WRITTEN TESTIMONY OF
DR. VAL MIFTAKHOV
FOUNDER AND CEO
ZEROAVIA

BEFORE THE
HOUSE TRANSPORTATION AND INFRASTRUCTURE COMMITTEE
SUBCOMMITTEE ON AVIATION

HEARING ON AIRPORTS AND SUSTAINABILITY

March 17, 2022

Chairman Larsen, Ranking Member Graves, and Members of the Subcommittee, 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 US-headquartered leader in designing and building zero-emission, hydrogen-electric powertrain systems and deploying them to commercial aircraft. It is my privilege to speak to you about airports and sustainability, the work we are doing at ZeroAvia, and the steps we can take to facilitate the transition to a green hydrogen economy.

Zero-emission aviation is happening.

In 2017, after years of building –and eventually selling– the largest smart charging network for electric vehicles, I launched ZeroAvia with one purpose: to tackle the mode of commercial transportation where it has proven most difficult to deliver emissions abatement: aviation.

Aviation is responsible for just under three percent of global carbon emissions, but its footprint goes much deeper than just carbon.[1] A number of recent climate modeling techniques and associated published papers suggest that total aviation emissions are warming the climate at about three times the rate of CO2 aviation emissions alone.[2] Combustion creates and releases airborne nitrogen oxides (NOx), particulate emissions (soot), and high-temperature water vapor at high altitudes where they all contribute significantly to overall climate impact

[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

[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

from aviation. These non-CO2 emissions, as well as contrails, are known to have a 'multiplier effect' on climate change.[3] Science also tells us that around 10 percent of aircraft emissions come during taxi, takeoff, initial climb, and during the approach and landing, amplifying the impact on local populations.[4] Some studies have shown adverse respiratory health outcomes for residents within 10 km of the major airports, for example.

When we started ZeroAvia, we took an open approach to finding the most scalable solution that would mitigate the greatest share of aviation's climate impact, and, given my prior company was focused on electric vehicle charging, we certainly looked at battery-electric approaches. Battery-electric propulsion, which is currently leading the vehicle industry, can eliminate most of the emissions, but unfortunately batteries are just too heavy for commercial-scale larger aircraft, and battery-life constraints mean frequent –and costly– replacement, which would also significantly disrupt any high-utilization commercial applications of such aircraft.

Alternative combustion fuels like Sustainable Aviation Fuels are a good starting point, and a good first step in *reducing* carbon emissions. With predicted demand growth in aviation, however, we need to develop technologies to *eliminate* carbon emissions and tackle other remaining types of emissions. ZeroAvia is focused on that goal. We look at it in stages of evolution, with SAF, as noted above, helping to reduce carbon output as we transition to hydrogen. Even hydrogen combustion, while of course zero-carbon, still carries negative effects

---

[3] 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.
[4] 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

of NOX and high-temperature water vapor emissions. Finally, all combustion technologies suffer from lower efficiency compared to the electrified powertrains, including hydrogen fuel-cell based.

So, for a holistic solution, the answer must be electrification, and this can be achieved through electric propulsion using hydrogen fuel-cells. This technology eliminates CO2, NO2, SOx, and soot. Its only emission is the water vapor by-product of the fuel-cell, but even that occurs at low temperature (below 200C vs. 1,000C+ for the combustion engines), which allows clever management of this output to avoid all negative climate effects. Additionally, the hydrogen-electric approach is truly scalable, as ZeroAvia has been demonstrating.

A number of third-party research efforts now support these findings. For example, in a study published in June 2020, 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, and SAFs can reduce it by between 30 and 60 percent. The study's authors believe that the fuel cell has the potential to reduce *full* climate impact by 75 to 90 percent.[5] Further, the most recent output of the landmark FlyZero project by the UK's Aerospace Technology Institute points to hydrogen as a primary vector to fight the climate impact of aviation, with hydrogen-electric approaches achieving the highest - at least 90% - levels of abatement. In a table below, I summarize these various factors for all six major approaches to aviation climate impact.

