HyDEX.ac.uk

HyDEX

Creating a new hydrogen economy in the Midlands

Accelerating hydrogen adoption across the economy: Decarbonising key UK industries

Funded by UKRI Research England

Delivered by ERA ENERGY RESEARCH ACCELERATOR

Contents

Foreword

With the election of a new government, which seeks to make the UK a clean energy superpower and has committed to a strong net-zero ambition, there has been a renewed sense of vigour across the energy sector.

We have seen the accelerated implementation of policy that the industry has been demanding for many years – the removal of the de facto ban on onshore wind, the approval of an energy 'superhighway' between Scotland and England, as well as the National Wealth Fund that will co-invest in the clean industries of the future. Although these are positive first steps and it is still early in this Government's premiership, we have heard little on its plans for the UK hydrogen sector.

It is well documented that the UK has a significant geological advantage when it comes to hydrogen, and with this, presents a substantial economic opportunity. With a recent wave of final investment decisions made on European hydrogen projects, it's clear that our international counterparts are moving fast and without further progress in the UK, we risk losing our competitive edge in the market.

The HyDEX programme, which is run by the Energy Research Accelerator and funded by Research England, has been designed to address a market failure and challenge: How do you rapidly build a new business, industrial and manufacturing sector in hydrogen when very little exists already? This is what many industry insiders refer to as the 'chicken-and-egg' problem and is a limiting factor in the sector's growth.

The challenge here, however, is not insurmountable, and in convening a variety of cross-sector organisations across the hydrogen supply chain, HyDEX has sought to create a set of recommendations to address this.

This roundtable series, centred on the role of hydrogen in decarbonising four sectors (aviation, industry, road transport, construction, quarrying and farming), outlines how the UK can grasp the opportunity hydrogen presents, creating a leading hydrogen economy anchored in our industrial heartland of the Midlands. The roundtables brought together government, industry, academia, and trade association representatives whose contributions informed this report.

Throughout the series, stakeholders consistently emphasised the opportunities presented by the new government for the hydrogen sector. However, it is crucial for this new government to articulate a clear vision for the industry, recognising the importance of market certainty and the potential role of the government as a customer. Current cost incentives are proving to be insufficient, and there are significant challenges related to the security of hydrogen supply, where government intervention could provide the necessary market confidence. An industrial strategy specifically tailored to the sector is essential, along with better integration of policymaking and collaboration between government departments and the industry.

The HyDEX community looks forward to working with government and other stakeholders in the Midlands and across the UK to implement these recommendations and make the UK a world leader in hydrogen.

Professor Martin Freer
Academic Chair of HyDEX


12.2656
26.4613
83.145

Cross-sector commonalities and recommendations

It is integral that as the adoption of hydrogen increases, siloes are broken down across industries. Scaling the UK's hydrogen industry could be achieved faster and more efficiently through knowledge sharing, which would reduce the disjointed nature of the development of hydrogen as it spans many sectors.

In bringing together four different sectors where hydrogen is used but that aren't often discussed in relation to each other, this roundtable series sought to identify sector-specific solutions as well as highlight cross-sector commonalities.

Commonalities include:

- **A noted misalignment between government standards across departments, with specific reference to the Department for Energy Security and Net Zero (DESNZ) and the Department for Transport (DfT). The new government has an opportunity to join up thinking and policy between departments and prevent lengthy delays or stagnation to projects that straddle several departments – in most instances where hydrogen must be produced, stored, transported and used.**
- **Similarly, improving public understanding of the benefits and costs associated with hydrogen through a public communication campaign is required. This campaign could target everyone from corporate customers to members of the public, and will help increase sales and build confidence in the industry, which in turn would drive demand and help solve the 'chicken-and-egg' issue.**
- **Skills gaps and shortages are often touted as a significant barrier to the progression of the hydrogen industry, and the wider renewable energy industry. To address this, HyDEX is calling for the developing comprehensive training programs to address skills and labour requirements, as to ensure a smooth transition to hydrogen away from high-carbon energy sources.**
- **Greater clarity on the deployment of essential hydrogen infrastructure is required and can be achieved by government providing a comprehensive roadmap across various sectors. These roadmaps will guide industry stakeholders and project developers on how to effectively prepare and support the infrastructure rollout.**
- **Cost is often cited as a key barrier to the adoption of hydrogen, and one which was present in all four roundtable sessions. More impactful financial incentives are therefore needed to be put in place to deter continued reliance on fossil fuels. For example, raising the carbon price will motivate first-movers to get projects over the line.**

Industry

Overview

Industry, including heavy industries, manufacturing, and others such as ceramics, aluminium, cereals, are huge economic drivers in the UK. They are also major emitters.

