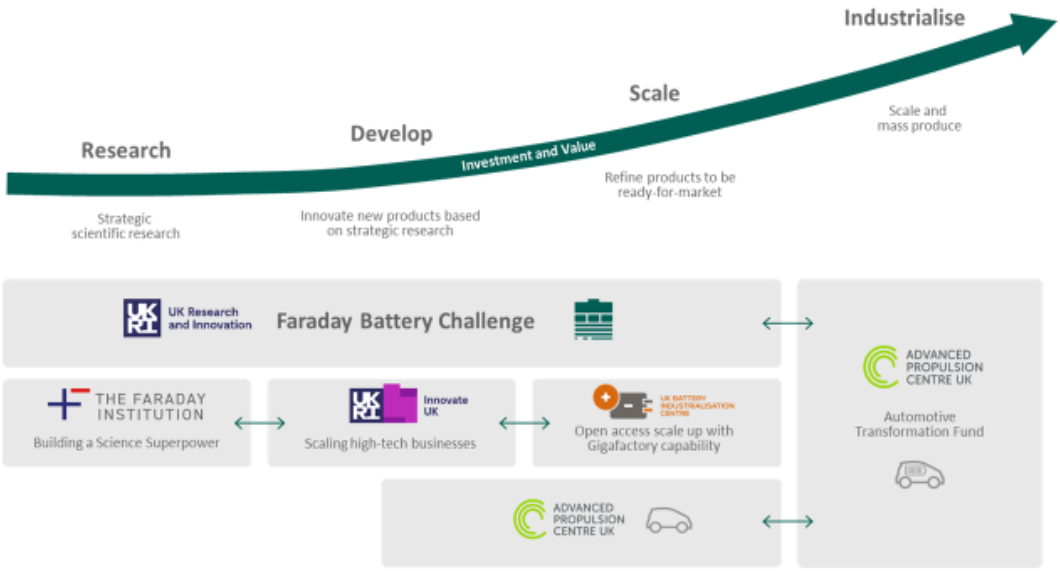
[113] British Business Bank. 'Case Studies: Alexander Technologies.' 2023.
[114] UK Infrastructure Bank. 'Strategy Update: Private Sector Investments.' 2023.
[115] UK Infrastructure Bank. 'Bank Invests to Strengthen Domestic Lithium Supply Chain and Boost Cornish Economy'. 2023.
[116] UK Infrastructure Bank. 'Bank investment provides significant boost to UK battery storage sector.' 2023.
[117] UK Export Finance. '£500 million loan guarantee supports Jaguar Land Rover's electric vehicle plans.' 2022.
[118] UK Export Finance. 'Ford accelerates electric car production with UK Government support.' 2022.
[119] UK Export Finance. 'Government Support Unlocks £300k for AceOn's Energy Transition Ambitions'. 2023.
[120] UK Export Finance. 'Annual Report and Accounts 2022-2023.' 2023.

Capital in this rapid-growth industry is internationally mobile and the UK operates in a competitive regulatory and subsidy landscape. The Government has published Lord Harrington's Review of our approach to attracting foreign direct investment alongside Autumn Statement 2023, responding and accepting his headline recommendations in principle. A new Ministerial Investment Group will be established, tasked with driving the Government's ambition on investment. This will be backed by additional resource and an improved toolkit for the Office for Investment, allowing it to deepen its world-class concierge offer to strategically important investors.

Success will require incentivising investment in large-scale capital projects through Government-backed support programmes that are predictable and sustained. We need to ensure that the current UK offer, as shown in Figure 7, is addressing the key barriers to investment and market failures in the battery supply chain as it develops. The Government will work with key public finance institutions to review their offering across advanced manufacturing sectors, with a view to identifying any potential gaps and opportunities for further interventions. We will consider taking a blended risk approach, creating a balanced portfolio that includes not just established companies but also new entrants at the technological frontier. Blended finance approaches offer an opportunity to mobilise private investment into key sectors for the net zero transition. The government has committed to exploring the use of blended finance approaches ahead of the next spending review and recently announced funding to deliver the Net Zero Blended Finance Project (NZBFP). We will assess how novel financial instruments could potentially be tested, adopted, and offered over suitably long periods where existing ones cannot satisfy demand.

Working with Public Finance Institutions and engaging businesses and investors, we will better understand these approaches and ensure public investment crowds in significant private finance. The Government is committed to seizing the opportunity for the UK to become a world leader in green finance.

Figure 7: UK Battery Grant Support Eco-System



Source: UK Research and Innovation. 2023.

We will explore the case for new financial mechanisms to support start-ups in critical technological areas such as battery technologies, allowing them to scale, including through public/private equity investment with government seed funding. This will include looking at existing proposals by organisations such as the Green Finance Institute.

Battery Safety

There is growing interest in the safety of lithium-ion batteries following an increase in incidents and, sadly, fatalities, in relation to non-industrial batteries for e-scooters and e-bikes. Current evidence does not suggest that electric vehicle fires are more likely to occur than in petrol or diesel road vehicles and, whilst the use of lithium-ion batteries is rising, the frequency of failure remains low.[121] However, the increasing demand and use of batteries means greater attention is being paid to their safety.

Safety emerged as a prominent concern for respondents in the Call for Evidence, who noted that, even though industry has responded accordingly, local authorities still reportedly seek greater fire safety measures. [122] Across Government, an urgent programme of work is being carried out by key departments including the Office for Product Safety and Standards in the Department for Business and Trade, the Home Office, and the Department for Transport to understand why fire incidents occur and deliver the right policy and regulatory interventions to tackle safety risks. Officials have engaged with stakeholders including Electrical Safety First, the Fire and Rescue Services, the National Fire Chiefs Council, and the London Fire Brigade - including their Scientific Advisers.

The UK has a strong health and safety and regulatory framework covering the breadth of different batteries. Across Government, work continues on the issues of battery safety and

[121] Swedish Civil Contingencies Agency. 'Fires in Electric Vehicles in 2022.' 2023.
[122] See Annex II

regulatory enforcement, including the Maritime & Coastguard Agency (MCA), National Fire Chiefs' Council, National Police Chiefs' Council, Health & Safety Executive (HSE) and others.

Technical activities affecting battery standardisation constitute a key area of ongoing work, which is being led by the British Standards Institution (BSI). Between 2019-2021, BSI spearheaded a standards programme with the Faraday Battery Challenge, engaging a range of industry stakeholders from OEMs, academia, Government, fire experts, and trade associations. Their efforts resulted in the development of a standards landscape document,[123] three Publicly Available Specifications (PASs) on health and safety and environmental considerations,[124] a base document for the safe storage of lithium-ion batteries,[125] and a strategic roadmap for future standards and standards uptake activities.[126] The document addresses the need for detailed and systematic guidance on fire risk management across the battery lifecycle. BSI continues to engage with the battery manufacturing industry in the UK and participates in various international technical committee activities.

Large battery manufacturing and recycling facilities can pose risks due to the presence of dangerous chemicals, which may mean they have to comply with COMAH (Control of Major Accident Hazard Regulations 2015).[127] Sites in scope of COMAH may be checked for compliance by the Health and Safety Executive's (HSE) Competent Authority partners. Batteries used in challenging locations (such as offshore or in mines) can pose higher risks, and HSE requires additional measures including a detailed risk assessment and consideration of appropriate mitigations to prevent, detect and respond to battery failure. The Government has also set up an industry-led electricity Storage Health and Safety Governance Group to ensure that an appropriate, robust, and future-proofed health and safety framework is sustained as the industry develops and electricity storage deployment increases.[128]

In addition, the Government's Planning Practice Guidance has been updated to encourage grid-scale battery storage developers to engage with local fire and rescue services before submitting a planning application.[129] This allows them to identify and address any siting or location issues before applications are made. Local planning authorities refer to the guidance on BESS published by the National Fire Chiefs Council for consideration when determining applications and consult with local fire and rescue services before issuing decisions. The Government have also committed to consult on including BESS in the environmental permitting regulations at the earliest opportunity.

It is vital that the UK continues to support research on the safety implications of emerging battery chemistries and the consequences of mismanaging them. In 2021, the Faraday Institution launched the SafeBatt research programme, which aims to understand the causes of battery failure, investigate the chemical processes that result in adverse impacts, and develop new tools that enhance the safety and reliability of batteries.[130]

As well as the safety of the wide range of products that use batteries, the Call for Evidence responses highlighted the need for the UK to continue to invest in safety in production,

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[123] British Standards Institution. 'Standards Landscape Report.' 2023.
[124] British Standards Institution. 'Faraday Battery Challenge.' 2023.
[125] British Standards Institution. 'BSI Faraday Battery Challenge: Workshop 2.' 2023.
[126] British Standards Institution. 'Faraday Battery Challenge: Battery Manufacturing and Technology Standards Roadmap.' 2023.
[127] Health and Safety Executive. 'Control of Major Accident Hazards Regulations 2015 (COMAH).' 2015.
[128] Department for Energy Security and Net Zero. 'Electricity Storage Health and Safety Standards: Gap Analysis.' 2023.
[129] Department for Levelling Up, Housing and Communities. Renewable and low carbon energy – Guidance. 2023
[130] The Faraday Institution. 'SafeBatt: Science of Battery Safety.' 2023.

including end of first life handling.[131] This necessitates that businesses invest in specialist and technical skills to handle EV battery packs as well as safely storing, transporting, and processing waste batteries. The UK has expertise and a large labour pool (2.6 million in manufacturing as a whole) [132] that could re-skill and up-skill in battery technologies, including in their safety. The Health and Safety at Work Act places legal duties on employers to manage risks to employees and anyone else who may be affected by their work activities, and to develop improved ways of working if required to protect employees.[133]

The Government will continue to prioritise cross-departmental work into the ongoing safety of industrial-scale batteries.

[131] See Annex II
[132]Office for National Statistics. 'JOBS03: Employee Jobs by Industry.' 2023; Office for National Statistics. 'JOBSO4: Self-Employment Jobs by Industry.' 2023.
[133] Health and Safety Executive. 'Health and Safety at Work Act 1974.' 1974.

Build

The battery sector is one of the highest growth clean energy sectors[134] and the UK is well placed to reap the rewards thanks to its comparative advantage in research and automotive manufacturing.

The Government is committed to making the UK one of the best places in the world to build and invest. At Autumn Statement 2023, the Government announced that it is making full expensing of plant and machinery investment permanent, supporting businesses to invest and grow by allowing them to write off the full costs against their taxable profits. This significant reform makes the UK's plant and machinery capital allowances regime one of the most generous in the world.

Drawing from the responses received through the Call for Evidence[135], we will build up the battery sector, secure a resilient UK battery manufacturing supply chain, and remove barriers to investment by:

d. Strengthening the resilience of UK **supply chains** including through the Automotive Transformation Fund and the UK Critical Minerals Strategy.

e. Building on our extensive **international collaboration** work with our partners to open new markets.

f. Continuing to support **energy intensive industries** and speeding up **energy grid connections.**

g. Ensuring **planning and permitting** reform actions will benefit the emerging battery sector.

Supply Chains

As highlighted in businesses' responses to the Call for Evidence,[136] the rapid growth of global battery demand and other net zero enabling technologies is putting pressure on the global upstream (critical minerals) and midstream supply chains. The Government is already responding to this challenge by working to ensure that the supply chains for net zero are secure and that the UK's clean growth sectors have access to the critical inputs that are essential to their success. A further challenge comes from securing battery manufacturing equipment, as global demand has led to proven suppliers receiving an unprecedented number of orders from the new gigafactories, challenging the UK's ability to scale up capacity. Across the value chain, prices and waiting times have increased as countries race to shift their industrial capacity towards making batteries. These challenges are amplified by the highly concentrated nature of many of the resources and critical inputs needed for battery production, which increases supply chain vulnerability.

We rely on a consistent and predictable flow of goods and raw materials to support our battery industry. This is contingent on an effective trading system which provides a diverse supply base. The UK and others benefit from an open international trading system and our priority is to work with allies and partners to promote it.

