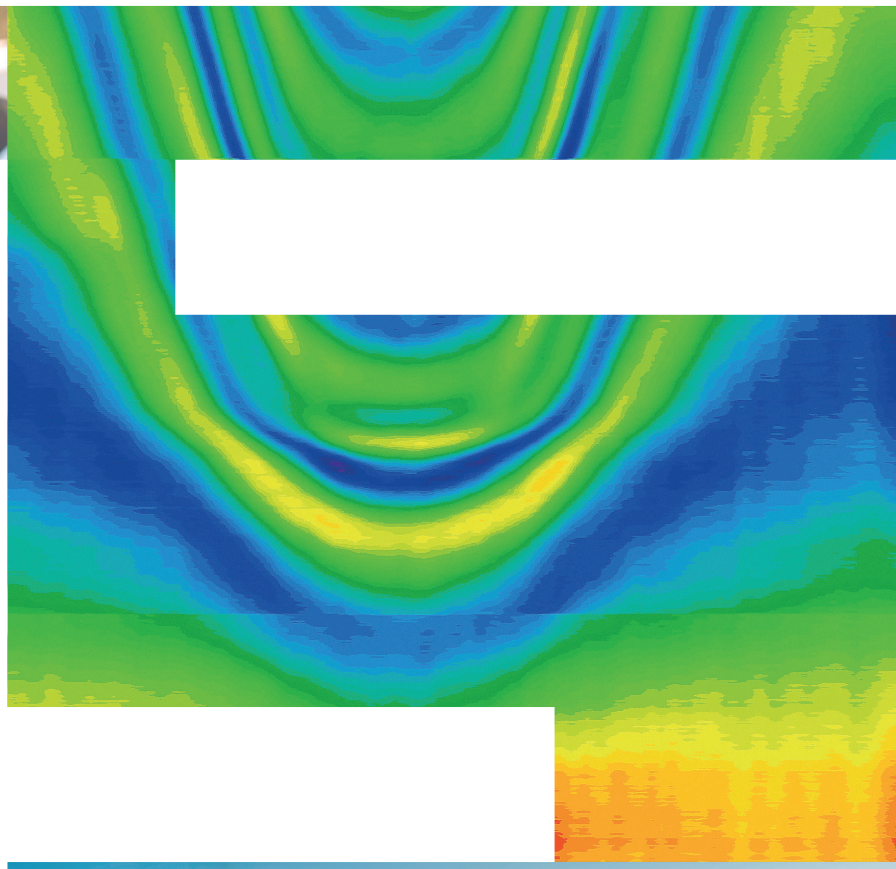
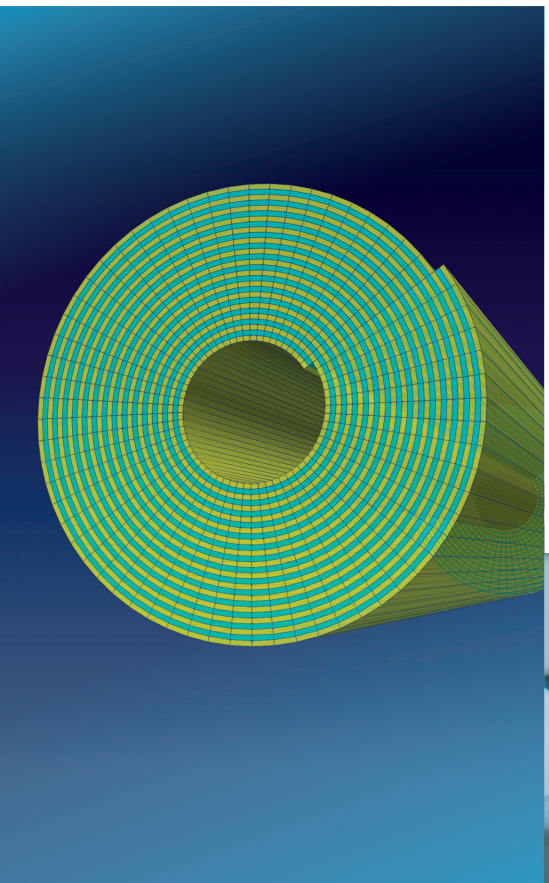
Powering Britain's Battery Revolution

Executive Summary

THE FARADAY INSTITUTION





2021/2022

'A thriving British battery industry will be grounded on a strong UK-based research and innovation ecosystem, developing batteries fit for purpose, lower cost, safer and fully recyclable. The 500-strong Faraday Institution research community is a cornerstone of this national initiative.'

