WORKFORCE TO DELIVER LIQUID HYDROGEN POWERED AIRCRAFT

FLY ZERO

AEROSPACE TECHNOLOGY INSTITUTE

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ABOUT FLYZERO

Led by the Aerospace Technology Institute and backed by the UK government, FlyZero began in early 2021 as an intensive research project investigating zero-carbon emission commercial flight. This independent study has brought together experts from across the UK to assess the design challenges, manufacturing demands, operational requirements and market opportunity of potential zero-carbon emission aircraft concepts.

FlyZero has concluded that green liquid hydrogen is the most viable zero-carbon emission fuel with the potential to scale to larger aircraft utilising fuel cell, gas turbine and hybrid systems. This has guided the focus, conclusions and recommendations of the project.

This report forms part of a suite of FlyZero outputs which will help shape the future of global aviation with the intention of gearing up the UK to stand at the forefront of sustainable flight in design, manufacture, technology and skills for years to come.

To discover more and download the FlyZero reports, visit **ati.org.uk**

ACKNOWLEDGEMENTS

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FlyZero contributing companies: *Airbus, Belcan, Capgemini, easyJet, Eaton, GE Aviation, GKN Aerospace, High Value Manufacturing Catapult (MTC), Mott MacDonald, NATS, Reaction Engines, Rolls-Royce, Spirit AeroSystems.*

Department for Business, Energy & Industrial Strategy

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EXECUTIVE SUMMARY

The ATI FlyZero project has identified liquid hydrogen as the zero-carbon emission fuel with the greatest potential to power commercial aircraft up to midsize [1]. Developing and producing hydrogen powered aircraft will require a workforce with skills that do not exist in the UK's aerospace sector today.

Hydrogen technology and aircraft programmes have already launched around the world. It is expected that sub-regional and regional hydrogen fuel cell electric aircraft will enter service by 2030, and that liquid hydrogen gas turbine powered aircraft will follow in the mid-2030s. To gain a strong position in this new market, the UK aerospace sector needs to act urgently; investing in R&D and developing the workforce with the skills needed. A skilled workforce and strong research capability attracts overseas companies to locate in the UK, anchoring production and high-value jobs.

This report identifies a high-level view of skills requirements and outlines recommendations for the way forward.

New skills for hydrogen powered aircraft are required in the areas of gas turbines, electrical, fuel cells, systems and structures. Skills in hydrogen and cryogenics are particularly lacking in the UK.

To deliver this aerospace technology revolution, skills will also be needed in innovation processes, aircraft and systems integration, sustainability, digital, safety and certification, automation and robotics.

The FlyZero recommendations on skills are:

- **Elevate the skills agenda for hydrogen.**
- **Conduct a full foresighting assessment of skills requirements for the priority gaps.**
- **Address the near-term need for critical skills by ensuring research projects have an emphasis on upskilling.**
- **Make work visas available to experts in hydrogen, cryogenics and electrical.**
- **Prepare to upskill the UK workforce ready for major hydrogen aircraft programmes (development and production) through collaborative action from industry and educators.**

01. INTRODUCTION

The ATI FlyZero project has identified liquid hydrogen as the zero-carbon emission fuel with the greatest potential to power large commercial aircraft **[1]**. Developing and producing hydrogen powered aircraft will require a workforce with skills that do not exist in the UK's aerospace sector today.

In 2021, the UK aerospace sector directly employed 116,000 people **[2]**, of whom 87,000 (75%) work in commercial aerospace. Aerospace is a high-value, high-skill sector, and with 88% of these jobs located outside London and the South East this benefit is distributed across the UK.

The UK government's 'Ten Point Plan for a Green Industrial Revolution' **[3]** aims to create and support up to 250,000 green jobs by 2030. ATI FlyZero has forecast that by 2050, >90% of new aircraft could be hydrogen powered and UK aerospace could support ~160,000 jobs. This assumes continued growth in the aerospace market and that the UK takes advantage of the current technological disruption to strengthen its position.

Hydrogen technology and aircraft programmes have already been launched around the world. It is expected that sub-regional and regional hydrogen fuel cell electric aircraft will enter service by 2030 and that liquid hydrogen gas turbine powered aircraft will follow in the mid-2030s. To gain a strong position in this new market, the UK aerospace sector needs to act urgently, investing in R&D and developing the workforce with the skills needed. A skilled workforce and strong research capability attracts overseas companies to locate in the UK, anchoring production and high-value jobs.

This report identifies the high-level skills requirements and outlines recommendations for the way forward.

02. SKILLS REQUIREMENTS FOR HYDROGEN AIRCRAFT

Over the course of the one-year project, FlyZero has engaged across the aerospace sector and other industries to assess the UK capability in technologies relevant to zero-carbon emission aviation and to develop technology roadmaps.

In the forming of the project, FlyZero recruited a team of approximately 100 specialists in under four months. Through these activities, FlyZero has formed a high-level view of the skills requirements and gaps for a workforce to develop and manufacture liquid hydrogen aircraft technologies. This work has also highlighted opportunities for cross-sector collaboration on skills.

