HENRY ROYCE INSTITUTE

ROYCE

THE ROYCE HYDROGEN ACCELERATOR

Delivering the material innovations needed for the UK to lead the global hydrogen economy

GOVERNMENT SUPPORT FOR THE ROYCE HYDROGEN ACCELERATOR

Department for Science, Innovation & Technology

"His Majesty's Government is committed to developing the UK's low carbon hydrogen economy: hydrogen is critical to delivering energy security and our decarbonisation targets and presents a significant growth opportunity for regions across the UK. My department heartily supports the ambition of the RHA to build a robust private sector hydrogen materials supply chain and anchor it within the UK. I look forward to receiving updates on Royce's Hydrogen Accelerator and the innovative materials that will ultimately support delivery of the hydrogen economy."

George Freeman MP
Minister of State for the Department for Science, Innovation, and Technology

Department for Energy Security & Net Zero

"We are pleased to see the addition of the Accelerator to the portfolio of work that Royce is undertaking, as materials R&D is essential for plugging the supply chain gap (including production, storage and distribution) to realise hydrogen commercialisation at scale and pace. The RHA will sit alongside other government initiatives to advance the UK's hydrogen capabilities – contributing to the government's goals of reaching net zero and developing a thriving hydrogen sector."

Lord Callanan
Minister for Energy Efficiency and Green Finance for the Department for Energy Security and Net Zero

Department for Business & Trade

"Government will support engagement with investors and industry to drive investment into the UK's hydrogen economy and showcase UK hydrogen investment opportunities. We anticipate that you will work closely with government to ensure that the economic opportunities to grow a UK hydrogen materials supply chain will be fully realised. Royce is well placed to convene and lead this work."

Lord Johnson
Minister for Investment for the Department for Business and Trade

THE CHALLENGE

Hydrogen offers a genuine pathway towards decarbonisation, particularly for energy-intensive industries which are difficult to abate through solar, wind or nuclear alone.

Hydrogen is particularly relevant to the transport, aerospace, marine, steel, glass and ceramics sectors, among others. Strengthening the UK hydrogen industry will build national energy resilience, deliver green jobs, and ensure that future emissions targets can be met.

Hydrogen supply chains will be key to the future energy system, given hydrogen's ability to act as both an energy source and storage mechanism. Significant progress is already being made towards the adoption of hydrogen worldwide, but the UK needs to act now to ensure it becomes a key player in the industry's future.

Despite the major advantages that hydrogen offers, there are several challenges constraining the development of the UK and wider global hydrogen industry.

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There is a need for material innovations to improve the efficiency, durability, and performance monitoring of hydrogen-related technologies. The high-pressure and/or low-temperature storage requirements of hydrogen require dedicated infrastructure to be developed for its transportation and storage.

To reach net zero targets, the fraction of hydrogen produced using renewable energy (known as 'green hydrogen') needs to increase considerably. Significant improvements in the efficiency of materials for electrolysis are required for this pathway to become cost effective.

Connections between industry and academia must also be strengthened, and research should be targeted effectively at finding solutions, allowing new technologies to mature rapidly to deployment.

By enabling the rapid innovation, scaling and adoption of advanced materials that tackle these challenges and unlock the hydrogen supply chain, the Royce Hydrogen Accelerator will attract investment and secure a leading position in the global market for the UK.

UK STRENGTHS

The UK has unique structural advantages which, if capitalised on, will drive the development of its hydrogen industry.

RESEARCH & DEVELOPMENT

It is home to globally-leading R&D capabilities and has a long-standing history of research excellence. It hosts world-class universities, has robust IP legislation, and a highly-skilled workforce which can be leveraged for the development and deployment of hydrogen technologies. Existing government-backed research centres, like the UK Hub for Research Challenges in Hydrogen and Alternative Liquid Fuels (UK-HyRES), complement the academic and industry-led research programmes in hydrogen.

RENEWABLE ENERGY

The UK also has access to significant renewable energy resources, especially for wind generation. The seas around Britain represent the greatest wind energy potential in Europe and are already home to the world's largest offshore wind farms. An abundance of renewable energy is crucial for the sustainable production of green hydrogen through electrolysis.