Professor Pam Thomas FInstP, CPhys
Chief Executive Officer

'Energy storage research and innovation, the core mission of the Faraday Institution, has grown in importance in both the national and global energy agendas. The improvement and scale up of manufacture of these technologies will be the collective challenge of our lifetimes.'

Professor Peter B. Littlewood FRS, Chair

Introduction from Professor Pam Thomas

I am pleased to share our latest annual report for 2021/22, which outlines achievements, milestones, and progress we have made for the UK in energy storage research, early-stage commercialisation, market analysis and skills development. It also provides a moment to reflect on how much has been accomplished in our first five years to advance the UK down the path to electrification.

The Faraday Institution is increasingly fulfilling its potential to position the UK as a research powerhouse in energy storage. More than 500 researchers at all stages of their careers are working together to solve some of our most significant challenges in energy storage. Together we are making tremendous progress toward realising our research goals.

Professor Pam Thomas, CEO
The Faraday Institution

Pam Thomas

Read the full Faraday Institution annual report 2021/2022.

About the Faraday Institution

The Faraday Institution is the UK's flagship institute for electrochemical energy storage research, skills development, market analysis and early-stage commercialisation.

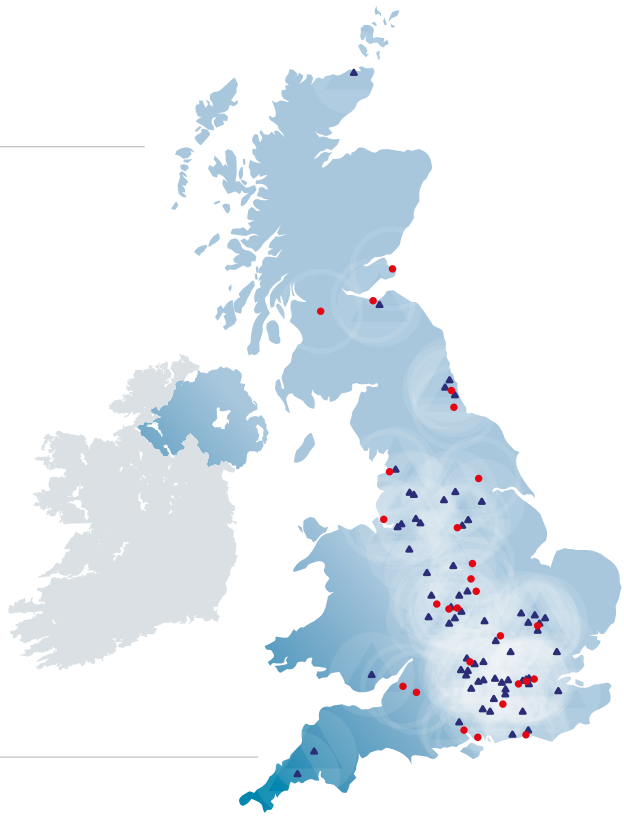
It brings together research scientists and industry partners to work on projects with commercial potential that will reduce battery cost, weight, and volume; improve performance, efficiency, and reliability; develop scalable designs; improve manufacturing abilities; develop whole-life strategies; and accelerate the outputs towards commercial outcomes.

We have five strategic priorities

- Driving discovery in application-inspired research
- Convening a world-class research community
- Empowering industry through early-stage commercialisation
- Informing policy makers through evidence-based insights
- Creating a diverse and dynamic pool of talent

Making an Impact

The Faraday Institution is a collaborative, multidisciplinary research community, bringing scientists and engineers together across the UK. As a national programme and a delivery partner for the Faraday Battery Challenge, we are focused on accelerating breakthroughs in energy storage technologies to benefit the UK in the global race to electrification.