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[134] McKinsey Battery Insights Team. 'Battery 2030: Resilient, Sustainable and Circular'. 2022.
[135] See Annex II
[136] See Annex II

Government is already taking action to secure critical goods and build resilience into international supply chains. We have published the UK's Supply Chains Resilience Framework, which highlights five areas to be explored when reducing dependencies in supply chains.[137] We have also worked with the National Protective Security Authority and the Chartered Institute of Procurement and Supply to develop and publish a set of guidance materials. These will provide businesses with tools to help them gain greater understanding of their supply chains and manage risks and future shocks.[138]

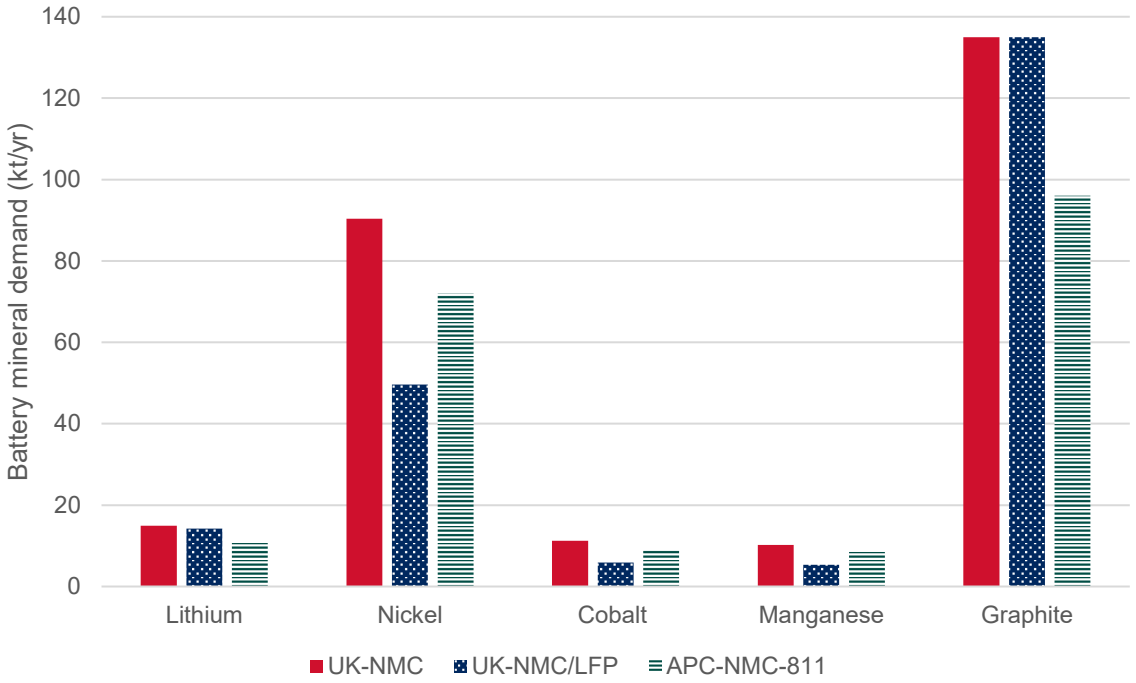
Critical Minerals

The UK's demand for critical minerals is set to increase significantly by 2030. According to an estimate from the UK Critical Minerals Intelligence Centre (CMIC) in 2022, battery manufacturers in the UK could require approximately 15,000 tonnes of lithium, 90,000 tonnes of nickel, 11,000 tonnes of cobalt, 10,000 tonnes of manganese, and 135,000 tonnes of graphite annually by 2030.[139] This is shown as the UK-NMC scenario in Figure 8 and is based on the various battery chemistries that the announced UK gigafactories in 2022 planned to produce, which mainly had a high nickel content.

Supply shortfalls in these battery minerals are anticipated. The future demand for critical minerals depends on developments in battery chemistries, energy density, the EV market, critical mineral costs, and technological advancements - hence, multiple scenarios could occur.[140] Figure 8 also shows two other scenarios to highlight this uncertainty. The UK-NMC/LFP scenario models a shift to 50% production of NMC batteries and 50% production of LFP batteries, which do not require nickel, cobalt nor manganese. The APC-NMC-811 scenario is based on the APC predictions of vehicle production and assumes all batteries produced are NMC with a high nickel content (80%). These results are lower than the UK-NMC scenario because of the difference in total assumed production - since the APC only considers demand for EV batteries. More detail on critical mineral demand modelling can be found in Annex III.

[137] Department for Business and Trade and others. 'Supply Chains Resilience Framework.' 2022.
[138] National Protective Security Authority. 'Supply Chain Guidance.' 2023.
[139] See Figure 8: Estimated Annual UK Demand for Battery Minerals by 2030.
[140] See Figure 8: Estimated Annual UK Demand for Battery Minerals by 2030.

Figure 8: Estimated Annual UK Demand for Battery Minerals in 2030



Source: UK Critical Minerals Intelligence Centre. 'Study on future demand and supply of lithium, nickel, cobalt, manganese and graphite for electric vehicle batteries.' British Geological Survey. 2022.

Notes: The UK-NMC (nickel, manganese, and cobalt) scenario is based on the various battery chemistries that the announced UK gigafactories planned to produce at the time, which are mainly high nickel content batteries.

The UK-NMC/LFP scenario assumes a major shift towards LFP (lithium, iron, and phosphate) batteries with the planned gigafactories producing 50% LFP batteries and 50% NMC batteries.

The third demand scenario (APC-NMC-811) is based on forecasts of UK light duty electric vehicle production and assumes all cells have a nickel-rich composition (80% nickel, 10% manganese and 10% cobalt).

To tackle these challenges, the UK's Critical Mineral Strategy sets out the Government's plans to accelerate the growth of domestic capabilities, collaborate with international partners, and enhance international markets to make them more responsive, transparent, and responsible.[141]

The Government provides direct support to firms developing domestic mining capabilities, with the Automotive Transformation Fund playing a key role. Since 2019, British Lithium has received government R&D grants totalling £5.5 million to assist with the development of their proprietary process for sustainable production of lithium from Cornish granite. With the assistance of a Small Business Research Initiative grant in 2021, British Lithium built a state-of-the-art lithium pilot plant which successfully produces and refines battery-grade lithium carbonate. This is currently working under a £2 million Scale-up Readiness Validation grant from the ATF.[142] The Imerys-British Lithium joint venture proposes the construction of an integrated quarry, beneficiation plant and refinery in Cornwall to produce 20,800 tonnes of lithium carbonate per year – enough for 500,000 electric vehicles for at least 30 years.[143] This forms part of the funding that the ATF is investing in late-stage R&D and industrialisation

[141] Department for Business and Trade and others. 'UK Critical Minerals Strategy'. 2023.
[142] Imerys. 'Imerys and British Lithium Joint Venture.' 2023.
[143] Advanced Propulsion Centre UK. 'Automotive Transformation Fund.' 2023.

projects that facilitate the development of an internationally competitive zero-emission vehicle supply chain in the UK.

The UK Infrastructure Bank has also provided support to major projects that strengthen our access to critical minerals. In August 2023, UKIB announced a £24 million equity investment in Cornish Lithium for its Trelavour hard-rock lithium extraction project.[144] This is part of a larger funding package of up to an additional £168 million in potential second-stage financing to improve the UK's domestic supply of lithium for the manufacture of EV batteries.[145]

In addition to building domestic capability, the Government is working to strengthen the resilience of global critical mineral supply chains through international collaboration. The Government has signed international critical mineral agreements with seven countries: Australia, Canada, Japan, Kazakhstan, Saudi Arabia, South Africa, and Zambia, to help diversify supply chains and increase the UK's security of supply. Each agreement leverages the UK's strengths in mining services, finance, and R&D, and seeks to build high environmental, social, and governance standards.

In the process of diversification of supply chains, we want the UK to contribute its expertise in responsible mining and enable UK businesses to play a role in the development of global supply. Whilst the participation of UK companies in the supply chains does not necessarily guarantee supply to the UK, it acts to positively influence security of supply through financial and commercial relationships, as well as shared values between producers and downstream manufacturers.

However, the UK will not sponsor or support the issuing of any deep-sea extraction licences until sufficient scientific evidence is available to assess the potential impact of deep-sea mining activities on marine ecosystems and strong, enforceable environmental regulations, standards and guidelines have been developed and adopted by the International Seabed Authority (ISA). An announcement supporting a moratorium on granting of exploitation licences for deep sea mining by the ISA was made on 30 October 2023.[146]

We will expand market access for the trade of critical minerals and promote high international standards in supply chains when negotiating new Free Trade Agreements.

The Government is engaging with UK mining, mining finance and metals trading communities to facilitate and encourage greater private sector capital investment in critical mineral projects along the value chain. This is helping position the UK as a global centre of responsible mining finance. The UK is also leveraging engagement with our international partners to promote and secure opportunities for UK companies overseas through trade missions. In addition, we are assessing the need for further financing support in relation to critical minerals, and considering options for how any gaps identified might be addressed. This includes assessing the role that UKEF could play where finance is needed and there is a clear link to exports.

Further information on the Government's international approach is set out in the International Collaboration section.

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[144] UK Infrastructure Bank. 'Bank invests to strengthen domestic lithium supply chain and boost Cornish economy.' 2023.
[145] UK Infrastructure Bank. 'Bank invests to strengthen domestic lithium supply chain and boost Cornish economy.' 2023.
[146] See Department for Business and Trade. 'UK supports moratorium on deep sea mining to protect ocean and marine ecosystems.' 2023.

Midstream

Before entering the battery manufacturing process, critical minerals need to first undergo transformations to be turned into active materials for cathodes and anodes. At present, China is the world's main critical mineral refiner, including for minerals which do not have a domestic source in China.[147] China processes 57% and 65% of all lithium and cobalt respectively and produces 69% of cathode active materials.[148] Of the latter, only 5% of global supplies are produced outside of East Asia.[149] Even though China imports 85% of its needle coke feedstocks for synthetic graphite production from the US and the UK, it produces nearly 100% of synthetic graphite used in anodes globally.[150] Given that cathodes and anodes make up the majority of the value of a cell,[151] establishing UK domestic production of these components, and their precursors, is a priority.

The UK has strong chemicals and metals sectors with the potential to establish globally significant capabilities in critical minerals refining and processing. For example, Vale's Clydach refinery based in the South Wales Industrial Cluster is the only high purity nickel refinery in the UK and one of the largest in Europe,[152] and makes high purity nickel products that can be utilised in cathode production. Secondly, the Phillips 66 Humber Refinery in North Lincolnshire, is Europe's only manufacturer of speciality-grade petroleum coke, a key input in the manufacturing of synthetic graphite for battery anodes.[153] Building on these existing capabilities to produce cathodes and anodes could boost the UK battery ecosystem.

Cathode and anode production present a distinct opportunity for the UK to leverage its established talent and expertise in minerals refining. Cathodes contain the most valuable chemicals in a battery, making up over a third of the value of a cell, according to the Faraday Institution.[154] Domestic cathode and anode production would help ensure that the UK's gigafactories have a secure supply of active materials while simultaneously supporting UK manufacturers and their efforts to meet the Rules of Origin requirements in the UK-EU TCA. There is work already underway towards securing the UK's international competitiveness in the field of advanced battery materials production including both in cathodes and anodes.

To further support investment in chemicals processing for the EV battery supply chain, the Government makes funding available through the ATF. Recent projects include:

1. Aberdeen Minerals – received a £294,000 grant in October 2023 for its feasibility study into innovative and environmentally-responsible methods to accelerate the production of cathode materials.[155] This forms part of a broader package of Government and industry funding through the APC for zero emission vehicle technologies.[156]
2. Green Lithium – secured £14.1 million of funding to date, including £3.8 million in UK Government grants won across 2022-23, to support its plans to build and operate a

[147] Center for Strategic and International Studies. 'Building larger and more diverse supply chains for energy minerals.' 2023.
[148] EY. 'De-bottlenecking the battery materials midstream.' 2023.
[149] EY. 'De-bottlenecking the battery materials midstream.' 2023.
[150] EY. 'De-bottlenecking the battery materials midstream.' 2023.
[151] Benchmark Mineral Intelligence. 'Battery Cathode Prices Rise for First Time This Year as Lithium Costs Increase.' 2023.
[152] Vale. 'Transforming the future: Vale in Wales, UK.' 2023.
[153] Phillips 66. 'Specialities'. 2023.
[154] See Figure 5: Approximate Value of Lithium-Ion Battery Pack Components
[155] Aberdeen and Grampian Chamber of Commerce. 'Aberdeen Minerals awarded UK Government grant for Aberdeenshire battery metals project.' 2023.
[156] Advanced Propulsion Centre UK. '£86.9 million for scale-up and R&D of net-zero vehicle technology.' 2023.

large-scale merchant lithium refinery in Teesside, which will employ a sustainable process with a carbon footprint that is 75% lower than the traditional process currently used internationally. Once fully operational, the refinery will produce 50,000 tonnes of battery-grade chemicals annually, enabling the production of approximately 1.2 million EVs.[157]

3. Echion Technologies – received a £450,000 grant in June 2022 for its feasibility study into the commercialisation of a new generation of anode materials that could enable battery charging in less than 6 minutes.[158] Echion Technologies spun-out of Cambridge University in 2017 and its Project SHARP will inform the company's high volume anode manufacturing strategy, including preparation of a roadmap for rapid deployment.[159]

The Government's 2023 Advanced Manufacturing Plan will build on the work of the Advanced Propulsion Centre and the Automotive Transformation fund and further strengthen the resilience of the UK battery supply chain.

We will continue to provide targeted support for zero emission vehicles, batteries, and their supply chains, including through over £2 billion of new capital and R&D funding for five years to 2030. This will allow us to take advantage of our potential in the growing battery materials midstream.

The chemicals sector will also be critical for recycling and recovering valuable materials from end-of-life batteries. This not only reduces waste, but also alleviates pressure on primary supply. Importantly, the chemicals sector can provide a key link to enable domestic critical mineral recovery from battery recycling, as precursor and active material producers could directly source the feedstocks they need from recyclers. The Circular Economy section explores battery recycling, as well as reusing and repurposing, in more depth.

Manufacturing Equipment

Turning active materials into cells at gigafactories requires highly specialised equipment in a clean room, with a tightly controlled environment. Every stage of the process, from mixing and coating to electrolyte filling and aging, necessitates sophisticated systems that incorporate robotics, automation, and digitalisation to guarantee precision and safety. This makes battery manufacturing a relatively more complex process compared to conventional manufacturing. Access to reliable manufacturing equipment is an integral part of the battery industry, as it enables efficient production, ensures product quality, and positions manufacturers for growth and competitiveness.

