Innovation Driving Sustainable Aviation

First Edition - November 2021

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INTRODUCTION

With a view to minimize the adverse effects of international civil aviation on the global climate, ICAO formulates policies, develops and updates Standards and Recommended Practices on aircraft emissions, and conducts outreach activities. ICAO Member States have agreed on two global aspirational goals for international aviation: 2% annual fuel efficiency improvement through to 2050, and carbon neutral growth from 2020 onwards.

To achieve these global aspirational goals and to promote the sustainable growth of international aviation, ICAO is pursuing a basket of measures including aircraft technology, operational improvements, sustainable aviation fuels, and market-based measures (CORSIA).

Currently, ICAO is also exploring the feasibility of a long-term global aspirational goal for international aviation (LTAG). Significant progress has been made on this effort through the ICAO Committee on Aviation Environmental Protection (CAEP) and through major initiatives such as the ICAO Stocktaking. The overall process is aiming to conclude at the 41st Session of the ICAO Assembly in 2022.

The 2021 ICAO Stocktaking was one of the most important global events of the year on the sustainability of the aviation sector. The Stocktaking provided a forum for the exchange and collection of information and data between all aviation stakeholders and provided key inputs to the ICAO work on the feasibility of an LTAG.

What was shown at the Stocktaking is that a range of evolutionary and revolutionary changes are occurring through innovations to reduce carbon emissions from aviation, and this effort involves global stakeholders, some of which are new to aviation. To help bring all stakeholders together, ICAO has issued an open invitation to all interested parties to join the ICAO Global Coalition on Sustainable Aviation.

The ICAO Global Coalition is a forum for stakeholders which aims to raise awareness of the latest innovations being developed to bring about the green transition of the sector, building on existing leadership and champions, partnerships and initiatives. Many Coalition partners have already joined ICAO in this effort and new partners are joining frequently.

As part of the Coalition initiative, in order to monitor the latest innovations from aviation stakeholders, the ICAO tracker tools of aviation CO_2 emissions reduction initiatives are set up to regularly provide a wealth of information on measures to reduce the environmental footprint of aviation, including details on the most ambitious actions being taken.

ICAO Tracker Tools of aviation CO_2 emissions reduction initiatives

This publication provides an overview of the innovations presented during the 2021 ICAO Stocktaking on technology, operations, fuels, and initiatives to enable sustainable aviation. This publication also contains the latest updates on sustainable aviation initiatives received from the Coalition Partners. We hope you enjoy this **First Edition of *Innovation Driving Sustainable Aviation*.**

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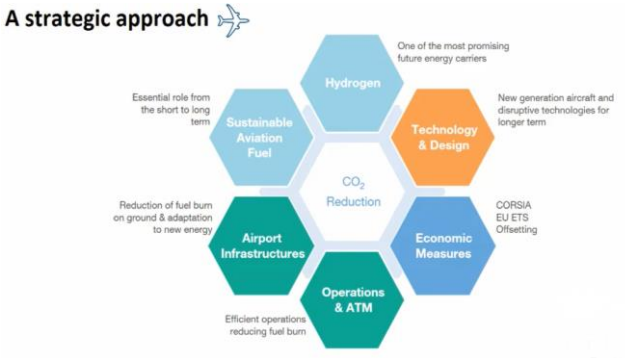
TECHNOLOGY

Innovation in technology is crucial to build the sustainable aircraft fleet of the future. These include developments in airframe design, materials and propulsion. During the 2021 Stocktaking, stakeholders presented their latest aircraft technologies, providing detailed information on innovations that will drive the shape of aircraft in the future.

This Stocktaking session on aircraft technology began with an introductory presentation on the technology assessments being carried out as part of the ICAO work on the feasibility of a long-term aspirational goal on CO_2 reduction potential of new and evolutionary technologies. The work on the LTAG is considering **airframe improvements** (aerodynamics, structures/materials, systems, and vehicle integration), **propulsion system improvements** (improved turbofan, unducted propulsor, turboelectric, hybrid), and **advanced Concepts and Energy Storage** (hydrogen and electric aircraft concepts, flying wing, strut-braced wing).

Examples of aircraft being considered in the LTAG work

The session then turned to the innovators, beginning with Embraer and their environmental commitments and support of a net-zero carbon aviation by specific greener aircraft projects. **Coalition Partner Airbus** then provided details on a strategic approach toward reducing emissions and the hydrogen-powered ZEROe concept roadmap.



Airbus Hydrogen ZEROe concept roadmap. Airbus expects the Zero-emission aircraft to enter into service by 2035.

Safran Group presented their vision of a roadmap toward carbon neutral aviation and the CFM Rise program, and **Coalition Partner GE Aviation**, which also participates on the CFM Rise programme, showcased their hybrid electric technology demonstrator.

GE Aviation continues to mature hybrid electric technology. A set of maturation flights and ground tests are planned and underway.

Bombardier described their initiatives on sustainable business aviation and its first-ever environmental product declaration. ATR shared their vision on regional aviation, shaping regional air travel in an innovative, sustainable and modern way.

From the research perspective, DLR presented its EXACT project which is focused on eliminating the climate impact from aviation based on potential key technology solutions such as electric regional aircraft, novel turboprop aircraft and hydrogen-powered aircraft.

Pratt & Whitney showcased their recent engine efficiency improvements and hybrid-electric demonstrator as steps toward sustainable propulsion. Finally, Rolls Royce presented their vision of a sustainable future for aviation with the necessary building elements, including the new UltraFan engine and radical alternatives such as electrification and hydrogen-powered projects.

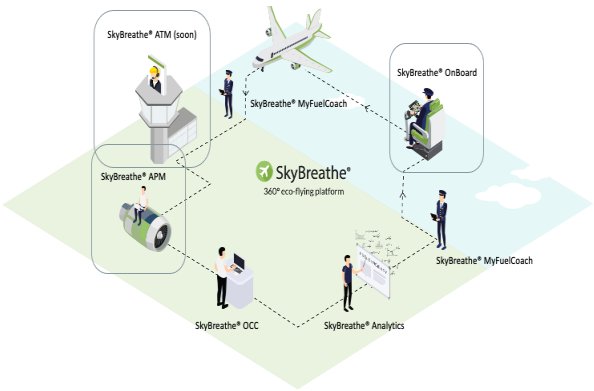
The technology tracker tool on the ICAO website captures all the latest initiatives from all stakeholders, containing initiatives on electrification, hydrogen, Urban Air Mobility / Advanced Air mobility (UAM/AAM) and all aircraft technologies.

OPERATIONS AND INFRASTRUCTURE

Operational measures offer a win-win situation for the aviation industry by reducing costs while also reducing carbon emissions. The ICAO Stocktaking 2021 included a focused session on Sustainable Airport Operations and Infrastructure, which displayed innovative solutions on operational measures. This session highlighted that operational measures are a critical component to reducing emissions from the sector, while infrastructure development is key to the green transition.

This Stocktaking session began with an introductory presentation on the operations assessments being carried out as part of the ICAO work on the feasibility of an LTAG on CO_2 reduction, including the potential of innovative operational measures.

Coalition Partner Open Airlines presented their SkyBreathe technology, which utilize big data to improve operations, and announced the SkyBreathe ATM, an initiative focused on improving the performance of Air Navigation Service Providers (ANSPs).



