CAAS
Civil Aviation Authority of Singapore

Singapore Sustainable Air Hub Blueprint

Contents

Executive Summary

Climate change is an existential challenge that can cause widespread disruptions and impact air travel directly, affecting critical airport infrastructure and aircraft performance and causing operational delays and disruptions. Combating climate change is a matter of great urgency and priority. Recognising this, the International Civil Aviation Organization (ICAO) and its Member States have adopted a long-term global aspirational goal (LTAG) of net zero carbon emissions for international aviation by 2050. This sends a strong signal on the international community's commitment towards sustainable aviation. The realisation of LTAG requires global joint effort shared across all countries, sectors, and vocations, as well as greater climate consciousness amongst businesses and the travelling public.

As an international business, aviation and aerospace centre, the sustainable development of the Singapore air hub is a priority for Singapore as we press ahead to grow the air hub. The Civil Aviation Authority of Singapore (CAAS) has developed the Singapore Sustainable Air Hub Blueprint as Singapore's State Action Plan for the decarbonisation of its aviation sector and sustainable aviation growth. Through the Blueprint, Singapore also hopes to be a pathfinder and convenor for cross-sectoral and public-private partnership, to work with other countries and international organisations to support sustainable aviation growth.

The Blueprint adopts a balanced approach to the long term, sustainable growth of Singapore's aviation sector. Environmental sustainability needs to be balanced with the Singapore air hub's competitiveness to support the growth of the aviation industry in the upcoming decades. The Blueprint demonstrates this resolve and sets out Singapore's medium-term and long-term targets, as well as concrete steps that CAAS and the aviation stakeholders will take to decarbonise Singapore aviation.

Under the Blueprint, CAAS will work with aviation stakeholders to reduce domestic aviation emissions from airport operations[1] by 20% from 2019 levels (404ktCO_2) in 2030 and achieve net zero domestic and international aviation emissions[2] by 2050. To achieve these goals, CAAS will roll out 12 initiatives across the airport, airline, and air traffic management (ATM) domains to decarbonise the Singapore aviation sector. CAAS will also put in place five enablers to create the conditions for the effective implementation of these decarbonisation initiatives.

[1] This covers emissions from operations of vehicles, facilities, and buildings for aircraft, passenger, baggage, and cargo handling at Changi Airport Terminals 1 – 4 and Seletar Airport. It does not include targets for Changi East developments, including Terminal 5, which are not yet operational today. These will be determined separately.

[2] This covers emissions from international flights operated by Singapore-based operators.

Singapore Sustainable Air Hub Blueprint

Reduce domestic aviation emissions from airport operations by 20% from 2019 levels in 2030 and achieve net zero domestic and international aviation emissions by 2050

Airport domain

Maximal efforts to reduce energy use and deploy renewables

- Solar power deployment
- Clean energy airside vehicles
- Building energy efficiency
- Low-carbon electricity imports
- Resource circularity through waste-to-energy

Airline domain

Build ecosystem to support the use of Sustainable Aviation Fuel (SAF) in Singapore

- National SAF target and SAF levy
- Central SAF procurement
- SAF production in Singapore and the region
- Airline fleet renewal and operational improvements

Air Traffic Management domain

Operational improvements to increase efficiency and reduce fuel burn

- Advanced demand-capacity balancing implementation
- Performance-based navigation enhancement
- Gate-to-gate trajectory optimisation

Critical Enablers

Build coalitions for action

- Policy and regulation
- Industry development
- Infrastructure planning and provision
- Workforce transformation
- International partnerships and collaborations

Airport domain:
Maximal efforts to reduce energy use and deploy renewables

Airports are complex ecosystems serving as gateways for air travel and connectivity. Due to their large-scale infrastructure, operational systems, and ground operations, they are highly energy intensive. CAAS will advance five initiatives to reduce emissions and scale up green energy use at Changi Airport. These include:

a) Solar power deployment

CAAS and Changi Airport Group (CAG) are working to increase solar power deployment at Changi and Seletar Airports, by installing more solar photovoltaic (PV) systems on available rooftop spaces of airport buildings and studying the feasibility of airfield solar deployment. As of end-2023, Changi Airport has more than 20MWp of installed solar capacity, generating close to 4% of its 2019 electricity consumption of about 700GWh. Ongoing plans to install more solar PV systems on available rooftop will generate a further 6%. Solar panels will also be deployed at Seletar Airport.

b) Clean energy airside vehicles

The Changi Airport community is committed to expand the use of cleaner energy for airside vehicles, to have the entire airside vehicle fleet operate on cleaner energy sources by 2040, and for all new light vehicles, such as cars, vans and minibuses, and selected new heavy vehicles like forklifts and tractors to be electric from 2025, along with the installation of additional charging stations. To support this transition, CAAS will work with stakeholders to commence a trial on the use of renewable diesel (RD) for airside vehicles, particularly heavy and specialised vehicles, in 2024. The trial will allow CAAS and the airport community to better understand the feasibility, costs, and operational impact of using RD as a cleaner energy source for airside vehicles.

c) Building energy efficiency

CAAS , CAG, and other airport partners are working to continually improve the energy efficiency of Changi Airport's terminal buildings, especially for air-conditioning systems, which account for more than half of the buildings' total electricity consumption. Besides progressively upgrading the chiller systems in the terminal buildings, Changi Airport has been pursuing passive design strategy such as the use of heat reflecting facade materials to lower energy use from air-conditioning systems. The new Terminal 5 will also be designed to achieve the stringent Green Mark Platinum Super Low Energy Building standard.

d) Low-carbon electricity imports

As most of the carbon emissions from airport operations is due to electricity consumption at the airport, the airport will leverage the Energy Market Authority's (EMA) plans to reduce our national grid emission factor (GEF), including the use of low-carbon electricity imports, for the aviation sector to reach net zero domestic emissions by 2050.

e) Resource circularity through waste-to-energy

CAAS will work with stakeholders to study the potential and feasibility of an on-site waste-to-energy facility at Changi Airport, which could possibly use waste as a feedstock to generate electricity or biofuel for use within the airport. The study will entail waste audit and technical assessment to establish the viability and most effective waste-to-energy pathway.

Airline domain:
Build ecosystem to support the use of SAF in Singapore

Flight operations account for the bulk of international aviation emissions and emissions from aircraft operations are inherently hard to abate. The use of SAF is a critical pathway for the decarbonisation of aviation and is expected to contribute around 65% of the carbon emissions reduction needed to achieve net zero by 2050. CAAS will undertake four initiatives to build an ecosystem to support and sustain the use of SAF in Singapore and to progressively decarbonise airline operations. These include:

a) National SAF target and SAF levy

To kickstart SAF adoption in Singapore, flights departing Singapore will be required to use SAF from 2026. We will aim for a 1% SAF target for a start, to encourage investment in SAF production and develop an ecosystem for more resilient and affordable supply. Our goal is to raise the SAF target beyond 1% in 2026 to 3 – 5% by 2030, subject to global developments and the wider availability and adoption of SAF. CAAS will introduce a SAF levy for the purchase of SAF to achieve the uplift target. As the market for the supply of SAF is still nascent and the price of SAF can be volatile, this approach will provide cost certainty to airlines and travellers.

b) Central SAF procurement

To further manage the cost of using SAF, the procurement of SAF will be centralised, using the levies collected to aggregate demand and reap economies of scale. Businesses and organisations will also be invited to use the central procurement mechanism for their respective voluntary SAF purchases to reduce their carbon emissions from air travel in a credible and cost-effective manner.

c) SAF production in Singapore and the region

CAAS and the Singapore Government will work closely with industry partners to increase SAF production capacity in Singapore and the region. We can tap into the wide availability of potential feedstocks in the region and the presence of an existing petrochemical sector in Singapore. This will support the increasing demand for SAF in Singapore and the wider region.

d) Airline fleet renewal and operational improvements

Singapore carriers have continuously embarked on fleet modernisation, investing in newer and fuel-efficient aircraft, which also reduce emissions. Our carriers have also made operational improvements to reduce fuel burn, such as weight reduction initiatives and reduction of aircraft auxiliary power unit use on ground. In addition, flight plans and flight management are optimised for in-flight fuel savings; this includes improving airspace congestion and identifying more efficient routes as well as the use of data analytics and digital solutions.

