Written Evidence Submitted by ZeroAvia

(HNZ0019)

ZeroAvia is an innovative UK-based business, and our mission is to accelerate the world's transition to sustainable aviation.

We will do this by producing the world's first practical zero emissions powertrain for aviation, aiming to first decarbonise regional aviation and then scale-up this technology to decarbonise larger and longer distance aircraft too.

To accomplish this rapidly and at scale, we have determined that the best route forward is by using **hydrogen-electric technology**.

Aviation is flying into a crisis, with the sector projected to represent an ever-growing and very significant percentage of the world's climate impact by 2050. The vital importance of decarbonising aviation is well understood by government, industry and consumers worldwide.

There are two main routes to decarbonising aviation: synthetic aviation fuels, such as biomass derived fuels, and electric aviation. Synthetic fuels, while potentially carbon neutral, also create other greenhouse emissions when used in propulsion. Moreover, costs are likely to be prohibitive for commercial uptake. The costs of bio-based fuels is estimated 3-10x of fossil jet fuel according to industry sources. The advantage of synthetic fuel, however, is that it can be used in the traditional aircraft engine over any distance flights, making it an important part of the immediate decarbonisation agenda.

Electric aviation is the only route to achieving truly zero emissions aviation. This uses electrical motors and high power electronics for propulsion. The power delivered to electrical motors can come either from batteries or from hydrogen fuel cells.

Given that aviation is extremely weight-sensitive, the energy density of current and anticipated pipeline of battery technologies mean that battery-electric propulsion will certainly not be able to deliver long range flight. As a result, battery-electric powertrains are unlikely to be viable for delivering commercial zero emissions aviation, while hybrid-electric solutions would still create significant carbon emissions.

Hydrogen fuel-cells have a much higher energy density, and advances in safety and technology mean that hydrogen-electric aviation is the most practical, viable route to successfully decarbonising aviation. At the same time, the transition to electric engines is projected to significantly improve the longevity of aircraft powertrains, improving costs for operators without significant loss in operations.

In September 2020, ZeroAvia achieved a world's first – the first hydrogen-electric powered flight of a commercial grade aircraft. ZeroAvia's 6-seat Piper Malibu took off, flew and landed at Cranfield Airport. This was made possible by the support of the Aerospace Technology Institute (ATI), the Department for Business, Energy, Innovation and Skills (BEIS) and InnovateUK, who supported ZeroAvia with grant funding in September 2019.

Of course, this is only the first step to decarbonising aviation. In December 2020, we announced HyFlyer II, which will mature our technology in a certifiable 19-seat configuration, culminating in another world's first flight in 2021. Crucially, this will be certified and market-ready by 2023, meaning airlines can begin offering zero emissions flights to their passengers. It demonstrates that hydrogen is ready to begin truly making net zero a possibility for aviation, starting with regional aviation. We are members of the Jet Zero Council, a Government-led initiative to put the UK at the forefront of clean aviation technologies, and I was proud to join the Prime Minister for its inaugural meeting in July. We are confident that hydrogen can be instrumental in making the Jet Zero mission of long distance emissions free passenger flights possible.

It is crucial that the fundamental generation and fuelling infrastructure is ready to make this possible, and we welcome recent announcements by the Government that back the increased production of hydrogen. Because of their predictable demand, early uptake of hydrogen at airports can provide the hubs needed to drive wider adoption.

We encourage this Committee and the Government to deliver a truly ambitious Hydrogen Strategy for the UK in 2021, and look closely at the role that aviation and airports can play in driving its adoption.

Investment and direction at this stage in hydrogen – both the fundamental generation infrastructure and end use cases – can mean the UK has the potential to deliver on its net zero objectives, to create new green jobs, and help the world transition to green aviation.

1. The suitability of the Government's announced plans for "Driving the Growth of Low Carbon Hydrogen", including:

- **the focus, scale and timescales of the proposed measures;**
- **how the proposed measures—and any other recommended measures—could best be co-ordinated;**
- **the dependency of the Government's proposed plans on carbon capture and storage, any risks associated with this and how any risks should be mitigated; and**
- **potential business models that could attract private investment and stimulate widespread adoption of hydrogen as a Net Zero fuel;**

As this response will outline, the hydrogen-electric solutions ZeroAvia is developing for aviation will soon be ready to begin enabling operators to provide zero emissions flights to passengers, from 2023.

Investing in the fundamental generation, storage and fuelling infrastructure at airports to enable those operations to successfully and rapidly grow will be vital to ensuring it can be widely adopted.

