

The Cascade Effect

How Boeing's net-zero modeling tool maps the future of sustainable flight

BY QUEENA JONES, BOEING WRITER

Navigators know alternate routes exist for most destinations, but a map helps them see their options.

As the global aviation industry charts the path to its goal of net-zero carbon emissions by 2050, Boeing is taking the guesswork out of decarbonizing aerospace by creating a map.

Called the Cascade data modeling tool, it identifies the effects different sustainability solutions have on carbon emissions. It examines the full life cycle of alternate energy sources, from production through distribution and use. And it quantifies the power of multiple strategies to cut emissions.



FUTURE FUEL

Boeing's Cascade modeling tool shows sustainable aviation fuel (SAF) as the most effective near-term strategy to reduce emissions. The Boeing ecoDemonstrator program has been flying with and testing SAF since 2012.

PHOTO: PAUL WEATHERMAN/BOEING

“The Cascade model allows the industry to visualize for the first time the real climate impact of each of Boeing’s major paths to decarbonize aviation and to inform the most probable and effective strategies to reach net-zero by 2050.”

CHRIS RAYMOND,
CHIEF SUSTAINABILITY OFFICER



TOKYO TOUR

Sharing Cascade at the opening of a sustainability research facility in Tokyo, Chief Sustainability Officer Chris Raymond explains how the modeling tool projects the multiple paths to net-zero carbon emissions.

PHOTO: BOEING

“The Cascade model allows the industry to visualize for the first time the real climate impact of each of Boeing’s major paths to decarbonize aviation and to inform the most probable and effective strategies to reach net-zero by 2050,” said Chris Raymond, Boeing’s chief sustainability officer. “All this allows data to be front and center of the conversation as airlines and governments discuss priorities and enablers for decarbonization.”

The efforts align with the industry’s long-term goal of achieving net-zero carbon emissions by 2050, an initiative the International Civil Aviation Organization recently adopted as well.

In 2019, the civil aviation industry generated 900 million tons (816 million metric tons) of carbon emissions, which is 2.6% of the world’s total emissions and 12% of transportation emissions.

To reach net-zero aviation emissions, Cascade highlights four strategies as the most impactful:

■ **Fleet Renewal**

New airplanes provide significant efficiency gains, as each generation reduces fuel use and emissions between 15% and 25%. Flying the latest-generation airplanes is the most significant contribution to carbon emissions reduction available over the next decade.

■ **Operational Efficiency**

Future flight must be safe and sustainable. More efficient air traffic management operations — such as continuous descent approaches — can reduce emissions by about 10%, according to Eurocontrol, a collaboration to make aviation in Europe safer, more efficient and more cost-effective, with minimal environmental impact.

■ **Renewable Energy Transition**

Renewable energy is critical to reducing carbon emissions, both in industry operations and in products and services. For Boeing products, renewable energy can include sustainable aviation fuels (SAF), green hydrogen and batteries. After 15 years of research and testing, SAF is widely accepted today as a drop-in replacement for conventional jet fuel. SAF works with existing airplanes and offers the greatest potential to reduce carbon emissions in all aviation segments by 2050.

■ **Advanced Technology**

Meeting the industry’s net-zero commitment by 2050 will require more than SAF. Boeing research, testing and partnerships are developing the “SAF and” technologies necessary for sustainable aviation. These include the latest digital design, test and production tools, along with new airframe, propulsion and systems technologies. Alternate power and energy solutions will apply to various markets and different aircraft sizes.

One of the variables that Cascade assesses is how different types of renewable energy impact the environment throughout their life cycle. This includes the emissions required to produce, distribute and use energy carriers such as hydrogen, electricity and SAF.



WHAT IF

Steve Altus, Boeing Technical Fellow, runs different sustainability strategies through Cascade during a GreenBiz Group event in California.

PHOTO: MONICA ZIMMER/BOEING

“Cascade helps airline operators, industry partners and policymakers see when, where and how different fuel sources affect their sustainability goals,” said Neil Titchener, Cascade program leader. “The tool shows how incremental changes can cut emissions in commercial aviation.”

Cascade models indicate that electric- and hydrogen-powered aircraft are likely to have limited impact on sustainability by 2050. Range constraints will diminish the market potential of electric aircraft. Hydrogen, when made from renewable energy sources, has the potential to improve the production of drop-in SAF and to evolve into a low-carbon-impact fuel for

use with future propulsion, flight and infrastructure technologies. But, long development cycles, certification timelines and production ramp-up times will restrain the near-future influences of hydrogen aircraft. Further studies will determine the sustainability of these and other energy sources.