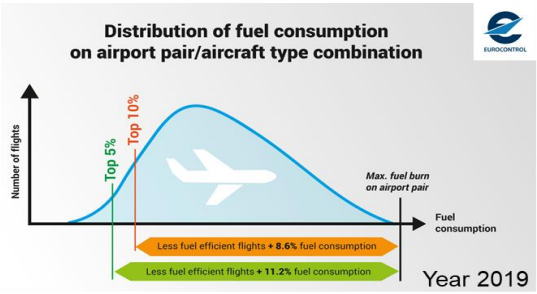
Open Airlines SkyBreathe technology

Air France described a roadmap detailing their goals and vision of the airline including its sustainability strategy and commitment to the objective of reducing its CO_2 emissions by 50% per passenger/km by 2050, compared to 2005 levels.

REGENT Craft addressed their commitment to fast, sustainable, regional transportation by 2025. Their innovative REGENT seagliders aims to increase efficiency due to “ground effect”, wave tolerance and crowded harbour operability, flight stability, and maritime situational awareness.

Airspace Intelligence described their “Flyways AI” platform, which uses artificial intelligence (AI) and machine learning to assist dispatchers in making flight operations more efficient and sustainable by optimizing routes and improving the predictability and flow of airline traffic.

Coalition Partner Eurocontrol highlighted the importance of new performance indicators and introduced their initiatives such as the Excess Fuel Burn Indicator, the creation of an ATM/ANS Transparency group, and the future work of the SES Performance Scheme which is built on five pillars: Performance, Safety, Technology, Airport and Human Factors.



A number of airports contributed to the session highlighting the crucial role of airports in the sustainability of the sector. Delhi Airport highlighted its target to become a “Net Zero Emission Airport” by 2030, with an objective of replacing electricity with hydro-based clean electricity. Hamburg Airport described the pivotal nature of synthetic, climate-friendly fuels, and Hydrogen as an indispensable fuel for the future. Kansai Airport highlighted their net zero CO_2 emissions commitment through multiple projects that include Hydrogen and green energy.

Finally, **Coalition Partner Urban Air Port** described their work to create and operate airports for drones and eVTOLs. The Urban Air Port is one third of the cost of traditional air infrastructure, 60% smaller footprint than comparable heliports, is scalable, uses renewable energy, is vehicle agnostic and is rapidly deployable.

Urban Air Port compact and deployable infrastructure

The operations tracker tool on the ICAO website captures all the latest initiatives from all stakeholders, containing initiatives on Green Infrastructure, and operations in the air and on the ground.

FUELS

Early in 2019 the first edition of what would become the full ICAO Stocktaking started with a focus on Sustainable Aviation Fuels, with the ICAO Stocktaking Seminar towards the 2050 Vision for Sustainable Aviation Fuels. Since then, ICAO is periodically reviewing the progress on SAF development and deployment through the Stocktaking process.

The latest information on fuels is being considered under the ICAO LTAG work in three main fuel categories: **LTAG sustainable aviation fuels** – drop-in aviation fuels made from renewable or waste resources, such as biomass, solid/liquid/gaseous wastes (e.g. Municipal Solid Waste, CO/CO_2 waste streams), and atmospheric CO_2; **LTAG lower carbon aviation fuels** – fuels made with petroleum improvements to reduce lifecycle CO_2 emissions (e.g. reduced flaring, venting and fugitives, use of renewable energy, carbon capture), and **Non drop–in fuels** – aviation fuels that require changes to existing and legacy airframes and fuelling supply infrastructure, such as Hydrogen and Electricity.

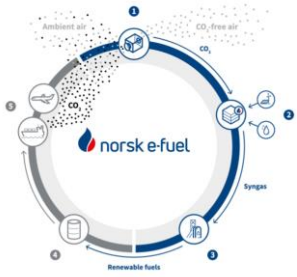
The 2021 Stocktaking confirmed the strong momentum in the establishment of SAF policies, partnerships and new production facilities. Stakeholders made critical announcements on SAF during the event: IRENA (International Renewable Energy Agency) launched a new report "Reaching Zero with Renewables: Biojet Fuels", which provides a comprehensive study of SAF as an emissions reduction option for the aviation sector.

Coalition Partner Smartenergy announced they are pursuing a first Power to Liquid (PtL) project to produce SAF in Iberia, in partnership with Sunfire; Germany announced a funding regime for market uptake of PtL SAF and for a PtL demonstration platform. The ISCC (International Sustainability and Carbon Certification) announced their first three certificates under the ISCC CORSIA certification standard. Air Canada announced the formation of the Canadian Council for Sustainable Aviation Fuels (C-SAF), an industry-led network to convene experts across the SAF value-chain and involve that ecosystem to deploy SAF in Canada.

Smartenergy-Sunfire announced projects on power to liquid fuels

Besides the main Stocktaking event, a pre-stocktaking webinar was focused on Synthetic fuels for aviation. **Coalition Partner Norsk e-fuel** presented their initiatives on Power To liquids, including the World's first PtL demonstration plant and the World's first industrial-sized Direct Air Capture plant.

Norsk e-fuel technology to produce SAF from atmospheric CO_2.



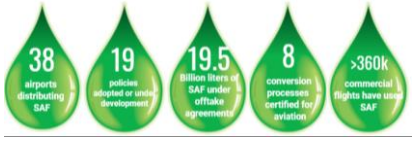
Several fuel producers presented their plans and expectations for the future of SAF, such as Lanzajet, Byogy, Velocys, Neste, SkyNRG and Nuseed. On the policy side, many ICAO Member States and observer Organizations highlighted their efforts to develop policies to foster the deployment of SAF, such as Brazil, Germany, Japan, Netherlands, Norway, Pakistan, the United States, and the European Union. Airlines such as United also pointed out their commitments to support further deployment of SAF for commercial flights.

The number of facilities capable of producing SAF around the world is increasing rapidly, but there is still significant uncertainty on the share of this capacity that will be directed to SAF compared to other fuels. The upward trend however is clear, and an exponential increase in SAF initiatives and plans was registered in 2021.

GFAAF

All the announcements and related data on fuels are tracked and updated daily by ICAO, and can be found navigating through the SAF tracker tools available on the ICAO webpage.

ICAO SAF Tracking tools



ENABLING ACTION

The transition to sustainable aviation requires interdisciplinary cooperation on a wide set of issues, involving a variety of stakeholders. The ICAO Stocktaking 2021 highlighted initiatives to enable the realization of innovations and green solutions, such as research projects, financing opportunities and partnerships between stakeholders.

Commercial Aviation Alternative Fuels Initiative (CAAFI) shed light on the efforts of the commercial aviation sector to engage the emerging alternative fuels industry and utilizes low-cost feedstock streams.

The UNEP FI (United Nations Environment Programme Finance Initiative) presented their work with more than 400 members – banks, insurers, and investors – and over 100 supporting institutions – to help create a financial sector that serves people and the planet while delivering positive impacts. ICAO and UNEP-FI also announced a future collaboration to bring together the aviation and the financial services sectors to accelerate green transition investments.

The European project "Clean Sky 2" showcased how the European aeronautics sector is working on the roadmap to achieve carbon neutrality over the next decade with hybrid electric, ultra-efficient and full electric architectures, and disruptive technologies to enable hydrogen-powered aircrafts.

Coalition Partner SkyNRG presented their "BoardNow: programme to reduce the price gap of sustainable aviation fuels, and showed that corporate offtake commitments for SAF can help bridge the price premium, create stable demand signal for SAF, aiding financing of new production facilities and reducing emissions from flying.

