WRITTEN TESTIMONY OF
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BEFORE THE
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HEARING ON "ADVANCING NEXT GENERATION AVIATION TECHNOLOGIES"

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Chair Cantwell, Ranking Member Cruz, and Members of the Committee, thank you for the opportunity to speak with you today. My name is Val Miftakhov, and I am the Founder and CEO of ZeroAvia, the U.S.-headquartered leader in designing and building zero-emission, hydrogen-electric aircraft propulsion systems for aircraft. It is my privilege to speak to you about advancing next generation aviation technologies, the work we are doing at ZeroAvia, and the steps we can take to facilitate the transition to hydrogen fuel-cell aviation and ensure continued U.S. leadership in aerospace innovation.

ZeroAvia is developing hydrogen-electric engines - essentially fuel cell systems which use hydrogen to create electricity and power electric motors, with the only emission being water vapor. We anticipate this to be the most environmentally friendly and most economically attractive solution for operators long-term. As I intend to make clear, with many leading nations focused on tackling climate change, advanced and sustainable propulsion systems will be the technology that the world will come to depend on for powering aviation and, therefore, an important strategic opportunity.

The United States has led the world in aerospace innovation since the Wright Brothers began their journey toward powered flight nearly 120 years ago. Those of us working to advance next generation aviation technologies in the U.S. today are doing our best to extend that history of leadership. As the aviation industry has changed during the last 120 years, and innovators no longer bring new technologies to market in a vacuum, it is imperative that the regulatory environment keeps passengers and crew safe and remains an essential driver of progress.

Zero-emission aviation is happening

Aviation is responsible for around 2.4% of global carbon emissions, but its footprint goes much deeper than just carbon.[1] Climate modeling techniques suggest that total aviation emissions could be warming the climate at about three times the rate of CO2 aviation emissions

[1] Graver, B., Zhang, K., Rutherford, D., 2019. CO2 Emissions from Commercial Aviation: 2018. *ICCT Working Paper 2019-16*. International Council on Clean Transportation. https://theicct.org/wp-content/uploads/2021/06/ICCT_CO2-commercl-aviation-2018_20190918.pdf

alone.[2] In addition, the FAA predicts enplanements to increase by 189 percent between 2021 and 2041.[3] As more and more people travel by air and other industries abate their emissions, aviation's share of emissions will only increase.

Drop-in Sustainable Aviation Fuels (SAF) are an important starting point, and have rightly been supported by Congress, the FAA, and NASA for more than a decade, but they do not eliminate carbon emissions in flight, nor do they significantly reduce other noxious and climate warming emissions. Combustion, even of SAFs, creates and releases airborne nitrogen oxides (NOx), sulfur oxides (SOx), and other particulates like soot. These non-CO2 emissions, as well as contrails, are known to have a 'multiplier effect' on climate change.[4] For communities living in and around busy airports, the air quality impact is also significant. Around 10 percent of aircraft emissions come during taxi, takeoff, initial climb, and during the approach and landing.[5]

With the demand growth in aviation predicted by the FAA, total carbon emissions will not reduce significantly overall if drop-in fuels are the only solution, and non-CO2 emissions may increase significantly. Fostering zero-emission technology for short-haul initially will have the added value of preserving SAF volumes for longer haul flights.

Combustion technologies, such as new hydrogen-burning engines which are in development, offer some further impact. However, while hydrogen combustion eliminates carbon emissions, it does not eliminate many of the non-CO2 emissions, the wider effects of which I have mentioned. Battery-electric propulsion, which is currently leading the energy transition in the vehicle sector, can eliminate emissions, but batteries are too heavy for commercial-scale aircraft, and battery-life constraints mean frequent replacement, with prohibitive costs, as well as further environmental damage.

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[2] Arrowsmith, S.,Lee, D., Owen, B., Faber, J., 2020. Updated Analysis of Non-CO2 Climate Impacts of Aviation and Potential Policy Measures. *Report from the European Commission to the European Parliament and the Council*. European Union Aviation Safety Agency. https://eur-lex.europa.eu/resource.html?uri=cellar:7bc666c9-2d9c-11eb-b27b-01aa75ed71a1.0001.02/DOC_1&format=PDF

[3] FAA Aerospace Forecast Fiscal Years 2021–2041

[4] Lee, D., Fahey, D., Forster, P., Newton, P., Wit, R., Lim, L., Owen, B. and Sausen, R., 2009. Aviation and global climate change in the 21st century. *Atmospheric Environment*, 43(22-23), pp.3520-3537.