02.1 UK CAPABILITY IN HYDROGEN AEROSPACE TECHNOLOGIES

The FlyZero project has identified a number of 'technology bricks' that will be critical to realising hydrogen powered aircraft. **Figure 1** shows these bricks and gives a high level overview of UK current capability and opportunities for each one. More detail can be found in the ATI FlyZero 'UK Capability in Zero-Carbon Aircraft Technologies' **[4]** and the ATI FlyZero Technology Roadmaps (full list in references).

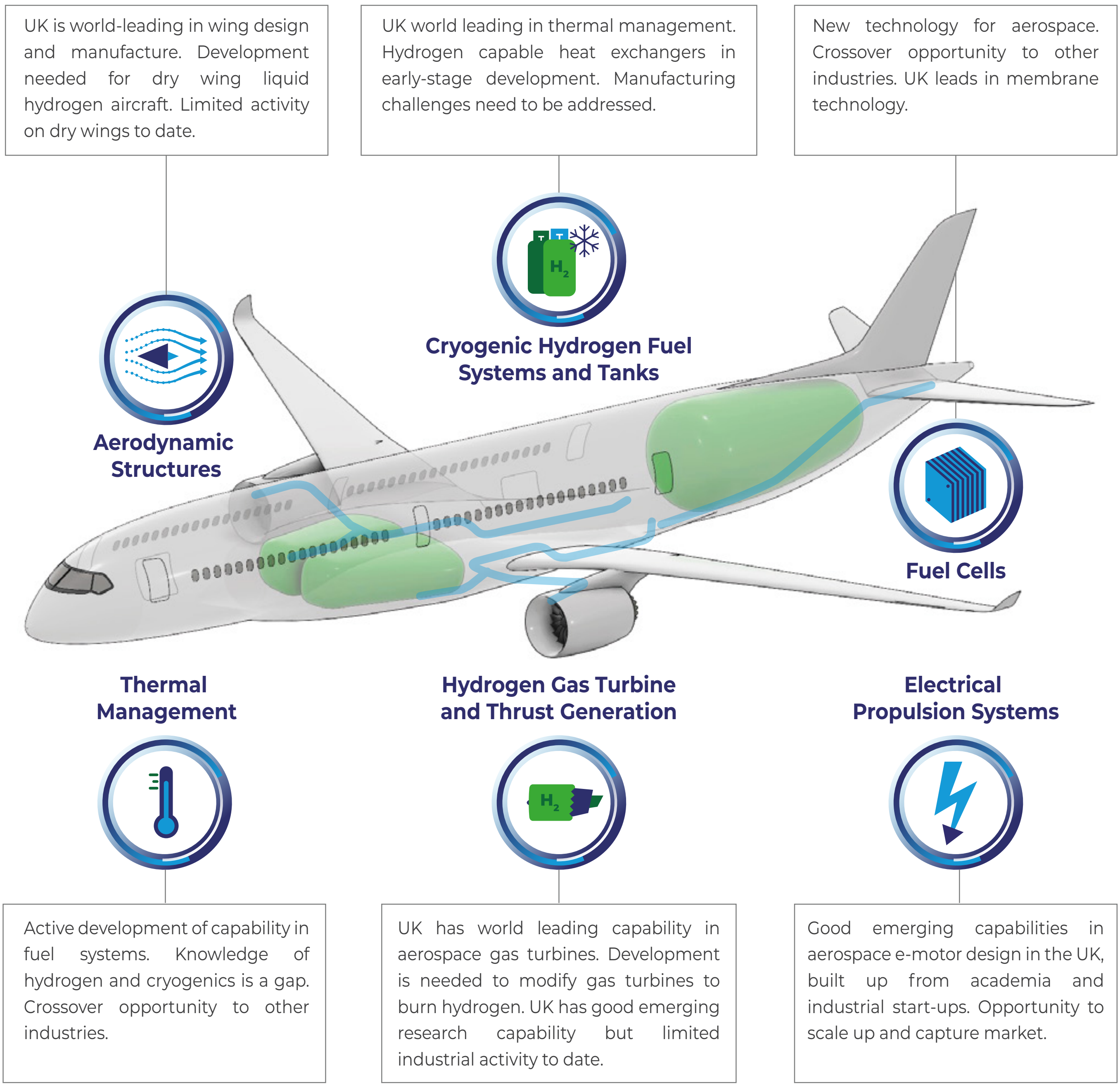


Figure 1 – UK Capability summary for key technology bricks

02.2 SKILLS REQUIREMENTS AND GAPS

Hydrogen technology and aircraft programmes have already been launched around the world. The number of skilled individuals working globally increases as an aircraft programme progresses, from initial technology development, through to supporting the aircraft in-service, as shown in **Figure 2**. The skillsets needed will also change.

FlyZero has formed a high-level view of the skills requirement and gaps for a workforce to develop and manufacture liquid hydrogen aircraft technologies. To do this the project has looked at the skills needed in propulsion (gas turbine, electrical and fuel cell), systems and structures and at cross-cutting skills. In this section, the cross-cutting skills are highlighted first, followed by the skills requirements and workforce gaps for propulsion, systems and structures.