Additionally, it can support business models that support wider private investment and stimulate investment. One of the key constraints identified in the adoption of hydrogen technologies is the need for investors to identify clear demand in order to invest in infrastructure, while potential end-users and consumers of hydrogen require hydrogen fuelling infrastructure to drive their purchasing decisions.

Aviation is a sector with predictable, stable demands for fuel and fuelling infrastructure. The early uptake of hydrogen by the aviation sector at airports can therefore provide the confidence that investors need in order to make infrastructure investment decisions, while providing multimodal ‘hubs’ for businesses and consumers where hydrogen is readily available.

For example, hydrogen fuelling infrastructure at an airport can also be used by public transport and HGVs, both of which would typically significantly interact with an airport environment already.

The Government’s recently announced 10 Point Plan and Energy White Paper make welcome commitments to the increased generation of hydrogen, and ZeroAvia looks forward to the Hydrogen Strategy in 2021.

However, in the process of investing in hydrogen and developing its Hydrogen Strategy, Government should consider where to locate investment and new infrastructure in order to achieve the maximum possible uptake and environmental benefit, as well as to establish investor and consumer confidence.

Aviation and airports are well suited to achieving this.

2. The progress of recent and ongoing trials of hydrogen in the UK and abroad, and the next steps to most effectively build on this progress;

In Autumn 2019, BEIS, the Aerospace Technology Institute and InnovateUK provided £2.7m grant funding support for ZeroAvia’s HyFlyer Project to demonstrate the integration of hydrogen-electric technology aboard a six-seat Piper M-class aircraft.

In September 2020, ZeroAvia then conducted the world’s first hydrogen-electric flight of a commercial-grade aircraft at Cranfield in Bedfordshire. It marked a significant milestone for ZeroAvia’s progress towards the first practical powertrain for zero emissions flight, and a major step forward for the UK, taking a leading position in sustainable aviation innovation through hydrogen.

Since this flight, ZeroAvia has conducted numerous flight tests to further develop its solution. In early 2021 ZeroAvia will achieve a further significant milestone, with a long-distance UK domestic flight of approximately 300nm. This is equivalent to a London-Edinburgh journey.

In December 2020, ZeroAvia was again awarded grant funding by the ATI Programme for HyFlyer II.

This project will see ZeroAvia scale-up its hydrogen-electric powertrain to power aircraft of up to 19-seats, with another world’s first flight at this scale set for 2021. Crucially, HyFlyer II will conclude with a certifiable, market-ready powertrain for 19-seat aircraft by 2023. It will mean that regional operators can begin offering emissions free flights to passengers.

It forms a part of ZeroAvia’s UK-based sequential R&D pathway for hydrogen-electric aviation, with the company progressively producing larger powertrains for aircraft capable of carrying more passengers over greater distances. By 2027, ZeroAvia aims to power aircraft in service of up to 80 seats, and by 2030, 100+ seat aircraft.

As ZeroAvia's 19-seat solution achieves market readiness in 2023, it will be crucial to make sure operators can take up the opportunity by ensuring that the regulatory environment keeps pace with the readiness of sustainable aviation technology, and airports invest in the hydrogen fuelling infrastructure required.

Doing this in tandem will ensure that the UK has the potential to lead the world when it comes to sustainable aviation through hydrogen. Through the successful ATI Programme, it is delivering the R&D funding to make this possible.

The Government should now ensure that the whole of the UK benefits – both in terms of sustainability and economic growth – by leading the world in preparing its operating environment as well.

3. The engineering and commercial challenges associated with using hydrogen as a fuel, including production, storage, distribution and metrology, and how the Government could best address these;

ZeroAvia anticipates that the fundamental science is ready to deliver large-scale hydrogen-electric, zero emissions flights, with no new key scientific breakthroughs required.

The challenge is in the application of engineering resources to deliver market-ready solutions.

At present, ZeroAvia utilises compressed hydrogen gas that can be readily stored via existing canister solutions in order to use hydrogen as a fuel in fuel-cell systems. This solution provides ZeroAvia with the energy density required to achieve the aims of the HyFlyer II project and bring 19-seat regional zero emissions flights to market readiness by 2023.

Beyond this point, storage of hydrogen in liquid form may be required, which will require further engineering, and collaboration with airframe manufacturers to develop appropriate solutions. However, the aerospace sector is increasingly supportive of this type of solution. Throughout 2020, Airbus has identified its pathway to integrate liquid hydrogen storage into the design of its next generation of aircraft.

Ensuring that the UK continues to invest in the appropriate research and development through initiatives like the ATI Programme can ensure that those engineering challenges will be solved too.

