How will we achieve carbon-neutral flight in future?

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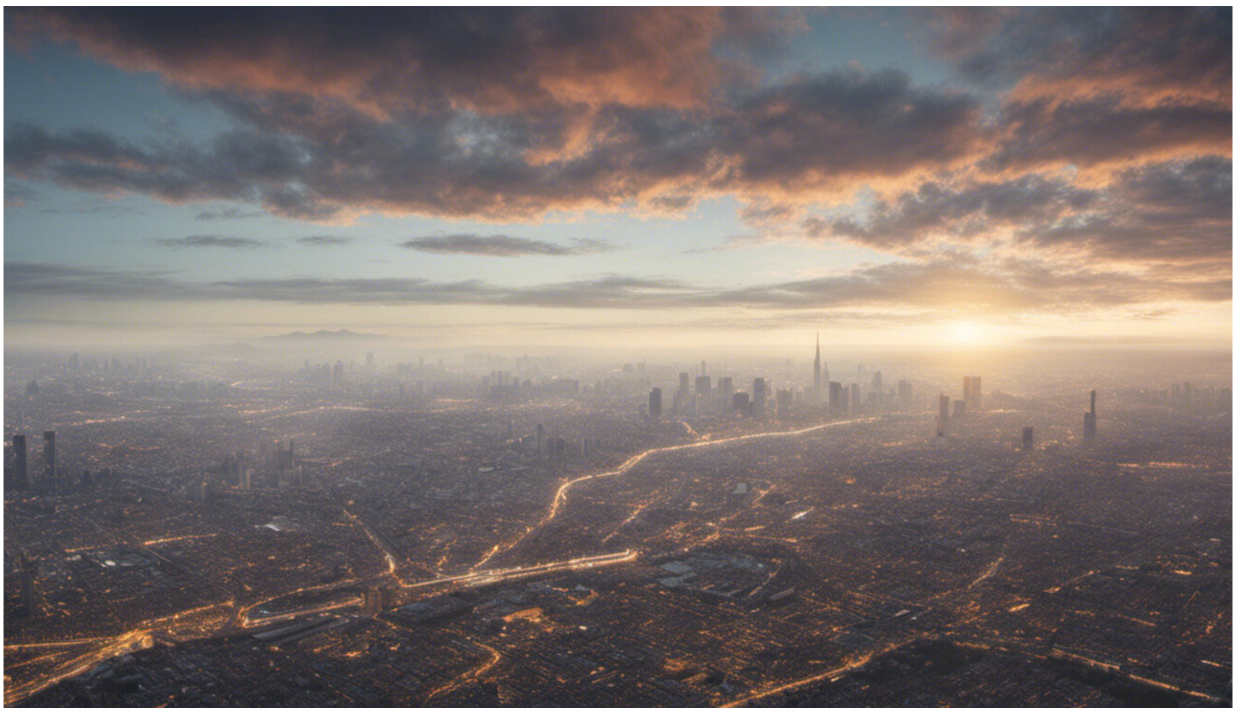

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Carbon-neutral aviation is possible, but in future, aircraft are likely to continue to be powered by fossil fuels. The CO_2 they emit must be systematically stored underground. This is the most economical of various approaches that ETH researchers have compared in detail.

It is politically agreed and necessary for climate protection reasons that our entire economy becomes climate-neutral in the coming decades—and that applies to air travel, too. This is a technically feasible goal, and there are numerous ways to achieve it. ETH Professor Marco Mazzotti and his team have now compared the options that appear to be the easiest to implement in the short and medium term and evaluated them according to factors such as cost-effectiveness.

The ETH researchers conclude that the most favorable option is to continue powering aircraft with fossil fuels in future, but then remove the associated CO_2 emissions from the atmosphere using CO_2 capture plants and store that CO_2 permanently underground (carbon capture and storage, CCS). "The necessary technology already exists, and underground storage facilities have been operating for years in the North Sea and elsewhere," says Viola Becattini, a postdoc in Mazzotti's group and the study's first author.