Air Traffic Management domain:
Operational improvements to increase efficiency and reduce fuel burn

ATM initiatives offer a win-win solution for the environment, airlines, and passengers. Operational improvements to increase efficiency and the optimisation of flight routes can reduce track miles and flight durations. This enables airlines to reap fuel savings and for passengers to get to their destinations quicker, while reducing emissions. These benefits can be multiplied over many flights. CAAS will implement three initiatives over the next five years to improve ATM operations to increase efficiency and reduce fuel burn. Collectively, these initiatives are expected to bring about a 10% reduction in additional fuel burn and emissions. These include:

a) Advanced demand-capacity balancing implementation

CAAS will work with stakeholders to enhance the management of air traffic vis-a-vis available capacity, including improving coordination and management of longer-haul flights, as well as enhancing the reliability, timeliness, and accuracy of weather forecast information through the use of predictive tools to support decision making.

b) Performance-based navigation enhancement

CAAS will collaborate with partner Air Navigation Service Providers (ANSPs) in the region to implement more direct routings on a wider scale and in the longer-term, work towards introducing Free Route Airspace to bring about optimised capacity and flexible flight trajectories. CAAS will also develop smart tools to facilitate the optimisation of descent flight profiles within Changi Airport which will help reduce fuel burn and emissions.

c) Gate-to-gate trajectory optimisation

CAAS is collaborating with stakeholders and partner ANSPs to work towards Trajectory-Based Operations. CAAS is also implementing a decision support tool to optimise the departure intervals between aircraft, which will enhance runway efficiency.

Critical Enablers:
Build coalitions for action

The effective implementation of sustainability initiatives across the three domains will require strong government action and close collaboration with the industry. As such, key enablers are necessary for providing the right conditions for success. These include:

a) Policy and regulation

Policy and regulation are key instruments for the government to set the sustainability direction for the aviation sector and provide standardisation across the industry when required. CAAS has set domestic and international emissions reduction targets to spur the local aviation community to be more sustainable, including a national SAF target to encourage SAF production and kickstart adoption in Singapore.

b) Industry development

Industry development is key in supporting the green transformation of the sector. To promote industry development, a S$50 million Aviation Sustainability Programme (ASP) was established by CAAS in 2023 to fund sustainable aviation projects. The first call for proposals was conducted in April 2023 and a second call will take place in April 2024. CAAS has also set up an International Centre for Aviation Innovation (ICAI) to drive innovation partnerships and initiatives across all aspects of aviation including sustainability.

c) Infrastructure planning and provision

Infrastructure planning and provision is necessary for aviation sustainability initiatives to be implemented smoothly. CAAS, CAG, and other stakeholders will undertake important infrastructure planning to ensure future developments can achieve high sustainability standards. The new Terminal 5 is being designed and developed to achieve the Building and Construction Authority's (BCA) Green Mark Platinum Super Low Energy standard.

d) Workforce transformation

Workforce transformation is necessary for the aviation sector to achieve its sustainability initiatives. Through a tripartite effort, including the Singapore Government, companies, and unions, we will identify new and emerging sustainability-related job roles, accompanied by upskilling and job redesign efforts supported by the National Trades Union Congress' (NTUC) Company Training Committees, relevant lifelong learning and skills-upgrading initiatives under SkillsFuture Singapore (SSG), and Workforce Singapore's (WSG) Career Conversion Programme. CAAS will also work with Institutes of Higher Learning to embed aviation sustainability resources and content into the curriculum and stimulate interest through sustainability-linked internships and learning journeys.

e) International partnerships and collaborations

Singapore can play an important role as pathfinder and convenor for international collaborations and partnerships to advance sustainable aviation. For example, Singapore has forged agreement on an ASEAN Sustainable Aviation Action Plan (ASAAP), which is a ten-year plan that will detail milestones and activities to drive sustainable aviation growth in ASEAN. To better address the Asia-Pacific region's unique circumstances, CAAS will work with partners to establish the Asia-Pacific sustainable aviation centre to develop capabilities for sustainable aviation policy research specific to the needs of the Asia-Pacific region. This includes building deeper scientific understanding of regional SAF feedstocks, validating prevailing policy recommendations against the region's context to add new perspectives, and providing capacity-building activities for countries and companies.

In developing the Blueprint, CAAS has incorporated and built upon the recommendations by the International Advisory Panel (IAP) on Sustainable Air Hub, published in September 2022. The IAP was formed in February 2022, bringing together 20 industry, technology, and knowledge partners from Singapore and around the world. The IAP was chaired by Professor Chong Tow Chong, President of Singapore University of Technology and Design. Members of the IAP include Directors-General from key aviation International Organisations, as well as C-suite aviation industry executives and renowned knowledge and technology partners. To canvass ideas from a wider array of stakeholders, the IAP engaged more than 120 representatives from 40 local and international partners. Following the submission of the IAP recommendations, CAAS conducted extensive consultations with stakeholders and detailed studies before finalising the targets and initiatives of the Blueprint.

The Singapore Sustainable Air Hub Blueprint is part of CAAS's strategy post-COVID-19 to make the Singapore air hub more competitive, resilient, and sustainable.

Singapore's Commitment to Sustainable Aviation

01

Air connectivity is essential to Singapore's existence as an island nation and a critical engine for Singapore's open economy. The aviation sector contributes about 5% of our gross domestic product and around 200,000 jobs for our country. It also supports other economic sectors such as tourism, manufacturing, and logistics and connects Singapore to the global economy.

To secure Singapore's air hub status and ensure its continued competitiveness and relevance, Changi Airport must continue growing to meet the increasing air travel demand from the region. To capture the growth opportunities in Asia-Pacific, we will continue to expand Changi with the construction of a fifth terminal and a third runway as part of the Changi East development.

However, our air hub needs to grow more sustainably and responsibly. The adoption of the LTAG of net zero carbon emissions for international aviation by 2050 at the 41st ICAO Assembly sends a strong signal on the international community's commitment towards sustainable aviation.

As an active member of ICAO and the international civil aviation community, sustainability will be a key priority for Singapore's aviation sector as we contribute towards the LTAG and the calls to action.

The Blueprint adopts a balanced approach to the long term, sustainable growth of Singapore's aviation sector. While we recognise the need for environmental sustainability, this must be balanced with the Singapore air hub's competitiveness, to support the growth of the aviation industry in the upcoming decades. The Blueprint demonstrates this resolve in setting out Singapore's 2030 and 2050 targets as well as concrete steps that the Singapore aviation sector will take to decarbonise Singapore aviation, while balancing our competitiveness with the need for early and robust action on sustainability. This Blueprint will also serve as Singapore's State Action Plan for submission to ICAO.

