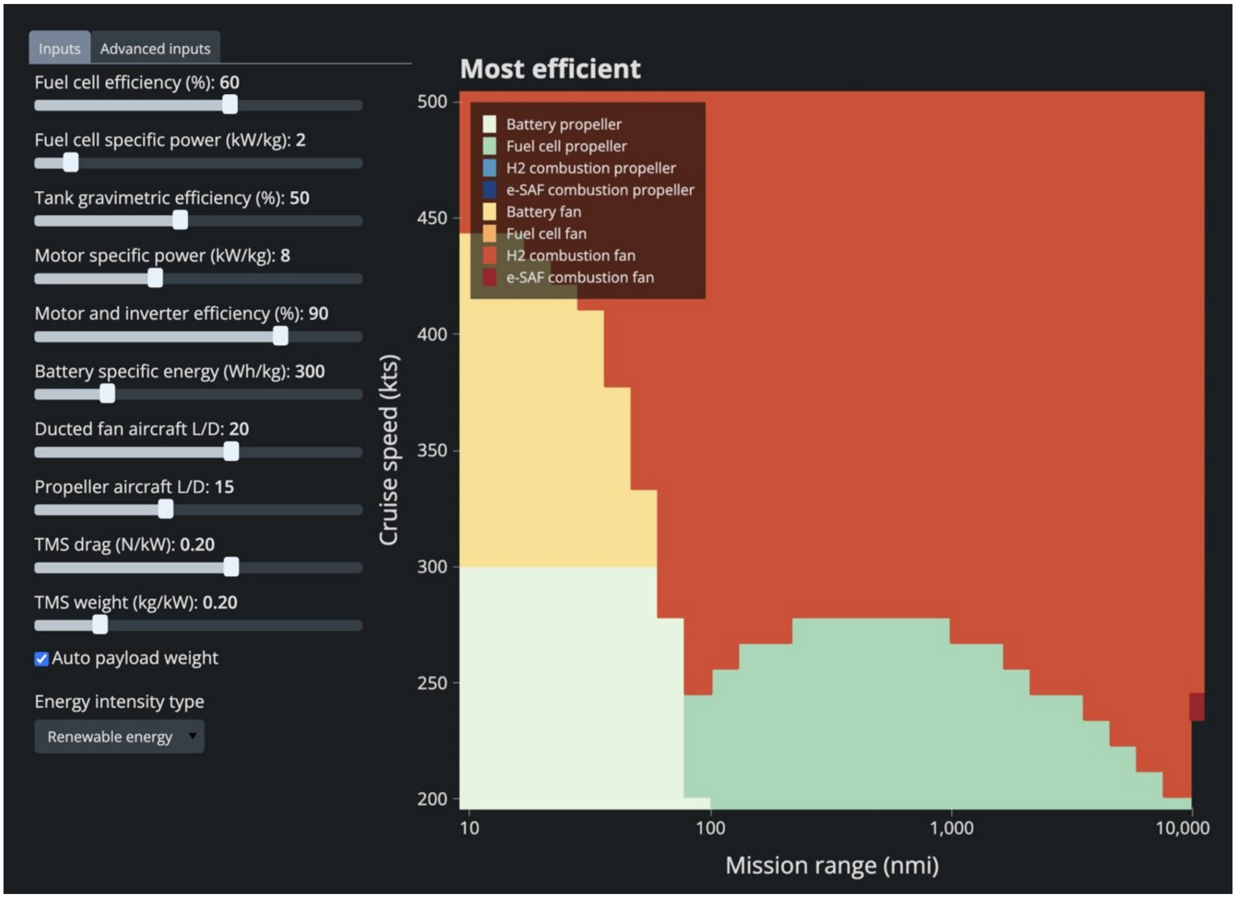
Interactive tool helps find most efficient carbon-neutral aircraft for your flight

January 29 2025, by Kate McAlpine



The StratiFly tool allows users to visualize how shifting technology assumptions (left) impact the most efficient propulsion system for each combination of cruise speed and mission range (right). Credit: *Progress in Aerospace Sciences* (2024). DOI: 10.1016/j.paerosci.2024.101051

OK, we admit, we're a long way from a carbon-free grid—but when we have one, what's the most efficient way to use that energy to fly planes? This question is explored by an interactive tool built by a team of University of Michigan researchers.