The market for battery manufacturing equipment is highly concentrated and localised. China, South Korea, and Japan dominate the market, with only modest European capacity, primarily in Germany and Austria.[160] A 2022 report by McKinsey found that most of established suppliers are already operating at more than 95% capacity, with demand expected to rise as new

[157] Green Lithium. 'Green Lithium's 50,000 tonne output merchant refinery to be commissioned in the near future.' 2022.
[158] Echion Technologies. 'Echion scales-up production of Mixed Niobium Oxide (XNO) battery materials to meet increasing commercial demand.' 2023.
[159] Department for Business, Energy and Industrial Strategy. 'Electric motorbikes and off-road trucks to unlock growth and jobs across the UK.' 2022.
[160] McKinsey and Company. 'Unlocking the Growth Opportunity in Battery Manufacturing Equipment.'2022.

gigafactory projects are announced worldwide.[161] As a direct consequence, industry stakeholders generally report lead times of around 12 to 24 months, with lead times specifically for electrode coating equipment and high-volume cell assembly currently exceeding 24 to 30 months from receipt of order.[162] This results in significant delays to scaling up operations that are already affecting UK battery manufacturing capacity.

The complex nature of battery manufacturing equipment and its limited supply make it notoriously expensive. Stakeholders reported that, at the pilot stage, firms can expect to spend at least £500,000 in equipment, with numbers rising rapidly as they grow to gigafactory scale.[163] According to the APC, gigafactory construction costs are benchmarked at approximately £85 to 100 million per GWh of capacity, with around 40 to 60% of the cost relating to process equipment alone.[164] While high quality equipment represents a significant expenditure, it is also a source of efficiency, presenting opportunities for process optimisation and energy cost reductions at every stage. This was reflected in the Call for Evidence, in which respondents asserted that investment in technological innovation must extend beyond battery chemistries to manufacturing and process R&D to capitalise on these gains.[165]

Despite these challenges, battery manufacturing equipment presents an opportunity for UK innovators and machinery businesses that will only grow as demand for batteries – and batteries of different chemistries – increases worldwide. Entry into this burgeoning market would support the long-term sustainability of the UK battery sector and help avoid risks associated with long lead times for equipment, as well as risks should machinery supplies be disrupted at any point. UK equipment manufacturers could leverage their existing machinery and expertise from similar processes to pivot into this market.

International Collaboration

The Government's *Integrated Review Refresh 2023: Responding to a more contested and volatile world* recognises that cultivating UK strengths in green industries is "foundational to our ability to protect and advance our interests".[166] The battery sector is one of the fastest growing areas of green industrial development, so it is essential that the UK continues to leverage its strengths including its openness, world-class educational and R&D institutions, and investment in innovation.

In the Call for Evidence, businesses and stakeholders highlighted the importance of the UK's international collaboration work in supporting a competitive battery sector.[167] In particular:

- multilateral and plurilateral frameworks to promote free trade and high environmental standards (covered in the Green Trade section below);
- strategic partnerships with our likeminded partners that strengthen clean energy supply chains, including for batteries;
- trade agreements that open new markets and remove trade barriers to increase supply chain resilience; and

[161] McKinsey and Company. 'Unlocking the Growth Opportunity in Battery Manufacturing Equipment.' 2022.
[162] Internal Analysis by Advanced Propulsion Centre UK and The Faraday Institution.
[163] Internal Analysis by Advanced Propulsion Centre UK and The Faraday Institution.
[164] Internal Analysis by Advanced Propulsion Centre UK and The Faraday Institution.
[165] See Annex II
[166] Cabinet Office. 'Integrated Review Refresh 2023: Responding to a more contested and volatile world.' 2023.
[167] See Annex II

- international research collaborations on new battery technologies and innovation to improve UK manufacturing processes and products.

Strategic Partnerships

Strategic partnerships set the framework for cooperation with our partners and allies. This enables mutually beneficial technology transfer, cooperation on supply chain resilience and innovation collaboration. A recent example is the 'Atlantic Declaration for a Twenty-First Century US-UK Economic Partnership,'[168] which committed to cooperation on diverse, resilient, and secure critical mineral and battery supply chains, including negotiations on a Critical Minerals Agreement.

Case Study 4: Commitments advanced in the US-UK Atlantic Declaration:[169]

- We are committed to deepening cooperation to develop and strengthen clean energy supply chains, including building diverse, resilient, and secure critical mineral and battery supply chains that reduce unwanted strategic dependencies to meet our defence, economic, energy security, and climate goals.
- We have progressed negotiations on a targeted critical minerals agreement covering the five relevant critical minerals most important for electric vehicles – cobalt, graphite, lithium, manganese, and nickel. Negotiations aim to agree that those which are extracted or processed in the United Kingdom count toward sourcing requirements for clean vehicles eligible for the Section 30D clean vehicle tax credit of the Inflation Reduction Act.
- We intend to conduct public-private consultation across key clean energy supply chains, including offshore wind and electric vehicle batteries, and conduct rapid stress-test exercises across key clean energy supply chains, which could form a model for future work on supply chain resilience.

The UK also has strong bilateral partnerships on battery supply chains and innovation with other G7 nations. In March 2023, the UK and Canada signed a landmark agreement to cooperate on critical minerals and boost green technology supply chains.[170] Japan is a key partner for the UK on batteries, offering opportunities in policy exchange, R&D, and industry partnerships. This year, the UK and Japan have signed a Memorandum of Cooperation on Critical Minerals that bolsters both countries' energy security and progress towards net zero.[171] Furthermore, the UK is negotiating a critical minerals agreement as part of the UK-Korea Accord.

On 13 October 2023, PM Rishi Sunak, jointly with Norwegian PM Jonas Gahr Store, formally launched their joint ambition to develop a Green Industrial Partnership. This will be a cross-cutting effort with the aim of deepening cooperation on the green transition, benefitting supply chains and supporting skills in low carbon sectors. Importantly, it will include collaboration on low emission transport and EV batteries.

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[168] Prime Minister's Office and others. 'The Atlantic Declaration.' 2023.
[169] Prime Minister's Office and others. 'The Atlantic Declaration.' 2023.
[170] Government of Canada. 'Joint Statement of Intent between Canada and the United Kingdom on Collaboration on Critical Minerals.' 2023.
[171] Department for Business and Trade. 'UK-Japan Critical Minerals Memorandum of Cooperation.' 2023.

Free Trade Agreements

The UK's Free Trade Agreements reduce barriers and deepen trade relations in geographies critical to battery supply chains. These agreements enable UK battery manufacturing and circular economy firms to have access to global supply chains, allowing them to specialise in high economic value adding activities where the UK has a comparative advantage. Recent examples include:

- **UK-Australia Free Trade Agreement** – Signed in 2021 and coming into force at the end of 2023,[172] the UK-Australia FTA reduces barriers to trade – including in critical minerals – with an estimated £10.4 billion in economic benefits for the UK by 2035.[173] Australia produces lithium, nickel, manganese and cobalt, and is looking to identify and promote strategic investments in the battery sector. The UK further deepened its partnership, signing a Critical Minerals Statement of Intent that offers significant opportunities for the emerging UK battery supply chain.[174]
- **The Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP)** – The UK concluded negotiations to join the CPTPP on 31 March 2023 and signed the Protocol of Accession on 16 July 2023.[175] Entry into force of the agreement is expected in the second half of 2024, once the UK and CPTPP parties have finished their legislative processes. UK manufactured goods exported to CPTPP were worth £24.6 billion in 2022[176], and could increase by over £1 billion in the long run, with the motor vehicles sector seeing the largest increase in exports worth £712 million.[177]

R&D Collaboration

The UK has a strong history of global R&D collaboration through international programmes and bilateral partnerships. As the UK expands its battery capacity, researchers and engineers are engaging with international partners to refine manufacturing, reuse, and recycling processes, and create the next generation of battery technologies.

Case Study 5: UKBIC and Fraunhofer Institute Memorandum of Understanding

UKBIC signed a Memorandum of Understanding (MoU) with Germany's Fraunhofer Research Institution for Battery Cell Production in May 2022.[178] The MoU assesses the potential for cooperation across key areas, including joint participation in European R&D consortia and strategically important projects, the development of a European battery technology roadmap, sharing best practice and experience of cell production, and championing of innovation and technology in battery cell production.

[172] Department for Business and Trade. 'UK-Australia Free Trade Agreement: Collection'. 2023.
[173] Department for International Trade. 'Impact Assessment of The Free Trade Agreement between the United Kingdom of Great Britain and Northern Ireland and Australia.' 2021.
[174] Australian Government Department of Industry, Science and Resources. 'Australia and UK Sign Statement of Intent to Support Critical Minerals Sector.' 2023.
[175] Australian Government Department of Foreign Affairs and Trade. 'Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP).' 2023.
[176] Office for National Statistics. 'Trade in Goods: Country-by-Commodity Exports'. 2023.
[177] Department for Business and Trade. 'Impact Assessment of the United Kingdom of Great Britain and Northern Ireland to the Comprehensive and Progressive Trans-Pacific Partnership'. 2023.
[178] UK Battery Industrialisation Centre. 'UKBIC and the Fraunhofer Research Institution'. 2022.

We will continue to explore options for international collaboration on batteries through new and existing forums. We will work to ensure that the sector develops practical, widely adopted international standards, and that those in existence keep up with technological developments.

National Security

The UK is one of the most attractive destinations in the world for inward investment. The Government will continue to welcome investment into this critical sector, whilst ensuring that it is scrutinised appropriately for national security concerns. The Government will properly consider the national security risks associated with investment into the UK battery supply chain, during their manufacture, development, and the ongoing operation of assets. This will allow us to identify and manage risks to our national security and will always be done in a sensible and proportionate way that allows vital investment into this sector to continue to flow.

The National Security and Investment (NSI) Act 2021 includes powers to intervene in transactions that give rise to national security concerns.[179] Energy is one of 17 mandatory notifiable sectors under the NSI Act, meaning that any battery transaction that meets the required thresholds will fall under this remit.

We will continue to create an environment that is welcoming to foreign investment. We will assess foreign investment into battery manufacturing and the supply chain under the NSI Act on a case-by-case basis, ensuring that proportionate mitigations are put in place only where it is deemed necessary for national security. We will work to identify and assess whether there are malicious suppliers in battery manufacturing and the wider energy sector to ensure it is secure and stable.

Energy

Battery manufacturing, as well as related upstream and downstream activities, is energy intensive and necessitates large power connections. According to the APC, the largest gigafactory in the UK is expected to consume over 2TWh of electricity per annum once fully operational.[180] In the Call for Evidence,[181] responders mentioned that energy prices and long lead times to access the grid feed into a high perceived cost of manufacturing in the UK and represent notable barriers to investment. Industry stakeholders in the chemicals processing, gigafactory, and recycling steps of the value chain have recently cited these as key determinants of location decisions. Ensuring the supply of competitively priced and sustainable electricity, as well as rapid access to grid connections, will be of paramount importance to locating high value segments of the battery supply chain in the UK.

[179] Cabinet Office. 'National Security and Investment Act 2021: Collection.' 2020.
[180] Advanced Propulsion Centre. 'Written Evidence from Advanced Propulsion Centre UK'. 2023.
[181] See Annex II

Competitive Electricity Prices

The Government has consistently taken decisive steps to reduce the price of energy and further strengthen the competitiveness of the UK's business environment:

- **Energy Bill Relief Scheme,** which provided energy bill relief for non-domestic consumers facing significantly inflated gas and electricity prices in light of global price pressures, triggered by Russia's invasion of Ukraine, through a discount on wholesale gas and electricity prices between 1 October 2022 and 31 March 2023.[182]
- **Energy Bills Discount Scheme**, which extended support from the Energy Bill Relief Scheme for non-domestic consumers by providing a discount on wholesale gas and electricity prices until April 2024.[183]
- **Net Zero Growth Plan**, published in March 2023, which sets the goal that Britain will have wholesale electricity prices that rank among the cheapest in Europe by 2035. The plan sets out the steps that the Government will take to ensure the UK is more energy independent, secure, and resilient.[184]

Battery manufacturing is an energy intensive activity that would face steep industrial electricity prices without Government support. Energy Intensive Industries (EIIs) in the UK currently benefit from two financial relief schemes that aim to reduce the cumulative impact of some energy and climate change policies on industrial electricity prices. These are:[185]

- **The EII compensation scheme,** which provides support for indirect carbon costs - the UK Emissions Trading Scheme (ETS) and the Carbon Price Support Mechanism (CPS). Launched in 2013, direct payments are made from Government to eligible firms.
- **The EII exemption scheme,** which provides relief for a share of the indirect costs passed on by suppliers for the cost of schemes designed to increase the share of renewable electricity – the Contracts for Difference (CFD), Renewables Obligation (RO) and Feed-In-Tariff (FIT). Launched in 2016, eligible businesses receive a discount on their electricity bills.