Performance and Targets

02

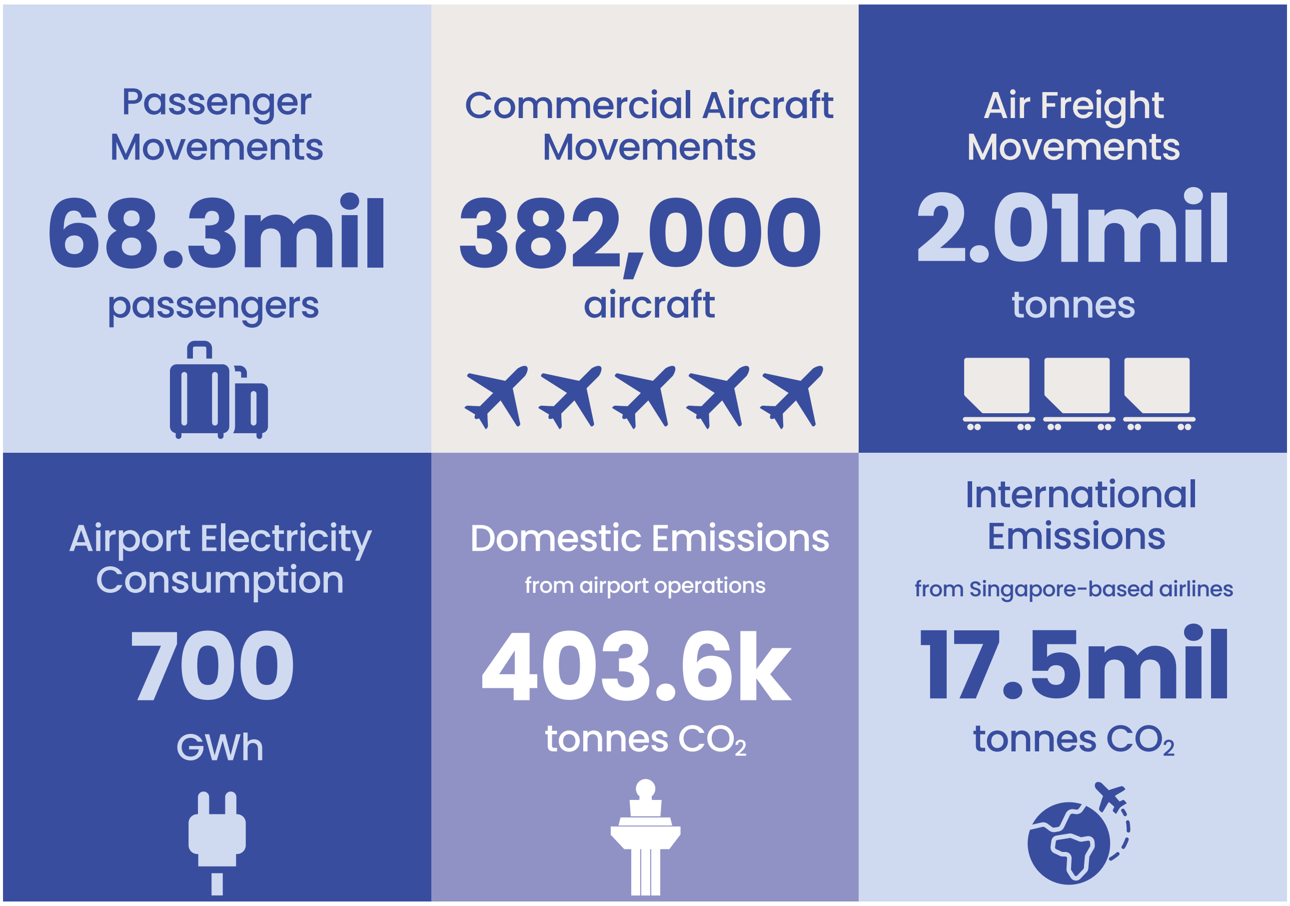
CAAS will work with aviation stakeholders to reduce domestic aviation emissions by 20%[3] in 2030 from 2019 level and achieve net zero domestic and international aviation emissions by 2050.

Decarbonising the Singapore aviation sector

In 2019, international emissions from Singapore-based airlines[4] reached 17.5 million tonnes of CO_2. Domestic emissions from airport operations were 404 ktCO_2 in the same period (Figure 1). With air travel steadily recovering post-COVID-19 and expected to grow further, carbon emissions will rise as Changi Airport grows to support increasing passenger travel and cargo demand.

To grow sustainably, we have set targets and worked with our stakeholders to identify initiatives to decarbonise the aviation sector. The targets demonstrate a balanced approach to the long term, sustainable growth of Singapore's aviation sector, taking into account the need for environmental sustainability while ensuring that the Singapore air hub remains competitive.

Figure 1: Airport activities that contribute to 2019 aviation emissions



Source: CAG and CAAS's calculations with inputs from stakeholders

[3] This covers emissions from operations of vehicles, facilities and buildings for aircraft, passenger, baggage, and cargo handling at Changi and Seletar Airports. It does not include targets for Changi East developments, including Terminal 5, which are not operational today. These will be determined separately.

[4] These covers emissions from international flights operated by Singapore-based operators.

Reducing our domestic aviation emissions

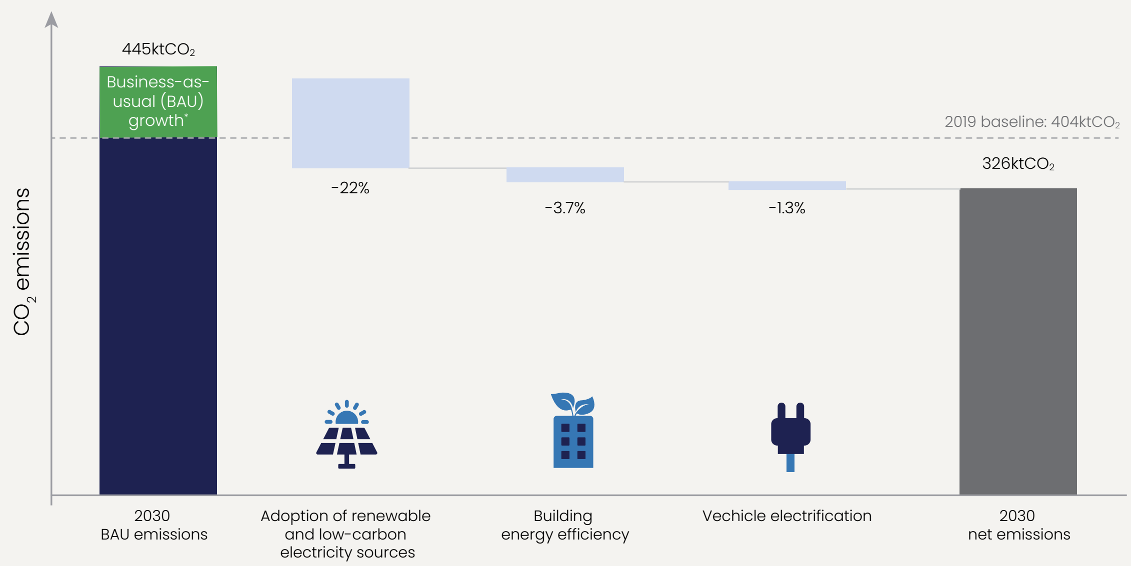
Domestic aviation emissions are defined by functions that are core to Singapore air hub, including the operation of cargo and passenger terminal buildings and ground support. These operations are highly energy intensive with substantial electricity and fuel requirements. To reduce our domestic aviation emissions, we need to decarbonise airport operations through reducing energy usage and switching to renewable sources.

The aviation sector in Singapore will reduce domestic aviation emissions from Changi and Seletar Airport operations by 20% in 2030, from 2019 levels. Through a suite of initiatives, we will reduce emissions from our 2019 baseline of 404ktCO_2 to 326ktCO_2 in 2030. Accounting for projected growth, this translates to a total projected reduction of 119ktCO_2.

By 2050, we target net zero emissions in line with Singapore's national commitments.

With inputs from industry stakeholders, our projected emissions and reductions from the suite of initiatives – adoption of renewable and low-carbon electricity sources[5], building energy efficiency improvements, and the adoption of cleaner energy options at the airside – are illustrated in Figure 2.

Figure 2: Projected reduction of domestic aviation emissions in 2030



*Refers to projected growth in emissions without any new initiatives post-2019
Source: CAAS' figures (with inputs from stakeholders)

[5] Comprises onsite solar deployment and projected decarbonisation of the national grid through low-carbon electricity imports, subject to developments.

