Implementing *Clean Technologies*

AVIATION ARTICLE COLLECTIONS

Planning Future-Proof Airports

Implementing Clean Technologies

Embracing Advanced Air Mobility

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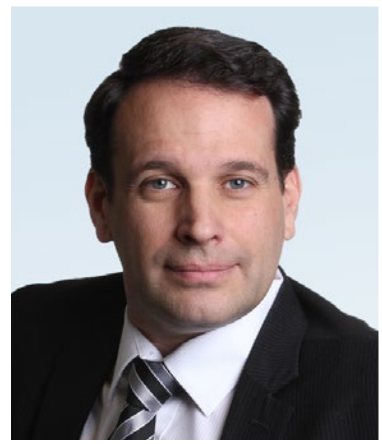
Moving Forward, Full Throttle, Wheels Up



Successful airports of the future will be agile airports. A range of factors—from the global pandemic to rapid technological advancements—requires airports to adapt and respond effectively. Another key factor is climate change, which is driving the need to implement net-zero practices for all elements of airports, from terminals and landside vehicles to aircraft and ground support equipment. Airports are under pressure, not only to develop infrastructure that supports projected travel demand but also to reduce carbon footprints.

Utilization of fossil-free energy sources—electric and hydrogen technologies and sustainable aviation fuel—is essential to connect more communities and advance equitable solutions while supporting sustainable growth. The challenge is to move forward as these clean technologies mature, enabling the development of new transportation services such as advanced air mobility.

We are pleased to offer WSP aviation insights on how to turn envisioned higher-level futures into 21st-century realities.

Here's to an exciting future for aviation.

Eric Peissel
Global Director, Transport & Infrastructure

1

Agility Underpins Future-Proof Airports

Providing spaces and services to support future travel demand and changing passenger preferences

October 13, 2021

Tim Morrison
Aviation Director
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Airports are at a crossroads, challenged to make decisions that will shape a strong future in the aftermath of the COVID-19 pandemic. Moving forward from a severely disrupted airport ecosystem requires a new way of thinking that incorporates agility at the core of all efforts.

What does agility involve? How can agility prepare airports for rebounds in air travel and effective response to heightened passenger expectations? In the following Q&A, Tim Morrison, Aviation Director, WSP in the UK, discusses how this capability can facilitate sustained positive change and support performance for years to come.

What is agility in the context of an airport, and why is it essential?

Tim Morrison: Agility is the power to adapt and adjust in a timely way; it is also the ability to anticipate and be responsive to customer needs. Agility requires an airport planning strategy that builds in flexibility.

An agile airport combines several key actions: embracing digitalization to improve operations and continuously advance the passenger experience; adapting to different economic models; and deploying Modern Methods of Construction [MMC] during redevelopment—all within an overarching decarbonization wrapper.

To be fully agile towards achieving optimal continuous service, each of these facets must reach their full potential. Taking a Future Ready[1] perspective will enable the best possible impact. Future Ready considers key trends—related to society, climate, resources, and technology—when making decisions to support today's and tomorrow's needs.

Airports are dynamic ecosystems, able to respond to change while also being catalysts for change. This dynamism has already been demonstrated in various ways, such as their finance structure, be it public or private or a combination of them; the application of technology enabling seamless home-airport-destination travel experiences as well as contactless security and CT [computerized tomography] scanning; and the generation of opportunities to advance the airport experience rather than encouraging passengers to rush through, to and from the gate. Airports have long embraced DfMA [Design for Manufacture and Assembly]; this MMC philosophy is the best way to expand and redevelop airports whilst maintaining operations. Utilizing pre-assembled modules—a kit of parts—is key. Looking into the future, facilities should embrace re-using a given kit of parts over and over again in different configurations to suit varying spatial requirements. This re-use practice, a natural extension of the MMC approach, enables projects to drive down the use of raw materials and reinforces the circular economy mindset too.

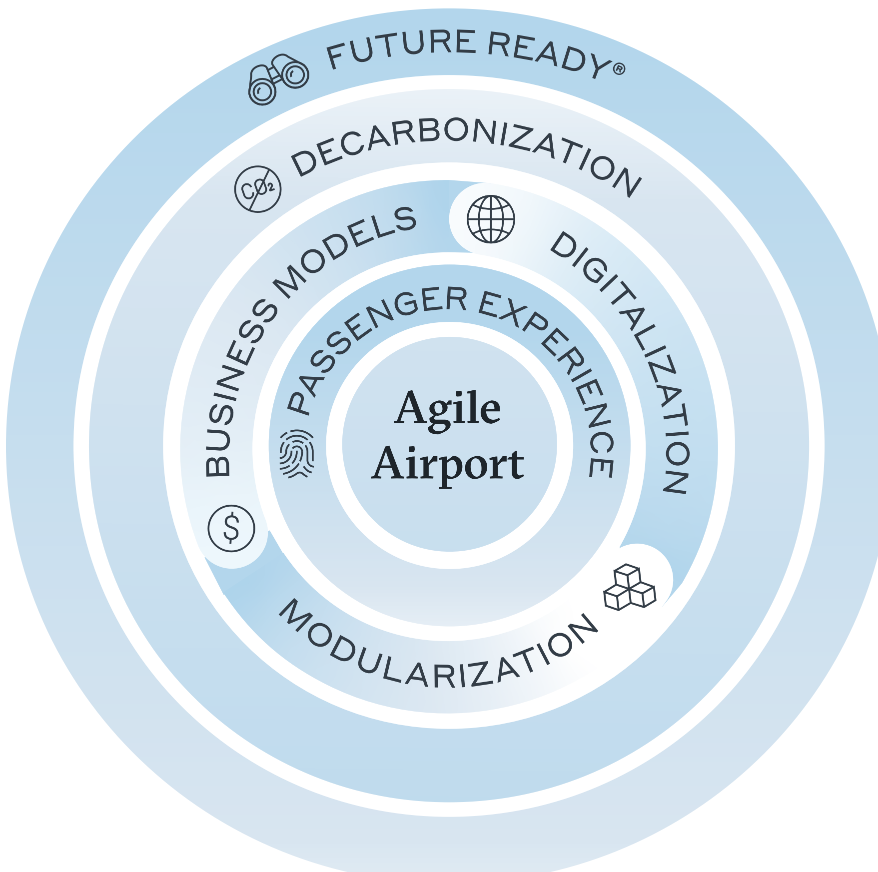

Figure 1 – Key aspects to develop agile airport ecosystems

1 Future Ready is WSP's global innovation program. Future Ready® is a registered trademark of WSP Global Inc. in Canada and New Zealand. WSP Future Ready (logo)® is a registered trademark of WSP Global Inc. in Europe, Australia and in the United Kingdom.

The impact of COVID-19 continues to test response and recovery capabilities across sectors and societies. How can airports leverage this experience as they move forward?

Tim Morrison: The last year has clearly demonstrated the importance of being agile or nimble, words not typically associated with airport infrastructure.

This agility is a function of mindset and behaviour and of the physical infrastructure. Experience over the past year has promoted a rethink regarding our surroundings and how to carry out business in an environment that will require business and industry to rapidly respond to more unexpected events; future occurrences will likely necessitate expediting or modifying plans to accommodate new needs.