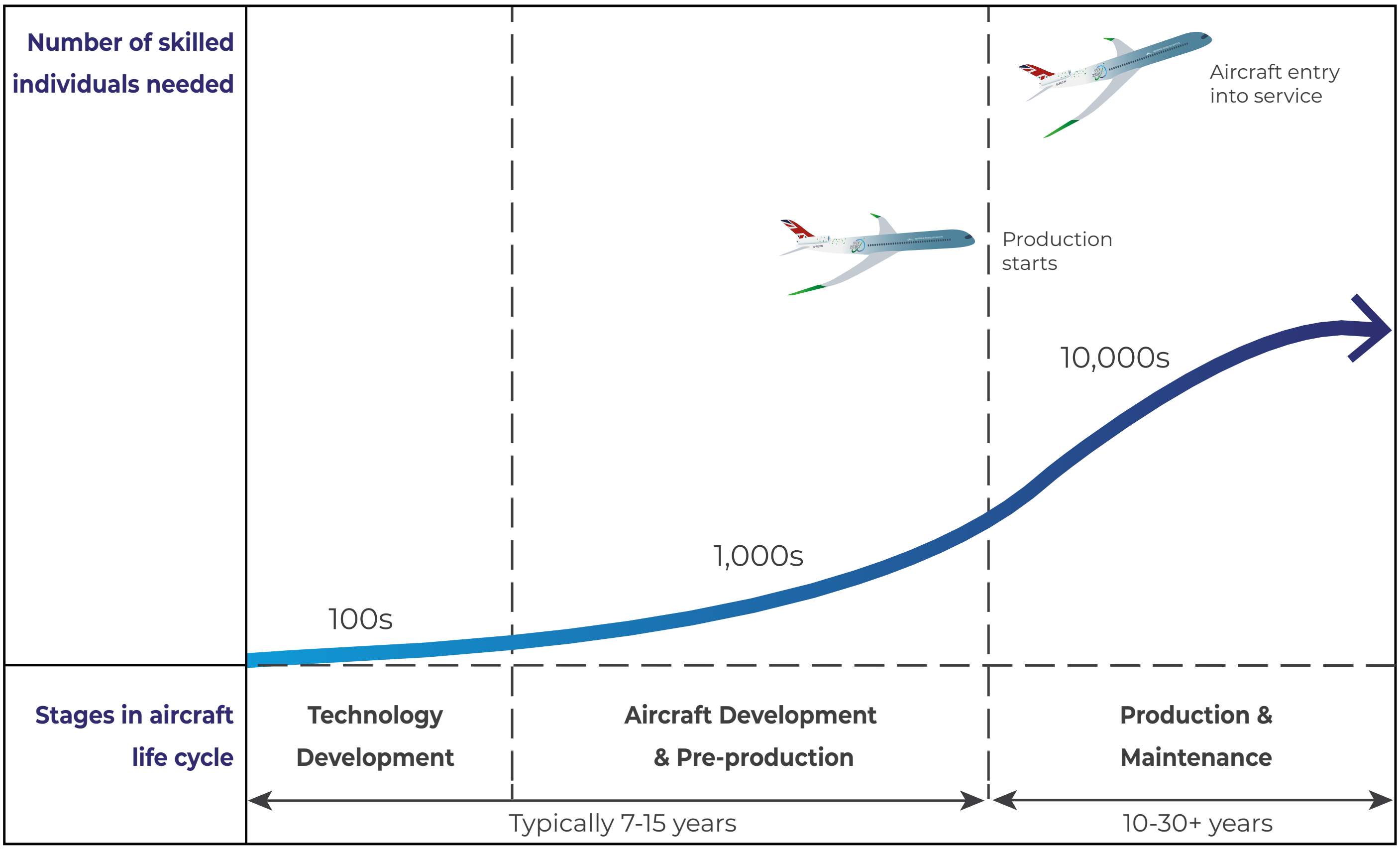


Figure 2 – Indication of the scale of number of skilled individuals needed globally at different stages in an aircraft lifecycle

Cross-cutting skills

Cross-cutting skills are needed in the UK workforce to deliver systems and technologies for hydrogen powered aircraft. Most of these skillsets are also relevant to future ultra-efficient aircraft burning kerosene or sustainable aviation fuel:

Innovation processes: skills required in innovation processes, capable of fostering innovation and driving forward complex programmes.

Aircraft and systems integration: whole aircraft modelling, concept design, systems and aircraft integration are fundamental skills needed to develop and integrate liquid hydrogen aircraft technologies.

Sustainability: skills required in design for sustainability, including lifecycle impact assessments and end-of-life management.

Digital: skills required to develop and implement digital tools to support design and production. Specific skills include model-based engineering, model-based systems engineering, multi-physics simulation, data analytics, data engineering, digital architecture design and connectivity.

Safety and certification: engineers familiar with certification specifications and an understanding of the design and safety challenges of hydrogen-powered aircraft.

Automation and robotics: required to support expected production rates and to ensure UK aerospace productivity continues to improve through this technology disruption.

Skills for propulsion, systems and structures

FlyZero has also looked at the skill requirements and workforce gaps to develop and manufacture liquid hydrogen aircraft technologies that relate to propulsion (gas turbine, electrical and fuel cell), systems and structures.