Between 2013 and 2021, these two schemes provided over £2 billion of relief from policy costs passed on by electricity suppliers to over 300 businesses across the UK. In 2021 alone, this support was worth over £360 million.[186] While initially intended to last until the 2021-22 financial year, the 2022 Energy Security Strategy announced that support for EIIs would be extended for a further three years with an increased aid intensity that represents a doubling of the previous annual budget.[187] Importantly, eligibility was extended to the manufacture of batteries, including lithium-ion batteries, and accumulators.

More recently, in February 2023, the Government announced further support for key EIIs in the form of the British Industry Supercharger. Over 300 businesses, including manufacturers of batteries and accumulators, will benefit from the additional targeted measures to ensure

[182] Department for Energy Security and Net Zero. 'Energy Bill Relief Scheme'. 2022.
[183] Department for Energy Security and Net Zero. 'Energy Bills Discount Scheme.' 2023.
[184] Department for Energy Security and Net Zero. 'Powering Up Britain: Net Zero Growth Plan.' 2023.
[185] Department for Business, Energy and Industrial Strategy. 'Energy Intensive Industries (EIIs).' 2023.
[186] Department for Business, Energy and Industrial Strategy. 'Government to consider further relief for energy intensive industries.' 2022.
[187] Prime Minister's Office. 'British Energy Security Strategy.' 2022.

that energy costs are in line with those of other major economies and level the playing field for UK companies.[188] This includes an increase from 85% to 100% of the value of an exemption from the costs of CFD, RO and FIT, as well as new reliefs from capacity market and network charges.[189] A review of eligibility for the Supercharger scheme will be completed in 2026 to ensure that the most electricity and trade intensive businesses most at risk of carbon leakage receive support.

Stakeholder engagement has shown that, while industry welcomes the Government's actions to lower energy costs, the process to qualify for support from the EII and Supercharger schemes is perceived as oriented towards established industries with existing infrastructure. New businesses in the battery supply chain that could be eligible, based on the sector they operate in, have found that they are not able to pass the Business Level Test. If firms are not able to access energy cost support, new entrants face significantly higher costs than European competitors. The Department for Business and Trade (DBT) is working closely with firms in the battery supply chain to ensure that they understand the eligibility requirements to submit successful applications.

Looking ahead, the Government is committed to ensuring that the costs of the UK's energy transition are fair and affordable for all consumers. The Review of Electricity Market Arrangements (REMA) is looking at our current market arrangements to ensure that they can deliver a secure, cost-effective, low carbon electricity system by 2035. REMA has been developing, refining, and narrowing down options for reform, working closely with industry and stakeholders, and expect to undertake further consultation in Autumn 2023. REMA's overall timescale will depend on the nature and complexity of reforms found to be necessary.

At Autumn Statement 2023, the Government announced it is providing support to help industry transition to a resilient, low-carbon, and competitive future. This includes spending £185 million on the Industrial Energy Transformation Fund (IETF) to support industrial sites with investment in more energy efficient and low-carbon technologies. This grant funding will come from the £6 billion announced at Autumn Statement 2022 to support energy efficiency from 2025, with further allocations set out in due course.

The Government is also providing around £300 million a year in tax relief in exchange for meeting energy efficiency targets under the new six-year Climate Change Agreement Scheme, with associated relief running until 31 March 2033. Sectors that meet eligibility requirements but do not currently participate in the Climate Change Agreements Scheme are invited to make a proposal to be added to it, including the battery manufacturing sector.

Grid Connections

The battery supply chain comprises multiple energy intensive activities, including chemicals processing, cell assembly at gigafactories, and hydrometallurgical recycling. APC analysis indicates that the battery sector alone may utilise up to 3% of the UK's total consumption by 2030, based on announced gigafactory capacity.[190] The expansion of the battery sector in the

[188] Department for Business and Trade. 'Government Action to Supercharge Competitiveness in Key British Industries and Grow Economy.' 2023.
[189] Department for Business and Trade. 'Government Consultation Response for British Industry Supercharger Package for Strategic Energy Intensive Industries (EIIs).' 2023.
[190] Advanced Propulsion Centre. 'Written Evidence from Advanced Propulsion Centre UK'. 2023.

UK comes at a time of growing demand for electricity connections from industry and renewable energy generation sources, leading to longer than anticipated lead times.

The Call for Evidence highlighted the importance of obtaining grid connections within a reasonable timeframe as a factor behind investment decisions.[191] Previous work has identified suitable sites for industrial development that require new or improved connections.

Network operators have met record demand for electricity grid connections in recent years. In fact, the UK has increased the amount of capacity connected to our grid more than sixfold, connecting the second highest amount of renewable electricity in Europe since 2010, according to statistics from the International Renewable Energy Agency.[192] But we want to go further and faster, so we are taking steps to rapidly bring even more projects online by accelerating plans to reform the connections process and reduce waiting times.

The Government has published a Connections Action Plan jointly with Ofgem, building on industry-led work, to provide direction on further actions to reduce the average delay a project faces to connect to the transmission network. The Government is working with Ofgem and network companies to release network capacity and accelerate connections. Actions already underway by network companies are expected to see a significant reduction in transmission connection timescales for most existing projects. This will help to enable the majority of projects to get their requested connection date with no wait and, for viable projects, reduce overall connection delays from 5 years to no more than 6 months.

The Electricity System Operator is also considering options for connections reform through their 5-step plan:[193]

1. Allowing customers to leave the queue without incurring penalties for doing so. The amnesty closed in April 2023 and received over 8GW of interest, alleviating pressures within the pipeline of projects.
2. Updating how project connection dates are calculated and working with GB's Transmission Owners to review and update existing contracts.
3. Changing the way storage impacts on the system are calculated.
4. Developing new contractual terms for connection contracts to manage the queue more efficiently.
5. Enabling energy storage projects to connect to the grid more quickly. This will speed up connections for up to 95GW of energy storage projects in the pipeline to ensure system security.

At the distribution level, the Energy Networks Association published a 3-step plan in April 2023, setting out immediate priorities:[194]

1. Reforming the distribution network connections queue, promoting mature projects that are closer to delivery above those that may be 'blocking' the queue.
2. Changing how transmission and distribution networks coordinate connections, improving their interactivity.
3. Greater flexibility for storage customers through new contractual options.

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[191] See Annex II
[192] International Renewable Energy Agency. 'Country Rankings'. 2023.
[193] Electricity Systems Operator. 'What are we doing now? Our five-point plan.' 2023.
[194] Energy Networks Association. 'Improving and Accelerating Customer Connections.' 2023.

The Government has also published its response to the report of the Electricity Network's Commissioner, Nick Winser, on how to halve the time it takes to build transmission network infrastructure. Key elements of this action plan include consulting next year on reforms to energy consenting rules in Scotland and committing to commission the Electricity System Operator to work with Government to produce a new Strategic Spatial Energy Plan. These actions will support the Government's efforts to electrify and decarbonise the economy and increase the UK's energy security.

The Government is also consulting on stronger guidance on the regulators' Growth Duty – extending the Growth Duty to Ofgem, Ofwat and Ofcom – and providing a new strategic steer for the Competition and Markets Authority. This will ensure the UK's regulators are pro-innovation, agile facilitators of growth in the sectors they regulate.

We will continue to work with industry, Ofgem, and the network companies to deliver the actions needed to accelerate connection timescales, including strategic investment, efficient and flexible management of network capacity, and a connections process that is fit for the future.

Planning and Permitting

The Call for Evidence[195] highlighted the critical role that planners at a national and local level play in driving forward the establishment and growth of the battery sector across the UK. However, as respondents to the Call for Evidence[196] noted, the planning and permitting processes can often take a significant amount of time, potentially deterring investment and limiting local development. This has been driven by competition for stretched local planning resources for complex cases and mixed knowledge sharing arrangements across the country.

Identifying a suitable site for a large-scale operation such as a gigafactory is a complex and multifaceted process. Gigafactories are expansive and energy intensive manufacturing facilities, so finding a contiguous, flat site of over 300 acres with access to a sufficiently powerful electricity connection can be a challenge. Successful sites must have convenient access to highways, railways, ports, and airports to facilitate the efficient movement of inputs and finished products. Additionally, gigafactories require a specialised labour force to be located nearby.

Once a suitable site has been identified, planning permission and environmental permits from local authorities are required to build and operate the new battery manufacturing facility. Moreover, facilities that hold greater quantities of dangerous substances need to demonstrate that appropriate measures have been taken to limit the consequences of an adverse event on communities and the environment.

Potential investors often perceive the planning and permitting processes to be onerous and risky. Call for Evidence respondents highlighted that timelines are dependent on varying levels of local capacity and knowledge of battery technologies, with little certainty regarding the total length of time that paperwork will take.[197] However, the UK is not unique in this respect, with

[195] See Annex II
[196] See Annex II
[197] See Annex II

many European and North American countries having recently implemented measures to address similar challenges.

The Government recognises that local authorities and the wider planning sector face serious capacity and capability challenges that have resulted in delays. To address this, the Government has recently announced a £24 million Planning Skills Delivery Fund to help local planning authorities clear planning backlogs and ensure that they have the required skills to respond to changes in the planning system.[198] The Planning Capacity and Capability programme delivers funding to local Government, providing upskilling opportunities for existing planners and further developing the future pipeline into the profession.[199] This programme also makes funding available to Public Practice, a social enterprise in the built environment sector, the Royal Town Planning Institute, and the Local Government Association to provide new pathways into planning.

Furthermore, the Government has laid draft regulations to increase planning fees by 35% for major applications and 25% for all other planning applications, together with a mechanism to allow for the annual adjustment of fees in line with inflation. The Environment Agency will continue to work with local authorities in developing environmental permits for battery manufacturing sites, to ensure the expertise is available to deliver permits as rapidly as possible.

At Autumn Statement 2023, the Government announced the introduction of new premium planning services across England, with guaranteed accelerated decision dates for major applications and fee refunds wherever these are not met. The Government will also invest £5 million to incentivise greater use of Local Development Orders in England, helping to end delays for businesses so that key commercial projects can secure planning permission faster.

The recent Levelling-Up and Regeneration Act reiterated the Government's commitment to improving the planning process and proposed reforms to deliver a more consistent, streamlined, and digitally enabled approach to the way planning applications are made, promoting faster and better decision making.[200] This builds on the National Planning Policy Framework introduced in 2012, which guides local decision makers and enables them to incorporate national policy objectives into planning decisions.[201] As part of the Act's implementation, the Government will consult on a more positive framework that drives economic development, including reviewing the approach to supporting employment, land, and the consideration of supply chain and connectivity issues.

To build upon the Government's levelling up objectives, Freeports[202] and Investment Zones[203] have been announced across the UK, creating distinct opportunities for economic growth and sustainable regeneration. Each of these offers varying incentives to businesses with focusses on net zero, renewables, R&D, advanced manufacturing, and innovative and future sectors.

The Government is committed to making the UK one of the best places in the world to invest and keeps actions to support those participating in capital-intensive projects under review.

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[198] Department for Levelling Up, Housing and Communities. 'Planning Skills Delivery Fund.' 2023.
[199] Department for Levelling Up, Housing and Communities. 'Building Planning Capacity and Capability.' 2023.
[200] House of Commons. 'Levelling up and Regeneration Act 2023.' 2023.
[201] Department for Levelling Up, Housing and Communities. 'National Planning Policy Framework.' 2023.
[202] Department for Levelling Up, Housing and Communities. 'Freeports.' 2023.
[203] Department for Levelling Up, Housing and Communities and others. 'Investment Zones.' 2023.

Sustain

The UK was the first major economy to commit to net zero and has reduced emissions the fastest amongst the G7.[204] Increasingly, businesses, financial institutions and consumers are demanding high environmental standards – as well as social and corporate governance – across product supply chains. The UK is well-placed to build on its sustainable production strengths to meet the growing demand for sustainable batteries. The Call for Evidence[205] highlighted how sustainability must be embedded in all corners of the UK battery industry. This will require a cross-Government effort, working with industry, to enable the development of a thriving and sustainable sector supported by pro-growth regulation.

The Government is working to ensure that industry has what it needs to thrive into the future. We will focus on:

a. Identifying and facilitating the **skills** needed for the battery sector.

b. Collaborating with our international partners on **green trade** to reduce barriers.

c. Exploring pro-growth regulation and industry standards to incentivise investment in the **circular economy**.

Skills

A thriving UK battery industry requires a productive workforce with skills along the entire battery value chain and at all levels. Access to skills is an increasingly important criteria for companies looking to make globally mobile investments in battery development and manufacturing. Call for Evidence respondents expressed that developing and nurturing the domestic talent pipeline is crucial, with an emphasis on upskilling across the supply chain.[206]

The Faraday Institution estimates that meeting domestic demand for batteries for EVs would boost UK employment by approximately 270,000 (full-time equivalent) jobs by 2040.[207] Of these, 100,000 would come from battery manufacturing plants and the supply chain, 145,000 from EV production, and 25,000 from HGV/bus production. In the specific case of the automotive sector, a further 700,000 people are estimated to be employed in 2040 in the wider industry and indirect supply chain including across logistics, engineering, construction, finance, administration, sales and marketing.[208] The positive employment impact of battery production would not just be felt across advanced manufacturing, but also in innovation and R&D.