Certainly, 2020 presented new considerations, such as how to integrate testing centres, quarantine hotels, alternative queuing; and how to use robots to maintain hygiene standards safeguarding staff and the public; it has also underlined the need for airports around the world to operate as highly diverse businesses in order to cope with the drop-off of traditional aeronautical revenues. Alternative non-aeronautical revenue opportunities include conference facilities, hotels, public arenas, sports facilities, pick-up points for internet retailers, leisure facilities, food and beverage destinations, quick-change stands or pop ups, and even pet kennels.

The agile mindset will help airports to embrace diversification of the traditional airport landscape. Contemporary airport designs have been exploring potential uses of airport spaces within and around these sizable built assets to make airports a destination and help them integrate further into their adjacent communities. This process started some years before the pandemic and will likely accelerate now—the pandemic has highlighted the vulnerability of non-aeronautical revenue generation, which has typically been associated with the flying passenger.

You mentioned that agility is not typically associated with airport infrastructure. Can you explore agility in relation to new assets and existing assets?

Tim Morrison: Airports represent a massive investment in fixed assets. These assets—terminals, runways, taxiways, carparks, rail stations, offices—are all built with a purpose and a lifespan. To be competitive, airports will increasingly need to repurpose these assets—to reinvent the uses of the assets and/or ensure they can expand or contract over time to support travel demand[2] and changing passenger preferences. The art of agility is to ensure the output solution to the original brief is not so rigid that the use is singular and therefore prevents any other use in the future, thus requiring a demolition to start again. This adaptability does not need to be accompanied by an increase in capital costs. In fact, the valuation of the built assets when they have this inherent adaptability will be greater as they will not have the traditional shelf life.

This 'loose fit' response to the brief does require a way of thinking that supports flexibility from the planning stage of infrastructure projects through the lifecycle of the asset. Using a digital toolkit, we are now more than ever able to create scenarios for well-considered decision-making. Indeed, the 'what if permutations are aplenty. The application of the digital tools by innovative thinkers also allows assessment of the asset's investment value in terms of the embodied carbon, not just the operational carbon. This whole-life carbon approach to development analysis will come to the fore as aviation endeavours to meet its 'license to grow' challenge. Whole-life carbon assessment is the rapidly emerging environmental measure associated with the built environment. This approach broadens consideration of carbon emissions, moving away from the focus on operational carbon in decision-making to tackle embodied carbon. Unlike operational carbon, which can be improved during the lifetime of a building, embodied carbon is all the emissions associated with the materials used—arising from extraction, manufacturing, transportation, installation, maintenance, and disposal.

The whole-life carbon analytical approach to the use of existing assets based on criteria such as embodied carbon will be driven by use of alternative materials in designs and digital tools that support such innovative applications.

2 "The Impact of COVID-19 on the airport business and the path to recovery," Advisory Bulletins, Airports Council International (ACI), March 25, 2021.

What lasting positive change can an agile mindset bring to the severely disrupted airport ecosystem?

Tim Morrison: While the pandemic experience has been harrowing, it has also presented opportunity to explore how to take stock and ensure we build back in ways that allow us to integrate fast-moving initiatives, especially those related to creating greener flight. This imperative requires collaborative efforts to accelerate the use of sustainable aviation fuel (SAF) and embark on paths to embrace hydrogen infrastructure and electrification of built assets, specifically ground support equipment and aircraft and; there is also a need to determine how to incorporate AAM [advanced air mobility] into the airport matrix. Each of these functions requires foresight, a will to embrace change and an appreciation of the transition periods. None of these will be overnight interventions; they will develop and co-exist for many years alongside existing infrastructure.

These green initiatives are key to meeting sustainability objectives and supporting the 2050 net-zero goal. There is a nice circularity here when considering these future aviation fuels and the local community; airports could also become the local hydrogen vehicle refuelling station and electric vehicle recharging facility, offering business diversification and a service to the local community.

As travel rebounds at different paces around the world, successful airports will be agile airports—those with adaptable physical infrastructure that enables effective response to changing circumstances resulting from a range of factors, be they economic or political events, a seismic mood change in retail, climatic disruptions, a national or international security incident, or a global pandemic.

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Advancing Sustainable Aviation Fuel

Overcoming the challenges of reducing greenhouse gas emissions from air travel

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Increasing investments in renewable power production, energy efficiency measures, and transportation electrification are all building momentum in the shift to fossil-free fuel.

With electric and hydrogen aircraft technologies still in development for commercial flights, there is a golden opportunity to advance the use of sustainable aviation fuel (SAF) as a near-to-medium term solution for reducing greenhouse gas emissions, expecting longer-term applications to be part of a comprehensive solution for removing greenhouse gases. SAF is a clean source of fuel compared to conventional fossil-based fuel, holding promise to meaningfully reduce the sector's global greenhouse gas emissions as business and personal air travel recovers.

SAF is advancing beyond initial tests and demonstration flights, with smaller-scale production starting to be integrated with airport fuel supply, specifically in Los Angeles, San Francisco, Amsterdam, Helsinki, and Singapore. Worldwide capacity is anticipated to surpass 600 million gallons (2 million tonnes) per year by the end of 2022, expanding to 2.6 billion gallons (8.7 million tonnes) by 2026.

Some other notable steps are recent commitments by the International Air Transport Association (IATA) member airlines to achieve net-zero carbon emissions by 2050, supported by the International Civil Aviation Organization (ICAO). The European Union Green Deal includes a proposed new ReFuelEU Aviation initiative that mandates gradual increases in SAF blending from 5 percent in 2030 to 63 percent by 2050. Furthermore, with increasing general transportation electrification the need for refineries to produce petroleum products is anticipated to decline, putting pressure on the production, supply and pricing of conventional jet fuel.

The primary constraint on initial growth in the SAF market has been the price differential relative to conventional fuels. A further challenge to increased SAF supply is market competition with sustainable diesel fuel; both are produced in the same facilities where limited production capacity currently exists. Financial incentives to meet advanced fuel blending requirements for sustainable diesel fuel have boosted demand, absorbing most of the existing and planned capacity for sustainable fuel production. Similar government mandates for SAF use, coupled with associated financial incentives, would support increased overall supply of sustainable fuels and encourage the production of both sustainable diesel and SAF.

New efforts toward this objective could emulate the stakeholder working group formed by San Francisco International Airport (SFO), a coalition of diverse partners, including airlines, airport authorities, energy companies/SAF producers, industry experts and non-profit organizations, convened to address the myriad of issues regarding SAF use and to strengthen advocacy efforts.

Building Momentum

Among the regulatory measures paving the way for the increasing use of SAF around the world is California's Low Carbon Fuel Standard (LCFS), which incorporates SAF into the provision of tax credits to reduce the carbon intensity of fuels within the state. Similar inclusion of SAF within the US national renewable identification numbers credit system, and any subsequent systems, would help to reduce the price premium of SAF versus conventional jet fuel and place SAF on par with sustainable diesel.

