Building Links Between BioimagingUK and the Faraday Institution

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(i.e. not employed by the Faraday Institution)

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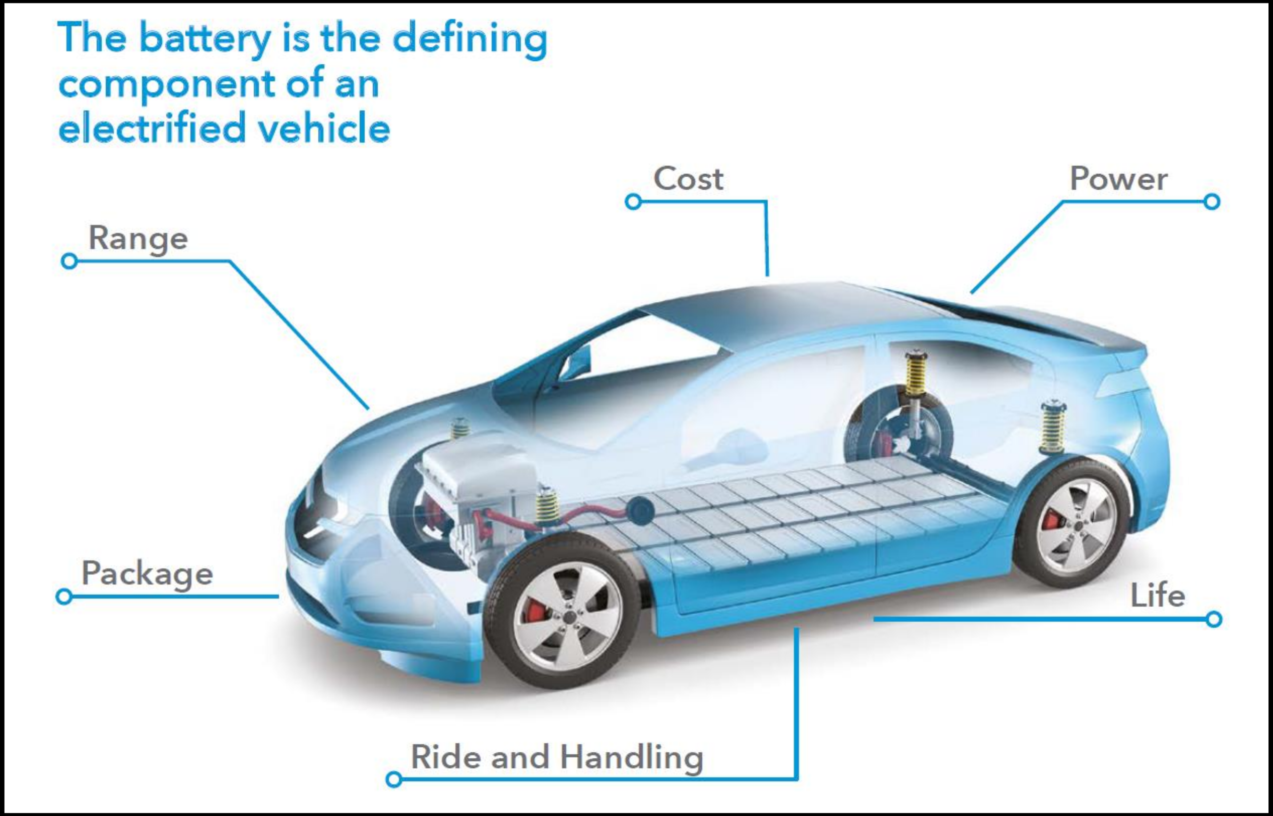
The Faraday Institution

UK's independent institute for electrochemical energy storage research and skills development. We bring together scientists and industry partners on research projects to reduce battery cost, weight, and volume; to improve performance and reliability; and to develop whole-life strategies including recycling and reuse.



