ELECTRIC AIRPLANES: BRIDGING THE TECHNOLOGICAL AND REGULATORY GAP

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I. INTRODUCTION

[1] Business success depends on two overarching factors: (1) filling a market niche, and (2) doing it better than the competition. Just such a market gap exists in aviation. Fuel prices rise over time, and the maintenance costs for aging aircraft contribute to skyrocketing costs for training pilots. While shifting pilot training to simulators and allowing the use of alternative types of aircraft to satisfy training requirements addresses some of the cost of aviation,[1] the basic truth remains that flying is expensive and involves burning a large amount of fossil fuel. However, battery breakthroughs usher in a new reality, one which offers a new way to reduce the cost of aviation while responding to mounting environmental degradation.

[2] Responding to rising pilot training costs and a lack of efficient alternatives, the Slovenian aircraft manufacturer Pipistrel aimed to fill the supply gap by developing its own electric-powered airplane, the Velis Electro. By combining its experience building gliders and small two-seat airplanes, along with its continuing relationship with regulators at the European Union Aviation Safety Agency (EASA), Pipistrel achieved the milestone of earning the world's first commercial electric airplane certification.[2] The simple business sense of applying innovative technology to a continuing market problem arrives at a critical moment, when rising costs in the market intersect with out-of-control greenhouse gas (GHG) emissions.

[3] This article focuses on electric aircraft certification in the United States and takes the position that aviation regulators must prospectively incorporate data and processes to enable certification of this new generation

[1] *See* Jim Moore, *FAA Cuts Cost of Training, Proficiency Instrument and Sport Pilots Big Beneficiaries*, AOPA (July 17, 2018), https://www.aopa.org/news-and-media/all-news/2018/june/27/faa-cuts-cost-of-training-proficiency [https://perma.cc/NX2D-65QP].

[2] *EASA Certifies Electric Aircraft, First Type Certification for Fully Electric Plane World-Wide*, EASA (June 10, 2020), https://www.easa.europa.eu/newsroom-and-events/press-releases/easa-certifies-electric-aircraft-first-type-certification-fully [https://perma.cc/E3H9-8EQT] [hereinafter EASA Pipistrel Certification].

of aircraft. The academic literature in this area tends to assume the completion of certification of aircraft, rather than to focus on the possibility of certification in the first place. Most of the academic emphasis in this area is on the application of federal aircraft certification to state products liability law.[3] Taking that further, some have argued that the Federal Aviation Administration's (FAA) review process of existing certifications, known as a special certification review (SCR), should be interpreted as a federal preemption of state law with respect to manufacturers' involvement in accidents.[4] Still other scholarship has discussed the regulatory issues involved in electric-powered urban air mobility, or "air taxis," that can take off and land vertically in any location and whisk passengers throughout a city.[5] In comparing these vehicles to the regulation of drones, the discussion focuses primarily on airspace and traffic regulation, rather than on the certification of the propulsion that would make these vehicles possible.[6] Instead, through a comparison of the regulatory frameworks employed by the EASA and the FAA, this article proposes changes to modernize the FAA's approach to type certification. But certification alone is only half of the solution; in addition, the article provides examples of programs that the FAA and other agencies may institute to provide industry with the leadership it needs to move away from still-profitable legacy technologies toward safer and climate-friendly electric airplanes.

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[3] *See, e.g.*, Robert F. Hedrick, *A Close and Critical Analysis of the New General Aviation Revitalization Act*, 62 J. AIR L. & COM. 385, 396–97 (1996) (discussing the interplay between the federal GARA and state products liability for manufacturers, suppliers, and distributors of aircraft).

[4] *See* Jack Milligan, Comment, *Bet on the Field: Why Field Preemption Should Apply to the Federal Aviation Act*, 85 J. AIR L. & COM. 507, 521–22 (2020); Thomas N. Tarnay, Comment, *Aircraft Designs Subjected to FAA Special Certification Review – Mitsubishi MU-2 and Beechcraft Bonanza: The Role of the SCR in Aircraft Design Certification and Implications on Federal Preemption*, 62 J. AIR L. & COM. 591, 622–23 (1996).

[5] Timothy Ravich, *On-Demand Aviation: Governance Challenges of Urban Air Mobility ("UAM")*, 124 PA. ST. L. REV. 657, 659, 666 (2020).

[6] *See id.* at 666–67.

[4] Aviation is a major driver of climate change, both in total emissions of carbon dioxide and in high-altitude nitrous oxide (NOx) emissions.[7] In fact, "aircraft account for 12% of all U.S. transportation greenhouse gas emissions and 3% of total such U.S. emissions."[8] Also, airports are associated with sound pollution, negatively affecting quality of life and property values in their vicinity.[9] As a result, aviation presents a significant environmental justice issue. As technology develops, electrifying all aspects of the aviation industry would go a long way to address these issues.[10] Federal and state regulation will need to anticipate and lead this paradigm shift to promote safety and equity.

[5] The current FAA regulations governing aircraft certification produce an "Innovation Paradox," wherein an attempt to allow flexibility for the industry instead creates a status quo market. While manufacturers produce modest improvements in existing fossil fuel powerplants, electric propulsion is needed to reduce aviation's impact on climate change and environmental justice, as well as to help ensure the future of civil aviation through available alternatives to the burning of fossil fuels.[11] FAA

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[7] *See* Harold S. Johnston et al., *Nitrogen Oxides from High-Altitude Aircraft: An Update of Potential Effects on Ozone*, 94 J. GEOPHYSICAL RSCH. 16351, 16361 (1989) (discussing results of scientific models that predict "ozone reduction for injections [emissions] at 20 km" and above).

[8] David Shepardson, *U.S. EPA Proposing First-Ever Airplane Emissions Standards*, REUTERS (July 22, 2020, 12:10 AM), https://www.reuters.com/article/us-usa-airlines-emissions/u-s-epa-proposing-first-ever-airplane-emissions-standards-idUSKCN24N0D3 [https://perma.cc/Z87G-M5KH].

[9] *See* Donald V. Harper, *Regulation of Aircraft Noise at Major Airports: Past, Present, and Future*, 17 TRANSP. L. J. 117, 129–30 (1988).

[10] *See* Brooks McKinney, *Electric Airplanes Promise Cleaner, Quieter Regional Air Travel*, NOW. (July 8, 2020), https://now.northropgrumman.com/electric-airplanes-promise-cleaner-quieter-regional-air-travel/ [https://perma.cc/JV43-SU9F].

[11] *See id.*

regulations disincentivize its development through a mix of outdated regulations and blind deference to industry consensus.

[6] The FAA individually certifies aircraft for commercial use through type certificates according to minimum requirements listed in the Code of Federal Regulations and defer to industry to determine how to comply.[12] These requirements specify minimum safety standards, whereas means of meeting that criteria are left to industry consensus.[13] For instance, while type certificate regulations mention "charging" as part of aircraft fueling, they offer little other guidance to fledgling certificate applicants looking to use innovative technologies.[14] Complicating matters, certification regulations dealing with engines encompass only reciprocating and turbine engines, while lacking flexibility for innovative designs such as electric propulsion.[15] Without regulatory assurance of the possibility of approval of such designs, potential market entrants are discouraged from investing capital to develop these designs.

[7] Meanwhile, a lack of market competitors leaves industry consensus to a handful of established manufacturers.[16] These entities lack incentive to

[12] *See, e.g.*, Carolina Anderson, *The Effects of Aircraft Certification Rules on General Aviation Accidents*, 4 J. AVIATION TECH. & EDUC. 32, 34 (2015) (describing the FAA's successful test of consensus standards for Special- and Experimental-Light Sport Aircraft in 2004, which was initiated in response to concerns over "rising certification costs and dwindling pilot populations").

[13] *FAA Accepts Wide-Ranging LSA-Style Certification Acceptance Standards for Part 23 Planes*, PLANE & PILOT (Sept. 29, 2020), https://www.planeandpilotmag.com/news/the-latest/2020/09/29/faa-accepts-wide-ranging-lsa-style-certification-acceptance-standards-for-part-23-planes/ [https://perma.cc/6LM3-R49K].

[14] *See* 14 C.F.R. § 23.2430(c) (2020).

[15] *See* 14 C.F.R. § 33.7(b)–(c) (2020).

[16] *See, e.g.*, *ASTM Organizational Membership Directory*, ASTM INT'L (2021), https://www.astm.org/MEMBERSHIP/memborg/index.htm#Bstart [https://perma.cc/F4ET-CXNV] (listing Boeing and Airbus as member organizations, which are both established aerospace industry giants, but not smaller manufacturers such

invest heavily in technology that undercuts their principal business.[17] Instead, these industry heavyweights tip the scale in their own favor,[18] limiting the ability of smaller companies and startups to enter the market with cheaper alternatives.