In Europe, countries can opt-in to the Renewable Energy Directive, with updates covering SAF as part of the indirect land-use change (ILUC) amendment, allowing member states to meet their overall obligations through the use of SAF. The Netherlands was the first country to opt-in to the directive, resulting in the first dedicated facility in Europe; set to start production in 2022, the site is a joint effort between Shell Aviation and SkyNRG, providing capacity to produce 100,000 tonnes (730,000 barrels) of SAF per year. The ReFuelEU initiative, while helping to promote SAF use, does not include specific financial incentives for production and supply. Consortiums such as the ALIGHT partnership led by Copenhagen Airport are looking at opportunities to address the lack of direct financial incentives through innovative supply, production and pricing structures.

Commercial aviation has successfully used blends of SAF and conventional jet fuel in thousands of flights around the world. Norway initiated use of SAF in 2016. Rolls-Royce recently confirmed its Trent engines can use 100 percent SAF by 2023, with current commercial engines approved for 50-percent blends.

As of January 2022, Norway, Sweden and France require jet fuel suppliers to blend no less than 1 percent of sustainable aviation fuel in all of their aviation fuel, with near-term fuel supply to come from the Preem renewable fuels facility in Gothenburg, Sweden and Neste's production facilities in Rotterdam, Holland and Porvoo, Finland. Swedavia, the largest airport operator in Sweden, receives SAF at Stockholm Arlanda and other major airports from suppliers including Neste, SkyNRG and World Energy.

Almost all aircraft flying out of Los Angeles International Airport (LAX) currently use a small blend of SAF based on the United Airlines contract to supply SAF from World Energy's biorefinery—incorporating used cooking oil and tallow as feedstocks—to LAX using common storage and distribution infrastructure. SFO is poised to receive SAF, as Shell Aviation and World Energy announced plans in January 2020 to supply SAF for Lufthansa's flights.

Producing SAF

SAF is produced from renewable and sustainable feedstocks, including waste oils, forestry waste products, algae, and animal fats—as opposed to conventional fuel, which is mostly refined from petroleum. SAF is considered a next-generation biofuel, with the majority of current first-generation biofuels produced from agricultural feedstocks, including soy, corn, palm oil or sugar cane. Certification of bio-based sustainable sources, provided by organisations such as the Roundtable of Sustainable Biomaterials ensures compliance with greenhouse-gas emissions reduction goals.

SAF also meets stringent global fuel quality standards, including ASTM in the United States, CEN in Europe, and JIS in Japan[1] and can therefore be blended at various levels with conventional fuel for distribution to airport fueling facilities. As a drop-in fuel, SAF leverages existing infrastructure and engine technology to deliver a low-carbon alternative to conventional jet fuel.

Current and upcoming producers include the Amyris facility in Brazil using sugar cane; the Red Rock facility in Oregon using forestry residues; the Fulcrum facility in Reno, Nevada using municipal solid waste; and the Total facility in La Mède, France using vegetable oils and animal fats.

Planned facilities include Sinopec in Ningbo, China; LanzaTech in Georgia, United States; Shell Aviation and SkyNRG in Delfzijl, Netherlands; Gevo in Minnesota, United States; and FORGE Hydrocarbons and Shell Ventures in Ontario, Canada.

The total production capacity of sustainable fuels from the existing and upcoming facilities around the world is approximately 260 million gallons, with close to 36 million gallons already committed to SAF production. Sustainable diesel fuel, with similar characteristics to SAF, represents a majority of the volume being produced from current production capacity and will likely represent a large share of production in some of the near-term biorefinery startups.

Moving the Needle for Widespread Use

Investments in SAF production combined with purchase agreements with suppliers would make SAF an affordable long-term alternative to traditional fossil-based fuels. For SAF to be widely available, the aviation sector will need to leverage existing supply chain infrastructure in combination with increased production capabilities to deliver this low-carbon alternative to conventional jet fuel.

Production of SAF and other transportation fuels is largely dictated by the pricing environment, with producers prioritizing revenue generation as they ramp up production and benefit from economies of scale. With limited existing dedicated production of SAF and fewer financial incentives to produce SAF instead of alternatives to conventional diesel, SAF carries a price premium compared to conventional jet fuel.

In the United States, the national renewable identification numbers (RINs) credit system under the Environmental Protection Agency's Renewable Fuel Standard is available for sustainable diesel production to reduce the price premium versus conventional diesel. When incentives for SAF are introduced, such as California's expansion (2018) of the state's LCFS credits, they tend to encourage a more balanced production of sustainable diesel and SAF.

While programs such as California's LCFS provide a portion of the price premium for SAF, the remaining price differential may be offset by revisions to existing programs, co-funding opportunities and carbon offsets. For example, the proposed measure within the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) would price carbon offsets to reduce the differential in SAF prices compared to conventional jet fuel prices.

Cultivating a Viable Alternative Fuel

Steps to reduce carbon emissions, specifically the transition from fossil fuels to other propulsion methods such as electric, are increasing in the transportation market. In addition to personal vehicles, transit and trucking fleets are developing strategies to segue from fossil fuels and internal combustion engines to electric propulsion.

However, the aviation, rail and maritime sectors often require major technological advancements to address range and weight restrictions, with greater capital investment needed to support related infrastructure. Furthermore, assets tend to be utilized for longer durations, extending their lifecycle and reducing the opportunity for more frequent replacement. The challenges of reducing carbon emissions through electrification are therefore more difficult to overcome.

1 ASTM – formerly known as American Society for Testing Materials; CEN – the European Committee for Standardization; JIS – Japanese Industrial Standards.

SAF helps to address this lag in technology development while addressing immediate emissions concerns. Depending on the production method and feedstock source, SAF has the potential to reduce emissions by 80 percent to more than 100 percent when accounting for carbon sequestration associated with some of the feedstock sources.

Meeting the Short-Term Challenge

The existing supply chain fueling infrastructure presents a short-term challenge in the transition to the widespread use of SAF. The majority of large airports are supplied with jet fuel through terminals and pipelines linked with large regional refining assets. Since current SAF production facilities are not always centered around existing petroleum refining assets, but rather the feedstock supply, there are incremental costs involved in supplying SAF to airports. In addition, many large pipeline operators require certification of any products entering their pipelines as well as volume commitments.

As demand and production increase, there will be greater opportunity to supply SAF either directly into a pipeline asset connected with large-scale production facilities and/or through an integrated approach, such as utilizing train or maritime supply to a terminal facility connected to a pipeline feeding a major airport. There will likely be a transition period where SAF is blended with conventional jet fuel at a variety of locations, including airport fuel farms, traditional fuel piping terminals and SAF production facilities. In order to accommodate blending, these sites will need to provide additional tanks or transition existing tanks to allow for adequate capacity for storage of neat SAF and blended SAF prior to being provided to the fuel farm hydrant systems.

Transitioning Away From Fossil Fuels

Future increases in SAF volumes will be dictated by pricing dynamics, consumer preferences as well as government mandates. Pricing dynamics may start to favor SAF as conventional fuel production and refineries switch to biorefining in response to declining demand for conventional gasoline and diesel as the vehicle fleet transitions to electric motor options.