The clearest and most urgent requirement for increasing the battery workforce capability and capacity is currently in supporting the expansion of cell manufacturing. Each gigafactory necessitates a workforce with advanced skills to ensure the production of high-performance, cost-effective batteries while maintaining stringent safety standards. Recent announcements by AESC as well as Tata-Agratas will increase production by at least 52GWh of capacity by 2026.[209] This requires a manufacturing workforce of over 7,000 people to be up-skilled, re-skilled or new-skilled in the next 2 years.[210]

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[204] Department for Business, Energy and Industrial Strategy. 'Why Net Zero.' 2022.
[205] See Annex II
[206] See Annex II
[207] The Faraday Institution. 'UK Electric Vehicle and Battery Production Potential to 2040.' 2022.
[208] The Faraday Institution. 'UK Electric Vehicle and Battery Production Potential to 2040.' 2022.
[209] The Faraday Institution. 'UK Electric Vehicle and Battery Production Potential to 2040'. 2022.
[210] The Faraday Institution. 'UK Electric Vehicle and Battery Production Potential to 2040'. 2022.

The growing demand for EVs will require many workers from the existing automotive sector to transition to meet the needs of this technology. The manufacturing and processing skills are quite similar, and many vehicle components will remain the same regardless of whether the vehicle is powered by an ICE or an EV powertrain. Nonetheless, comprehensive reskilling and upskilling programs will be essential to ensuring the availability of the required workforce at the right time and place.

In recent years, the Automotive Council Skills group, the Faraday Institution, HVM Catapult, and others have worked to develop an in-depth understanding of the job roles and associated skills levels needed. For example, production staff in the core process elements of cell production make up approximately 50% of the workforce, requiring qualification levels of L2/L3. A further 30% are maintenance and engineering technicians requiring L3 to L6.[211] Other positions in a gigafactory are highly skilled, with most requiring degree qualifications or higher.

The Government has put employers at the centre of the skills system to ensure that skills provision meets current and future skills needs, offering a wide range of high quality training from apprenticeships to shorter flexible courses such as Skills Bootcamps. In September 2023, the Faraday Battery Challenge appointed three leading universities to share £3.2 million in funding and support the UK's battery-related sectors by identifying and addressing their skills gaps.[212] This includes two Battery Workforce Training Initiatives focussing on the delivery of Level 2-3 training. Based in the North East and the Midlands, they will support the UK's growing regional battery industries and deliver innovative vocational and technical training, bolstering local workforces with enhanced skills, qualifications, and diversity. These are the first battery manufacturing specific centres in the UK and will provide up-skilling, re-skilling, and new-skilling for cell production staff.

The Faraday Battery Challenge also funds the National Electrification Skills Framework and Forum (NESFF), which aims to coordinate a nationally consistent, responsive, and quality-assured courses specific to emerging skills needs in the sector. [213] NESFF will champion the need for electrification workforce development programmes across all skills levels. Together, these approaches mean that immediate skills needs can be met, and longer-term planning can be facilitated, allowing for the pace of training and development to match that of technological progress.

At Autumn Statement 2023, the Government committed £50 million to delivering a 2-year apprenticeship pilot that explores ways to stimulate training in growth sectors and address barriers to entry in high-value standards. The Government will continue working towards the creation of a talent pipeline that is well-prepared for the transition to net zero, leveraging our skills ecosystem to promote battery manufacturing as a high-technology, high value career to young people of all backgrounds and abilities.

It is clear there is more to be done around signposting inward investors to the skills offer in the UK workforce. This is why the Government is developing employer toolkits that map out skills clusters across the UK and help guide conversations on investing in their staff. This will help ensure that employers can continue to make informed decisions around investment or expansion.

[211] The Faraday Institution. 'UK Electric Vehicle and Battery Production Potential to 2040'. 2023.
[212] UK Research and Innovation. 'UK battery industry boosted by initiatives worth £3.2 million.' 2023.
[213] The Faraday Institution. 'UK Electric Vehicle and Battery Production Potential to 2040'. 2023.

We will continue to ensure that manufacturing skills training and education is well supported by a high quality and employer led skills system. We will work closely with academia and industry (including taskforce members, where appropriate) to identify areas of highest demand and promote best practice to develop an inclusive talent pipeline.

Green Trade

Trade in batteries, their materials, components, and end-of-life and manufacturing waste is expected to rise exponentially over the coming decade as, according to the IEA (International Energy Agency), battery demand for EVs alone will increase sixfold.[214] The large-scale deployment of batteries that enables the substitution of polluting internal combustion engines (ICEs) and fossil fuel power also carries residual risk of environmental damage, if not managed properly. Businesses and governments are responding with environmental and social standards for the battery supply chain, including minimum recycled material requirements and embedded emissions requirements.

Businesses and the Taskforce note that the proliferation of standards and reporting requirements can, and risk, acting as non-tariff trade barriers. A thriving and competitive UK battery sector will rely on access to markets as we specialise in areas of comparative advantage within the global value chain. To facilitate green trade, the UK is working with international partners to align environmental standards and remove barriers to trade. For example, the UK advocates for collective agreement at the Trade and Environmental Sustainability Structured Discussions (TESSD) at the WTO while also working through bilateral and plurilateral channels to lower barriers. The UK is also a member of the G7 Climate Club, which aims to advance international climate partnerships and cooperation agreements.[215]

Businesses also flag the costs of importing as a concern for battery supply chains. The UK's Free Trade Agreements help bring down these costs, but the tariff reductions are subject to Rules of Origin requirements, meaning that products must have a certain amount of content that has been manufactured in the UK or our FTA partner countries to benefit. Businesses are particularly concerned about Rules of Origin, and the potential for tariff burdens, in trade with the EU.[216]

Technology will have a key role in facilitating green trade. For example, digital trade will be important, as data on a battery pack's historical performance and cycles will remove barriers to their efficient repair, reuse, and repurposing by re-manufacturing businesses, reducing environmental damage. In the EU, a Battery Passport will become a mandatory requirement by 2026 to support sustainable battery life cycles, with other regions likely to follow.[217]

We will continue to strike the right balance, when developing our international trade policy, between attracting domestic value add in the battery supply chain and making it easy and economical for businesses to import critical battery inputs.

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[214] International Energy Agency. 'Global Supply Chains of EV batteries.' 2022.
[215] European Parliament. 'G7 Climate Club: At a Glance.' 2022.
[216] See Annex II
[217] Council of the European Union. 'Council Adopts New Regulation on Batteries and Waste Batteries.' 2023.

Circular Economy

Life cycle considerations are an integral part of the battery value chain in a world of growing competition for finite and valuable resources. Thanks to technological advances, batteries can be reused and repurposed and the critical minerals they contain can be increasingly recycled.

As highlighted in the Call for Evidence responses,[218] the development of a circular economy would allow for significantly more of a battery's economic value to be kept within the UK economy while reducing our dependence on others for critical minerals and lowering the environmental footprint of battery manufacturing. Reusing and repurposing batteries can significantly extend their useful life and so increase the supply of cells for different applications. The largest second-life activity for EV batteries is anticipated to lie in stationary energy storage, a growing sector in the UK.[219] However, companies innovating in this space are finding that not all batteries are suitable for reuse and repurposing, so new standards and regulations are beginning to emerge to support these activities.

Addressing a battery's whole life cycle will only grow in importance as tonnes of EV batteries begin to reach end-of-life, creating new challenges and opportunities for the UK. For instance, at the end of 2022, there were more than 660,000 electric cars on the road in the UK including 265,000 newly registered electric vehicles, a growth of 40% on 2021.[220] The Faraday Institution estimates that 16,500 tonnes of battery packs will need to be processed by 2028, with volumes rising rapidly thereafter to about 150,000 tonnes by 2035.[221] Stockpiling and exporting batteries for processing is logistically difficult. Most importantly, it implies exporting the critical minerals contained within, the most valuable of which are present in the battery's cathode. Although automotive lithium-ion batteries differ in chemistries, cells with nickel or cobalt generally contain around £7/kg material value.[222] Analysis by the Green Alliance found that recycling could supply at least 10% of EV battery critical mineral requirements in 2035.[223] Developing full commercial recycling capabilities is a significant opportunity for the UK given the growing demand for EVs and the stated objectives of our Critical Minerals Strategy.

Recycling can be divided into two main stages: mechanical processing and mineral recovery. Mechanical processing entails discharging and disassembling batteries to then shred their components, producing a powder-like substance called black mass. Mineral recovery from black mass is usually done through hydrometallurgical refining, which is energy intensive, complex, and expensive. One of the main challenges that countries across the world are facing is the need to achieve sufficient scale to make recycling commercially viable given that not enough EV batteries have reached end-of-life yet.

Many nations are rapidly expanding their capacity to carry out all stages of the recycling process. China has the world's largest recycling capacity, supported by mineral recovery rate targets and regulatory incentives to pursue vertical integration. For instance, China's biggest battery manufacturer, CATL, holds a 65% stake in recycler Brunp.[224] In January 2023, they announced an investment of approximately £2.8 billion in the construction of a large shredding, material recovery and refining facility that will process waste cathodes and anodes and turn

[218] See Annex II
[219] McKinsey and Company. 'Second-Life EV Batteries: The Newest Value Pool in Energy Storage.' 2019.
[220] Society of Motor Manufacturers and Traders. 'Vehicle Data: Car Registrations.' 2023.
[221] The Faraday Institution. 'The importance of coherent regulatory and policy strategies for the recycling of EV batteries.' 2020
[222] Innovate UK. 'The 2035 UK Battery Recycling Industry Vison'. 2023.
[223] Green Alliance. 'Powering up the UK Battery Industry Report.' 2023.
[224] Hampel C. 'CATL invests €3.25 billion in recycling plant in China.' 2023.

them into the precursors for the manufacturing of new ones.[225] Germany is likewise pursuing an integrated model, announcing the construction of Europe's largest shredding facility collocated with a refinery and cathode active materials production plant in June 2023.[226] Spain is building a black mass processing plant that will recover higher rates of lithium through a pyrolysis process before carrying out hydrometallurgical refining with support from the European Union.[227] Other countries such as Korea[228] and Japan[229] have committed considerable sums to R&D programmes that seek to increase the rates of critical mineral recovery during the recycling process. The extent of international activity in this space highlights the growing importance of recycling in the battery supply chain.

Realising the UK's potential in battery recycling is more important than ever. Call for Evidence respondents viewed this as an area where the UK can become competitive, suggesting that the recycling industry in the UK should be scaled up.[230] In July 2023, the European Union adopted regulatory changes to incentivise battery recycling, establishing mandatory minimum levels of recycled content for batteries sold within its borders.[231] As of August 2031, batteries must contain at least 16% cobalt, 6% lithium and 6% nickel that come not from mining but from recycling, with these percentages rising to 26%, 12% and 15% respectively by 2036.[232] To continue exporting EVs into the EU, UK EV battery producers will need to meet these requirements.

The Government has recently supported R&D into battery reuse, repurposing, and recycling, for example:

- **RECOVAS**, led by EMR, will introduce a new circular supply chain for electric vehicle batteries in the UK by developing the infrastructure to collect and recycle electric vehicles and their batteries. Thanks to a £4.4 million grant from the APC covering nearly half the cost of the project, RECOVAS is designing guidelines and developing a process to analyse used batteries and direct them to the most appropriate stream, be that repair, reuse, or recycling. This project is taking place in partnership with leading automotive manufacturers, who have agreed to collaborate on the design and construction of their batteries to enable greater potential future uses and material recovery once they reach the end of their life in a vehicle.[233]
- **RELIB**, which received £18.5 million from the Faraday Institution and aims to develop vast improvements in recycling technologies including cathode leaching and binder recovery.[234] The project, led by the University of Birmingham, will also create recycling routes based on digital diagnostic tools that can interface with battery passports, and identify new research topics.

The UK currently has an emerging capacity to recycle lithium-ion batteries, with most EV batteries being dismantled and shipped to Europe. Recyclus Group, based in Wolverhampton,

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[225] Hampel C. 'CATL invests €3.25 billion in recycling plant in China.' 2023.
[226] BASF. 'Battery materials meet recycling.' 2023.
[227] European Commission. 'Projects Selected for Grant Permission: BASF'. 2022.
[228] Alfred H Knight. 'Battery Recycling in South Korea - Circular Economy.' 2023.
[229] Global Trade Alert. 'Japan: NEDO allocates USD 1.2 billion for the development of next-generation batteries and motors under the Green Innovation Fund.' 2022.
[230] See Annex II
[231] European Parliament and The Council. Regulation (EU) '2023/1542 of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries.' Official Journal of the European Union, 2023.
[232] European Parliament and The Council. Regulation (EU) '2023/1542 of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries.' Official Journal of the European Union, 2023.
[233] Advanced Propulsion Centre. 'Funded Projects: RECOVAS.' 2023.
[234] Faraday Institution. 'ReLiB: Recycling and Reuse of EV Lithium-ion Batteries.' 2023.

is the country's first and only industrial-scale recycling facility. It is licenced to turn 22,000 tonnes of spent lithium-ion batteries, taken from a range of sources including electric cars, each year into black mass without using water, and has a low carbon footprint.[235] According to Innovate UK, 150,000 tonnes of waste will need to be recycled each year by 2035.[236] The APC estimates that three large material recovery recycling facilities will be needed to process 10,000 tonnes of waste cell material per year.[237] This means that multiple recycling and recovery facilities will be needed by 2040.[238]

The Government is conducting further work on regulatory levers to incentivise reuse, repurposing, and domestic recycling infrastructure for all battery chemistry types, including lithium-based technologies.

