

Boosting the adoption of green innovation for aviation

By ICAO Secretariat and the Solar Impulse Foundation

ICAO embraces innovation

The First Industrial Revolution used power from water and steam to mechanize the production of goods. The Second Industrial Revolution harnessed electric power to turn it into mass production. The Third one used electronics and information technology to unleash the full potential of automation.

Today, a Fourth Industrial Revolution is blurring the boundaries between the physical, digital, and biological spheres of innovation. It is marked by emerging advancements and breakthroughs in a number of fields, including robotics, artificial intelligence, nanotechnology, biotechnology, internet, 3D printing, and transportation systems.

While previous industrial revolutions were characterized by a negative spill over on the environment in terms of pollution and climate change, the revolution we are

experiencing today is placed to offer a viable, sustainable, and environmentally friendly approach to industrialization, through the use renewable resources, new materials, and recyclable bio-based products. This approach, boosted by a post COVID19 green recovery, is key to promoting and enabling a full decarbonisation of the society.

The Fourth Industrial Revolution is paving the way for transformative changes happening at an unprecedented pace, and is completely reshaping the way we live, work, and interact. It is radically affecting almost every business sector and aviation - by nature an innovative industry - is no exemption.

On environmental protection, fast-paced innovative and green solutions in aviation are being pursued to decarbonize the sector. Various types of drop-in sustainable aviation fuels (SAF) are already available for use in aircraft, and further *CO₂ reductions are being pursued via new aircraft technologies and operational procedures.*



FIGURE 1: ICAO Tracker Tool



FIGURE 2: Freedom Pines: The home of the successful AtJ Pilot and LanzaJet’s future AtJ Commercial Plant



FIGURE 3: Pipistrel Velis Electro earns first all-electric aircraft type certification



FIGURE 4: In March 2021, ZeroAvia launched the development programme for a 2MW hydrogen-electric powertrain for full-size regional aircraft



FIGURE 5: Lillium electric vertical take-off and landing jet



FIGURE 6: Otto Aviation Celera 500L laminar fuselage aircraft

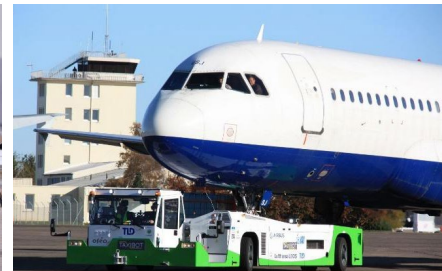


FIGURE 7: Taxibot

In the mid-to-long term, many innovations are looking into game-changing technologies including electric, hybrid and hydrogen-powered aircraft. ICAO has been tracking all these projects and developments under the ICAO Stocktaking Process¹, which has collected more than 100 existing and foreseen initiatives from aviation stakeholders.

A full overview of these initiatives can be found on the ICAO Tracker Tool², which is part of the ICAO Global Coalition for Sustainable Aviation³.

The tracker tools are organized in four main streams: Technology, Operations, Sustainable Aviation Fuels, and Net Zero Initiatives.

Some examples include:

- Several brand-new facilities being built around the world to produce next generation sustainable aviation fuels, for example by Shell, Fulcrum, LanzaJet, etc. **Figure 2**

- New production processes for Sustainable Aviation Fuels, such as the IHI Corporation Algae-based fuels, and the Applied Research Associates (ARA) Catalytic hydrothermolysis fuels
- Pipistrel Velis Electro, the first electric aircraft to obtain a type certification by the European Union Aviation Safety Agency. **Figure 3**
- Zeroavia zero-emission flight powered by hydrogen **Figure 4**
- Various vertical take-off and landing (VTOL) projects, for example by Bell Nexus, E-Hang, Kitty Hawk, Lillium, Uber Elevate, Volocopter etc. **Figure 5**
- Otto Aviation Celera 500L laminar fuselage aircraft, characterized by lower fuel consumption and reduction in operating costs. **Figure 6**
- Taxibot, a semi-robotic hybrid vehicle made for towing an aircraft without the use of the aircraft’s engines, allowing fuel savings during taxiing for up to 95%. **Figure 7**

The ICAO Global Innovation Symposiums⁴ also regularly features sessions entirely dedicated to green innovation.

1 <https://www.icao.int/Meetings/Stocktaking2021/Pages/default.aspx>
 2 <https://www.icao.int/environmental-protection/SAC/Pages/GCSA%20main%20page.aspx>
 3 <https://www.icao.int/environmental-protection/SAC/Pages/learn-more.aspx>
 4 <https://www.icao.tv/global-symposium-on-the-implementation-of-innovation-in-aviation>



Innovation is, at its core, about solving problems — and there are as many ways to innovate as there are associated challenges to solve.

