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The Challenges of Scaling Up Battery Technologies

Or How do I learn to make a 1,000,000,000 good cells

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Fellow IoP

Agenda

- The Challenges of Scaling
- UKBIC
- Some Answers

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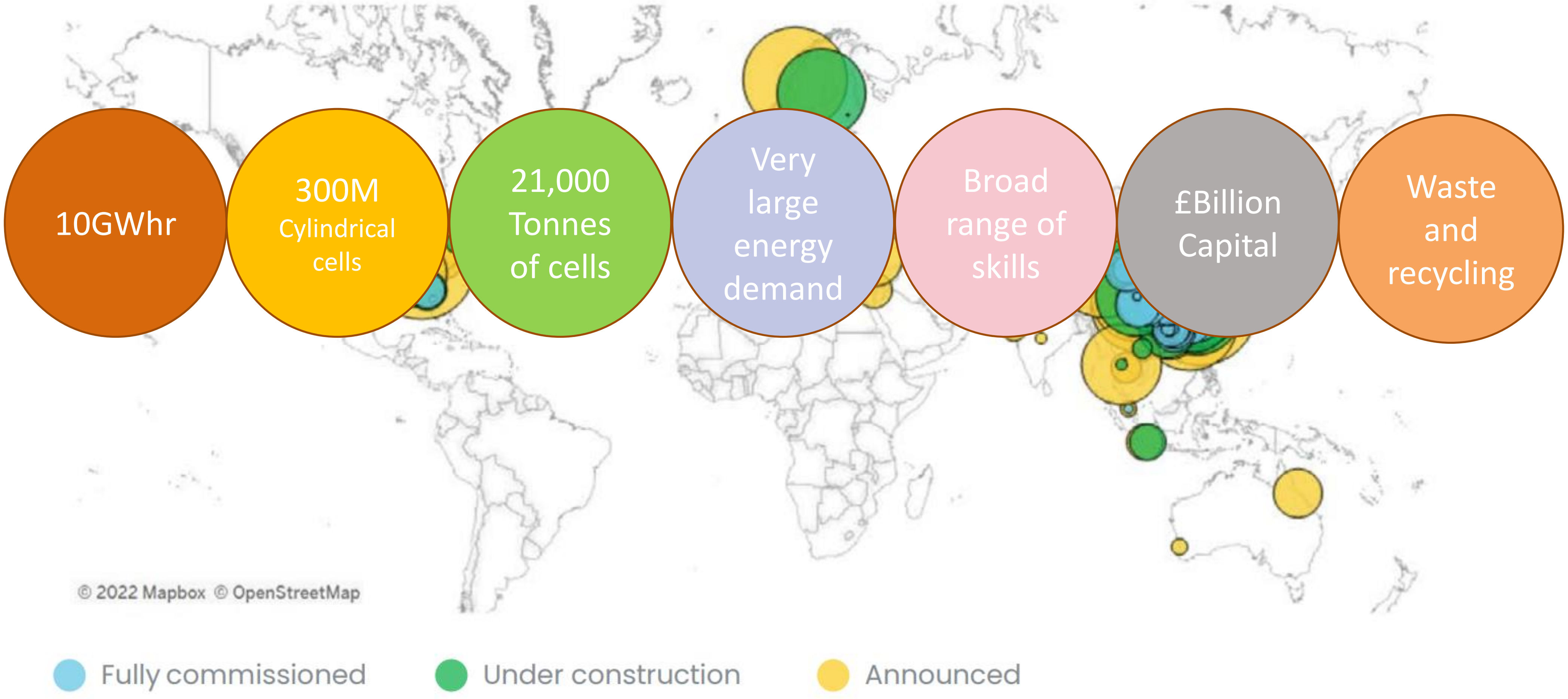
Gigafactories Worldwide



Bloomberg New Energy Finance (2022) Battery Cell Manufacturers Interactive Dataset

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Production Supply Chain for Automotive EV Batteries

Electrochemical Powders → Electrode, electrolyte, separateor, binder → Cell (Cylindrical, Pouch, Prismatic) → Modules → Packs & BMS → Vehicle Application → Second Life / Recycling