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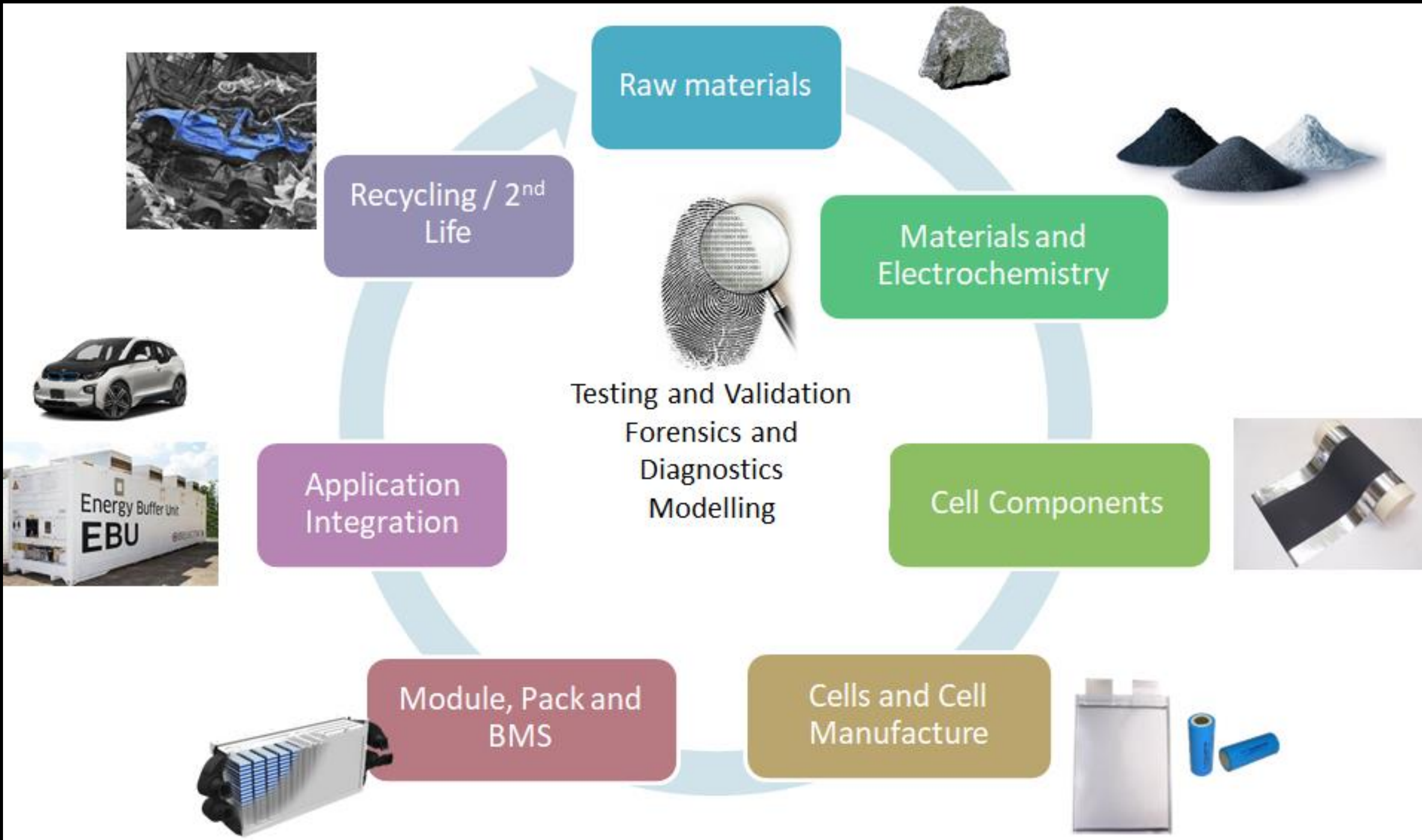
Rapidly Address all parts of the Battery Life-Cycle

UK Goals: 50% electric vehicles by 2040, 90% by 2050 (40 million vehicles)



