Highlighted Research Themes to enable UK Hydrogen Adoption

Outputs from the EPSRC – Innovate UK Hydrogen Industry Workshop

18th October 2022

UK Research and Innovation

Engineering and Physical Sciences Research Council

Innovate UK

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1. Summary

1.1. Introduction

On the 18th October 2022, EPSRC and Innovate UK arranged an in-person workshop to bring together key hydrogen business stakeholders. The aim of the event was to explore the existing research and innovation opportunities to support and accelerate the establishment of the Hydrogen economy in the UK beyond 2030.

The event sourced valuable industrial input into the development of proposals for EPSRC's proposed investment in two Hydrogen Hubs led by EPSRC's two Hydrogen Coordinators:

- Hydrogen Research Challenges, led by Professor Tim Mays (University of Bath)
- Hydrogen Systems Integration, led by Professor Sara Walker (Newcastle University)

The event also provided input into Innovate UK who were seeking to understand where industry sees a role for further innovation in this space, to inform future strategy and activities.

The workshop allowed for the exchange of ideas via presentations, table discussions, flipcharts and mind-maps. The **outputs** section of this report exhibits the key themes and re-occurring research challenges highlighted by those in attendance. It should be emphasised that **the research scope supported through the EPSRC Hydrogen Hubs Programme extends beyond, and is not limited to the themes captured in this report.**

The first session focussed on identifying the challenges for the 2030s and beyond across the hydrogen value chain in production, storage and transport of hydrogen that industry needs research to address. After lunch, we looked at the value chain from the end user perspective. For each of the sectors – industry, power, heat and buildings and hydrogen for transport, we investigated how research can remove sector-specific barriers to the uptake of hydrogen and how to address the challenges of scaling up hydrogen use. In the final session, the wider picture of the role of hydrogen in the whole energy system, as well as supply chain and skills challenges were discussed, and suggestions made for how research and innovation can address these challenges.

The workshop demonstrated the enthusiasm in the research and innovation community regarding the opportunities to support and accelerate the establishment of the Hydrogen economy in the UK beyond 2030. The wide range of research and innovation challenges demonstrate the breadth of activities needed to be addressed to ensure the hydrogen economy in the UK is established and can play its key role in the deep decarbonisation of the UK economy.

The outputs from this workshop are published for the community to consider how these opportunities can be addressed through the different activities within the research and innovation community.

EPSRC will continue to work in partnership across UKRI, the hubs, and the public and private sector to unlock further growth in the area.

1.2. Attendees

Attendees were invited from industry, policy, and the academic community.

Organisations represented included:

- Advanced Propulsion Centre
- Aerospace Technology Institute
- BEIS
- Cadent
- Carbon Trust
- Ceres Power
- Clean Power Hydrogen
- Cranfield University
- Energy systems Catapult
- Environment Agency
- Glass Futures
- HVM Catapult
- Ingersoll-Rand
- National Composites Centre
- National Grid
- Net Zero Technology Centre
- Ofgem
- ORE catapult
- Pure Energy Professionals
- Riversimple
- RWE
- UK-Aerospace Research consortium
- UK National Nuclear Laboratories
- University of Bath
- University of Birmingham
- University of Glasgow
- University of Sheffield

and EPSRC and Innovate UK

1.3. Workshop agenda

Date: **Tuesday 18 October 2022**
Time: **09:15 – 16:00**
Venue: **Novotel Manchester Centre**
21 Dickinson Street, Manchester, M1 4LX

Time	Session
09.15	Arrival and networking
10.00	Welcome by Dr Kedar Pandya, EPSRC
10.10	Introduction by EPSRC and Innovate UK
10.30	EPSRC Hydrogen Coordinators • Professor Tim Mays, University of Bath • Professor Sara Walker, Newcastle University
11.00	Break and networking
11.15	Challenges across the hydrogen value chain: production, storage, and transport
12.15	Lunch and networking
13.15	Challenges across the hydrogen value chain: end use
14.15	Break and networking
14.40	Supply chain development and integration
15.40	Outputs and next steps
16.00	Close

1.4. Useful links

EPSRC Hydrogen Hubs funding opportunity: https://www.ukri.org/opportunity/epsrc-hydrogen-programme-to-establish-hydrogen-research-hubs/

2. Summary of outputs

The following has been compiled from the outputs recorded from the workshop sessions.