SkyNRG's *Board Now* Initiative

Coalition Partner Joby Aviation highlighted that with 1,000 test flights, they are breaking ground on their first large-scale manufacturing facility, certifying an eVTOL aircraft in 2023, and starting commercial operations in 2024.

Coalition Partner Team ABC presented their work as a venture capital fund which finds, supports, scales early-stage disruptive technologies which improve sustainability, including innovations like LanzaJet's alcohol-to-jet technology, Phycobloom's technology which reduces cost of SAF production by 70% using oils secreted by algae, Wastefuel which conceptualizes in manufacturing fuel from municipal and agricultural waste, and Caphenia, which has a patented Power-and-Biogas-to-Liquid (PBtL) process to convert CO_2 and biogas into renewable synthetic fuels.

Coalition Partner Canadian Advanced Air Mobility consortium (CAAM) presented their projects to support the adoption of advanced air mobility solutions in Canada, and their vision that every aircraft in Canada flying under 500km will operate with zero emissions by 2040.

CAAM projects on advanced air mobility in Canada

Air Canada announced the formation of the Canadian Council for Sustainable Aviation Fuels (C-SAF), an industry-led network which has the purpose to convene experts across the SAF value-chain.

Coalition Partner Groningen Airport Eelde presented their vision towards 2030 –2035 to become an important node for inter-regional air mobility and to trigger an impulse in economic development around the airport and in the region.

Various other institutions presented their multistakeholder partnerships ongoing to foster a sustainable aviation, such as DHL, the Global Alliance Powerfuels and German Environmental Agency, and VITO G-Stic. The International Business Aviation Council (IBAC) highlighted the establishment of the Council on SAF Accountability (CoSAFA), a partnership across the civil aviation industry with the purpose to develop and make available a Book & Claim standard for SAF.

AVIATION STAKEHOLDERS SETTING A CLEAR PATH FOR SUSTAINABLE AVIATION

Since the science has clearly shown the necessity to significantly reduce anthropogenic CO_2 emissions from all sectors in order to meet global temperature targets and goals, many governments and aviation stakeholders have developed new roadmaps, showing the way forward for achieving CO_2 emissions reductions and setting clear sustainability pathways for the aviation sector.

The 2021 ICAO Stocktaking received details on the latest developments and implementation of roadmaps from a diverse range of governments, industry and other aviation stakeholders that have committed to major reductions in CO_2 emissions from international aviation.

A major announcement at the 2021 Stocktaking was made by **Coalition Partner oneworld Alliance** outlining its path to achieving net zero emissions by 2050, and reiterating its commitment to sustainability across the alliance's 14 member airlines. The initial oneworld carbon roadmap unveiled at the 2021 Stocktaking illustrated how the alliance will meet its net zero emissions target that was first announced in September 2020.

In line with their overall vision to achieve net zero aviation emissions by 2050, the United Kingdom presented the publication of their "Jet Zero Consultation", outlining the UK vision for the aviation sector. Through the rapid development of technologies, the UK is seeking to maintain the benefits of air travel and maximize the opportunities that sustainable aviation can bring.

Germany introduced their ambitious climate targets of 65% reduction by 2030 (compared to 1990) and climate neutrality by 2045, and related aviation measures which include a focus on measures related to hydrogen and SAF.

The Russian Federation described their research initiatives towards zero emission propulsion, covering electric and hydrogen systems.

The Aerospace & Defence Industries Association of Europe (ASD) detailed their roadmap "Destination 2050 – a route to European net zero aviation", which included specific reduction targets by 2050 for technology (37%), operations (7%), SAF (34%); and economic measures/offsets (8%).

Boeing presented their views on how electric, hydrogen and SAF will be deployed throughout different aircraft categories.

The Airports Council International (ACI) and the International Petroleum Industry Environmental Conservation Association (IPIECA) also presented the initiatives from airports and the oil industry on the sustainability of the aviation sector.

The ICAO tracker on Aviation net zero initiatives showcases the latest commitments from aviation stakeholders and contains roadmaps which highlight the increasing ambitions of the aviation sector to address its climate impacts.

GREEN POLICIES

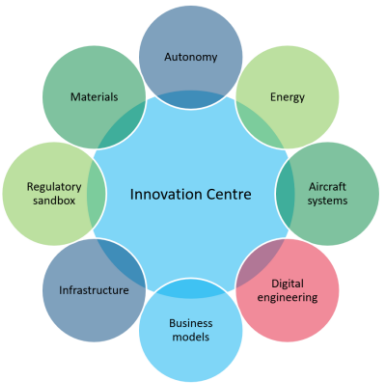
The 2021 ICAO Stocktaking included a Green Policy Day, opened by Jaco Stremler, Acting Director General of Civil Aviation of the Netherlands, who called for the policy day to be seen as the start of a green policy decade for aviation.

Several ICAO Member States have adopted or are developing green policies to facilitate the realization of CO_2 reduction measures, including net zero commitments. Japan presented their project for a Green Innovation fund, which will be used to support technology development, including technologies to allow hydrogen use on aircraft, and reduce the weight of aircraft structures. Regarding SAF, Japan is supporting the development of Fuel production technology using CO_2 as a feedstock. Projects are also ongoing to turn airports into renewable energy hubs, with 21 airports selected for further sustainability plans. The United Arab Emirates informed the Stocktaking on their recent establishment of a committee on Lower Carbon Aviation Fuels and Sustainable Aviation Fuels, with the objective to set a national strategy and policy for LCAF and SAF.

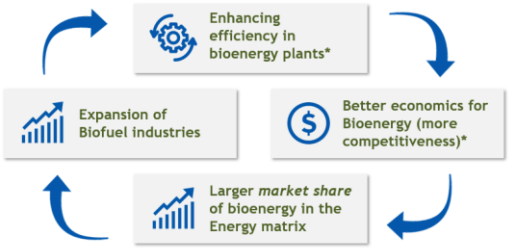
The European Union introduced their proposed policy for Sustainable Aviation Fuels, as part of a package of proposals to make the EU's climate policies fit for reducing net greenhouse gas emissions by at least 55% by 2030. The RefuelEU aviation initiative aims to accelerate the green transition of aviation with a gradual ramp-up of SAF, guaranteeing a level playing field in the aviation sector, allowing for gradual and fair uptake of SAF by all airlines at major EU airports, and addressing supply and demand issues to ensure that SAF is made available to airlines at competitive prices. Pakistan highlighted their leadership in the restoration of ecosystems, and the results acknowledged by the United Nations Environmental Programme. Moving forward, Pakistan presented their plans to expand its leadership on aviation aspects and feasibility studies on the use of renewable energy and sustainable aviation studies are under way.

Norway presented their results of an innovation eco-system for zero emission aviation, an initiative that engaged more than 60 stakeholders with the objective of achieving faster reduction of emissions, creating opportunities and contributing to improved mobility solutions.

Areas of interest – Norway innovation ecosystem



Brazil presented their RenovaBio policy being developed to assist a SAF takeoff in Brazil, which is based on targets for carbon intensity reduction of the fuel mix used in Brazil.