APC estimated a £12B opportunity for UK players in the Battery Sector

Slide source: WMG, University of Warwick

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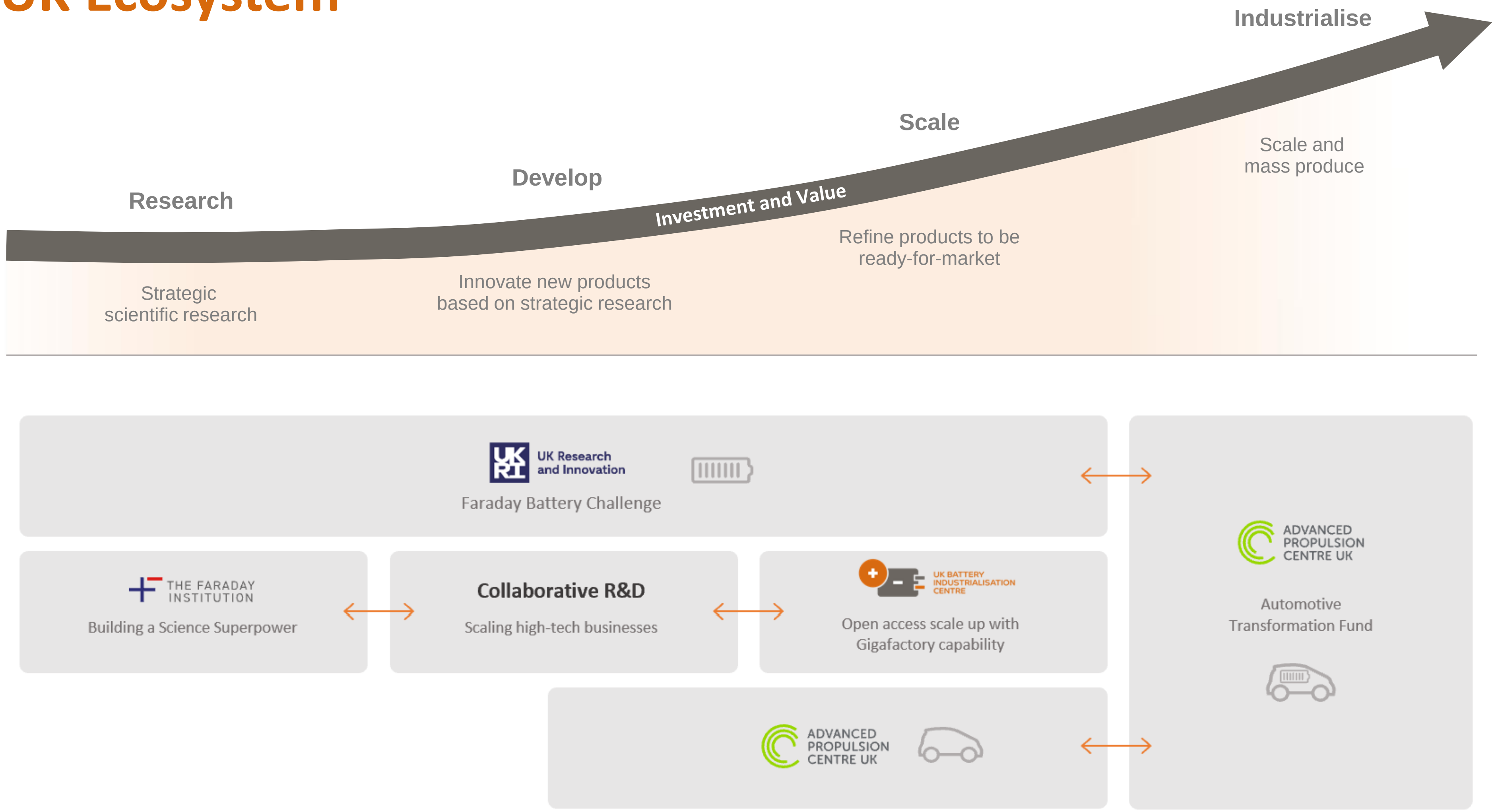
The UK Ecosystem



Source: Advanced Propulsion Centre

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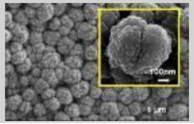
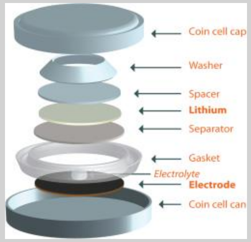
Bridging the Gap from R&D to Mass Production

UKBIC scope

Volume, TRL, MRL

Gramme Scale

Characteristic

- University scale research labs using small quantities of hand-made materials.
- Fundamental materials research
- Initial half-cell experiments at coin cell scale.

Kilogramme Scale

- Corporate R&D pilot line or university / Catapult centre.
- Used to demonstrate early scalability of materials to full size cell
- Develop and demonstrate electrode mixtures, deposition processes and cell formats.

Tonne Scale

- Full-scale GWh/yr manufacturing facilities used at low output rate.
- Used to develop and validate materials, cell design, manufacturing processes and parameters at industry rates prior to full plant investment.

Giga Scale

- Full-scale, high volume manufacturing plant. Typically 6-50GWh/year.
- Used to deliver very large volumes of cells with no variation or flexibility to chemistry, format or quality.
- Cost/kWh and process consistency are critical.

Technology Readiness

TRL 1	TRL 2	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Principles & Research	Explore Applications	Analytical Experiments	Validation & Requirements	Design & Performance	Model & Prototype	Performance & Testing	Test & Demonstrate	Real World & Launch

Research & Development | Industrial Engineering | Commercialisation

Manufacturing Readiness

MRL 1	MRL 2	MRL 3	MRL 4	MRL 5	MRL 6	MRL 7	MRL 8	MRL 9	MRL 10
Implication & Materials	Identify Processes	Proof of Concept	Identify Technology & Test	Prototype Materials, Tools & Skills	Processes & Detailed Costs	Pilot Line & Materials	Process Maturity Demonstration	Manufacturing Processes Proven	Production Ready
Material Solution Analysis				Technology Development		Engineering & Manufacturing Development		Production & Deployment	Operation & Support

UKBIC Scope

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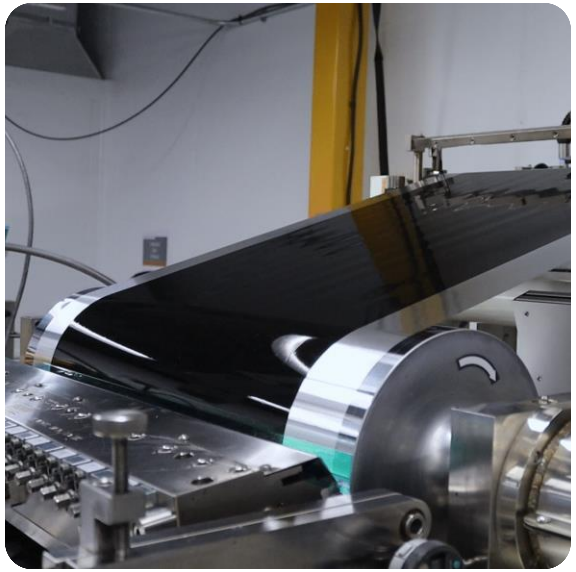
Electrode Processing