Hydrogen offers a viable pathway to decarbonisation and can be effectively integrated with electrification and Carbon Capture and Storage (CCS) technologies. It has been a staple in industrial applications for decades. However, the methods for producing low-carbon hydrogen, such as through electrolysis or through reformation with the aid of Carbon Capture, Utilisation, and Storage (CCUS), are comparatively new.

The UK Government has been supportive towards of the use of hydrogen in industry, with initiatives like the Low Carbon Hydrogen Agreement (LCHA), the Industrial Fuel Switching Trials of which Phase 2 is taking place at the time of writing, the Hydrogen Allocation Rounds (HAR) and the newly announced National Wealth Fund.

We're seeing relatively high technology readiness levels (TRL 7-9) in sectors such as ceramics, which are transitioning to first commercial applications. Similarly, local clusters are actively working on fuel switching and decarbonisation projects (for example, KP Snacks and local bakeries).

Overall, the UK is favourably positioned internationally in terms of hydrogen applications in industry. However, it risks losing its lead without further investment and policy support, especially given the progress being made in Europe, America and China.

Current state of play: challenges

Despite initial progress, barriers remain to the adoption of hydrogen in industrial applications. These can be segmented into economic and regulatory barriers, and technological and operational issues.

Economic and regulatory barriers

The current carbon price in the UK Emissions Trading Scheme (ETS) is not high enough to drive widespread adoption of hydrogen. As referenced earlier, without sufficient financial incentives to make hydrogen economically viable for heavy industries, they will continue to rely on carbon intensive fossil fuels.

Hesitancy remains at board level about the introduction of hydrogen into existing infrastructure, particularly in untested environments where the impact of hydrogen used in expensive equipment is unknown. Without adequate testing and reassurance, the notion that hydrogen could possibly devalue an asset, such as industrial ovens, is delaying sign-off for projects.

There is also need for regulatory changes to facilitate hydrogen adoption and ensure safety. The Carbon Border Adjustment Mechanism (CBAM) will help aid this but most industries aren't covered by the ETS so this will likely apply little pressure or incentive.

Technological and operational issues

Retrofitting existing equipment to use hydrogen is another major challenge, particularly in older industrial facilities, some of which date back to the Victorian era. These were not designed with hydrogen in mind and converting them to accommodate hydrogen can be technically complex and expensive. Issues such as material compatibility, safety standards, and the need for specialised components can complicate the retrofitting process. Additionally, the downtime required for such retrofits can be a significant deterrent for industries that operate on tight schedules and margins.

Much discussion in the sector has focused on the lack of final investment decisions made on UK hydrogen projects. Uncertainty in the insurance sector regarding the risks associated with hydrogen use is a contributing factor to these delays. Without clear guidelines and risk assessments, insurers are hesitant to underwrite hydrogen-related ventures, leading to delays in project approvals and investments.

Moreover, hydrogen, being a highly flammable gas, presents unique risks that are not fully understood or quantified by the insurance industry, especially in novel use-cases. This uncertainty makes it difficult for companies to secure the necessary insurance coverage at reasonable rates, adding another layer of financial risk to hydrogen projects.

Solutions

Policy recommendations

To overcome these barriers to scaling the use of hydrogen in industry, the sector is calling for the following policy measures:

- **First and foremost, sign the set of Hydrogen Allocation Round 1 projects to deploy these first-mover projects and add another order of magnitude in terms of scale of production.**
- **To reassure concerns around reliability and security of supply, the implementation of government-owned storage facilities to provide a buffer stock is recommended.**
- **A hydrogen network serves as the ultimate risk mitigation mechanism. To achieve this, we need an ecosystem with a robust supply chain. The Low Carbon Hydrogen Agreement (LCHA) prevents intermediary reselling of hydrogen at inflated prices, while Contracts for Difference (CfD) deter profiteering. However, overall, a more liquid market is essential for optimal functionality.**
- **Advocate for the transition of gas grids to hydrogen and blending as a backstop can help manage risk, as demonstrated by results seen in Germany. This will play a key role in holistically decarbonising the gas grids, as well as increasing demand for on-site generation. This is particularly pertinent for early hydrogen production projects but will also support strategically located electrolytic projects, facilitating the deployment of renewable electricity generation assets.**
- **Financial support for retrofitting existing equipment to use hydrogen, especially in older facilities, is required. Engagement with the insurance sector is needed, to address uncertainties and develop appropriate risk management strategies.**

