ADVANCED MATERIALS RESEARCH & INNOVATION

BLUEPRINT

UK HYDROGEN PRODUCTION: ELECTROLYSIS

GAP ANALYSIS AND NEXT STEPS

ROYCE

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Introduction

Green hydrogen production (via electrolysis) at Terawatt-scale (TW) levels is critical to widescale hydrogen deployment in a 2050 timescale, as described in the Henry Royce Institute (Royce) Materials for End-to-End Hydrogen report published in 2021.

Over the past 3 months Royce has been working with a cross industry/academic Working Group to develop a blueprint of the UK's electrolysis needs. The blueprint development has involved consultation with businesses, research technology organisations (RTOs), and universities to build a comprehensive picture of current UK electrolysis capabilities and complete the gap analysis to identify areas for future funding.

This blueprint provides, for the first time, a comprehensive view of the UK electrolysis capabilities to inform future spending plans in this area. We expect the blueprint to be refined further as we continue to receive feedback and as the hydrogen sector evolves.

UK Electrolysis Needs

The UK's electrolysis needs for hydrogen can be broadly divided into a series of scale up, electrolysis type and monitoring domains (see Figure 1) with the aligned industry and academic needs identified for each.

Scope	**Electrolysers:** Proton Exchange Membrane water, Alkaline water, Solid Oxide water and Anion Exchange Membrane water		
Scale up & Electrolyser Testing	Meet efficiency, potential scalability to 1TW , durability, recyclability and carbon footprint targets		
PEM Electrolysis	Iridium free or low iridium catalysts	Develop new conductive and stable materials for current collectors, porous transport layers and catalyst support	Contaminants – mitigate impact and scale up away from pure water
Alkaline Electrolysis	Improve sluggish hydrogen evolution reaction & oxygen evolution reaction kinetics through catalyst development		
Solid Oxide Electrolysis	Improve electrode and electrolyte materials		
AEM Electrolysis	Improve membrane stability and conductivity and catalyst activity		
Monitoring	Online techniques enabling real time measurement of reaction progression, impact of impurities, and degradation pathways affecting ageing		

Figure 1 - UK Electrolysis Needs

UK Existing Facilities

The UK currently has electrolysis research facilities available which we were able to map across businesses, universities, and RTOs to provide for the first time a consolidated picture of the UK capabilities in this space.

Capability Areas	Scale up & Electrolyster Testing	PEM Water Electrolysers	Alkaline Water Electrolysers	Solid Oxide Electrolysers	AEM Water Electrolysis	Monitoring
Universities	UCL Imperial	UCL Imperial Oxford Southampton Cambridge Manchester Met Strathclyde	Loughborough	Imperial Oxford St Andrews	Surrey Newcastle	UCL Imperial Oxford Warwick
Businesses	Johnson Matthey Ceres Power ITM Power	Johnson Matthey ITM Power	Johnson Matthey INEOS AFC Energy	Johnson Matthey Ceres Power	AFC Energy	Johnson Matthey ITM Power Ceres Power
Research Technology Organisations	NPL	NPL	NPL	NPL		NPL

Figure 2 - UK Electrolysis – Existing Facilities and Programmes Needs

UK Electrolysis Hardware Priorities

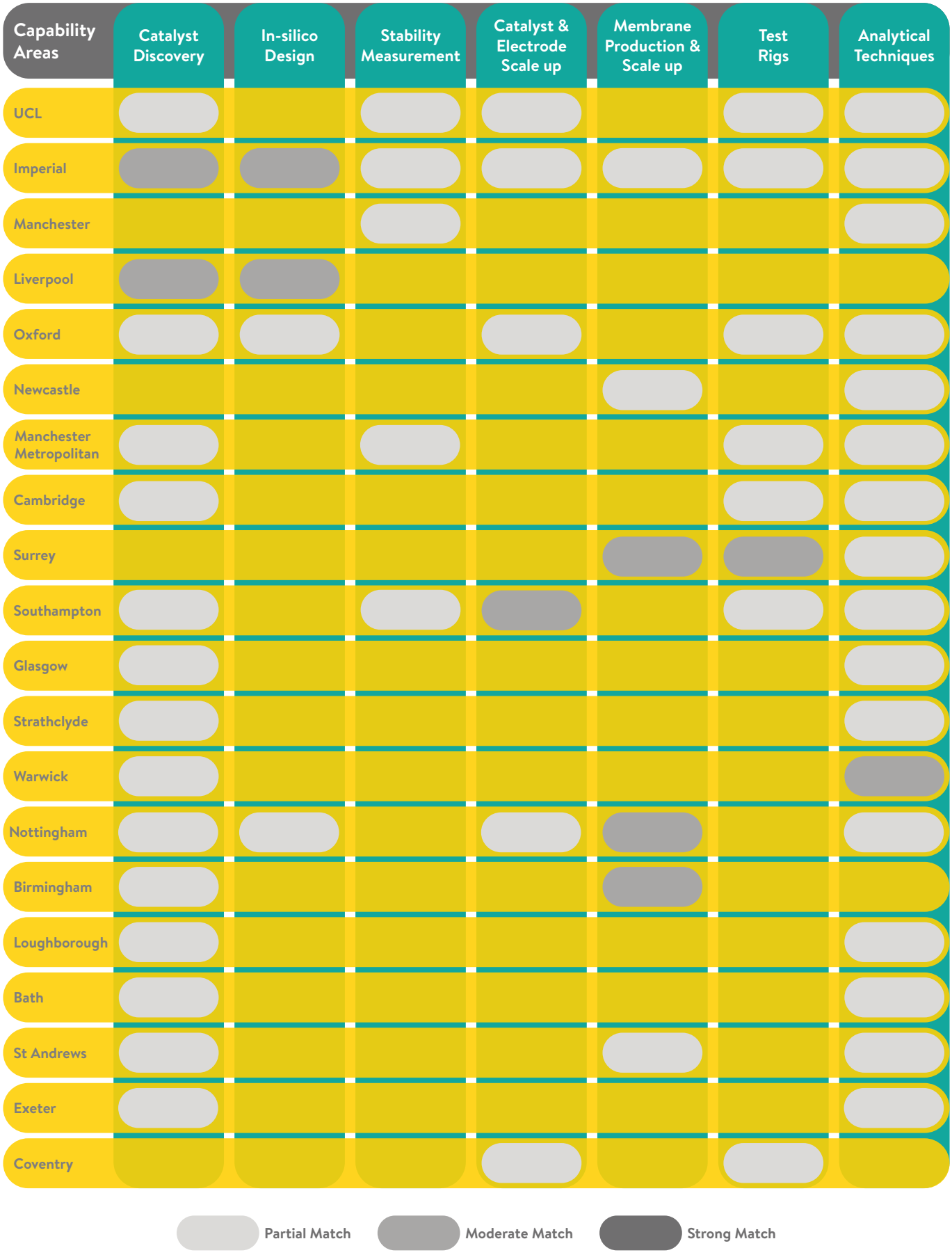
From this analysis we were able to determine the hardware priorities to support the testing needs, namely:

- Catalyst discovery for low iridium / iridium free catalysts including catalyst preparation, characterisation, and high-throughput testing
- Use of computational tools to discover new materials in silico
- Facilities for rigorous stability measurements, for example, inductively coupled plasma mass spectrometry
- Catalyst and electrode scale up facilities
- Membrane production and scale up facilities
- Test rigs for electrolyser systems to validate new materials under relevant in-operando conditions
- Analytical techniques to drive understanding of degradation and other processes in real time

Hardware Priority Mapping

Based on the input from our cross industry/academic Working Group we were then able to map the existing university capabilities against the hardware priorities.

Figure 3 - UK Electrolysis – Hardware Priority Mapping



Gap Analysis

The UK has core capabilities in the electrolysis area. The analysis highlighted areas in which we need to invest further to ***strengthen the base*** to provide resilience and develop the future talent pool.

Specifically, this related to university activities in the following areas:

- Strengthen **electrocatalysis** activities in **UK Catalysis Hub** members linking with the University of Bath's EPSRC Hydrogen Research Coordinator
- Further build on **in-silico electrocatalysis programmes for example at the Universities of Liverpool, Nottingham and Imperial**
- Draw on University of **Surrey membrane** expertise for **electrolysis applications**
- Draw on **Ulster** University expertise in **hydrogen safety related issues**
- Access **Newcastle University systems integration expertise** via new **EPSRC Systems Coordinator**
- Utilise transferrable elements of **H2FC SUPERGEN** hardware and skills base

The study further highlighted some significant ***gaps to address***, specifically related to university activities in the following areas:

- Research effort directed specifically towards **electrocatalysis**
- **Scale up capabilities** (multiple units required to address current constraints) to system level to address current lack of **electrochemical cells** and long order lead times
- **Electrolyser test facilities at operating scale** i.e., multiple kilowatts (KWs) and 24/7 duration
- **In-silico approaches and intelligent electrode design** to complement current physical ones across the spectrum
- **Stability measurement** and ultra-sensitive **analytical techniques** to track real time changes
- Extend **membrane fabrication facilities** to **further understanding of catalysts and barrier layers**
- **Techno-economic assessment tools** to aid target setting and monitor progress

Recommendations and Next Steps

The recommendations and next steps will ensure the UK has the required electrolysis materials resources to support hydrogen production at TW levels.

Recommendations

An initial £5m investment to address specific areas highlighted in the blueprint, namely;

- Provision of multiple electrochemical test cells (single to part stack)
- Development of an intelligent electrode design facility
- Provision of membrane scale up facilities
- Integration of blueprint findings into the Department for Business, Energy and Industrial Strategy, EPSRC (Hydrogen Research Co-ordinators) and Innovate UK hydrogen future funding plans

Next steps

- Complete development of a publicly accessible hydrogen materials database
- Define required UK investment to support the remaining priorities in the strengthening of the base and addressing the gaps areas referenced in the electrolysis blueprint
- Submit funding bids to address electrolysis blueprint priority areas and leverage further funding from BEIS, EPSRC, Innovate UK and the private sector
- Develop comparable blueprints for end-use, distribution and storage
- Complete talent pipeline assessment to support materials blueprint delivery

HENRY ROYCE INSTITUTE

Authors: Robert Sorrell, Robin Morris, Tim Sudmeier

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royce.ac.uk

info@royce.ac.uk

Henry Royce Institute

@RoyceInstitute

henryroyceinstitute

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