FlyZero has prepared infographics to illustrate a high-level view of skills requirements and workforce gaps over two time periods:

- **Short-term: 0-5 years** (See Figure 3)
- **Long-term: 5+ years** (See Figure 4)

The assessment has been carried out against three broad role groups described below along with their alignment to national qualification levels [5]:

- **Technicians/operators (qualification levels 3, 4) -** this group covers the roles which would be mostly vocationally-trained professionals, working directly in laboratories, on test rigs, manufacturing shop floors or in maintenance and overhaul facilities.
- **Engineers (qualification levels 5, 6, 7) -** this group includes engineering professionals, usually educated to undergraduate degree level or above, involved in roles such as materials evaluation, design, validation, manufacturing methods, technology insertion, maintenance methods and procedures.
- **Researchers (qualification levels 7, 8) -** this group covers individuals who are applying creative thinking and problem solving to develop (conceive, design, build, test) new technology.

The assessment covered four areas across a product lifecycle:

- **Materials -** Covers assessment of existing and development of new materials for use in hydrogen aircraft.
- **Design and validation -** Covers system, sub-system and component design and validation through pre-production and entry into service.
- **Manufacturing -** Covers manufacturing technology development, implementation of manufacturing lines and operation.
- **Maintenance -** Covers development of retrofits, repair and inspection technologies, maintenance regimes.

Figure 3 - Short-term skills priorities (0-5 years)

Requirements and gaps for workforce* to deliver liquid hydrogen powered aircraft technologies

- **New skills required in short-term (0-5yrs)** Areas of high novelty. These areas require urgent action to deliver the workforce required.
- **Significant workforce volume increase needed**
- **Existing skills & upskilling** Continued development of workforce that exists today within the UK.

Skills Areas	Materials: Technicians/ Operators	Materials: Engineers	Materials: Researchers	Design & Validation: Technicians/ Operators	Design & Validation: Engineers	Design & Validation: Researchers	Examples of skills requirements and gaps
Propulsion – Gas Turbines	Existing skills & upskilling; significant workforce volume increase needed	New skills required	New skills required	Existing skills & upskilling	Existing skills & upskilling	New skills required	Materials scientists and engineers required to understand effects of hydrogen on materials. Chemists and fluid dynamics specialists for hydrogen combustion design & validation. Materials testing in a hydrogen environment will require increased number of lab technicians.
Propulsion – Electrical & Fuel Cells	Existing skills & upskilling	New skills required	New skills required; significant workforce volume increase needed	New skills required; significant workforce volume increase needed	New skills required; significant workforce volume increase needed	New skills required; significant workforce volume increase needed	Materials scientists developing novel material applications e.g. magnetic materials, electrical insulation and fuel cell membranes. Specialists required who understand advanced electrical motors, superconductivity and thermal management. Engineers with an understanding of integration of fuel cell and electrical systems onto aircraft.
Systems	Existing skills & upskilling	New skills required; significant workforce volume increase needed	New skills required; significant workforce volume increase needed	New skills required; significant workforce volume increase needed	New skills required; significant workforce volume increase needed	New skills required; significant workforce volume increase needed	Materials scientists and engineers required to understand effects of hydrogen on materials. Chemists and fluid dynamics specialists to develop modelling capability and support system design. Design, development and test engineers for cryogenic fuel distribution systems, hydrogen heat exchangers and systems related to increased electrification. Systems and automation engineers to develop refuelling solutions, hydrogen detection and fire suppression systems.
Structures	Existing skills & upskilling	New skills required; significant workforce volume increase needed	New skills required; significant workforce volume increase needed	New skills required; significant workforce volume increase needed	New skills required; significant workforce volume increase needed	New skills required; significant workforce volume increase needed	Materials specialists developing new alloys or composites, potentially using new processes providing higher performance. Engineers who understand safe handling and storage of liquid hydrogen for design, validation and testing.

Plus cross-cutting skils (see page 9)

Innovation Processes | **Aircraft and Systems Integration** | **Sustainability** | **Digital** | **Safety & Certification** | **Automation & Robotics**

**This infographic has been created to highlight areas where actions are needed to address skill gaps in the UK. The analysis of UK capability is addressed in the ATI FlyZero 'UK Capability in Zero-Carbon Aircraft Technologies' [4].*

Figure 4 - Longer-term skills priorities (5+ years) **

Requirements and gaps for workforce* to deliver liquid hydrogen powered aircraft technologies.

- **New skills required over longer term (5+yrs)** Areas of high novelty. These areas require action to deliver the workforce required.
- **Significant workforce volume increase needed**
- **Existing skills & upskilling** Continued development of workforce that exists today within the UK.