Elevated awareness of the benefits of SAF locally, regionally, nationally and internationally can quicken the pace of SAF development. The current environment offers a rare opportunity to advance efforts that support the production and use of SAF, and the logistics to supply SAF into more airports.

Taking key steps now will position commercial aviation for a cleaner and stronger path forward, toward net-zero emissions by 2050—supporting a healthier future for communities and the planet.

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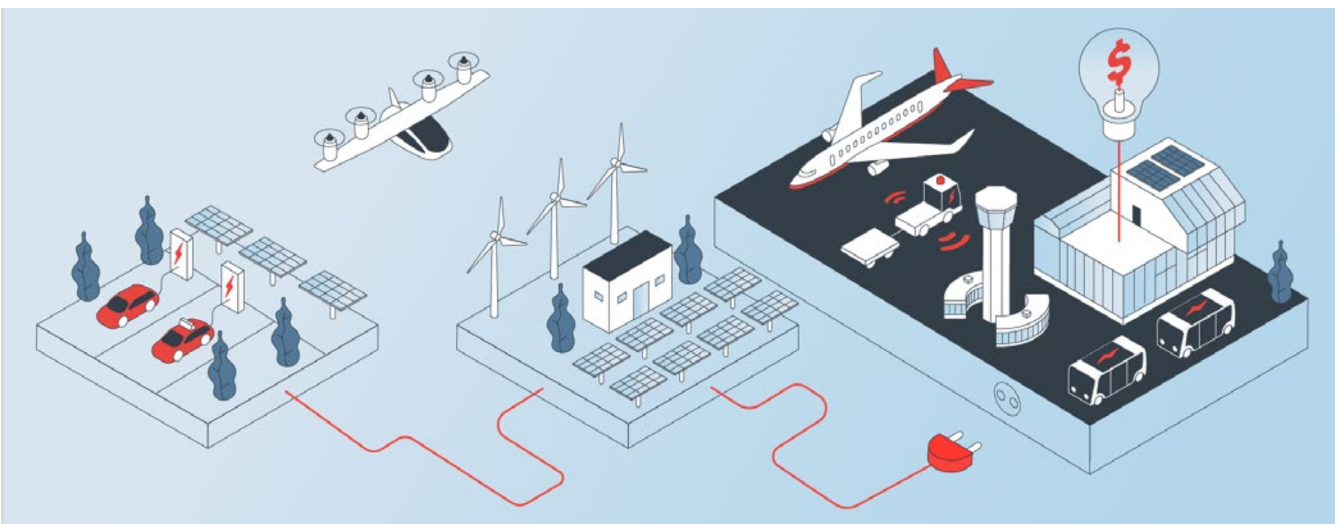
3

Electrification of Airports from Landside to Airside

Generation and storage of electricity to support infrastructure development objectives, operations and cleaner flight



May 18, 2022

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The electrification of mobility will be a game changer for airports. Emerging transportation technologies are shaping the next generation of air and ground transportation, which will transform operating conditions at airports and significantly help to reduce environmental footprints.

Electrification will decrease dependency on hydrocarbon-based fuels, improve public health and accelerate progress to achieve net-zero carbon emissions by 2050.[1] Maximizing electricity's potential will lead to a future characterized by lower-emissions travel, advanced aircraft design, cleaner solutions for the first and last mile, new transportation services such as advanced air mobility (AAM), an increase of connected and automated vehicles within the airport landscape, and innovative business models to support and leverage emerging and new technologies. As current and future mobility hubs, airports will need to invest in capacity and resilience of their existing electric distribution grids.

1 Net Zero 2050, Air Transport Action Group (ATAG).

Changing Landscape

Vehicles and Facilities

Electric powertrains are the future of automobiles as they are enabling zero-emissions at the tailpipe. Battery-electric vehicles (BEVs) and hydrogen fuel-cell-electric vehicles (FCEVs) are part of a larger movement toward connected and automated vehicles (CAVs) powered by advanced propulsion systems. These innovations will impact mobility from, to and at the airport—both airside and landside. Electric buses are increasingly populating airport landscapes; they are used to provide mass transit solutions for ground access, move passengers from the curbside to parking garages, and provide airside connectivity between terminals and serving aprons.

Ground Support Equipment (GSE) is a critical part of airline operations to enable a safe and efficient aircraft turnaround. Not only does GSE electrification save money on fuel and maintenance costs, it also contributes positively to the respiratory health of airport workers and supports efforts to enhance air quality and reduce carbon footprints. Airlines have been leading the way, but they are often constrained by existing airport electric grid infrastructure.

Electrification is progressing in passenger terminal facilities as well with, for instance, replacement of fossil-fuel-based building heating systems with fully electric solutions using geothermal and high efficiency air source heat pumps.

The stationary battery is often referred to as the Swiss Army Knife of the electric grid—it can do almost anything. As the up-front prices come down, and markets (revenues) for battery services increase, airport grid operators will find that stationary batteries will become a key tool to support electrification efforts (outlined here). This may be done in a distributed fashion, with batteries paired with all DC fast chargers, or may be centralized near the current substation or central plant.

Change to Come

Flight

Short-haul flights performed by electric aircraft is on the horizon. These small, quieter planes are part of advanced air mobility (AAM). AAM is not only about new aerospace technologies; it is a brand-new way to travel by air within large metropolitan areas (urban air mobility) with vertical or short takeoff and landing (VTOL/STOL) aircraft, as well as between small cities and rural areas (regional air mobility) with conventional takeoff and landing (CTOL) aircraft. These vehicles will use zero-emission, low-noise electric or hybrid propulsion systems. The technologies should have lower total cost of operation due to a reduction in maintenance cost from systems that have far fewer moving parts, potentially making air travel even more accessible. AAM could become a commercial reality within the coming years, offering short-haul flights that provide point-to-point, on-demand services, which could be combined with ground mobility to form a door-to-door, smartphone-based Mobility as a Service (MaaS) offer.

AAM will provide vast potential to transform intraregional air travel, connect more communities to air travel, and boost smaller airports with increased activity. It will not only expand variety in aviation aircraft and service concepts at commercial service airports, but also introduce a new paradigm for general aviation facilities in terms of level and type of operations.

Airports at the Center of Transformational Change

Advancing "Electrification of Everything" (EoE)

Though widespread change depends on the pace of technological progress within regulatory and policy frameworks that support electrified air travel, airports should today focus attention on a more energy-efficient path to support infrastructure development objectives to proactively and holistically address these emerging needs.[2]

Electric vehicles provide opportunity to advance airports as energy hubs and infrastructure assets for electric generation, storage, and distribution. Many airports have space for utility scale stationary batteries, solar farms, or other power generation systems that can supply the entire airport in case of an outage (micro-grid approach), increase power supply resilience for communities nearby, and generate non-aeronautical revenues by reselling the surplus. A new generation of backup systems, based on highly efficient battery powerpacks or hydrogen fuel-cells, is replacing traditional diesel generators. Moreover, electric buses and cars, already part of airport land transport, can be linked to the airport electric distribution grid to transfer power from one vehicle to another, and/or to act as a localized battery pack providing cost savings to be shared among the airport and the vehicle owner.