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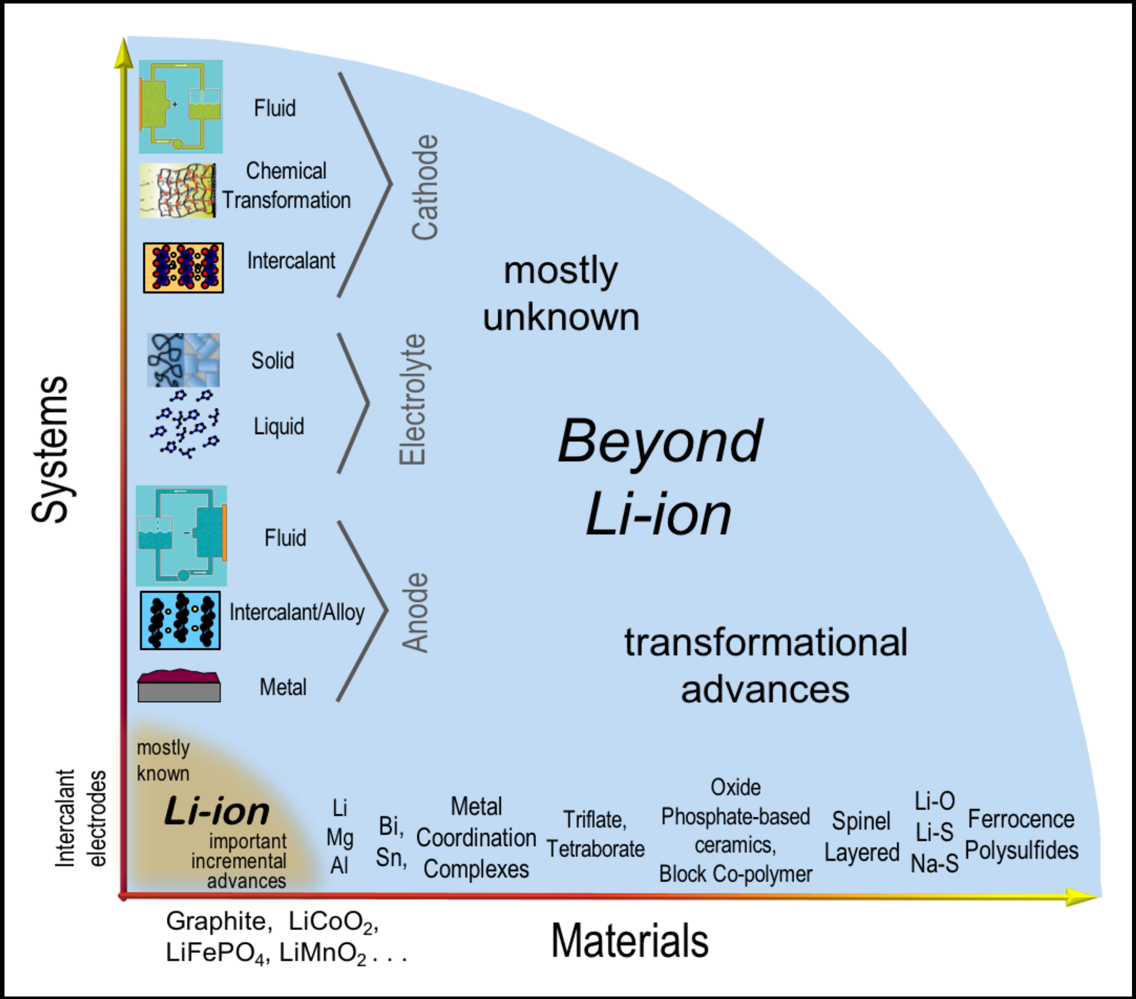
The Research Challenge