[8] Emissions targets have long provided incentive for industry shifts in both aviation and ground transportation. Over the past decade, the FAA worked with airlines to develop and test alternative fuels, such as biofuel.[19] Though these fuels produce some savings in emissions, they cost more than legacy aviation fuels and can be difficult to produce at scale.[20] Meanwhile, the FAA's focus has evolved away from fuel development toward an

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as Pipistrel, Eviation, or magniX; however, Siemens is a member organization, which is a leader in electric motor development).

[17] *See* Olivia Bugault & Dieter Holger, *Airlines Push to Reduce Carbon Footprint with Greener Fuels*, WALL ST. J. (Feb. 9, 2021, 1:00 PM), https://www.wsj.com/articles/airlines-push-to-reduce-carbon-footprint-with-greener-fuels-11612893657 [https://perma.cc/BM8Q-56XC] (explaining that airlines "don't have much incentive to buy more" biofuels because they "cost up to four times more than conventional fuel," and "the business case falls apart").

[18] *See, e.g.*, Peter Robinson & Margaret Newkirk, *Relationship Between Boeing, FAA Safety Regulators Under Scrutiny*, INS. J. (Mar. 25, 2019), https://www.insurancejournal.com/news/national/2019/03/25/521514.htm [https://perma.cc/2WLM-NFCZ] (detailing the close relationship between FAA officials and Boeing, allowing the company to rush forward a defective aircraft design in the 737 Max).

[19] *See* UNITED STATES AVIATION GREENHOUSE GAS EMISSIONS REDUCTION PLAN 28–30 (2015), https://www.faa.gov/about/office_org/headquarters_offices/apl/environ_policy_guidance/policy/media/2015_US_Action_Plan_FINAL.pdf [https://perma.cc/HJW9-TQ9B] [hereinafter GHG REDUCTION PLAN].

[20] *See* Pharoah Le Feuvre, *Are Aviation Biofuels Ready for Take Off?*, IEA (Mar. 18, 2019), https://www.iea.org/commentaries/are-aviation-biofuels-ready-for-take-off [https://perma.cc/3WRA-3JV2].

emphasis on energy efficiency through better traffic management.[21] But in response to international pressure, the Environmental Protection Agency (EPA) issued a proposed rule in August to establish air pollution standards for large airplanes.[22] Much like the automobile industry, standards such as these may inspire airplane manufacturers to seek new ways to reduce emissions, including zero-emission electric airplanes. The FAA, enabled by appropriations from Congress and in coordination with the Internal Revenue Service (IRS), can support this shift through the award of tax credits or initial purchase incentives.

[9] The fledgling electric airplane market would also benefit by the example of the rise of the electric automobile market. Spurred by purchase incentives aimed to achieve emissions reduction goals, electric cars are a growing segment of U.S. vehicle sales.[23] Federal incentives can provide for both aircraft and charger purchase/installation. Expanded solar and energy storage incentives can help airport managers fuel airplanes from the sun at minimum cost.[24] As each airplane's safety margin is better understood over time, the FAA can adjust required inspection schedules to save operators' maintenance costs, just as electric cars save their owners thousands of dollars in regular maintenance (e.g. no oil changes and rare brake pad

[21] *See* FED. AVIATION ADMIN., NEXTGEN IMPLEMENTATION PLAN 2018-19 ii–iv (2019), https://www.faa.gov/nextgen/media/NextGen_Implementation_Plan-2018-19.pdf [https://perma.cc/4E6M-3RMY].

[22] *See* Control of Air Pollution from Airplanes and Airplane Engines: GHG Emissions Standards and Test Procedures, 85 Fed. Reg. 51,556, 51,565 (Aug. 20, 2020) (to be codified at 40 C.F.R. pts. 87, 1030).

[23] *See EV Market Share by State*, EVADOPTION, https://evadoption.com/ev-market-share/ev-market-share-state/ [https://perma.cc/9LTP-W6D5] (indicating a total increase in electric vehicle sales between 2017 and 2018 of 74.54% nationwide, and an increase of electric vehicle market share of over 63%).

[24] *See* NAT'L RENEWABLE ENERGY LAB'Y, NREL/TP-7A40-62349, IMPLEMENTING SOLAR TECHNOLOGIES AT AIRPORTS 1 (2014).

replacements).[25] States and localities can use their tax and fees discretion to support public health and reduced noise benefits through electric aircraft infrastructure investments.

[10] This article proposes adjustments the FAA's regulatory approach to aircraft certification considering EASA progress in electric aircraft certification, as well as suggests additional policies that will help spur the market for these critical assets. Part I explores the type certification process in the United States and explains how it currently produces an innovation paradox. Explaining further the tension between industry efficiency and deliberative safety is a discussion of the certification of the Boeing 737 Max, wherein regulatory capture played a part in two preventable fatal mishaps. Part II examines the process that enabled the world's first electric airplane certification and applies that example to the FAA. Part III discusses programs that the FAA, in concert with other agencies, states, and localities, can bring to bear to incentivize adoption of electric aircraft and mitigate emissions. Finally, Part IV concludes that government provides the goals to which industry aspires; the FAA must provide the leadership that industry needs to prioritize decarbonization.

II. AIRCRAFT CERTIFICATION & THE INNOVATION PARADOX

[11] The development of electric aircraft faces a roadblock under current FAA regulations. As part of its mission, the FAA must promote safety.[26] To accomplish this goal, the agency relies on the experience of its inspectors and on "tried and true" methods of keeping the flying public safe. This body

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[25] *See* RYAN LOGTENBERG ET AL., COMPARING FUEL AND MAINTENANCE COSTS OF ELECTRIC AND GAS POWERED VEHICLES IN CANADA 11–12 (2018), https://2degreesinstitute.org/reports/comparing_fuel_and_maintenance_costs_of_electric_and_gas_powered_vehicles_in_canada.pdf [https://perma.cc/R7YV-ASDB].

[26] Tarnay, *supra* note 4, at 599 (explaining that promotion of civil aviation and that of aircraft design safety were intended as simultaneous goals on equal footing, such that the FAA would exist both to protect the flying public as well as to promote commerce through aviation).

of knowledge is codified in the process of aircraft certification.[27] But the agency also must pursue a second goal: promotion of civil aviation.[28] The lengthy process of certifying a new aircraft design disincentivizes innovation, instead pushing manufacturers toward known technology rather than investment in promising but unproven alternatives. This dichotomy contradicts and undermines the FAA's role in promoting aviation commerce.[29]

A. Certification

[12] The aircraft certification process is a deliberative ordeal that ensures design safety before allowing a particular product to enter the market. Any manufacturer seeking to build and sell aircraft in the United States for commercial use must seek a type certification from the FAA.[30] The Administrator of the FAA is authorized to issue rules, subject to notice and comment rulemaking under the Administrative Procedure Act, that promote aviation safety.[31] In turn, the FAA regulates the safety of aircraft designs

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[27] *See*, 49 U.S.C. §§ 44704(a)(1)–(2) (authorizing the FAA Administrator to specify requirements for type certificates "in the interest of safety" and based upon investigation and tests).

[28] Tarnay, *supra* note 4, at 599 (explaining that promotion of civil aviation and that of aircraft design safety were intended as simultaneous goals on equal footing, such that the FAA would exist both to protect the flying public as well as to promote commerce through aviation).

[29] *See id.* at 598–99.

[30] *See* Matt Thurber, *The Aircraft Certification Process*, AINONLINE (Dec. 18, 2006, 5:41 AM), https://www.ainonline.com/aviation-news/aviation-international-news/2006-12-18/aircraft-certification-process [https://perma.cc/9AK6-FPNB] (explaining that a production certificate is required to manufacture an aircraft for sale, which in turn requires a type certificate that may be pursued in parallel).

[31] 49 U.S.C. § 106(f)(3)(A) (2019).

through the type certification process.[32] Following initial application, the FAA requires inspections and tests of all aspects of the aircraft design, including noise, emissions, and manufacturing processes.[33] Also, "at least 150 hours of operation" is required in flight tests for non-turbine powered aircraft.[34] Each type certificate is scrutinized against applicable airworthiness standards.

[13] Airworthiness standards are set separately for each category of aircraft. Of note, airplanes with a maximum takeoff weight of 19,000 pounds or less fall within the "normal" category.[35] For purposes of certification, this category is further subdivided by maximum seating configuration, with an absolute maximum of nineteen passenger seats.[36] By comparison, the "transport" category includes aircraft capable of carrying larger numbers of passengers.[37] Each of these categories provides overall limitations for performance that apply generally to regulated aircraft within the category.[38] The scope of certification covers a very wide range of factors, delineating minimum requirements in each measure before an aircraft is produced and flown.[39] However, the means of compliance with

[32] 14 C.F.R. § 21.21(b) (2020).

[33] 14 C.F.R. § 21.33 (2020).

[34] 14 C.F.R. § 21.35(f)(2) (2020).

[35] 14 C.F.R. § 23.2005(a) (2020).