Singapore supports and will contribute to ICAO's goals of carbon neutral growth from 2019 and the long term global aspirational goal for international aviation of net zero carbon emissions by 2050.

To support our ambition, flights departing Singapore will be required to use SAF from 2026. We will aim for a 1% SAF target for a start. Our goal is to raise the SAF target beyond 1% in 2026 to 3 – 5% by 2030, subject to global developments and the wider availability and adoption of SAF.

Reducing our international aviation emissions

Aircraft Technology | **Operations & Infrastructure** | **Sustainable Aviation Fuel** | **Market-based Measures**

Net Zero 2050

Singapore affirms and supports ICAO's leadership in addressing international aviation emissions. We will play our part to contribute to ICAO's goals of carbon neutral growth (CNG) from 2019 and the LTAG for international aviation of net zero carbon emissions by 2050.

To achieve these goals, ICAO has identified a basket of measures, comprising:

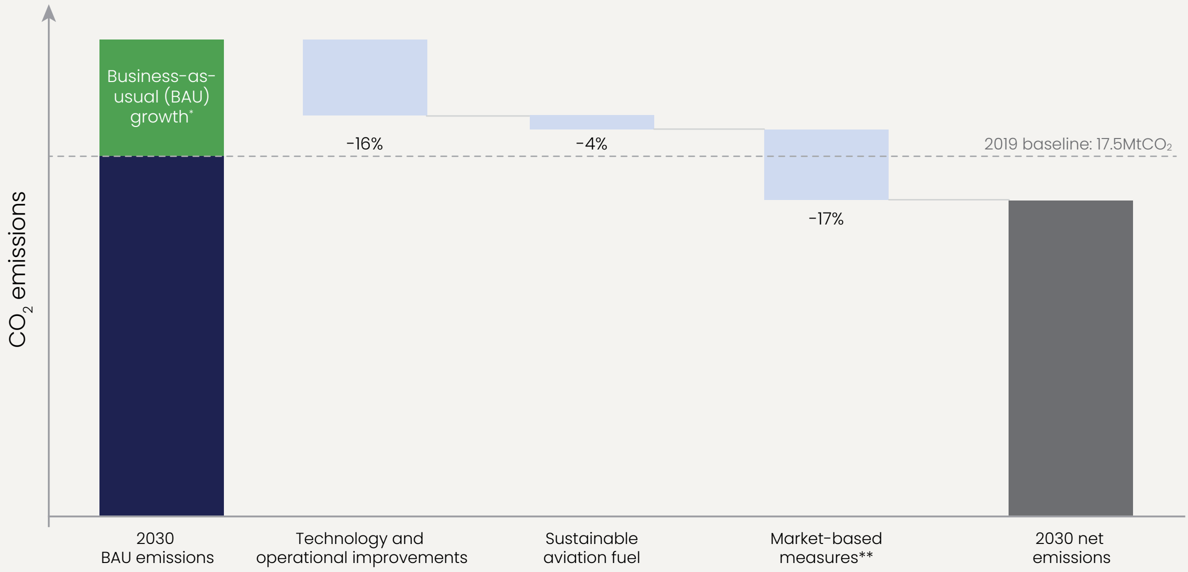
- Technology and operational improvements, arising from the use of more fuel-efficient aircraft and improved operational measures;
- Use of SAF and other aviation cleaner energies; and
- Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), which complements the other measures through the use of carbon credits. Under CORSIA, airlines from participating States need to offset their carbon emissions (through use of SAF and/or carbon credits) between 2021-2035, to achieve CNG from 2019 levels. The voluntary phase of CORSIA is ongoing, and it becomes mandatory from 2027.

More recently, ICAO and its Member States agreed on a collective global aspirational Vision to reduce international aviation emissions by 5% by 2030 through the use of aviation cleaner energies at the Third ICAO Conference on Aviation and Alternative Fuels in November 2023.

Singapore will play its part in contributing to ICAO's targets and work with our stakeholders to implement ICAO's basket of measures. We have been participating in CORSIA from its voluntary pilot phase and continue to do so. To demonstrate our commitment, we will take decisive actions to encourage SAF use and production in Singapore. We will aim for a 1% SAF target for a start. Our goal is to raise the SAF target beyond 1% in 2026 to 3 – 5% by 2030, subject to global developments and the wider availability and adoption of SAF.

Figure 3 shows projected emissions from Singapore-based airlines from the implementation of ICAO's basket of measures in the medium term. We estimate that technology and operational improvements can bring an emissions reduction of 16% from 2030 BAU levels. In addition, SAF and market-based measures can reduce emissions by about 4% and 17% respectively. This would bring our 2030 international aviation emissions below the 2019 baseline.

Figure 3: Contributions to reduction in international emissions



*Refers to projected growth in emissions without any new initiatives post-2019
**Arising from CORSIA offsetting
Source: CAAS' figures (with inputs from stakeholders)

Airport Domain Initiatives

03

Airports are complex ecosystems serving as gateways for air travel and connectivity. They are highly energy intensive due to their large-scale infrastructure, operational systems, and ground operations. To reduce our airport carbon footprint, the Singapore aviation ecosystem will increase adoption of cleaner energy, further improve energy efficiency, and switch away from fossil fuels.

Image credit: CAG

CAAS and CAG are working to increase solar power deployment by installing more solar photovoltaic systems on available rooftop spaces of airport buildings to increase solar power generation to 10% of Changi Airport's 2019 electricity consumption. Airfield solar panels, if assessed to be feasible, can potentially generate another 5%.

Solar Power deployment

Harnessing renewable energy is key to reducing an airport's carbon footprint. Solar energy is the most viable source of renewable energy as Singapore's geography does not favor alternatives such as hydro or wind power.

As of end-2023, Changi Airport has more than 20MWp of installed solar power capacity, generating close to 4% of its 2019 electricity consumption of about 700GWh. Ongoing plans to install more solar photovoltaic (PV) systems on the available rooftop spaces of airport buildings will further generate 6%. Solar panels will also be deployed at Seletar Airport.

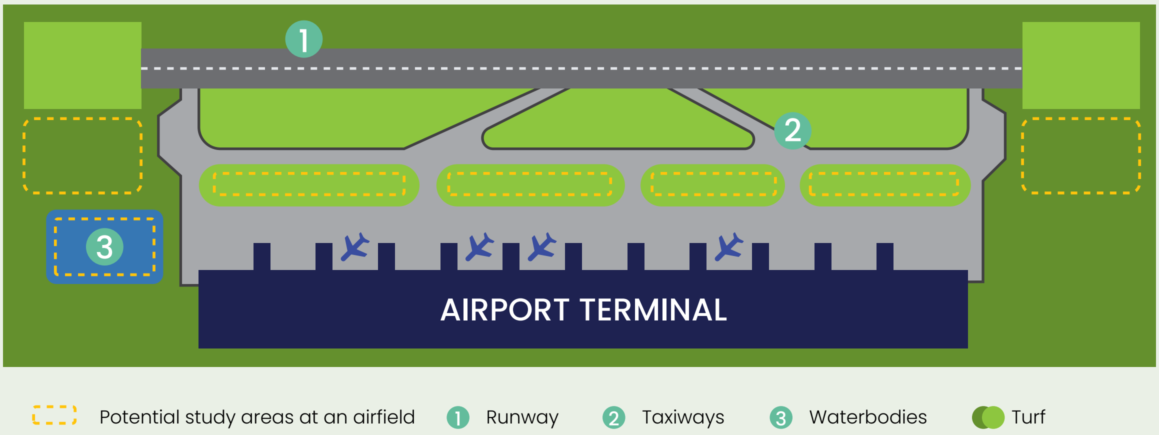
To further increase solar power capacity, Changi Airport will be commencing a study to assess the feasibility of installing solar PV systems on untapped areas such as open turfed areas and, potentially, water bodies within the airfield, without compromising ICAO and local requirements for safety and efficiency of airport operations.