Opportunity Space is Large/Unexplored



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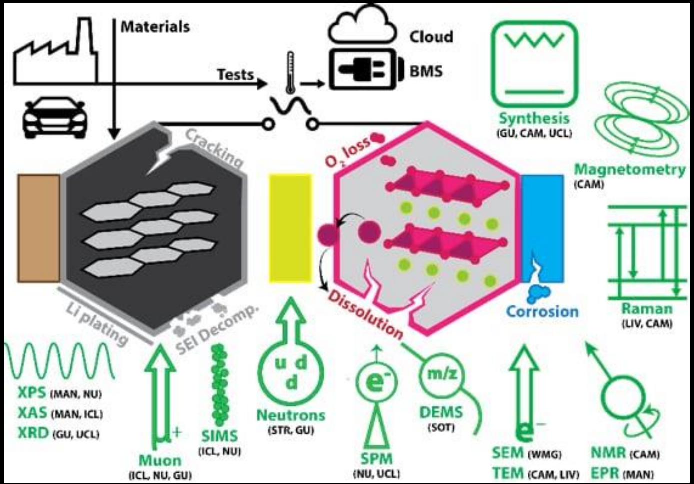
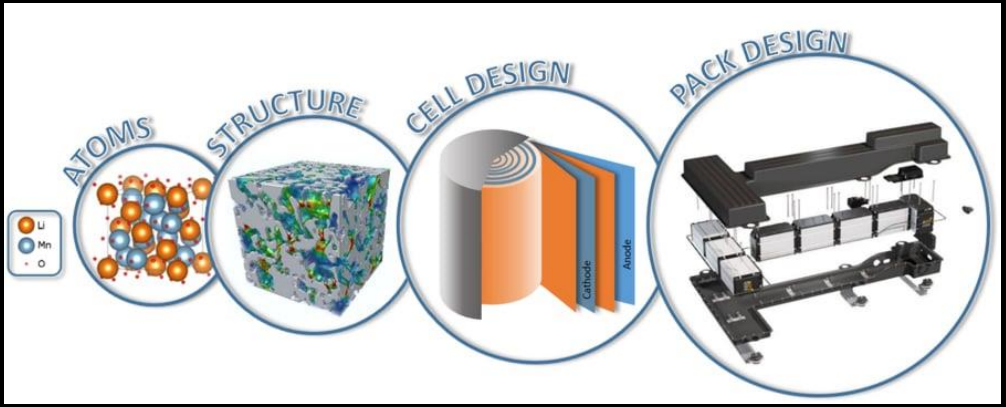
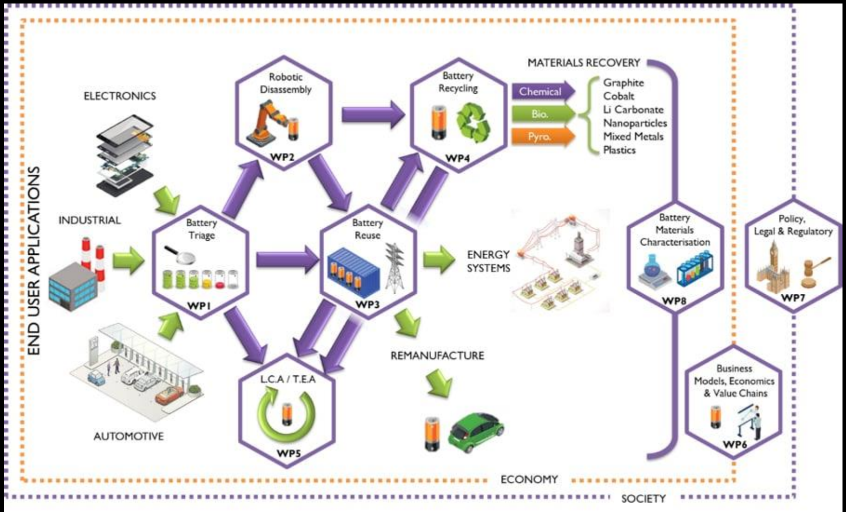
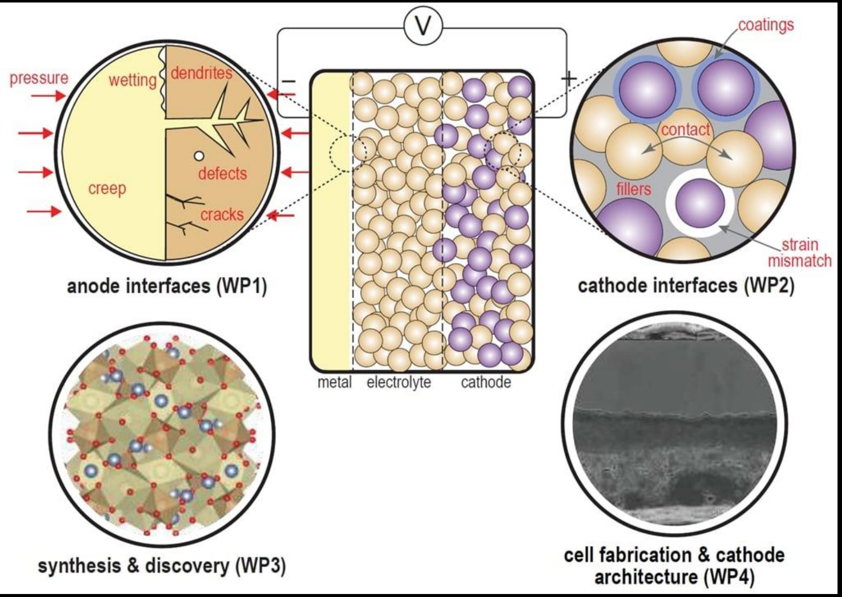
Faraday Institution Research Projects