University partners

Industrial partners

Outcomes and Impacts

The Faraday Institution continues to deliver excellent scientific and industry-relevant impacts since the launch of its research programmes in 2018, including:

An internationally recognised research powerhouse

A community of
500+ battery researchers

Across **27** UK universities including
4 of the world's top **20**
(Oxford, Cambridge, Imperial, UCL)

10 large-scale research projects
2 projects for emerging economies
16 seed projects

640+ high-quality scientific publications to date

with **1865** authors
across **343** institutions,
35 countries and **6** continents

Commercially relevant impacts

85 industrial partners
8 spin-out companies
36 inventions identified
18 patents filed and 6 published
15 industrial fellowships
11 industrial sprints

FARADAY
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Impact to policy makers

14 Faraday Insights

10 reports / joint reports

7 national consultations

Next generation of talent

205 undergraduate interns

70+ funded PhD researchers

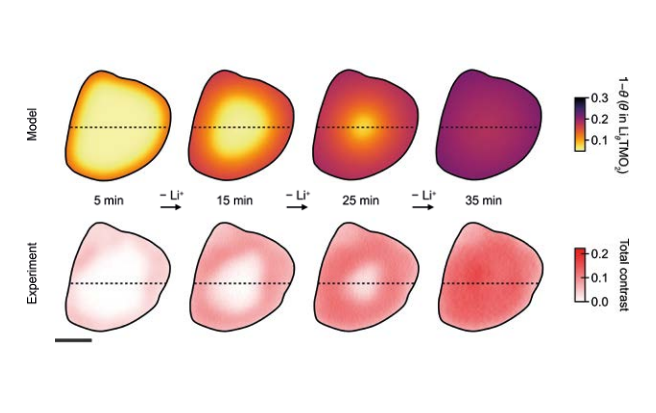
100+ additional project-affiliated PhDs

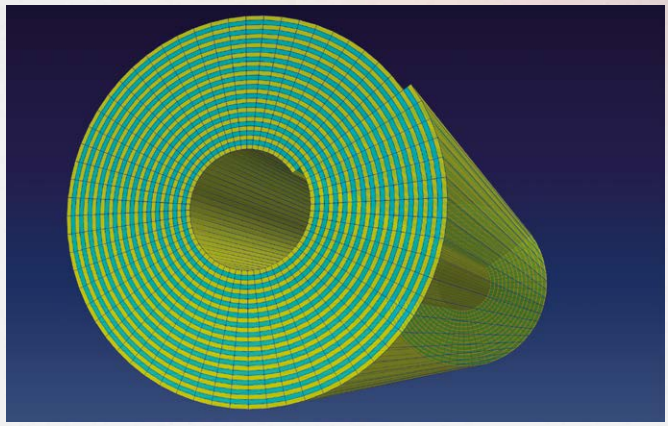
12,000+ engaged through STEM programming

Research Highlights

Megan Groom, PhD researcher, Cavendish Laboratory, University of Cambridge

Over the past year, the Faraday Institution has continued to drive discovery in application-inspired research, working to solve some of the most significant energy storage challenges in current and next generation batteries.



