FUEL CELLS

UK Capability and Overseas Landscape

FLY ZERO

AEROSPACE TECHNOLOGY INSTITUTE

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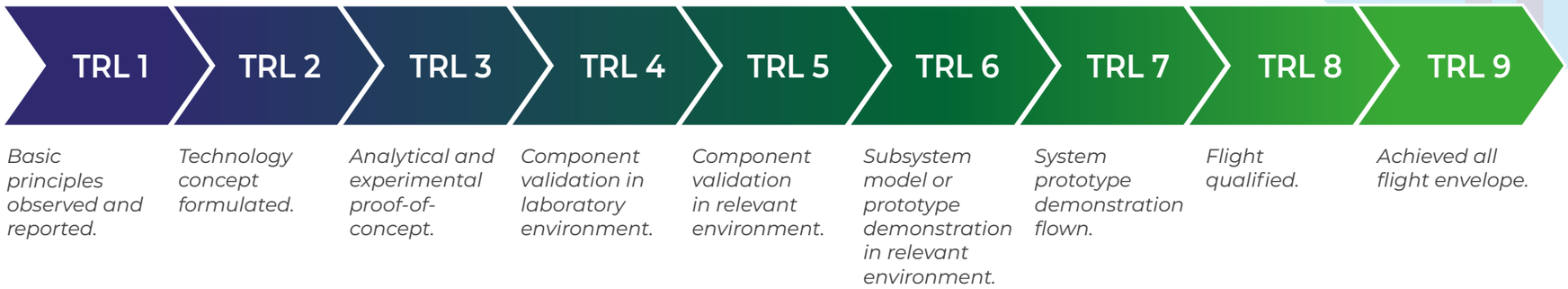


Figure 1 – Technology has been assessed against the NASA Technology Readiness Level (TRL) scale

UK CAPABILITY

The UK has hydrogen fuel cell technology capability in various companies, including Intelligent Energy, Core Technology, Johnson Matthey, Ceres, Fuel Cell Systems and AVL. In the ATI-funded H2GEAR programme, GKN Aerospace is developing a hydrogen fuel cell-powered propulsion system with fuel cell manufacturer Intelligent Energy. The UK also has significant research strength in this sector.

The UK is leading in PEM membrane technology within the fuel cell, making this a potential area of high opportunity for a UK “play to win”.

A typical fuel cell stack currently takes 1.5 days to build by hand, with a high potential for build errors culminating in leaks that trigger rework. AMRC Cymru, part of the High Value Manufacturing Catapult, is setting up a cell to demonstrate and optimise the automation of fuel cell assembly. This would focus on improving rate capability and achieving a repeatable build. The technology readiness level (TRL) for a generic fuel cell is TRL 8, with its incorporation growing in commercial road transport applications. Globally there are several flight-based trials where the fuel cell is being evaluated in flight and operating at TRL 5.

Figure 2 – Global TRL level for PEM fuel cell

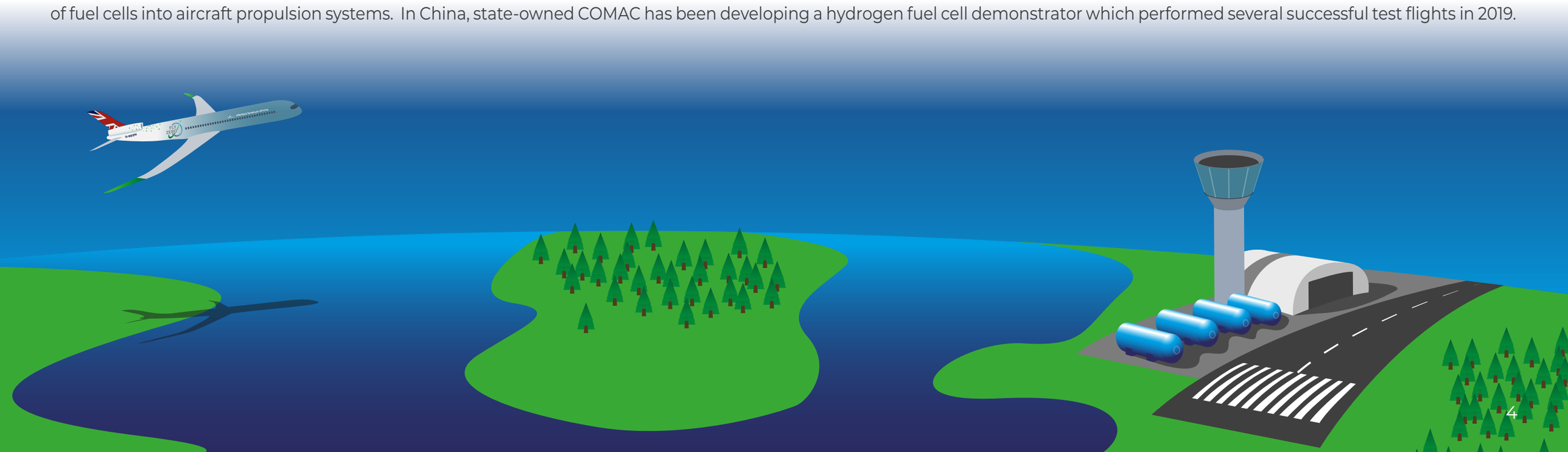
Early flight-based trials where the fuel cell performance is being evaluated, manufactoring rate development taking place.

OVERSEAS LANDSCAPE

The countries that are leading in fuel cells include Germany, Japan, South Korea, Sweden, the USA, Canada, and China.

In Germany, Liebherr and General Motors have created an aerospace/automotive partnership on fuel cell development. The German Aerospace Centre, DLR, is working on fuel cell powered demonstrator aircraft projects, BALIS and DLR-HY4. Projects APUS H2, H2FLY and the joint ElringKlinger/Airbus project are industrially funded fuel cell demonstrator projects in Germany complementing the work at DLR. Sweden's PowerCell has supplied fuel cells for ZeroAvia UK-based demonstrator aircraft, USA's HyPoint and Hyzon Motors have also both supplied fuel cells for evaluation to ZeroAvia. Another USA supplier Plug power has partnered with Universal Hydrogen to deliver the hydrogen fuel cell technology.

Japan's strong position in fuel cells comes from its automotive industry which has ambitious plans to deploy 300,000 fuel cell electric vehicles by 2030. In South Korea outside of aerospace, Hanwha is industrialising hydrogen fuel cell power generation technology, with the recently completed Daesan plant claimed to be the world's first and largest hydrogen fuel cell plant. The National Research Council of Canada's Low-emission Aviation programme aids the aviation sector's decarbonisation transition including the development and integration of fuel cells into aircraft propulsion systems. In China, state-owned COMAC has been developing a hydrogen fuel cell demonstrator which performed several successful test flights in 2019.



KEY MESSAGE

Hydrogen fuel cells are relatively mature in other sectors so there is an opportunity for technology transfer.

However, given the high safety standards required by aviation, the levels of production control will be more stringent. Production facilities for aerospace applications will likely cost more than for automotive applications due to the higher levels of quality assurance required by aerospace. There is no current incumbent UK industrial capacity for manufacturing fuel cells for aerospace applications at required production rates however this presents a significant production capacity growth opportunity.

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

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**

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These roadmaps have been developed with a view to accelerate zero-carbon technology development and maximise the potential future value for the UK. They are unconstrained by the availability of funding.

Department for Business, Energy & Industrial Strategy

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