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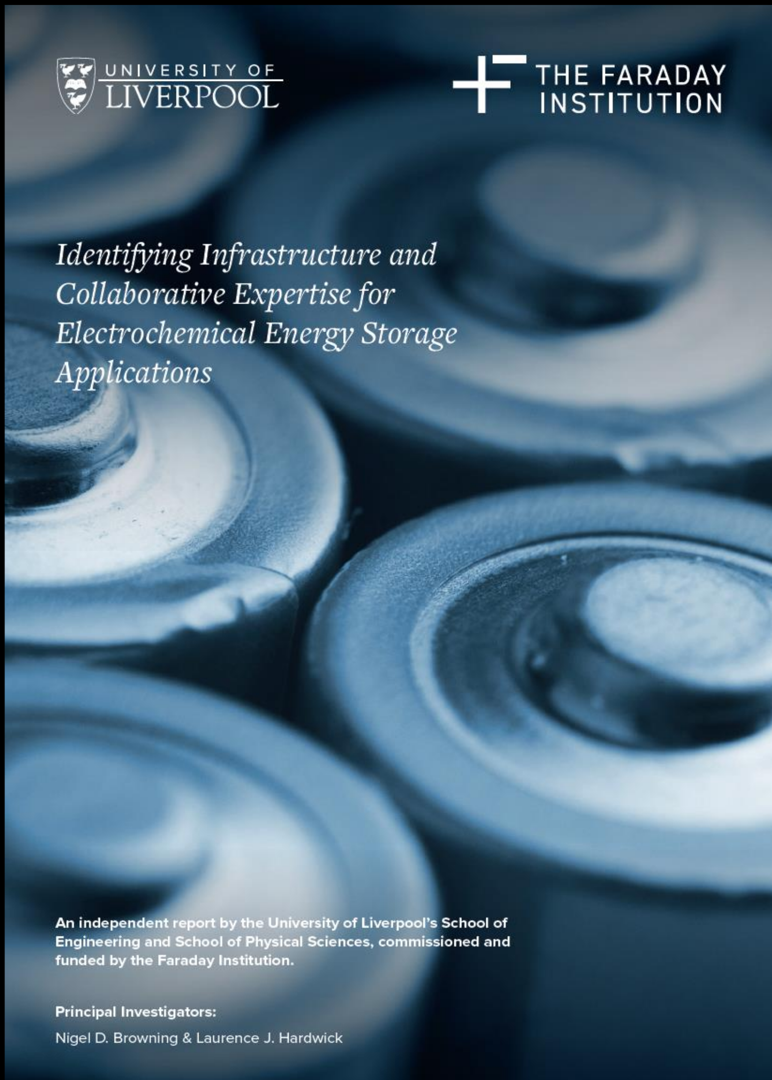
Faraday Institution Characterisation Report



- Information gathering through the distribution of a survey - self-reporting of expertise and capabilities (all EES systems and not just fast start projects)
- Identification of experts in the community to help recognize the gaps where they exist and approach contributors
- A community workshop was organised to discuss characterisation methods and identify key limitations
- Results of community input distilled into recommendations going forward