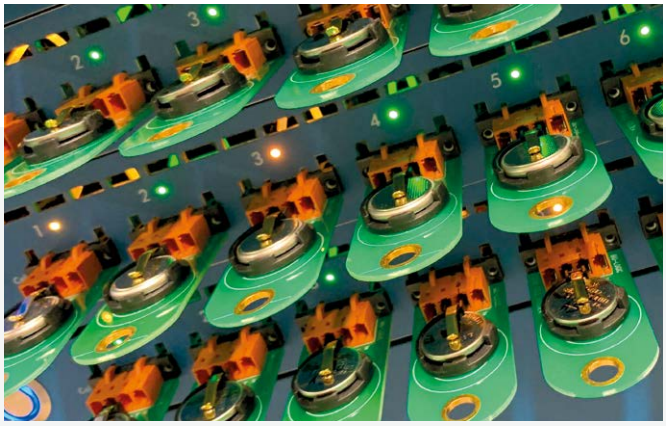


Watching lithium in real time could improve battery materials performance

A team from Professor Dame Clare Grey's group at the University of Cambridge tracked the movement of lithium ions inside a promising new battery material in real time. By tracking how light interacts with active particles during operation under a microscope, they observed sluggish movement of lithium ions, which could be reducing their capacity and hindering their performance. The research could help improve existing battery materials and accelerate the development of next-generation batteries.

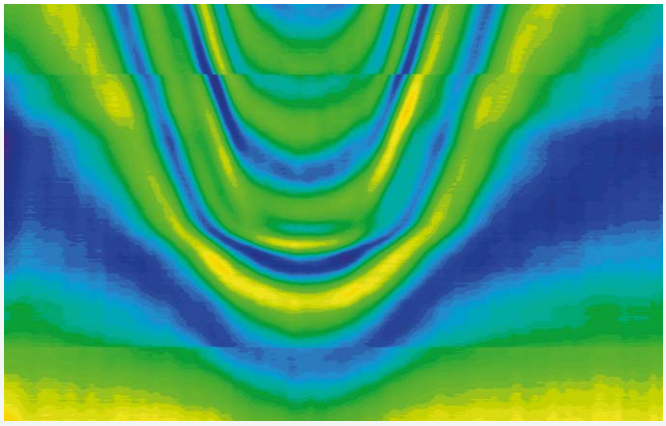
A model to predict battery failure

Batteries are complex devices, containing many different materials working together. Detecting battery failure before it happens, therefore, requires not just an understanding of each potential degradation process, but how they dynamically interact. Researchers from the Multi-scale Modelling project led by Imperial College London have simulated these processes and combined them into a single model. This work brings researchers much closer to being able to predict how and when a battery might fail, laying the foundations for battery management systems to intervene and prevent failure during use.



Recovery and regeneration of cathode materials

Scientists in the ReLiB project, led by the University of Birmingham, have patented a selective leaching technology to recycle, upcycle and regenerate cathode materials. This allows the manganese-rich materials to be separated from the other valuable battery components. These materials can be regenerated or can be upcycled for use in next generation cathode materials. By combining this technology with a direct recycling approach, the remaining high value Ni- and Co-rich materials can also be recovered and regenerated, thus enhancing the UK's capability in battery recycling.



Quantifying thermal runaway within batteries

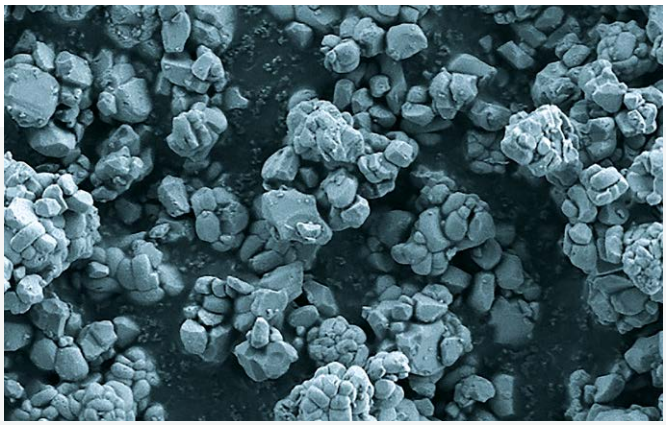
Battery failure can happen due to electric short-circuits, overheating or through impact or penetration. This can ultimately lead to a process known as 'thermal runaway'. A team led by Professor Paul Shearing of University College London and collaborators at the UK National Physical Laboratory, the US National Renewable Energy Laboratory, and the European Synchrotron Radiation Facility have developed an image processing toolbox that can quantify for the first time, the rate of propagation of battery failure mechanisms revealed by high-speed X-ray radiography. This tool can be used to standardise battery failure testing procedures, helping manufacturers track where and how failure starts in the battery.