2.1. Research challenges across the hydrogen value chain to address the needs of the 2030-2040s+

*Aim: to consider (1) what key research industry needs to see happening now to unlock hydrogen for the 2030s, and (2) what further research should begin now to address industry needs for **beyond the 2030s**.*

Attendees were asked to consider the research challenges across the hydrogen value chain with a focus on production, storage, and transport / distribution. At the end of the session, attendees were invited to complete a prioritisation activity. The challenges which were most prioritised are indicated by an asterisk *.

Safety, policy, society and regulations

- An assessment for the need of hydrogen purity and the challenges posed by contamination*
- **[Beyond 2030s]** The solutions to ensure purity from production and during storage and transport, including material design, repurposing of traditional gas-storage (salt caverns and gas-fields) and repurposing infrastructure*
- Developing safety standards and regulations for hydrogen storage and transport *
- Creation of zero-leak secure storage and pipeline and transit systems*
- Increasing public awareness, acceptance, and training of a hydrogen skillset workforce

Environment and health

- Climate, environmental, ecological and health impacts of hydrogen leakage/ ammonia leakage (air, groundwater, human environments, oceans, upper atmosphere etc.). monitoring devices and evolution of network
- Impact of hydrogen production on local and national water demand / nexus*
- **[Beyond 2030s]** Carbon measurements of hydrogen production to address net-zero
- **[Beyond 2030s]** Public acceptance and consumer behaviour*

Storage and flow technicalities

- Overcoming the differences in volumetric / flow capacity requirements for hydrogen vs. natural gas (methane)*
- Energy density for onboard storage and future solid-state storage*

- Technology to address input / output gas flow differences when storing hydrogen vs. natural gas (methane)
- **[Beyond 2030s]** Feasibility and demonstration of large-scale liquid hydrogen storage for airports
- Assessing the potential for competition between hydrogen and CO_2 storage during a global net-zero transition
- **[Beyond 2030s]** Material optimization for different hydrogen states e.g. liquid, gas, compound-carriers (such as ammonia or liquid organic carriers, LOHCs) *
- Liquefaction of hydrogen*
- Modular and rapid refuelling*

Integrating hydrogen and scaling-up

- Integration to renewable energy network; preventing competition between hydrogen production and electricity demand*
- Expanding the grid to cope with extra electrical supply to create or release hydrogen or release electricity from hydrogen.
- Scaling up fuel cell production for inclusion in the electrical grid vs. combustion of hydrogen
- **[Beyond 2030s]** Scaling to GW production with efficiency and cost in mind

Power networks

- **[Beyond 2030s]** Assessing and improving the resilience and responsiveness of green energy sources to meet hydrogen production-demand and assist with constrained electricity networks*
- **[Beyond 2030s]** Micro vs. macro / national hydrogen networks, and the role of public infrastructure for storage/transport*
- Load balancing of a distributed hydrogen system*
- Cybersecurity of hydrogen network and hydrogen-electricity dependence
- Assessing the use of existing gas pipelines for hydrogen distribution

Hydrogen production

- Full and open cost comparison taking into account the location, application and optimization of various green-hydrogen production methods *
- **[Beyond 2030s]** Fundamental science for thermally assisted hydrogen production (nuclear, solar thermal, steam, thermochemical).
- Scaling up electrolyser materials*
- Optimizing the PEM (polymer electrolyte membrane) for reduced-cost design and materials and scaling up electrolyser materials
- Maintenance of off-shore wind-hydrogen combi production
- Transitioning from blue to green (or other mix e.g. pink)

- Utilising the biproducts (e.g. salts from ocean) of Hydrogen production in a sustainable way

2.2 Challenges facing the end-use of Hydrogen

Aim: to consider (1) how research can remove the sector-specific barriers to uptake of hydrogen, and deliver a more cost-effective, sustainable, resilient solution to the net zero transition, and (2) how research can help address potential scaling-up challenges in this sector.