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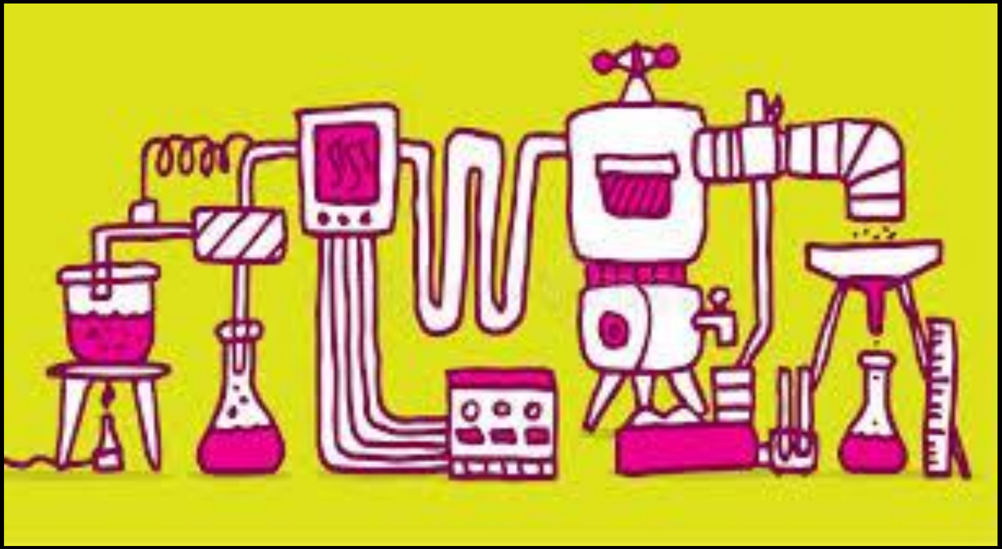
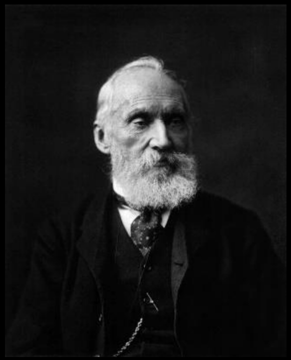
More than just identifying "Nice Pieces of Kit"



- Determine the key small, medium and large scale infrastructures and expertise that will promote innovation in energy storage materials and technologies
- Identify whether the infrastructure/expertise is currently available in the UK, could/should be developed or could/should be obtained through partnership
- Examine capital purchase options, sharing models and access mechanisms that can ensure the widest use of the existing key infrastructures to accelerate UK innovation
- Highlight infrastructure/expertise gaps where there is critical need for new investment and how/where it can be implemented for maximum impact

Critical Methods for Advancing *all* Batteries



Lord Kelvin: To measure is to know. If you cant measure it, you cant improve it.

There is a dizzying array of measurement methods available in the UK, with facilities and expertise comparable to the best in the world......

STXM, XPS, Tomography, Ptychography, XAS, In-situ X-rays, X-ray Diffraction, X-ray PDF, SAXS/WAXS, XANES, In-situ Neutrons, NeuNMR, Neutron Imaging, In-situ Muons, SEM, TEM, EELS, EDS, Electron Diffraction, Electron Tomography, In-situ TEM, Atom Probe, FIB, HIM, SXES, EPMA, NMR, MRI, In-situ NMR & MRI, EXAFS, NEXAFS, XCT, NanoSIMS, Raman, SERS, SHINERS, FTIR, IRRAS, IRAS, DRIFTS, RAIRS, ATR-IR, SEIRAS, UV/Vis, EPR, ESR, In-situ EPR, SECM, SECCM, SECM-AFM, EIS.........

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All can provide fundamental new insights into batteries......