Though the benefits are clear, airports often have limited spare electric capacity and find it cost-prohibitive to upgrade their electric services. This is especially true at smaller and remote airports. This is where a carefully crafted energy-efficient and smart power-management strategy can make a strong positive impact. Airports are known to be large consumers of electric power for airfield operations and terminal needs, including heating systems, flight information displays, escalators, baggage handling and conveyer belts, service/visitor lifts, shops, and restaurants. Targeted energy-efficiency measures applied to nearby circuits can free up the capacity needed for these new electric loads. Smart charge management systems can ensure that most charging is completed when electricity is least costly, usually overnight, as other airport electric loads are low during this time. Smart power management can also reduce peak load at existing facilities with power sharing—for instance, between jet bridges and electric GSE chargers.

Movement toward electric and autonomous vehicles will influence land use at airports and impact traditional parking requirements. With less need for on-site parking, land and facilities can be freed up for other purposes, including energy production, stationary battery electric storage, and recharging of new mobility[3] vehicles—thus creating new sources for revenue enhancement. Vehicles in shared mobility networks could plug into these electric charging stations, and hotel and city transit buses passing through airports could also access recharging points located in former parking facilities.

Similarly, traditional taxis and transportation network companies (TNCs) can connect for a recharge while wait for their next pick-up cycle to begin. Some airports, recognizing that electric will play a vital role in fostering better traffic flow, are already providing ultra-fast charging stations for TNC vehicles to get topped up. The emergence of CAVs might adversely impact airport parking garage revenues, but it will also create further opportunities to optimize these processes as well as accommodate the CAV hubs at airport parking garages.

State-of-the-art technological impacts are wide-ranging in the airport infrastructure ecosystem. New mobility pilot programs are increasingly being conducted, including the use of robots to provide passenger information and autonomous vehicles to carry baggage in terminals and serve as airfield shuttles for employees. Smartphone connectivity, digital wayfinding and biometric scanners are already transforming today's passenger experience. As the whole airport-scape evolves with the application of environmentally-oriented solutions such as solar panel use, the outlook and plans regarding electric power at airports should progress in tandem. Whether developing as mini-cities themselves, aka the aerotropolis, or as smaller upgraded structures offering air travel and diverse terminal amenities, each airport should assess current energy use and generation potential as an integral step in its future-ready planning.

2 WSP has developed ACRP Research Report 236: Preparing Your Airport for Electric Aircraft and hydrogen Technologies for the US Transportation Research Board (TRB). Along with the research report, an assessment tool is available, to estimate the long-term electricity demand of the entire airport ecosystem considering the "electrification of everything"—from the curbside to the runway.

3 New mobility refers to transport changes from electric and autonomous technologies, connectivity, and shared use.

Supporting Expansion and Sustainability

Electrification can align expansion efforts meant to support increased passenger levels with initiatives to reduce carbon footprints—seemingly opposing challenges that can become compatible. With greater capacity needs, airports worldwide must now effectively address how to progress on a more environmentally-conscious and energy-efficient path to reach development objectives. This effort requires taking a closer look at current energy management practices—to assess how to better manage electric use and production through existing or potential on-site generation. Now is the time for airports to prioritize electric power as central to a long-term carbon- and cost-reduction strategy and determine how to leverage current and future new mobility electric assets to bring about greater efficiency—to meet sustainability goals and to generate new sources of revenue.

Today, aviation accounts for about 2 percent of carbon emissions and 3.5 percent of the drivers of climate change.[4] The goal is to continue taking steps to reduce emissions and achieve carbon neutrality by 2050,[5] with individual airports and air carriers taking a pledge to reach net-zero emissions as soon as 2030. A focus on sustainable energy practices, with an increasing emphasis on renewables, can be integrated into airports' overall energy-planning efforts to help reach this goal.

4 Intergovernmental Panel on Climate Change, World Meteorological Organization, United Nations Environment Programme; in addition, according to a Manchester Metropolitan University-led international study: when the non-CO2 impacts were factored in, aviation's part was calculated to be 3.5 per cent of all human activities that drive climate change.

5 Net Zero 2050, Air Transport Action Group (ATAG).

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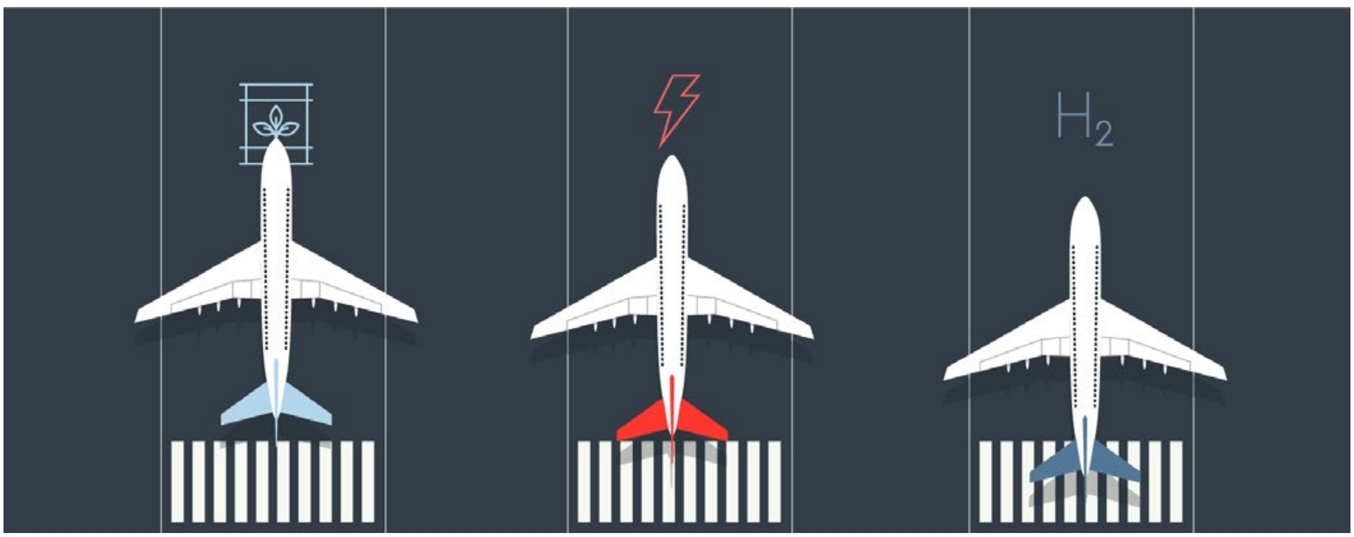
4

Greening Future Flight

Planning holistically for electric aircraft, hydrogen aviation, and greater use of sustainable aviation fuel—to reduce aviation's carbon footprint



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Technology continues to advance decarbonization efforts in aviation. Research and development toward low-emission and zero-emission flight includes electric and hydrogen technologies. Together with sustainable aviation fuel (SAF), these technologies hold promise to deliver enduring solutions that address carbon-emissions reduction.