- **To provide financial incentives to make hydrogen more attractive to heavy industries. This could include increasing the carbon price to make alternative carbon sources less economically viable.**
- **Enhance certification and simplifying the application process for existing funding models, all while maintaining rigorous screening standards.**
- **Swiftly implement the Review of Electricity Market Arrangements (REMA), ensuring that consumer interests are accurately represented can help avoid delays caused by complexity.**
- **Demand-side mechanisms should be implemented to create market pull for investments. This effort should focus on two key levers - green public procurement, which leverages government purchasing power, and the implementation of low carbon production standards.**
- **To avoid a continued cluster-centric approach will lead to further siloes, a decentralised approach beyond clusters should be taken as to bolster flexibility and service industrial end users based elsewhere.**
- **Explore various storage options, including on-site and large-scale storage, to build resilience and confidence in the industrial sector. The UK Government should consider government-supported storage facilities to ensure a consistent supply of hydrogen, particularly given the industry's nascency.**
- **To stimulate domestic supply chains is vital to bridging the 'valley of death' between R&D stage and commercialisation of hydrogen.**

Road transport

Overview

Transport is the largest emitting sector in the UK, with the majority of emissions coming from domestic road transport.

Innovative hydrogen vehicle roll-outs are occurring with buses in cities such as Birmingham, London and Belfast, but for Heavy Goods Vehicles (HGVs), deployment is still in the early stages. Activities stimulated so far by the Department for Transport (DfT) and UK Research and Innovation (UKRI), particularly in Tees Valley, have focused on vehicle trials and refuelling infrastructure.

In terms of a comparison with international counterparts, the largest hydrogen refuelling station (HRS) exists in China and the EU is broadly leaping ahead with regulations stipulating Hydrogen Refuelling Stations every 200km. Hydrogen refuelling is also significantly cheaper in the EU, so much so that British vehicles can currently refuel in Belgium and return to the UK at a cheaper rate than filling up at the pump in the UK.

Current state of play: challenges

Economic and regulatory barriers

Further investment in hydrogen-ready vehicles is crucial. Supply chains in the UK are tight, with little support for batteries, tanks, and fuel cells.

One of the critical issues is the insistence on using green hydrogen exclusively, rather than adopting a technology-agnostic approach. This narrow focus has created supply chain issues and limited the availability of hydrogen, hindering the development of a more robust and flexible supply chain.

Departmental coordination also impacts real-world implementation, underscoring the need for a unified approach across various government and regulatory bodies. This is particularly emphasised with DESNZ and DfT. Without cohesive coordination, efforts to integrate hydrogen into the wider transport sector, including to the aviation sector, remain fragmented and less effective.

The Renewable Transport Fuel Obligation (RTFO) was intended to be the primary policy lever for promoting hydrogen adoption. However, it has not achieved the desired level of success, largely due to the complexities and challenges associated with investment. The Hydrogen Production Business Model, while promising, involves significant risks for intermediaries, further complicating its adoption and implementation. This model requires substantial financial backing and long-term commitments, which are currently difficult to secure.

Technological and operational issues

Infrastructure for hydrogen in road transport can be scaled, evidenced successfully in China and Europe. The key issue, however, is the rollout of vehicles, and the UK is behind other countries in this regard. This is exacerbated by the fact the UK drives on the left side of the road and a redesign of hydrogen trucks for a single market is unattractive for vehicle producers.

Moreover, distribution of hydrogen remains a challenge in the UK given that 50% of hydrogen in the UK is produced in Teesside.