"The approach may become a cost-competitive mitigation solution for air travel in case, for example, a carbon tax or a cap-and-trade system were imposed on emissions from fossil jet fuels, or if governments were to provide financial incentives for deploying CCS technologies and achieving climate goals," says ETH professor Mazzotti.

Directly or indirectly from the air

Basically, there are two ways to capture CO_2: either directly from the air or indirectly at a site where organic material is burned, for example in a waste incineration plant. "Roughly speaking, half of the carbon in the waste burned in municipal incinerators comes from fossil sources, such as plastic that has been produced from petroleum. The other half is organic material, such as wood or wood products like paper and cardboard," Mazzotti says.

From a climate action perspective, capturing and storing the share of carbon that has fossil origin is a zero-sum game: it simply sends carbon that originated underground back to where it came from. As to the share of carbon from organic sources, this was originally absorbed from the air as CO_2 by plants, so capturing and storing this carbon is an indirect way to remove CO_2 from the air. This means CCS is a suitable method for putting carbon from fossil aviation fuels back underground—and effectively making air travel carbon-neutral.

In their study, the ETH scientists were able to show that indirect carbon capture from waste incineration gases costs significantly less than direct carbon capture from the air, which is also already technically feasible.

Synthetic fuels more expensive

As a further option, the scientists investigated producing synthetic aviation fuel from CO_2 captured directly or indirectly from the air (carbon capture and utilization, CCU). Because the chemical synthesis of fuel from CO_2 is energy-intensive and therefore expensive, this approach is in any case less economical than using fossil fuel and CCS. Regardless of whether the CO_2 is captured directly or indirectly, CCU is about three times more expensive than CCS.

ETH Professor Mazzotti also points out one of CCU's pitfalls: depending on the energy source, this approach may even be counterproductive from a climate action perspective, namely if the electricity used to produce the fuel is from fossil fuel-fired power plants. "With Switzerland's current electricity mix or with France's, which has a high proportion of nuclear power, energy-intensive CCU is already more harmful to the climate than the status quo with fossil aviation fuels—and even more so with the average electricity mix in the EU, which has a higher proportion of fossil fuel-fired power plants," Mazzotti says. The only situation in which CCU would make sense from a climate action perspective is if virtually all the electricity used comes from carbon-neutral sources.

More profitable over time

"Despite this limitation and the fundamentally high cost of CCU, there may be regions of the world where it makes sense. For example, where a lot of renewable electricity is generated and there are no suitable CO_2 storage sites," Becattini says.

The ETH researchers calculated the costs of the various options for carbon-neutral aviation not only in the present day, but also for the period out to 2050. They expect CCS and CCU technologies to become less expensive both as technology advances and through economies of scale. The price of CO_2 emissions levied as carbon taxes is likely to rise. Because of these two developments, the researchers expect CCS and CCU to become more profitable over time.

Infrastructure required

The researchers emphasize that there are other ways to make air travel carbon-neutral. For instance, there is much research underway into aircraft that run on either electricity or hydrogen. Mazzotti says that while these efforts should be taken seriously, there are drawbacks with both approaches. For one thing, electrically powered aircraft are likely to be unsuitable for long-haul flights because of how much their batteries will weigh. And before hydrogen can be used as a fuel, both the aircraft and their supply infrastructure will have to be completely developed and built from scratch. Because these approaches are currently still in the development stage, with many questions still open, the ETH scientists didn't include them in their analysis and instead focused on drop-in liquid fuels.

However, the researchers emphasize that CCS, too, requires infrastructure. The places where CO_2 can be captured efficiently and where it can be stored may be far apart, making transport infrastructure for CO_2 necessary. Science, industry and politics will have to work hard in the coming years to plan and build this infrastructure—not only for CO_2 from aviation, but also for emissions from other carbon-intensive sectors such as chemicals or cement.

More information: Viola Becattini et al. Role of Carbon Capture, Storage, and Utilization to Enable a Net-Zero-CO2-Emissions Aviation Sector, *Industrial & Engineering Chemistry Research* (2021). DOI: 10.1021/acs.iecr.0c05392

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