Some airports in other parts of the world have installed solar PV systems near the airfield. However, deploying solar PV systems in the airfield where aircraft taxi, land, and take-off involves significantly more design challenges. The solar panels may potentially cause visual disturbances to pilots and air traffic controllers or interfere with radar signals.

Jet blasts from aircraft or adverse weather elements may also dislodge components of the solar PV systems over time, creating foreign object hazards to aircraft engines. Operationally, the solar installations may obstruct aircraft rescue and fire fighting emergency response and there could be access constraints in carrying out installation and maintenance amidst continuous airfield operations and aircraft activity.

Changi Airport's study will examine the viability of deploying solar PV systems on a wider scale and at much closer proximity to aircraft operations, such as within the non-graded areas of the runway and taxiway strips as shown in Figure 4, for which there are currently no known cases being implemented. The study can potentially further reduce the airport's carbon footprint by unlocking more untapped spaces, pushing the boundary for harnessing solar power beyond rooftop spaces, and chart the way forward for wider solar deployment in airports worldwide.

Figure 4: Potential scope of the solar airfield study



The solar airfield study, which will cover the existing Changi Airport Terminals 1 to 4 and the future Changi East sites where Terminal 5 will be located, is expected to start in early 2024 and will take approximately twelve months to complete. The study is supported under the ASP. If feasible, airfield solar installations could potentially provide enough solar power capacity to support up to 5% of the airport's 2019 energy consumption.

Clean energy airside vehicles

Today, airside vehicles and equipment used for airport ground operations generate polluting greenhouse gas emissions from burning conventional fossil fuels, typically fossil diesel. We can reduce our carbon footprint by switching the existing airside vehicle fleet to use cleaner energy options.

In March 2023, Singapore announced targets for the transition of Changi Airport's airside fleet to cleaner energy options. By 2040, all airside vehicles should run on cleaner energy. We have also set an interim target for all new airside light vehicles, such as cars, vans and minibuses, and selected new heavy vehicles like forklifts and tractors to be electric from 2025.

The Changi Airport community is committed to expand the use of cleaner energy for airside vehicles with a commitment to transition the entire airside vehicle fleet to operate on cleaner energy sources by 2040, and for all new light vehicles and selected new heavy vehicles to be electric from 2025.

These targets were set in close consultation between CAAS and key airport stakeholders such as CAG, dnata, SATS, and SIA Engineering Company, with the following considerations:

Technological availability
Ensuring that the identified vehicle types have cleaner energy variants.

Operational viability
Ensuring that the cleaner energy variants can meet our local operational context.

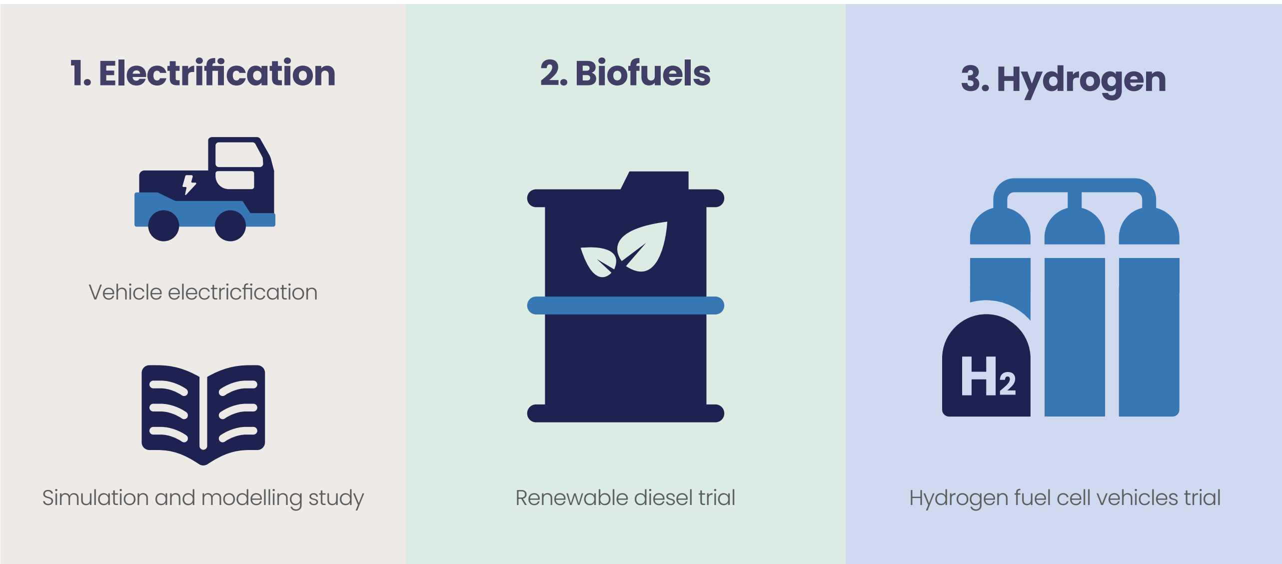
Total cost of ownership
Impact of upfront costs of switching to cleaner energy variants and the cost of operation, compared to operations using conventional fossil fuel, on stakeholders.

Fleet transition plans
Stakeholders' replacement timeline for current airside vehicle fleet.

Space and grid adequacy
Ensuring sufficient space and grid capacity are available to support the ramp-up of electric charger network.

Drawing from the IAP's recommendations, Singapore is pursuing a range of initiatives to facilitate the transition with better understanding of the deployment scale, concept of operations, challenges, policies, and regulations. This is underpinned by three main pathways: electrification of the airside fleet, use of biofuels, and conversion to hydrogen-powered airside vehicles (Figure 5).

Figure 5: Pathways to facilitate transition to cleaner airside vehicles



Pathway 1: Electrification

Image credit: CAAS

Electrification is the main cleaner energy pathway, given the maturity of the pathway and the wide availability of viable electric variants for airside vehicles. Unlike internal combustion engine vehicles, electric vehicles do not produce tailpipe emissions.

Under the electrification pathway, Singapore has already taken strides to deploy electric vehicles at the airside. Efforts began in 2017 and CAG has successfully worked with the ground handlers to convert all baggage tractors entering the baggage handling areas across Changi Airport to electric versions. To date, 20% of around 2,500 airside vehicles at Changi Airport are electric. There are over 100 EV charging stations located at the airside across the four terminals, and this will increase to over 300 chargers in the next few years.

In July 2023, following the IAP's recommendations, CAAS commissioned the Agency for Science, Technology and Research to conduct a simulation and modelling study, Air-SITEM, to study the infrastructure changes needed to support wider electrification of the airside fleet. The Air-SITEM study will model and produce a high-fidelity simulation of the behaviour, movement patterns, and expected charging requirements of all airside vehicles. It will then be able to quantify the resulting impact of different electrification levels on the grid infrastructure. The study will also provide recommendations regarding the management of electric vehicle charging patterns to minimise peak load as well as optimal locations for charging stations. This will facilitate a better understanding of the deployment scale of electric vehicles. The study is expected to be completed in early 2025.

Pathway 2: Biofuels

The use of biofuels, in particular RD, is also another key pathway to decarbonise vehicle operations at the airside. RD has lower lifecycle carbon emissions compared to conventional fossil diesel, making it a good cleaner energy option, particularly for those vehicles without viable electric or hydrogen variants. RD can provide near-term potential for carbon abatement because it can be used as a "drop-in" replacement for existing diesel engines, diesel transportation, storage, and distribution infrastructure, with minimal adjustments.