Mix



Coat

Calender

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Cell assembly - cylindrical

- Environment:
  - ISO7 clean room & dew point = -40°C
  - Dew point at electrolyte fill = -50°C
- Cell format: 21700
- Rated at up to 20 cells per minute

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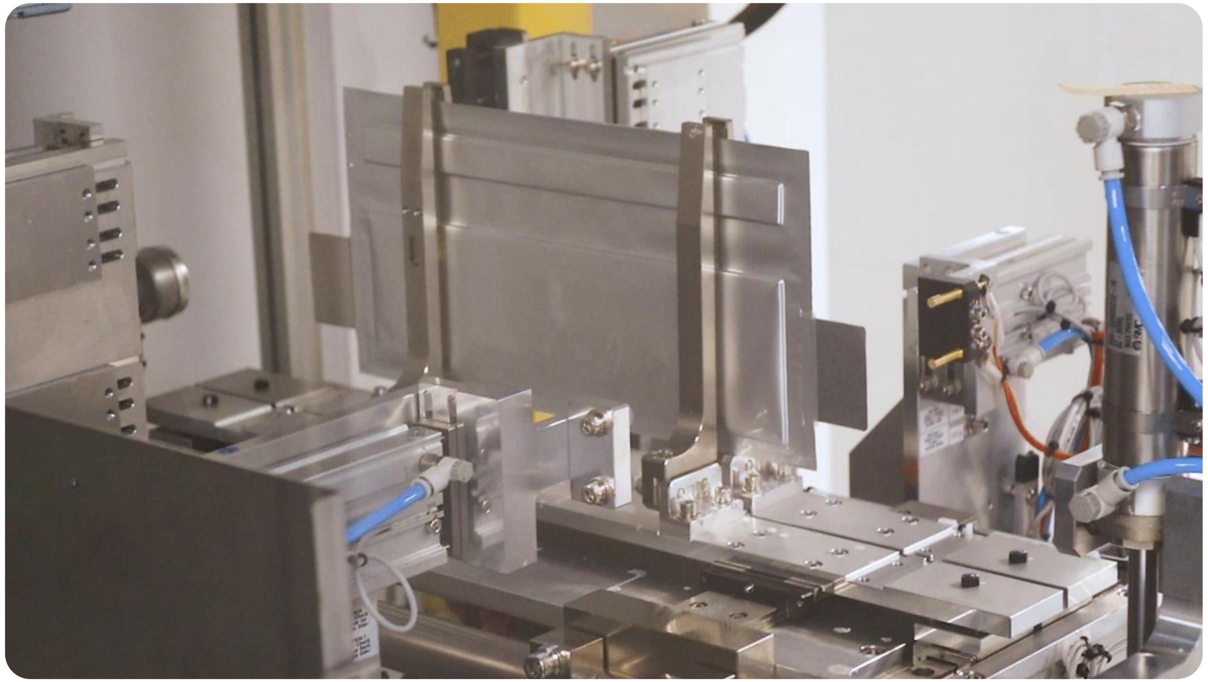
Cell assembly - Pouch



- Environment:
  - ISO7 clean room & dew point = -40°C
  - Dew point at electrolyte fill = -50°C
  - Cell format: 300mm x 100mm x 10mm
- Technology: Z-fold stacking

Module Assembly

- Environment: ISO class 9, factory conditions
- Formats: cylindrical or pouch cells
- Max. dimensions: 0.4m x 0.4m x 0.25m
- Max. weight: 30kg
- Max. voltage: 60V
- Max. capacity: 200Ah
- Laser welding and wire bonding capabilities
- End-of-line testing
- Configurable process

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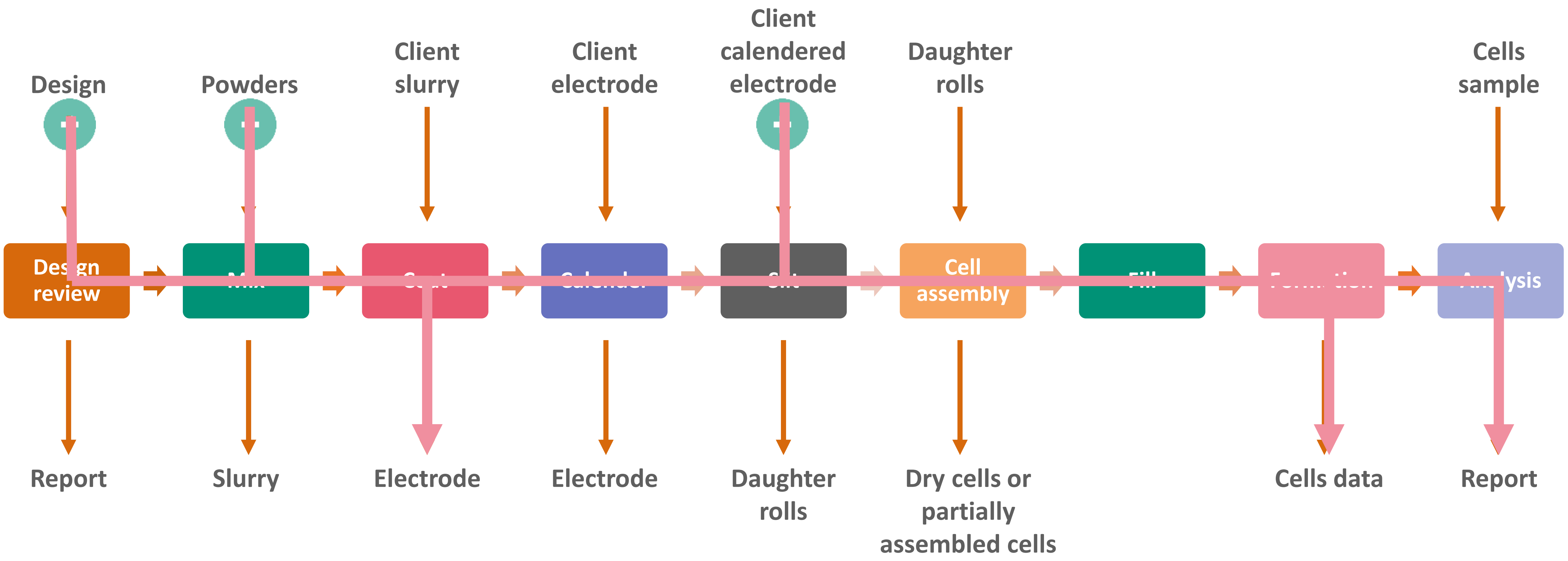
A Modular Capability



