

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	<b>Electrolysers:</b> 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 & Electrolyser 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

Capability Areas	Catalyst Discovery	In-silico Design	Stability Measurement	Catalyst & Electrode Scale up	Membrane Production & Scale up	Test Rigs	Analytical Techniques
UCL	Partial Match		Partial Match	Partial Match		Partial Match	Partial Match
Imperial	Moderate Match	Moderate Match	Partial Match	Partial Match	Partial Match	Partial Match	Partial Match
Manchester			Partial Match				Partial Match
Liverpool	Moderate Match	Moderate Match					
Oxford	Partial Match	Partial Match		Partial Match		Partial Match	Partial Match
Newcastle					Partial Match		Partial Match
Manchester Metropolitan	Partial Match		Partial Match			Partial Match	Partial Match
Cambridge	Partial Match					Partial Match	Partial Match
Surrey					Moderate Match	Moderate Match	Partial Match
Southampton	Partial Match		Partial Match	Moderate Match		Partial Match	Partial Match
Glasgow	Partial Match						Partial Match
Strathclyde	Partial Match						Partial Match
Warwick	Partial Match						Moderate Match
Nottingham	Partial Match	Partial Match		Partial Match	Moderate Match		Partial Match
Birmingham	Partial Match				Moderate Match		
Loughborough	Partial Match						Partial Match
Bath	Partial Match						Partial Match
St Andrews	Partial Match				Partial Match		Partial Match
Exeter	Partial Match						Partial Match
Coventry				Partial Match		Partial Match	



Partial Match



Moderate Match



Strong Match

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## 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

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