Solutions

Policy recommendations

To encourage the adoption of hydrogen in road transport, the following policy measures should be taken:

- **Applying greater strategic attention must be paid to hydrogen so that the technologies can complement one another, taking a hand in glove approach. Historically, much emphasis has been placed on battery electric technology, including within government departments such as DfT.**
- **A mixed-fuel future fleet, combining hydrogen and electrification, is necessary. The government should also remain technology agnostic, supporting both hydrogen combustion and fuel cell technologies, as well as the development of blue and green hydrogen.**
- **A clear roadmap for hydrogen road transport adoption, including a low-carbon fuel strategy should be put forward. As part of this, the strategic development of hydrogen infrastructure, including refuelling stations and grid connections where it can best stimulate regional uptake of hydrogen technologies, should be prioritised.**
- **Further research into long-range storage of hydrogen on vehicles is required. As is the exploration of hydrogen combustion as an alternative to fuel cells, which can retrofit existing fleets.**
- **A greater focus on port-related hydrogen production will provide a quick win given that 93% of imports and exports go through ports.**
- **Establishing a core network of hydrogen refuelling stations using demand data and strategic locations will be critical.**

- **Vast and swift infrastructure development is not viable due to high capital expenditure, making it crucial to strategically locate resources. This has been done in part by The Department for Transport (DfT) and UK Research and Innovation (UKRI), who have focused on vehicle trials and refuelling infrastructure, particularly in Tees Valley, in collaboration with Local Enterprise Partnerships (LEPs) to optimise resource allocation.**

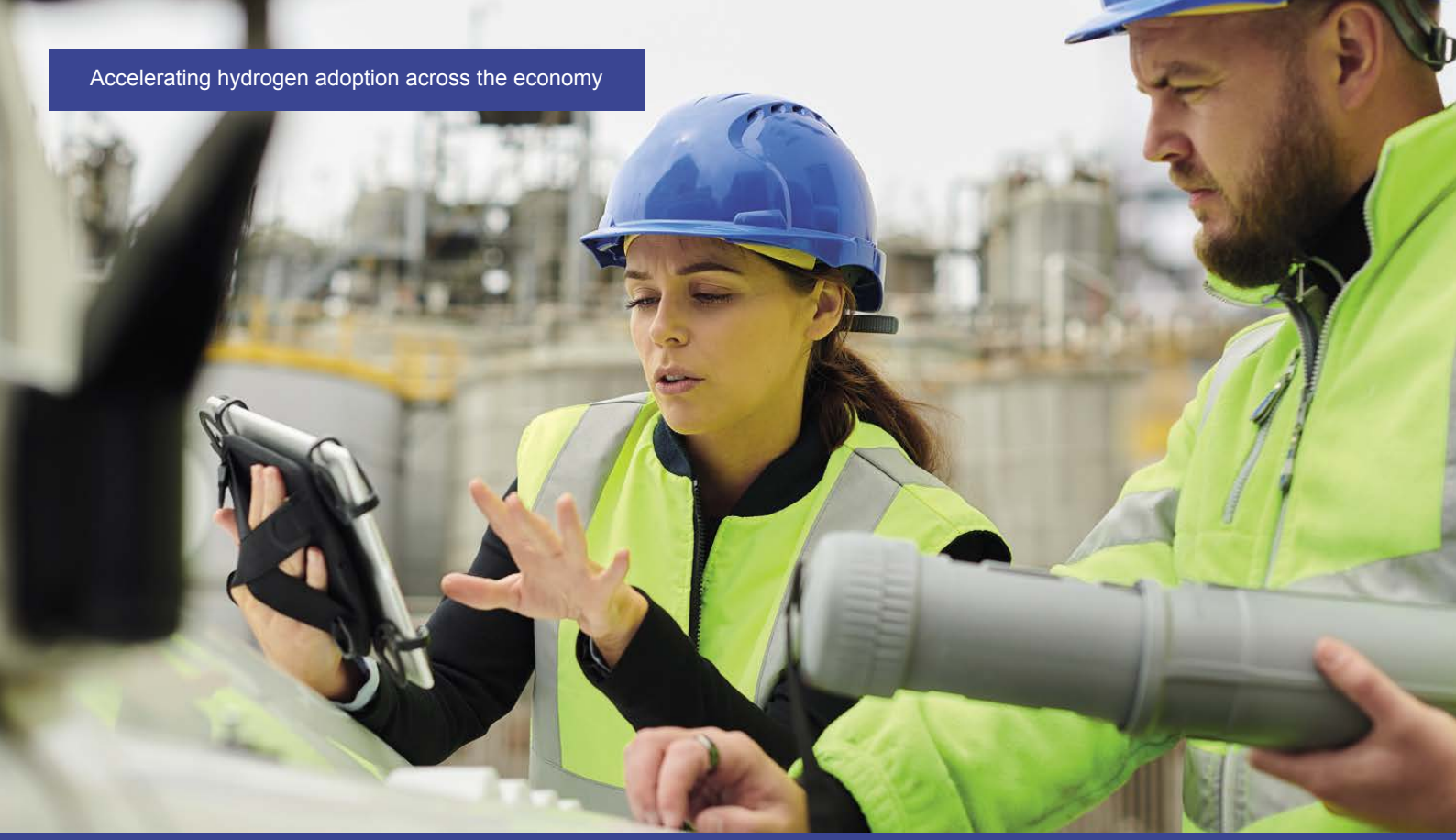
- **Better collaboration is required cross-departmentally, as well as with regional authorities. A dedicated office for hydrogen (in the way the UK Government has an Office for Zero Emission Vehicles) that works on accelerating net-zero initiatives and working with regional authorities and businesses will help inform strategic areas for the deployment of hydrogen technologies.**