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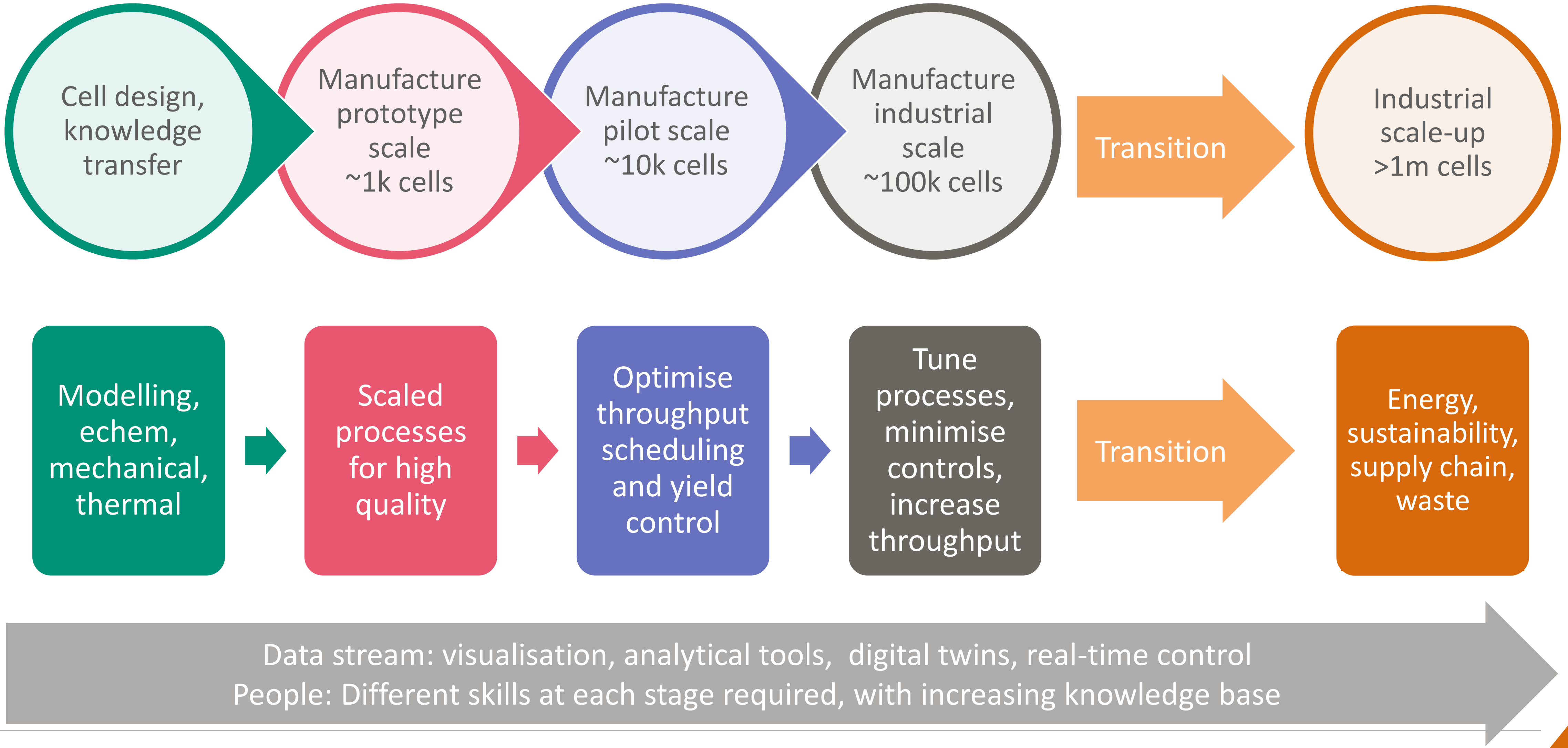
The Scale-up Journey