---

[5] 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

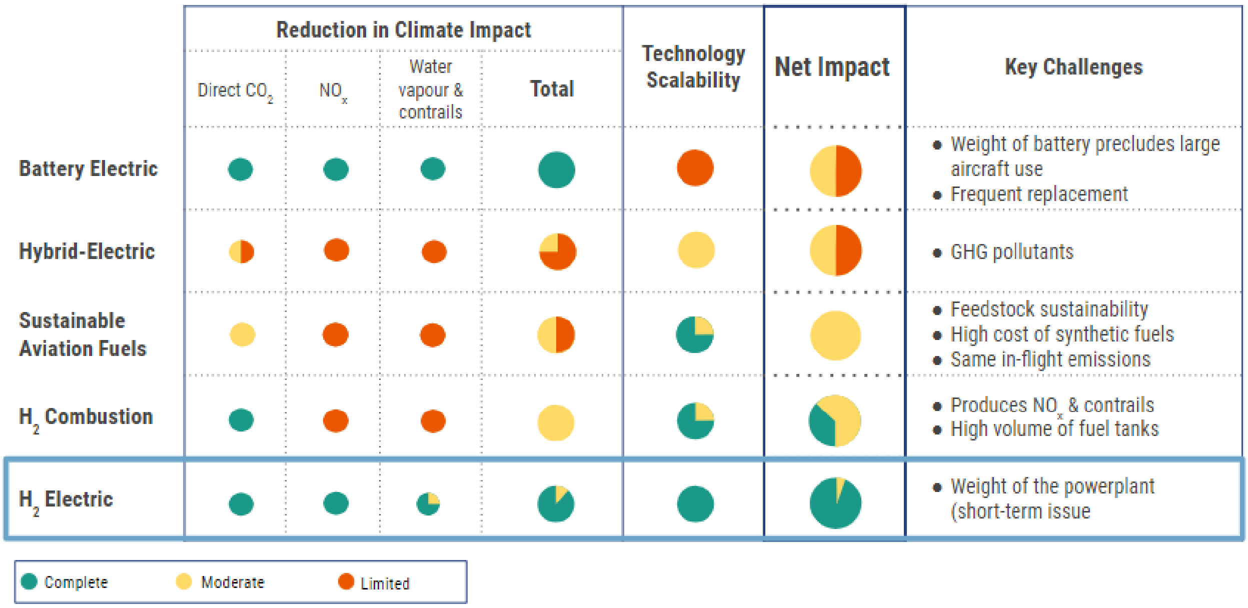

Figure 1: H2-Electric is the only scalable, zero-emission solution.

To be clear, we are not talking about technology for 2050 or even 2035. In September 2020, ZeroAvia flew a 6-seat aircraft equipped with our ZA600, 600-kilowatt powertrain, the largest H2-electric aircraft ever flown. In the coming weeks, we will fly a 19-seat, twin-engine aircraft powered by one of our hydrogen-electric ZA600s. By 2024, we expect to see commercial service with aircraft powered by ZA600 powertrains, delivering true zero climate impact flights. And, by 2026, we anticipate 40-80 passenger commercial aircraft flying with our next-size ZA2000 2-to-5 megawatt powertrains, also currently in development and with partnerships in place with the likes of Alaska Airlines and United Airlines as early adopters.

Figure 2: ZeroAvia's flight path - all segments, starting with 500-mile range, 10-20 seat capacity

Importantly, aviation is a great use case for hydrogen fuel-cell adoption, not just because it is a practical solution to aviation's climate change impacts, but also because the economics are attractive. With significantly lower material stresses compared to modern combustion turbines, major overhaul and repair costs will be significantly lower than they are for combustion engines. It is a common misconception that hydrogen fuel costs will be a barrier to aviation uptake when it is, in fact, likely to be a key selling point. Green hydrogen - which is made using only renewable energy and water - can have a cost today as low as $3 per kg, which is equivalent to $1.50 per gallon of jet fuel and which is, of course, already substantially below the current wholesale cost of jet fuel. For smaller operators in sub-regional and regional sectors, hydrogen-electric operation can already deliver dramatic cost savings. We calculate rapidly falling green hydrogen prices with $2.2/kg in the near term, and major governments, including the recently announced U.S. DOE effort, target $1/kg by the end of the decade. So, the environmental and economic cases are strong, but what does that mean for likely adoption?