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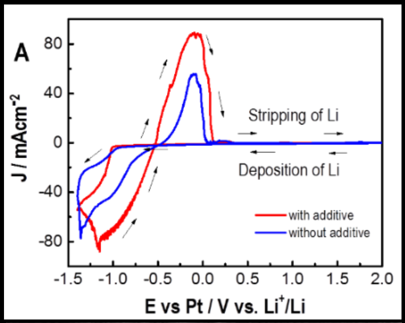
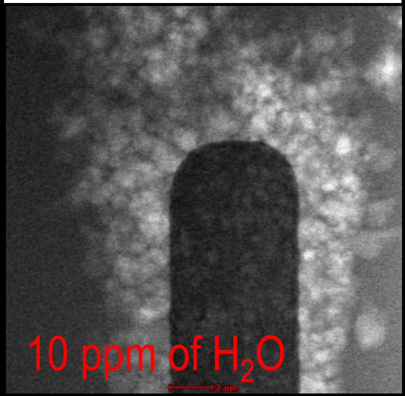
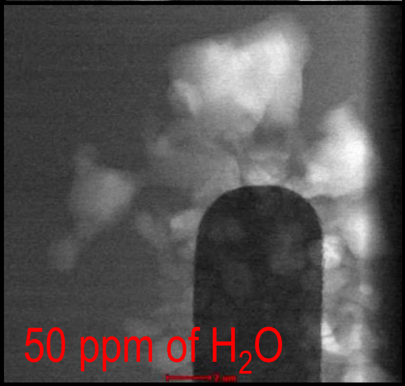
Challenges for State-of-the-art Characterisation







- **The best instrumentation and expertise for batteries distributed around the country** – the instrumentation and the expertise to use it are not necessarily always in the same place
- Standards for characterisation are developed locally – **only sometimes is the "expertise" buried in the supplementary information of papers**
- Projects occasionally perform a round robin characterisation of a standard sample – **high degree of variability in results, which highlights the "battery challenge"**
- Training performed in an *ad hoc* manner – **people protect leading expertise so student graduation and mobility is the main mechanism of dissemination**
- **Access is limited** – by who you know, cost or proposal process

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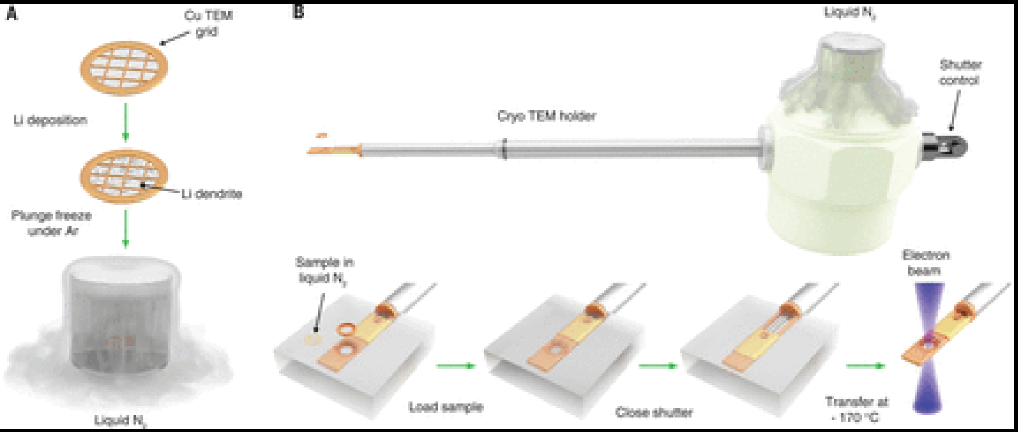
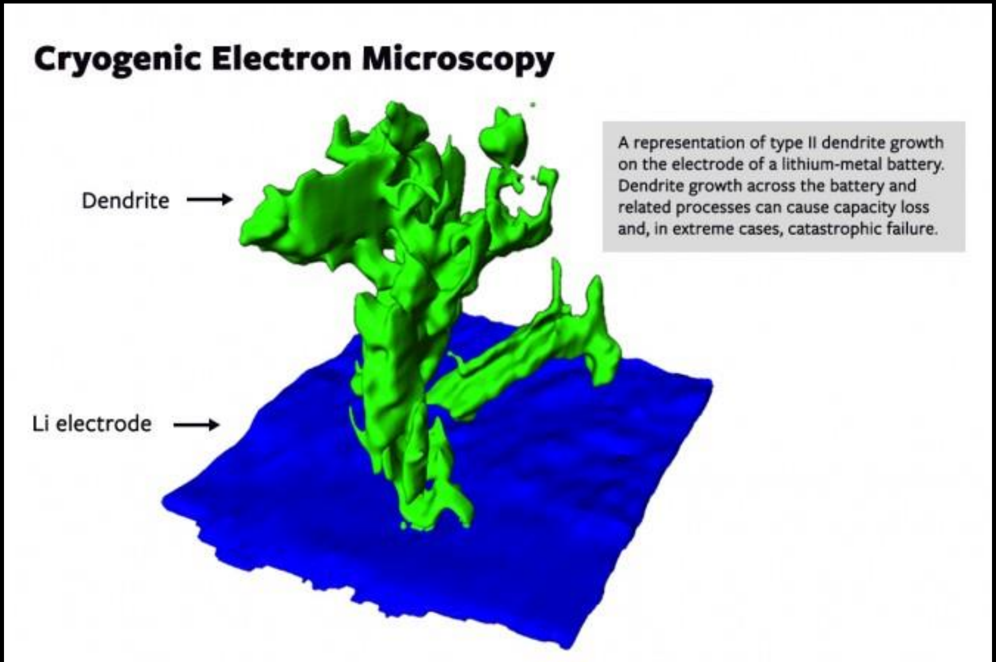
Recent Applications of Cryo-EM to Batteries