[5] Overton, J., 2019. The Growth in Greenhouse Gas Emissions from Commercial Aviation. *Fact Sheet*. Environmental and Energy Study Institute. https://www.eesi.org/papers/view/fact-sheet-the-growth-in-greenhouse-gas-emissions-from-commercial-aviation

For a holistic solution, the answer must be electric propulsion powered cleanly and effectively through hydrogen fuel cells. This technology eliminates CO2, NO2, SOx, and soot; its only emission is the water vapor by-product of the fuel-cell. And, it is scalable, as ZeroAvia has been demonstrating.

A study published in June 2020 by Clean Sky, the largest European research program, estimated that direct-burn hydrogen systems can reduce the global warming effect of flying by between 50 and 75 percent; SAFs can reduce it by between 30 and 60 percent; and the fuel cell has the potential to reduce *full* climate impact by 75 to 90 percent.[6]

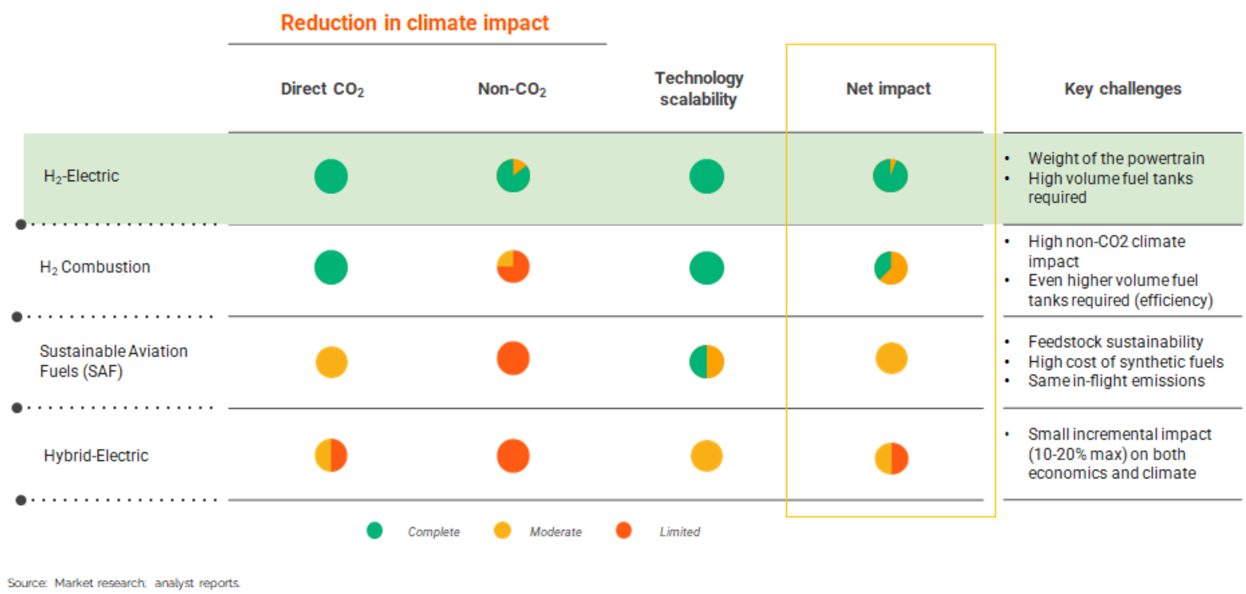

Figure 1: H2-Electric is the only scalable, zero-emission solution.

The technology for true zero-emission aviation exists today and promises an economically attractive model. We will see commercial hydrogen fuel-cell air service before this decade is halfway through.

[6] Hydrogen-powered aviation: A Fact-Based Study Clean Sky May 2020 - https://www.fch.europa.eu/sites/default/files/FCH%20Docs/20200507_Hydrogen%20Powered%20Aviation%20report_FINAL%20web%20%28ID%208706035%29.pdf

In September 2020, ZeroAvia flew a 6-seat aircraft equipped with a 250-kilowatt powertrain, the largest hydrogen-electric aircraft ever flown at that time. In January of this year, we flew a 19-seat aircraft with our ZA600 engine. At nearly 600 kilowatts, we have more than doubled our previous power output in less than three years. Earlier this month, ZeroAvia achieved record-breaking power generation from our proprietary HTPEM fuel cells. This is the key that unlocks hydrogen fuel cell powertrains for use in the narrow–body jets – like Boeing 737s and Airbus 320s – that account for more than 50 percent of aviation's total emissions. By 2025, we anticipate commercial service with aircraft powered by ZA600 powertrains, delivering zero-emission cargo and passenger flights.