- **Support for supply chains is essential to ensure a robust and reliable hydrogen ecosystem. Diversifying hydrogen production methods, including CCUS-enabled hydrogen, will ensure availability and resilience.**

- **Modelling for road freight refuelling has highlighted issues between production sites and refuelling stations, with truck delivery being a major limitation. A national approach, potentially led by DfT, the Office for Zero Emission Vehicles or a future 'Office for Hydrogen' must ensure optimal station placement to avoid redundancy and inefficiency.**

- **Long-term planning and partnerships between the public and private sectors is required to understand and address market needs.**

- **Incentives, such as subsidies, grants, and tax breaks are ultimately required to incentivise hydrogen adoption and compete internationally. These financial incentives will encourage hydrogen adoption and reduce initial costs.**



Construction, quarrying and farming

Overview

The industries of construction, quarrying, and farming are currently widely dependent on fossil fuels. From powering heavy machinery to providing energy in remote, off-grid locations, these sectors face major challenges in decarbonising their operations.

While these three sectors are relatively distinct, they share common decarbonisation challenges and solutions. For all three sectors, the adoption of hydrogen-powered low-carbon technologies is a promising step towards decarbonisation, but barriers remain.

Addressing these challenges is crucial to unlocking the potential of hydrogen and other low-carbon solutions. A comprehensive strategy that fosters innovation, provides economic incentives, disseminates knowledge, and develops robust infrastructure is essential to empower these sectors to embrace a sustainable future.

Current state of play: challenges

Economic and regulatory barriers

Current regulations often stifle the adoption of low-carbon hydrogen technology. The lack of clear regulations and incentives for hydrogen adoption creates investment hesitancy and hinders market growth. Without a supportive regulatory framework, companies are less likely to invest in new technologies that could potentially disrupt their existing operations. Additionally, there is a noticeable absence of policy and financial incentives to encourage the adoption of these technologies. Establishing regional funding competitions, similar to Germany's HyStarter under its HyLand model, can incentivise the rollout of regional hydrogen and fuel cell technology hubs.

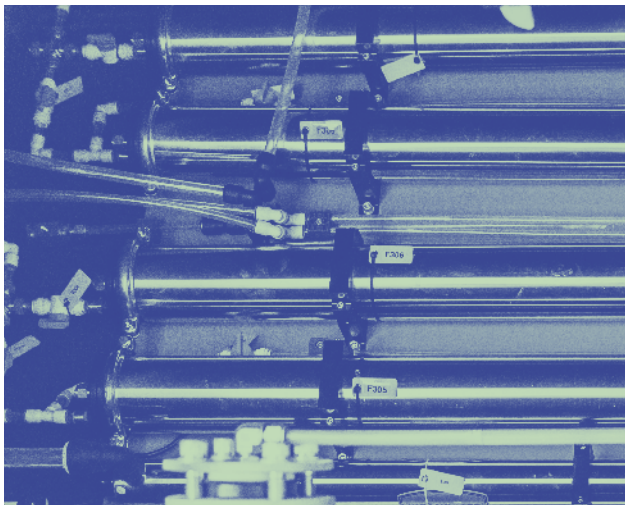
The prohibitive cost of transitioning to and maintaining new technologies is another significant barrier. Hydrogen-powered equipment is significantly more expensive than fossil fuel alternatives, affecting both capital and operational expenditures. This financial burden makes it difficult for companies to justify the switch, especially in industries with tight profit margins.