Skills Areas	Manufacturing: Technicians/ Operators	Manufacturing: Engineers	Manufacturing: Researchers	Maintenance: Technicians/ Operators	Maintenance: Engineers	Maintenance: Researchers	Examples of skills requirements and gaps
Propulsion - Gas Turbines	Existing + volume increase	Existing + volume increase	New + volume increase	Existing + volume increase	Existing + volume increase	New + volume increase	Manufacturing and maintenance specialists required to bring in new process technologies, particularly for combustor components and heat exchangers.
Propulsion - Electrical & Fuel Cells	New + volume increase	New + volume increase	New + volume increase	New + volume increase	New + volume increase	New + volume increase	Process specialists identifying advanced technologies for electrical system and component manufacture. Automation engineers and manufacturing specialists with knowledge of fuel cell products and safe working with chemicals. Maintenance engineers and technicians who understand fuel cells and electrical systems.
Systems	Existing	New + volume increase	New + volume increase	New + volume increase	New + volume increase	New + volume increase	Manufacturing and repair specialists who can embed and maintain integrated sensors. Manufacturing and maintenance specialists experienced at working with liquid hydrogen and vacuums (for e.g., dual-walled fuel system pipes). Manufacturing and maintenance engineers skilled in working with integrated systems, including electrification.
Structures	Existing	Existing	New + volume increase	New + volume increase	New + volume increase	New + volume increase	Manufacturing specialists developing manufacturing technologies for dry wings. Manufacturing and maintenance specialists experienced at working with liquid hydrogen, vacuums (for e.g., dual-walled tanks) and composite repairs.

Plus cross-cutting skils (see page 9)

Innovation Processes | **Aircraft and Systems Integration** | **Sustainability** | **Digital** | **Safety & Certification** | **Automation & Robotics**

** This infographic has been created to highlight areas where actions are needed to address skill gaps in the UK. The analysis of UK capability is addressed in the ATI FlyZero 'UK Capability in Zero-Carbon Aircraft Technologies' [4].*

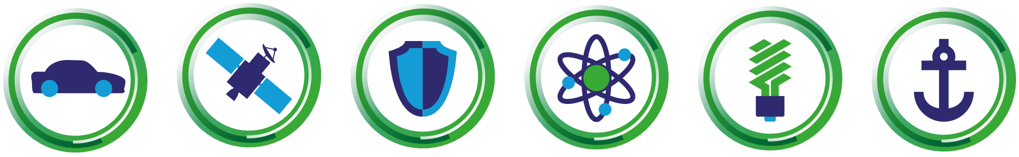
*** Longer term priorities are affected significantly by aircraft volume increase therefore all technology areas will see a workforce increase in demand, as shown in Figure 2.*

02.3 CROSS-SECTOR COLLABORATION

Figure 5 highlights opportunities for cross-sector collaboration on skills.

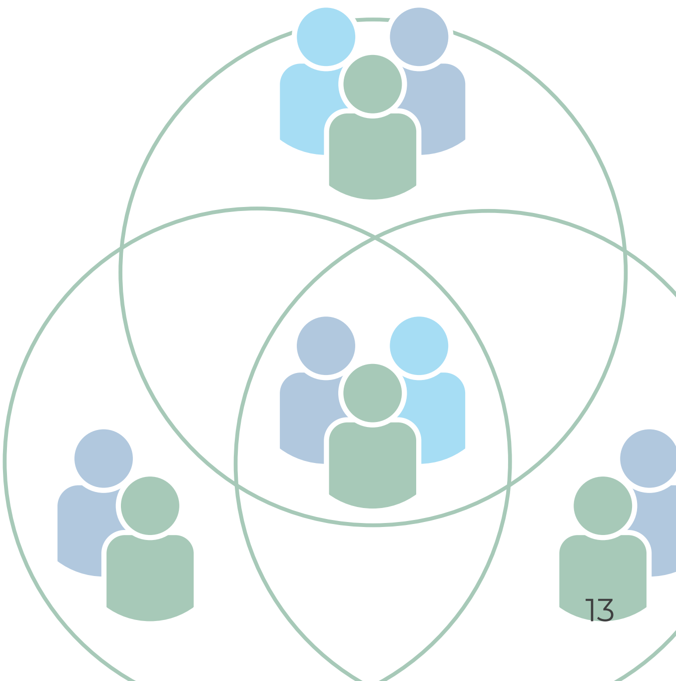
For areas where significant volume increase is required as shown in **Figures 3** and **4**, these sectors will also be competing for skilled individuals. The UK Hydrogen strategy projects that there will be 100,000 jobs in the hydrogen economy by 2050 **[6]**, across all sectors. This highlights the urgency for the aerospace sector to act, mapping out a clear evidence-based plan and working wherever possible to combine the demand signal for skills with other sectors.

A National Electrification Forum and Framework has been set up in the UK to address the emerging skills gaps in developing electrical technologies across multiple sectors. A similar approach is needed for hydrogen.



	Automotive	Space	Defence	Nuclear	Energy	Marine
Propulsion - gas turbines			●		●	●
Propulsion – electrical and fuel cells	●		●		●	●
Systems		●	●	●	●	●
Structures			●		●	●

Figure 5 – Opportunities for collaboration with other sectors in skill areas associated with hydrogen aircraft development



03. RECOMMENDED ACTIONS

This report has identified the skills requirements and workforce gaps that must be addressed for the UK to gain a strong position in hydrogen powered aircraft. This includes both a short-term view to support materials, design and development, and longer-term view to support production and in-service requirements.