At the same time, we have already begun ground-testing our next step forward, the 2-to-5 megawatt ZA2000 for larger aircraft. By 2027, you can expect to see 40-80 passenger commercial aircraft flying with these powertrains. The same ZA2000 powertrain will be quickly adapted to power regional jets.

ZeroAvia is not alone in this space. We have competitors, some of whom are sharing this very hearing, who are also demonstrating the near-term viability of hydrogen fuel cell aviation. We have significant investors whose capital is a testament to the technology's promise. And, we have an order book with airlines like United, American, Alaska, and others who recognize not just the sustainability benefits we offer, but also the tremendous cost savings of our technology. To get a sense of how seriously airlines are taking this, note that American Airlines has invested in both ZeroAvia *and* Universal Hydrogen. That is beyond a box-checking corporate gesture; it is a vote of confidence in the hydrogen fuel-cell technology pathway.

The driver of these advancements is not limited to environmental factors – it is matched with a strong, attractive business case, with emission-abating technology saving carriers on operating expenses. As a lower intensity system, major overhaul and repair frequency will be significantly lower than for traditional combustion engines. And, previous Federal investments in the hydrogen economy, like those Congress included in the Infrastructure Investment and Jobs Act of 2021 and the Inflation Reduction Act of 2022, will reduce the cost of clean hydrogen to a price that makes it quickly at parity with gray hydrogen and kerosene-based jet fuel, and ultimately a lower cost fuel. According to a report from McKinsey and Clean Aviation, hydrogen, even in liquid form, is predicted to be five times more cost-effective than Synthetic Fuel by 2050.[7]

A kilogram of clean hydrogen today can have a cost as low as $3, the power density of which translates to a $1.50 per gallon price on jet fuel. The U.S. Bureau of Transportation Statistics reports that, in January 2023, one gallon of jet fuel cost an average of $3.28[8]. For hydrogen, we calculate rapidly falling prices in the future as the ecosystem scales up, with $2.2/kg in the near term and, as major governments continue to invest in hydrogen, $1/kg by the end of this decade. It's this business case that is also driving major investments in hydrogen by the world's leading fuel producers.

At an estimated $9.23 per gallon in January, sustainable aviation fuel (SAF) prices are nearly triple that of Jet-A and, notably, moving higher not lower. For smaller operators in sub-regional and regional sectors, today's fuel economics are even worse because these carriers lack the purchasing power to command an economical price even if they are able to get access to SAF after the major airlines have claimed what little is available.

Perhaps one of the most promising near-term benefits of hydrogen fuel-cell aviation is changing the economic models for routes to small and rural communities that were once less than cost-effective for airlines, a subject this Committee examined just last week. Small airports that have lost service or suffered reduced service could see service improvements because of the efficiencies brought by hydrogen-electric aircraft, reconnecting underserved communities to hub airports and saving residents from increasingly long drives to access air travel.

Roadblocks toward zero-emission aviation

The transition that we envision to zero-emission aviation driven by U.S. innovation is not without its challenges. The new technologies we are introducing require FAA certification, an uphill climb for an already resource-challenged program office. The use of hydrogen will require the FAA to provide guidance and standards to U.S. airports. And, both of those pain points beg the question of whether these new technologies can be developed quickly enough given the

[7] https://www.euractiv.com/section/aviation/news/fossil-jet-fuel-price-expected-to-soar-as-eu-taxes-bite/
[8] https://www.bts.gov/newsroom/us-airlines-january-2023-fuel-cost-gallon-43-december-2022-aviation-fuel-consumption-down

imbalance of R&D funding flows to alternative combustion fuel development. Only by resolving these three issues can we enter the market, realize the potential economic and environmental benefits of advanced aviation technology, and defend U.S. aerospace leadership against inroads being financed by other nations.

Entry-into-service requires FAA certification

One critical part of bringing sustainable products and technologies into service is the FAA's certification process. Certification is also integral to fulfilling the environmental commitments the aviation industry and the FAA have already made. For the aviation manufacturing industry to introduce innovative technologies and more sustainable and economical products into the global market, an effective, reliable FAA certification process – with new and updated regulations, policy, and guidance– is vital.

