THE FUTURE OF SUSTAINABLE

AVIATION:

BETTING ON JET PROPULSION & LOWER NET CARBON FUELS

GREEN AVIATION STARTS HERE

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The Future of Sustainable Aviation: Betting on Jet Propulsion and Lower Net Carbon Fuels

A booming middle class, expected to reach 5 billion people by 2030, will likely double the demand for air travel in the next 20 years.[1] Urbanization trends suggest that this growing middle class will reside primarily in cities, increasing the need for commercial aviation as people travel the world for business and pleasure.[2] Global aviation plays a vital role in advancing the healthy growth of urban areas around the world. By enhancing "air connectivity," commercial air travel promotes innovation, trade, and tourism, supporting directly or indirectly 3.4 percent of the world's economy.[3] However, global connectivity comes at a cost. Commercial air travel accounts for about 2 percent of man-made carbon dioxide emissions,[4] a figure that is projected to rise to 3 percent by 2050.[5]

Luckily, the aviation industry is tackling the issue head-on.[6] In October 2016, the United Nations' International Civil Aviation Organization (ICAO) established the first-ever carbon dioxide reduction mandate for air travel.[7] The new ICAO regulations:

- Aspire for carbon-neutral growth for international air travel after 2020. Beginning in 2021, participating countries must not exceed carbon dioxide emissions levels consistent with carbon-neutral growth by adopting new fuel-efficient technologies, utilizing lower net carbon fuels, and/or investing in certified carbon offsets.

- Require that new airplanes certified after 2023 reduce carbon dioxide emissions substantially based on a metric accounting for aircraft size and weight.

Meeting these efficiency and emissions reduction goals would represent an inspiring story of sustainability from one of the world's truly global industries. To be successful, however, candor is essential. Hype — especially around technology — can create unmet expectations, divert resources, and undermine progress.

This paper is Part 2 in a series of three. Click to read Part 1, "The Modern Silk Road: Aviation in the Age of Sustainable Urbanization."

IN BRIEF

- With global air traffic expected to increase by 4 to 5 percent annually, the aviation industry has committed to aggressive goals to support this economic growth while substantially reducing carbon emissions.
- For the next several decades, the future of cleaner, greener aviation rests heavily upon gas turbines.
- Investment in design, infrastructure, and operations can also play a meaningful role in reducing aviation emissions.
- With continued investment from industry and support from government, lower net carbon fuels can enable commercial aviation to meet its most aggressive, long-term sustainability goals.

A Reasonable Path Forward

Although the path toward achieving the ICAO targets is promising, there are three fundamental limitations that must be addressed:

No Substitutes: About 80 percent of all aviation industry greenhouse gas (GHG) emissions are related to passenger flights exceeding 900 miles, for which there is no other feasible travel alternative in terms of speed, efficiency, and cost.[8] As a result, aviation must meet its sustainability goals in a world where air travel is expected to double in the next 20 years.

No "Magic Bullets": The development of new power sources in aviation is time-consuming and expensive. In the aviation industry, resources are typically devoted to sophisticated products that will be in service for decades. Although progress in solar and electric propulsion is interesting, the future of cleaner aviation rests in more practical solutions, like enhancements in gas turbine propulsion.

No Quick Fix: Alternative fuels are rapidly developing but still available only in minimum quantities. These fuel sources are "wild cards" with respect to meeting the industry's sustainability goals. Making these new energy sources widely available and affordable without delay has the potential to advance commercial aviation to meet its aspirational 2050 goals.

Given these limitations, and assuming 4 to 5 percent annual growth in passenger demand,[9] one reasonable path forward to a carbon-neutral future includes:

Gas Turbine Propulsion: The industry could find 1.5 to 2 percent of its annual GHG emissions reductions from enhancements in gas turbine propulsion. Equipment manufacturers historically have delivered 1 to 1.5 percent improvements in fuel efficiency and carbon reduction on an annual basis.[10] Through fleet renewal and retrofit, the first geared turbofans are now poised to meet or exceed this historical reduction in carbon emissions. Success will require investment and adoption across the industry. It is a large undertaking: Today's fleet of 26,020 aircraft is expected to grow to over 52,000 by 2036.[11] This level of growth would require the production of new airplanes valued at more than $5 trillion.[12]

Design, Operations, and Infrastructure: Another 0.5 to 1 percent improvement in annual GHG emissions could come from new airframe efficiencies and enhancements to general operations and industry infrastructure. These improvements might include reduced wing drag, lighter cabins, improved air routes, and a focus by airports on sustainability. Together with improved gas turbine technology, these enhancements can recapture 2 to 2.5 percent in emissions – about half of the 4 to 5 percent growth in expected demand.

