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Sustainable Aviation Fuel: Reality or Mirage?

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Sprinkled among posters touting tropical beaches, snow-covered mountains, and foreign capitals, recent travelers through airports may have noticed airlines promoting a new destination: a commitment to a sustainable future.

These advertisements, hung along jetways and broadcast in seat-back displays, reflect the aviation industry's efforts to both recognize and reduce the impact of its operations on climate change, especially those associated with greenhouse gas (GHG) emissions.

And while progress will be made, the question remains whether an on-time arrival to the green destination suggested by these advertisements is achievable and, if so, which technologies will contribute most to the journey.

Houston, We Have a Problem

Similar to trends seen in other industries, passenger and cargo airlines are taking steps to increase the visibility of efforts to reduce and mitigate GHG emissions. Their actions reflect the expansion of government regulatory initiatives and the changes in consumer preferences driven by public awareness of adverse environmental impacts of businesses. By communicating GHG goals, such as the pledge made by most major U.S. airlines to be net-zero by 2050, the aviation industry is demonstrating to businesses and consumers that it is serious about emissions and climate change. Achieving those goals and satisfying related regulatory requirements, like the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), however, will require real progress toward both eliminating and mitigating aircraft GHG emissions.

But for the aviation industry, finding solutions that reduce or mitigate GHG emissions is especially difficult. While operational changes (e.g., single engine taxiing) provide limited immediate and near-term GHG reductions, and some mid- to long-term GHG reductions will come from technological advances (e.g., advanced materials and engine efficiency), neither address the elephant in the fuselage: No viable alternative to hydrocarbon-based aviation fuel exists for powering large aircraft or long-distance flights. As explained below, this is not a matter of a lack of industrial will — it is the consequence of today's battery technology and the laws of physics as currently understood.

Recognizing that the combustion of hydrocarbon-based fuels will be an essential component of air travel for the foreseeable future, the majority of the industry's sustainability and GHG reduction efforts are focused on making the fuels consumed sustainable. Rather than eliminating GHG emissions from the combustion process, these fuels — collectively referred to as sustainable aviation fuel or SAF — mitigate those emissions on a "lifecycle" basis as part of the production process. By using renewable feedstocks and various existing and developing technologies, SAF producers create a fuel for which the combination of GHGs removed and avoided during production result in net GHG emissions that are far less than those associated with jet fuel produced using conventional hydrocarbon feedstocks.

Despite the apparent promise of SAF, it remains uncertain whether SAF will be able to satisfy the sustainability needs of the aviation industry. In particular, can SAF production be scaled to the volume needed to satisfy fuel requirements, which the U.S. Department of Energy estimates to increase from roughly 100 billion gallons presently consumed each year to 230 billion gallons per year in 2050? And if SAF volumes can be scaled, can it be done quickly enough to enable airlines to satisfy their GHG emissions goals?

Why SAF?

Accepting the importance of SAF to the future sustainability of the aviation industry requires making a comparison of the benefits, disadvantages and practical realities of the various alternatives. Along with SAF, the aviation industry has given significant attention to electrification of aircraft via batteries and hydrogen fuel cells and to the direct combustion of hydrogen, particularly due to the potential to completely eliminate GHG emissions from their use. Unfortunately, while SAF alternatives likely have a role to play in the future of air travel, each has substantial barriers that dramatically limit their feasibility for most applications within the industry.

The most readily apparent limitation associated with the use of alternative aviation technologies is one of infrastructure and design. The current aviation industry is based on existing aircraft types and technologies that rely on liquid fuels. Converting to an electric or hydrogen-combustion aviation industry would first require further development and maturation of the necessary aviation technologies, followed by the design, testing and certification of new aircraft types based on those technologies.

