Sustainable energy for aviation: What are our options?

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Scientists and industry leaders worldwide are looking for answers on how to make aviation sustainable by 2050 and choosing a viable sustainable fuel is a major sticking point. Phil Ansell, aerospace engineer

at the University of Illinois Urbana-Champaign, took a full inventory of the options to make a data-driven assessment about how they stack up in comparison. He reviewed over 300 research projects from across different sectors, not just aerospace, to synthesize the ideas and draw conclusions to help direct the dialogue about sustainable aviation toward a permanent solution.

The study, "Review of sustainable energy carriers for aviation: Benefits, challenges, and future viability," by Phillip J. Ansell, appears in the journal *Progress in Aerospace Sciences*.

Ansell said several key energy carriers emerged, including bio jet fuel pathways for synthetic kerosene, power-to-liquid pathways for synthetic kerosene, liquid hydrogen, ammonia, liquid natural gas, ethanol, methanol, and battery electric systems. Ansell compared each of them to conventional fossil-derived aviation turbine fuel.

For each of the alternate fuels Ansell addressed factors such as how their material properties impact aircraft performance and fuel handling, emissions, cost and scalability, and resource and land requirements, as well as social impacts, which can be difficult to measure.

"Let's face it, if we want to do this at scale, we need all three pillars of the environmental, economic, and societal contributions, to make that energy carrier sustainable, and every stakeholder in the value chain sees the challenges differently," Ansell said.

"Because the production and infrastructure costs required to adopt an alternative fuel source are significant, people think we can only pick one, the biggest contenders being bio jet fuel and hydrogen," Ansell said. "But the choice doesn't have to be mutually exclusive. For example, we can use hydrogen to produce synthetic aviation fuels like the power-to-liquid pathway or use biomass to produce hydrogen."

Ansell admitted this is not what he typically studies, but his research and teaching areas in aircraft design and aerodynamics must consider where the energy will come from to make flight possible. So, for any fuel associated with a bio aspect Ansell had to look at the stresses it might create for crops.

"I leaned on a lot of the observations from the community, especially for the land use change question," he said. "It is so driven case by case. Making a broad assessment doesn't do it justice, because land use changes depend on their location."

Ansell said he has been working with hydrogen for several years and battery/electric systems before that, so he needed to remain objective and all the data to drive the conclusion.

"About eight years ago, I realized that battery systems are a pie-in-the-sky solution. The technology challenge is insurmountable. The weight and volume required for batteries is too difficult to close. I think my biases were from the fact that I've been studying hydrogen for a long time, and I think it has real potential. That's one of the conclusions I arrived at from the data, and I think I would have learned that independently."

Ansell said hydrogen presents infrastructural and integration challenges, unique to the aircraft platform and unique to the cryogenic handling of fuel on aircraft.

"The technological challenges of hydrogen are very solvable. And I can say that with confidence because we've done it as a society." He referred to Tupolev 155, a commercial scale aircraft which was flown by the former Soviet Union with liquid hydrogen in the 1980s on a relevant airframe. Even earlier experimental studies were conducted by NASA. "It will take a bit longer to implement at scale, but it's doable."

In the study, Ansell examined numerous options to produce biofuel from just about anything, from municipal waste to seaweed and algae.

"Basically, anything that you can burn, create energy from, decompose, can be turned into a jet fuel. We've already been using corn to produce ethanol. But if you were to take corn, ferment it, then turn that ethanol into jet fuel, you now have lost the ability to feed people or animals that corn. This is one of the challenges of all first-generation biofuels."

He said people are trying to use the stover, the parts of a corn plant left on the ground after harvesting to make fuel. Corn stover is full of sugar but it's difficult to extract.

Why is an aerospace engineer studying feedstocks?

"I want to be able to know enough to interact with scientists who are tackling these options," Ansell said. "And it's important that the aviation community understands where the challenges exist. We need to draw the lines between the aircraft as a system, the aircraft operating in an airspace, and how that connects with energy. With a goal of net zero CO_2 by 2050, I want the aviation community to recognize how big of a task this is.

"As a society, we are often attentive to challenges that are right in front of us, with limited foresight to plan for the future. So even as it pertains to the greenhouse gas effect, we still don't have an appreciation for the long-term sense of the damage that produces. We have other immediate concerns to spend money on. But without that foresight, we are going to struggle and regret decisions not to make investments and not to take seriously these aviation sustainability challenges when we still had time."

Again, Ansell stressed that it might not need to be a one-fuel-fits-all solution. In fact, countries may need different strategies, different rates

of implementation, and adoption of renewables, based on their own resources. For example, Denmark doesn't have as much land as the U.S. and so is making great use of offshore wind turbine platforms.

"Maybe we should play to our strengths. The U.S. has one of the world's largest agricultural sectors in the world. We may have more land than Europe that can be allocated to feedstock development, which can be used for a variety of bio-jet fuels or hydrogen production pathways. In contrast, Europe has an extensive network of clean energy, and as such is doing a lot of work in electrolytic hydrogen production."

More information: Phillip J. Ansell, Review of sustainable energy carriers for aviation: Benefits, challenges, and future viability, *Progress in Aerospace Sciences* (2023). DOI: 10.1016/j.paerosci.2023.100919

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