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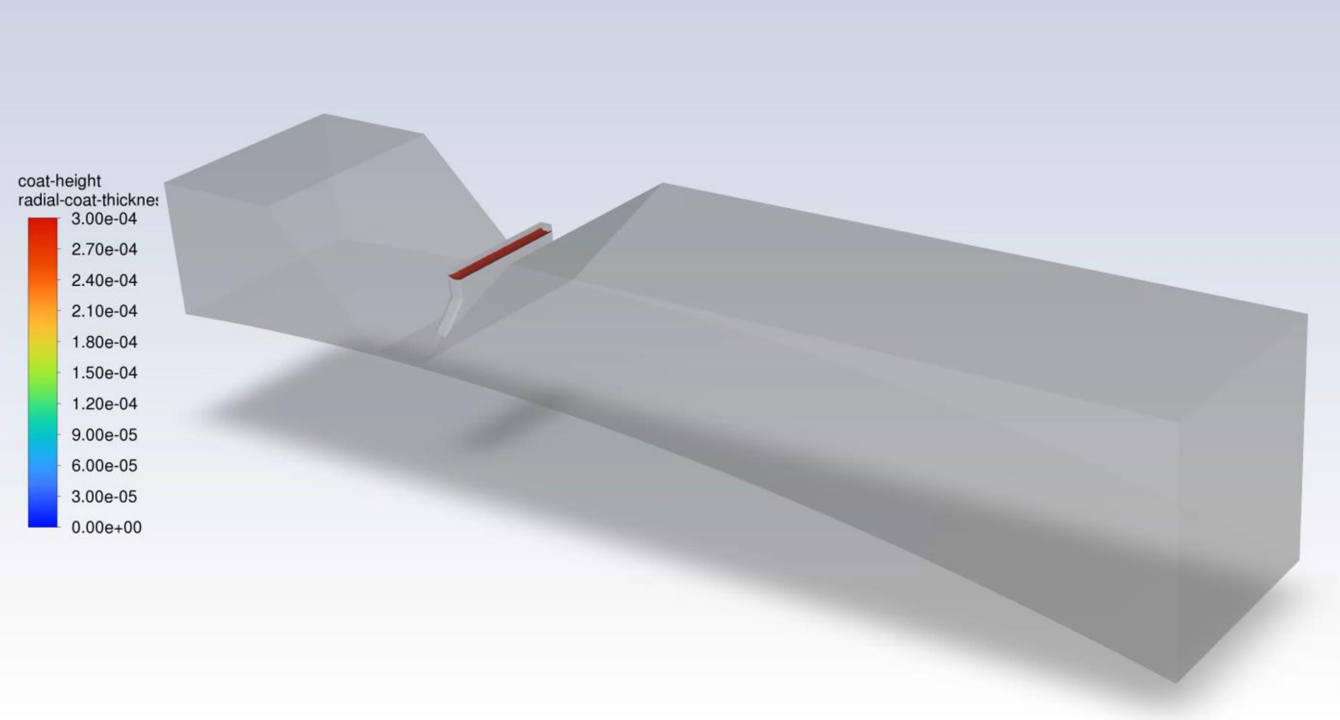
Process Simulation

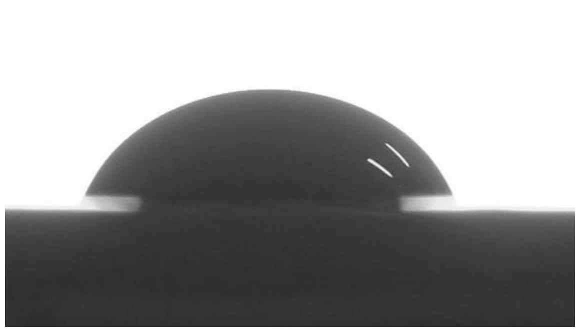
- Slot die coating
  - Anode and cathode models
  - Continuous and intermittent models
  - Roller-backed and web-tensioned
- Flotation drying process
- Calendering model
  - FEA mechanical modelling of calendering to predict defects in mass-free zones
  - Electromagnetic and thermal modelling of induction and infrared heating during calendering



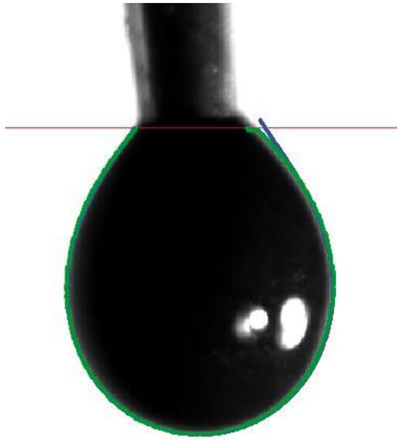
Model Inputs

Accurate and reliable modelling is contingent upon high quality model inputs. In particular, the electrode slurry material properties. This includes

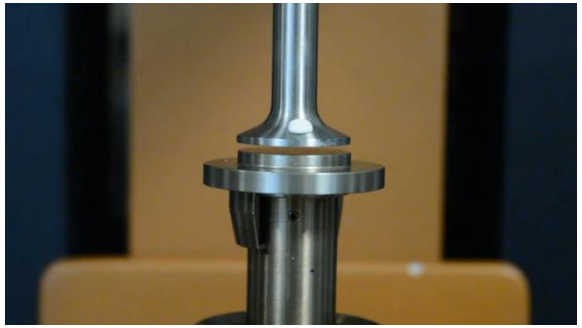
- Contact angle with substrate
- Surface tension of slurry
- Non-Newtonian, viscoelastic rheology



Droplet of anode slurry during contact angle assessment. Credit to Carl Reynolds, School of Metallurgy and Materials, University of Birmingham.



