Hydrogen
An energy carrier to fuel the climate-neutral aviation of tomorrow
Innovative technologies are putting meaningful reductions in aircraft emissions tantalisingly within reach. It’s now up to the entire industry to decide whether we’re ready to seize this opportunity or simply carry on with business as usual.

At Airbus, we’ve made our decision. Yes, we’re ready. Today. Immediately. We want to be the catalyst for change and are prepared to explore any technology pathway that has the potential to take us there. And hydrogen is emerging as a game-changing contender in this respect.

Why hydrogen? There are a number of reasons.

First, hydrogen offers the possibility to significantly reduce and potentially eliminate all of aviation’s greenhouse gas emissions. In other words, a potential “true zero” solution: no CO₂, NOx, SOx, and soot emissions. That’s astounding progress compared to today’s conventional jet engines. Water vapour is still emitted via hydrogen, but by eliminating soot, persistent contrails can be significantly reduced or eliminated.

Second, “green hydrogen” (i.e., produced by renewable sources) is expected to ramp up at a large scale over the next decade, which will make hydrogen increasingly cost-competitive with existing options, such as jet fuel. It would also essentially allow aviation to be powered by renewable energy.

Third, a major advantage with hydrogen is that it can complement existing refuelling options at most major airports, thereby facilitating wide-scale adoption.

And the list of hydrogen’s advantages goes on, many of which are described in further detail in the pages to come.

Although there’s no “silver-bullet” solution to emissions reduction, we’re confident hydrogen will put us on the right track towards climate-neutral aviation. It’s an investment we’re willing to make today to ensure the viability of our industry tomorrow.

These are exciting times for the aviation industry.
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The emergence of a game-changer

From the hot air balloons of the 19th century to the rockets hurtling towards outer space, hydrogen has fuelled some of humankind’s earliest and most audacious attempts to reach the sky. Today, hydrogen is enjoying unprecedented momentum as a versatile energy carrier that could play an important role in potentially decarbonising a range of industries struggling to reduce emissions on a meaningful scale.

Versatile, zero-emission and storable, hydrogen has all the qualities of a future game-changer in the global energy transition. According to the International Energy Agency (IEA), demand for hydrogen has more than tripled since 1975—and continues to rise each year.1 Although today’s hydrogen is mostly used by industry for oil refining and fertilizer production, tomorrow’s hydrogen is destined for greater levels of grandeur.

The Earth’s lightest, most versatile element
As one of two elements that forms water, hydrogen occurs in vast quantities in oceans, rivers, lakes and the atmosphere. With a standard atomic weight of 1.008, it is the lightest element in the periodic table.

Contrary to popular belief, hydrogen is not an energy source in itself: it is an energy carrier. This means it does not produce energy, it simply contains energy from another source. This distinction makes hydrogen an ideal solution to transport energy for a variety of end uses.

The transition to “green hydrogen”
Hydrogen may be the most abundant element on Earth, but it can be found only rarely in its purest form. It must therefore be extracted using almost any energy source—fossil or renewable. Today, hydrogen is almost entirely produced from fossil fuels. As a result, hydrogen production is an energy-intensive process—responsible for approximately 830 million tonnes of CO₂ per year.2

“Green hydrogen,” or hydrogen produced entirely via renewables, is a low-emission alternative. The IEA predicts the rapid market growth of renewables, particularly solar and wind, over the next decade will exponentially increase the availability of renewable electricity. This is expected to significantly support the wide-scale scale-up of green hydrogen by the 2030s timeframe.

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Hydrogen benefits

Zero emission
No CO₂ emissions when generated from renewables via electrolysis

Energy dense
The highest energy density of any common fuel by weight

Storable
Transportable across long distances via compressed gas or liquid

Safe
No more or less dangerous than other fuels, including natural gas

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Unlocking hydrogen’s potential in aviation

Hydrogen has been the fuel of choice for space exploration since the 1950s. But aside from a few small-scale projects over the last two decades, hydrogen-powered aircraft has yet to take off. Increased industry pressure to decarbonise and innovative hydrogen-propulsion systems are helping to change that.

Today, the aviation industry represents approximately 2.5% of global greenhouse gas emissions. Although aircraft fuel burn is decreasing by approximately 1% per year, aircraft fleet sizes have been consistently growing. As a result, the aviation industry is now in need of long-term, disruptive change to business as usual. And hydrogen has emerged as an attractive option.

Why hydrogen?

- **A potential “true zero” & “carbon zero” solution:** Hydrogen fuel cells are one of only two technology pathways, alongside battery electric, through which no greenhouse gases are emitted. And if fuelled by “green hydrogen,” this could ensure zero emissions throughout hydrogen’s entire lifecycle. Hydrogen combustion also significantly reduces emissions and, when combined as part of a hybrid configuration, the power from the fuel cells helps reduce overall emissions.

- **High energy density:** Hydrogen has a gravimetric energy density that is three times superior to jet fuel and much superior to lithium-ion batteries, making it a good option to fuel large aircraft over long distances. However, hydrogen has a lower volumetric density, thereby requiring a different storage solution on aircraft.