Sustainable Aviation Fuels (SAF) is today a proved and promising technology, with one of the greatest potential to reduce the sector's CO₂ emissions (up to 80% aviation CO₂ on a life cycle basis), while still contributing to the social and economic pillars of sustainable development. SAF is a perfect example of innovation and technology that can be transferred to all States to unlock their potential to contribute to the reduction of international aviation CO₂ emissions while ensuring that No Country is Left Behind.

The challenge expended for the coming years associated with these fuels is be in terms of feedstock and processes used, and production capacity. While the number of facilities capable of producing SAF is growing exponentially around the world, there is still significant uncertainty on the share of this capacity that can be directed to aviation, compared to fuels produced for other sectors of the global economy. The price gap with conventional fuels, coupled with policy incentives, also represent key drivers for the full deployment of SAF, taking also into consideration that the recent fossil fuel prices have risen the economic case for diversification of aviation energy sources.

For electric aircraft, the main challenge is to increase the energy density of batteries, which would allow electric aircraft to be used on longer routes, with higher payload capacity. Other challenges include the necessary infrastructure to recharge aeroplanes, the disposal of exhausted batteries and electronic components, as well as ensuring that the electricity used is generated from environmentally-friendly sources and processes.

Similar challenges surround the broader adoption of hydrogen to power aircraft, including storage, distribution, and clean sources of energy for its production. In addition, the production of green hydrogen at scale remains the biggest challenge to be addressed.

Regulatory challenges also need to be overcome in order to gradually introduce innovation and disruptive technologies in a manner which ensures that aviation retains the confidence of the public as the safest, most efficient, and most reliable mode of transport.

The capacity of the aviation community to face the challenges and address them efficiently stands with the fact that it has always endeavored to find global solutions through ingenuity and interdisciplinary cooperation, involving a variety of stakeholders, and ensuring that sustainability is maintained throughout the full lifecycle of the aircraft production and operation.

In 2014 Solar Impulse made aviation history when it completed the longest solo solar-powered flight ever achieved without fuel. The revolutionary plane flew around 40 000 km in 17 months, including one leg that lasted five days non-stop, using only the energy of the sun. The vision of the Solar Impulse project initiator Bertrand Piccard was to embrace clean technologies and energy efficiency to explore the unknown, while providing a benefit for the whole world. Together with co-founder and CEO André Borschberg, he made that a reality, looking beyond the realm of aviation to find the solutions they needed. While many doubts were initially raised on the feasibility of this project, its full success was the feat of visionary imagination, inspiration, and technical innovation.

Insights from the Solar Impulse Foundation

When Dr. Bertrand Piccard completed the first ever solar-powered flight around the world in July 2016, he emphasised that Solar Impulse had not been built to carry passengers, but to carry a message: that clean technologies exist today that can achieve more than we thought possible just a few short years ago, and help us to improve quality of life on earth. Further, the wide implementation of these solutions will be a fundamental driver of the economy of the 21st century, an economy based on efficient use of energy and resources and cleaner modes of production. By doing this across all sectors, the pilots envisioned that we can protect natural resources and improve the quality of life on Earth.

The Solar Impulse Efficient Solutions Label

To this end, Bertrand Piccard set out to identify these solutions, across multiple themes: energy, construction, mobility, freight, industry, pollution and waste management, and food & agriculture. The innovators behind these



FIGURE 8: Solar Impulse

solutions are invited to submit their solution for assessment by a community of experts, with those meeting criteria thereby receiving the *Solar Impulse Efficient Solutions Label*. As of early 2022, the Foundation had already identified some 1300 solutions, and all of them can be discovered and filtered on the entirely open Solutions Explorer that has been launched.

The Solar Impulse Foundation seeks to support these labelled solutions in various ways. This includes finding opportunities to engage with potential clients through events or direct matchmaking. The Foundation also seeks to shine a light on their activities through communications platforms and through advocacy work. It calls on policy makers to put in place regulations - such as more stringent energy efficiency requirements - that recognize the value of solutions and will draw them to market.

Lastly, the Foundation has recently launched two investment funds with its partners BNP Paribas for venture capital, and Rothschild & ALIAD for buyout growth. These two investment funds have already begun to select labelled solutions from the portfolio of the Solar Impulse Foundation which they are investigating further.

Considering its legacy of flying around the world in a solar plane, the Solar Impulse Foundation closely follows innovations emerging from the aviation industry. Air traffic

has a significant carbon footprint, and one that is only set to grow over the coming years. It is what is referred to as a “hard-to-decarbonise*” sector and thus it is a critical area to find ameliorations.