INFRASTRUCTURE

Infrastructure required for traditional hydrogen production already exists in the UK for large-scale refining and chemical production processes, much of which is concentrated in coastal industrial centres, such as in the North East. As materials innovation drives down the cost of green hydrogen production, these industrial ports, amongst others, can act as centres for scaling up its use.

POLICY

The government policy landscape of the UK is also well-prepared for the future role of hydrogen. 'The UK Hydrogen Strategy', published in 2021, targets the installation of 10GW of low-carbon hydrogen production capacity by 2030. Other recent national strategies – profiled on page 10 – include the Hydrogen Innovation Initiative and HI-ACT (Hydrogen Integration for Accelerated Energy Transitions), which aim to overcome nationwide barriers to hydrogen adoption.

INDUSTRY

The UK is already home to key players across the hydrogen supply chain, including bp, INEOS, Rolls-Royce, Johnson Matthey, National Gas, AFC Energy, Ceres Power and ITM. The depth of the UK's hydrogen industry is notable, spanning the full range from burgeoning SMEs and mid-size firms to global industry leaders.

THE SOLUTION

THE ROYCE HYDROGEN ACCELERATOR

Through its unrivalled access to the extensive UK research base, the Royce Hydrogen Accelerator (RHA) will:

1. Scan the UK research landscape to identify world-leading materials solutions.

2. Determine if these solutions are internationally competitive, viable, and scalable.

The result of this process will be de-risked investment opportunities spanning the breadth of the hydrogen supply chain.

The Accelerator is designed to tackle the materials challenges which are constraining the hydrogen supply chain. It will achieve this by bridging the gap which exists between lab-based materials research and proven technologies executed at scale.

The RHA's market-driven approach ensures that nonviable solutions are discounted quickly, and feasible technologies are rapidly scaled up to solve hydrogen materials challenges.

The support of the UK's national advanced materials centre, the Henry Royce Institute, will focus attention on the role of materials in the hydrogen industry. It will also allow the Accelerator to draw from well-established partnerships throughout the hydrogen supply chain and ensure that new investment helps people, businesses and growth in the UK.

The RHA is designed to tackle the materials challenges which are constraining the hydrogen supply chain.

The RHA will focus on several research areas in parallel to reflect the most pressing problems faced by the UK hydrogen industry. This agile structure will enable the RHA to address the barriers to the UK hydrogen economy rapidly, while minimising the risk to investment.

Through close cooperation with industry and academia over the last two years, Royce has already identified the key challenges for materials in the production, storage, distribution, monitoring and use of hydrogen. These can be seen on page 8.

The RHA will assemble a broad base of decision makers and subject matter experts, including representatives from industry, finance, government, and academia. The composition of the RHA's governance will reflect the major research challenges across all TRLs, as described on page 9, ensuring that the Accelerator is steered by a board with relevant expertise to the challenge being addressed.

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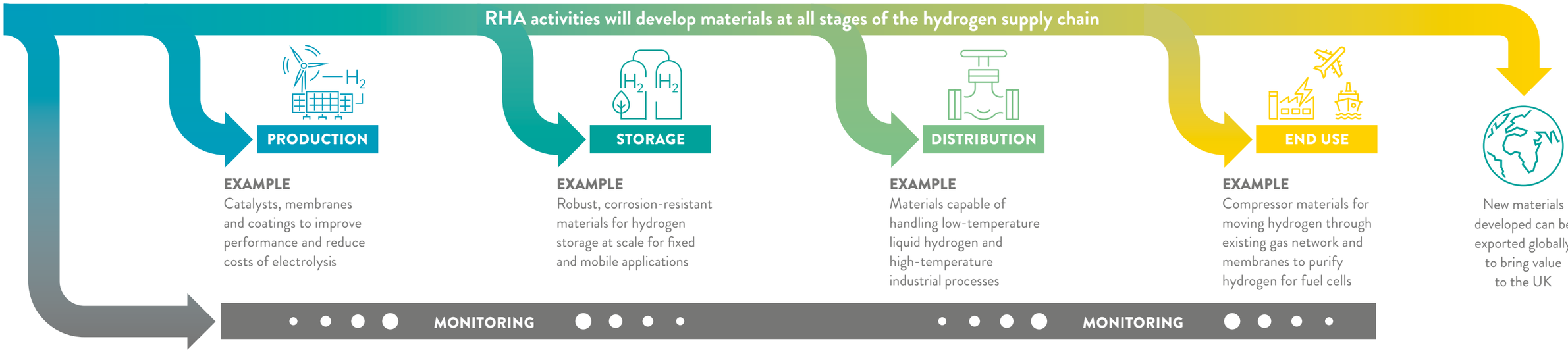

