FLYZERO EXECUTIVE SUMMARY

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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Front cover image © ATI

FOREWORD

Decarbonising aviation is the challenge of our generation.

The aircraft being manufactured today are more efficient than ever before and will increasingly operate using fossil fuel alternatives representing great strides towards our global climate commitments on carbon emissions.

But what if we could eliminate carbon emissions altogether? This question was the catalyst for FlyZero, a 12-month research project which began in early 2021 to realise zero-carbon emission commercial flight by the end of the decade.

This report, as part of a suite of outputs, presents a vision for aviation which keeps businesses, cultures, families and nations connected without the carbon footprint.

Realising this vision for liquid hydrogen powered flight presents challenges for all facets of our aerospace and aviation sectors as well as wider industries and energy infrastructure. An integrated, collaborative, international approach is needed to protect our planet, maintain the benefits of aviation and secure economic growth.

There is a compelling case for taking action today.

The UK is ideally positioned to build on decades of expertise in aerospace innovation to develop, test and certify the advanced technologies which will propel a new generation of liquid hydrogen powered aircraft into our skies. As has historically been the case, the UK would need to work in collaboration with global OEMs, governments and regulatory bodies to deliver the technologies, policies and certification at pace.

The project has made some initial conclusions that require further investigation and investment to understand the feasibility and approach to innovation for the next phase. To this end the Aerospace Technology Institute (ATI) will incorporate the findings from the project into its Technology & Portfolio Strategies and look to pursue opportunities for the UK.

FlyZero has generated a rich resource of learning that supports the transition to hydrogen technologies and would not have been possible without the support of BEIS and the ATI team, FlyZero's contributing companies and our supporting organisations.

A new era for aviation is on the horizon.

Chris Gear, Project Director – FlyZero

Gary Elliott, CEO - ATI

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INTRODUCTION TO FLYZERO

The FlyZero project was initiated in late 2020 by the Aerospace Technology institute (ATI) and the Department for Business, Energy, and Industrial Strategy (BEIS) to determine whether zero-carbon emission flight was feasible for large commercial aircraft. This supports the Jet Zero Council aim to deliver zero emission transatlantic flight within a generation.

The FlyZero team consisted of 100 engineers and aviation professionals made up of secondees from our 13 industrial partners together with independent experts. FlyZero's delivery was also supported by 16 universities and research organisations, a further 34 aerospace companies, five airports and three airlines. Advisory groups and community workshops further validated the projects priorities and findings. The FlyZero team were located across all parts of the UK and utilised remote working to deliver the projects aims despite the COVID-19 pandemic.

EXECUTIVE SUMMARY

Zero-carbon emission flight can be a reality. The target to reach net zero by 2050 requires large zero-carbon emission aircraft to enter service by 2035. The scale of the challenge is huge, but the ambition to succeed is strong. It will require a collaborative and urgent approach, with aerospace companies, airlines, airports, governments, regulators, and adjacent sectors such as energy working together at pace.

Zero-carbon emission aircraft will be powered by green liquid hydrogen. The UK can become a leader in the necessary technology, systems and processes, influencing how they are introduced across the world. To do so, it must rapidly develop its infrastructure, capabilities, and regulatory regime for hydrogen. To enable large commercial aircraft to enter service by 2035, it must also commence an ambitious aircraft research programme on technologies such as cryogenic hydrogen fuel systems, gas turbines, and airframes for ground and airborne demonstration. In parallel, the UK must also continue to advance technologies required for sustainable aviation fuels (SAF). SAF and liquid hydrogen are both needed to achieve the net zero 2050 target.

The economic opportunity for the UK is also significant. By 2050, it could grow its market share in civil aerospace from 12% today to 19%, increasing the sector's gross value added to the economy from £11bn to £36bn, and expanding the number of aerospace jobs from 116,000 to 154,000.

FLYZERO CONCLUSIONS

1. FlyZero has compared zero-carbon emission energy sources such as batteries, hydrogen and ammonia and concluded that **green liquid hydrogen is the most viable**, able to power large aircraft utilising fuel cell, gas turbine and hybrid systems. For aviation to achieve net zero 2050 FlyZero determined that we must invest now in both the development of sustainable aviation fuel (SAF) and green liquid hydrogen technologies.