Coventry University brings new prototyping facility to Lithium Sulfur project

Significant research progress has been made by LiSTAR in several areas including cathode, electrolyte and additive development. In April, the project welcomed a team led by Professor Alex Roberts from Coventry University to increase its cell fabrication capability, which will allow researchers across the project to test their developments in a pouch cell format. This new capability will ensure the developments achieved can be demonstrated at a scale with direct industrial relevance, increasing the impact of the work undertaken in the project.

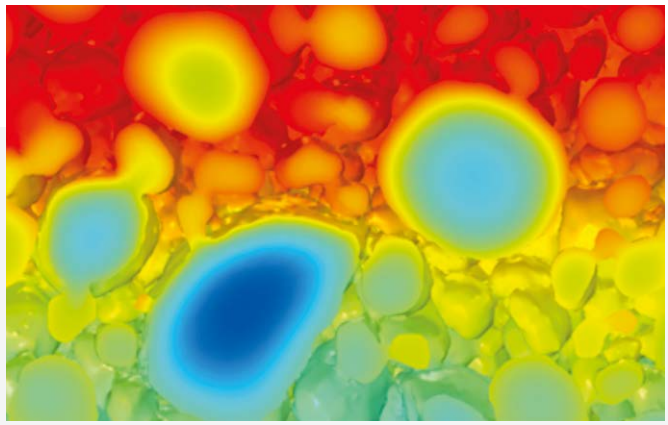
Exploring oxygen redox in layered Ni-rich cathode materials

FutureCat researchers at the universities of Warwick and Sheffield are applying advanced characterisation techniques, available through the UK's national synchrotron science facility, Diamond Light Source, to unravel the role of oxygen redox (involving storing charge on oxide ions as well as transition metal ions) in high nickel layered oxide cathodes. Understanding this role offers the chance to access high capacities for next generation lithium-ion batteries.



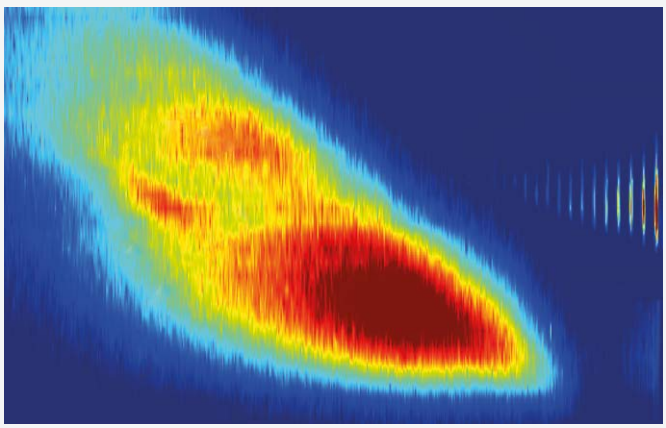
Smart processing of high energy density cathodes

Scientists in the SOLBAT project at Oxford University have produced a composite cathode with outstanding performance. Smart processing and cycling protocols were used to optimally engineer interactions between particles, enabling ion flow whilst minimising damage. The application of a new asymmetric pressure cell design enabled the anode and cathode to be maintained at different pressures during cycling. The research shows that cold-pressed single crystal NMC composites could deliver superior performance and are less likely to crack during processing and cycling.