The Department for Environment, Food and Rural Affairs (Defra), in collaboration with the Devolved Administrations, is committed to publishing a consultation and Call for Evidence as early as possible in 2024, focussing on increasing collection rates for batteries and encouraging best practice in end-of-life management of all battery types and chemistries. Defra will work with the whole supply chain to consider regulation for the entire eco-system.

Businesses and the Taskforce noted the opportunity for pro-growth regulation to support the circular economy, particularly when aligned with international partners to facilitate trade. Enablers highlighted included:

- designing for reuse, recycling, and repurposing;
- access to first life battery data for repurposing and reuse, including through certification schemes;
- liability and ownership transfer, to enable repurposing and second life, and to avoid “do not fix” default; and
- certification and re-certification for second life and repurposed batteries.

We will continue to influence and adopt international standards for reuse, repurposing, and recycling in line with our closest trading partners, where it is in our national interest and achieves our desired policy objectives.

The Government is taking forward the recommendation from Dame Angela McLean’s Pro-Innovation Regulation of Technology Review to ensure the UK regulatory environment supports the safe development and deployment of emerging technologies to drive innovation and growth in advanced manufacturing.

[235] Recyclus Group. ’The UK’s First Battery Recycling Plant Opens.’ 2023.
[236] UK Research and Innovation. ’The 2035 UK Battery Recycling Industry Vision.’ 2023.
[237] Advanced Propulsion Centre. ’Battery Recycling: UK Automotive Strategy Planning 2021.’ 2022.
[238] Advanced Propulsion Centre. 'UK Automotive Strategy Planning 2021.’ 2022.

Part 3: Delivering the Strategy and Measuring our Success

This strategy is designed to set an ambition and the Government's framework for implementation. The actions cut across Government departmental boundaries, so it will be important that departments work together effectively.

With the launch of this strategy, different arms of Government are engaging to agree an action log to manage its delivery. Actions will be assigned, monitored, evaluated, and adapted through established governance and accountability arrangements across Government.

We will continue to convene a Battery Strategy Taskforce, adapting its scope (and membership, if needed) to advise on the delivery of the strategy, emerging risks to security of supply, and opportunities for the UK Government.

We are committed to ongoing engagement with businesses, through representatives on the Taskforce and wider engagement, to ensure that implementation works for businesses.

We will consider in due course the most appropriate metrics and reporting mechanism to measure our delivery against the strategy and its effectiveness.

There is also a call on business in the battery ecosystem to support the delivery of the strategy. In addition to the targeted support that the Government will provide, we expect businesses to match this level of ambition with their investments. This includes directly with new capital investment, but also investment in people, skills, training, and R&D. As the strategy highlights, there are important contributions to be made throughout the battery ecosystem, from the complete range of subsectors within the wider battery sector.

Annexes

Annex I: Glossary and Acronyms

Glossary

Battery: Generally taken to mean a battery pack, which usually comprises several connected battery modules made up of a cluster of cells.

Battery energy storage systems (BESS): Within the context of this document, this is taken to mean the products or equipment as placed on the market and will generally include the integrated batteries, power conversion and control. They are key to the net zero transition as they enable us to use energy more flexibly, for example, maximising the use of intermittent low carbon generation.

Black mass: A form of electronic waste created by crushing and shredding discarded battery cells at the end of their life, including the valuable metals within them.[239]

Cell: A single unit, comprised of an anode and cathode, that converts chemical energy into electrical energy.

Circular economy: Most of what we consume flows through a linear, 'take, make, waste' economy. According to the UKRI National Circular Economy Research Hub, a circular economy, by contrast, focuses on regeneration, restoration, and reuse at all stages of a resource's life cycle. This allows products, materials, and components to remain in circulation at their highest value for the longest period, and the waste generated by a linear economy is designed out from the start. Importantly for critical minerals, it also alleviates pressure on the supply of primary (mined) resources.[240]

Critical minerals: Minerals of both high economic importance and high risk of supply disruption. For further information on how minerals are evaluated to be "critical," see the UK criticality assessment of technology critical minerals and metals.[241]

Electric vehicle: A vehicle that is powered by an electric motor that draws electricity from an on-board battery. Electric vehicles include passenger cars, large commercial vehicles, and micromobility transportation devices like scooters.

First life: A battery's primary intended purpose as set out by the manufacturer.

Gigafactory: A facility to manufacture batteries at scale.

Grid connection: The connection of power generation equipment to the public electrical supply, with the purpose of providing distributed generation.

Hydrometallurgical recycling: A chemical process that recovers valuable minerals from waste battery materials for reuse.

Net zero: Net zero refers to a countries' greenhouse gas emissions being equal to, or less than, the emissions they remove from the environment. The UK Government's net aero target

[239] Alfred H Knight. 'Black Mass and the Battery Revolution.' 2023.
[240] UK Research and Innovation National Circular Economy Research Hub. 'What is a Circular Economy?'. 2023.
[241] British Geological Survey. 'UK Criticality Assessment of Technology Critical Minerals and Metals.' 2022.

refers to a commitment made for the UK to reduce its greenhouse gas emissions by (at least) 100% from 1990 levels by 2050.[242]

Second life: A battery's new use after having reached the end of its first life and having been repurposed for an application other than that originally intended by the manufacturer.

Supply chain resilience: A resilient supply chain is one that can withstand and proactively tackle the challenges of today and the future. These challenges include changes in the global economy, geopolitical environment and climate that have recently increased the frequency and magnitude of both demand and supply shocks to industry globally.

Watt-hour: Unit of electrical power equivalent of the total energy supplied if electrical power of one watt is maintained for one hour. One gigawatt hour (GWh) is equivalent to 1 billion watt-hours, and 1 terawatt hour is equivalent to 1 trillion watt-hours.

Acronyms

APC – Advanced Propulsion Centre

ATI – Aerospace Technology Institute

ATF – Automotive Transformation Fund

BBB – British Business Bank

BESS – Battery Energy Storage System

BSI – British Standards Institution

CFD – Contracts for Difference

CMIC – Critical Minerals Intelligence Centre

COMAH – Control of Major Accident Hazard Regulations

CPS – Carbon Price Support Mechanism

CPTPP – Comprehensive and Progressive Agreement for Trans-Pacific Partnership

DBT – Department for Business and Trade

EIIs – Energy Intensive Industries

ETS – Emissions Trading Scheme

EVs – Electric Vehicles

FIT – Feed-In-Tariff

FBC – Faraday Battery Challenge

FTA – Free Trade Agreement

GWh – Gigawatt Hour

HGV – Heavy Goods Vehicle

[242] Department for Energy Security and Net Zero and others. 'Net Zero Strategy: Build Back Greener.' 2022.

HSE – Health and Safety Executive

ICE – Internal Combustion Engine

IEA – International Energy Agency

ISA – International Seabed Authority

LEPs – Local Enterprise Partnerships

LCVs – Light Commercial Vehicles

LODES – Longer Duration Energy Storage Demonstration

LFP – Lithium Iron Phosphate

MCA – Maritime and Coastguard Authority

MoU – Memorandum of Understanding

NMC – Nickle Manganese Cobalt

NSI Act – National Security and Investment Act

OEM – Original Equipment Manufacturer

PAS – Publicly Available Specification

REMA – Review of Electricity Market Arrangements

RO – Renewables Obligation

RoO – Rules of Origin

R&D – Research and Development

SME – Small and Medium Sized Enterprise

SMMT – Society of Motor Manufacturers and Traders

TCA - Trade and Cooperation Agreement

TESSD – Trade and Environmental Sustainability Structured Discussions

TWh – Terawatt Hour

UKBIC – UK Battery Industrialisation Centre

UKEF – UK Export Finance

UKIB – UK Infrastructure Bank

UKRI – UK Research and Innovation

VFB – Vanadium Flow Battery

Wh – Watt Hour

WMG – Warwick Manufacturing Group

WTO – World Trade Organisation

Annex II: Call for Evidence Responses

The Battery Strategy Call for Evidence survey was publicly available online via GOV.UK from 24 August to 4 October 2023. It consisted of 35 open-ended questions followed by closed demographic questions. Social researchers at DBT employed thematic analysis to process the responses. Anonymous quotes have been included for illustrative purposes but are not intended to be representative of all 84 respondents.

Conclusion

Responses to the Call for Evidence survey focused on seven key areas:

- Strategic Priorities
- National and International Landscape
- Markets
- Technology
- Safety
- Life Cycle and End-of-Life

Regarding the overarching strategy, respondents felt that sustainability should be prioritised and argued that the planned strategy should include specific timelines and actions. International competition was seen as a key barrier to investment, in addition to the lack of a circular domestic supply chain. Market regulation was largely viewed as ambiguous across the supply chain. Respondents typically perceived electric vehicles as the battery application that should be prioritised in the strategy and expressed that R&D investment should not focus solely on battery chemistries. Safety also emerged as a concern of respondents, particularly in relation to fire risk and hazardous waste. Lastly, respondents reported that the battery recycling industry could be a key area where the UK could gain a competitive edge.

The main suggestions from respondents were to embed sustainability more deeply into the strategy, reduce UK dependence on potentially insecure trade links, strategically invest in all stages of the battery supply chain, particularly mid-stream and recycling, clarify regulations, upskill the UK workforce, and adopt a flexible approach to R&D investment.

Findings

Strategic Priorities

The Call for Evidence asked for comments on the proposed DESIGN-BUILD-SUSTAIN strategic priorities, as well as any other additional priorities that could be considered. Three themes emerged from the responses.

The first theme focused on the need for the strategy to be specific. Respondents commented that '*at present, policies and … mechanism are fragmented'* and highlighted how the planned strategy *'would benefit from having tangible goals.' e.g. Design: how much smaller, lighter, etc, by when?'* There was a demand for specific goals in the strategy, such as financial investment and incentives, support for organisations, and legislation that encourages and protects R&D, e.g., '*the UK battery strategy should aim to provide financial support to incentivise the growth of batteries to support the growing demand.'*

The second theme centred on the DESIGN-BUILD-SUSTAIN structure of the strategy. Respondents suggested that the SUSTAIN priority should be embedded within the other

priorities, rather than acting as a separate entity, e.g., '*the "sustain" phase's success depends on choices taken during the Design and Build phases.'* When referring to the DESIGN and BUILD priorities, some respondents emphasised the need for careful planning around sustainability, e.g., '*Design and Build with the thought of a circular life cycle in mind. Having to resource new materials to cover 100% of new build will be expensive and costly in manufacturing and the end user.'*

A shared view on the third theme emphasised the desire for a domestic materials sourcing industry that would support manufacturers, e.g., *'It is critical that the UK is able to responsibly and sustainably source the battery materials needed for battery and EV manufacturing in the UK.'* Respondents described how this could ease the manufacturing process, which would have benefits for both industry attractiveness and innovation, e.g., '*this will also lower the risk in shipping delays, further UK economy, increase transparency and knowledge as domestic governance standards would be employed across the supply chain.'*

National and International Landscape

When asked how the national and international context might impact the strategy's aims, responses focused on five themes: high perceived cost of doing business in the UK; planning system challenges compared to other industrialised nations; uncertainty of UK policy environment; lack of skills in the UK; and higher subsidies in other countries. Overall, respondents emphasised that being dependent on other countries' industries places the UK in a precarious position e.g., *'The Government should prioritise domestic supplies of battery raw materials where possible. This can include the processing of foreign sourced raw materials but ultimately such sources can be disrupted by political turmoil.'* However, respondents also highlighted how an approach to facing international competition could include collaboration, since an entirely domestic UK battery supply chain may not be feasible. As suggested by an industry association, '*collaborate to maximise our strategic advantages.'*

For the first theme, a commonly held view was that the high cost of manufacturing in the UK is a barrier to investment: '*The barriers to investment are viability with global competition given the high local cost base.'* Respondents frequently discussed the '*cost of locating and operating in the UK relative to other countries,'* with '*high energy costs'* being seen as a significant barrier. The remuneration of grid-scale energy storage was mentioned as a barrier to scaling up, potentially limiting investment opportunities, as elaborated by a private company, '*longer duration systems are not viable with current pricing but would allow faster grid decarbonization by smoothing the generation profile of intermittent renewables.'*

Planning systems challenges were discussed, with respondents highlighting how difficulties in acquiring permits and uncertain development timelines, including long grid connection timescales, can impact the success of projects. An academic institution stated, '*Some SMEs have told us that permits … can take up to 18 months, leading to a loss of competitive advantage compared to establishing facilities in other locations.'* Future barriers to investment were generally predicted to be the same as current barriers. However, concerns around abrupt policy changes were raised, as stated by one private company: '*Changes in regulation… will have an impact on any future demand projections.'*

Another barrier was the perceived lack of skills that prevails across the battery supply chain, *'There simply isn't expertise across all parts of the product life cycle.'* Respondents identified a need for '*design, engineering and construction skills to deliver the physical infrastructure, but also a skills pipeline to attract inward investment/facilities.'*

Higher subsidies in other countries also emerged as a pressing issue. Responses suggested that investors overlook UK-based companies due to more attractive incentives elsewhere. One private company remarked, '*The EU, USA, Australia and China are offering very substantial financial incentives to attract investment in the LIB supply chain to those regions.'* Notably, the Inflation Reduction Act was raised: '*The Inflation Reduction Act in the US will incentivise scale up manufacturers to invest in the US rather than the UK.'* These concerns over other countries' higher subsidies led respondents to stress the need for the UK Government to make the UK a more attractive place to invest: '*At a national level, the UK battery strategy needs to continue to look at Rules of Origin to incentivise companies to invest in the UK. Without this, UK suppliers and manufacturers risk being priced out by low-cost sources such as China where significant government subsidies are investing in battery tech.'*

Markets

In response to questions concerning supply constraints, regulation, consumer interests, and barriers for companies entering auxiliary systems and integration markets, the speed of market growth was consistently emphasised. Respondents stressed that the Government must, '*work out what to implement and do it quickly.'* Respondents also echoed the sentiment of one private company that '*progress is better than perfect'* and suggested numerous solutions to improve legislation across industry sectors.