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Between 2009 and 2014, the air transport industry improved annual fuel efficiency by 2.4 percent, a rate surpassing its initial annual goal through 2020 of 1.5 percent[13] and in line with this forecasted path forward.

Lower Net Carbon Fuels: The remaining 2 to 2.5 percent annual reduction in GHG emissions required to meet the 2050 ICAO goals could come from the development and implementation of lower carbon, sustainable fuels, especially biofuels. A number of promising biofuels have been adopted on a limited basis, and some even have the potential to cut lifecycle carbon dioxide emissions by up to 80 percent compared to traditional jet fuel,[14] but it is a challenge to produce and distribute new energy sources like this on a large scale.

However, economics is currently more of a hurdle than technology or scale. Airlines face intense competition for passengers, while oil prices remain volatile. Biofuels, although a sustainable alternative, can cost airlines up to three times more per gallon than traditional jet fuel, which costs less per gallon than the bottled water served to passengers.

As industry and government are successful in addressing these economic hurdles, lower net carbon fuels are expected to account for about half of aviation's GHG reductions through 2050. The industry can also employ economic instruments like carbon offsets and global emissions trading to bridge some delays in technology adoption.

A Sure "Big Bet": Gas Turbines

Equipment suppliers have been tackling environmental issues head-on in response to airline requests for more efficient aircraft, and the results have been significant throughout the last few decades. Commercial jets are now about 70 percent more fuel-efficient than they were in the 1960s, and noise reduction has improved even more. Over 5 billion metric tons of carbon dioxide have been avoided since 1990 through the production of 25,000 new aircraft at the cost of $3 trillion.[15] Between 2000 and 2014 alone, U.S. airlines carried 20 percent more traffic using 8 percent less fuel, which resulted in an 8 percent reduction in carbon emissions.[16]

Each year, civil aviation invests some $20 billion in research and design, about 70 percent of which is dedicated to fuel reduction technology

These gains were not accomplished by luck or chance, but from substantial investments and decades of relentless focus on innovation by a host of committed companies. Each year, civil aviation invests some $20 billion in research and design, about 70 percent of which is dedicated to fuel reduction technology.[17]

For the foreseeable future, cleaner, greener aviation will depend heavily upon gas turbines. Pratt & Whitney's PurePower® Geared Turbofan™ (GTF) engine, for example, is poised to transform the single-aisle commercial aviation segment by reducing fuel burn by 16 percent, particulate emissions by 50 percent, and noise footprints by 75 percent overall. In 2016, the company achieved a milestone when Airbus delivered the first GTF-engine-powered A320neo to Lufthansa German Airlines. Coupled with the addition of winglets (devices that are added to the end of an aircraft's wings to help reduce drag), the A320neo achieved a 20 percent increase in fuel efficiency.[18] Following Airbus was the delivery of the GTF to Bombardier Aerospace for its CSeries. The GTF is now in production for 70 customers in more than 30 countries including the Embraer E-Jets E2 family (with 16 to 24 percent in emission reductions expected per seat[19]), the Irkut MC-21, and the Mitsubishi Regional Jet, among others.[20]

The environmental benefits of the GTF engine are so significant that all of the world's single-aisle airliner manufacturers have either announced new aircraft featuring the engine or are re-engining existing models.

Over the next 10 years, Pratt & Whitney's GTF engine has the potential to enable airlines to save about 11 billion gallons of fuel valued at about $25 billion (at current prices), avoiding 106 million tons of greenhouse gas emissions.[21] The GTF engine itself has a potential upgrade that could reduce fuel burn and carbon dioxide emissions by an additional 2 percent in 2019.

A collaborative test performed on a Pratt & Whitney advanced concept combustor in a NASA test cell shows some of the new opportunities presented by the GTF engine. The results demonstrate a reduction in oxides of nitrogen (NOx) to about 88 percent below current regulations.[22] This outcome is a good example of how revolutionary technology like the geared turbofan can inspire a steady stream of incremental improvements that could substantially boost the impact of the original technology.

What about other potential "big ideas," like electric propulsion, long promised as a greener alternative to gas turbines?

Ironically, modern commercial aircraft engines at cruise altitude are more efficient at producing power than ground power production and distribution. In fact, a large airplane engine is the most efficient device on the planet for making power. Even if a commercial electric aircraft could operate with a small, light battery — still beyond today's technology — it would produce more total carbon dioxide than a gas turbine-powered plane. Today's commercial fleet of airplanes actually creates less carbon dioxide than the world average for electric production – a trend that is expected to continue for the next few decades.