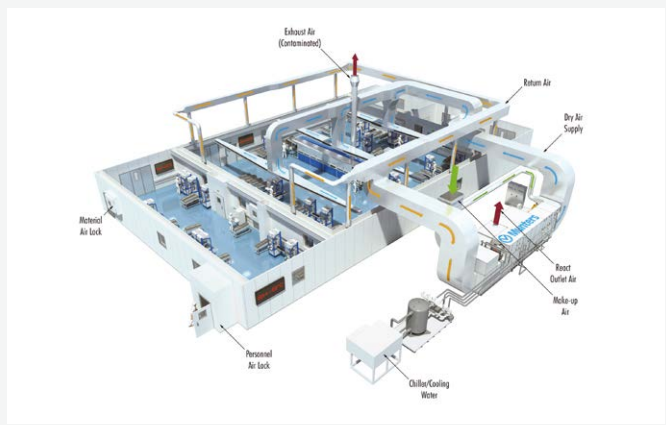
A framework for digital calendering

Calendering, the process of compressing the electrode to improve its structure and conductivity, is a critical step in manufacturing battery cells. If advances are to be made in integrating energy dense, thick electrodes into production, then understanding the impact of calendering during processing is crucial. Researchers at the University of Sheffield and UCL in the Nextrode project have developed a digital calendering and electrochemical testing workflow to give new insight into the process. This work paves the way for the evaluation of next generation electrodes and the required step change in the manufacturing process for improving the energy and power density of lithium-ion batteries.



Advances in lithium-rich materials for higher energy density batteries

Researchers on the CATMAT project have made further major advances in understanding critical properties and limitations of lithium-rich layered oxide and disordered rock-salt cathodes. The team has been the first to use an advanced 4D scanning transmission electron microscopy technique to provide atomic-resolution imaging of the evolution of key structures in Li-rich layered oxides that are critical in understanding the operation of these high energy density battery materials. Advances in this underpinning science could lead to the development of novel solutions to maintain their high energy densities that could support the development of EVs with extended range.



New pouch cell prototyping facility

The University of St Andrews has created a versatile battery scale-up facility. Thanks to funding from Scottish Enterprise (ERDF), St Andrews and the Faraday Institution, the facility features state-of-the-art equipment, a dry room, and testing chambers. The site can produce several hundred cells per year. Researchers will be able to combine and test nascent materials from the NEXGENNA project and beyond to manufacture cells in commercially relevant formats – a powerful tool to support the commercialisation of sodium-ion batteries.

A Year in Highlights

A world-class research community

The Faraday Institution continues to convene and grow a world-class research community, which today numbers over 500 researchers from a range of disciplines, universities, projects, and career stages. This year:

- The Faraday Institution North East (FINE) Office along with Newcastle University launched the North East Battery Alliance (NEBA), convening academic researchers, battery manufacturers, suppliers and local government to communicate and collaborate in anticipation of the region's role and growth in battery production.
- In June, we initiated 16 small, fast-paced, focused projects in topic areas not covered within our existing battery research portfolio. In doing so we have widened our research scope, and set of partners, in an initiative that will inform future priorities for our research programme beyond March 2023. The initiative includes two flow-battery projects supported by the Transforming Energy Access programme and funded by UK Aid focusing on the use of batteries in emerging economies.
- We signed memorandum of understanding with the US Department of Energy's National Renewable Energy Laboratory in late July to jointly pursue research to reduce dependency on critical minerals and to ensure battery recyclability. This effort has been supported through additional funding from the UK Department for Business, Energy and Industrial Strategy and the US Department of Energy.
- In October, a further £211 million in funding for the Faraday Battery Challenge was announced, £90 million of which has been allocated to the Faraday Institution for research until March 2025. Anticipating this next phase, this year we have been conducting the important process of reshaping our research programme to ensure it is industrially relevant and scientifically robust.

Early-stage commercialisation

The Faraday Institution's early-stage commercialisation effort is unique among research organisations in that we work to actively develop discoveries from our battery research laboratories into technologies with the potential to have significant impacts for UK industry.

- Today over 85 industry organisations are working in collaboration with our research projects to inform research directions and accelerate routes to market. These include major auto makers, battery manufacturers and materials suppliers, along with small and medium-sized enterprises that work across the battery value chain.
- From our research projects, 36 inventions have been identified to date, of which 18 patents have been filed and 6 published.
- Investment and advice given through our entrepreneurial fellowship programme have propelled several start-ups to the next stage of their development, with successful funding rounds, product launches and growth, by, for example, Cognition Energy, About:Energy and Breathe Battery Technologies. A total of eight spin out companies to date have emerged from the Faraday Institution.
- We have supported several new industrial fellowships and sprints – a total of 26 since 2019 – to enable academic and industrial collaboration and to ensure our research expertise impacts commercial applications.