Consider the example of the motor vehicle industry. After decades of efforts to make engines for passenger cars and heavy trucks more efficient, those incremental steps were quickly overtaken by a fundamental shift to electric-drive vehicles. In 2010, I saw that change coming and started a company to build the charging infrastructure those vehicles would need. Today, a relatively new US-based car manufacturer - Tesla - virtually controls this new vehicle market, and is one of the most valuable companies in the world. Now, commercial aviation is on the brink of a similar overtaking.

Of course, a large-scale transition to hydrogen-electric aircraft presents airports with the similar challenge of preparing their infrastructure for a more sustainable future. However, given the concentration of flights in commercial aviation, the infrastructure challenge is not nearly so daunting as it would be for migrating ground transport to a new drive technology. Consider the fact that 97% of all commercial traffic in the US is concentrated in just 150 airports. To repower aviation, the industry would therefore need about a hundred hydrogen fueling locations - contrast that with the more than 100,000 automobile gas stations in operation in the US today.

Furthermore, because of the hydrogen volume required by hydrogen-electric aircraft propulsion, airports also have an enormous opportunity to become centralized hydrogen hubs. ZeroAvia calculates, for example, that Houston Airport (IAH) would require 10 tons of hydrogen per day to operate just 50 percent of its sub-250 nautical mile flights. Given the volumes required as the system converts to hydrogen propulsion at scale across the sizes of aircraft and ranges of travel, the case for on-site production becomes quite 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 further emissions reductions. This more deeply 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. In addition to our aircraft, we operate multiple hydrogen fuel-cell road vehicles as part of our operations at Cotswold Airport in the UK 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.

Airports Need Support to Build Infrastructure for Sustainable Aviation.

Transitioning to a green-hydrogen economy will require support. Airport funding programs in their current incarnations do not help airports make these investments. While the Department of Energy Hydrogen Hub program should prioritize supporting a handful of airports (especially given the impacts that airports can have as Hubs in themselves), that program alone will not be enough to facilitate widespread adoption of this game-changing technology.

In the United Kingdom, ZeroAvia's expanding operations are supported by grants from the UK's Aerospace Technology Institute and Innovate UK. In addition, our landside-to-airside hydrogen airport pipeline, Europe's first, received support from the UK Government's Department for Transport and the Connected Places Catapult as part of the Zero Emission Flight Infrastructure program to enable airports and airfields to prepare for the future of zero-emission operations.

The U.S. lacks such a zero emission airport infrastructure program. But, modifying existing Federal Aviation Administration airport funding and other financing programs can make a significant difference, encouraging adoption and helping restore the U.S. leadership in new aviation technologies. Historically, the FAA's airport programs and aircraft programs have been fully separated. Programs to develop more sustainable aviation are walled off from programs that help airports develop more sustainable ground operations. A solar array that generates the energy needed for the electrolysis that produces hydrogen will serve both aircraft *and* ground vehicles, but to which FAA office does the airport director apply? The transition to hydrogen will require leadership to open those silos.

Amending aspects of the Passenger Facility Charge (PFC), Airport Improvement Program (AIP), and Voluntary Airport Low-Emission (VALE) tools to include hydrogen production projects that supply 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 advancements 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.

Credit programs like the U.S. Department of Transportation's TIFIA program will also help. In the Infrastructure Investment and Jobs Act (IIJA) enacted last year, airport landside TIFIA eligibility, which was not prohibited in TIFIA's initial parameters, was explicitly included in the program, but the language does not encourage an airport project that supports ground transportation as well as aviation. Whether this takes the form of expanded TIFIA eligibility or a new aviation-specific credit program, the same investment-friendly terms will incentivize the transition to sustainable aviation. When airports use renewable energy sources to 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 green-hydrogen production. Within a new Federal clean fuel program, for example, airports investing in green-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. 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 green-hydrogen production to support more sustainable ground operations as well as zero-emission aviation. We at ZeroAvia look forward to working with the Subcommittee, with our colleagues in sustainable aviation, and with America's airports to expedite this crucial transition.

Commercial Aviation Emissions Can Be Abated.

Under the right conditions, a path to initial safe, zero climate impact commercial flight by 2024 and large-scale removal of emissions from regional aviation by 2030 are 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 impact, with many estimates suggesting a 25-50% share for aviation by 2050 in the business-as-usual scenario. 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.[6]

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

The technology for zero-emission aviation exists today, and we will see commercial hydrogen-electric service before this decade is halfway through. 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.

[6] 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