[36] *Id.* (defining Level 1 for 0 to 1 passenger, Level 2 for 2 to 6 passengers, Level 3 for 7 to 9 passengers, and Level 4 for 10 to 19 passengers).

[37] *See* 14 C.F.R. Pt. 25 SFAR No. 109 (2020).

[38] *See, e.g.*, 14 C.F.R. § 23.2105 (2020) (providing the environments in which manufacturers must provide performance data); 14 C.F.R.§ 25.107 (defining takeoff performance metrics for transport category aircraft based on engine configurations).

[39] *See* Tarnay, *supra* note 4, at 602–03 (explaining that the regulations stipulate many obscure requirements identifying the outer bounds for categories of designs, including the

regulations are left generally to industry consensus.[40] This process also applies to individual components of aircraft that might be installed in other aircraft designs, such as for engines.[41]

[14] In addition to aircraft certification, the FAA requires certification of each engine used in the design.[42] Any manufacturer that applies for aircraft type certification "must show compliance with the applicable requirements" of Parts 33 and 34, pertaining to engine certification and fuel venting.[43] Part 33 provides many requirements for engine design and usage, all of which deal with the particularities of reciprocating and turbine engines.[44] Though some physical characteristics align, these regulations do not anticipate the use of electric motors for propulsion.

[15] The FAA must adjust its procedures to make space for the possibility of new technologies. For instance, the FAA issues "advisory circulars" to expand upon "methods applicants can use to describe and analyze systems to demonstrate compliance."[45] When a manufacturer proposes to utilize equipment not contemplated in the regulations, the FAA must publish "a notice of proposed special conditions . . . in the Federal

"limit side force equal to 0.036 times the design maximum weight" for skis equipped on snow-capable airplanes).

[40] 14 C.F.R. § 23.2010 (2020) (including in "means of compliance" the use of "consensus standards" for "normal" category airplanes).

[41] 14 C.F.R. § 33.1 (2020).

[42] *Id.*

[43] *Id.*

[44] 14 C.F.R. §§ 33.31, 33.61 (2020).

[45] *Lessons Learned from the Boeing 787 Incidents: Hearing Before the Subcomm. on Aviation of the H. Comm. on Transp. & Infrastructure*, 113th Cong. 31 (2013) (statement of Margaret M. Gilligan, Associate Administrator for Aviation Safety, Federal Aviation Administration).

Register . . . ."[46] These conditions give industry and concerned parties an opportunity to offer relevant data to guide the FAA in determining the risks involved in approving the novel technology. As such, the comment period provides an opportunity for communication and collaboration. These special conditions supplement existing type certification requirements and establish a route for manufacturers and the FAA to agree on the use of novel technology. This exchange of ideas prompts give-and-take between the FAA and industry throughout the certification process. Without concessions, manufacturers that seek to change their products for the better are incentivized to instead cling to obsolete, dirty technologies that are already known to pass certification and produce a profit. While all of this process is intended to result in a safe product as understood in the context of legacy technologies, it stifles the possibility of even greater levels of safety possible through the use of new technologies and techniques.

B. The Innovation Paradox

[16] Despite its aim of granting manufacturers more flexibility as technology develops, the FAA created an environment in which uncertainty discourages innovation. Industry consensus relies on the influence of its members to come to agreement. Those members with influence have an interest in maintaining technology status quo so that they can maximize profit on their current products. Using their leverage, these members stifle progress on consensus standards, providing little basis for FAA approvals. Without that basis, the companies seeking FAA approval of novel technologies are left without a marketable product.

[17] Under industry consensus, privately developed standards provide the basis for regulatory compliance. As discussed above, the FAA sets outer limits for aircraft designs, but allows manufacturers to comply under industry consensus standards.[47] Those standards are codified and published

[46] *Id.* at 29.

[47] 14 C.F.R. § 23.2010(a) (2020).

by ASTM International.[48] With 30,000 members from 140 countries, ASTM manages standards across multiple industries and materials.[49] By referencing a particular ASTM standard, the FAA—as well as other international regulatory bodies—accepts that standard as the basis upon which a manufacturer may rely for compliance with regulations.[50]

[18] Confusion arises when ASTM standards mismatch FAA regulations. For instance, airplane type certificate powerplant compliance references ASTM F3464-19, which in turn references numerous ASTM standards to establish criteria for each component of the airplane.[51] Interestingly, one of those references is ASTM F3239-19, which is a publication that provides standards for electric propulsion.[52] While this standard is referenced within an FAA-accepted standard, the FAA regulations themselves do not provide safety limitations for electric propulsion. Although there are limited references to "recharging" of fuel systems,[53] there is nothing as specific or extensive as the reference to reciprocating and turbine engines in Part 33.[54] As a result, manufacturers desiring to certify electric airplanes are left either to (1) guess whether the FAA will consider electric propulsion to be compliant with current regulations, or (2) petition the FAA for special-conditions rulemaking.

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[48] *See, e.g.*, 85 Fed. Reg. 59,400, 59,403 (Sept. 22, 2020) (referencing ASTM F3264-19 for powerplant compliance).

[49] *What is ASTM?*, ASTM INT'L, https://www.astm.org/ABOUT/factsheet.html [https://perma.cc/YR4W-4LGF].

[50] 14 C.F.R. § 23.2010 (2020).

[51] *ASTM F3264-19, Standard Specification for Normal Category Aeroplanes Certification*, ASTM INT'L, https://www.astm.org/Standards/F3264.htm [https://perma.cc/R8UP-ADLC].

[52] *See id.*

[53] *See* 14 C.F.R. § 23.2430 (2020).

[54] *See* 14 C.F.R. §§ 33.31, 33.61 (2020).

[19] Both options involve uncertainty, which in turn discourages investment. Either through agency interpretations not yet made or through future action not yet contemplated, the likelihood of a company bringing a product to market depends on the agency. Additionally, whenever considering new or updated rules, “the agency faces a choice between imposing certain losses to avoid uncertain ones or to create the potential for uncertain gains.”[55] Investors are caught between the agency’s and the company’s competing predictions of regulatory outcome.[56] As investors await regulatory approval of new technologies that promise low operational cost, they shy away from contributing funding to their development.[57] Instead, investment shifts to established technologies known to produce a profit.[58] The innovation paradox results when flexibility intended to allow industry consensus compliance instead contributes to consolidation of investment in proven, profitable technologies.

[20] Development of electric airplanes suffers from this paradox. Although there are numerous startups attempting to develop electric aircraft, none hold a type certificate nor have products available on the market.[59] Meanwhile, major manufacturers focus their efforts on iterations of current products, saving costs on acquiring new type certificates while leveraging existing relationships with the FAA to conduct much of their

[55] Mark Seidenfeld, *Why Agencies Act: A Reassessment of the Ossification Critique of Judicial Review*, 70 OHIO ST. L. J. 251, 289 (2009).

[56] *See id.*

[57] *See* Abby Narishkin et al., *Why Electric Planes Haven’t Taken Off Yet*, BUS. INSIDER (Mar. 31, 2020, 1:15 PM), https://www.businessinsider.com/electric-planes-future-of-aviation-problems-regulations-2020-3 [https://perma.cc/U86X-JFHP].

[58] *See* Bugault & Holger, *supra* note 17 (explaining why airlines continue to rely on jet fuel rather than investing in higher cost, lower carbon alternatives).

[59] *See 8 Electric Airplane Startups Trying to Get Off the Ground*, NANALYZE (May 1, 2019), https://www.nanalyze.com/2019/05/electric-airplane-startups/ [https://perma.cc/4HPK-M4L3].

own testing and validation.[60] A high-profile example of this tendency is the recent saga of the Boeing 737 Max.

[21] Boeing developed the 737 Max with a great deal of deference from the FAA.[61] The 737 Max was developed quickly to compete with Airbus by producing "a more fuel-efficient version of its best-selling 737."[62] Flight testing to validate the design took place only between March 2017 and February 2018, culminating in "an amended type certificate" for the 737 Max.[63] However, test data and system operations parameters were all collected and reported to the FAA by Boeing itself.[64] In turn, FAA managers "took Boeing's side" by overruling their own inspectors' objections to Boeing's design.[65] This lack of oversight resulted in two critical problems: (1) the stall protection system, which is critical to the aircraft's airworthiness, was capable of "push[ing] the nose down a lot more than the FAA thought possible;" and (2) the stall protection system "could reset itself after pilots intervened," resulting in the system continuously pushing the aircraft's nose down.[66] In fact, the airframe changes and resulting flight

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[60] *See, e.g.*, Natalie Kitroeff et al., *The Roots of Boeing's 737 Max Crisis: A Regulator Relaxes Its Oversight*, N.Y. TIMES (July 27, 2019), https://nyti.ms/2K0xdd7 [https://perma.cc/HW6T-7A9S] (describing the inadequate certification process that contributed to the crash of two Boeing 737 Max aircraft).