Technological and operational issues

Limited access to hydrogen refuelling and production infrastructure, including on-site hydrogen-powered generators, poses a major obstacle. Without robust supporting transport and storage infrastructure, the adoption of hydrogen technologies remains impractical for many companies. Supporting the adoption of independent hydrogen generation systems on off-grid sites can help overcome these limitations, but this requires substantial investment and planning.

Another critical issue is the shortage of a skilled workforce trained in operating and maintaining hydrogen-powered equipment. This skills gap hinders adoption and creates a need for upskilling initiatives to ensure that workers are prepared to handle new technologies.

Additionally, addressing industry and public apprehensions regarding the safe handling and operation of hydrogen technologies is crucial. Many stakeholders and members of the public are unaware of the benefits, practicalities, and safety aspects of hydrogen technologies, which further complicates their adoption.

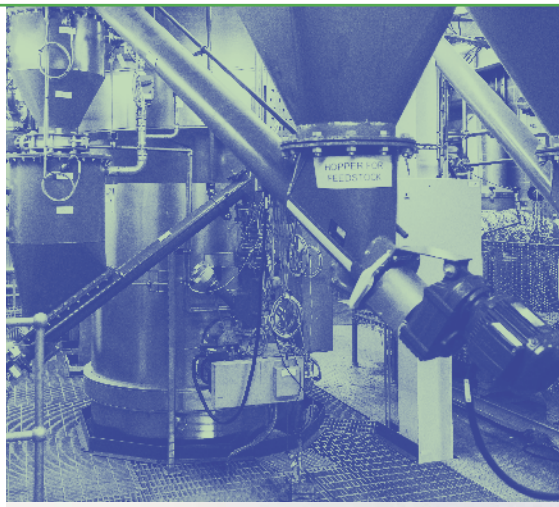


Solutions

Policy recommendations

A comprehensive strategy that fosters innovation, provides economic incentives, disseminates knowledge, and develops robust infrastructure is essential to empower the construction, quarrying and farming sectors to embrace a sustainable future. Policy measures to achieve this include:

- **Implementing policies that mandate emission reductions and incentivise hydrogen adoption is essential for overcoming these barriers.**
- **Developing strategies that address both Non-Road Mobile Machinery (NRMM) adoption and infrastructure development to ensure synchronised progress is also crucial.**
- **Allocating further funding for research and development of hydrogen and its derivatives, such as ammonia, as a fuel source for the farming sector, exploring its feasibility and benefits, is also important. This investment in research can unlock new applications and improve the efficiency of existing technologies.**
- **Implementing a strategic and coordinated approach to hydrogen infrastructure development, including production, storage, and distribution, is crucial for making hydrogen a viable alternative to fossil fuels in construction, quarrying, and farming.**




T.S.T.

Aviation

Overview

The aviation industry is one of the UK's most valuable sectors, contributing over £24 billion to the economy. Airlines, aircraft manufacturers and other industry members have pledged to reach net-zero by 2050 through a variety of means, with much attention being paid towards Sustainable Aviation Fuel (SAF).

Hydrogen is widely recognised as a key technology to achieve this 2050 net-zero target, with applications extending beyond propulsion, and sustainable aviation fuels production to ground operations and infrastructure support.

The UK aviation industry has made some progress in terms of decarbonisation, seen with the assembly of the Jet Zero Council, the design and expected implementation of the SAF mandate in 2025, as well as research and development of zero-emissions aircraft. The UK's hydrogen-specific aviation policies, however, lag in comparison with its international counterparts. For example, Germany has had a strong focus on securing hydrogen supply, the Netherlands on providing ground power solutions, New Zealand on decarbonising remote airports, and Australia on strategic master planning.

Current state of play: challenges

Economic and regulatory barriers

A perceived lack of progress for hydrogen in the UK's aviation sector are barriers to investment and risk taking. This is particularly pertinent around offtake agreements, and the difficulty in securing long-term, bankable offtake agreements, which are crucial as project finance is reluctant to invest without long-term commitments and bankable partners.

Additionally, current Hydrogen Production Business Model rules, originally designed to support the production and use of low carbon hydrogen, are inflexible. These favour large-scale co-located assets, thus limiting broader adoption.

Similar complexities remain about the certification of new fuels and aviation platforms. The certification process is lengthy and conservative, which in turn creates barriers to market entry. SAF certification is particularly challenging, requiring small refineries and extensive testing.

