White Paper

Haskel
An Ingersoll Rand Business

The pivotal role of infrastructure in achieving jet zero: a deep dive into the challenges and opportunities

Foreword

Given the recent announcement that Project HEART will be supported by the Future Flight challenge at UK Research and Innovation, and delivered by Innovate UK, we thought now would be a good time to reflect on the broader infrastructure issues facing the aviation sector in the coming decades. The aviation industry is just waking up to the scale of the challenge posed by infrastructure, which will need to match the pace of changes in aircraft and propulsion design. With the first hydrogen regional flights looking set for 2025, a blueprint for hydrogen-specific ground infrastructure is sorely needed.

Haskel are proud to be supporting Protium and NEL Hydrogen with Project HEART, which will bring forward a cost-effective and scalable infrastructure blueprint for the hydrogen-powered fleet of the future.

With the first trans-Atlantic flight using 100% sustainable aviation fuel recently, and emerging innovators making huge strides in developing hydrogen-electric aircraft, it is an exciting time for the sector. Haskel's track-record of quality and expertise will allow us to play a crucial role in the jet zero transition, building upon our successes in hydrogen refuelling and compression across the HGV and industrial sectors.

David Muckle,
Hydrogen Systems Business Unit Leader, Haskel

As the jet zero transition takes off, we know that infrastructure has a key role to play in the decarbonisation of the aviation sector. Haskel is involved in Project HEART, a multi-partner project developing a holistic operational, infrastructure and technology model for hydrogen aviation ground infrastructure, so we thought now would be a good time to delve into the complexities and labyrinth of challenges facing the sector.

The daunting challenge

Accounting for 2.5% of global annual CO_2 emissions and 3.5% of global warming, aviation is a significant contributor to climate change[1]. As sectors such as power generation are rapidly decarbonising, aviation could find itself shouldering a larger slice of the global emissions pie, lagging other forms of transport that are easier to decarbonise through electrification.

The pollutants from today's global aviation sector extend beyond CO_2 emissions to include other damaging substances such as NO_x, contrails, and particulate matter, exacerbating aviation's impact on global warming.

With an ambitious domestic net zero target of 2050, the UK aviation industry is on a stringent timeline, aiming for interim targets of 15% and 40% reductions in net emissions by 2030 and 2040, respectively. This means reducing emissions by 3% a year for the next 30 years.

[1] Climate change and flying: what share of global CO_2 emissions come from aviation? - Our World in Data

Simultaneously, the road to zero-carbon aviation is fraught with unique challenges including weight and size constraints, a strong safety-first imperative, long innovation lead times, and the relative cost of zero-carbon alternatives. Direct electrification is simply not an option for heavier aircraft using current technology, as the weight of large batteries becomes too heavy. Nonetheless, direct electrification has a role to play in lighter aircraft, just as it has for passenger road vehicles.

Whilst the sector is innately 'hard-to-abate', the aviation industry is taking steps to reduce emissions - including developing more efficient aircraft, improving overall operational efficiency and carbon offsetting. However, the effectiveness of these steps is offset by growing demand. From 2005 to 2019, the aviation industry improved fuel efficiency by approximately 39 percent, but the absolute growth of emissions increased over the same period – driven by ever-increasing demand for global connectivity[2].

What this shows is that in the long run, a move away from fossil fuels is the only sustainable solution, without compromise to the vital service that aviation provides. In this paper, we explore what this transition could look like, the hurdles that stand in the way of success, and the role that Haskel can play.

The promise of alternatives

The search for sustainable alternatives to fossil fuels has led us to Sustainable Aviation Fuels (SAFs). SAFs, made from sustainable feedstocks like used cooking oil, agricultural waste, or atmospheric CO_2, are gaining traction in the aviation industry.

International Air Transport Association (IATA) estimates that SAFs reduce emissions by 80 per cent over the course of the "fuel life cycle"[3].

[2] Fuel efficiency: Why airlines need to switch to more ambitious measures (mckinsey.com)

[3] Net zero 2050: sustainable aviation fuels (iata.org)

The UK Government's Jet Zero Strategy has committed to having at least 5 commercial-scale UK SAF plants under construction by 2025, along with a SAF mandate which will come into force in 2025. The SAF mandate will set an obligation on fuel suppliers to reduce the greenhouse gas emissions of aviation fuel by using at least 10% SAF by 2030[4].

However, there are some substantial challenges associated with the use of SAFs. The Royal Society estimates at least half of all UK agricultural land would be needed to grow enough feedstock to support all the UK's jet fuel requirements[5], and SAFs still aren't price competitive with traditional fuels.

Another potential alternative fuel for low-carbon aviation is hydrogen.

