

What sustainable options are there for jet fuel?

Researchers:

Ausilio Bauen,
Niccolò Bitossi,
Lizzie German,
and others

Associate Editors:

Allison Gamzon and Alexandra Appleton



Abstract

If you could travel anywhere in the world, where would it be? Is it a tropical paradise or the snow-capped mountains? Wherever it is, you might need to take an airplane to get there. Airplanes use kerosene jet fuel to take you to your travel destination. Kerosene jet fuel comes from fossil fuels. When burned, fossil fuels produce carbon dioxide. Carbon dioxide is a greenhouse gas that contributes to global warming.

To reduce global warming, carbon emissions from airplanes

must decrease. That means airplanes will need new fuel sources. We wanted to identify possible sustainable aviation fuels. We also wanted to know if they are already in use or if they are in the research and development stage. So, we did a research review of alternative jet fuels. We found that there are three main alternative fuel types. These include biofuels, hydrogen (and hydrogen-derived) fuels, and electricity. One of the biofuels is already used in airplanes. The other alternatives are still in the research and development phase.

Introduction

Burning fossil fuels is one of the main causes of global warming. This is because fossil fuels produce carbon dioxide when burned. Carbon dioxide is a **greenhouse gas**. It traps outgoing energy from the Earth's surface. Extra carbon dioxide in the atmosphere causes the Earth to warm. A main contributor to carbon emissions is airplane travel. That's because airplanes use jet fuel that comes from oil. This jet fuel has a high **energy density** – a large amount of energy stored in a small amount of fuel. Airplanes need to keep the weight of their fuel down so that they can travel long distances and carry more people and luggage. Air travel currently produces 2% of all greenhouse gas emissions. This will increase as more people travel by airplane.

So, how can the aviation industry lower their carbon emissions? Airplanes will need to use alternative fuels known as **sustainable aviation fuels**. We wanted to know more about the availability and use of alternative fuels for airplanes. That is why we reviewed and summarized information about alternative jet fuels.



Airplanes use jet fuel from fossil fuels and account for about 2% of all greenhouse gas emissions.

Methods

We reviewed information about different sources of fuel for airplanes. These sources are not made from fossil fuels. Then we summarized our findings. We organized what we learned into three categories:

- **Biomass**
- Hydrogen
- Electricity

Results

There are many alternative fuels for airplanes (Fig.1).

Biomass Alternatives

Biomass is organic matter that can be used for fuel. Biomass includes:

- agricultural crops
- forest residues such as leaves, branches, or bark
- waste oils and fats
- sewage
- **manure**
- garbage



Figure 1

The status of different sustainable aviation fuel sources.

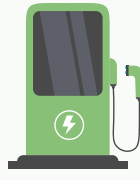
Making fuel from biomass requires different processes.

That's because the structure of each type of biomass is different. Examples of biomass conversion processes are:

Hydrogenation: Scientists add the element hydrogen to vegetable oils and animal fats. This process changes their structure, making them usable as fuel. This is the only commercial **biofuel** alternative used currently by airlines.

Fermentation: Plant sugars and starch change to alcohol, such as ethanol. After the sugar transforms to alcohol, scientists change it into jet fuel.

What percentage of sustainable aviation fuel sources are in the research and development stage?

Biomass	Hydrogen	Electricity
 Oils and fats Status: Commercial use	 Status: Development	 Status: Development
 Garbage Status: Research & Development		
 Human and animal waste Status: Research & Development		
 Crop and forest leftovers Status: Research & Development		

Commercial use - already used by airplanes

Research - being explored by scientists and engineers

Development - being tested using prototypes

Hydrothermal liquefaction: Water and biomass experience high temperatures and pressure. The heat and pressure cause the biomass to change into bio-crude oil. This crude oil is then refined into jet fuel. Scientists are still researching this process.

