Hydrogen and Sustainable Aviation

Until recently, fossil-based liquid fuel has been the primary energy source and carrier for powering flight. Aviation is transitioning to renewable energy sources to reduce life cycle CO_2 emissions. Hydrogen produced with renewable energy sources can greatly improve production of drop-in sustainable aviation fuels and has the potential to be a low carbon impact fuel for use in fuel cell or combustion aircraft propulsion systems.

BOEING'S HYDROGEN DEMONSTRATION PROJECTS

Boeing has conducted six demonstration projects and has extensive experience using hydrogen as a fuel for launch vehicle and space applications. We continue to study and test the potential of this energy source.

2008 Boeing's Fuel Cell Demonstrator, a two-seat Dimona, flew three flights in Spain—representing the first piloted airplane in history to use power generated solely by hydrogen fuel cells.

2012 Boeing's Phantom Eye high-altitude and long-endurance uncrewed aircraft flew several flights in California powered by liquid hydrogen.

2020 Insitu completed the first flight of their ScanEagle3 unmanned aerial vehicle powered by an all-electric, hydrogen fueled, proton exchange membrane (PEM) fuel cell.

2012 Our ecoDemonstrator program tested similar regenerative fuel cell technology for onboard auxiliary power applications on a Next-Generation 737-800.

2015 A second project in Spain completed over 100 hydrogen flights on an uncrewed flight demonstrator.

2021 A new type of composite cryogenic fuel tank was designed and manufactured by Boeing, signifying this lightweight storage technology is mature, ready and safe for use in aerospace vehicles.

CHALLENGES & OPPORTUNITIES

Producing green hydrogen for sustainable aviation fuels requires abundant renewable energy to ensure emissions reductions from flying are not negated during the production portion of the fuel's life cycle.

The larger fuel volume and very cold temperatures required for storage of liquid hydrogen present significant innovation opportunities in aircraft design and systems integration.

All-new distribution, storage and fueling infrastructure for airports around the world must be established for use of hydrogen-fueled airplanes.

WHAT'S NEXT?

Given the urgent need for emissions reductions, our near-term emphasis is on implementation of drop-in sustainable aviation fuels (SAF). Our current and future investments in green hydrogen for aviation will enable the next generation of low-impact, drop-in SAF production as well as future flight and propulsion concepts for **zero carbon emissions.**

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Green hydrogen is produced using renewable energy and can reduce life cycle carbon emissions. Its use in aircraft propulsion requires new design studies, safe certification approaches and platform developments coupled with new system-wide ground and network infrastructure. Based on the level of innovation and infrastructure investment required, hydrogen's role in aircraft propulsion could begin to make an impact in the longer term.

RENEWABLE ENERGY SOLUTIONS EVOLUTION

	NOW & TOMORROW	2030	2040 & BEYOND
Urban 1–8 passengers Range up to 100 nm **Sub-regional** 9–19 passengers Range up to 500 nm	**Battery & Fuel Cell** Low-carbon, electric-powered urban air mobility vehicles such as those powered by batteries or hydrogen fuel cells offer potential to accelerate battery technology development. Battery performance currently limits passenger and range capability.	**Battery & Fuel Cell** Small electrified regional and sub-regional aircraft could be flying in this decade as battery capability improves. Life cycle CO_2 reduction will depend on renewable energy to charge batteries or create hydrogen.	**Hydrogen Fuel Cell** Fuel-cell powered air vehicles could start to penetrate the market in the regional and sub-regional segment. Abundant renewable energy and a widespread hydrogen economy will be required.
Regional 20–80 passengers Range up to 1,000 nm **Short & Long haul** Over 80 passengers Range over 1,000 nm	**Sustainable Aviation Fuels** Outside of operational efficiencies, drop-in SAF is the best available solution to reduce emissions from today's airliners and those that will be built in the coming decades. Currently, drop-in SAF is less than 1% of aviation fuel and high in cost. Innovation, supportive policies and public-private partnerships are crucial to help catalyze commercial-scale production and use.	**Hydrogen for SAF** Hydrogen is required to produce almost all SAF—and must be produced and scaled sustainably to improve life cycle emissions reductions. Over 96% of hydrogen produced today comes from fossil fuels—mostly natural gas.	**Hydrogen Combustion** Aircraft powered by turbine engines using liquid hydrogen fuel are feasible for regional, short-haul and long-haul aircraft. Liquid hydrogen requires over four times the volume of today's jet fuel for the same given energy and must be cooled to -253°C.