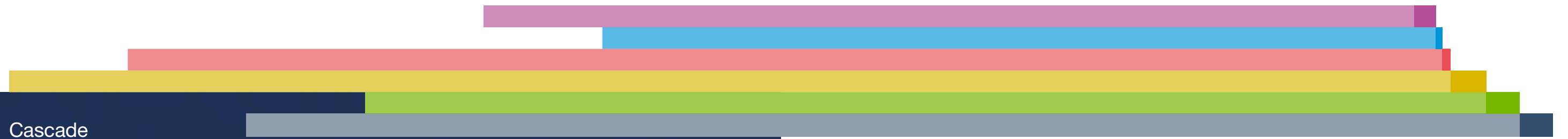
“Cascade highlights the importance of calculating emissions across the entire life cycle of the energy source, not just at the point of use,” said Titchener. “The total climate impact of a solution’s cumulative emissions determines its sustainability. Zero tailpipe emissions is not the only goal.”

Origin Story: Where Does SAF Come From?

A variety of feedstock sources give power to SAF



GRAPHIC: BOEING
PHOTOS: GETTY



Cascade



In a Cascade demonstration using a sample of 2019 global flight data, Raymond showed how replacing previous-generation jets with current airplanes would reduce global carbon emissions by 17%. Operational efficiencies, such as winglet retrofits and air traffic management improvements, would drop carbon another 6%. Converting to a half-SAF blend alone would more than match those numbers, with a 29% emissions-reduction benefit.

“Clearly, SAF offers the most immediate and greatest potential to reduce carbon emissions in aviation over the next 20 to 30 years,” said Raymond. “Depending on the feedstock, or the SAF source, carbon emissions over the fuel’s life cycle can be lowered by up to 80%.”

BY THE NUMBERS

A global group of Boeing engineers, analysts and software developers designed Cascade to calculate the effects of multiple variables on carbon emissions. As a user enters data, Cascade immediately projects potential impact.

IMAGE: BOEING



“ Cascade helps airline operators, industry partners and policymakers see when, where and how different fuel sources affect their sustainability goals. The tool shows how incremental changes can cut emissions in commercial aviation.”

**NEIL TITCHENER,
CASCADE PROGRAM LEADER**

PHOTO: JOSH GREEN/BOEING

FILL IT UP

Aviation maintenance technicians Peter Nease and Clarence Santiago fuel the 2022 Boeing ecoDemonstrator, which flies on a 30/70 blend of SAF and conventional jet fuel.

PHOTO: BOEING



“It will take multiple ways and means to a future where aviation has a net-zero climate impact. Credible data and analytical models are showing us the most direct path to our net-zero destination.”

**CHRIS RAYMOND,
CHIEF SUSTAINABILITY
OFFICER**

The Power of Cascade

**Chris Raymond,
Chief Sustainability Officer**

The aviation industry connects people and cultures, ships goods to people’s doorsteps, provides humanitarian relief and national security and takes people to space. To put it mildly, our industry does amazing things.

Collectively, as we maintain and grow those societal benefits, our goal is to have zero impact on our planet. When it comes to industry decarbonization, we believe it will take “everything for zero.”

Everything includes a mix of four strategies: fleet renewal, operational efficiency, renewable energy and advanced technology.

However, it can be daunting to think about those approaches and the complexity around them. There are a lot of potential technologies we could use to achieve our industry’s goal to reach net-zero emissions. It’s not always clear how any one of those technologies, when inserted into the fleet, actually impacts total life cycle emissions.

In order to start to bring to life our four strategies with respect to the technologies and the products that we’re building or will build in the future, we produced Cascade.

Where Cascade is really powerful is not just in providing operational statistics, but in actually inserting different technology interventions — such as hydrogen or electric aircraft — into the fleet to see how much of a life cycle climate impact they have.

We intend to make this tool available to the community, to policymakers, to customers, to engineers, to anyone who wants to use it to understand how these technologies and strategies will affect the fleet.

Cascade is helping to put data front and center in the conversation about decarbonizing aviation — and that’s exciting.



CHRIS RAYMOND
Chief Sustainability Officer

PHOTO: LARRY CANNER

SAF can be made from various materials, called feedstocks, including nonedible plants, agricultural and forestry waste, nonrecyclable municipal waste and industrial plant off-gassing. The fuel’s production requires multiple feedstocks to meet the demand, Raymond said. And its development and production create jobs across multiple industries and drive economic growth around the world.

Non-drop-in fuels and energy carriers such as hydrogen can complement SAF in our efforts to decarbonize aviation, according to Titchener. However, there is a lot of uncertainty as they will require radically different designs, new safe certification approaches, and systemwide ground and network infrastructure updates.

Modeling tools like Cascade can help us evaluate the opportunities and challenges of these diverse approaches under various scenarios with different assumptions — and ultimately help us meet our sustainability goals.

“It will take multiple ways and means to a future where aviation has a net-zero climate impact,” Raymond said. “Credible data and analytical models are showing us the most direct path to our net-zero destination.” **IQ**



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