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Other Good Bets: Design, Infrastructure, and Operations

When the International Air Transport Association (IATA) laid out a path to meet aviation's goal of 1.5 percent annual GHG reductions through 2020, it relied heavily on engine efficiency gains from fleet renewal.[23] This is consistent with the "reasonable path forward" discussed earlier. However, IATA offered a series of other improvements to help reach both the 2020 and 2050 ICAO goals, provided they are implemented simultaneously and receive adequate investment over time.

Composites are one such technology. Engineers have continually introduced newer and better materials into aircraft design. Recently, for example, carbon fiber reinforced plastic used in the fuselage and wings has reduced weight and helped streamline aircraft. Improvements to the landing gear on a jet, which can contribute 15 percent to improved efficiency, rely on roughly 50 composite technologies that are formally tracked and managed.[24] New materials have been introduced to reduce the weight of everything from food service carts to baggage containers. Even seats have seen upgrades; some airlines replaced existing seats with new composites that were 30 percent lighter and offered more leg room to passengers.[25]

On the ground, airports have been increasingly focused on sustainability as part of aviation's overall commitment to going green

In addition, small changes to the airframe design, broadly applied, can substantially diminish GHG emissions. The installation of winglets has saved almost 5.3 billion gallons of jet fuel and 56 million metric tons of carbon dioxide emissions since 2000.[26]

The aviation industry has been unyielding in identifying any small advantage to reduce weight and drag. Even heavy, paper-based flight manuals have been swapped for lighter tablet computers — a small but real contribution to reducing GHG emissions.

On the ground, airports have been increasingly focused on sustainability as part of aviation's overall commitment to going green. This includes their pivotal role in optimizing the movement of aircraft around the world. This area offers a wealth of potential improvements that must be tackled as flight volumes grow.

Single European Sky ATM Research (SESAR)

The Single European Sky ATM Research (SESAR) project was founded in 2007 to coordinate resources and ensure the modernization of the European air traffic management system. Current estimates suggest that the European ATM system will need to handle over 46,500 flights daily by 2030. This number could swell to 50,000 flights on especially busy days. Compare these projections to the figures in 2010: At that time, the European ATM system was responsible for 9.5 million flights that generated 19.4 million minutes of delays, costing an estimated €4 billion (US $4.5 billion).[27]

Now in its eighth year, SESAR consists of 45 partners who run 84 implementation projects in 23 European countries. Members include air navigation service providers, airport operators, and airspace users.[28] The organization's vision is "trajectory-based operations," which allows an aircraft to fly in the most direct path possible without being constrained by airspace configurations. SESAR's goals include higher levels of security and safety, up to 40 percent reduction in air navigation services per flight, and a system capable of handling 100 percent more capacity while reducing departure delays by 30 percent. If successful, the SESAR project could create up to 6 percent reduction in flight times, 10 percent reduction in fuel burn, and a 10 percent reduction in carbon emissions, resulting in improved air quality and less noise.[29]

U.S. FAA Next Generation Air Transportation System (NextGen)

The U.S. Federal Aviation Administration (FAA) is undertaking similar work in its Next Generation Air Transportation System (NextGen). NextGen launched in 2007 and is designed to move airplane guidance systems from radar to satellite, shortening flight paths, expanding airspace without compromising safety, and burning less fuel. By 2035, the FAA expects the 90,000 flights a day it currently handles to grow to 125,000.[30] As in Europe, flight delays in the U.S. have already taken their toll on airlines and passengers. In 2014 alone, U.S. commercial airlines lost $9.1 billion to delays, including $4.3 billion in wasted fuel.[31]

Once all planned NextGen programs are in place, the FAA expects this initiative to deliver $160.6 billion in benefits through 2030. This includes societal benefits equalling $114.2 billion in the value to passengers of time saved, and $212 million in reduced carbon dioxide emissions.[32]

The simple arithmetic of performance-based navigation enabled by SESAR and NextGen is a compelling reminder of how critical these initiatives are to meeting aviation's 2020 and 2050 goals. For each metric ton of fuel saved, carbon dioxide emissions are reduced by more than 3 metric tons.[33]

The global nature of aviation presents challenges for uniform environmental and economic standards. Nations can have unique development needs and economic factors that impact compliance. With this fact in mind, the ICAO has been tasked with devising a market-based measure to assist with carbon-neutral growth, intended to be applicable to the entire aviation industry. A single, global plan is scheduled for review in the fall of 2016 and slated for implementation in 2020. Options under consideration include a global levy or tax and a global emissions trading scheme. The current preferred option, a carbon offset mechanism, allows for qualifying offsets to be purchased on the open market. Properly constructed, this measure would give developing nations a real chance to grow air travel in ways that support economic development and healthy urbanization while still meeting aviation's overall emissions targets.