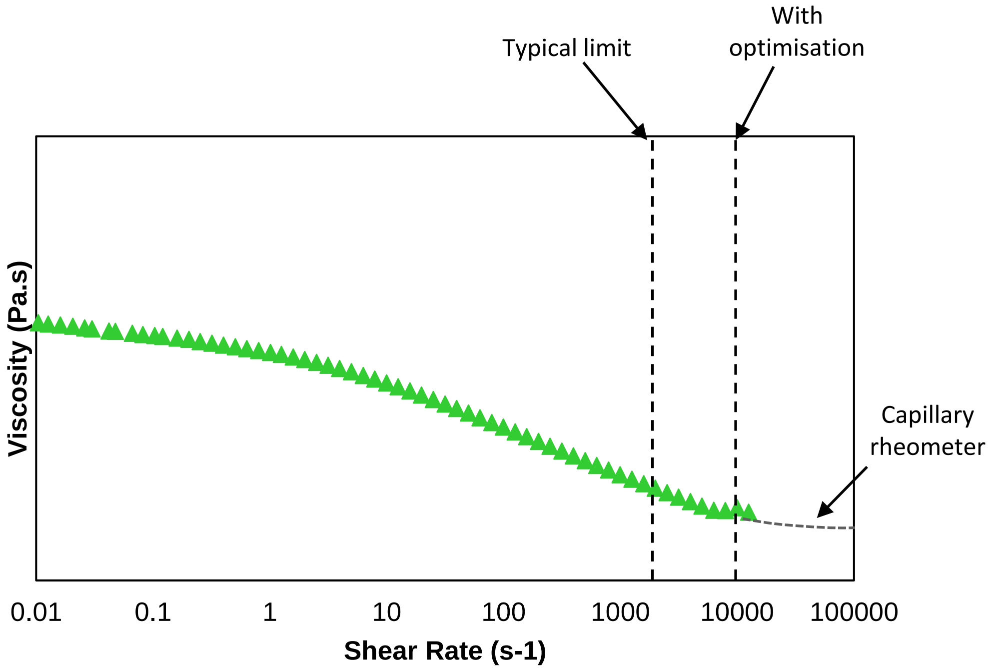
Surface tension measurement using pendant drop methodology. Credit to Carl Reynolds, School of Metallurgy and Materials, University of Birmingham.



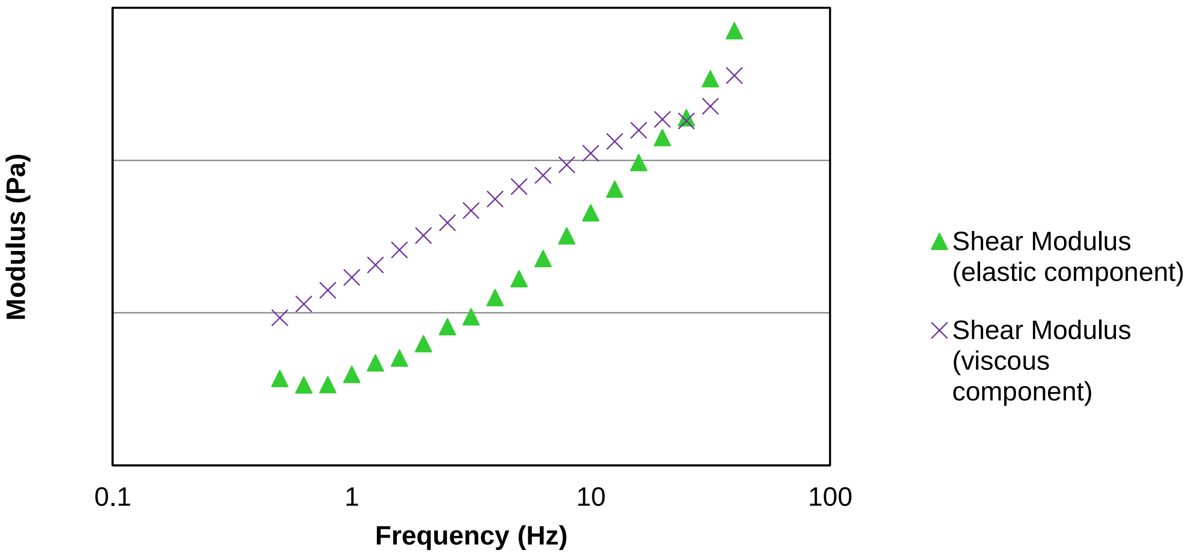
Oscillatory measurements give the elasticity of an electrode slurry. Credit to Carl Reynolds, School of Metallurgy and Materials, University of Birmingham.

Model Inputs

Both non-Newtonian and viscoelastic elastic properties need to be determined to fully understand how the slurry will behave. This can present challenges, with shear rates experienced within coating often exceeding the capability of the most widely used commercial rotational rheometers.



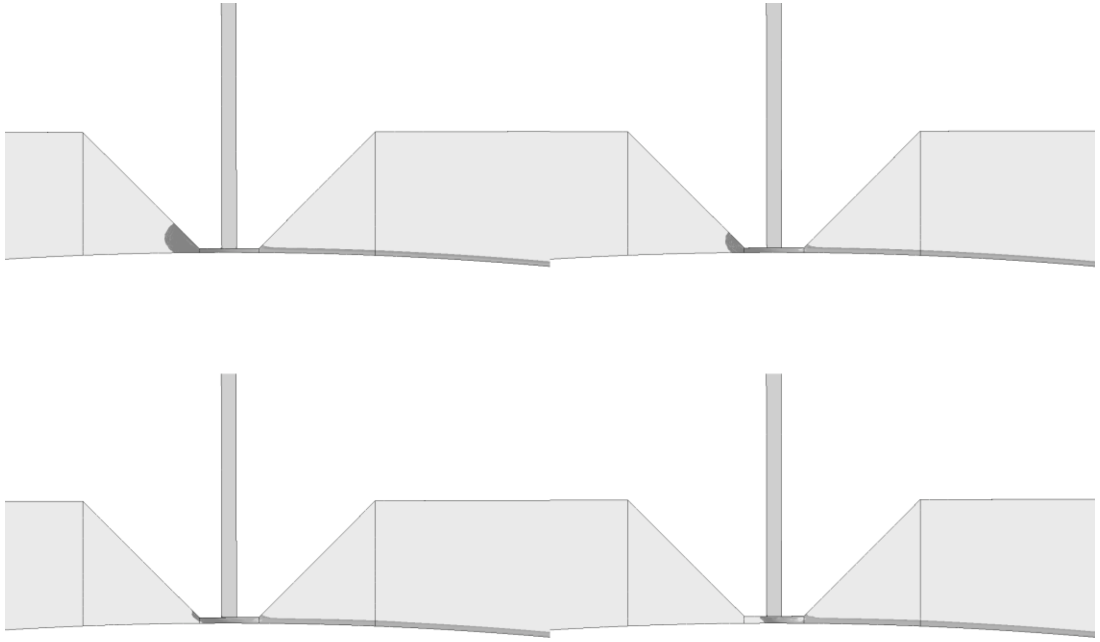
Flow curve giving non-Newtonian properties of the slurry. With optimisation, shear rates up to 10,000s^{-1} can be determined.