[61] *Id.*

[62] *Id.*

[63] *737 MAX 9 Awarded Type Certification*, BOEING (Feb. 16, 2018), https://www.boeing.com/features/2018/02/737-max-9-certification-02-16.page [https://perma.cc/4XHS-VGJC].

[64] *See* Steve Dent, *Report: Boeing's Crucial 737 Max Safety Analysis Was Flawed*, ENGADGET (Mar. 18, 2019), https://www.engadget.com/2019-03-18-boeing-737-max-faa-certification-flaws.html [https://perma.cc/R37K-ND7H].

[65] *See* Kitroeff et al., *supra* note 60.

[66] Dent, *supra* note 64.

control compensation to produce the desired fuel savings meant that the 737 Max was a more novel aircraft than the name would suggest, to the extent that FAA officials "sat incredulous as Boeing executives explained details about the system that they didn't know" following the first 737 Max crash.[67] The lack of understanding of these system risks led the FAA to designate the activation of this system by a single sensor, rather than the usual two sensors for redundancy, not as "catastrophic" but as "hazardous."[68] Even though each aircraft component's risk may be low, combined with other systems the overall risk may rise to an unacceptable level.[69] After the second crash of a 737 Max under similar conditions occurred, resulting in a total loss of life of 346 people, the FAA grounded all of the aircraft pending investigation.[70] These misunderstandings led to two preventable fatal mishaps.

[22] The failure of Boeing and the FAA to together prevent this loss of life highlights the importance of the balance of the dual roles of the FAA. In this case, it is arguable that the FAA focused primarily on its goal to advance aviation commerce by deferring to Boeing in the 737 Max certification. But deferring exclusively to a single manufacturer, to the extent that oversight reliance shifts entirely to that manufacturer, reduces the perspectives available to oversee the design process. This problem is

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[67] *See* Kitroeff et al., *supra* note 60.

[68] Dent, *supra* note 64; *see* Dominic Gates & Mike Baker, *The Inside Story of MCAS: How Boeing's 737 MAX System Gained Power and Lost Safeguards*, SEATTLE TIMES (June 24, 2019, 5:25 PM), https://www.seattletimes.com/seattle-news/times-watchdog/the-inside-story-of-mcas-how-boeings-737-max-system-gained-power-and-lost-safeguards/ [https://perma.cc/5BBX-W39J] (explaining that "catastrophic" events result in the loss of the airplane, whereas a "hazardous" event causes "serious or fatal injuries to a small number of people").

[69] *See Swiss Cheese Model – Aviation Safety*, AVIATIONFILE (Sept. 13, 2020), https://www.aviationfile.com/swiss-cheese-model/ [https://perma.cc/ZF3H-GQMQ] (explaining how the "Swiss Cheese Model" represents each risk as the holes in a slice of swiss cheese, which in turn illustrates how an accident occurs when the holes align).

[70] *See* Kitroeff et al., *supra* note 60.

further exacerbated when the agency's own experts are ignored. That expertise is the driving force behind the safety mission of the aircraft certification process. Prioritization of this resource is critical in completing certification, and it is a review that cannot be skipped. It is reasonable to expect the agency to accordingly prioritize the review of an aircraft seen as critical to U.S. aviation commerce. But for the 737 Max, the FAA assumed that Boeing would produce a safe aircraft, rather than rely on its own independent examination of the aircraft's design changes. The FAA abdicated its safety role by relying so extensively on Boeing in the approval of its own aircraft. While shifting some responsibility for compliance to manufacturers is useful for efficiency, it is critical that the FAA maintain its oversight function.

[23] Part of that oversight depends upon a reasonable understanding of how to achieve safe outcomes in aviation. The type certification process applies to new aircraft and component designs.[71] After certification, the FAA may revisit design certification through the special certification review (SCR) process.[72] Just as in the initial certification, this investigation addresses potentially unsafe aspects of an aircraft's design.[73] Depending on what FAA inspectors find, the review may either confirm the terms of the original certification or recommend modifications to the aircraft's requirements.[74] The investigation may also produce findings to improve the "uniform application of the certification rules throughout the FAA."[75] Although process improvement may prevent the need for a redundant investigation such as a SCR, the findings from these investigations all focus on existing approvals, rather than prospectively on how to account for new technology in a safety review. This environment in turn leaves

[71] *See* Tarnay, *supra* note 4, at 602–03.

[72] *See id.* at 607–08.

[73] *See id.*

[74] *See id.* at 608.

[75] *See id.*

manufacturers with an inconsistent expectation of whether their new technology can achieve certification through the review of FAA experts who are unfamiliar with the technology.

[24] Without consistency, new manufacturers are hampered from entering the field, and the resulting lack of investment starves ASTM of members with expertise in electric propulsion. Manufacturers who specialize in electric propulsion provide critical perspective on best-practices in that area, and their absence limits the organization's ability to promulgate up-to-date standards.[76] Under this paradigm, incentives disfavor the taking of investment risk on technologies lacking a clear path to approval, where such approval is a prerequisite to marketability. Breaking this cycle requires a renewed focus on the balance between promotion of civil aviation with the promotion of safety, along with a reimagining of how to achieve desired safety outcomes.

III. SOLUTIONS TO THE INNOVATION PARADOX

[25] A market for electric airplanes is unlikely to develop without reform in the FAA's process of certifying airplanes. Reform of the certification process with respect to electric airplanes should also take priority to best serve the FAA's role in promoting aviation safety. Aircraft simplicity plays a key role in the number of hours and difficulty required for adequate pilot training.[77] Also, common technologies in one arena can pose unexpected threats in another. For instance, lithium-ion batteries are limited aboard aircraft due to their potential to cause fires.[78] Similarly, early quality control

[76] *See What is ASTM?*, *supra* note 49.

[77] *See* Phillip Palmer, *Are Electric Planes the Future for Air Travel?*, ABC7 (July 23, 2020), https://abc7.com/aviation-news-new-airplanes-electric-planes-eflyer2/6327758/ [https://perma.cc/GDY3-N7MM] (claiming that learning to fly this electric model will be less time-consuming than learning to fly an older model with a combustion engine).

[78] *See* Thomas Hornigold, *Are Electric Planes the Future of Aviation?*, SINGULARITYHUB (June 28, 2018), https://singularityhub.com/2018/06/28/are-electric-planes-the-future-of-

issues on "aircraft-grade" lithium-ion batteries aboard the Boeing 787 Dreamliner required subsequent safety retrofits.[79] This event illustrated the learning curve needed for this technology, but that early issues may be overcome and contribute to a successful and safe product. Clarification in the certification process will ease investor sentiment toward these new and critical technologies.

[26] Electric airplanes must be commercially viable to cultivate customers, and customers in turn are required for investors to be willing to invest in the development of electric airplanes. The European Union Aviation Safety Agency (EASA) operates a regulatory regime similar to that employed by the FAA. Aircraft design certification proceeds over many years, based on lists of criteria appurtenant to various categories of aircraft. But even with this regulatory structure imposing a potential barrier to innovation, the EASA forged a path to commercial electric airplane certification. It is instructive to look to the example set by the EASA in approving the world's first certified electric airplane.[80]

A. Real-World Example—Pipistrel Velis Electro

[27] In June 2020, the EASA issued a type certificate for the Pipistrel Velis Electro. This Slovenian two-seat airplane is capable of flights of more

aviation/ [https://perma.cc/A4L7-Y47A] (insinuating that the inherent danger in using lithium batteries may stifle the use of electric airplanes).

[79] *See* Umair Irfan, *How Lithium Ion Batteries Grounded the Dreamliner*, SCI. AM. (Dec. 18, 2014), https://www.scientificamerican.com/article/how-lithium-ion-batteries-grounded-the-dreamliner/ [https://perma.cc/T5BA-4PW5].

[80] *See* Type-Certificate Data Sheet No. EASA.A.573, For Type Virus SW 121, EASA (Jan. 25, 2021) (including type certification for the Velis Electro) [hereinafter Data Sheet]; *see also* Brian Garrett-Glaser, *Pipistrel Receives First EASA Certification for an Electric Aircraft. Who's Next?*, AVIATION TODAY (June 12, 2020), https://www.aviationtoday.com/2020/06/12/pipistrel-receives-first-easa-certification-electric-aircraft-whos-next/ [https://perma.cc/TS8J-KXEW].

than an hour in duration, "intended primarily for pilot training."[81] The certification of this airplane occurred through two development streams: (1) "typical certification activities related to the aircraft," and (2) "a coordinated flight test program using a fleet of (non-certified) Alpha-Electros under EASA permit to fly," conducted in parallel.[82]

[28] The close partnership between regulators and company engineers using real-world data from demonstrator aircraft was critical in producing the knowledge base required for certification of this aircraft. Pipistrel leveraged its background in gliders and small airplane trainers to develop the original Alpha Electro, which was the direct precursor to the Velis Electro.[83] Lacking previous experience in electric airplanes, the EASA partnered closely with Pipistrel's team to guide its regulatory approach to the company's upgraded commercial iteration.[84]

[29] The EASA, as an agency formed by the European Union (EU), enjoys a unique role in issuing regulations to member states. Established in the early 2000s, the EASA coordinates with each member states' aviation authorities, serving as "both a decision-making and quasi-rulemaking agency."[85] Like the FAA, the EASA issues type-certificates for specific airplanes, as well as licensing of pilots.[86] Two consultative bodies support the EASA, including the Advisory Group of National Aviation Authorities

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[81] EASA Pipistrel Certification, *supra* note 2.