85 industry organisations are working in collaboration with our research projects

FINE launched the North East Battery Alliance

16 small, fast-paced seed projects commenced

£211 million in funding for the Faraday Battery Challenge announced

Identified 36 inventions and filed 18 patents

Memorandum of understanding signed with the US Department of Energy's National Renewable Energy Laboratory

A dynamic and diverse pool of talent

We remain keenly focused on developing a dynamic and diverse pool of talent for the fields of battery technology and energy storage. This year:

- In April, we held the first Faraday Career Week to raise the profile of training and professional development across the community. We provide a training budget of £2,000 per researcher per year to be spent on professional development; this year the programme was extended to include affiliated PhD researchers, project managers and project staff members.
- Our first cohort of 13 PhD researchers are graduating and moving on to their first academic posts, industrial roles, and in some cases launching their own companies, such as About:Energy, which has secured its first round of funding. The productive cohort has published 65 papers, with over 1300 citations, and filed two patents. In October, our 5th PhD cohort started the training programme, taking the total to 71 PhD researchers since the programme began.
- Over the summer, 55 undergraduate students participated in our 8-week FUSE internship programme; more than 200 having interned since the progamme began in 2018, with a number having successfully gone on to pursue battery careers in industry and academia.
- 280 researchers attended our first in-person Early Career Research Conference in October, giving them a chance to disseminate their research results, grow their networks and boost their professional researcher identity.

Informing policy makers

As an independent organisation with deep expertise in energy storage market intelligence, research, skills and regulatory policy, we continue to inform policy makers with evidence-based insights. This work has grown in importance as the UK develops intelligent policies on energy independence and electrification of broader segments of transport. This year:

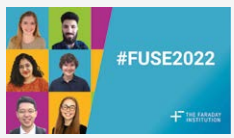
- In May, we submitted written evidence for the House of Lords Science and Technology Committee inquiry into the Government's plans to deliver a UK science and technology strategy.
- Research leaders from the ReLiB project at the University of Birmingham took a leading role in informing the government's Critical Minerals Policy, published in July.
- In June, we comprehensively updated our seminal publication 'UK Electric Vehicle and Battery Production Potential to 2040', which predicts that there will now be demand for ten UK-based gigafactories by 2040, each producing 20 GWh per year of batteries.
- We published new, and updated previous, Faraday Insights throughout the year, providing up-to-date analyses on a range of topics that enable government and other stakeholders to have concise and insightful information on electrification, covering a range of battery chemistries and applications to critical mineral supply chains.

First cohort of 13 PhD researchers graduating

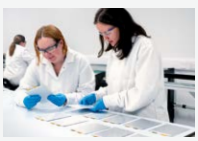
Held the first Faraday Career Week

280 researchers attended our first in-person Early Career Research Conference

55 undergraduate students participated in our FUSE internship programme



26 industrial fellowships and sprints



Informing policy makers with evidence-based insights

About the Faraday Battery Challenge

The Faraday Battery Challenge at UK Research and Innovation (UKRI) is delivered by Innovate UK. It is making the UK a science and innovation superpower for batteries, supporting the UK's world-class battery facilities along with growing innovative businesses that are developing the battery supply chain for our future prosperity. Its aim is to build a high-tech, high-value, high-skill battery industry in the UK.

The £541 million challenge has built globally competitive, scientific capability at scale. Harnessing the UK's best talent to solve the challenges of battery technology. It combines:

Research and capability development
at the Faraday Institution, uniting 500 researchers across more than 25 universities and 85 industrial partners to improve current and develop future battery technologies.

Collaborative business-led innovation, development of the wider ecosystem and skills
needed to manufacture through Innovate UK. 149 organisations have been supported through the CR&D programme with over £500m forecasted in co-investment.

Manufacturing scale-up and skills development
at the UK Battery Industrialisation Centre (UKBIC). Opened in July 2021, UKBIC has so far supported over 140 UK battery developers working on more than 80 research and innovation projects.