For answers surrounding barriers that organisations face when entering auxiliary systems and integrations markets for grid storage, respondents cited cost, including the '*start up and initial investment' and* '*total cost of ownership.'* Another barrier was the '*lack of market clarity for BESS developers i.e., there is a need to remove certain regulatory barriers to ensure the process of planning and permitting is quick and efficient.'* Other barriers identified by private companies included '*ongoing supply concerns,'* the '*lack of long-term revenue certainty,'* and *'technical capabilities.'* To help combat some of these issues, respondents highlighted '*the need for cooperation up and down the supply chain.'*

Regarding the UK battery supply chain, the importance of all aspects of the supply chain, especially midstream, was raised. Respondents stated that '*increased circularity'* of the supply chain should be a priority, with '*domestic recycling and reprocessing of batteries'* needing additional governmental support. Skills training was also identified as essential for developing a supply chain in the UK, with one respondent stating that efforts should be made to '*develop a critical mass of domestic capability and training capacity, while recognising that development of a domestic talent pipeline will take some time.'* To build a resilient supply chain, respondents recommended that diversification was important, with one private company stating, '*companies should be encouraged to diversify their customer base (i.e., sell more) so that dependence doesn't start to grow between companies.'*

Views regarding the impacts of regulations on the market were mixed. Several respondents reported that regulations did not have a big, direct impact, e.g., *'can't say I've seen anything slowed down or speeded up due to regulations in the 10 years I've been in the industry.'* Others stated that there had been some positive impacts: '*stringent safety and environmental standards have boosted consumer confidence.'* However, several respondents noted how regulation was unclear with an academic institution arguing that, *'the lack of certainty regarding the new battery regulations in the UK has impacted negatively on growth of the UK battery market.'* Concerns regarding regulations being unable to keep up with technological innovation were also raised: *'There is still some confusion on which UN38.6, 3536 etc. are*

required for Li-ion batteries and standards for non-lithium-ion batteries. This needs to be reviewed as new chemistry will develop in future.'

In response to the question asking how the strategy can protect consumer interests, respondents felt that they were best protected by ensuring the quality of batteries, e.g., '*make sure that the batteries perform as expected.'* Price point was frequently mentioned, with suggestions to reduce the cost on consumers focusing on developing a domestic supply chain e.g., '*localised capacity in both manufacturing and recycling.'* Other respondents raised the importance of providing the proper infrastructure for consumers and the benefits of '*allowing full usage of storage to save network costs.'* Respondents also touched on consumer education, with a private company asserting that, '*consumers should be protected through education on batteries and how the batteries used in the goods purchased have been manufactured.'* The expectation of consumers that the products they purchase are sustainably manufactured was also mentioned: '*the UK Battery Strategy should require manufacturers to demonstrate and prove the sustainability credentials of their sourcing and manufacturing practices.'* Respondents suggested establishing battery passports to meet consumers' sustainability requests, e.g. '*The implementation of battery passports could provide better traceability of batteries, and useful foot-printing information for consumers.'*

Technology

By asking respondents about battery technology options, three themes emerged: application; battery chemistries; and open and flexible funding. The questions in the Call for Evidence survey covered applications of technology, future technology, and the suitability of emerging technology for non-transport applications in contrast to electric vehicles.

For the application theme respondents were supportive of the focus on mobility in the Call for Evidence documents, e.g., '*future mobility is a key application sector.'* Respondents were clear that the strategy would need to include reference to the automotive and aerospace sectors as this '*drive[s] the subsequent markets (for technology)'.* Respondents also noted the importance of energy storage, e.g., '*energy storage for both industrial and domestic use is also a key area.'* Another application highlighted by respondents was diagnostics, with one private company suggesting exploration into '*diagnostic systems that can identify potential issues and enable preventative maintenance, reducing the risk of unplanned downtime.'* For electric transport, the main diagnostic challenges were to accurately predict the range of vehicles and in, '*improving in-service and real-time diagnostics for providing confidence to consumers and increasing electric vehicle adoption.'*

The second theme, battery chemistries, illustrates the wide range of chemistries that respondents viewed as important investments for the UK. This was regarded as integral to the UK Battery Strategy, with one academic institution asserting that, the '*UK is already playing catchup on existing technology - only through developing new chemistries will there be an opportunity to lead the world.'* For electric vehicles, lithium-ion batteries were presented as the best option, whereas sodium-batteries were frequently discussed as preferable to lithium in non-transport applications. As one respondent stated, '*Sodium-ion batteries are emerging as a favourable option for stationary energy storage.'* Respondents argued that '*lithium ion has a better power to weight ratio.'* However, sodium-ion batteries advantages were reported by an academic institution to be their '*cost competitiveness, performance parity and abundant feedstock materials.'* Hydrogen was also discussed by several respondents as a promising battery chemistry that should be explored.

The third theme that emerged was open and flexible funding. This covered the UK's overarching approach and aims for investment in technology. The view of respondents was that there must be a '*wide consideration for emerging technologies.'* This was in line with multiple calls for a technology-agnostic approach, with one private company stating, '*funding mechanisms should be as technology agnostic as possible, to allow the best to compete and emerge as the most valuable technologies.'* Respondents also emphasised the importance of not narrowing the focus of R&D investment, e.g., '*research and industrial R&D must not forget to include a critical focus on manufacturing and process R&D, not just traditional chemistry/materials and product R&D.'* Throughout the responses, the importance of investment strategies to respond to market changes was highlighted, as an academic institution stated, '*listen to the market then write a strategy to support the market and not try to create a market.'*

Safety

Though it was not a question in the Call for Evidence survey, many respondents offered comments on battery safety. Such concerns focused not only on the inherent risk that batteries pose, but also the risks to the wider environment if they are mismanaged, for example '*it is vital that a UK Battery Strategy considers the safety implications of some battery chemistries and the damage they can cause to UK infrastructure if they are mismanaged.'* Specifically, two themes emerged:

The first theme was fire risk. Respondents commented on the gaps in current UK safety regulations, with one industry association saying, '*Combustion in lithium-ion batteries is a legitimate issue for the industry, and safety standards for lithium-ion BESS needs developing to ensure sufficient fire safety measures are in place.'* Respondents noted that the industry is taking steps to improve safety e.g., *'fire safety is of paramount importance for any projects … and the industry is already taking significant action to minimise any risks posed.'* However, there was a clear demand for further regulations on this matter, '*while sites are designed to meet international fire safety regulations, local authorities are asking for more measures to be taken.'*

The second theme focused on disposal of batteries. Respondents reported that the lack of specialist and technical skills in the UK is a barrier, with the transition from '*internal combustion engines to handling EV battery packs ... impeded by a fragmented training landscape.'* The lack of regulations on this was also reported to be '*limiting the opportunity for the UK to start effectively and safely storing, transporting and processing battery waste.'*

Life Cycle & End-of-life

The Call for Evidence survey asked for any barriers to battery reuse and recycling in the UK. Three themes emerged in respondents' responses to questions on the battery life cycle: recycling; battery health monitoring; and the regulatory environment.

For recycling, respondents suggested that the pre-existing battery recycling industry needs to be scaled up to include all types of batteries, particularly for EVs, which is in-line with goals for a circular economy. One private company detailed how, '*the UK can become competitive in this area by supporting battery recyclers that can pivot between different battery chemistries in the pre-treatment (e.g., black mass refining) phase.'*

Respondents noted that battery health monitoring is integral to an efficient recycling industry, as it enables transparency of the life cycle of the battery; '*A means to track batteries in their*

first life and understand the characteristics of use in first life will be key in determining if a battery is suitable for a second life.' To improve monitoring, respondents suggested solutions such as '*embedded smart health monitoring,'* and *'telematics through the charging infrastructure.'*

The third theme focused on the regulatory environment around battery end-of-life and recycling. While some commented that there are lenient testing standards for end-of-life batteries resulting in pre-emptive disposal e.g., '*Failure to enforce current waste battery regulations has meant that the... support [of] any nascent battery recycler of chemistries other than lead has been artificially constrained,'* others noted that current regulation is out of date and does not consider new technology: '*The absence of dedicated List of Waste codes for lithium batteries and black mass makes it difficult to restrict their export under the Basel Convention.'*

Annex III: Demand Modelling

Annex III provides an overview of the main UK battery and critical minerals (CRMs) demand models as well as assessment of the UK battery supply-chain. Significant modelling already exists; hence we have summarised existing work here and have used these models to inform the UK Battery Strategy. Our summary of existing demand models does not include a comprehensive assessment of different scenarios related to the demand for grid storage.

Battery Demand Modelling

UK battery demand is forecast by external bodies to be likely to reach over 100GWh per annum by 2030 and around 160GWh by 2035, reaching nearly 200GWh in 2040. These estimates are based on comprehensive battery models by The Faraday Institution[243] and BloombergNEF[244] which include EVs, micromobility,[245] and stationary storage. The APC also provides battery demand modelling results but in contrast to The Faraday Institution and BloombergNEF, this excludes stationary storage.[246]

The majority of projected battery demand is made up by EV batteries. The Faraday Institution[247] and BloombergNEF[248] estimate that the demand for UK EV battery manufacturing capacity will reach around 100GWh per annum in 2030, predominately for private cars and light commercial vehicles (LCVs). This demand is the equivalent of five large gigafactories running at full capacity. The latest Advanced Propulsion Centre (APC) estimates of battery electric vehicles (BEV) battery demand are slightly more pessimistic compared to The Faraday Institution and BloombergNEF BEVs battery demand projections and estimate UK battery demand at 90GWh (a reduction from previous projection of 97GWh).[249] Please note, The Faraday Institution's estimates were produced in June 2022. SMMT data suggests that the actual figures for vehicle production in 2022 and 2023 (to date) are lower than the Faraday Institution forecast. However, the overall long-term transition to 2030 and 2040 is still reasonable as it is consistent with results from more recent BloombergNEF analysis.

Both The Faraday Institution and BloombergNEF models use National Grid: Future Energy Scenarios[250] to estimate demand for grid storage. They model demand for energy storage under different scenarios of the whole energy system to 2050, including falling short of Net Zero commitments and reaching net zero by 2050 in three different ways, to reflect the inherent uncertainty in these estimates. They estimate that BESS could provide 10-20GW of capacity to the UK grid by 2030, and 30-35GW by 2050, representing the largest installed capacity compared to other storage technologies. In their models of total demand, The Faraday Institution and BloombergNEF estimate around 5-10GWh demand for grid storage by 2030.

These battery demand models are built on assumptions around EV production, the battery energy storage demand per year, and battery capacity forecasts. Differences in these key assumptions explain some of the variation between different models. Further details are available on The Faraday Institution[251] and Bloomberg[252] models.

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[243] The Faraday Institution. 'UK electric vehicle battery production potential to 2040.' 2022.
[244] BloombergNEF. 2023.
[245] Micromobility covers lightweight vehicles including e-bikes, scooters, skateboards and three wheelers.
[246] Advanced Propulsion Centre UK. 'Q2 2023 Automotive Industry Demand Forecast'. 2023.
[247] The Faraday Institution. 'UK electric vehicle battery production potential to 2040.' 2022.
[248] BloombergNEF. 2023.
[249] Advanced Propulsion Centre UK. 'Q2 2023 Automotive Industry Demand Forecast'. 2023.
[250] ESO. 'Future Energy Scenarios'. 2023.
[251] The Faraday Institution. 'UK electric vehicle battery production potential to 2040.' 2022.
[252] BloombergNEF. 2023.

Critical Minerals Demand Modelling

The future demand for critical minerals in the UK is highly uncertain as it depends on future battery chemistries, battery energy density, the EV market, costs, and technological developments. Multiple different scenarios could occur depending on when battery technologies become commercially available.

Lithium-ion is currently the most common battery chemistry used for EVs.[253] The number of CRMs required will depend upon the types of lithium-ion battery produced. The two primary types of lithium-ion batteries used in EVs today are nickel manganese cobalt (NMC) and lithium iron phosphate (LFP).[254]

The UK Critical Minerals Intelligence Centre (UK CMIC) provides CRM demand estimates by 2030 which are based on two different future battery technology scenarios.[255] In the first scenario UK produced batteries are mainly NMC. In the second scenario there is a major shift towards LFP and 50% of batteries produced are LFP. This analysis is based on the announcements of various battery chemistries and the output capacity by gigafactories in the UK as of 2022. These have since changed. For example, Tata Group has announced its 40 GWh gigafactory[256] and British Volt has gone into administration. Whilst the stated 135GWh potential production in the UK by 2030 may be optimistic, it is not unreasonable.