[82] *Id.*

[83] *See* Paul Bertorelli, *Alpha Electro: One Fish, Small Pond*, AVWEB (Jan. 8, 2020), https://www.avweb.com/features/alpha-electro-one-fish-small-pond/ [https://perma.cc/9EBT-NEC8].

[84] *See* EASA Pipistrel Certification, *supra* note 2.

[85] Johannes Saurer, *The Accountability of Supranational Administration: The Case of European Union Agencies*, 24 AM. U. INT'L L. REV. 429, 463–64 (2009).

[86] *See id.* at 464.

(AGNA), and the Safety Standards Consultative Committee (SSCC), "which is mostly comprised of private experts coming from the airplane industry."[87] While proposals from the EASA are not considered formally binding, the airline industry relies on its specifications, and the EU empowers the agency "to conduct standardization inspections of Member States competent authorities."[88] The agency also operates a Board of Appeals to, among other things, hear appeals from "rejected applicants for airworthiness certificates."[89] These reforms provide important advantages to the regulatory structure of the EU.

[30] By consolidating the certification process from multiple states' agencies into a single agency, the EU increases the efficiency of its role in protecting its citizens. Providing a set of standards for manufacturers gives them a consistent benchmark for their products throughout the EU.[90] While each state's aviation agency maintains individual certificates for aircraft within its territory, the EASA monitors these agencies "to ensure they apply rules and regulations correctly."[91] This structure streamlines activities for manufacturers, whose primary regulatory coordination is with the EASA and only secondarily with each state. As illustrated in the certification of the Velis Electro, this process results in certification work occurring primarily with the EASA, facilitated by experts from concerned state agencies.[92] This work was useful in expanding the EASA's rules moving forward in certifying electric aircraft over the coming years.

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[87] *Id.*

[88] *Id.* at 465–66.

[89] *Id.* at 466.

[90] *See Safety*, EASA, https://www.easa.europa.eu/light/safety [https://perma.cc/9EBT-NEC8].

[91] *Id.*

[92] *See* Garrett-Glaser, *supra* note 80.

[31] Combining flight test experience and ongoing process updates, the EASA developed several rules with an eye toward electric aircraft certification more generally. The EASA issued a proposed special condition in January 2020 for Electric/Hybrid Propulsion System.[93] This set of proposed standards is tailored to the needs of an electric aircraft, applying relevant language to guide development of safe components.[94] While as of writing the final rule is pending, the EASA issued a final special condition for electric propulsion units in certain "normal" category airplanes.[95] This rule clarifies certification criteria for these types of engines and incorporates means of compliance from ASTM F3338-18, "Standard Specification for Design of Electric Propulsion Units for General Aviation Aircraft."[96]

[32] Meanwhile, the Velis Electro's certification process proceeded with individual component certifications. Following application for certification in December 2017, the EASA issued a type-certificate for the intended engine for the aircraft, known as the E-811, just over two years later.[97] This certificate specifies critical measurements for the E-811 engine, such as its operating limitations and required operating/maintenance manuals.[98] As the most critical single component of the entire aircraft, the engine's certification was a critical step toward overall aircraft certification. The Velis Electro's certification followed in June 2020, coming in just under three years from application to certification.[99] Since the Velis Electro was

[93] *See* Special Condition (EASA) No. SC E-19 of Jan. 2020.

[94] *See id.*

[95] Special Condition (EASA) No. SC E-18 of Oct. 2020.

[96] *Id.* at 1, 5.

[97] *Type-Certificate Data Sheet No. EASA.E.234, For type E-811 Engine*, EASA (May 18, 2020).

[98] *Id.* at 6–7.

[99] Data Sheet, *supra* note 80, at 8.

an iteration of the previously certified Pipistrel Virus, the EASA added it to the Virus's overall type-certificate.[100] This certificate lists various limitations, including operation only in the day and during visual flight conditions.[101] Of note, the fuel system is also specifically listed as an "Energy Storage System" and is limited to batteries of the designation "Pipistrel PB345V124E-L," precluding the use of any other types of battery cells or installations.[102]

[33] By partnering with Pipistrel and learning from its experience with its already-flying prototypes, the EASA drastically reduced the time required to certify the Velis Electro, compared to other type certifications and despite a dearth of experience with electric propulsion. Critically, as an iteration of a previous model, the agency was able to focus on the aircraft's electric propulsion components rather than to also scrutinize every aspect of the airframe. Also, the use of the Alpha Electro prototype, which matched the Velis Electro in many ways, simplified the agency's testing of operational data and highlighted needed operational criteria.[103]

B. Application of EASA's Experience to the FAA

[34] Like the EASA, the FAA lacks experience in electric aircraft and must find ways to either correct that condition or make up for it through partnerships. Recognizing its lack of experience, the EASA worked directly with Pipistrel to check the company's work and incorporate its lessons into the agency's own rulemaking. That effort will provide benchmarks for other companies developing electric aircraft. The FAA's "Aircraft Certification Service includes more than 1,300 engineers, scientists, inspectors, test pilots

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[100] *Id.*

[101] *Id.* at 10.

[102] *See id.*

[103] EASA Pipistrel Certification, *supra* note 2.

and other safety professionals" who provide for all type certifications.[104] Some part of this cadre should work directly with electric airplane firms to develop their own corporate knowledge while enabling commercial viability for those firms.

[35] Also, the time required to achieve certification presents a barrier to the development of electric airplanes. Even without utilizing novel technologies, "certification of a new aircraft type can take between 5 and 9 years."[105] Unproven technologies add to that time in the absence of institutional knowledge, since inspectors must learn about the technologies themselves to understand the risks involved in their application to aviation. Updated regulations that provide flexibility for companies to achieve target safety benchmarks through means beyond those contemplated through the use of dated technology will help. But the need for proper oversight will still require understanding on the part of the FAA, to avoid the trap found in the exclusive reliance on Boeing in the certification of the 737 Max. The long periods of time required to achieve this institutional knowledge may result in regulatory change during the development of an aircraft, resulting in shifting benchmarks for manufacturers of new aircraft designs.

[36] During the five- to nine- year certification timeframe, regulations can change, requiring firms to adjust their compliance measures. Even if the FAA passed regulations explicitly codifying minimum safety standards for electric propulsion systems, a shifting goal post may discourage investment in beneficial products for the fear of additional delays in reaching market. That said, grandfather clauses, such as that included in the EPA's recent

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[104] *How Does the FAA Certify Aircraft?*, FED. AVIATION ADMIN. (Dec. 18, 2020), https://www.faa.gov/aircraft/air_cert/airworthiness_certification/#:~:text=Amended%20type%20certificates%20typically%20take%203-5%20years%20to,of%20the%20flight%20control%20system%2C%20including%20the%20MCAS [https://perma.cc/VMR9-8BMW].

[105] *Id.* (explaining that an amended type certificate, by comparison, typically takes 3 to 5 years from start to finish).

emissions rule, can limit this factor.[106] More importantly, market conditions can change significantly. For instance, the overall drop in fuel prices over the past decade reduces the revenue incentive for airlines to invest in fuel efficiency.[107] Although at one point an electric airplane may look attractive through operational cost alone, the calculation can change dramatically within a few years.

[37] The EASA's collaborative approach with Pipistrel is replicable in the U.S. and should be used to accelerate electric aircraft certification. Most directly, the FAA may work with the EASA to validate its certification of the Pipistrel Velis Electro for bilateral certification in the U.S.[108] Accomplishing this process would establish availability of this aircraft for sale in the U.S without "reinventing the wheel." In turn, the aircraft would provide a test bed for the development of FAA regulations defining safe limits for electric aircraft. But even without this transfer of certification, the FAA may still emulate the EASA's example by permitting domestic aircraft manufacturers to conduct test flights,[109] but also to collaborate with the tests in the interest of developing generally applicable rules. This collaboration will help garner trust between company engineers and FAA inspectors. That trust in turn will reduce turnaround time on certifications, due to a better understanding of the technology involved.

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[106] *See* 85 Fed. Reg. at 51,565–66.

[107] *See Jet Fuel Daily Price*, INDEX MUNDI, https://www.indexmundi.com/commodities/?commodity=jet-fuel&months=120 [https://perma.cc/8TND-BPP4] (reflecting a drop from a high $3.27 per gallon to $1.79 per gallon pre-COVID-10 pandemic, with further drops thereafter).