The certification and regulation of hydrogen is understandably stringent given the historical perception of hydrogen as unsafe. Consumer buy-in is essential for the success of the technology, and consumers must feel safe to drive demand for hydrogen flight. Public education and awareness campaigns are required to foster such community acceptance. This is critical as infrastructure projects require community and stakeholder involvement to ensure acceptance and support, and without this, barriers will remain for the uptake of hydrogen.

Technological and operational issues

Primary issues on the operational challenges of the use of hydrogen in aviation centre on infrastructure, notably, the sheer volume of energy required. At present, hundreds of billions of gallons of kerosene are consumed by the aviation industry each year. These large energy needs will translate to the production and storage of hydrogen at airports, requiring significant upgrades to existing infrastructure. It is estimated that the majority of investment the sector requires will go towards meeting these energy needs.

The UK must also ensure that hydrogen infrastructure aligns with aviation routes and platform requirements to ensure its fit for purpose.

Transitioning to hydrogen aviation requires a holistic approach that integrates the entire energy ecosystem, including waste heat and power management. This involves using renewable energy for hydrogen production, optimising storage and heat recovery systems, and ensuring efficient power distribution within aircraft. Key elements include robust refuelling infrastructure, a reliable supply chain, and addressing environmental and economic impacts through lifecycle analysis and cost management. Safety protocols, supportive regulations, and collaborative efforts between industry, energy providers, and government agencies, along with ongoing R&D, are essential for sustainable hydrogen adoption in aviation.

Whilst it has been noted that there is a lack of specific training programs for cryogenic hydrogen systems and other specialised skills, this high demand for skills is driving up the price of hydrogen, making it harder for SMEs to compete. Managing different types of hydrogen (gaseous and liquid) at airports also adds complexity and cost.

Solutions

Policy recommendations

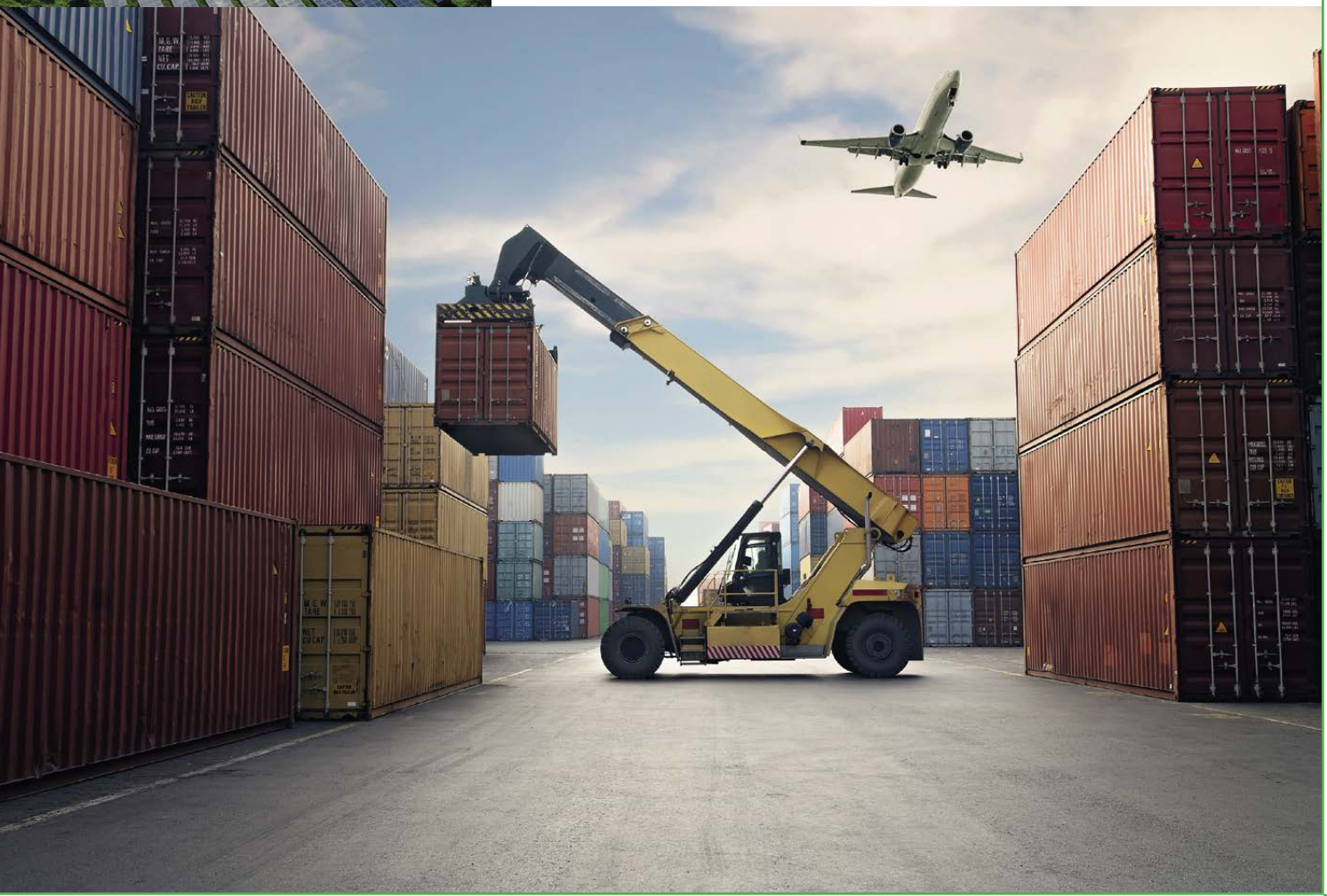
To promote the uptake of hydrogen in aviation, HyDEX is recommending several key policies:

- **It is recommended to utilise the newly announced National Wealth Fund (NWF) to support hydrogen production and infrastructure projects. This approach will address off-take risk and provide necessary financial guarantees to encourage investment, as well as sign off from project finance.**
- **Increasing the flexibility in Hydrogen Business Model (HBM) rules is crucial. By allowing for risk-taking intermediaries, a broader range of projects can be supported, fostering innovation in hydrogen technologies.**
- **A clear and aligned roadmap is essential for the successful adoption of hydrogen and Sustainable Aviation Fuel (SAF). Developing a comprehensive roadmap that ensures alignment with global infrastructure and regulatory standards will facilitate international cooperation and standardisation.**
- **Implementing a phased program for hydrogen adoption in aviation is recommended. Starting with regional applications and gradually moving to larger-scale implementations will ensure a smooth transition and scalability.**
- **Advocating for global carbon pricing is necessary to create a level playing field, as it will incentivise the adoption of low-carbon alternatives by making them more economically viable.**

- **Implementing a tax or levy on kerosene will make business-as-usual practices more expensive. The revenue generated from this tax or levy can be used to fund hydrogen and SAF projects, thereby promoting cleaner alternatives.**

- **Providing financial guarantees for the development of hydrogen infrastructure at airports will ensure that airports are ready for hydrogen adoption and can support the new technology. Including requirements for low-carbon infrastructure in airport expansion plans is also recommended. This will ensure that future airport developments are prepared for hydrogen and other low-carbon technologies.**

- **Integrating hydrogen production with regional energy ecosystems is crucial. Addressing grid constraints and ensuring community acceptance by planning holistically and considering the broader energy landscape will support the successful implementation of hydrogen infrastructure.**



Appendix

Thank you to the following organisations for participating in the HyDEX roundtable series:

- **AECOM**
- **Airbus**
- **BOC UK & Ireland**
- **British Ceramics Confederation**
- **Durham University**
- **E3G**
- **Element Energy**
- **Element 2**
- **European Climate Foundation**
- **GeoPura**
- **Exolum**
- **Hive Composites**
- **HVS**
- **Hybrid Air Vehicles**
- **Hydrogen UK**
- **High Value Manufacturing Catapult**
- **JCB**
- **Make UK**
- **Midlands Connect**
- **Phillips 66**
- **Progressive Energy**
- **Protium**
- **Ryze Hydrogen**
- **Teesside University**
- **The Department for Energy Security and Net Zero**
- **The Department for Transport**
- **The Road Haulage Association**
- **The University of Nottingham**
- **Uniper**
- **ZeroAvia**

HyDEX

Contact us

To find out more about our facilities, demonstrators and research services that we can offer please get in touch:

enquiries@era.ac.uk
hydex.ac.uk

@HyDEXMidlands hydex

Funded by UKRI Research England

Delivered by ERA ENERGY RESEARCH ACCELERATOR