Dynamics of the RenovaBio SAF policy in Brazil

Industry representatives also presented their views on the policies needed to speed up the green transition of the aviation sector. **Coalition partner Neste** presented their ambitious plans to ramp up production of SAF, and highlighted that the acceptance of various feedstocks is critical for ensuring that ambitious SAF scale up targets are achievable. The International Coordinating Council of Aerospace Industries Associations (ICCAIA) noted that new or adapted standards may be needed for the green technologies being developed. Airlines for America (A4A) presented their Flight Plan, a policy roadmap requiring partnership across the aviation industry, with government and other industries. To complement the discussions, Ontario Tech University reminded that there are environmental and human costs associated with sustainable technologies, which should also be addressed.

At the end of the Policy Day, the 2021 ICAO Stocktaking was closed by Salvatore Sciacchitano, President of the ICAO Council, Gonzalo Muñoz, High-Level Climate Champion, COP25, and included a video from the United States special envoy for climate, John Kerry, on the United States ambitions and initiatives to reach a net zero emissions economy by 2050.

COALITION PARTNERS

The ICAO Global Coalition is a forum for stakeholders which aims to raise awareness of the latest innovations being developed to bring about the green transition of the sector, building on existing leadership and champions, as well as strengthening current partnerships and initiatives. The following pages present the contributions received from Coalition Partners on their latest innovations. For more information on joining the Coalition please visit:

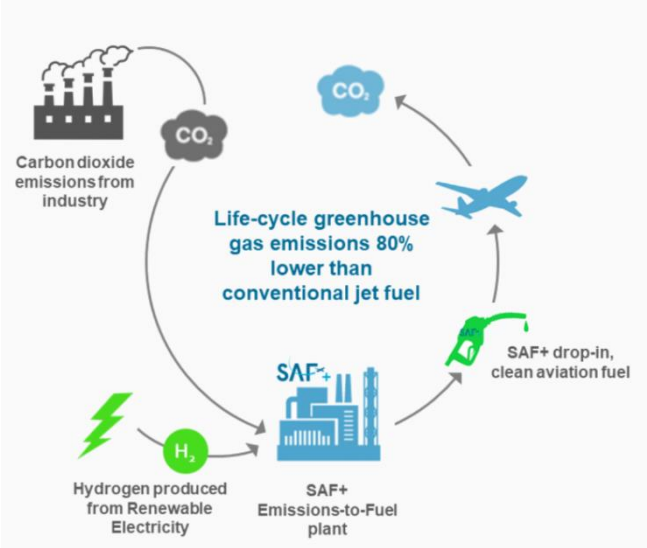
www.icao.int/environmental-protection/SAC/Pages/learn-more.aspx

AIR TRANSAT

As part of the SAF+ Consortium https://safplusconsortium.com/, Air Transat is making a major investment in sustainable aviation fuel production in Canada. Carbon dioxide from industrial smokestacks is captured, converted to carbon monoxide, combined with hydrogen produced from hydro-electric power and converted into synthetic fuel by the Fischer-Tropsch process. This process is called power to liquid or "e-fuel". It is the opposite of traditional combustion. Instead of burning jet fuel to produce energy, we apply energy to captured CO_2 to produce jet fuel.

The project is one of the finalists in the "Sky is the Limit" contest run by Natural Resources Canada https://impact.canada.ca/en/challenges/green-aviation/finalists and has received the Solar Impulse Efficient-Solution-Label. https://solarimpulse.com/efficient-solutions/saf

In August 2021, the SAF+ pilot plant produced the one of the first batches of PtL SAF in North America. We plan to build a commercial refinery by 2025-2026, producing approximately 30 million liters of SAF per year.



AIRBUS

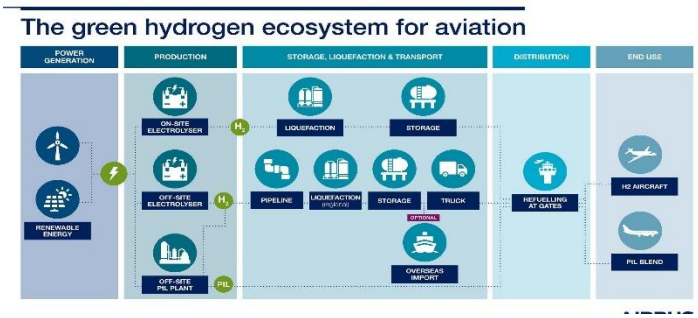
Airbus is committed to leading the decarbonisation of the aerospace sector and achieved net zero emissions by 2050, as adopted by IATA and ATAG. ICAO will have a key role to play to embrace the same objective and ensure a global level playing field for sustainable aviation.

This can be achieved via sustained investment in new energies and in new generation technologies including hybrid-electric engines, alternative fuels, and hydrogen propulsion systems.

At Airbus, our ambition is to put the first hydrogen-powered zero emission aircraft into service by 2035. Airbus is also focused on accelerating a mix of solutions, including the replacement of airline fleets with new fuel-efficient aircraft, improvements in operations and infrastructure, and the increased use of sustainable aviation fuels (SAF).

Our aircraft are already certified to fly with fuel blends including up to 50% of SAF, this will be 100% within the decade, thanks to our VOLCAN and ECLIFF3 research programmes.

Aviation is a global industry and all efforts to accelerate our route to net-zero will benefit airlines, passengers and societies.



Green hydrogen ecosystem for aviation

Aviation's path towards zero emissions

ARCHER

Archer is redefining transportation for today and for generations to come, leading the fourth transportation revolution by advancing the benefits of sustainable air mobility. Archer was founded to improve mobility and drive the world towards a zero-emissions future. We are designing and developing an eVTOL aircraft for use in Urban Air Mobility ("UAM") that can carry passengers up to 60 miles at speeds of up to 150mph while producing minimal noise and zero emissions. Our all-electric aircraft addresses the environmental issues caused by road transportation and urban overloading, working to curb carbon emissions, decrease traffic and create the multimodal transportation networks of the future. Beyond just commuters, this revolution in air mobility will usher in the age of the micro explorer, untethering people from their daily lives. Micro-exploration is a new way of life, putting soul-satisfying adventure at your fingertips and creating transformative travel experiences each day —even if you're just commuting to work.

CAAM

Canadian Advanced Air Mobility is building an ecosystem of national collaboration towards sustainable, equitable, and profitable Advanced Air Mobility industry in Canada, with the mission of ensuring that 1 in every 5 aircraft that you see in Canada will be flying with zero emissions by 2040.

The focus on sustainability is showcased through CAAM's Vancouver AAM White Paper's Environmental Life Cycle Analysis which analyze and measure the direct and indirect environmental impacts associated with the integration of AAM technology. Continuing across Canada - the recent release of CAAM's Toronto AAM White Paper will also be followed by a release of its region-specific Environmental Analysis in the coming months.

Toronto AAM White Paper

CFM INTERNATIONAL

Since introducing the first CFM56 engine in 1982, CFM International has focused on developing products that have cumulatively reduced CO2 emissions by 40 percent.

In June 2021, CFM parent companies GE and Safran jointly launched the CFM RISE Program to develop and demonstrate the uncompromising propulsion technologies required to meet the industry's net-zero ambition by 2050. The RISE program encompasses an advanced suite of technologies that will reduce fuel consumption and CO2 emissions by more than 20 percent compared to today's most efficient engines using traditional jet fuel.

Both GE and Safran have spent decades developing key technologies, such as hybrid electric capability; compatibility with 100 percent Sustainable Aviation Fuel, with hydrogen options in scope; composite fan blades; metal alloys with high temperature capability; ceramic matrix composites (CMCs); and additive manufacturing. These technologies are the foundation for the next-generation CFM engine that could be available by the mid-2030s.