[108] *See generally* FAA & EASA, TECHNICAL IMPLEMENTATION PROCEDURES FOR AIRWORTHINESS AND ENVIRONMENTAL CERTIFICATION 30-32, 36 (2019) (explaining the process for technical validation of novel or unusual design features).

[109] *See, e.g.*, Judith Kohler, *Arapahoe County Aerospace Company Says Pandemic Hasn't Grounded Quest to Produce Electric Airplanes*, DENVER POST (Aug. 3, 2020, 6:48 PM), https://www.denverpost.com/2020/08/03/aerospace-company-pursues-electric-planes/ [https://perma.cc/DZ29-RLSV] (indicating that Bye Aerospace is continuing to press forward with test aircraft production under FAA oversight).

[38] Correcting the timeline barrier to certification can be approached in a way like that used by the EASA. Like Pipistrel in basing the Velis Electro on the Virus, holders of design certificates for airplanes that can be modified for electric propulsion can pursue a supplemental certificate.[110] What takes multiple years for a new design certification requires only an amendment to the original type certificate in response to a "major change" to the design.[111] While this helps existing manufacturers to fast-track aircraft electric conversions of existing aircraft into production, new designs that optimize the performance of electric powerplants—especially by startup companies seeking to specialize in electric aircraft—must still go through the full certification process.[112] And unlike the 737 Max, these aircraft would involve electric propulsion components clearly requiring new certification, not simply "minor" design modifications. Certification of legacy aircraft would not be especially problematic for a firm seeking to build aircraft that make new uses of existing technologies; the FAA already has institutional knowledge of fossil fuel systems and of best practices in their application. The problem lies in the lack of any institutional knowledge of electric propulsion at all. The firm building a new fossil fuel powered aircraft knows what to expect when beginning the type certification process; the electric aircraft startup is travelling into uncharted waters. The certification process for electric propulsion, without codification of safety limits, involves a great deal of uncertainty in the individual knowledge and risk tolerance of FAA inspectors. Even if inspectors want to certify an airplane, there is no codified basis upon which a company could rely to reasonably expect certification. Although the first certifications to occur in this environment will produce lessons learned to aid in future certifications, the stage is set for great difficulty in accomplishing the initial work.

[110] *See Velis Electro Is for You Because You Are Looking For...*, PIPISTREL, https://www.pipistrel-aircraft.com/aircraft/electric-flight/velis-electro-easa-tc/ (describing how the Velis Electro is a "derivative of the proven Virus"); 14 C.F.R. § 21.113 (2021).

[111] 14 C.F.R. § 21.113 (2021).

[112] *See id.*

[39] Like the EASA, the FAA lacks a cohesive regulatory structure for electric airplanes. Worse still, many regulations contain language that precludes the use of electric motors without the issuance of special conditions.[113] Fortunately, the FAA can issue special conditions to provide certification standards that supersede these preclusions, just as the EASA did in proposing special conditions for electric propulsion.[114] Special conditions would provide an interim solution to provide guidance for industry until sufficient consensus can coalesce into established safety regulations. That consensus is already well on its way in the form of ASTM standards, and the EASA leveraged that institutional knowledge in its own certification program.[115]

[40] The EASA's experience with the Velis Electro illustrates the potential in revamping established certification processes, even when faced with disparate national interests. As the aviation regulator of the European Union, the EASA serves the national interests of numerous countries, as well as other "EASA associated countries."[116] Notably, among the first countries receiving deliveries of the Pipistrel Velis Electro is Switzerland, whose officials composed a large portion of the certification team for the

[113] *See* Rob Mark, *Pipistrel's ALPHA Electro Earns Canadian Certification*, FLYING (Feb. 15, 2018), https://www.flyingmag.com/pipistrels-alpha-electro-earns-canadian-certification/ [https://perma.cc/6PRR-WVC3] (explaining the provisions for "light sport aircraft" require the installation of "a single, reciprocating engine, if powered").

[114] *See* 14 C.F.R. § 11.19 (2020) (explaining the definition of a "special condition" and how it can be used to fill in the gaps in airworthiness regulations that "do not contain adequate or appropriate safety standards, because of a novel or unusual design feature").

[115] Data Sheet, *supra* note 80, at 11 (relying on ASTM F2840-11 for engine and engine parts specifications).

[116] *Frequently Asked Questions – European Aviation Safety Agency (EASA)*, FED. AVIATION ADMIN. (May 8, 2012), https://www.faa.gov/aircraft/air_cert/international/easa/media/EASA_FAQ.pdf [https://perma.cc/N83X-Y5ZG].

aircraft.[117] By comparison, the FAA's interests are much more consolidated than those of the EASA. Whereas the EASA must regulate under the complicated EU governing structure, the FAA receives its mandate from Congress and works directly with interested parties.[118] The FAA's rules and orders are binding on regulated parties, compared with the more limited role of the EASA in relying on member states' aviation authorities to implement its standards.[119] Although states retain jurisdiction over product liability claims against aircraft manufacturers,[120] the federal supremacy enjoyed by the FAA on certification prevents the agency from having to rely on individual states' assent to pass rules that promote increased efficiency and safety in aviation. That said, the willingness of the Administration to prioritize regulatory expansion into electric propulsion plays a critical part in whether the FAA will have an easier time in passing such rules. Structurally, the FAA is just as capable as the EASA in making the changes needed to enable the certification of electric airplanes. Politically, the FAA's priorities depend largely on those of the President, subject to institutional inertia.[121] Just as did the EASA in certifying the Velis Electro in under three years, prioritization of airplane electrification would move

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[117] *See* Garrett-Glaser, *supra* note 80; EASA, *supra* note 2.

[118] *See A Brief History of the FAA*, FED. AVIATION ADMIN. (Jan. 4, 2017, 4:42 PM), https://www.faa.gov/about/history/brief_history/ (explaining the evolving role of the FAA from its inception through its work with industry to advance safety and capacity in aviation).

[119] *See, e.g.*, *FAQ n.19224: What Does the Agency Do?*, EASA (Nov. 29, 2013), https://www.easa.europa.eu/faq/19224 (explaining the EASA's role in "monitor[ing] the implementation of standards through inspections in the Member States . . .").

[120] *See* Sonja Soehnel, Annotation, *Products Liability: Personal Injury or Death Allegedly Caused by Defect in Aircraft or its Parts, Supplies, or Equipment*, 97 A.L.R. 3d 627 § 2 (2020) (indicating that "the courts have generally held that compliance may be considered by the trier of fact in aircraft products liability cases, with a few courts adding that compliance cannot be a complete defense).

[121] *See, e.g.*, *FAA Top Policy Issues*, U.S. DEP'T TRANSP. (Oct. 26, 2016) (delineating the agency's policy priorities in a call for Congressional re-authorization).

the ball on the development of either special conditions for electric propulsion, or a revamp of Part 33 to include such standards. Either of these options is a question of political will to pursue climate change goals and to enable cost reductions for industry. As the Biden Administration propagates its policy goals throughout federal agencies, prioritizing FAA certification efforts toward electric aircraft understanding and industry cooperation would go a long way toward supporting wider climate objectives. Following the EASA's example would be a strong first step. But an important question remains if an electric airplane is certified for commercial use in the United States: who will buy it?

IV. Mitigation Through Incentives

[41] Up-front cost is a major factor in any purchase decision, regardless of the expected long-term savings.[122] Although the market scale is different, the electric automobile incentive structure provides a compelling example for how to promote investment in electric airplanes. The choice between a fossil fuel powered vehicle and an electric vehicle usually comes down to initial cost, even though buyers realize long-term savings through reduced maintenance costs.[123] Economies of scale and wide availability for refueling on-the-go both lower the cost of fossil fuel vehicles and make them appear more approachable for long-term usage in all conditions.[124] Like purchasers of cars, airplane customers face the same pressures.

[42] Encouraging the adoption of electric automobiles, Congress enacted statutes intended to reduce carbon dioxide emissions from transportation through two primary routes: (1) greenhouse gas emissions standards

[122] *See* K. Nandini Tornekar, *Barriers & Solutions to EV Adoption*, ELECTRICVEHICLES.IN (Nov. 23, 2019), https://electricvehicles.in/barriers-solutions-to-ev-adoption/ [https://perma.cc/7PMZ-CQNC].

[123] Amy Stein & Joshua Fershée, *Decarbonizing Light-Duty Vehicles*, 48 ENVTL. L. REP. 10596, 10603–04 (2018).

[124] *See id.* at 10609.

(including alternative fuel programs),[125] and (2) purchase incentives.[126] Emissions standards require manufacturers to produce vehicles that, on average, achieve a certain level of reduction of carbon dioxide output. Although the Clean Air Act empowers the EPA to set vehicle emissions standards, Section 209 allows California to seek a waiver to enforce its own standards, so long as the standards are "at least as protective of public health and welfare" as federal standards.[127] Further, other states may adopt California's standards as long as "such standards are identical to the California standards for which a waiver has been granted for such model year."[128] The mandate of particular levels of efficiency directly affects the supply and types of vehicles available from which purchasers may choose.