In the following Q&A, WSP's Mattias Frithiof, Director, Advisory, Sweden, and Gaël Le Bris, C.M., P.E., Senior Aviation Planner & Senior Technical Principal, United States, explore the challenges that the sector must address to turn these fossil-free fuel alternatives into viable options; they also consider the potential for wider positive impact.

How do you see fossil-free fuel alternatives shaping aviation for future flight?

Mattias Frithiof: Generally speaking, aviation provides fast transport over large distances, which increases accessibility and connectivity. This is a cornerstone component in the processes that create societal and economic development in a globalized world. So, there are tangible values and benefits from this form of transportation. Of course, though, there are negative impacts as well. The introduction of alternative fuels and propulsion techniques should be seen as a way to further improve the balance between the costs and benefits of aviation.

As with any technology shift, change will come gradually; implementation will start small, and the scale will then increase. Already today, the deployment of SAFs is increasing and improving aviation's environmental performance. SAFs will most likely be the main focus in the short and medium term—with a more disruptive technology shift on the horizon, as the sector moves towards electrified aircraft. Here too, change will likely be gradual, as tests are increasingly carried out in small- and medium-sized aircraft on short and medium distances.

While disruptive technology itself is interesting and exciting, there is real potential for multifaceted positive impact, enabled by gradual development. Current fleets, systems and infrastructure will not be obsolete overnight. This situation is good for the economy from both public and private perspectives; it facilitates well-considered collaboration and innovative initiatives. With the gradual introduction of new technologies, small aerial vehicles over shorter distances will first change the landscape for regional accessibility. New possibilities will arise for more connections and thus improved economic relations and business activity as well as better accessibility in new directions. Formerly "disconnected" areas may be revitalized as they can structurally compete with more accessible geographies. A more geographically distributed and less monocentric economic development may be one very positive outcome of this process.

Gaël Le Bris: Improved accessibility and economic outcomes would certainly reinforce aviation's established role around the world. In the fight against climate change, the aviation community has been at the forefront of research for change. The 1999 special report on Aviation and Global Atmosphere of the Intergovernmental Panel on Climate Change [IPCC] was extensively discussed at the ICAO[1] level. The first national and regional research and development initiatives specifically targeting carbon emissions started in 2001, resulting in lower-emission aviation policies, practices, and technologies. They have been implemented since the mid-2000s with effective results.

Today, aviation accounts for about 2 percent of carbon emissions and 3.5 percent of the drivers of climate change.[2] As a sector, we have a plan—Fly Net Zero[3]—to go farther and significantly reduce our carbon footprint. The goal of this roadmap is to continue taking steps to reduce emissions and achieve carbon neutrality by 2050, with individual airports and air carriers taking a pledge to reach net-zero emissions as soon as 2030. SAFs are already a reality. These fuels are made using a variety of waste products and renewable and sustainable feedstocks in order to prevent deforestation and competition with food production. They can reduce the lifecycle emissions of commercial flights by up to 80 percent.[4] The good news is that technologies and standards exist for producing affordable SAFs meeting the criteria of existing jet fuels. This means that they can be blended with conventionally sourced Jet A-1. Furthermore, aircraft and engine manufacturers are now certifying their aircraft to fly with 100 percent SAF.

The next step is electric aviation. Prototypes have been flying for a few years. The first electric commuter aircraft with batteries are on track to be certified in 2022 or 2023. They might open a new era of zero-emission regional air mobility. Regional aircraft may follow at the 2025-2030 horizon, potentially powered with fuel cells converting hydrogen into electricity. Based on current technologies, it is unclear if all-electric larger commercial service aircraft are feasible. However, hybrid propulsion systems—using an electric engine for most of the cruise and a conventional thermal engine to deliver more thrust during takeoff and landing—hold promise. Regarding the potential of electric propulsion, though electric technologies are evolving rapidly and breakthroughs are happening regularly, we have so far barely explored the tip of the iceberg.

The future of medium- and long-haul commercial aviation using hydrogen burnt as an aviation fuel in lieu of kerosene in jet engines is achievable. As part of its ZEROe program, Airbus is committed with

1 International Civil Aviation Organization.

2 Intergovernmental Panel on Climate Change, World Meteorological Organization, United Nations Environment Programme; in addition, according to a Manchester Metropolitan University-led international study: when the non-CO_2 impacts were factored in, aviation's part was calculated to be 3.5 per cent of all human activities that drive climate change.

3 Air Transport Action Group (ATAG), Aviation: Benefits Beyond Borders, Commitment to Fly Net Zero.

4 IATA, Developing Sustainable Aviation Fuel.

CFM International to fly a hydrogen jet engine demonstrator on a modified A380 in 2026, and to bring the first hydrogen jet aircraft to market by 2035. Embraer has unveiled the Energia E50-H2GT concept for a regional hydrogen turboprop aircraft that could fly commercially by 2040. However, going from technical feasibility to introducing a brand-new fuel in commercial aviation and making it widely available is a long journey. In parallel with the effort to develop aircraft technologies, a viable hydrogen supply chain for the aviation market should be established, and airports need to adapt in order to store and deliver large quantities of hydrogen at the gate.

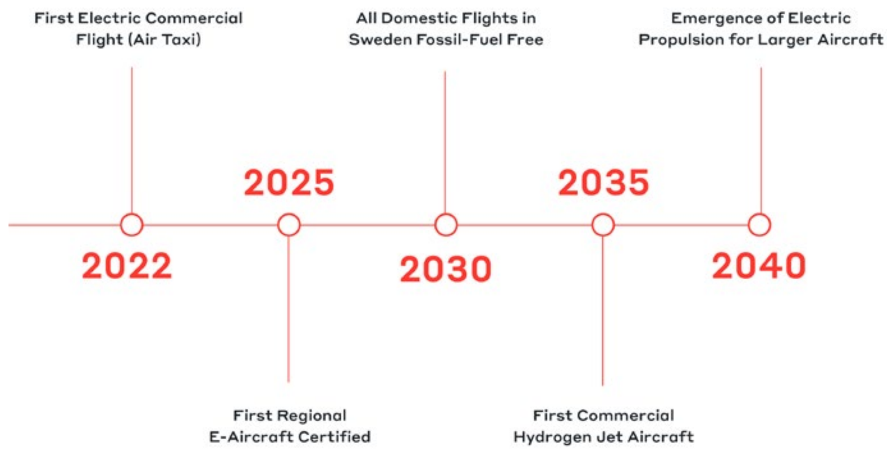

Figure 1 - Potential timeline for greener aircraft technologies

In addition to supply chain development, what are the current challenges that the sector must address to turn these fossil-free fuel alternatives into viable options?

Gaël Le Bris: There are many issues to be addressed, and both aerospace and airport standards will need to evolve to account for these new energy sectors. For example, there are National Fire Protection Association (NFPA) standards in the US applying to hydrogen and aircraft fueling, but they are separate documents.

There is also the infrastructure challenge. Making electric aviation viable implies that airports can accommodate these aircraft. Today, around the world, there is no charging or hydrogen infrastructure to ensure access to the airport and to support ground operations. Electric chargers are not eligible for existing national or local funding mechanisms.