In 2024, CAAS and stakeholders will commence a trial to use RD for airside vehicles, focusing on heavy and specialised vehicles for which there are fewer viable electric variants. These include ground power units, air tugs, and transporters. This trial is receiving funding under the ASP and will provide insights on the feasibility, cost, and operational impact of using RD as a cleaner energy source for airside vehicles. Such insights will inform the Changi Airport community on the best approach to encourage adoption of RD for these equipment until electric or hydrogen powered variants become viable in the future.

Pathway 3: Hydrogen powered vehicles

Finally, CAAS will also explore the use of hydrogen-powered vehicles in airport operations. This includes working to conduct hydrogen fuel cell vehicle (HFCV) trials at the airside to complement the existing electric vehicle fleet in transitioning all airside vehicles to cleaner energy by 2040. HFCVs have no tailpipe emissions, with water vapour being the only by-product. These trials will help the various stakeholders better understand the regulatory challenges, operational impact, and infrastructural changes required to support HFCV adoption at the airport.

Given that the use of hydrogen at the airside is relatively nascent, piloting the use of hydrogen-powered airside vehicles in Singapore's context would be important to help determine its feasibility. HFCVs would have to be brought into an airport environment and relevant refueling infrastructure would need to be installed to understand how hydrogen can be used safely.

Low-carbon electricity imports

Singapore's land and natural resource constraints limit the amount of renewable energy we can produce. Hence, the import of cross-border low-carbon electricity is an important complementary decarbonisation lever for Singapore and our airport operations.

EMA targets for Singapore to import up to 4GW of low-carbon electricity by 2035, making around 30% of Singapore's electricity supply then, with imports potentially starting from 2027. In July 2022, EMA invited interested companies to submit proposals to import and sell up to 4GW of electricity in Singapore. As of end-2023, Singapore is on track to achieving its target with Conditional Approvals granted by EMA to projects that will import electricity from Cambodia, Indonesia, and Vietnam.

As most of the carbon emissions from airport operations are due to electricity consumption at the airport, we will leverage the EMA's plans to reduce our GEF, including the use of low-carbon electricity imports, for the aviation sector to reach net zero domestic emissions by 2050. In addition, airport stakeholders will have the option of securing direct power purchase agreements with importers for additional low-carbon electricity.

Image credit: CAG

Building energy efficiency

CAAS, CAG, and other airport partners are working to continually improve the energy efficiency of Changi Airport's terminal buildings, especially for air-conditioning systems, which account for more than half of the buildings' total electricity consumption. The air-conditioning systems at our airport terminals are designed to provide thermal comfort and good indoor air quality given the hot and humid climate in Singapore. Improving the energy efficiency of the air-conditioning systems has greatest potential to move the needle in decarbonising airport operations.

As part of its environmental sustainability thrust, CAG has been pursuing passive and active strategies to lower energy use associated with air-conditioning systems. An example of a passive design strategy would be the use of façade materials (for example, glass and aluminum cladding) for terminal buildings, which are designed to comply with BCA's code for building envelope solar heat gain.

The airport has also trialed cooling films to reflect external heat and extract internal heat for discharge to the outdoors thereby reducing air-conditioning cooling loads.

In terms of active strategy, CAG has upgraded the chiller systems at Terminals 1 and 2 to achieve best-in-class efficiency levels. The upgrading works were carried out through Energy Performance Contracts (EPC) where the efficiency of the chiller plants are being maintained and guaranteed by the EPC contractor over the lifespan of the system to ensure sustained energy performance. The collective energy saving from the upgrading projects is equivalent to reducing nearly 30% of energy consumption. The chiller systems at Terminals 3 and 4 would also be upgraded as they approach the end of their asset lifespan.

Best-in-class energy efficient designs will also be incorporated in the new Terminal 5 to achieve the Green Mark Platinum Super Low Energy Building standard. As a greenfield development there will be opportunities for Terminal 5 to incorporate more passive and active design strategies for higher energy efficiency. This can include a district cooling system where chilled water produced centrally is delivered to various zones through a network of pipes instead of installing smaller standalone chiller systems distributed across the terminal. Such a design strategy will achieve economies of scale thereby reducing capital and maintenance costs. Another example is space stratification, which caters for differentiated cooling needs to optimise the cooling load in each zone. A smart energy management system will also be considered to provide optimal cooling and lighting to minimise energy consumption.

Resource circularity through on-site waste-to-energy facility

CAAS, together with stakeholders and with support from experts in the waste-to-energy and waste management field, will undertake a study of the potential and feasibility of establishing an on-site waste-to-energy facility at Changi Airport. Such a facility could use waste as feedstock to generate biofuels, electricity, heating, or even cooling for the airport, thereby reducing electricity uptake from the national grid and decarbonising airport operations. The study would involve a waste audit to determine the type and quantity of viable waste and make a technical assessment to establish the most effective waste-to-energy pathway. This builds upon the IAP recommendation to enhance resource circularity.

The siting of such facilities within the airport would need to be carefully assessed to avoid conflicts with airport operations, deterioration of ambient air quality, or the generation of odour, noise, and dust. It must also comply with regulations and any need to mitigate potential risks.

Airline Domain Initiatives

04

To kickstart the adoption of Sustainable Aviation Fuel (SAF) in Singapore, flights departing Singapore will be required to use SAF from 2026.

We will aim for a 1% SAF target for a start. Our goal is to raise the SAF target beyond 1% in 2026 to 3 – 5% by 2030, subject to global developments and the wider availability and adoption of SAF.

Carbon emissions from flying are inherently hard to abate. Aircraft technology has improved over the years, bringing about higher efficiency and more fuel savings. Today's new-generation aircraft can achieve a 20% reduction in energy use compared to the aircraft they replace. However, game-changing aircraft technology that can drastically reduce emissions would still require several decades to develop for use in Singapore's context.

SAF is a lower carbon fuel that can be produced from a number of sources (feedstock) including waste fats, oils and greases, municipal solid waste, agricultural and forestry residues, as well as non-food crops cultivated on marginal land. They can also be produced synthetically via a process that captures carbon directly from the air. SAF is chemically similar to fossil jet fuel and can be safely used as a drop-in fuel with no modifications needed to aircraft or infrastructure.

The use of SAF is expected to be the most critical aviation decarbonisation lever, contributing to around 65% of the carbon emission reduction needed to achieve net zero by 2050. It has the potential to reduce carbon emissions by up to 80% on a lifecycle basis compared to fossil jet fuel.

However, SAF adoption remains low with significant hurdles in terms of higher costs compared to conventional fossil jet fuel, and the need for feedstock diversification through new production pathways for longer-term scale up of supply.

In 2023, recognising the importance of SAF to aviation decarbonisation, the ICAO and its Member States agreed to a collective global aspirational Vision to reduce international aviation emissions by 5% by 2030 through the use of SAF and other aviation cleaner energies.

National SAF target and SAF levy

Experience around the world and a SAF pilot[6] in Singapore conducted by CAAS, GenZero, and SIA have shown that the adoption of SAF cannot depend on voluntary use alone, due to the high cost of SAF.

To kickstart SAF adoption in Singapore, flights departing Singapore will be required to use SAF from 2026. We will aim for a 1% SAF target for a start to encourage investment in SAF production and develop an ecosystem for more resilient and affordable supply. Our goal is to raise the SAF target beyond 1% in 2026 to 3 – 5% by 2030, subject to global developments and the wider availability and adoption of SAF.

The current global supply of SAF is less than 1% of global jet fuel demand. Capacity will need to increase exponentially to meet the demand in 2050 so that the aviation sector can achieve its net zero goal. It is critical that we provide fuel producers with a demand signal to give them the confidence to make further investments in SAF production, and accelerate global SAF production.

[6] CAAS worked with GenZero and SIA to conduct a 20-month SAF trial at Changi Airport. Under the pilot, SIA purchased 1,000 tonnes of neat SAF which generated 1,000 SAF credits, corresponding to approximately 2,500 tonnes of carbon dioxide reductions. Of these 1,000 credits, only about two-thirds were sold to a handful of businesses and cargo users.