PhD researcher Beatrice Browning, the University of Birmingham

Connect with Us

'Investments by the Faraday Battery Challenge have supported businesses and organisations of all sizes from across the supply chain and throughout the nation. We look to build on this solid foundation by consolidating and exploiting our position as a science superpower in batteries, driving from research excellence and technological potential to commercial dominance in next generation technologies and ensuring our national industrialisation infrastructure remains world leading in this fast-evolving critical net zero technology.'

Faraday Battery Challenge Director Tony Harper

Headquartered at the Harwell Science and Innovation Campus, the Faraday Institution is a registered charity with an independent board of trustees. It is a key delivery partner for The Faraday Battery Challenge at UK Research and Innovation (UKRI), delivered by Innovate UK.

To learn more about how you can support our vision to accelerate research breakthroughs in energy storage technologies to benefit the UK, please visit our website at www.faraday.ac.uk or contact us at opportunities@faraday.ac.uk or 01235 425300.

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Making an Impact

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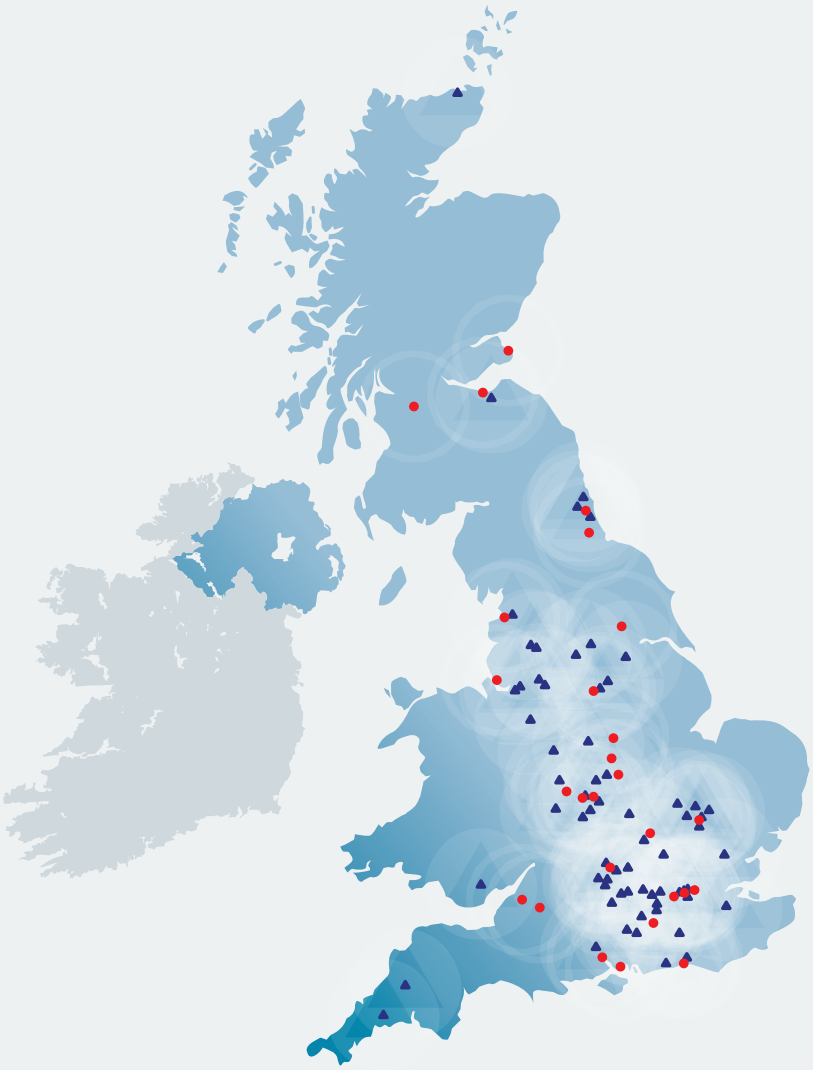

● **University partners**

▲ **Industrial partners**

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