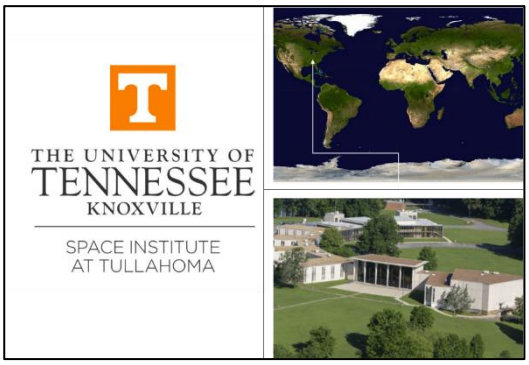
The CFM RISE open fan architecture that will undergo ground & flight testing by mid-decade.

C-PARC

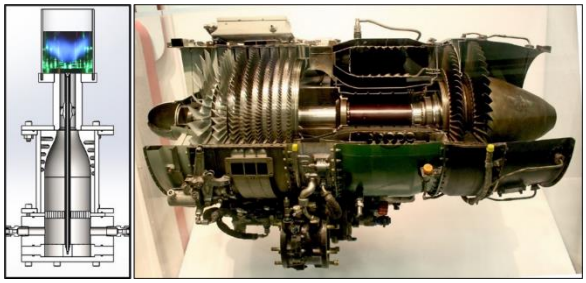
The Combustion and Propulsion for Aviation Research Center (C-PARC) is conducting research to develop technologies for premixed combustion enabling higher efficiency. One key goal of the C-PARC is to describe and demonstrate swirling flame stabilization for 100% hydrogen content under premixed combustion regime at scales ranging from laboratory to full jet engine conditions within the facilities available at UTSI and thus eliminating the emission of CO_2.

The C-PARC and its affiliates are currently recruiting graduate students (MS and PhD) and post-doctoral research associates. Several members recently joined the team and upcoming hires will be soon joining. In addition, collaborations are being set with C-PARC to achieve its goals. A consortium will be established in a near future. Discussions are ongoing and proposals are also being developed.

The most recent technical advance includes design of a baseline laboratory-scale combustor to undertake hydrogen/air premixed combustion (Figure).



The University of Tennessee Space Institute (UTSI) is a vast and beautiful campus that is ideal for propulsion tests.



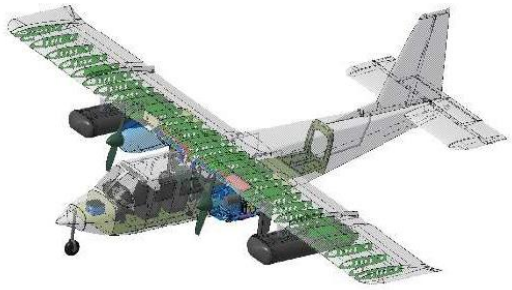
Left: Experimental setup CAD design and superimposed notional flame image. Right: typical J85 engine available for test.

CRANFIELD AEROSPACE SOLUTIONS

Cranfield Aerospace Solutions (CAeS) are leading a consortium of companies to develop a hydrogen-fuel cell propulsion system for the 9-seat Britten-Norman Islander aircraft www.projectfresson.uk .

Using its 25 years' experience in designing & certifying complex modifications to aircraft and working in partnership with the aircraft manufacturer, Britten-Norman, CAeS intend to deliver the world's first regulatory certified zero-emissions aircraft into passenger service by 2025. CAeS is working with a number of airports and operators to understand the implications of using hydrogen as an aviation fuel in a regulated airport environment, including maintenance, emergency procedures and safe working practices, leading to the creation of new standards, processes & procedures that will enable the operation of future hydrogen aircraft.

Vision of the future: Hydrogen Islander



Engineering concept design

CUBERG

Transforming electromobility means integrating breakthrough lab technology into great products.

That's why Cuberg works with customers and partners to build the world's first aviation specific lithium metal battery pack, delivering exceptional performance, robust safety, and competitive pricing.

Cuberg emphasizes a transparent and collaborative approach with customers and puts independently validated results front and center for you to see. In 2020, Cuberg's battery technology demonstrated an exceptional combination of specific energy, specific power, and cycle life in an independent testing and verification process conducted by the U.S. Department of Energy. Cell performance of our next generation cell, coming soon, will also be independently verified.

The results (369 Wh/kg, 2000 W/kg, and 370 cycles at C/2 charging, 1C discharge) represent a major step forward in the performance and maturity of battery technology.

Our Focus: Enabling the future of electric aviation

Cuberg	Q1 2021	Q4 2021
Energy Density	660 Wh/L	660 Wh/L
Specific Energy	370 Wh/kg	370 Wh/kg
Power	> 2,000 W/kg	> 2500 W/kg
Cycle Life (0.5C/1C)	>370 cycles	500 cycles
Max Charge rate	C/2	1C

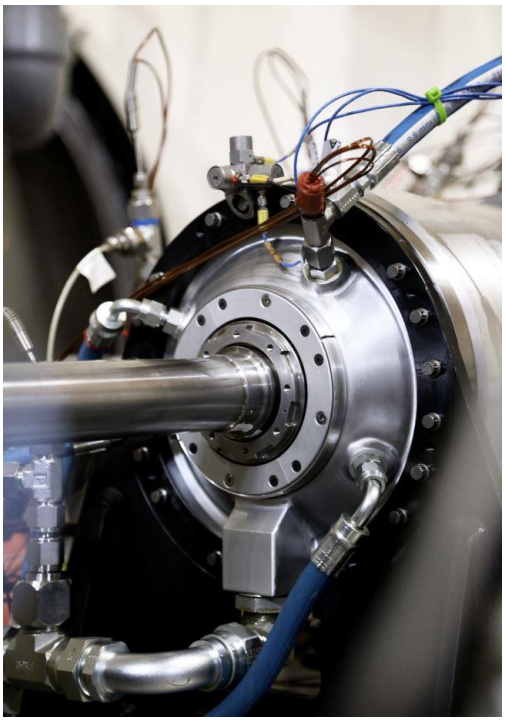
Independently verified by the US Department of Energy

GE AVIATION

GE Aviation has embarked on multiple aircraft engine technology demonstrators to accelerate emissions-lowering technologies for aircraft propulsion.

Partnering with NASA, GE Aviation announced in October 2021 plans to mature an integrated megawatt class hybrid electric powertrain. This will demonstrate flight readiness of a hybrid electric propulsion system for single-aisle aircraft, with flight tests taking place by the mid-2020s.

All GE Aviation engines can operate with approved Sustainable Aviation Fuel (SAF) produced from alternative feedstocks, which lowers lifecycle CO_2 emissions compared to petroleum-based fuels. GE has been involved in assessing and qualifying SAF since 2007 and works closely with producers, regulators and operators to help ensure SAF can be widely adopted for aviation use.



GE-NASA Hybrid Electric Powertrain

HYBRID AIR VEHICLES

Hybrid Air Vehicles is the company behind the innovative Airlander 10. From 2025 we will offer a hybrid-electric Airlander 10 that will produce 90% fewer emissions that other conventional aircraft while flying up to 100 passengers or 10 tonnes of freight. By 2030 an all-electric Airlander 10 will be available, generating zero emissions in flight. The aircraft's unique design characteristics also make it an ideal platform for the use of hydrogen fuel cells.