"Airlines are committed," says Sharon Pinkerton, Senior Vice President of Legislative and Regulatory Policy for Airlines for America. "We've got the goals. But we do see some of the fast-growing countries saying, 'We haven't had our chance to grow.' Our challenge really comes down to government-industry collaboration."[34]

The global nature of aviation presents challenges for uniform environmental and economic standards

One estimate suggests that the industry will need to invest $5.6 billion in offsets in 2030.[35] If successful in creating a single, global market-based measure, ICAO and the commercial aviation industry will demonstrate a powerful and unique kind of climate leadership.

A Promising "Big Bet": Lower Net Carbon Fuels

The steady replacement of traditional fossil-based jet fuel by lower net carbon energy sources represents the most promising bridge between today's improving performance and aviation's ultimate goals. Lower net carbon energy sources include synthetic fuels involving coal, natural gas, and biomass feedstocks from a variety of plants.

Any alternative fuel designed for commercial aviation must pass several tests. A biofuel, for example, must have high energy density and a low freezing point. It must work with existing aircraft anywhere in the world. It must neither compete with food production nor damage biodiversity.[36] It must provide investors with a competitive return. And, of course, it must be affordable and price competitive, either through market forces or with government assistance.

There is obvious interest; between 2003 and 2013, biofuel research attracted more than $126 billion in investments.[37]

Alternative Fuels in Flight

Virgin Atlantic flew the first commercial flight powered by biofuel in 2008 when it added coconut and nut oil to the engines of a 747. This proved the viability of biofuel and encouraged the industry to seek new, sustainable agriculture-related sources.

In 2009, United Airlines became the first U.S. carrier to operate a demonstration biofuel flight. Two years later, United operated the first commercial advanced biofuel flight.[38] In 2014, Finnair flew an Airbus A330 fueled with 10 percent biofuel derived from cooking oil.[39]

Substantial gains have been made in a relatively short period. Second- and now third-generation fuels are virtually identical to the Jet A-1 fuel currently being used, which means they require no new engines or aircraft, or even a separate delivery system. In March of 2016, United flights between Los Angeles and San Francisco began using renewable fuel. The fuel, sourced from non-edible natural oils and agricultural wastes, was the first of its kind in the U.S. used for regular commercial flights. The mix of 30 percent biofuel resulted in GHG emission reduction of about 60 percent.[40] Also in March, KLM Royal Dutch Airlines successfully launched a series of test flights from Oslo to Amsterdam using biofuel produced from camelina oil (sometimes called “false flax”).[41] This is a particularly attractive energy source because it is grown on marginal farmland and helps enrich the soil for food crops.

Most recently, in one of the largest renewable jet fuel purchases to date, JetBlue announced plans in September 2016 to acquire 330 million gallons of blended jet fuel over 10 years. Produced from rapidly renewable, bio-based feedstocks, this fuel is targeted to achieve a 50% or higher reduction in greenhouse gas emissions per gallon, based on a life-cycle analysis.[42]

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On the Horizon

Industry can now produce attractive, sustainable fuels from used cooking oil, municipal waste, algae, agricultural and forestry waste, non-edible crops, carbon monoxide (from steel production), and a nicotine-free variety of tobacco. Grown in South Africa, this variety of tobacco creates not just fuel, but a byproduct that can be fed to animals — a second cash crop for struggling farmers.[43] In the United Arab Emirates, work is underway to produce biofuel by growing saltwater-tolerant plants using wastewater from aquaculture.[44]

The industry goal is to replace 6 percent of fuel with biofuel by 2020

Canada's Biojet Supply Chain Initiative (CBSCI) is a three-year collaborative project designed to introduce over 105,000 gallons of biofuel into a shared fuel system at a Canadian airport. Fourteen stakeholders are involved in attempting to create a sustainable supply of biofuel using renewable materials.[45] FedEx, which operates a fleet of more than 600 aircraft, has pledged to obtain 30 percent of its jet fuel from alternative sources by 2030. FedEx will use waste wood biomass for jet fuel production, which promotes smart forest management and supports sustainable local businesses in a number of locations.[46]

The Sustainable Aviation Fuel Users Group (SAFUG) was founded in 2008. Today, it is comprised of airlines that make up 33 percent of the global commercial aviation fuel demand.[47] SAFUG is committed to the development of alternative fuels that do not reduce food security and are sustainable in respect to land, water, and energy.