We all recognize that the FAA is already operating with a large backlog under the current authorization. The combination of several factors, including the rapid arrival of the electric vertical takeoff and landing (eVTOL) segment, the Boeing 737 Max and 777X certifications, the pandemic, and a loss of personnel, has set back the FAA's Aircraft Certification Office (AIR) considerably. But, the prospect of innovators having to get in line behind an already daunting backlog and proceed through an uncertain certification path is gravely concerning. It could well defer the climate improvements we are working so hard to implement and the U.S. aerospace leadership we are trying to extend. These are the aviation technologies the world will come to depend on, and efficient and safe certification is one strong plank in building a thriving sector in the U.S.

We believe the FAA is doing what it can, but the AIR program is severely resource-constrained. If the next FAA Authorization Bill directs the certification program to increase and upskill staff, we believe we can work closely with the agency to craft a clear, rigorous path to certification. Without such a standardized way forward, ZeroAvia and others developing hydrogen fuel-cell aviation will face an unpredictable path to market full of FAA Special Conditions that will deter investment and dampen adoption.

Airports need support to build infrastructure for sustainable aviation

The transition to hydrogen-electric aircraft presents U.S. airports with the challenge of preparing their infrastructure for a more sustainable future. However, the concentration of commercial service airports in the U.S. makes the overall infrastructure challenge less daunting.

In some ways, airports present a valuable opportunity for the hydrogen economy. Because of the hydrogen volume required by hydrogen-electric aircraft propulsion, airports will likely serve as centralized hydrogen demand hubs. ZeroAvia calculates, for example, that George Bush Intercontinental Airport in Houston (IAH) would require 30 metric tonnes of hydrogen per week to operate just 25 percent of its sub-250 nautical mile flights. Given the volumes required as the system converts to hydrogen propulsion at scale, the case for on-site production becomes compelling. And, economies of scale can deliver low hydrogen production costs, creating a big opportunity to convert ground operation vehicles, onward transportation, and proximate industry to hydrogen fuel where it can deliver emissions reductions. This further reduces the climate change impact of the aviation sector at large and improves air quality for the airport and its neighboring residents.

ZeroAvia is already demonstrating this potential on a small scale. We operate multiple hydrogen fuel-cell road vehicles as part of our operations at Cotswold Airport in the U.K. and at Hollister Municipal Airport in California, demonstrating the value of hydrogen fuel cells for ground transport and ground operations. Airports that leverage this opportunity by producing low-carbon hydrogen on-site will create a new and valuable airport revenue stream and set the stage for true zero-emission aviation in the United States.

This transition to a clean-hydrogen economy will require support. Airport funding programs in their current incarnation do not help airports make these investments. While the Department of Energy Hydrogen Hub program is anticipated to develop hydrogen at a handful of airports, that program alone will not be enough to facilitate widespread adoption of this game-changing technology. Modifying existing FAA airport funding and financing programs can make a significant difference, encouraging adoption and helping restore U.S. leadership.

Amending aspects of the Passenger Facility Charge (PFC), Airport Improvement Program (AIP), and Voluntary Airport Low-Emission (VALE) tools to include hydrogen production and refueling projects that support airport vehicles *and* aircraft will be a great step forward. For example, in the current VALE Technical Report (version 7), published 12 years ago, both fuel-cell technology and transport of hydrogen are labeled as being, “in the R&D stage and not yet commercially viable.” Given the advances we and others are making technically and commercially, this urgently requires revision. Bringing program guidelines up-to-date will result in tools that better serve today’s airports and their new infrastructure needs.

Credit programs like the U.S. Department of Transportation’s TIFIA program can also help. The Infrastructure Investment and Jobs Act of 2021 (IIJA) defined airport landside projects as TIFIA-eligible, but the language does not encourage an airport project that supports ground support equipment (GSE) and other airside activity. Whether this takes the form of expanded TIFIA eligibility or a new aviation-specific credit program, the same investment-friendly terms will help incentivize the transition to sustainable aviation. When airports produce hydrogen that can be both used in their ground operations vehicles and sold to air carriers, they will have access to new revenue streams that can be used to service loans in the same way that highway tolling provides a loan service stream for a traditional TIFIA loan.

Infrastructure credits offer another approach to incentivize airports toward on-site hydrogen production. Within a Federal clean fuel program, for example, airports investing in clean-hydrogen would earn credits that can be sold to fuel providers whose products garner deficits by exceeding a statutory carbon-intensity (CI) standard. This is one aspect of California’s successful Low Carbon Fuel Standard (LCFS) program, recently adopted as well by the State of Washington. In the LCFS, an entity that provides electric-vehicle charging stations earns credits that can be sold to a transportation fuel supplier whose fuel mix does not meet State CI standards.