To address these gaps and help gear up the UK to stand at the forefront of sustainable aerospace technology, FlyZero has made the following recommendations for action on skills:

Elevate the skills agenda for hydrogen

Skills for hydrogen and related technologies needs to be raised up the agenda in the UK. Routes for doing this include the Jet Zero Council for aerospace skills and Hydrogen Advisory Council for cross-sector skills. An approach similar to the National Electrification Skills Framework and Forum is needed for hydrogen.

Conduct a full foresighting assessment of skills requirements for the priority gaps

For the priority gaps identified within this report, a fuller assessment of the skills requirements (a 'foresighting' exercise) should be undertaken – following the model demonstrated in the Emerging Skills Project (**see Case Study 1**). This report and the FlyZero Technology Roadmaps can be used as a starting point.

The Aerospace Growth Partnership Skills Working Group is ideally positioned to lead this foresighting activity, with support from various organisations (such as academic institutions, the Catapult network and UKRI). This will progress the high-level analysis undertaken by FlyZero into detailed skills requirements and a plan of action.

Make work visas available to experts in hydrogen, cryogenics and electrical

The UK has less capability in hydrogen and cryogenics than other countries. It also has a shortage of electrical engineers. To fill these gaps, the UK urgently needs to attract brilliant minds from around the world to locate in the UK, prioritising visas for individuals in these fields. These experts will be critical for upskilling the UK workforce.

Address the near-term need for critical skills by ensuring research projects have an emphasis on upskilling

Research projects are a vehicle for discovery, exploration, innovation and learning. Creating a critical mass of research projects in the UK will, as a by-product, upskill researchers in this emerging application area. Research projects can also be more consciously designed to upskill. FlyZero itself is a good example of how a research project can be a sandpit for people to develop new skills (see **Case Study 2**).

Projects need to bring together researchers with knowledge of aerospace applications and emerging technology areas (e.g. hydrogen and electric).

These skilled individuals become a nucleus around which all other activity springs up – both commercialisation of the technology and production. Once a critical mass of skilled researchers and design engineers is in the UK, it is important to anchor them with sustained activity. Industry, academia, research organisations, the Catapult network and research funding bodies such as the ATI, EPSRC and Innovate UK all have an important role to play here.

This research can happen in industry, academia and research organisations. One option highlighted in FlyZero's assessment of UK capability **[4]** is to establish a UK hydrogen technology programme, centre or network of centres, which could benefit multiple sectors and act as a skills sandpit.

Prepare to upskill the UK workforce ready for major hydrogen aircraft programmes (development and production) through collaborative action from industry and educators

This will require technicians and engineers to be equipped to work in the areas of hydrogen fuel systems and storage, hydrogen gas turbines, electrical systems, fuel cells and structures. New training provisions, including short courses, apprenticeships, and degrees will be needed. Where the aim is to upskill people as quickly as possible, models that fuse taught elements and on-the-job learning, such as apprenticeship and degrees based in industry are particularly successful.

Delivery will require close collaboration between industry and educators. Employer led Institutes of Technology, such as the West of England Institute of Technology described in **Case Study 3**, illustrate how industry and educators can work together to close skills gaps in the workforce.

UK organisations need to continuously encourage students from primary school through to university to consider a career in aerospace to sustain the talent pipeline. According to the Children's People and Nature survey in 2021 **[7]**, over 80% of 8- to 15-year-olds want to do more to help the environment. The aerospace community should use the transition towards greener technology to inspire the next generation into aerospace careers, bringing hydrogen and electric aircraft into schools and universities. Through partnerships with educators, engineering institutions and STEM outreach organisations, STEM outreach can be embedded within R&D programmes. Cranfield University is leading by example with their participation in the Nuffield Research Placement Scheme (**Case Study 4**).

Case Study 1 - Skills Value Chain and The Emerging Skills Project

In 2020, the High Value Manufacturing Catapult (HVM Catapult) published the Manufacturing the Future Workforce report [8] - an international study of good practice in Centres of Innovation. A major recommendation of this report was to implement a Skills Value Chain (SVC) approach; which uses 'skills foresighting' to ensure that the right skills are in industry at the right time for emerging technologies.

In early 2021, the HVM Catapult was appointed by the Department for Education to lead the 'Emerging Skills Project', to address future skills gaps in key sectors such as manufacturing and engineering. Working with the Institutes of Technology and other providers, the project aim was to identify future gaps in the provision of education and training, using sector and technology roadmaps and the principles of SVC. Subjects covered were digitalisation, electrification, additive manufacturing, and advanced composites. The work on electrification led to a multi-sector approach to skills for electrification detailed in the report 'Opportunity for a National Electrification Skills Framework and Forum' [9].

A similar foresighting approach should be adopted for hydrogen. The early work on defining the skills required for hydrogen aircraft captured in this report provides a sound platform and focus for further work to establish a pipeline of skills required for each stage of technology development and application.