More than 2,000 commercial flights by more than 20 airlines have used alternative aviation fuel from renewable sources.[48] The industry goal is to replace 6 percent of fuel with biofuel by 2020.[49] Full lifecycle assessments of some biofuel alternatives indicate potential improvement over fossil fuel by 80 percent.[50]

The upside of lower net carbon fuels can be spectacular. But one industry observer noted, "For the coming years, the price gap between sustainable and fossil jet fuel remains the biggest challenge to create a stable market for sustainable jet fuel."[51] Since 1998, jet fuel has ranged from a low of $.30 per gallon to a high of $4.00 per gallon, with a three-year stretch beginning around 2011 of $3.00 per gallon falling dramatically from 2014 to about $1.00 per gallon today.[52] At $3.00 per gallon, investment in alternative fuels can be attractive. At $1.00, few investors are anxious to scale production in a way that will match the growth in passenger miles.

Economic and regulatory policies must play a role if sustainable fuels are to be commercialized at a pace required to meet the industry's carbon emission goals. Questions include the balancing of priorities between air and road sectors, and between alterative and fossil fuels; supporting research aimed at alternative energy; supporting public and private investment in often expensive production facilities; and incentivizing airlines to use alternative fuels once they are available.

Pratt & Whitney and Sustainability

UTC and Pratt & Whitney are committed to keeping the GTF engine as the green solution of aviation technology, creating a cleaner world for generations to come

Pratt & Whitney completed the development of its first aircraft engine in 1925. Over 90 years later, the company has become a world leader in the design, manufacture, and service of aircraft engines and auxiliary power units. Pratt & Whitney's parent company, United Technologies Corp., provides high-technology systems and services to the building and aerospace industries. "At our core, UTC is an engineering and manufacturing leader that solves big problems and does big, complex things," says President and CEO Greg Hayes. "Our world is changing, and trends in urbanization and population growth require more sustainable products and behaviors."[53]

In 2015, the Air Transport Action Group (ATAG) cited Pratt & Whitney's PurePower® Geared Turbofan™ engine as an Aviation Climate Solution at the Global Sustainable Aviation Summit in Geneva, Switzerland.[54] Aviation Climate Solutions was released alongside an open letter from industry chief executives that reaffirmed the industry's commitment to climate action. In the same letter, governments were called upon to support ATAG with the development of a global market-based measure for aviation emissions, improved efficiency in air traffic management, and accelerating research for alternative fuels and new technology.

Pratt & Whitney's GTF engine exemplifies the long-term commitment United Technologies Corp. has to innovation and sustainability in products and operations. The company was named Engine Manufacturer of the Year in the 2016 Air Transport News Awards. UTC and Pratt & Whitney are committed to keeping the GTF engine as the green solution of aviation technology, creating a cleaner world for generations to come.

Pratt & Whitney's story is part of a broader shift in the U.S. aerospace manufacturing sector, which exported $126.3 billion and imported $64.2 billion worth of goods in 2013.[55] Over the next five years, Pratt & Whitney plans to double commercial and military engine production from about 700 engines in 2015 to about 1,400 by 2020.

By 2025, Pratt & Whitney aims to have zero waste in its factories, but 100 percent of all factory waste that is produced will be recycled. Greenhouse gas emissions, already reduced by 30 percent, are targeted to decline in this period by 80 percent.[56] Consumption of water is also targeted to decline by 80 percent.[57]

The company's Revert Management Program is designed to capture scrap aerospace engine materials at the end of their life and return as much as possible to the industry's supply base for reuse. In three years, the Revert Management Program has processed and shipped more than 600,000 pounds of material back to Pratt & Whitney suppliers for recycling. The recycling and reuse of scrap resulted in companywide savings of approximately $5 million.[58]

Pratt & Whitney is also an active member of the Aircraft Fleet Recycling Association (AFRA), a Boeing-led partnership that strives to recycle aircrafts, components, engine material, and other resources critical to the aerospace industry.[59]

At the parent company level, United Technologies is uniquely positioned to meet the challenge of efficient aviation head-on through existing technology, processes, and innovation. The company has tripled its revenues since 1997 while reducing water consumption by 57 percent and GHG emissions by 34 percent. The company is on track to reduce GHG emissions 80 percent by 2050 in support of the United Nations climate goals.

Sustainability is core to UTC's business growth. For almost 30 years the company has made significant progress and is committed to doing more. When it comes to sustainability, it's not an option – it's an imperative.

By 2025, Pratt & Whitney aims to have zero waste in its factories, but 100 percent of all factory waste that is produced will be recycled

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