Hydrogen's high energy density and potential for carbon-free emissions when produced through electrolysis make it a strong contender. Hydrogen's energy density is much higher than battery electric engines, and this means that it can be scaled to larger and more demanding modes of transport. A simple rule of thumb states that the larger the mode of transport, the more suitable hydrogen becomes, and the smaller the mode of transport, the more suitable battery electric motors become. This is what makes battery electric so well suited to domestic EVs, and hydrogen so well suited to aviation, HGVs, and cargo shipping.There are two types of hydrogen engines – hydrogen fuel cell (HFC) and hydrogen combustion:

- In a hydrogen fuel cell engine, hydrogen and oxygen are fed into fuel cells, where they generate electricity via an electrochemical reaction, which powers the electric motor, negating the need for large battery storage.
- In hydrogen combustion, hydrogen is burned in a modified gas-turbine engine, like traditional kerosene jet engines.

[4] jet-zero-strategy.pdf (publishing.service.gov.uk)

[5] Net zero aviation fuels: resource requirements and environmental impacts | Royal Society

The race to net-zero has thrust hydrogen into the limelight as the aviation fuel of the future. As we enter this new era of global hydrogen use for low-carbon solutions, adaptable and low-cost technology will be essential to avoid a crunch in supply. As leading experts in high-pressure gas compression and transfer, Haskel is pioneering hydrogen-based technologies and are ideally positioned to support the growth of the low-carbon aviation sector.

David Muckle,
Hydrogen Systems Business Unit Leader, Haskel

The Aerospace Technology Institute's FlyZero study has determined that green liquid hydrogen, a by-product of the electrolysis process that splits water into hydrogen and oxygen, is the most viable zero-carbon fuel for aviation with the potential to scale to larger aircraft[6].

The use of green hydrogen opens the possibility for large aircraft to utilise fuel cell, gas turbine, and hybrid systems for power. It is projected that green liquid hydrogen will become a cheaper and more eco-friendly alternative to Sustainable Aviation Fuels (SAFs) due to carbon pricing and the production inefficiencies associated with SAFs[7].

[6] FZO-AIN-REP-0007-FlyZero-Zero-Carbon-Emission-Aircraft-Concepts.pdf (ati.org.uk)

[7] FZO-ACA-REP-0056-Academic-Programme-Research-Findings.pdf (ati.org.uk)

Ultimately, a combination of approaches including the use of hydrogen, SAFs, and carbon offsets, will be necessary for the aviation sector to reach net zero.

The UK Government's Jet Zero Strategy has recognised the potential of hydrogen in revolutionising the aviation industry, placing it at the heart of its sustainable aviation roadmap[8]. With this Jet Zero Strategy, the UK Government is demonstrating a strong commitment to accelerating the pace of hydrogen aviation. Indeed, the country possesses a competitive advantage in this area on the international stage. This commitment was further underscored in March 2022 when £685m in government R&D funding was granted to the Aerospace Technology Institute (ATI) Programme over 2022-2025[9]. The funding is earmarked to support the development of zero-carbon and ultra-low emission aircraft technology.

The ATI Programme has played a crucial role in supporting the technological development of hydrogen aircraft such as GKN's H2Gear and ZeroAvia's HyFlyer. With leading-edge companies like ZeroAvia, Rolls Royce, and Airbus at the helm of hydrogen aviation innovation, the UK is well-positioned to make significant strides.

[8] jet-zero-strategy.pdf (publishing.service.gov.uk)

[9] Green aerospace tech to receive record government funding - GOV.UK (www.gov.uk)

Overcoming barriers

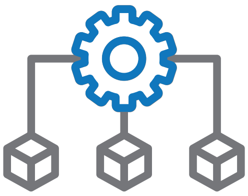
However, despite these initiatives, hydrogen aviation is not without its challenges.

On the fuel side, the production of low-carbon hydrogen, a critical component for hydrogen aviation, needs to scale up significantly. The UK government, recognising this challenge, has pledged support through several initiatives and revenue support schemes outlined in the Energy Act 2023. These initiatives aim to drive cost reductions and create the necessary momentum for the scaling up of low-carbon hydrogen production.

Secondly, there are technical challenges for the design of aircraft themselves. While hydrogen boasts a higher energy density than aviation fuel by mass, it is less dense by volume, thus presenting a challenge in terms of onboard fuel storage. The refuelling of aircraft also brings new challenges, as hydrogen has many properties which differ from traditional jet fuels. To be used as liquid hydrogen, it must be cooled to -253 degrees Celsius, which entails complex handling and compression procedures. Whilst companies such as ZeroAvia have successfully tested regional size aircraft using hydrogen-electric engines, innovation is relatively slow, as the technology naturally takes time to mature, and the Civil Aviation Authority rightfully imposes strict requirements on new commercial aircraft. Whilst slow, progress is being made.