2. **Technology acceleration is key as industry and aviation can only afford one fleet refresh between now and 2050. This gives a window of opportunity to introduce zero-carbon emission aircraft** in the regional, narrowbody and midsize market segments. FlyZero has modelled these concepts and determined that it is feasible to design and **fly an experimental aircraft across the Atlantic by 2030 powered by hydrogen gas turbines.**

3. The optimum route to decarbonising aviation is through acceleration of a large (narrowbody and midsize) commercial aircraft into service. **FlyZero's midsize aircraft is able to reach all destinations in the world with a single stop.** Less commercially risky than developing a narrowbody first, it would allow infrastructure development to be focused on fewer, but larger international hub airports.

4. **Global cumulative CO2 emissions from aviation could be reduced by 4 gigatons (Gt) by 2050 and 14 Gt by 2060.** This requires 50% of the commercial fleet to be hydrogen-powered by 2050 and assumes midsize hydrogen-powered aircraft are operating by 2035, with hydrogen-powered narrowbody aircraft in service by 2037. It is critical to achieve these dates to hit the net zero 2050 goal.

5. **Revolutionary technology breakthroughs are required in six areas** to achieve zero-emission flight: hydrogen fuel systems and storage, hydrogen gas turbines, hydrogen fuel cells, electrical propulsion systems, aerodynamic structures and thermal management. The UK has expertise and capability today in these, but little in liquid hydrogen fuels. **Climate science is also fundamental to aerospace research.**

6. From the mid-2030s, **liquid hydrogen** is forecast to become **cheaper as well as greener** than Power to Liquid SAF which is expected to be the primary SAF as demand increases. PtL SAF requires more electrical energy to produce than liquid hydrogen. Scalability of other SAFs is limited by availability of raw materials.

7. Hydrogen-powered aviation will require **new aircraft certification policies. New health and safety regulations** will also be needed for transporting and storing liquid hydrogen at airports and refuelling aircraft. Regulators will need to take a **global approach** to developing and adopting these.

8. By leading these developments, the UK could by 2050 grow its **market share** in civil aerospace from 12% to **19%**, its **gross value added (GVA)** from £11bn to **£36bn** and increase **aerospace jobs** from 116,000 to **154,000**. Failure to act could result market share reducing to 5%, with £14bn GVA and sector jobs declining to 74,000.

9. **Failure to decarbonise may result in measures to restrict aviation, impacting the UK economy heavily.** In 2019 aviation and aviation facilitated tourism worth some £77.5bn GVA to the UK, supporting over one million jobs. With decarbonisation, this is forecast to grow to £177 bn GVA and 1.5 million jobs in 2070. Without decarbonisation the project growth will be significantly reduced.

FLYZERO RECOMMENDATIONS

1. **Industry and government should work internationally to bring large zero-carbon emission aircraft to market as soon as possible.** Industry should demonstrate the potential of the technology to transform the global fleet and deliver environmental and economic benefits. Government should facilitate research as well as support the infrastructure and regulatory changes required for zero-carbon emission flight. Urgent investment in green energy infrastructure is required to deliver green hydrogen. There should be a rapid roll-out of SAF in the 2020s and early 2030s to deliver early decarbonisation.

2. **ATI and BEIS should create strategic partnerships to pursue mission-led R&D programmes** to demonstrate UK capability, maximise UK supply chain participation and broker international collaboration. They should cover early-stage industrial R&T (unproven higher-risk, higher-reward technologies), directed R&T (innovation in critical areas required for hydrogen aviation), test infrastructure and demonstrations.

3. **Critical technologies must be progressed to technology readiness level (TRL) 5-6 by 2025** if UK equipment is to stand a chance of making it on to the first liquid hydrogen-powered aircraft. The AGP and Jet Zero Council should consider how best to create a new hydrogen and zero emission supply chain in the UK. Stimulating industry access to private finance would help support the development of zero-carbon emission aircraft systems and components in the UK.