Attendees were asked to consider the research challenges focussed on the end-use of hydrogen across a number of sectors (industry, power, heat and buildings, and transport).

Safety, policy, society, and regulations

- Importance of hydrogen purity for industrial needs*
- Addressing the public perception on safety of using hydrogen

Cost and energy solution optimisation

- Assessing the power efficiency and overall-cost of electrification vs. hydrogen by industry, making it clear to public and policy *****
- Cost and efficiency comparison of heat pumps vs. hydrogen for heating buildings - consider size/location of buildings. Is it advantageous for hybrid technologies?
- New pipelines or existing gas network lifecycle and cost assessment
- Hydrogen vs. ammonia for shipping
- Socio-economic factors for fuel switch

Integrating hydrogen and scaling-up

- Connecting hard-to-electrify industries of high-carbon emission such as steel, cement, and chemical industry to hydrogen supply *****
- Planning permissions (and improved planning protocols) and cost-effective scaling for innovation
- Understand key demand clusters for hydrogen – e.g. airports
- Framework for rapid prototyping and demonstration of hydrogen low-risk decision making and handling of hydrogen by consumers.
- Targets for a future hydrogen system time-lined, in similar way to the targets that government have set for electric transport systems alongside net zero goals*
- TRL (technology readiness levels) feedback loops*
- Hydrogen supporting power network for resilience / smart grids and energy storage*
- Scaling up fuel-cells for integration with the electrical grid.

Environment and health

- Assurance of water supply*
- Measurements of nitrous oxide (NO_x) emissions during hydrogen combustion, condensation trails particulates (Ammonia, hydrogen)
- Mitigation of nitrous oxide gases during hydrogen combustion, especially within combined-cycle gas turbines

Sustainability

- Moving away from limited material resources in fuel cell design that are not compatible for mass manufacture e.g. platinum catalysts and buildings
- System level design need*

2.3. Research to improve the supply chain development and integration

Aim: to consider (1) the research and innovation challenges that need to be addressed to develop robust hydrogen supply chains in the UK and to ensure hydrogen can play a vital role in the net zero transition (2) the hydrogen skills needs across the UK, for research, development and early deployment, to support and ensure a hydrogen economy can be supported within the UK

Attendees were asked to consider the opportunities for the UK around supply chain development within the UK hydrogen economy. Highlighted challenges included:

Training, workforces and capability *(Highlighted as one of the major barriers to hydrogen adoption)*

- Can we cross train skilled staff easily from other sectors? (e.g. focussing on the oil and gas sector)
- General re-skill in hydrogen operation (e.g. STEM fields, materials, etc.)*.
- Can we identify pinch points in skills pipeline? *
- Consider public engagement to harness skills
- Skills, tech apprenticeships should be considered. Also, the skills training should be more hands-on and technical
- Employ more control system engineers
- Coordination across industrial and public sectors

Creating an environment for innovation

- There is a need for a full life cycle assessment (LCA), demonstrating feasibility and protecting IP to encourage business innovation*
- Start-ups in the UK to be encouraged to create supply chain capability*
- Important question of how to support small businesses must be pondered on*
- Exploring use of Contracts for Difference (CFDs) for hydrogen uptake in the same way the government successfully applied to renewable energy.
- UK can't do it all, a strategic plan required, and the UK's distinct capability discovered*
- Assessment of the rate of supply chain scale-up required to deliver the hydrogen value chain in terms of net-zero. Therefore, identification of viable pathways to transition to the required hydrogen value chain is essential*
- Improving access to customers, requirements and open and understandable knowledge sharing (science communication) *

Social perception and public / private engagements

- Consumer acceptance: what tech would consumers choose and are they suitably informed to make credible choices?