Figure 9: Estimated Annual UK Demand for Critical Minerals in 2030, kilotonnes (kt)

Scenario	Assumed Production (GWh)	Lithium (kt)	Nickel (kt)	Cobalt (kt)	Manganese (kt)	Graphite (kt)
UK-NMC	135	14.9	90.4	11.2	10.2	135.0
UK-NMC/LFP	135	14.2	49.6	5.9	5.3	135.0
APC-NMC-811	96	10.7	72.0	9.1	8.5	96.0

Source: UK Critical Minerals Intelligence Centre. 'Study on Future UK Demand and Supply of Lithium, Nickel, Cobalt, Manganese and Graphite for Electric Vehicle Batteries'. British Geological Survey. 2023.

Notes: The UK-NMC (nickel, manganese and cobalt) scenario is based on the various battery chemistries that the announced UK gigafactories planned to produce at the time, which are mainly high nickel content batteries.

The UK-NMC/LFP scenario assumes a major shift towards LFP (lithium, iron and phosphate) batteries with the planned gigafactories producing 50% LFP batteries and 50% NMC batteries.

The third demand assessment/scenario (APC-NMC-811) is based on forecasts of UK light duty electric vehicle production and assumes all cells use NMC-811 (80% nickel, 10% manganese and 10% cobalt).

In both scenarios, as shown in Figure 9, the demand for lithium is similar and around 14-15,000 tonnes annually for 135 GWh of production. UK CIMC compare their results to the Advanced Propulsion Centre's estimates of future anode/cathode demand, which is based on all batteries being NMC811 (high-nickel chemistry). The APC predict around 11,000 tonnes of lithium will be required for 96GWh;[257] the difference is explained by the difference in total assumed production, since the APC only considers demand for EV batteries.

[253] International Energy Agency. 'Global Electric Vehicle Outlook 2023: Trends in Batteries.' 2023.
[254] UK Critical Minerals Intelligence Centre. 'Study on Future UK Demand and Supply of Lithium, Nickel, Cobalt, Manganese and Graphite for Electric Vehicle Batteries'. British Geological Survey. 2023.
[255] See Figure 9
[256] Tata Group. 'Tata Group to set up a Battery Gigafactory in the UK.' 2023.
[257] Advanced Propulsion Centre UK. ' Automotive industry demand forecast Q4 2021 Update'. 2022.

In the NMC scenario, UK CMIC estimate that 90,000 tonnes of nickel, 11,000 tonnes of cobalt and 10,000 tonnes of manganese will be demanded by 2030.[258] These all decrease by around 50% in the 50% LFP scenario. The demand for graphite is assumed to be 135,000 tonnes in both scenarios. The APC's estimates of demand for nickel, cobalt, manganese, and graphite are all similar to the UK CMIC's NMC scenario estimates, once the difference in capacity has been accounted for.[259] This is in part due to the fact that both UK-NMC and APC-NMC-811 scenarios incorporate relatively high uptake of NMC-811 battery technologies. However, the demand for nickel, manganese and cobalt increase under APC-NMC-811 scenario when compared to high LFP scenario.

The Faraday Institution also publish the results of their modelling of UK demand for critical minerals. Taking into account EV sales, battery demand, chemistry mix and material intensity, the Faraday Institution estimates UK 2030 demand of 87,000 tonnes of nickel, 18,000 tonnes of cobalt and 15,000 tonnes of lithium (equivalent to 80 kt of LCE).[260] This shows that UK CMIC UK-NMC scenario modelling and Faraday Institution modelling of the demand for CRMs (namely lithium, nickel and cobalt) are consistent.[261] Both modelling results are based on the assumption of relatively low uptake of LFP batteries.

UK-NMC/LFP scenario provides CRMs demand estimates with a relatively high LFP uptake (LFP=50%) and show that as a result the demand for nickel, cobalt and manganese reduces by more than half in most cases (by 55%, 54% and 50% respectively) compared to UK-NMC scenario. This scenario explores the potential influence of a major shift towards LFP batteries. This could be because of performance improvements in LFP technologies and/or the production of LFP batteries becoming more cost effective than NMC chemistries, owing to them not requiring nickel and cobalt. The likelihood of this market evolution is supported by recent industry developments, for example, the share of LFP batteries used by Tesla increased from 20% in 2021 to 30% in 2022.[262] Many other major automakers plan to use LFP batteries in standard-range and entry-level vehicles.[263]

The Faraday Institution estimates that over the next decade (2020-2030) there is likely to be a transition to low cobalt/high nickel content cathode materials due to the demand for increased energy density and the ethical considerations associated with mining of cobalt.[264] UK CMIC UK-NMC-811 scenario provides estimates of relatively high uptake of Lithium nickel manganese cobalt oxide (NMC811)-high nickel batteries.[265] NMC811 is considered one of the most promising future cathode materials for lithium-ion batteries in electric vehicles due to its high specific energy density, favourable rate capability and relatively low-cost production.[266] Moreover, if alterative battery technologies do reach commercial maturity, there could be a significant impact on mineral demand. For example, solid state, lithium-air or lithium-sulphur do not require significant quantities of nickel, cobalt nor manganese.[267] A transition towards

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[258] UK Critical Minerals Intelligence Centre. 'Study on Future UK Demand and Supply of Lithium, Nickel, Cobalt, Manganese and Graphite for Electric Vehicle Batteries.' British Geological Survey. 2023.
[259] Advanced Propulsion Centre UK. ' Automotive industry demand forecast Q4 2021 Update.' 2022.
[260] The Faraday Institution. 'Lithium, Cobalt and Nickel: The Gold Rush of the 21st Century.' 2022.
[261] The latest Faraday Institution CRM modelling does not include manganese and graphite.
[262] International Energy Agency. 'Global Electric Vehicle Outlook 2023: Trends in Batteries.' 2023.
[263] Asad H. 'Ford, VW, Tesla lean in to LFP battery technology for EVs. Environment and Energy Leader.' 2021.
[264] The Faraday Institution. 'Written Evidence Report, BAT0012.' 2021.
[265] UK Critical Minerals Intelligence Centre. 'Study on Future UK Demand and Supply of Lithium, Nickel, Cobalt, Manganese and Graphite for Electric Vehicle Batteries'. British Geological Survey. 2023.
[266] Nickel Institute. 'High-Nickel Cathodes: An Overview'. 2023.
[267] UK Critical Minerals Intelligence Centre. 'Study on Future UK Demand and Supply of Lithium, Nickel, Cobalt, Manganese and Graphite for Electric Vehicle Batteries'. British Geological Survey. 2023.

sodium-ion batteries and the use of silicon anodes would influence demand for lithium and graphite.

Next generation technologies including silicon anodes, solid state batteries and sodium-ion batteries may shift raw materials supply-chains. In its latest EV outlook, BloombergNEF updated its battery chemistry forecasts, which now includes sodium-ion batteries accounting for 3% of passenger car market battery demand in 2035 and 30% of battery demand in the two and three-wheeler segment. According to BloombergNEF,[268] the next generation anode technologies could displace 46% of graphite in 2035, compared with an all-graphite scenario. Similarly, sodium-ion cells may displace 7% of lithium demand in 2035, compared to a no sodium-ion scenario. In the even more extreme scenario, where sodium-ion batteries are used in all small vehicles, lithium displacement reaches 37% in 2035. However, this scenario would require a rapid supply-chain manufacturing expansion with sodium-ion cells in 2035 being more than twice in volume of lithium-ion in 2023, a scale that has taken decades to reach.

In addition, next generation flow batteries provide particularly suitable storage solutions for large-scale applications due to their large discharge time. Applications of flow batteries can include utilities, microgrids and EVs. Flow batteries are a suitable solution for EVs because of their ability to quickly replace electrolyte liquid or “recharge”. The next generation of flow batteries could potentially displace a proportion of demand for CRMs (commonly found in lithium-ion batteries) as common materials found in flow batteries include vanadium and iron. Their primary advantage over lithium-ion batteries are longevity and safety, but they are heavier than lithium-ion batteries and take up significantly more space, have a smaller power density and are currently more costly to produce.[269]

Ending UK sales of new vehicles running on diesel and petrol by 2035 will significantly increase the UK demand for lithium, cobalt and nickel used to manufacture EV batteries. Raw materials are needed for all parts of the battery including the cathode powder, graphite for the anode, separators, and other key chemicals that are used in the manufacturing process. Demand continues to increase sharply after 2030 as other countries around the world transition to EVs and given that approximately 80% of cars produced in the UK are exported.[270] The UK will face scale-up challenges more focused on the chemical industry, imports, and the supply-chain rather than mineral extraction. Establishing a resilient supply-chain in the UK is important and will improve the availability and affordability of key chemicals, materials, and components.

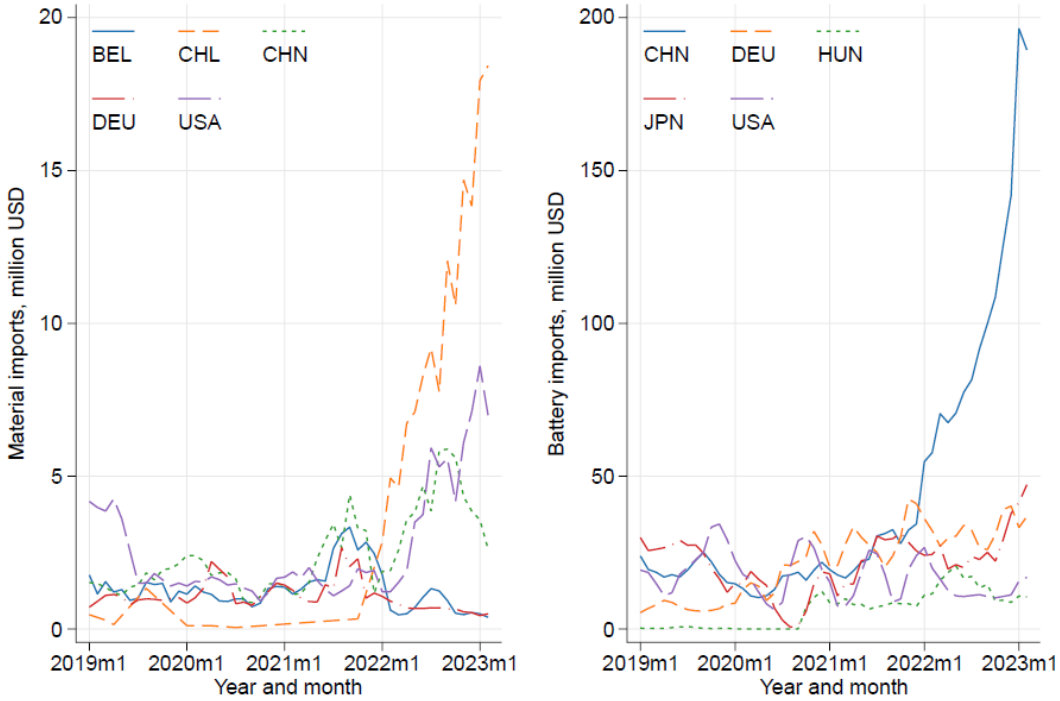
Currently, the UK relies heavily on imports of CRMs and batteries. Figure 10 illustrates the primary sources of materials and batteries imported to the UK in 2019-2022. Initially, materials imports were predominantly from the United States. However, throughout 2020 and 2021, the import of materials was minimal from all countries. Beginning in 2022, the import of materials intensified, with China, Chile, and the United States becoming the top three sources for battery production materials.

The right-hand chart in Figure 10 displays the value of battery imports to the UK. Starting from 2022, China emerged as the main source of batteries, with imports to the UK increasing nearly tenfold. The UK's use of Chinese-built batteries may pose a problem if UK automakers fail to

[268] BloombergNEF. ‘Electric Vehicle Outlook 2023’. 2023.
[269] Government Office for Science. 'Rapid Technology Assessment: Novel Batteries.' 2023.
[270] Society of Motor Manufacturers and Traders. ‘Key Exports Data.’ 2023.

meet the Rules of Origin (RoO) thresholds required to export electric vehicles into the EU under the tariff-free regime. Given that batteries account for approximately 40% of the car's cost,[271] the utilisation of materials from Chile and batteries from China may hinder key automakers from meeting RoO requirements.

Figure 10: Top Sources of UK Imports – Materials and Batteries 2019-2023 (USD millions)



Source: Du J and Shepotylo O. 'Powering the Future: Unveiling Economic Policy and Global Value Chain of the UK Electric Vehicle Industry'. Centre for Business Prosperity Working Paper. Forthcoming.

In summary, the combination of TCA value-added requirements, rising raw material prices, and the industrial policies of the UK's main industrial competitors have created a challenging landscape for the UK battery sector, including EV production. The purpose of this strategy is to address these developments and set out a framework for our future work.

[271] Institute for Energy Research. 'Electric Vehicle Battery Costs Soar'. 2022.

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Published November 2023
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