The first in a planned family of aircraft, Airlander 10 can take off and land from virtually any flat surface and offers a powerful combination of flexibility, persistence, payload and efficiency. Airlander's characteristics enable it to fill the gap between fast, expensive, carbon-intensive air options and slower, infrastructure-limited, less carbon-intensive ground options in mobility, logistics, experiential travel, and communications & surveillance.

Airlander 10 production standard design

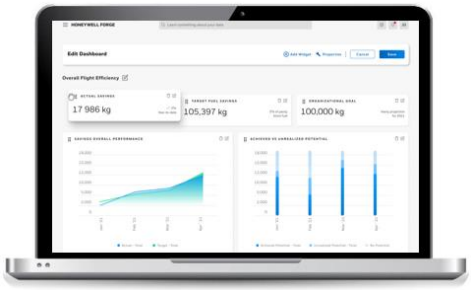
HAV's pathway to a zero emissions aircraft

HONEYWELL

Working in collaboration with many of the world's most environmentally conscious airlines, Honeywell Forge Flight Efficiency has been developed to enable the drive towards more sustainable flight operations.

The solution not only enables airlines to maximise industry best practises to reduce fuel consumption, but also uncovers hidden potential to go even further. Through advanced analytics, the airline can identify opportunities to reduce emissions through all phases of flight as well as during the turnaround on the ground. An example is the use of complex statistical analysis to safely optimise the use of contingency fuel.

The system streamlines and automates the entire process of data collection, cleansing and analysis, often replacing multiple-point solutions and manual processes. Honeywell Forge connects all relevant departments across the aircraft organization to promote a carbon reduction culture. Providing each stakeholder with the relevant information and insights they need to improve operational efficiency.



Flight Efficiency Portal

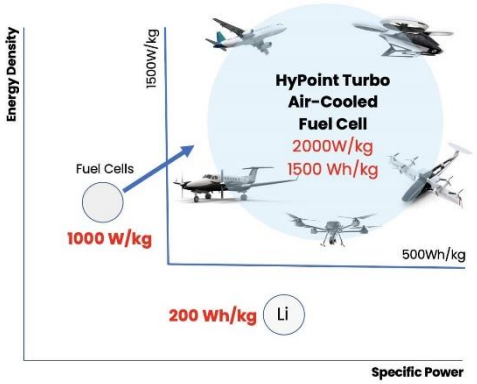
Flight Efficiency Pilot Application

HYPOINT

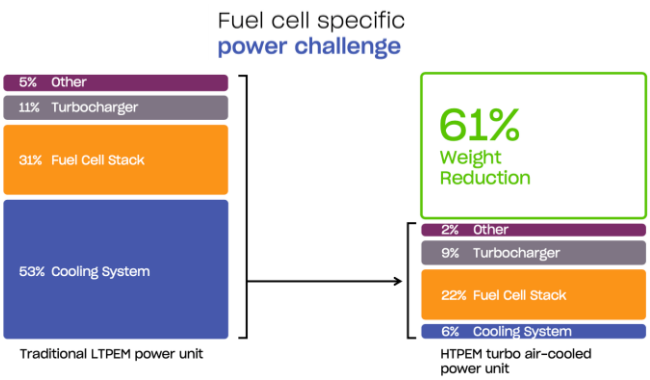
HyPoint powers zero-emission hydrogen aviation, aeronautics, and air mobility.

HyPoint's breakthrough turbo air-cooled high-temperature hydrogen fuel cell system is the first to deliver at least 2,000 W/kg of specific power and up to 1,500 watt-hours per kilogram of energy density, with specific power expected to increase to 3,000 W/kg by 2024 as a result of a new partnership with BASF, the global chemical leader. The lightweight, climate-independent, extended-lifespan system dramatically increases operational time and utilization rate while decreasing total cost of ownership by as much as 50%. A recent partnership with Piasecki will enable the aircraft maker to produce the first manned hydrogen-powered helicopter by 2025.

In 2020, the company won the NASA iTech Initiative in which inventive technologies were ranked based on criteria that included technical viability, benefits to humanity, and commercialization potential.



HyPoint's turbo air-cooled hydrogen fuel cell system dramatically outperforms existing battery and hydrogen fuel cell systems



INTERNATIONAL AIRLINES GROUP

IAG was the first airline group to commit to Net Zero Emissions by 2050 in October 2019 and the first European airline to commit to replace 10% of its fossil fuels with sustainable aviation fuels (SAF) by 2030 which is 1 million tons, saving 2 million tons of CO_2 per year. IAG has committed $400m investment to SAF over the next 20 years. We have five key SAF projects including:

- Velocys Altalto waste to SAF plant in the UK starting in 2025
- Lanzajet - Freedom Pines, US production starting in 2022
- Velocys – US plant, production starting in 2026
- Atmosfuel – Lanzajet and Carbon Engineering, UK – CO_2 removal using Direct Air Capture into SAF via ethanol
- Speedbird – UK, woody residues into ethanol then into jet with Nova Pangea and Lanzajet

British Airways will be operating all of its 140 flights from London to Glasgow during COP26 on 100% SAF saving over 4000 tons of CO_2.

IAG / BA – Europe's first waste to SAF plant in Europe

BA Better World Aircraft operating 100% SAF equivalent on all flights to COP 26

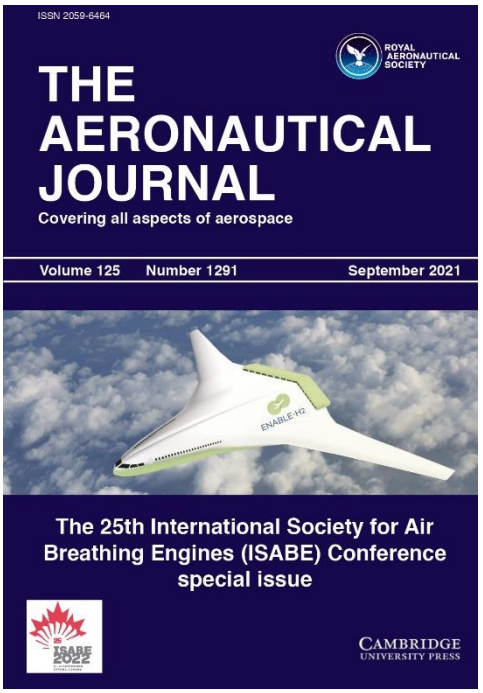
ISABE

The International Society for Air Breathing Engines (ISABE) addresses the whole value chain and supports knowledge exchanges in airbreathing propulsion for flight vehicles.

Civil aviation has, beneficially, changed our lives from businesses to the socio-economics and culture of nations and individuals. That could not have been achieved without the efforts of thousands of specialists who made advanced, reliable, and very safe propulsion technologies a reality.

Through technology, ISABE's community visualises the solutions to protect the environment and the socioeconomic benefits of civil aviation. These technologies range from hydrogen and sustainable aviation fuels to electrification and hybrid gas turbines. The zero-carbon flight goal is attainable given two requirements:

- Communicate widely and robustly the socioeconomics of aviation while simultaneously persuading governments and international bodies to contribute to the transition costs.
- Communicate the exciting and important intellectual challenge to the younger generation to bring them to the industry.



ISAE-SUPAERO

At the heart of a major university city and aeronautical hub, ISAE-SUPAERO is creating an academic institution that foster interdisciplinary research on the route towards a sustainable future for aviation.