5 WAYS THE RHA WILL DELIVER:

FOR THE UK

1. ADVANCING CRITICAL TECHNOLOGY AREAS

Driving the focus and funding of materials R&D activities to tackle the hydrogen materials challenges.

2. BRIDGING THE TECHNOLOGY INNOVATION GAP

Prioritising and scaling new hydrogen technologies from research to commercialisation.

3. LEVERAGING INVESTMENT TO UNLOCK A HYDROGEN INDUSTRY

Creating compelling and de-risked investment propositions by engaging the key hydrogen innovators and decision-makers.

4. CAPTURING THE LIFETIME VALUE OF R&D FOR THE UK

Embedding stakeholder connections and structuring investment terms to ensure that value accrues to the UK.

5. BUILDING ENERGY RESILIENCE AND REACHING NET ZERO

Delivering specific materials solutions required for a hydrogen supply chain that enables UK's net zero goals.

The RHA creates value for the national economy by building a sustainable and globally-significant hydrogen supply chain that is grounded in the UK.

FOR INVESTORS

1. EARLY ACCESS

Delivering specific investment recommendations for the materials solutions that will accelerate and scale the technologies required for the development of the hydrogen economy.

2. RESEARCH AND INDUSTRY INTEGRATION

Engaging directly with all the key participants delivering the hydrogen solutions value chain, from electrolysis to distribution, from world-leading universities to end users.

3. POLICYMAKER RELATIONSHIPS

Engaging with the departments of the UK government enabling the hydrogen economy – the Department for Science, Innovation and Technology (DSIT), the Department for Energy Security and Net Zero (DESNZ), and the Department for Business and Trade (DBT).

4. COMMUNITY

Assembling interested investors across the Technology Readiness Levels together into one community. Through the RHA, technologies will be developed from end-to-end in a continuous investment environment.

5. CONFIDENCE

Providing assurance that the investment opportunities have been filtered through the Accelerator's Board to confirm their scientific viability and commercial potential.

The RHA is an aggregator of investment opportunities to accelerate the rapid scaling and deployment of capabilities for the hydrogen economy.

THE HYDROGEN MATERIALS CHALLENGES

Royce has worked extensively with a wide range of stakeholders from across industry and academia to identify the major materials technology challenges.

The overriding challenges to widespread adoption and deployment of hydrogen were laid out in the 2021 report, '**Materials for end-to-end hydrogen**'.

The report prioritised the five key research challenges which are crucial to the delivery of a functioning UK hydrogen ecosystem in line with 2050 net zero targets. Overcoming these will enable hydrogen to be produced, distributed, stored, used and monitored at scale to decarbonise a wide range of sectors.

The purpose of the RHA is to guide the research and funding of materials R&D in the UK to deliver solutions to these challenges.

HYDROGEN MATERIALS CHALLENGES

PRODUCTION

Materials-led solutions to radically improve performance, reduce cost, and extend operational lifetimes of green electrolysis routes.

STORAGE

Robust structural materials to enable large-scale hydrogen storage for fixed and mobile applications.

DISTRIBUTION

Materials capable of sustaining the thermal and mechanical strains associated with transporting hydrogen and purifying at point of use.