"Aircraft provide a fantastic means to transport people and goods anywhere in the world within a day. We want to keep this capability, but with a lower climate impact," said Joaquim Martins, the Pauline M. Sherman Collegiate Professor of Aerospace Engineering at U-M and co-author of the study published in *Progress in Aerospace Sciences*.

Sustainable aviation doesn't have a silver bullet, but it does have a bunch of options. Battery-powered motors would be most efficient if it weren't for the weight of the batteries: 85% of the electricity makes it to the aircraft.

Unfortunately, weight is a big deal. Extra weight demands more lift—the force that holds an aircraft in the air. More lift creates more drag, which demands more thrust, which requires more battery power, which adds weight, and pretty soon the battery is taking up the entire weight formerly allocated to cargo or passengers. As a result, battery power is really best for short hops—metro to regional journeys.

The tool lets users see this and also game out different scenarios. For each combination of range and speed, the researchers pinpointed the least energy-hungry option from four sustainable propulsion systems: e-SAF (synthetic jet fuel produced with carbon captured from the air), battery-electric, hydrogen fuel cell and hydrogen combustion.

"The tool provides a strategy for thinking about what sustainable aviation should look like. It's not an ultimate answer, but a means to compare and evolve these ideas further," said Eytan Adler, a recent doctoral graduate of aerospace engineering at U-M and first author of the study.

The team defined efficiency as the amount of renewable electricity required to generate the fuel that propels an aircraft on a specified mission, which accounts for both sustainability and cost. Currently, fuel makes up 25%–30% of airlines' operating costs and can even edge up to 40% for flights that cross the Atlantic or Pacific oceans.

Of the fuels, e-SAF is the most compatible with existing aircraft. The synthetic fuel would replace jet fuel, negating the CO_2 released in flight with the CO_2 captured from the air during synthesis. Battery-electric aircraft work just like electric cars, using batteries to power an electric motor, but require different aircraft designs to accommodate batteries.

The two hydrogen propulsion systems differ from one another in the way that hydrogen reacts with oxygen from the air. Fuel cells produce electricity, which powers an electric motor. Combustion produces heat, which drives a turbine. While hydrogen fuel cells do not produce nitrogen oxides—a major contributor to air pollution—and may be more efficient than hydrogen combustion engines in some cases, they are heavier.

To assess the propulsion systems, the research team developed a methodology to rapidly estimate aircraft energy consumption for a given mission. It incorporates currently available or soon-to-be available technologies, and users can adjust sliders to find out how changes in key properties of these technologies change which aircraft is best for a given flight.

It answers questions like what if the battery could store more energy for the same weight? What if we could store more hydrogen without increasing the weight of the tank? What if fuel cells were more efficient? And it also addresses properties of the propeller, motor, fan and more.

While batteries are limited to about 100 miles with current technology, they could be good for up to 800 miles or so if the "Batt 1K" target of 1000 watt hours per kilogram is reached.

For longer haul flights, hydrogen fuel is the most efficient. Although producing hydrogen with electricity is half as efficient as sending that electricity straight to a battery-electric aircraft, liquid hydrogen is two orders of magnitude lighter—even considering the weight of the tank. Of the two hydrogen propulsion options, combustion uses renewable electricity most efficiently for faster flights over about 300 knots. Fuel cells are best for slower flights because they are more efficient than small combustion engines.

Since e-SAF requires a large amount of energy to produce, only 26% of the electricity makes it to the aircraft in the form of fuel. This prevents the synthetic fuel from outcompeting hydrogen or battery options with the given technology assumptions.

More information: Eytan J. Adler et al, Energy demand comparison for carbon-neutral flight, *Progress in Aerospace Sciences* (2024). DOI: 10.1016/j.paerosci.2024.101051

Tool: stratifly.engin.umich.edu/gui

Provided by University of Michigan