While we recognise the importance of catalysing SAF production, we need to balance this against the economic impact on the industry and its users and Singapore air hub's competitiveness. Today, SAF is priced about 3 to 5 times conventional jet fuel. There is a need to manage the impact of SAF adoption on the cost of air travel.

CAAS will introduce a SAF levy for the purchase of SAF to achieve the uplift target. As the market for the supply of SAF is still nascent and the price of SAF can be volatile, we will adopt a fixed cost envelope approach to provide cost certainty to airlines and travellers. The levy will be set at a fixed quantum based on the SAF target and projected SAF price at that point in time. For example, the quantum of the SAF levy in 2026 will be set based on the volume of SAF needed to achieve a 1% SAF target and the projected SAF price in 2026. The amount collected through the SAF levy will be used to purchase SAF, based on the actual price of SAF at the time of purchase. The SAF levy will not change, even if the actual SAF price differs from what is projected. Instead, the actual uplift volume of SAF will be adjusted based on the pre-determined SAF levy and prevailing SAF price.

The levy will vary based on factors such as distance travelled and class of travel. As an indication, we estimate that the levy to support a 1% SAF uplift in 2026 for an economy class passenger on a direct flight from Singapore to Bangkok, Tokyo and London to be S$3, S$6 and S$16 respectively. Passengers in premium classes will pay higher levies.

CAAS will continue its close consultation with stakeholders on the implementation of the SAF levy, before announcing more details in 2025 nearer the date of implementation.

Central SAF procurement

To support the implementation of the national SAF target and further manage the cost of using SAF, the procurement of SAF will be centralised. The levies collected will be used to aggregate demand and reap economies of scale.

Besides SAF demand from the national target, there are also opportunities to aggregate voluntary SAF demand from businesses and organisations looking to purchase SAF to reduce their air travel carbon footprint. Businesses and organisations will be invited to use the central procurement mechanism to reap economies of scale.

The central procurement function can also take on the management and allocation of SAF credits generated from SAF use through central purchases. For SAF procured under the national targets, SAF credits will be allocated back to the airlines based on the share of levies collected. Credits generated from SAF procured voluntarily by businesses and organisations will be allocated based on the amount of SAF bought.

Image credit: Neste

SAF production in Singapore and the region

In 2023, global SAF production was estimated to be over 600 million litres, which was double the production volume in 2022[7]. For the aviation sector to achieve net zero emissions by 2050, 65% of the total emissions reductions will likely need to be achieved through the use of SAF. Based on IATA's estimates, this will translate into 450 billion litres of SAF being needed[8]. This will require significant increases in SAF production facilities across the world.

The presence of an existing petrochemical sector in Singapore provides a good base for new SAF facilities in Singapore. Neste has expanded their refinery capacity in Singapore with the capacity to provide 1.25 billion litres[9] of SAF annually since their initial investment in Singapore in 2007.

Nonetheless, given the tremendous increase in SAF production capacity required globally, there is scope for more SAF production to be based in Singapore, which will also support the needs of Changi Airport. CAAS and the Singapore Government will work closely with industry partners to expand Singapore's SAF production capacity, in line with our national targets set out under the Sustainable Jurong Island[10] plan to increase the production of sustainable products.

[7] Source: International Air Transport Association, Press release 69, "SAF volumes growing but still missing opportunities, 6 December 2023.

[8] Source: International Air Transport Association. Net Zero 2050: sustainable aviation fuel.

[9] Based on standard density of 0.8kg/litres for jet fuel as listed in CORSIA Annex 16, Volume IV: Part II, Chapter 2, 2.2.3.

[10] In 2021, EDB launched the Sustainable Jurong Island (JI) report, detailing the Government's plans to transform JI into a Sustainable Energy & Chemicals (E&C) Park that operates sustainably and exports sustainable products globally. As part of this, EDB will set out to achieve the following key targets for the E&C sector by 2030: (i) to increase the output of sustainable products by 1.5 times from 2019 levels, (ii) ensure that refineries and crackers in Singapore are in the top quartile of the world in terms of emissions intensity, and (iii) realise at least two million tonnes of carbon capture potential.

Besides anchoring new SAF investments in Singapore, there is also opportunity for more SAF production in our region. SAF production is limited by overall feedstock availability due to constraints in feedstock supply as well as competition for feedstock from other sectors such as shipping, road transport and energy. There is a need to widen feedstock availability across different regions to unlock more SAF production globally. To do this, there should be consistent rules for acceptability and sustainability requirements for feedstock. Singapore promotes the recognition of CORSIA's sustainability criteria as the accepted basis for the eligibility of SAF. We encourage the industry to adopt a feedstock-neutral approach and not exclude any particular feedstock, as long as it meets the CORSIA sustainability criteria and delivers the required carbon emissions reduction.

CAAS is participating in a regional study, led by Boeing and the Roundtable on Sustainable Biomaterials, to develop a Sustainable Aviation Fuels Roadmap to ascertain the availability and sustainability of feedstock in Southeast Asia, and identify feasible SAF production pathways that meet the CORSIA Sustainability Criteria. The study will also identify potential pilot projects that can be developed further to spur SAF production in Southeast Asia.

Airline fleet renewal and operational improvements

Singapore air carriers are major proponents of fleet modernisation programmes. They continue to invest in the replacement of their current fleet with more fuel-efficient aircraft models.

The SIA Group has invested in modern and fuel-efficient aircraft which has significantly reduced fuel consumption and emissions. This includes the Airbus A350 and Boeing 787, which are about 25% more fuel efficient than their older generation counterparts. The SIA Group is further investing in new generation aircraft, including the Boeing 777-9 and Airbus A350F, which will be delivered in the coming years. Arising from its fleet modernisation efforts, the SIA Group currently operates one of the youngest aircraft fleets globally, with an average age of about 7 years.

Our carriers also embarked on various operational improvements to reduce fuel burn, such as weight reduction initiatives and reduction of aircraft auxiliary power unit use on ground. In addition, they have optimised flight plans and management, including improving airspace congestion and identifying more efficient routes, as well as tapping into data analytics and digital solutions for in-flight fuel savings.

Air Traffic Management Domain Initiatives

05

CAAS will undertake three ATM initiatives over the next five years to improve operations to increase efficiency and reduce fuel burn. Collectively, these initiatives are expected to bring about a 10% reduction in additional fuel burn and emissions.

ATM initiatives offer a win-win solution for the environment, airlines, and passengers. Operational improvements to increase efficiency and the optimisation of flight routes can reduce track miles and flight durations. This enables airlines to reap fuel savings and for passengers to get to their destinations quicker, while reducing emissions. These benefits can be multiplied over many flights.

Singapore's efforts to optimise ATM for improved environmental performance will be closely aligned with plans and guidance from ICAO. ICAO has developed the Global Air Navigation Plan which comprises Aviation System Block Upgrades (ASBUs) as a strategy and roadmap and seeks to achieve a global interoperable air navigation system that is safe, efficient, and environmentally sustainable.

Singapore will roll out three initiatives over the next five years to improve the efficiency of ATM operations and procedures and reduce fuel burn by leveraging new ATM technologies, implementing new concepts of operations, and deepening collaboration with aviation stakeholders, including ANSPs and airlines.