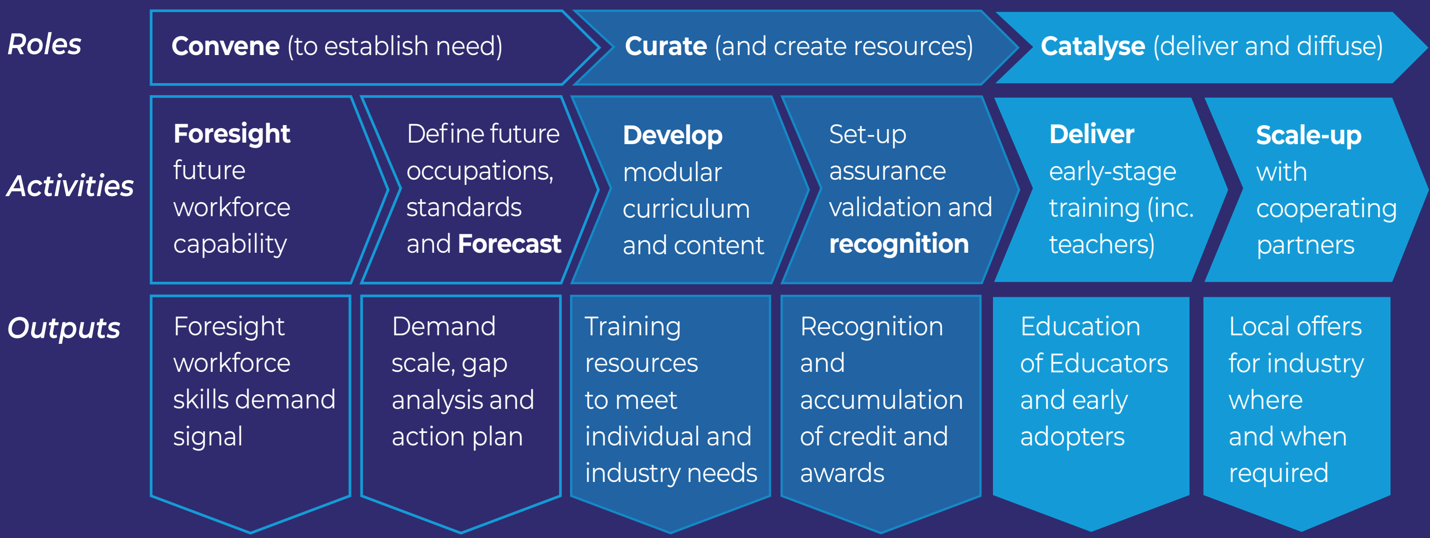


Figure 6 – Skills Value Chain Approach © 2022 High Value Manufacturing Catapult

Case Study 2 - ATI FlyZero as a 'Skills Sandpit'

In FlyZero, the UK's Aerospace Technology Institute brought together a team of 100 experts from across UK aerospace, aviation and academia for a one-year feasibility study into zero-carbon emissions flight.

Recruitment of specialists in the areas of hydrogen and electrical proved challenging for the project, exposing a critical skills gap. To fill these gaps, FlyZero contracted work packages from specialists in industry and academia.

Members of the FlyZero team significantly furthered their skills and capability through the sharing of knowledge between people from different technical domains and organisations. In an internal survey, 81% of respondents agreed "I feel I am learning new things which will help me later in my career". Research programmes like FlyZero can be a sandpit for skills development.

FlyZero team and contributing companies © 2022 Aerospace Technology Institute

Case Study 3 - West of England Institute of Technology

The West of England Institute of Technology (WEIoT) is one of 20 IoTs in the UK, in which employers design and lead skills programmes in partnership with research institutions and education providers. Modules developed within each IoT are made freely available for access by other regions, which provides benefits to supply chains across the UK.

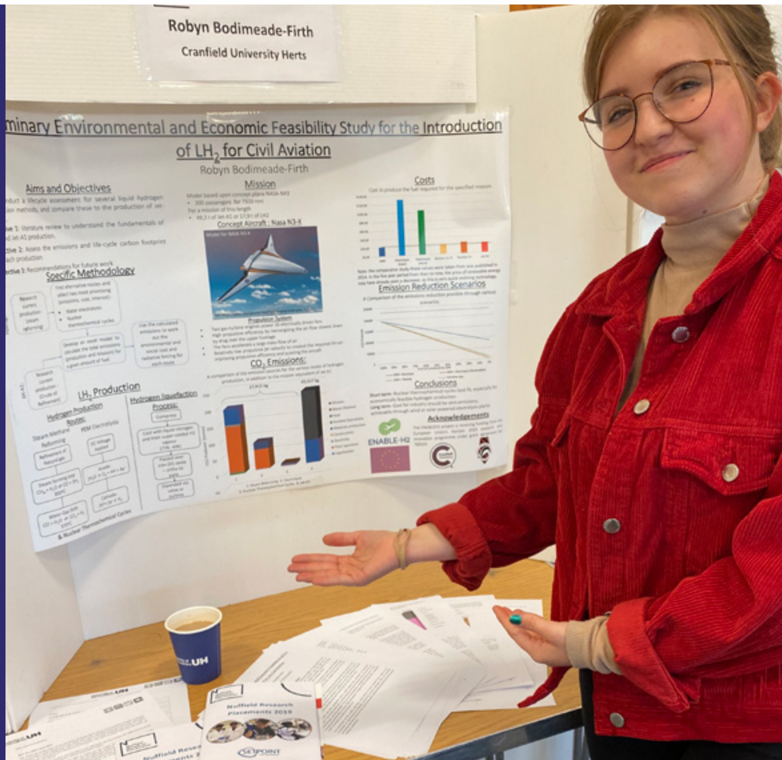
WEIoT specialises in advanced engineering and high value manufacturing, digital, and health and life sciences. A significant proportion of the employer partners come from aerospace technology employers within the region, including GKN Aerospace, which in September 2021 opened a new WEIoT Weston College training facility within their new flagship Global Technology Centre (GTC). This example demonstrates a proactive approach to feeding cutting edge aerospace technologies into skills provisions.