END-USE

Materials to withstand the full temperature range required for hydrogen use – from cryogenic liquid hydrogen to transport and fuel switching applications that operate at over 1000°C.

OPERATIONAL MONITORING

Smart materials for real-time monitoring of critical infrastructure with the ability to report, mitigate or resolve problems before or as they arise.

Sector-wide engagement has identified three initial focus areas for the RHA which target these challenges.

ELECTROLYSIS

To produce low-cost green hydrogen at scale, significant improvement in electrolyser technology is required. The major competing technologies at present are alkaline water electrolysis (AWE), proton exchange membrane (PEM), and solid oxide electrolysis (SOE). The UK is well placed to lead research into electrolysis, with leading academic teams in all three technologies already working with major UK electrolyser manufacturers.

LIQUID HYDROGEN

Liquid hydrogen is critical for use in hard to abate sectors like aviation. However, the low-temperature storage requirements, and associated corrosion post combustion, pose significant challenges to its use. To tackle this, the UK has a strong academic base, world-leading materials research facilities and an established aviation manufacturing industry.

HYDROGEN MONITORING AND DETECTION

The ability to provide assurances on infrastructure resilience and leak detection is critical to widescale public and regulatory acceptance of hydrogen. The UK is an ideal environment to employ innovative AI-led modelling and monitoring of hydrogen infrastructure and sensor technologies. Additionally, UK agencies such as the National Physical Laboratory and British Standards Institute will play a role in establishing global standards for the safe operation of hydrogen energy systems.

STRENGTHENING THE EXISTING ECOSYSTEM

The Accelerator has been carefully designed to complement the UK's established hydrogen research ecosystem.

It will be additive to existing government investment, filling the gap between fundamental research support and funding for technologies already proven at scale.

The UK has a strong experimental research infrastructure, underpinning early-stage hydrogen technologies. Research programmes of this kind are normally EPSRC-funded and university-led.

- **UK-HyRES** (the UK Hub for Research Challenges in Hydrogen and Alternative Liquid Fuels) is investigating the research challenges that underpin the production, storage, distribution and end use of hydrogen and alternative liquid fuels.
- **HI-ACT** is examining the challenges of integrating hydrogen into the overall energy system.

The role of the RHA will be to support this ecosystem from within, bolstering the UK's ability to pull hydrogen-related materials solutions through to market. It will not be constrained by traditional funding boundaries and will enable materials innovation across the entire TRL spectrum to support hydrogen deployment.

A wide array of commercial hydrogen demonstrators and industrial innovation projects in the UK support the introduction of new technologies to the fast-evolving hydrogen landscape.

- **The Hydrogen Innovation Initiative** (HII) promotes industry-led innovation across the generation, distribution and consumption of hydrogen.
- **HyNet** – the UK's leading industrial decarbonisation project – is seeking pathways to net zero for hard-to-abate sectors including fuels, heating, and flexible power generation.
- **The Carbon Trust Clean Hydrogen Innovation Programme** (CHIP) is working with industry to accelerate green hydrogen deployment by reducing production costs of electrolyser components.

MINIMISING RISK AND MAXIMISING RETURN

The Accelerator's flexibility and evolving focus will provide assurances that it is returning value for money by continually targeting the most viable solutions.

The RHA board will comprise a mix of sector leaders in industry, finance, academia, and government. This wide-ranging support network will build confidence for investors.

The broad expertise of the RHA will allow solutions to be rapidly identified, assessed for economic and technical viability, and brought into the innovation pipeline. The result will be a compelling, de-risked pipeline of investment opportunities to be presented to investors.

The leadership of the RHA understands that financial institutions, venture capital, private equity, family wealth offices, and sovereign wealth funds are increasingly looking to invest in emerging technologies that will enable critical applications in future energy systems.

These investments have the potential for high returns and will also encourage the emergence of additive opportunities through a ripple effect similar to that of technology sectors in the past. The RHA is creating the base for a multiplier effect that creates increasingly attractive investment opportunities.