While efforts are underway in these areas, their success is uncertain and, in any event, many years away from being realized. For example, Airbus has set a target date of 2035 for the development of the world's first hydrogen-powered commercial aircraft through its ZEROe hydrogen program. But even if new aircraft based on electric or hydrogen combustion technologies are eventually introduced, replacement of the existing fleet would take over 20 years and some applications, such as long-haul flights, may never be suitable for electric or hydrogen-combustion. The need for side-by-side operation of such new aircraft types would require extensive, and very expensive, changes to the existing airport infrastructure. Boeing's chief sustainability officer, Christopher Raymond, stated the issue plainly in his January 2023 article published by Fortune: "it is arithmetically impossible to replace the world's fleets with hydrogen-powered airplanes in time to meet the industry's 2050 [net-zero] target."

Even ignoring design and infrastructure challenges, a significant barrier to the adoption of electric and hydrogen aircraft is found in the technology itself. A key consideration for any potential aviation power system or fuel is its energy density, or the amount of energy it provides in relation to its mass or volume. Fuel with high energy density, like jet fuel (including SAF), provides more "bang for the buck" than fuels with a low energy density, like batteries and hydrogen. It is the high energy density of jet fuel that, for example, makes a nonstop flight from Houston to Sydney, Australia, possible today.

Because of the low energy density of the fuel source, for an electric or hydrogen-powered aircraft to achieve the same range as a conventional aircraft, much more space must be dedicated to battery or fuel storage. This additional space for battery or fuel storage means that much less space is then available to carry passengers or cargo. For hydrogen, the storage of fuel at temperatures below negative 420 degrees Fahrenheit (yet one more challenge to overcome) would occupy as much as four times the volume of jet fuel and, unlike jet fuel, cannot be stored in the wings of the aircraft. And without radical advancements in battery technology, the weight of the batteries required makes more than a flight from Austin to Houston with just a few passengers practically impossible.

Compared to battery and hydrogen-powered aircraft, increased use of SAF presents far fewer challenges to implementation. In particular, substantial net reductions in GHG emissions can be achieved immediately by blending SAF and conventional jet fuel to meet standards required for use in existing aircraft. Even now, such blended SAF is being delivered and comingled with conventional jet fuel at airport fuel storage facilities around the world. As a next step in SAF evolution, aircraft and engine manufacturers are working on modifications to existing designs that will enable SAF to be used as a "drop-in" fuel in aircraft types already in production. This evolution is already well on the way to realization, as evidenced by the December 2021 announcement by United Airlines, working with GE Aviation, Boeing and others, of the first commercial passenger flight conducted using 100 precent SAF in one of the plane's two engines.

Is SAF Scalable?

While SAF offers many benefits that can help the aviation industry achieve its net-zero GHG emissions goals and regulatory requirements, it remains to be seen whether it will be possible to produce SAF in the volumes required to materially reduce reliance on conventional jet fuel and, if so, how quickly that capacity can be brought online. Given the potential impact that increased production of SAF may have on other industries, the outcome of the question will likely be affected by the influence of competing interests on economic considerations, regulatory developments, and policy preferences. And while current trends support the investment in infrastructure required to produce SAF along with research into advanced SAF production methods, this has not always been the case and may change again in the future.

One key to the successful development and growth of SAF infrastructure is the relationship between the price for SAF and the price for conventional jet fuel. According to data from the U.S. Department of Transportation's Bureau of Transportation Statistics, fuel costs represented approximately 25 percent of the total operating expenses of U.S. passenger airlines for 2022. As such, even small differences between the price of SAF and the price of conventional jet fuel can have significant impacts on a carrier's bottom line. If SAF is not available at prices comparable to conventional jet fuel, competitive considerations among airlines will likely limit purchases of SAF, pushing the industry to instead meet sustainability targets indirectly through carbon offsets and thereby slowing development of SAF production capacity.

Across the transportation sector, the cost of producing renewable and low-carbon fuels has been higher than the cost of producing conventional fuels. Various production and blending credits, together with low-carbon fuel standards, can help offset that additional cost, but policy considerations have historically favored the production of renewable diesel. Because the substantial overlap in hydrocarbon composition and boiling point range of diesel and jet fuel allows refineries to produce either product with little modification in equipment, the availability of such incentives for renewable diesel has discouraged the production of SAF. Statistics published by the U.S. Department of Energy show that in 2018 refiners produced over 300 million gallons of renewable diesel but only 2 million gallons of SAF using the same technology.