There are various measures that the Foundation supports so as to ensure aviation continues to evolve;

- Scaling up investment in the development and commercialization of Sustainable Aviation Fuels (SAF) and its infrastructure, thereby increasing its deployment over the 1% currently produced.
- Putting a price on carbon in the form of an eco-tax (collected by governments) on airline tickets as opposed to offsetting emissions (30-120\$ depending on final destination). The revenue from the tax would have to be spent on clean forms of transport.
- Massive investment from governments in technologies and infrastructure that can speed up the uptake of alternative propulsion, thus investing in storage and production of energy (electricity, hydrogen) for use in aircraft.

Partnership with Air France

The Solar Impulse Foundation seeks to partner with industry - including those with some of the most challenging sectors - to aid them in the ecological transition. With this

in mind, a partnership with Air France was established in 2019 to support the airline in this transition, to better understand the drivers and to inspire a way forward for the entire industry. Ecological and environmental issues have been a core concern for the airline for many years⁵.

With Air France, the innovation research is focused on 6 leverages covering a very broad field:

- The carbon footprint
- Energy efficiency
- Noise pollution
- Waste Reduction
- Ground Operations
- Future aviation and new energies

The outcome of this collaboration with Air France is reflected in a specific platform on the Foundation's website. Several dozen solutions have already been labelled in this "Cleaner Aviation"⁶ category. These solutions are aimed at the aviation industry in general and are intended to be disseminated for the benefit of the entire industry. Pursuing this engagement towards a more sustainable and virtuous aviation model calls for a collective and cross-functional commitment from all stakeholders. Several of these solutions have been adopted by Air France, in the areas of flight operations, ground operations, cargo or maintenance.

The platform

The Foundation's aviation platform shows how solutions that can be implemented today can drastically reduce the environmental impact of the sector while still being profitable for the users.

- A major leverage for cleaner aviation that can be deployed quickly is alternative fuels. For this reason, several SAF solutions have been labelled by the Solar Impulse Foundation, including eFuels, such as Synhelion's, SAF+ and Carbon recycling from Lanzatech.
- For the ground operations leverage for instance, the Smart Airport System (SAS) company has three

solutions labelled by the Solar Impulse Foundation. Engine OFF, also known as the Taxibot[®], allows aircraft to be towed with the engine shut down, thus drastically reducing fuel consumption. The APU OFF solution, as its name indicates, allows the aircraft's auxiliary engine to be turned off during parking while maintaining the necessary electrical power supply. TractEasy is an autonomous electric baggage tractor that allows operators to save on operating costs while reducing their environmental impact. Maintenance is also a key element of ground operations and aircraft efficiency. Air France, for instance, has developed the predictive maintenance solution Prognos, which enables it to perform the required maintenance at the optimal time. This avoids grounding an aircraft and changing parts that are not necessary or, conversely, doing it too late and risking a failure that can be highly expensive. According to the company, this solution allows it to avoid up to 50% of cancellations and delays due to a malfunction. And since a breakdown often means chartering a replacement aircraft, the environmental benefit is also obvious.

- As flight efficiency is an essential leverage to reduce the impact of aviation, the Solar Impulse Foundation has several solutions in its portfolio of labelled solutions to optimize the flight. For instance, the Pacelab FPO solution gives recommendations to pilots to reduce flight consumption. DecisionX: Satavia's Netzero gives advice to the crew to avoid the formation of contrails in the atmosphere.
- Because of its history, the Solar Impulse Foundation also believes in the leverage that decarbonized energy represents for aviation, including electrification. As the technological spin off of the Solar Impulse project and its 16 years of experience in electric aviation, H55 supports the industry through certified electric propulsion solutions, integrating its technology in a range of applications suitable for both existing airplane designs and future concepts such as VTOLs and e-commuter aircraft. H55 develops patented, modular, and certified electric propulsion, battery storage and energy management systems. The

5 See here for more information: https://corporate.airfrance.com/sites/default/files/air_france_dossier_presse_uk_v3_modifs_21-04_0.pdf

6 solarimpulse.com/cleaner-aviation



company's products include: a fully integrated EPS system comprised of the motor, motor controller, and power controls, together with battery storage and energy management systems; and standalone battery packs and energy management systems. Its technology has been validated in 4 airplanes which have flown more than 1600 electric flight hours. Its EPS will be certified by the end of 2023.

The work of the Solar Impulse Foundation for cleaner aviation, supported by its partnership with Air France, shows that solutions exist. The Solar Impulse Foundation is constantly looking for new solutions to promote through its label and is calling on all innovators to reach out. Acting as a catalyst, the Solar Impulse Foundation's urges all stakeholders to implement solutions for an aviation industry at the forefront of the ecological transition. The pioneering spirit that has guided this industry from its very beginnings over a century ago must continue today by integrating the technologies that will enable it to perpetuate itself in a sustainable world.