The RHA has already identified investment opportunities for hydrogen materials in the UK totalling in excess of £175 million, including:

£100 MILLION in accelerating novel materials into end-use applications.

£50 MILLION in materials discovery.

£25 MILLION in research challenges for large-scale storage and distribution infrastructure.

These investments have the potential for high returns and will also encourage the emergence of additive opportunities through a ripple effect similar to that of technology sectors in the past.

CAPTURING VALUE FOR THE UK

Once the UK's R&D ecosystem has created solutions to the high-value, transformational challenges, they must be translated into real economic value for the country.

The UK is already home to companies of all sizes across the hydrogen supply chain, including bp, INEOS, Rolls-Royce, Johnson Matthey, National Gas, AFC Energy, Ceres Power and ITM. It can continue to build on this vibrant community to establish a high-value hydrogen economy, centred on new materials technologies.

The Accelerator will connect the R&D landscape with industry, end-users and investors from the start. These connections will nurture the research ecosystem as it grows, bolstering its ability to tackle the hydrogen materials challenges.

The RHA's operation and investment conditions will be designed to safeguard R&D and commercialisation outputs. This will ensure that the value of innovation accrues to the UK and is not lost overseas.

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ENSURING GLOBAL COMPETITIVENESS

The UK urgently needs to match the investments of other countries if it wants to occupy a globally competitive position in the emerging hydrogen economy.

The pace of international research on hydrogen technologies is increasing, and there is a risk that investment opportunities will soon disappear overseas.

The US Inflation Reduction Act and the EU Green Deal Industrial Plan have been very successful at incentivising domestic low-carbon hydrogen development, drawing attention away from the UK. A clear signal of the UK's capabilities and potential is needed.

The Royce Hydrogen Accelerator will ensure that the UK can establish its place at the forefront of hydrogen innovation by directing local and international investment, scaling up new technologies, and ensuring they succeed in the global market.

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RHA LEADERSHIP

Dr Robert Sorrell
RHA CEO

Robert is the chair of the NPL Science and Technology Advisory Committee (STAC) as well as a non-executive Director on the NPL Board. He chairs the Campaign for Science and Engineering (CaSE) and is a Strategic Advisor to the National Centre for Universities and Business (NCUB). He also chairs the UK Research Partnership Investment Fund.

Prior to that he held various senior technology roles at bp, joining them in 1987 from Durham University. He served as bp's senior technology policy advisor for the UK and EU, and his final role at bp was as the Technology Vice President for Research & Innovation for its global Formulated Products (Fuels and Lubricants) Technology.

Robert has a chemistry degree from the University of London's Queen Elizabeth College and earned his PhD from St John's College, University of Cambridge. He is a fellow of the Royal Society of Chemistry.

Jack Boyer OBE
RHA Chair

Jack is Chair of the Board at the University of Bristol, is on the Board of Bristol Innovations and previously chaired the technology transfer office of the University of Southampton. He is a former board member of the Henry Royce Institute, Deputy Chair of the Advanced Materials Leadership Council (BEIS), a Council Member of the Engineering and Physical Sciences Research Council (EPSRC) and of the Innovate UK Energy Catalyst.

His career includes the spin-out and/or transition to IPO of Ilika plc (advanced materials), Elcogen plc (hydrogen fuel cells) and Seeing Machines plc (artificial intelligence). He has been the CEO of TCG AG (engineering) and an M&A banker at Goldman Sachs. He is currently the Senior Independent Director of TT Electronics plc, a NED at Ricardo plc and at the Department for Education.

He holds degrees from Stanford University (BA), the London School of Economics (MSc) and Insead (MBA). In 2015, Jack was awarded an OBE in the Queen's Honours for services to Science and Engineering.

HENRY ROYCE INSTITUTE

The Henry Royce Institute was established to ensure the UK can exploit its world-leading expertise in advanced materials and accelerate innovation from discovery to application. With over £200 million of facilities in dedicated state-of-the art laboratories, Royce is ensuring that academics and industry in the UK's materials community have access to world-class research capabilities, infrastructure, expertise, and skills development.

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October 2023