As evidenced by the enactment of the Inflation Reduction Act of 2022, domestic policy incentives are gradually shifting in a direction that supports SAF production. Under the Inflation Reduction Act, tax credits starting at $1.25 per gallon are available in connection with the sale or use of SAF having at least a 50 percent reduction in lifecycle GHG emissions, with the amount of the credit increasing by one cent per gallon for each additional percent of reductions in excess of the 50 percent minimum. And while it remains to be seen what other incentives may emerge from the program, the federal government's Energy, Agriculture and Transportation departments have created a "Sustainable Aviation Fuel Grand Challenge" that, in collaboration with industry, includes goals of 3 billion gallons of domestic SAF production by 2030 and 35 billion gallons (100 percent of projected domestic jet fuel use) by 2050.

If It's Meant to Be …

Despite the various uncertainties related to the growth of SAF, perhaps the greatest indicator of what the future may hold is the actions of the aviation industry and its business customers. With government priorities changing from election cycle to election cycle, some members of the aviation industry and related businesses have adopted the position that direct involvement is necessary to overcome challenges to large-scale SAF production. The investments such companies are making, both directly and through contractual obligations, demonstrate a commitment to SAF as a necessary component of the future of sustainable flight.

Over the past few years, airlines have started making long-term SAF purchase commitments with companies developing SAF refineries and advanced technologies. Given the time and expense associated with developing and constructing SAF refineries, obtaining a long-term fuel offtake agreement is often necessary to support the financing of a project. United Airlines, for example, has already announced SAF agreements with multiple producers and covering over five billion gallons. These contracts reflect an expectation that, despite open issues ranging from the future availability of government incentives to unresolved logistical matters related to SAF blending and transportation, all elements of the SAF industry will mature significantly over the next few years.

Various airlines are also providing support for the growth of SAF through direct investments in startup companies developing advanced feedstock and production methods and construction of SAF refineries. With the range of SAF technologies under development, these investments provide financing for further research and scaling necessary to determine which will be the most viable solutions. One such investment, the United Airlines Ventures Sustainable Flight Fund announced in February 2023, reflects a nearly $200 million commitment by United Airlines and its fund partners, including Air Canada, American Express Global Business Travel, Aramco Ventures, Bank of America, Boeing, Boston Consulting Group, GE Aerospace, Hawaiian Airlines, Honeywell, JetBlue Ventures, JPMorgan Chase and others, intended to accelerate SAF research, technologies and production.

In addition, airlines are collaborating with business customers from industries as diverse as athletic apparel manufacturers, consulting firms and tech companies to help share in the cost and benefits of SAF production and use. As these companies work to reduce their own GHG emissions, they must also account for the emissions of their vendors and suppliers, including those that occur when employees and cargo fly on aircraft operated by airlines. This collaboration reflects that the achievement of sustainability goals by non-aviation companies is in part dependent on the achievement of goals within the aviation industry. By participating in programs like United's Eco-Skies Alliance, which allows participants to receive GHG reduction benefits by helping to cover the additional cost of SAF as compared to conventional jet fuel, and American Airlines' Cool Effect program, which allows passengers to buy carbon offsets to offset emissions on their ticketed flights, airline customers support the additional purchase and use of SAF.

Looking Forward …

For all the uncertainty regarding the extent to which SAF will actually enable airlines to achieve ambitious 2050 net-zero targets, its importance to those goals is apparent. While the development of alternative technologies from batteries to hydrogen-based fuels is progressing, practical realization of those technologies is still years away and, given energy density issues, is likely to be reserved for niche uses such as hydrogen-powered commuter flights and intercity passenger drones and perhaps some midrange aircraft applications. And though government and industry commitments to the development of SAF are helpful, expanding the availability of feedstocks and production capacity to meet growing demand for jet fuel will be a difficult process. Building on years of progress, the aviation industry will undoubtedly continue to reduce its impact on the environment, but only time will tell just how green the skies may be when 2050 arrives.

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