Initiatives are underway to ensure airports have access to the engineered solutions required to store and provide hydrogen as a fuel for aviation. ZeroAvia's groundbreaking hydrogen-electric flights through Project HyFlyer, have been powered by an innovative mobile solution on-site at Cranfield Airport, consisting of a re-deployable modular electrolyser, trailer mounted air compressor and a first of its kind ADR-certified 350 bar refuelling truck.

Major industrials involved in current aviation fuels, such as Shell, are supportive of increased hydrogen infrastructure at airports. Airbus has also engaged with a wide range of partners to identify the infrastructure requirements to power its planned hydrogen aircraft.

Commercially, hydrogen-electric aviation is a highly cost-effective solution. In the Green and Sustainable Connectivity report produced by the European Regions Airlines Association[1], it identifies that hydrogen-electric can result in the win-win of zero emissions flight while lowering operating costs for airlines. For example, its case study of the 10,000 passenger per annum Glasgow to Barra route – on which Loganair currently uses 19-seat aircraft for its service – found that hydrogen-electric operations would reduce the 'CASK' (cost of available seat kilometres – a unit of operating efficiency for airlines) by 16% compared to the current available fuels. It compares with only a 6% reduction for battery-electric technologies, and 37% for sustainable aviation fuels.

4. The infrastructure that hydrogen as a Net Zero fuel will require in the short- and longer-term, and any associated risks and opportunities;

In order to unlock the benefits of hydrogen for aviation, it is crucial that:

- Hydrogen storage and fuelling infrastructure is installed at airports, ensuring that operators can easily establish hydrogen-electric aircraft services as they become available.

- Investment in hydrogen production infrastructure also continues. Due to the continual and predictable demand for hydrogen that aviation will provide, proximity to airport sites may be a consideration.

Steps should be taken to ensure that airports and regions have access to appropriate finance – such as, for example, the new National Infrastructure Bank – to invest in the new infrastructure they need while minimising their commercial risk.

5. Cost-benefit analysis of using hydrogen to meet Net Zero as well as the potential environmental impact of technologies required for its widespread use; and

6. The relative advantages and disadvantages of hydrogen compared to other low-carbon options (such as electrification or heat networks), the applications for which hydrogen should be prioritised and why, and how any uncertainty in the optimal technology should be managed.

Aviation is flying into a sustainability crisis.

While it represents between 5% and 10% of the total human climate impact today, this is projected to grow to between 25% and 50% by 2050 as other sectors decarbonise more rapidly while aviation demand grows. In the Climate Change Committee's recent 6^{th} Carbon Budget, it identifies that aviation emissions will be some of the most challenging for the UK to decarbonise, and due to the significance of their impact, recommends adding the UK's contribution to international aviation emissions to its net-zero objectives.

Hydrogen-electric propulsion is the most practical scalable solution to decarbonise aviation.

Both current and projected battery technologies do not achieve the energy density required, at around 40x lower energy density compared to existing jet fuels. Additionally, the short lifecycles of batteries and costs of recycling mean that they would represent significant operational costs for operators. Hybrid solutions have limited benefit on all but the shortest routes.

Biofuels and synthetic fuels are both meaningful as intermediary solutions but have inherent long-term constraints as a route to decarbonising aviation. It will be extremely challenging to scale biofuel production to meet the aviation sector's fuel requirements, while their production is incompatible with the recently published UK Government Path to Sustainable Farming strategy. Synthetic fuels will require extensive investment, while representing significantly increasing costs of utilisation. While reducing carbon emissions and improving sustainability, both biofuels and synthetic fuels would still generate NOx and particulates, which contribute to aviation's climate impact.

While hydrogen can also be used in a gas hybrid turbine, it is less efficient than hydrogen-electric as a solution. Moreover it will be prone to generation of NOx and other greenhouse gases during combustion.

At the same time, hydrogen-electric solutions can achieve:

- Lower, stable fuel costs – green hydrogen production already achieves costs that outperform jet fuels, with a pathway through increased production volumes to achieve even lower costs.

- Lower maintenance costs, with electric propulsion systems achieving 10x lower maintenance costs, and fuel-cells achieving over 3,000 more operating hours before needing major maintenance than even the best turbines in service.

- Lower noise levels – By eliminating the noise of jet exhausts, only the propulsor noise remains, with scope for further improvement as electric aviation technology progresses.

ZeroAvia anticipates that hydrogen-electric powertrains for aviation will be not only more sustainable, but a fundamentally better product and more scalable solution.

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[1] https://www.eraa.org/sites/default/files/era_green_and_sustainable_connectivity_v1.pdf

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