At the very heart of the Toulouse metropolitan area devoted to aeronautics, the Institute for Sustainable Aviation aims at addressing the aviation sustainability question by bridging disciplines at the crossroad of societal, economic, scientific and technological challenges raised by aviation sustainability. Gathering world-class institutions that have a long-term academic legitimacy in their field of research, the Institute for Sustainable Aviation aims at the construction of refined holistic models and diagnosis methods to perform a multidimensional analysis of the transition of aviation towards a sustainable, economically viable, and technically feasible future.

Among others, the Institute for Sustainable Aviation is opening research on the life cycle assessment of the SAF supply chain, on man-machine collaboration to implement AI based ATM schemes that target mitigation of non-CO_2 effects, on the efficiency of financial incentives and eco-taxes for an economic-driven transition towards sustainability and on the social norms about the fair place of air transport in a sustainable transport chain.

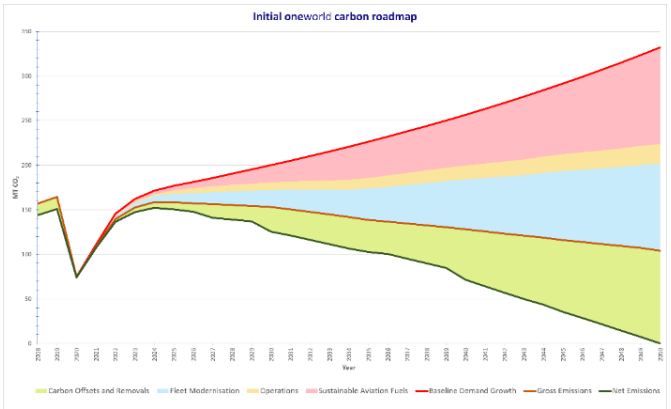
INSTITUTE FOR SUSTAINABLE AVIATION

ONEWORLD

Oneworld was the first global airline alliance to commit to net zero emissions by 2050 in September 2020, under the leadership of oneworld's Environment and Sustainability Board chaired by IAG Head of Sustainability Jonathon Counsell and with representation from all member airlines.

In 2021, oneworld strengthened its commitment to sustainability with the publication of a carbon roadmap charting the alliance's path to net zero emissions. oneworld has also committed to a 10% sustainable aviation fuel target across member airlines' consolidated fuel volumes by 2030. In addition, the alliance is supporting member airlines to register for the IATA Environmental Assessment (IEnvA) through the award of training scholarships for employees.

Environmental sustainability is a fundamental priority for oneworld member airlines, who are committed to partnering with governments and stakeholders to accelerate the de-carbonisation of aviation. Oneworld members are actively collaborating in environmental sustainability, with additional milestones to be announced in due course.



Oneworld Carbon Roadmap - Net Zero 2050

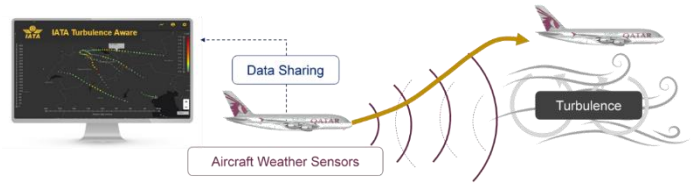
QATAR AIRWAYS

Qatar Airways has one of the most modern fleet and advanced aircraft technology in the sky. We have continuously placed aircraft orders to keep our fleet young and efficient.

Qatar Airways became the first carrier in the Middle East to join the IATA Turbulence Aware data exchange platform, equipping 120 aircraft with the technology, with plans to expand to the rest of our fleet.

From a flight planning perspective, dispatchers can accurately see via the Turbulence Aware tool the real time position, altitude and intensity of turbulence. Comparing this objective, aircraft generated data with forecast products enables efficient flight planning in terms of routing and altitude selection.

Having access to real time wind and temperature data is particularly beneficial for the flight deck to update the flight management computers and extract the most optimal flight levels for fuel consumption, hence reducing CO_2 emissions and minimising the environmental impact.



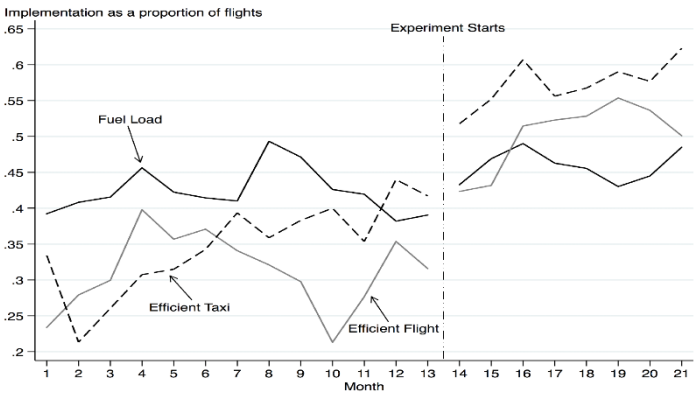
Qatar Airways contribution with the IATA Turbulence Aware Platform

Estimated CO_2 savings

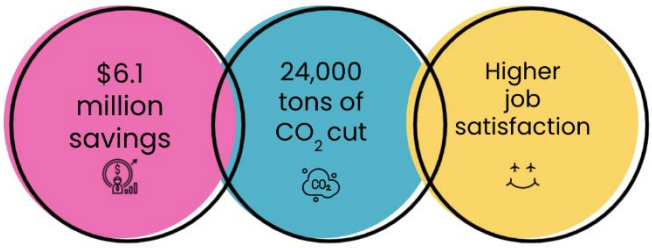
SIGNOL

Signol is a software platform which delivers fuel efficiency improvements without major capital investment. Using deep behavioural and data science expertise, Signol motivates pilots to consistently implement fuel-saving operational best practices. Like a "FitBit for work", Signol delivers personalised targets and feedback to individuals - connecting them to the direct impact of their actions and nudging them to cut costs and emissions for their businesses.

We have already saved Virgin Atlantic Airlines $6.1 million (1% of total fuel costs) and over 24,000 tons of CO_2 emissions in an eight-month trial. Our feedback and incentives also significantly improved captain job satisfaction. The study results were published in the top-ranked Journal of Political Economy (Gosnell et al, 2020).



Instant Impact - Signol's Behavior Change at Virgin Atlantic



Signol's results over 8 months with 335 Virgin Atlantic Captains

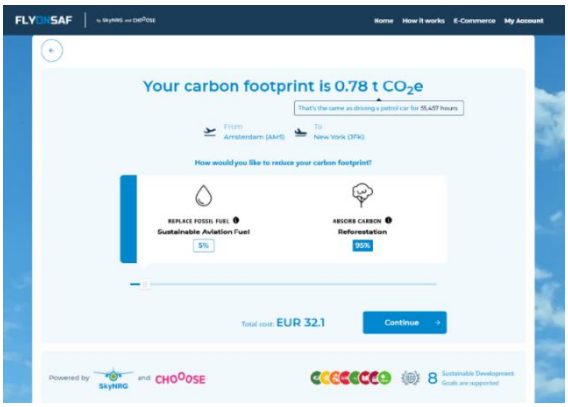
SMARTENERGY

Recent policy developments at the EU level put on pressure on fuel suppliers to blend increasing levels of SAF in jet fuels and distribute them at initial hubs by 2025 and at all EU Airports already by 2030. Specific targets for aviation have also been set, with concrete penalties to be defined by EU countries. The momentum for the de-carbonization of aviation is there and Smartenergy is committed to be in the frontline with the development of innovative E-fuels projects in Iberia, which due to its favorable conditions allows for a large production in a cost effective way. As an example, one of our e-fuels projects in Southern Spain will generate e-crude from CO_2 and water using 100% renewable electricity from more than 100 MW PV. The facility is being established in the vicinity of a port, allowing the e-crude to be easily exported and to be refined into jet fuel for distribution to the airlines all over Europe. This forefront project is an important step to start the decarbonization of aviation in shorter term with the already existing infrastructure while further technologies are being introduced.