Result of oscillatory measurements giving the viscous and elastic components of the shear modulus of an electrode slurry.

Informing Process Parameters – Die offset

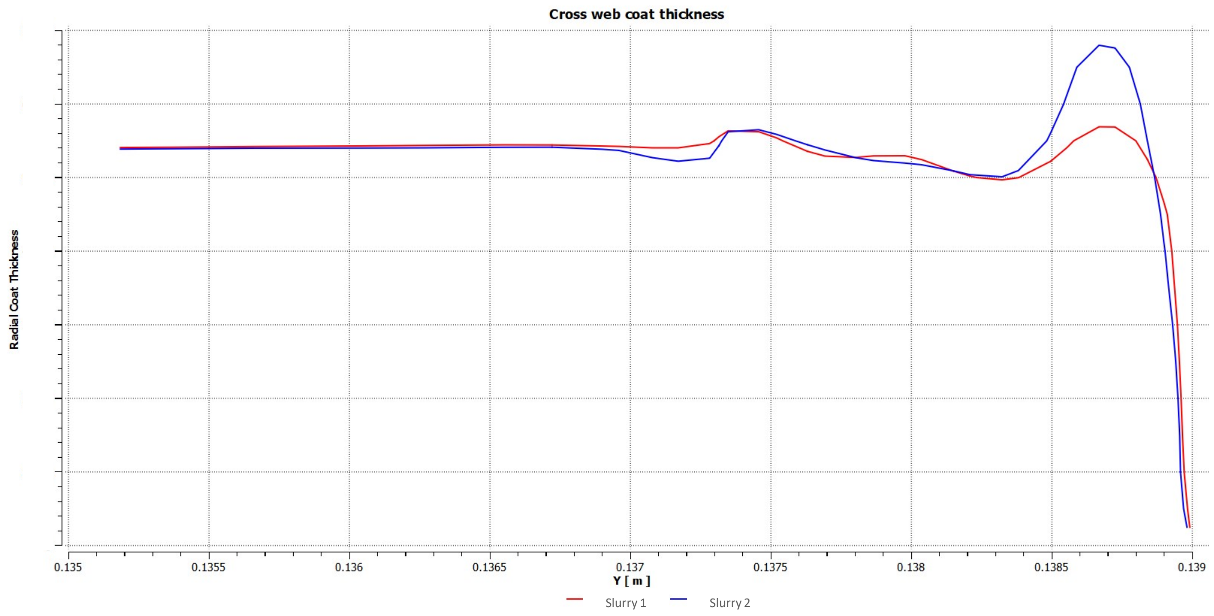
The model can predict meniscus location and stability which is key in avoiding air entrainment during coating and controlling coat width. The model can be used to recommend a gap setting optimising the coating process and reducing dialling in waste.



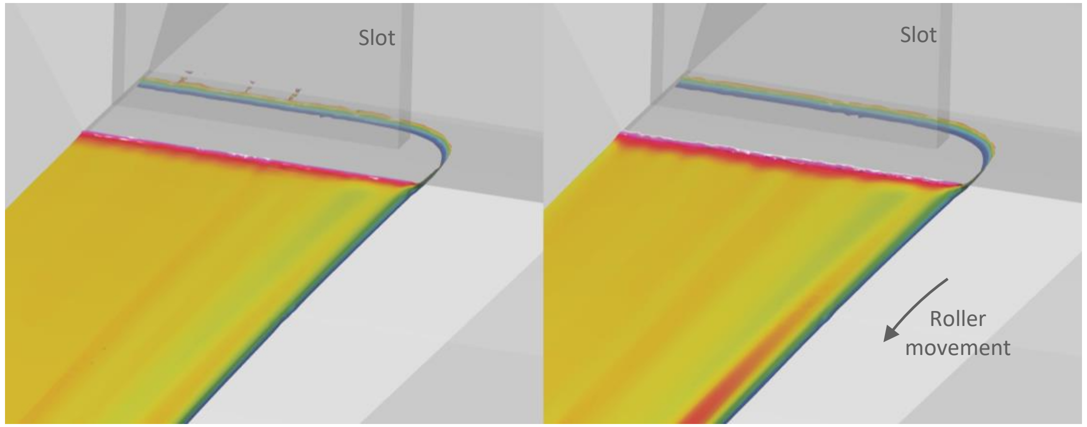
Slurry meniscus with die offset increasing from top left to bottom right.

Determining Slurry Limitations

Some processes may be inherently limited by slurry material properties. For example, for thin coatings, a slurry with a high contact angle or surface tension may inevitably lead to high edges and modelling can determine this before coating.



Near-edge coat thickness comparison for two slurries coated with the same process parameters but with different rheology.