- **Emerging hydrogen economy:** Industries like automotive are taking the lead on maturing end uses for hydrogen. This will help to speed up technology development and drive down infrastructure and production costs, all of which will benefit the aviation industry.

- **Declining costs:** The cost of hydrogen is likely to significantly fall over the next decade, largely due to the declining cost of renewable electricity and the scaling up of the hydrogen economy. This is expected to make zero-emission flying increasingly economical.
The road to zero emissions

Change in emission levels

LOW

Incremental
Greenhouse gas emissions are partly reduced

Net Zero
Net emissions are reduced

Carbon Zero
All gross carbon emissions are reduced to zero

Carbon+ Zero
All gross carbon emissions are reduced to zero. NOx & persistent contrails are significantly reduced

True Zero
All gross emissions are reduced to zero

Engine efficiencies

Net Zero
Net emissions are reduced

Offsets

Hydrogen combustion

Hybrid hydrogen
(hydrogen combustion + fuel cells)

True Zero
All gross emissions are reduced to zero

Hydrogen fuel cells

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Operational improvements
(i.e. ATM)

Sustainable Aviation Fuel

Battery electric
(including propulsion)

Electrification
(excluding propulsion)

Despite its enormous potential to help disruptively decarbonise the aviation industry, hydrogen still faces significant challenges. The availability and cost of hydrogen, as well as infrastructure and public perceptions, remain among the leading challenges.

**Key hydrogen challenges**

- **Technology constraints:** Technologies matured by the automotive and space industries need to be made compatible with commercial aircraft operations, notably by bringing weight and cost down. Also, future hydrogen aircraft will need to achieve equivalent or better safety levels compared to today’s kerosene-powered aircraft before it can take to the skies.

- **Hydrogen availability & cost:** Today, hydrogen is more expensive per kWh than jet fuel. However, declining costs for renewable electricity and the scaling up of green hydrogen production worldwide could make hydrogen increasingly cost-competitive with existing options, such as jet fuel and sustainable aviation fuels.

- **Infrastructure:** Large-scale transport and infrastructure solutions are required to supply airports with the necessary quantities of hydrogen to fuel aircraft. Repurposing existing pipelines to transport large hydrogen quantities and truck transport for smaller quantities are both options. On-site hydrogen production is another option, particularly if a renewable energy supply is within close proximity.

- **Public perceptions:** For over 40 years, hydrogen has been safely used in vast quantities as an industrial chemical and as fuel for space exploration. However, public perception on hydrogen’s safety remains mixed. The growth of hydrogen-powered transport solutions like cars and buses will likely help positively change perspectives.
Hydrogen combustion: the “carbon zero” solution

Hydrogen is combusted in a modified gas-turbine engine to generate thrust, a process that is identical to traditional engine combustion.

- The upside: CO₂ and the majority of soot emissions are eliminated.
- The opportunity: To significantly reduce NOx and persistent contrails.

Hydrogen fuel cells: the “true zero” solution

Fuel cells convert energy stored in hydrogen atoms into electrical power via an electrochemical reaction.

- The upside: CO₂, NOx, SOx, and soot emissions are eliminated.
- The opportunity: To potentially eliminate persistent contrails and Aviation Induced Cloudiness (AIC).
Hydrogen at the heart of climate-neutral aviation

Hydrogen is one of the most promising zero-emission technologies to reduce aviation’s climate impact. This is why Airbus considers hydrogen to be an important technology pathway to achieve its ambition of bringing a zero-emission commercial aircraft to market by 2035.

Hydrogen is expected to be a solution for several industries to meet their climate targets. And the aviation industry should be no exception: internal Airbus calculations estimate that hydrogen has the potential to reduce aviation’s CO₂ emissions by up to 50%. This is the disruptive change the aviation industry needs to meaningfully tackle its climate impact while building the foundation for climate-neutral aviation—the ultimate goal.

Hydrogen-powered commercial aircraft may not take to the skies for another decade, but Airbus is already working to make it happen. An initial set of hydrogen-powered concept aircraft—known as ZEROe—was unveiled to the world in 2020. These concepts focus on the transcontinental aircraft markets—the most propitious for hydrogen’s success. A final decision on technology choices and aircraft configurations is expected by 2025.

In parallel, Airbus is working alongside its airline and airport partners on “Hydrogen Hub at Airports,” an initiative that investigates infrastructure requirements for hydrogen deployment. Specifically, Airbus is collaborating with airports that are planning a stepped approach to deployment, including using hydrogen to decarbonise all airport-associated ground transport (forklifts, buses, tow trucks, etc.). This will pave the way to hydrogen availability for aircraft by the 2030s timeframe.

The road to climate-neutral aviation is still long. But Airbus strongly believes in hydrogen’s potential to make this vision a reality. To get there, significant investment and cross-industry collaboration will be required—two areas in which Airbus is fully committed over the long term.
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