SkyNRG

SkyNRG has developed Fly On SAF together with Chooose. Fly On SAF is a solution for travel companies to enable their customers to reduce their carbon footprint from flying with Sustainable Aviation Fuel (SAF) and Carbon Offsets.

Board Now (founded by SkyNRG) is a program helping corporations turn business commitments into action by choosing to fly on Sustainable Aviation Fuel (SAF), by supporting the business case for a new production facility. In this way, we reduce emissions from business travel and / or air cargo and support the development of an in-sector solution for sustainable flying. Current members include Microsoft, BCG, PwC and Skyscanner.



Fly On SAF's calculator

BOARD NOW

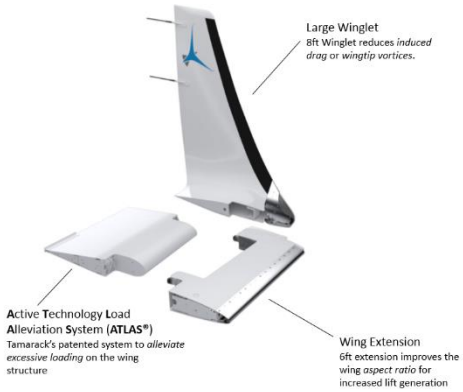
TAMARACK AEROSPACE

Tamarack's revolutionary SMARTWING significantly optimizes aerodynamic efficiency of existing aircraft by increasing aspect ratio, and is rapidly retrofittable to the wingtip of almost any airplane without the need for heavy wing reinforcement. By increasing lift and reducing drag SMARTWING technology delivers a significant reduction in both fuel burn, and associated CO_2e emissions.

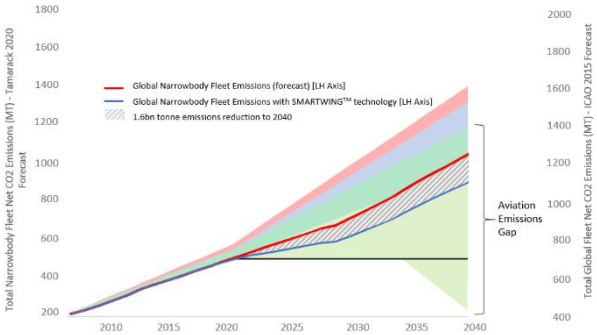
Over the last 5 years, our technology has transformed a fleet of over 140 business jets, achieving an average fuel burn reduction of 20%.

We are now adapting the SMARTWING to larger military, commercial and other civil aircraft applications where substantial global reductions in CO_2e emissions can be realized, alongside an anticipated reduction in noise emissions due to improved rate of climb and de-rated take-off.

We believe that modifying existing aircraft to maximize aerodynamic efficiency is key to delivering near-term de-carbonization of aviation, as presented in our US Congress testimony and summarized in our Company's Sustainability White Paper.



Tamarack SMARTWING includes load alleviation technology to maximize aerodynamic benefits



SMARTWING technology application on Global Narrowbody Fleet could close ICAO CO_2 Emissions Gap by 1.6bn Tonnes (20%) by 2040

TU DELFT

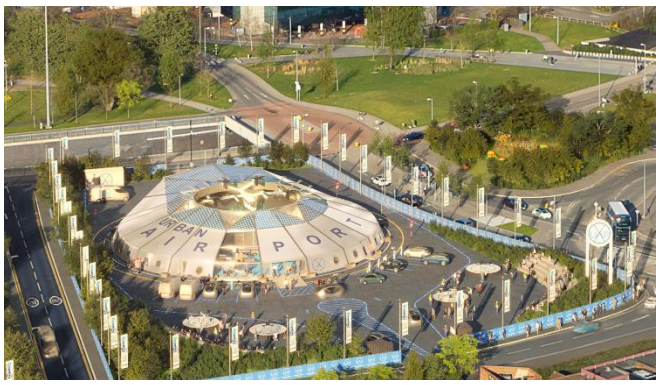
Delft University of Technology is one of the world's most comprehensive and highly ranked academic and innovation ecosystems on sustainable aviation. This enables us to adopt a system approach: we work on minimizing the climate impact of the entire aviation system. Ranging from the sustainable production, maintenance and circular life cycle of aircraft, highly energy efficient aircraft designs, to propulsion technology and energy carriers, green ATM and sustainable airports to multimodal transport and fundamental research into the climate effects of the system. Recent developments include: our research into non-CO_2 climate impact of aviation on the atmosphere, think of the effect of water vapour when flying on hydrogen at certain altitudes, a bio-inspired sustainable morphing aircraft wing, called SmartX and the launch of an open innovation ecosystem Flying Vision in which we collaborate with academic and industry partners to speed up sustainable aviation innovation and create economic opportunities.

SmartX-Alpha morphing wing during wind tunnel tests (credits: TU Delft)

URBAN AIR PORT

Urban-Air Port is a UK based start-up committed to designing, developing and manufacturing innovative Zero-Emission ground infrastructure for future Urban Air Mobility (UAM). Our mission is to remove the largest single constraint to sustainable air mobility, i.e. the lack of infrastructure, and to significantly cut congestion and air pollution from passenger and cargo transport. Our design is an ultra-compact, multi-functional operations hub for manned and unmanned vehicles providing aircraft command & control, charging & refuelling and cargo & passenger loading. Further details can be found at: www.urbanairport.co.uk .

Our design is intended to integrate this exciting new form of transport into our smart cities of the future and combine with our existing transport and logistics infrastructure as part of a consolidated city-wide multi-modal network. Our technology can be implemented by airports, cities, real estate owners, transport operators and logistics distribution centres, among many others.



Urban Air Port Infrastructure

ZEROAVIA

ZeroAvia is the leading innovator in zero emission aviation, focused on hydrogen-electric propulsion as the only viable way to tackle aviation's climate change impact at scale. The company is initially targeting the certification of a 600mW hydrogen-electric powertrain by 2024, in order to support 500-mile range in 9-19 seat aircraft used for commercial passenger transport, cargo, agriculture, and more. ZeroAvia plans to scale the technology for progressively larger aircraft.

In September 2020, ZeroAvia achieved a world's first hydrogen-electric flight of a six-seat aircraft, followed by more than 35 test flights. The company is now well advanced in its work to retrofit a Dornier 228 with its hydrogen-electric engine technology at its R&D base in the UK, with flight testing planned to commence before the end of 2021.

ZeroAvia is also developing a green hydrogen production and refuelling ecosystem for airports to support the adoption of hydrogen-electric aviation.

ZeroAvia's Roadmap for Introduction of Hydrogen-Electric Propulsion

ZeroAvia's Planned Ecosystem for Supporting Zero Emission Aviation at Scale

ICAO