At commercial service airports, operators and air carriers might find it beneficial to invest together to develop this infrastructure. Small airports may need to think out of the box and consider innovative approaches to funding. Similar to what we have seen with Tesla for electric vehicles, original equipment manufacturers (OEMs) could invest in the deployment of chargers.

With the advent of advanced air mobility powered by zero-emission quieter electric aerial vehicles, many in-between general aviation airports might be turned into mobility centers providing point-to-point regular and on-demand services to rural communities. While this is great news, that flying will become greener and more accessible to everyone, these airports could face a financial conundrum to accommodate the new demand. Future planning and policies should anticipate these emerging issues.

Laws and regulations will need to be reviewed as well. For instance, regulations on aviation services and those on utilities might conflict, potentially raising legal questions and preventing viable business models from emerging. Also, the long-term impact of new energy types on the aviation-fuel revenues of governments and stakeholders should not be underestimated. So far, the effort has been focused on fundraising and developing aerospace technologies. It is now the time for the sector to come together to holistically prepare for low-emission flight—advocate for greener aviation, educate policy makers and legislators on these issues, and work on removing obstacles to greater progress.

Figure 2 – Use cases for advanced air mobility with electric aircraft

Mattias Frithiof: The Nordic countries have ambitious agendas for the transfer away from fossil-based aviation fuels. Sweden aims for all domestic flights to be 100 percent fossil-fuel free by 2030 and for all international flights departing from Swedish airports to be fossil free by 2045.[5]

SAF is a key part of continuous efforts to improve the climate impact of the aviation sector, and electrified aviation will further enhance performance.

A number of initiatives, both public and private, are striving to realize the necessary development of regulation, infrastructure and aircraft technologies. As mentioned earlier, the development of alternative aviation fuels and technologies will be gradual and first deployed on a smaller scale. Ground infrastructure, airport systems, airline fleets and business models will take time, and funding, to readjust. However, herein also lies a possibility.

There are approximately 120 regional airports in the Nordic region with small-scale traffic, often feeding to the major hubs in a traditional hub-and-spoke system. Over the long term, in part due to initial limitations of new technologies, opportunity will arise to establish new connections and economic relations—in essence, a more distributed and decentralized system. This evolving situation offers an opportunity to better "manage the asset" among the 100-plus regional airports and within the surrounding support structures in the Nordic region—to generate greater value from the airport asset itself and enhance economic activity throughout the region.

What steps can airports take now to enable greener flight?

Gaël Le Bris: SAF is available at some airports in Western Europe and North America, including Los Angeles International Airport, Oslo Airport, and Stockholm Arlanda. Smaller airports such as Clermont-Ferrand Auvergne (CFE) in France and Ängelholm-Helsingborg in Sweden are joining the movement to transition to SAF.

The main obstacle to wider implementation at individual airports is the supply chain, as production must be further developed. Airport operators, such as San Francisco International Airport and Amsterdam Airport Schiphol, have been proactively advocating for these alternative fuels. For instance, SFO has a SAF Stakeholder Working Group bringing together the aviation stakeholders and the fuel industry. Stakeholders are working on increasing the production and supply at the national level as well— for instance, in the United States, through a partnership between Boeing and SkyNRG, established in July 2021.

Advanced air mobility (AAM)[6] has yet to become a commercial reality. There is still uncertainty on the timeline for the emergence of these new ways to fly. However, airport practitioners should start exploring high-level planning scenarios. They need to consult their air carriers and other flight operators as well as their fixed-base operators—with supporting guidance and tools.[7]

While power sharing and smart power management can provide a short-term solution, onsite power generation and storage should be on the table to increase resilience. Regarding hydrogen, there is a whole supply chain to develop. Ultimately, the emergence of a hydrogen economy will create a large-scale supply chain that will benefit aviation. In the meantime, we need to develop a cost-efficient, aviation-specific framework that can address the small demand of the first hydrogen-powered aircraft operators, especially at smaller, remote airports. Groningen Airport Eelde in the Netherlands is seeking to implement a hydrogen-unit production powered by an on-site 22 MW solar farm.

5 Fossil-Free Aviation 2045.

6 Advanced air mobility (AAM) includes urban air mobility (UAM) and regional air mobility (RAM). It encompasses a wide variety of vehicles with different capabilities: vertical takeoff and landing (VTOL), short takeoff and landing (STOL) operating on runway shorter than 1,500m (or 800m according to ICAO Doc 9150 – STOLport Manual), and conventional takeoff and landing (CTOL).

7 WSP developed ACRP Research Report 236: Preparing Your Airport for Electric Aircraft and Hydrogen Technologies for the U.S. Transportation Research Board (TRB). Along with the research report, an assessment tool is available, to estimate the long-term electricity demand of the entire airport ecosystem considering the "electrification of everything"—from the curbside to the runway.

Earlier, you mentioned the potential wider impacts from electric flight. Can you expand upon how electric flight can positively affect accessibility and economic vitality?

Mattias Frithiof: Connectivity and accessibility are key concepts in what is commonly called the "new economic geography," a concept coined by the economist and Nobel laureate Paul Krugman. Rapid technological advances, more cost-effective ways of transporting people and goods, and innovative communications create the conditions for spreading the competitiveness of individuals and companies beyond the local horizon. While originally a theory to explain international trade relations and macroeconomics, the concept provides a way to understand regional and local development. Increased accessibility will, according to the new economic geography theory, improve the performance of regional economies.

Aviation excels where demand is high and where connectivity is crucial, whether it is on an international, a national or a regional scale. Surely, major economic centers will still be vital destinations. But to what extent can greener aviation, initially constrained by technological limitations, generate new economic relations? Can shorter travel times, more competitive cost of travel, and higher frequencies open up medium-haul commuting in new geographies and to additional groups of travellers? A shift to greener flight can bring greater connectivity and wider benefits.

What are the main takeaways regarding planning for greener flight?

Gaël Le Bris: Greener flight must embrace greener solutions from the curbside to the airspace. So, holistic planning is essential. It requires increased collaboration among stakeholders to remove all obstacles to develop greener flight and ground infrastructure. Ground handling is just one example. The conversion of ground support equipment (GSE) to electricity is gaining traction. Individual airlines and ground handlers have been progressively transitioning to electric GSE.

Airports are also enacting policies for expediting this process. Virtually all airport vehicles can be electrified, from the buses to the aircraft de-icing trucks; models are already available commercially, and manufacturers are working on expanding capabilities to add to the list high-performance specialized vehicles, such as firefighting and winter operations apparatus.

Mattias Frithiof: Greener flight is essential to supporting the health of the environment and people, and it also brings greater opportunity to advance more distributed and decentralized economic activity and social sustainability. Pushing forward to implement new technologies is necessary in the broad effort to reduce carbon emissions and provide enduring solutions that preserve aviation's critical role around the world.

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Decarbonising Aviation From the Ground Up

From infrastructure to aircraft, embarking on a comprehensive path to achieve net-zero emissions

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Planning for the future of aviation is a multilayered endeavour that must include decarbonisation at the heart of all decisions.