[43] Incentives for the purchase of electric vehicles in turn reward consumers for making the choice to purchase an electric vehicle. This reward reduces the purchase price of the vehicle, usually through a tax

[125] *See generally* 42 U.S.C. § 7521 (2020); *Regulations for Emissions from Vehicles and Engines*, U.S. ENV'T PROT. AGENCY (Dec. 18, 2020), https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-onroad-vehicles-and-engines [https://perma.cc/X2XZ-R8SW] (consolidating emissions regulations for onroad vehicles, both light- and heavy-duty).

[126] *See* Shoshannah Lenski et al., *The Impact of 'Cash for Clunkers' on Greenhouse Gas Emissions: A Life Cycle Perspective*, 5 ENV'T RSCH. LETTERS 1, 1 (2010) (describing the emissions impacts of the Consumer Assistance to Recycle and Save (CARS) Act through rebates "toward the purchase of a new, more fuel-efficient vehicle"); *Federal Tax Credits for New All-Electric and Plug-In Hybrid Vehicles*, U.S. DEP'T ENERGY (Feb. 22, 2021), https://fueleconomy.gov/feg/taxevb.shtml#:~:text=Federal%20Tax%20Credit%20Up%20To%20%247%2C500%21%20All-electric%20and,of%20the%20battery%20used%20to%20power%20the%20vehicle [https://perma.cc/NV6R-PUV4] (listing electric and plug-in hybrid vehicles approved for tax credits, and the amounts of available credits).

[127] 42 U.S.C. § 7543(e)(2)(A) (2020).

[128] 42 U.S.C. § 7507(1) (2020).

credit, which encourages the consumer to make the jump.[129] Once past the initial sticker shock associated with current electric vehicles, the expectation is that the consumer will realize the long-term savings associated with the purchase so that they continue to keep and use the vehicle.

[44] Aviation would benefit by using similar incentives to encourage adoption of electric aircraft. The FAA has so far focused on design efficiencies and alternative jet fuels to achieve emissions reductions.[130] But the FAA, or other stakeholder agencies empowered by Congress, could incentivize airplane operators through purchase rebates, just as car purchasers are incentivized to purchase electric cars via tax credits. Each of these routes has a part to play in electric aviation.

A. Emissions Targets & Alternative Fuels

[45] Through its international obligations, the FAA is required to develop and implement GHG emissions reductions.[131] The International Civil Aviation Organization (ICAO), the aviation arm of the United Nations, "adopted a comprehensive climate change resolution committing to reducing" emissions, under which the FAA set an "aspirational goal of achieving carbon-neutral growth for U.S. commercial aviation by 2020, using 2005 emissions as a baseline."[132] The plan to achieve this goal focused on increased aircraft fuel efficiency through "programs in three primary areas: (1) improved aerodynamics, (2) weight reduction, and (3) increased

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[129] *See* Hearst Autos Rsch., *What is an Electric Vehicle Tax Credit?*, CAR & DRIVER, https://www.caranddriver.com/research/a31267893/electric-vehicle-tax-credit/ [https://perma.cc/5XXZ-KRAV].

[130] *See* NEXTGEN IMPLEMENTATION PLAN 2018-19, *supra* note 21, at 70.

[131] *See ICAO Council adopts new CO2 emissions standard for aircraft*, ICAO (Mar. 6, 2017), https://www.icao.int/Newsroom/Pages/ICAO-Council-adopts-new-CO2-emissions-standard-for-aircraft.aspx [https://perma.cc/S5B8-Z7LU].

[132] GHG REDUCTION PLAN, *supra* note 19, at 8–9.

engine efficiency."[133] In addition to addressing the fuel efficiency of individual aircraft, the FAA sought to increase system-wide efficiency by improving air traffic management through the NextGen system.[134] Finally, the FAA pursued development of "drop in" alternative jet fuels, or biofuels, to displace fossil fuels and produce 50 to 80 percent reductions in GHGs.[135]

[46] These efforts to reduce emissions in aviation have borne little fruit. Very few of the NextGen goals for system efficiency improvements have been achieved.[136] NextGen goals have shifted away from discrete efficiencies toward higher airspace capacity, leading to a net increase in traffic volume.[137] The overall focus of NextGen is to squeeze as much "juice" as possible out of the airspace structure, which in the end may see reduction in emissions per mile travelled per capita, but an overall increase in emissions through sheer volume of traffic. Further, aviation biofuels are "more expensive than jet fuel," proving to be an important barrier to adoption since fuel "account[s] for 22% of direct costs on average" to airlines.[138] Complicating matters for airlines, many members of the public view airlines negatively in the context of climate change, forcing airlines to address their carbon footprint to re-attract passengers.[139] Though airlines

[133] *Id.* at 16.

[134] *Id.* at 20–21 (describing NextGen, a foundational re-engineering of the air traffic control system, and how it equips operators with better aircraft separation capabilities and reduced wait times, leading to a reduction in fuel usage across the system per mile travelled).

[135] *Id.* at 28–30.

[136] NEXTGEN IMPLEMENTATION PLAN 2018-19, *supra* note 21, at 71 (indicating only three of twelve programs complete, plus four more that are "operationally available").

[137] *See id*. at ii.

[138] Le Feuvre, *supra* note 20.

[139] *See* Myanna Dellinger, *Airline Bailouts and Climate Change Re-regulation*, 47 KY. L. REV. 95, 98 (2020).

could pass these costs to customers as a premium for flying cleaner, the price sensitivity of the market is unlikely to support such a move.[140]

[47] In Fall 2020, the EPA stepped in to propose emissions standards for airplanes, much as it has done for automobiles nationwide. In order to comply with ICAO requirements and to satisfy its 2016 finding in regard to aviation emissions under section 231 of the Clean Air Act, the EPA proposed a rule applicable to turbojet and turbofan airplanes over 12,566 pounds and turboprop airplanes over 19,000 pounds.[141] Of note, the affected aircraft are those most likely to be able to travel internationally from the United States, and therefore be subject to jurisdiction in other countries under ICAO rules.[142] While establishing such standards prevents U.S.-built aircraft from being banned internationally, the rule may do little to meaningfully reduce emissions: it is applicable only to new type certificates with applications after January 1, 2023 and/or in-production types newly built after January 1, 2028.[143] Industry also indicates that the goalpost has shifted to "carbon neutral growth *in the near term* and to cut net carbon emissions in half in 2050 relative to 2005 levels."[144] That said, airplane manufacturers will likely build at scale in accordance with the most restrictive standards that they face, just as automobile manufacturers partner with the California Air Resources Board to develop standards that can apply

[140] *See id*. at 97.

[141] Control of Air Pollution from Airplanes and Airplane Engines: GHG Emission Standards and Test Procedures, 85 Fed. Reg. 51,556, 51,565 (Aug. 20, 2020) (to be codified at 40 C.F.R. pts. 87, 1030).

[142] *See* Kelsey Reichmann, *EPA Releases First US Airplane Emissions Rules, Environmental Groups Express Criticism*, AVIATION TODAY (Dec. 29, 2020), https://www.aviationtoday.com/2020/12/29/epa-releases-first-us-airplane-emissions-rules-environmental-groups-express-criticism/ [https://perma.cc/K4KF-9DPD].

[143] Control of Air Pollution from Airplanes and Airplane Engines: GHG Emission Standards and Test Procedures, 85 Fed. Reg. at 51,571.

[144] Shepardson, *supra* note 8 (emphasis added, internal citations omitted).

evenly nationwide without the manufacturers needing to produce multiple versions of a vehicle to meet varying standards.[145]

B. Federal Tax Credit

[48] As seen in the context of electric automobiles, tax credit programs serve a critical role in reducing the sting of high initial prices and establishing an initial market. In the U.S., new plug-in electric vehicles qualify for up to $7,500 tax credit on the first 200,000 qualifying vehicles from each manufacturer.[146] Given a choice of vehicles, "high purchase prices [are] a barrier to adoption and . . . consumers tend to ignore the potential for long term running cost savings" from reduced fuel consumption and minimal maintenance costs, all while the perception of shorter range tends to turn U.S. consumers away from electric cars.[147] Tax incentives counter this tendency by offsetting the initial higher price of electric vehicles. The effect would likely be more visible to consumers, and thus more effective, if the value of the offset was realized at the time of purchase rather than at the end of the tax year.[148] Subsidies must also be continued long enough for the market for electric vehicles to establish

[145] *See California and Major Automakers Reach Groundbreaking Framework Agreement on Clean Emission Standards*, CAL. AIR. RES. BD. (July 25, 2019), https://ww2.arb.ca.gov/news/california-and-major-automakers-reach-groundbreaking-framework-agreement-clean-emission [https://perma.cc/T3DT-TL7E] (explaining the importance of framework agreements in the context of regulatory rollback at the federal level).