Finally, the Government's Jet Zero Strategy acknowledges that there is still significant work to be done to ensure the concurrent development of aircraft and the necessary energy and ground infrastructure for their operation.

As we look towards 2025, when the first zero-carbon flights using low-carbon hydrogen are expected to occur, the task of developing the infrastructure necessary to support the roll-out of hydrogen aviation looks to be a major challenge.

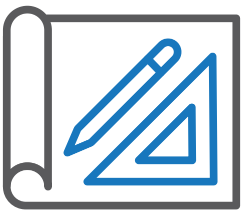


Infrastructure: the lynchpin of progress

One of the most significant challenges in the path of hydrogen aviation is the substantial investment required for ground infrastructure. This includes developing new procedures and infrastructure for hydrogen procurement, storage, processing, management, and aircraft refuelling. It is estimated that the investment needed for low-carbon airport infrastructure will be of a similar magnitude to the investment needed for a new terminal[10].

Furthermore, it involves creating new supply chains that can handle the unique requirements of hydrogen. It's crucial to ensure that these new supply chains can co-exist with the existing and emerging SAF supply chains, making the challenge multidimensional.

The Zero Emission Flight Infrastructure (ZEFI) programme, funded by the Department for Transport (DfT) and led by the Connected Places Catapult, is working to facilitate this needed transformation of hydrogen infrastructure.



Phase 1 of the ZEFI programme took place in 2021-22, which resulted in the release of a blueprint for Zero Emission Flight Infrastructure[11]. The blueprint looked to identify some of the new requirements for battery-electric and hydrogen aviation, identifying the following challenges for the implementation of hydrogen refuelling infrastructure:

- Limited apron space available for the required safety zone.
- Limited space for hydrogen infrastructure.
- The complex nature of stakeholders involved in the refuelling process.
- Securing green hydrogen supply.
- Relative cost of hydrogen compared to kerosene.

From the blueprint it is clear that a significant investment in infrastructure will be required to support early hydrogen flights, and a phased approach to roll-out will be necessary.

[10] target-true-zero-foundations-for-battery-and-hydrogen-powered-flight.pdf (mckinsey.com)

[11] Blueprint_for_Zero_Emission_Flight_Infrastructure.pdf

Project HEART

So, what could this infrastructure look like in practice?

The Future Flight challenge at UK Research and Innovation (UKRI) and delivered by Innovate UK is supporting innovative projects which can address the challenges of hydrogen aviation ground infrastructure.

UKRI is supporting Project HEART, which is a multiple-partner initiative focused on developing a holistic operational, infrastructure and technology model that is commercially viable, subsidy-free, and sustainable.

Project HEART will see Protium, the green hydrogen developer overseeing the hydrogen infrastructure at a South Wales site called Pioneer 2 with an electrolyser provided by Norway's Nel Hydrogen. According to Nel, it will be the company's largest electrolyser deployment in the UK to date. From Pioneer 2, hydrogen will be compressed with the use of Haskel's market leading GENO compression system, with a small amount of storage on site. The end-to-end hydrogen solution will encompass off-site green hydrogen production, its transfer to site, and the refuelling of fuel cell-electric propulsion aircraft via a mobile refueller.

Hosting the hydrogen production off-site offers several advantages compared to on-site or co-located hydrogen production which requires strict regulations and local planning rules, making it more difficult for a project developer. Such a strategy is enabled by a market-leading and versatile compression technology, such as Haskel's GENO compression system.

A key benefit of off-site hydrogen production, as shown at Pioneer 2, is that it is highly scalable. Containerised electrolyser systems are modular in design, and this is what allows them to scale up. Furthermore, Haskel's GENO compression system can equally be scaled to support growing demands and tailored to bespoke requirements without the need for up-front engineering.

Furthermore, off-site production negates concerns about the complexity involved in assembly of hydrogen infrastructure at airport sites.

The initial focus for Project HEART will be regional airports, targeting aircraft with a capacity of 9-19 passengers and a range of around 500 miles.

This production, storage and distribution system will be tested operationally in the second half of 2024 at Kemble Airport, in Gloucestershire, where some of the world's leading hydrogen-electric propulsion airplanes are being developed.

Project HEART is working with the Civil Aviation Authority, to provide learnings which will feed into future government decisions on ground infrastructure. Project HEART also has a role to play in engaging the public, as it will provide a "show-and-tell" case study on hydrogen aviation ground infrastructure.

Cleared for take-off?

While the hurdles are real and substantial, the case for transitioning the aviation sector away from fossil fuels is compelling.

With industry and government frameworks in place, including a UK Emissions Trading Scheme for the aviation sector, and alternative fuels like electricity, hydrogen, and SAFs demonstrating promising potential, the path to Jet Zero is clear and navigable.

Project HEART is playing a crucial role in ensuring that conditions are in place for a smooth take-off.

White Paper

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