Before the pandemic, aviation was responsible for about 2 percent of carbon emissions (and 3.5 percent of the drivers of climate change).[1] Interestingly, in comparison, the carbon emissions associated with the internet comes to 3.7 percent of greenhouse gas emissions.[2]

The sector has increasingly recognised the importance of reducing greenhouse gas (GHG) emissions and has already taken notable mitigating steps. Moving forward, to do its part in limiting the global temperature rise to not more than 1.5°C above pre-industrial levels by 2050,[3] the aviation sector must embark on a comprehensive path to achieve net-zero emissions.

1 Air Transport Action Group (ATAG), Facts & Figures; in addition, according to a Manchester Metropolitan University-led international study: when the non-CO2 impacts were factored in, aviation's part was calculated to be 3.5 percent of all human activities that drive climate change.

2 Climate Care, April 22, 2021.

3 Sustainable Development Goals, Partnerships Platform, Business Ambition for 1.5°.

The cornerstones to reduce aircraft emissions fall into four main categories:

- Improved aircraft and engine design – to improve fuel efficiency
- Improved airspace management – to minimise fuel consumption per journey
- Low-carbon power[4] – electric and hydrogen technologies and sustainable aviation fuel (SAF)
- Market-based mechanisms – to offset carbon emissions

Research continues to improve the viability of hybrid-electric and electric aircraft. These alternative technologies, while not poised to power large aircraft imminently, hold promise to increasingly power short- and medium-haul flights over the next decade and beyond. In light of this reality, continued concerted efforts are needed to bring about policies that will enable the commercialization of SAFs to reduce the impact of long-haul flights. Government backing will be vital to encourage and support the development of green technologies. Indeed, mandatory minimums quantities of SAFs look likely as the change is actively encouraged. Airlines and airports can lead the development of SAFs through purchase agreements with suppliers and/or investments in SAF supply, and reduced landing fees. Such steps can help SAFs become affordable alternatives to traditional fossil-based fuels.

Taking hybrid to an even greener level, hybrid-electric planes should be designed to be SAF compatible, especially as the aviation sector continues to ramp up the utilisation of these newer technologies. Considering the typical aircraft service life of 30 years, there will be a multiyear transition period as existing aircraft co-exist with new, making it critical to develop SAFs for the present-day fleets, not just the new aircraft.

Collective Action

For more than 10 years, the airport industry has embraced the global Airport Carbon Accreditation (ACA) programme, which provides a certification framework for airport carbon emissions management and reduction. This voluntary initiative was co-developed by Airports Council International (ACI) Europe and WSP,[5] and has become the international global standard for managing airport carbon emissions to support a climate-smart future. It has grown to include more than 390 airports, collectively located in more than 70 countries.

ACA delivers carbon-emissions improvements, as a combination of reductions and offsets, exceeding 1 million tonnes every year, and already has more than 70 airports certified as carbon neutral. In 2019, the ACI Europe Resolution committed Europe's airports to be net-zero carbon by 2050 for emissions directly under their control. More recently, in 2020, ACA introduced two new accreditation levels, Transformation and Transition, which commit airports to an emissions-reduction trajectory consistent with keeping a global temperature increase to less than 2°C.

Aviation's continued commitment to address emissions from aircraft—the main source of sector emissions—is well represented by CORSIA, the Carbon Offsetting and Reduction Scheme for International Aviation developed by the International Civil Aviation Organization (ICAO), a United Nations agency. CORSIA, an international sector-based approach to carbon-emissions reduction and offsetting emissions from airlines, completed its pilot phase (2019 – 2021) and is now underway in its monitoring, reporting and offsetting phase.

Whilst offsetting has a very important role to play in the transition to zero-carbon aviation, ultimately aircraft will need low- and zero-carbon fuels and radically different propulsion technologies, as outlined in IATA's Aircraft Technology Roadmap.[6]

4 Considers the impact of production/manufacture—low carbon but not zero.

5 The ACA programme has been administered by WSP since its launch in 2009.

6 IATA, Aircraft Technology Roadmap to 2050.

Designing the Path to 2050

Whilst the recovery in global passenger traffic post-pandemic is likely to take some time, (the consensus being mid-2020s for the industry to return to the 2019 levels[7]), over the longer term the number of people flying is still expected to increase significantly, potentially reaching 10 billion in 2050 from 4.4 billion in 2018.[8] More aircraft and more ground infrastructure will be needed to support this significant growth.

People's propensity to fly—to explore the world, to visit family and friends—coupled with international trade means that traffic is expected to outpace the gains made in reducing aircraft emissions through efficiency measures and technological advances over the next 20 to 30 years.

In recognition of this projection, the initiatives launched by ICAO, IATA, and ACI in recent years, demonstrate that meaningful and responsible progress is achievable—through close attention to each impact point in the emissions chain. Aviation is a sector renowned for innovation and collaboration; the UK's Sustainable Aviation[9] is a world-first strategy bringing together airports, airlines, manufacturers, air navigation service providers and other key business partners, all committed to achieving net zero by 2050.

While airports' ground operations and construction of airport infrastructure account for a relatively small proportion of the total global greenhouse gas emissions from aviation today, they are likely to attract escalating levels of scrutiny as the aviation sector takes an all-inclusive view of emissions sources, not just those generated by aircraft. This perspective also includes the carbon impact of putting new infrastructure in place as airports expand to handle the anticipated growth in air traffic demand; the sector is already developing low-carbon steel and concrete for airport applications.[10]

The path to cut emissions involves a host of measures, including increased use of electric vehicles; decarbonising national power generation; a heightened focus on energy efficiency and low-carbon technologies; a wholesale shift to renewable energy sources; partnerships to support the introduction of new aircraft technologies; and more efficient use of airspace. Airports will need to take a closer look at the emissions sources they control directly and actively develop an encompassing plan to reduce them to zero. They will also need to look hard at how to work with others to reduce the indirect emissions from assets and processes that the airport does not control, but can influence—in particular, companies operating on the airport site and passengers and staff travelling to and from the airport. Decarbonising surface access is key to the whole net-zero-carbon journey.

Global Collaboration

Tackling one of the most pressing global challenges requires strong measures from business sectors and societies worldwide. Aviation, today one of many sectors contributing to the global GHG emissions problem and arguably the most difficult to decarbonise, must lead by example if it wants to maintain its social license to operate and grow. Meaningful progress depends on the collective will and commitment demonstrated by diverse stakeholders as well as a supportive environment established by government—concerning policy, regulation and innovation. Innovative thinking and collaborative efforts are integral to the advancement of cleaner global aviation within countries and across continents as the world continues its journey to the pivotal mid-century destination of net-zero emissions. Aviation has to take bold steps now so that the numerous benefits of flying are not restricted in the future. We must remember that *carbon* is the enemy, not aviation.

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7 "The Impact of COVID-19 on the airport business and the path to recovery," Advisory Bulletins, Airports Council International (ACI), March 25, 2021.

8 IATA projections.

9 Sustainable Aviation.

10 In 2020, WSP in the UK committed to halving the carbon emissions of our designs and advice by 2030.

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