Continuous coating simulation showing the surface of the slurry coloured by the coat thickness with clear high edge developing

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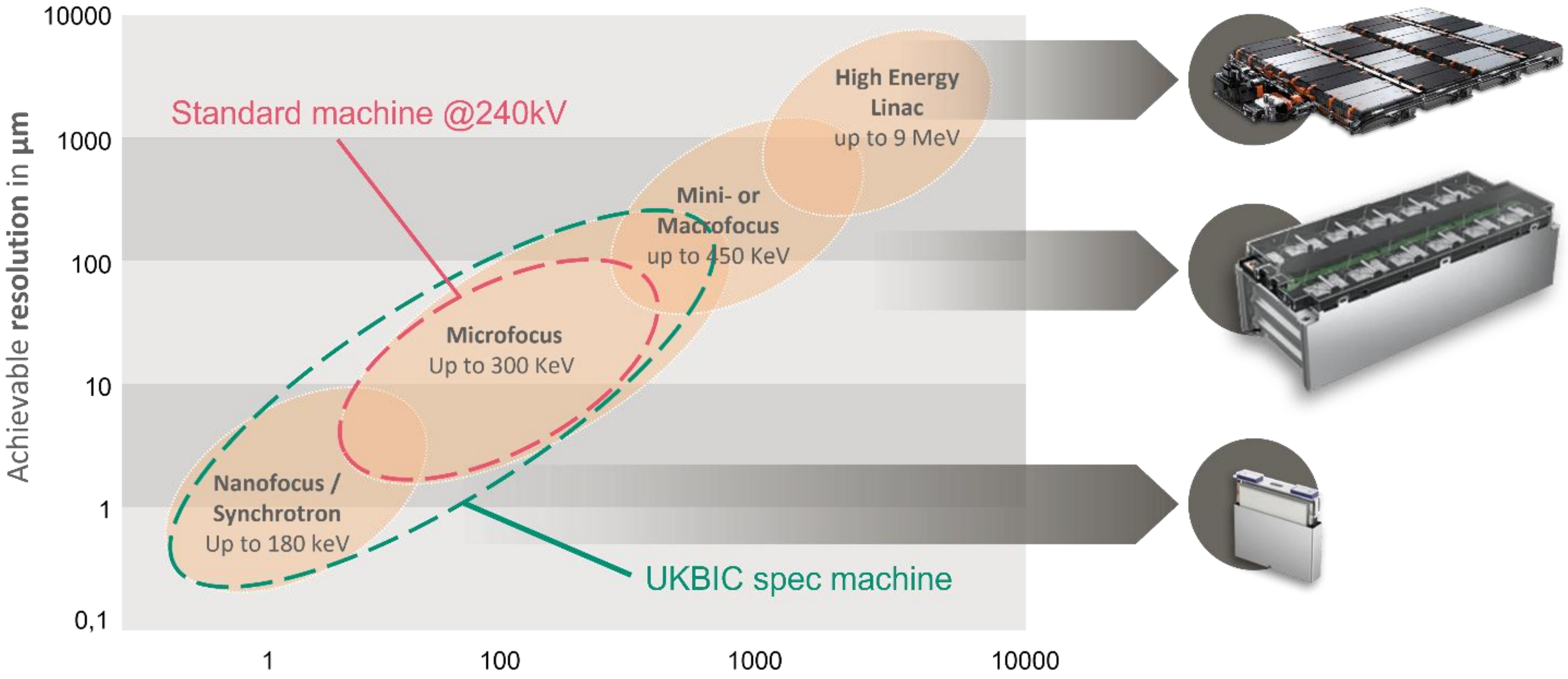
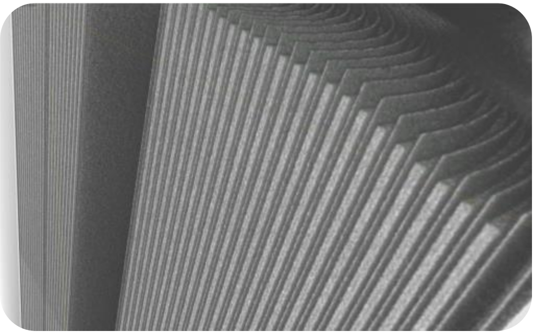
CT Scanner – A UKBIC & Waygate Collaboration

- Waygate Technologies, a Baker Hughes business, has supplied and installed a state-of-the-art CT open access and industrial X-Ray computed tomography (CT) digital solution at UKBIC.



Baker Hughes

Waygate Technologies



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Training at UKBIC

Introduction to…

- Electrode
- Cell assembly
- FA&T
- Module & pack

Hazardous voltage
Level 1 - 4

Bespoke
What do you need?

Battery design for sustainability

On the line training for operators
Writing standard work instructions

What does UKBIC do?

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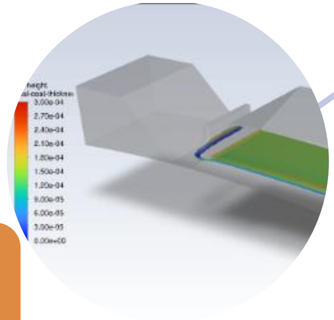
Low volume supply

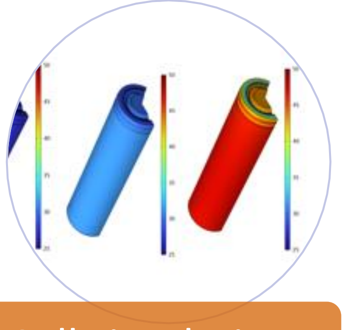
Industrialisation

Training

UKBIC

Process simulation





Cell simulations

Industrialisation advice and support

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