These are just a few avenues toward timely development of airport hydrogen production to support more sustainable ground operations as well as advanced aviation.

FAA research and development programs encourage some innovators to seek funding abroad

The ZA600 powertrain I spoke of earlier was largely developed using U.K. facilities and personnel thanks to the generous support of the U.K. Government through the ATI Programme; the Department for Business, Energy, and Industrial Strategy; Innovate U.K.; and Aerospace Technology Institute.

Securing U.S. R&D funding for hydrogen-electric propulsion R&D has been frustrating to say the least. The likeliest home to low-TRL technology research in sustainability should have been the FAA's Aviation Sustainability Center (ASCENT). However, on the Office of Environment and Energy's web page, where the ASCENT program is introduced, it is described as "the FAA's Center of Excellence (COE) for Alternative Jet Fuels and Environment." The ASCENT program has largely been a Sustainable Aviation Fuel program with nibbles at the margins of operational and engine efficiency but no step-changes in propulsion technology. The Inflation Reduction Act designated $250 million of its $300 million allocation to the FAA for SAF research. Congress also designated $46 million for low emission aviation technology, but the FAA Office of Environment and Energy has indicated instead an intent to channel a good portion of that $46 million for SAF work. While we do not discount the usefulness of sustainable aviation fuels as a bridge technology capable of delivering some carbon abatement, billions of taxpayer dollars and more than a decade have been spent, and SAF production has yet to make a dent. And, as we have seen, the price differential of these elusive fuels is expensive enough to result in increased ticket prices if SAFs increase their market share. While ASCENT has recently acknowledged a need for more hydrogen research, this is not nearly enough to qualify as tech-neutral and not nearly enough to match the level of funding for alternative propulsion technologies we've seen in the U.K.

At the same time, other nations have been working to stay apace with the U.K. The EU's Clean Aviation program supports alternative, sustainable technologies by funding advanced aviation innovation, including a significant investment in hydrogen. China is also racing to develop hydrogen fuel-cell aviation. While ZeroAvia very much wants to rebalance its resources back toward the U.S., the U.S. and the FAA are simply not as engaged as others in this area.

To this end, ZeroAvia encourages the Committee to include language in the upcoming FAA Reauthorization that directs the agency to pursue investigation into the safety and usefulness of alternative propulsion technologies and of hydrogen as a non-combustion source of aviation energy.

Adding sustainable aviation to the existing DOT/DOE Joint Office for electric vehicles

One solution that can help address both the certification challenges and the FAA's intransigence on alternative propulsion in one stroke would be an expansion of the DOT/DOE Joint Office of Energy and Transportation mission to include sustainable aviation, rather than limiting its mandate to only electric vehicles. This exchange of ideas and perspectives would allow the Department of Energy's experience with hydrogen to pollinate the FAA's AIR and AEE programs.

Commercial aviation emissions can be abated

Under the right conditions, a path to safe, sustainable commercial flight by 2025 and large-scale removal of emissions from regional aviation by 2030 is absolutely achievable. The costs of failure in this pursuit far outweigh the costs of implementation. First and foremost, failure means that, as other sectors successfully reduce their footprints, aviation will contribute a larger and larger proportion of climate-impacting emissions. Sustainable aviation technology already developed will languish on the shelf, benefiting no one. Air carriers will not be able to lower their emissions beyond the incremental improvements made possible by Sustainable Aviation Fuels and engine efficiencies, and U.S. skies will suffer. In that scenario, either people stop flying – as the growing pattern of European travel demonstrates – or the climate crisis worsens.[9]

Additionally, while some airports find the resources to make the necessary investments in hydrogen and begin to benefit from the new revenue streams it creates, other airports will

[9] Garay, E., 2022. How Short-Haul Flight Bans Are Transforming European Travel. Conde Nast Traveler. https://www.cntraveler.com/story/how-short-haul-flight-bans-are-transforming-european-travel

be unable to compete and will lose service. The immediate cost of airport closures is that travelers will have to drive longer distances to access air routes. Over time, however, the lack of air carrier access will impinge on communities' economic competitiveness.

Congress and the FAA have positioned the U.S. aviation system to lead the world. Those of us pursuing sustainable aviation welcome the opportunity to work with you to continue that leadership. Thank you for the opportunity to speak with you today, and I look forward to answering your questions.