[146] I.R.S. Notice 09-89, 2009-48, C.B. 714, https://www.irs.gov/pub/irs-drop/n-09-89.pdf [https://perma.cc/BNJ8-AU2U].

[147] Scott Hardman et al., *The Effectiveness of Financial Purchase Incentives for Battery Electric Vehicles – A Review of the Evidence*, 80 RENEWABLE & SUSTAINABLE ENERGY REVS. 1100, 1108 (2017).

[148] Zifei Yang et al., *Principles for Effective Electric Vehicle Incentive Design*, INT'L COUNCIL CLEAN TRANSP. 5 (2016).

beyond early adopters to the "late majority" of consumers.[149] Coupling these incentives with higher duties on fossil fueled vehicles amplifies the effect.[150] Regardless, government subsidies directly correlate to increased demand for electric vehicles, even during a time when demand "had been decimated by [a] pandemic."[151]

[49] Like cars, airplanes are operated by both individuals/families and by corporate fleets, and are thus an important target for electric airplane incentives. According to Mark Baker, president of the Aircraft Owners and Pilots Association, small airplanes (collectively referred to as "general aviation") serve numerous roles, from private transportation—including filling gaps to areas unserved by airlines—to disaster relief.[152] These aircraft are generally owned by individuals or small businesses, those most in need of support to shift to electric airplanes. These small businesses serve a large portion of the training market for pilots, a business for which the performance characteristics of electric airplanes are well-suited, providing training flights at lower hourly cost and with reduced airport noise.[153]

[50] The effects of purchase subsidies are not unique to automobiles, and a carefully designed regulatory structure could see significant cost savings leading to electric airplane proliferation. Purchase credits would help

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[149] Hardman, *supra* note 147, at 1110.

[150] *See id*.

[151] Oliver Sachgau, *Europe Electric-Car Subsidies Have Market Exceeding China Sales*, BLOOMBERG GREEN (Aug. 13, 2020, 11:38 AM), https://www.bloomberg.com/news/articles/2020-08-13/europe-s-electric-car-subsidies-has-market-exceeding-china-sales [https://perma.cc/3D5W-NJ33].

[152] *See* Rich Karlgaard, *Why Small Plane Aviation Boomed in the COVID Economy – And Why the Future is Electric. Q&A with AOPA's Chief, Mark Baker*, FORBES (Oct. 7, 2020, 2:58 PM), https://www.forbes.com/sites/richkarlgaard/2020/10/07/why-small-plane-aviation-boomed-in-the-covid-economy---and-why-the-future-is-electric-qa-with-aopas-chief-mark-baker/?sh=66a6d1f04262 [https://perma.cc/SN4P-6A7R].

[153] *Id.*

training providers acquire these airplanes, reducing costs for prospective students as well as burdens on the surrounding community. As the technology advances and aircraft with increasing range become available, additional incentives to encourage airports to install charging infrastructure will multiply adoption and such aircraft will be able to take on more roles beyond short-distance pilot training missions. Also, just as maintenance is less costly and less burdensome in electric cars compared to their internal combustion counterparts, electric airplanes are likely to require less repair. Regulations could take these realities into account in requiring different, and potentially less costly, maintenance intervals.[154]

[51] In addition to federal tax credits, states can provide incentives of their own to inspire electric aircraft adoption, just as they do for electric cars and supporting infrastructure. For instance, many states provide purchase rebates and tax credits for electric vehicles of various types.[155] They also, either directly or in partnership with utilities, provide incentives for businesses to install electric vehicle charging infrastructure.[156] These types of programs would translate well to local airports, where the benefits of reduced pollution and noise would improve the lives of state residents.

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[154] *See generally* Joseph Flaig, *Electric Aircraft Pose New Challenges for Maintenance and Repair*, INST. MECH. ENG'RS (Mar. 16, 2020), https://www.imeche.org/news/news-article/electric-aircraft-pose-new-challenges-for-maintenance-and-repair [https://perma.cc/7VCN-ZARU] (explaining that electric drive components will require unique maintenance actions, including potentially simplified processes through component replacement/recycling rather than direct repairs).

[155] *See Electric Car Tax Credits & Incentives*, ENERGYSAGE (June 30, 2020), https://www.energysage.com/electric-vehicles/costs-and-benefits-evs/ev-taxcredits/#:~:text=State%20and%20local%20electric%20car%20tax%20credits%20,or%20conversi%20...%20%2024%20more%20rows%20 [https://perma.cc/T7R3-UT3E].

[156] *See, e.g.*, *Electric Vehicle (EV) Charging Incentives*, CHARGEPOINT, https://www.chargepoint.com/incentives/commercial/?type=13&state=58 [https://perma.cc/U9HP-NRYE] (providing information, for instance, about Dominion Energy's Smart Charging Infrastructure Pilot Program, which "provides rebates for qualifying business customers to purchase EV charging stations" and other related services).

[52] Further, localities play an important part in investment decisions by airport operators and users. For a public airport, elected officials in cities and counties with jurisdiction over the airport make critical decisions on renovations that use tax revenue and bond debt.[157] Direct funding such as this would make an immediate impact if directed toward electric aircraft support infrastructure. But even private airports would benefit through targeted property tax incentives. Cities and counties could even broaden their focus, incentivizing installation of solar generation and battery storage resources on and around airport property. Together with electric airplanes themselves, this level of infrastructure investment would enable zero emission aviation alongside the numerous electrical grid reliability benefits provided by solar and storage.[158] By generating renewable fuel on-site, localities can reduce aviation's net impact on the energy balance to zero, producing significant savings for residents

V. CONCLUSION

[53] Federal policy changes according to the priorities of the administration in power. The government sets expectations against which industry functions. By setting benchmarks, such as emissions reduction goals, the government sends signals to market participants indicating society's values, above and beyond those values attenuated through the supply and demand process.[159] These values in turn play a critical role in

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[157] *See generally* Matt Olberding, *Lincoln Airport Moving Forward on Terminal Renovation, Will Use Property Tax to Fund It*, LINCOLN J. STAR (Oct. 24, 2020), https://journalstar.com/business/local/lincoln-airport-moving-forward-on-terminal-renovation-will-use-property-tax-to-fund-it/article_0b3757ae-1619-545f-b4ac-f4a48feadfa7.html [https://perma.cc/A3XH-4AP4] (describing city officials' plan to levy a property tax to fund a $44 million airport terminal renovation).

[158] *See Energy Storage*, U.S. DEP'T ENERGY, https://www.energy.gov/oe/energy-storage [https://perma.cc/TB64-2RBG] (describing the benefits of energy storage coupled with renewable energy generation resources, including grid stability and reliability and "cost reductions through capacity and transmission payment deferral").

[159] *See* Robin Paul Malloy, *Framing the Market: Representations of Meaning and Value in Law, Markets, and Culture*, 51 BUFF. L. REV. 1, 29 (2003).

the ongoing development of the market. Companies respond with research and development aimed at making the best product at the lowest possible price, within the constrains set by government-established benchmarks.

[54] All else being equal, competition drives innovation. But when the cost of aviation fuel lacks the externalities of climate change,[160] government incentive is needed to right the balance. As one of the largest single aviation markets in the world, the U.S. needs to stay at the forefront of technology innovations. Electric aviation is on the precipice of becoming a commercial reality; FAA certification will play a critical role in determining whether the U.S. market will continue to be competitive in aviation globally. Setting the expectation for the industry and guiding its expertise, through both targeted regulatory enhancements and financial incentives, will produce a revolution in aviation technology that will benefit communities and the world for decades.

[55] The Biden Administration should pursue electric aviation as one avenue to support climate objectives. Although current battery technology only supports limited use in small aircraft, the electric vehicle industry constantly drives improvement in batteries.[161] Batteries will soon support widespread commercial aviation use, and the Administration must anticipate that innovation with a regulatory effort that acknowledges and enables its incorporation. This effort will be a shining example of government and private industry moving hand-in-hand to produce a brighter future for all.

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[160] *See, e.g.*, Robert Rapier, *There Are Some Benefits to a Higher US Gas Tax*, BUS. INSIDER (Feb. 27, 2018, 7:33 PM), https://www.businessinsider.com/there-are-some-benefits-to-a-higher-us-gas-tax-2018-2 [https://perma.cc/TDP9-7XBC] (explaining the external costs of gasoline that are not reflected in the market price of the commodity).

[161] *See* Fred Lambert, *Tesla Battery Researchers Mention Enabling Electric Aircraft with New Batteries*, ELECTREK (Aug. 13, 2020, 11:09 AM), https://electrek.co/2020/08/13/tesla-battery-enabling-electric-aircraft/ [https://perma.cc/T92S-ZQUS].