Li et al, Science **358**, 506-510 (2017)



Zachman et al
Nature 560, 345–349 (2018)

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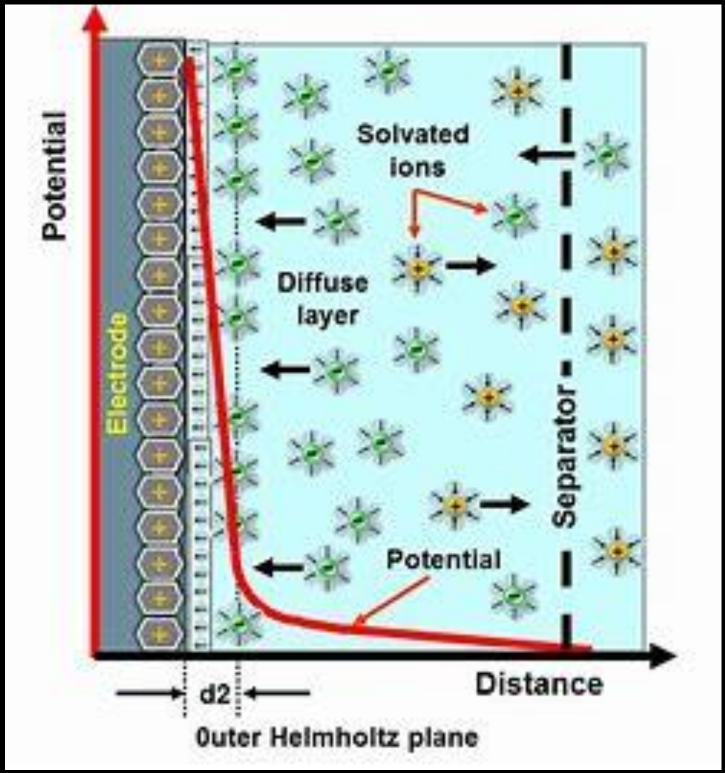
New Science from Characterisation?

Imaging the Kinetics of *all EES chemistries, mechanisms & applications*

- **Image and quantify ion transport on the atomic scale** – formation of the EDL, SEI and Interface Layers
- Map the chemical kinetics of ordered phase/interface/surface formation and stability under real world charging/use conditions
- **Measure solvation/de-solvation (coordination) dynamics under extreme electrochemical gradients**
- Understand diffusion and confinement effects across scales critical to application technologies



Responsive to challenges raised by fast start projects, industry and academia

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Summary of Recommendations

- A major advancement in the UK's ability to innovate new EES technologies would be achieved by introducing support mechanisms that both provide access to the best instrumentation and provide training in its use by experts in the characterisation of EES systems.

- By supporting researchers to collaborate extensively in coordinated research in a hubs and spokes model, unique methods and expertise in their use can be established amongst UK scientists in EES research.

- Characterisation usage can be optimised, avoiding much of the wasted effort that comes with un-calibrated claims, by setting out a coordinated policy for data calibration and reporting.

- Integrating scientists that generate data with scientists that curate and analyse data into a coordinated approach to characterisation can accelerate the application of optimised EES systems across all applications.

- All together, these approaches can stimulate the growth in EES expertise across the UK, rapidly advancing our ability to compete globally in this area.