4. To address the UK's limited hydrogen-related skills and testing capabilities, **a cross-sector hydrogen technology centre** with open access facilities should be created to facilitate research into fundamental hydrogen behaviour (including cryogenics), requirements for safe handling, standards and regulations, material properties and test specifications. **It should act as a centre of excellence and provide an anchor for industry in the UK**.

5. The UK needs to create an **integrated approach with the global aviation community** that involves aerospace, aviation and energy industrials, academia and research and technology organisations. The engagement needs to be done jointly with government and aviation authorities to create the infrastructure, legislation, policies and regulations, to secure and enable the safe operation of hydrogen-powered aircraft.

6. The **UK Civil Aviation Authority (CAA) should establish strong links with EASA and the FAA to create a future sustainability committee**. This committee should focus on the introduction of commercial aircraft using SAF and hydrogen based fuels. It should become responsible with industry for developing new global aviation policies, regulations, certification and operational requirements. It will also need to have close links into government departments on infrastructure, health and safety and environmental impacts.

7. **Academic research into the climate impacts of hydrogen-powered aircraft should be prioritised**. It should focus on predicting and modelling the impacts of water vapour and contrails for different atmospheric conditions and assessing the impact of different fuels and propulsion systems on emissions and contrails, through laboratory tests and airborne research.

8. Consideration should be given to using **incentives, pricing and taxation to influence passenger behaviour and shift demand to sustainable forms of aviation**. Using aviation tax or levy receipts to support the development of a zero-carbon emission aircraft should also be explored.

9. FlyZero has identified the UK aviation's hydrogen demand over the next 30-50 years. It is important that the UK government along with Hydrogen UK utilises our recommendation on **ensuring aviation is recognised as an important use case for H_2 in future energy strategies**.

10. The ATI, BEIS, DfT, the Aerospace Growth Partnership and the Jet Zero Council should play a leading role to urgently consider and take forward these recommendations through a coordinated series of actions across the aerospace, aviation and energy sectors.