- Some companies are not aware of the significant opportunities of being part of the hydrogen supply chain. A real challenge would be in understanding how to engage with these companies
- Lots of public engagement – ensuring the public is on board and that the development of a skilled workforce is available*
- Impartial whole energy system analysis is required to draw out the most promising roles for hydrogen in net zero
- Greater awareness required on hydrogen research opportunities and a better understanding of supply, end use, opportunities, and constraints.
- Raising awareness amongst the private sector of the opportunities of engaging in the hydrogen supply chain

<u>Safety, policy and regulations</u>

- Healthy and safety questions around hydrogen required for aviation.
- Safety – need to prove safety for use (for its general use but also for its uptake and support from the public)*
- De-risking hydrogen technologies with safe proof-of concepts*

<u>Integrating hydrogen and scaling-up</u>

- What are the materials needed for liquid hydrogen? Supply chains for liquid hydrogen fuel systems
- Place based clustering for key technologies*
- Technology proof points important to establish in terms of efficiency, cost, lifecycle etc*

<u>Production</u>

- Which hydrogen sources (electrolyser, biowaste, nuclear) best fit high priority applications*?
- Overwhelming need to match the demand side with the supply side*
- Enlarging the power generators and grid and an idea of how much more is needed? A combination of renewables, nuclear and CCS working together
- Smart power distribution and demand side response of hydrogen supply

<u>Engineering, materials and manufacturing</u>

- Is there manufacturing capability within the UK or will we need to import*?
- Supply chain sustainability – how much of the supply chain can be repurposed, re-manufactured and recycled?
- Compressors for electrolysers and refuelling stations, compression valves and equipment. Currently, technology is holding back hydrogen infrastructure*
- Support existing manufacturers into new products for example – those not making hydrogen related things yet but have the capability to do

- Design – maybe a call for action to derive computer-aided design (CAD) templates

2.4. Broader Themes

Throughout the event a number of topics were raised around the broader hydrogen systems. These included:

- Research and supply-chain design needs to be continuously built upon evidence-based feedback loops throughout TRL life*
- Open science sharing and international collaboration to accelerate solutions to global challenges*
- Education, training and upscaling future engineers and installer workforce*
- Public perception / education from school to higher education to citizens*
- Social assessment of supply chain and materials in it. Environment to drive research into commercialization
- University start-ups require proper support and guidance
- Carbon-effective operations for hydrogen sites and transport of hydrogen in the wider energy system
- We need a source of liquid hydrogen in the UK for security of supply, price of supply, and agility of supply. There is currently a huge gap in manufacturing hydrogen at scale. No significant plant or OEM currently in the UK to create a liquefaction plant
- UK’s distinct capability for hydrogen in the global market is not called out yet / Understanding UK’s place with respect to global hydrogen supply chains*
- Circular economy approaches to hydrogen infrastructure: Carbon fibre recycling & reuse for storage maybe as a storage alternative. Circular supply chain for high value catalyst materials in electrolysers (how much value can be recovered at end of life etc.)
- System design/modelling approaches
- Need to map out supply chain for different sectors*
- Consideration of release of moisture from hydrogen combustion is it any different in volume compared to the release of moisture from fossil fuels.
- Modelling materials interaction with hydrogen and developing an open material standards, and single-point of knowledge database*
- Hydrogen flame combustion characteristics and integration with chemical redox industry
- Examine trade-offs of hydrogen on generation side (CO_2, land-use, water)
- Storage for buildings cost / quantity / regulation and inter-seasonal heating (and so hydrogen) demand impacts
- Climate impact of different hydrogen ‘colours’ (production routes) and how to accelerate green hydrogen
- Cost assessment of incrementally swapping natural gas streams with hydrogen by % and the R&D to achieve 100% hydrogen supply leaping the need for substituting methane
- Increasing communication and co-ordinating a transition across sectors, keeping the public aware