West of England IoT Training Facility within GKN Aerospace Global Technology Centre © 2022 GKN Aerospace

Case Study 4 - Cranfield University Participation in Nuffield Research Placements Programme

Cranfield University is committed to encouraging high school students from diverse backgrounds to consider university degrees and careers related to zero emissions technologies. Nuffield Research Placements (NRP) [10] aim to increase opportunities for young people from disadvantaged backgrounds to access STEM university courses and STEM-related careers through impactful placement experiences. Cranfield University has therefore collaborated with NRP to host around 7 placements every year since 2010. Through this exciting opportunity, recent students have experienced first-hand the challenges of decarbonising aviation by working on the EnableH_2 project.

Inspiring and engaging the younger generations through targeted STEM Outreach campaigns is important to ensure the talent pipeline for the future. Climate change is a cause many young people are passionate about, so zero carbon aircraft projects present an opportunity to inspire people to choose a STEM career. Technology organisations can follow Cranfield's example by running STEM outreach alongside their R&D programmes.



Nuffield Research Placement student, Robyn Bodimeade-Firth, at Cranfield University © 2022 Robyn Bodimeade-Firth

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RELATED FLYZERO FURTHER READING

The ATI FlyZero project developed its technology roadmaps through a combination of broad industry consultation and assessment of technologies by experts. Technology assessment was carried out both by the FlyZero team and by approximately 50 industrial and academic organisations that partnered with FlyZero to support delivery. During the project, FlyZero developed three concept aircraft and used this exercise to gain a deep understanding of requirements and challenges for systems and technologies, which have been reflected in the roadmaps. Further detail of these technologies and developments can be found in the following reports, available to download from **ati.org.uk**

FlyZero

Zero-Carbon Emission Aircraft Concepts
Report
Ref. FZO-AIN-REP-0007

Technology Roadmaps
Report
Ref. FZO-IST-MAP-0012

Workforce to Deliver Liquid Hydrogen Powered Aircraft
Report
Ref. FZO-IST-PPL-0053

Hydrogen Aircraft

Aerodynamic Structures
Technical Report
Ref. FZO-AIR-REP-014
Roadmap
Ref. FZO-AIR-MAP-0015
Roadmap Report
Ref. FZO-AIR-COM-0016
Capability Report
Ref. FZO-AIR-CAP-0066

Electrical Propulsion System
Technical Report
Ref. FZO-PPN-REP-0028
Roadmap
Ref. FZO-PPN-MAP-0029
Roadmap Report
Ref. FZO-PPN-COM-0030
Capability Report
Ref. FZO-PPN-CAP-0070

Thermal Management
Technical Report
Ref. FZO-PPN-REP-017
Roadmap
Ref. FZO-PPN-MAP-0018
Roadmap Report
Ref. FZO-PPN-COM-0019
Capability Report
Ref. FZO-PPN-CAP-0067

Fuel Cells
Technical Report
Ref. FZO-PPN-REP-0031
Roadmap
Ref. FZO-PPN-MAP-0032
Roadmap Report
Ref. FZO-PPN-COM-0033
Capability Report
Ref. FZO-PPN-CAP-0071

Hydrogen Gas Turbines & Thrust Generation
Gas Turbine Technical Report
Ref. FZO-PPN-REP-020
Thrust Devices Technical Report
Ref. FZO-PPN-REP-021
Roadmap
Ref. FZO-PPN-MAP-0022
Roadmap Report
Ref. FZO-PPN-COM-0023
Capability Report
Ref. FZO-PPN-CAP-0068

Cryogenic Hydrogen Fuel System & Storage
Fuel System Technical Report
Ref. FZO-PPN-REP-024
Fuel Storage Technical Report
Ref. FZO-PPN-REP-025
Roadmap
Ref. FZO-PPN-MAP-0026
Roadmap Report
Ref. FZO-PPN-COM-0027
Capability Report
Ref. FZO-PPN-CAP-0069

Cross-Cutting

Aircraft Systems
Ref. FZO-AIR-POS-0013

Airports, Airlines, Airspace - Operations & Hydrogen Infrastructure
Ref. FZO-CST-POS-0035

Advanced Materials
Ref. FZO-IST-POS-0036

Lifecycle Impact
Ref. FZO-STY-POS-0034

Sustainable Cabin Design
Ref. FZO-AIR-POS-0039

Compressed Design and Validation - Culture and Digital Tools
Ref. FZO-IST-POS-0038

Advanced Manufacturing
Ref. FZO-IST-POS-0037

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