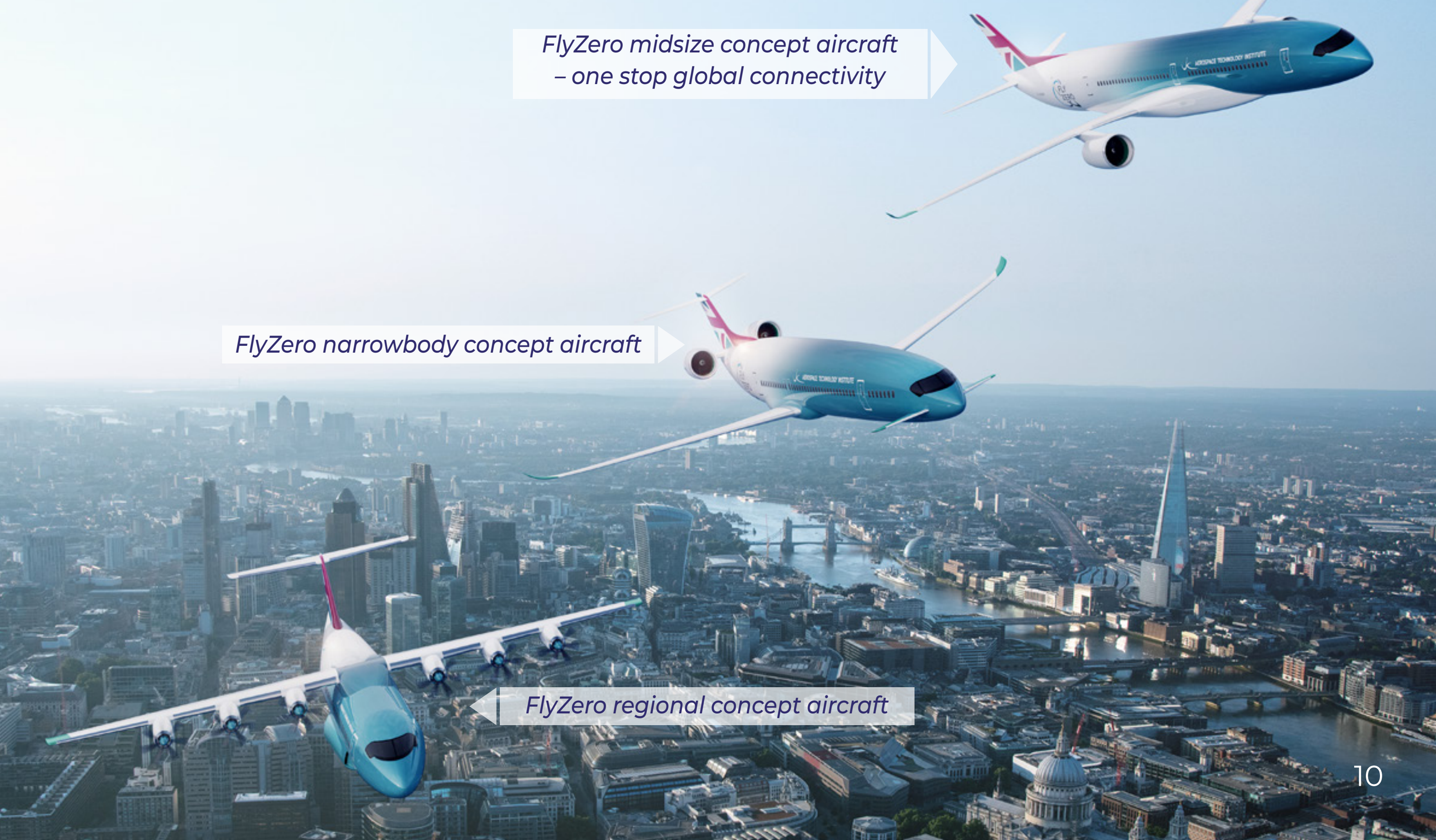
INTRODUCING THE FLYZERO CONCEPTS

FlyZero has developed three aircraft concepts which set out a vision for the next generation of commercial aircraft in the regional, narrowbody and midsize markets offering similar capability as today's aircraft while eliminating in-flight carbon emissions.

The regional concept, powered by fuel cells, carries 75 passengers up to 800 nmi at a speed of 325 knots. Fuel cells are likely to be more competitive at smaller aircraft sizes than the FlyZero regional concept where the overall power requirement is lower. Its main advantages are that it only emits water and eliminates all other exhaust emissions (CO_2, NO_x, particulates).

The narrowbody concept carries 179 passengers up to a design range of 2400 nmi at a speed of 450 knots. The concept has the energy storage and propulsion system located at the rear of the aircraft, this includes the fuel tanks, fuel system and gas turbines.

The midsize concept carries 279 passengers with a design range of 5750 nmi at a speed of 473 knots and an operational range of 5250 nmi. This means destinations including San Francisco (4664 nmi) and Beijing (4414 nmi) are within reach from London direct while Auckland (9991 nmi), Sydney (9198 nmi) and Honolulu (6289 nmi) are in reach with just one stop. FlyZero analysis concluded that a midsize hydrogen aircraft could efficiently address 93% of existing long haul scheduled flights and, therefore, the majority of emissions in this market sector.



CONCLUSION

For the UK to maintain or increase its stake in a global zero-carbon emission aircraft and aviation network, a de-risking development, testing and demonstration programme needs to be launched, focused on the use of liquid hydrogen. The FlyZero recommendations should be carried forward energetically and in an integrated way across technology bricks, infrastructure and climate science research. The ATI should lead this through a senior working group including organisations and individuals with expertise in areas falling outside the ATI's scope. Follow-up activities should also be promoted through existing mechanisms such as the Jet Zero Council, the Aerospace Growth Partnership, the ATI's advisory groups and the Sustainable Aviation Board. The time to act is now to secure the technology, to secure the exploitation pathway and to secure the route to net zero by 2050.

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FLYZERO
EXECUTIVE SUMMARY

FLY ZERO

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