Hydrogen

Scientists make hydrogen by splitting water (H_2O) into hydrogen gas (H_2) and oxygen gas (O_2) using electricity. To make the hydrogen more usable, scientists cool it down into a liquid. It is then stored in tanks. Using hydrogen requires a redesign of airplanes. They will need space to hold the hydrogen tanks. These tanks can be heavy, so the airplane design will need to include this extra weight. New airplanes also need to include a way to transform the hydrogen into electricity, such as a hydrogen turbine or **fuel cell**. There are several companies working on

hydrogen airplane designs. We can also combine hydrogen with carbon dioxide extracted from the atmosphere. This produces a hydrocarbon fuel similar to current jet fuel that we can use in existing planes. We call these e-fuels.

Electricity

Electric airplanes use batteries to store energy. Then the airplane's systems use this stored energy during flight. Currently there are many hybrid designs. These airplanes use jet fuel during the high energy parts of the flight, such as takeoff. They then switch to the batteries when the airplane is cruising. Many companies are also working on fully electric airplanes. Scientists need to design new battery systems that can store enough energy for long flights. They will also need to redesign the airplane to run only on electricity.

Discussion

Our review showed that there are many alternatives to conventional jet fuel. But we are still exploring many of these options. They are also more expensive. These fuels can be two to five times more expensive than regular kerosene jet fuel. But they do reduce emissions! We estimate that fuels developed using sustainable biomass can reduce emissions by 65% or more. Hydrogen and electricity emissions could decrease by 95%.

We found that biomass fuels and e-fuels are a good alternative fuel. That's because they can provide the same fuel energy density as regular kerosene jet fuel. Their

use also requires the least amount of airplane redesign. Hydrogen and electricity are also good options. But these options need large changes in airplane design. We need to do more research and development to make them usable for long flights.

Some alternative fuels need electricity for their production or use. So, can we still reduce carbon emissions? Yes, if the source of the electricity used to make these fuels is renewable. If the electricity comes from a fossil fuel power plant, the reduction of carbon emissions is much less, or even worse.

Conclusion

You can help reduce the carbon emissions produced by airplanes. Try to take as few airplane trips as possible. Instead, travel closer to home and use public transportation whenever possible. You can also plan a staycation! Take time

to enjoy relaxing activities at home or explore interesting sights in your area. And if you do travel by airplane, try to choose companies that are using sustainable aviation fuels.

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Glossary of Key Terms

Biofuel - a fuel derived from biomass (see below).

Biomass - organic matter. Biomass includes agricultural crops and residues, forest residues, waste oil, sewage, manure, and garbage.

Energy density - the amount of energy stored in a given amount of fuel. Fuel energy density can be measured in the amount of energy per liter of fuel or the amount of energy per kilogram of fuel.

Fermentation - a process performed by yeast and bacteria that breaks down chemicals into new substances. One example of fermentation is when sugars and starches change into alcohol. An alcohol is a chemical substance that contains a hydroxyl group (-OH), which is an oxygen and hydrogen bonded together.

Fuel cell - a device that produces electricity from a chemical reaction. A hydrogen fuel cell produces electricity when hydrogen gas and oxygen gas react to produce water.

Greenhouse gas - a gas in the atmosphere that traps outgoing energy from Earth. This causes Earth's surface to warm. Examples of greenhouse gasses include carbon dioxide, nitrous oxide, water vapor, and methane.

Manure - animal dung used for fertilizing land.

Sustainable aviation fuel - an alternative fuel made from a non-fossil fuel source that reduces emissions from air transportation. Common fuel sources include biofuel, hydrogen, and electricity.

Check your understanding

- 1 Why are we exploring the use of sustainable aviation fuels as a way to reduce global warming?
- 2 Why is the source of electricity used to make sustainable aviation fuels important?
- 3 What is one reason why sustainable aviation fuels are not widely used by commercial airlines?
- 4 Many of the sustainable aviation fuel options are also used for cars. Select one of the fuel types (biomass, hydrogen, or electricity). Research this fuel type and find out if it is an option for cars. If so, report on its status of use in cars. Then share your research with your class.
- 5 With a partner, develop a list of biomass resources available in your area that could be used to make sustainable aviation fuel. Then discuss whether you think these resources should be used to make sustainable aviation fuel. Consider possible pros and cons.

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