Advanced demand-capacity balancing implementation

a) Expand suite of Air Traffic Flow Management (ATFM) solutions to include Long Range ATFM (LR-ATFM)

CAAS has partnered ANSPs within the Asia-Pacific region to implement a Distributed Multi-Nodal ATFM network, termed as the Asia-Pacific Cross-border Multi-Nodal ATFM Collaboration (AMNAC)[11]. This has enabled the coordination and management of flights within the AMNAC network prior to take-off instead of only managing flights tactically through air traffic control (ATC) restrictions when they are in the air. For example, Ground Delay Programs regulate the departure of flights in anticipation of a period of projected demand-capacity imbalance at a destination airport. The affected flights depart as guided by calculated take-off times issued by ATFM units within the AMNAC network to avoid anticipated congestion in the air. The AMNAC has been effective in optimising traffic flows, increasing predictability of flights, and reducing holding in the air, thus reducing unnecessary fuel burn and carbon emissions.

CAAS is expanding beyond the AMNAC network to include longer haul flights. Operational trials on the LR-ATFM concept have been conducted with SIA for flights between Europe and Singapore, to speed up or slow down these flights enroute to Singapore. This can avoid arrival delays arising from unnecessary holding and vectoring and minimise unnecessary fuel burn. CAAS is developing the operational requirements for integrating the LR-ATFM concept into the existing ATFM system and engaging stakeholders and partner ANSPs to refine the concept of operations. Implementation of LR-ATFM operations is planned for 2026.

b) Strengthen integration between meteorology (MET) and ATM

Due to the convective weather in the region, disruptive conditions such as thunderstorms with possible wind shears are difficult to predict and can occur abruptly. Rain impedes visibility at or around an airport and can result in increased aircraft holding due to poor landing conditions and increased spacing between arrivals. These result in increased delays and additional fuel burn and emissions. As such, accurate and timely MET information is important to support better decision-making for ATM to reduce arrival delays and minimise unnecessary fuel burn.

CAAS has been working with stakeholders to improve the reliability, timeliness, and accuracy of weather forecast information provided to air traffic controllers for ATM decision-making. In particular, CAAS, together with local research partner, MITRE Asia Pacific Singapore (MAPS), developed a Convective Weather Impact Forecast (CWIF) prototype with stakeholders to improve forecasts for convective weather and contextualise the weather effects and impact on air traffic. For the next phase, CAAS is testing the prototype for decision support, fused with local weather insights and air traffic flow information for forward planning, with plans to operationalise the CWIF tool in 2028. This will help to reduce arrival delays arising from adverse weather conditions and minimise associated fuel burn.

[11] States/administrations participating in the AMNAC include Cambodia, China, Hong Kong China, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam.

Performance-based navigation enhancement

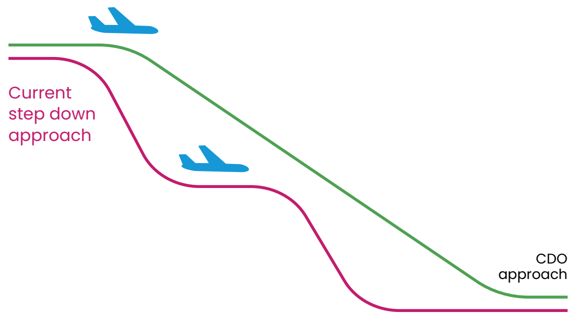
a) Develop smart tools to facilitate Continuous Climb and Descent Operations (CCO and CDO)

Conceptually, CCO and CDO would allow aircraft to fly on uninterrupted flight paths during climb and descent phases and remain at higher altitudes for longer periods of time at lower engine thrust, thus reducing fuel burn, as shown in Figure 6. CAAS has been facilitating CCO and CDO where traffic permits. CAAS has also collaborated with partner ANSPs from Japan and New Zealand to conduct trials on green ATM operations, including the facilitation of CCO and CDO for flights between both countries, since May 2023 and August 2023 respectively.

These operational trials have resulted in emissions reduction and demonstrated the potential to yield significant benefits when implemented on a wider scale. Specifically, CCO and CDO implemented at Changi Airport has enabled fuel savings of up to 150kg, and 470kg of CO_2 emissions reduction for each flight.

There remain several challenges to conduct CDO in actual ATC operations, such as the lack of awareness of the optimal top of descent (TOD) for all aircraft. In addition, high traffic density and a complex operational environment, especially around Changi Airport, will limit the extent to which CCO and CDO can be implemented. Therefore, CAAS is developing solutions to support ATC in conducting CDO, such as a smart advisory tool prototype in collaboration with local research partner, Aviation Innovation Research Lab (AIR Lab), to pre-identify suitable aircraft for CDO, provide optimal TOD information to air traffic controllers, and inform of CDO opportunities. This will facilitate ATC in carrying out CDO, which will then contribute to better optimisation of flight profiles and reduction in fuel burn and emissions. Operational trials for the smart advisory tool prototype were conducted in the first half of 2023, with the aim to operationalise the tool by 2028. Beyond this, CAAS continues to explore the development of other smart tools to support the optimisation of other ATM operations including CCO.

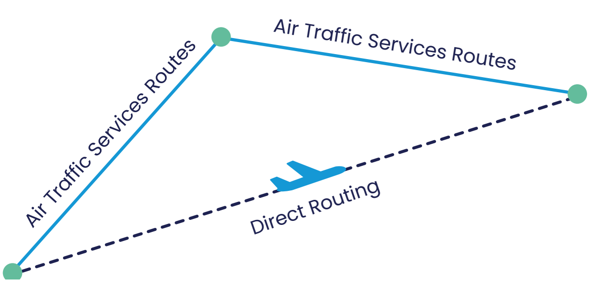
Figure 6: Continuous Descent Operations (CDO) approach vs non-optimal approach



b) Implement direct point-to-point routings

CAAS has progressively implemented direct point-to-point routings, shown in Figure 7, for specific route segments to improve flight efficiency and reduce fuel burn. CAAS is also collaborating with partner ANSPs in the region to implement Direct Route Operations on a wider scale, to yield greater benefits for airlines and the environment. The longer-term aim is to shift towards an eventual Free Route Airspace across contiguous volumes of airspace which will bring about optimised capacity and flexible flight trajectories.

Figure 7: Direct point-to-point routings



Gate-to-gate trajectory optimisation

a) Improve precision in separation between aircraft during take-off and landing

Runway throughput is determined by several factors, including the required minimum wake turbulence separation between aircraft as prescribed by ICAO. The re-categorisation (RECAT) of aircraft wake turbulence categories from four to seven groups based on ICAO provisions has enabled a further reduction in separation between aircrafts of certain weight categories. This allows the use of more precise separation standards between aircraft to reduce the time intervals needed between take-offs and landings, thus improving the overall runway throughput efficiency and capacity, and reducing delays and fuel burn.

Since 2022, CAAS has implemented the RECAT of aircraft wake turbulence categories to reduce separation between arrival flights, facilitated by an Approach Spacing Tool, a decision support tool for ATC. CAAS is extending the same initiative to departures, supported by a Departure Spacing Tool, developed with MAPS, to further optimise runway efficiency and increase fuel savings. CAAS has completed the scoping of the departure RECAT tool and will be conducting software testing and integration for operationalisation of the tool by 2028.

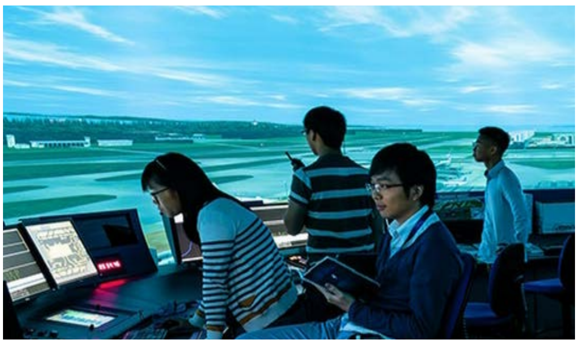


Image credit: CAAS

b) Implement enablers for Trajectory Based Operations (TBO)

The transformation of ATM, as shown in Figure 8, is needed to enable a quantum leap in operations that optimises the end-to-end trajectories of flights to support traffic growth in a more sustainable manner. Future concepts of operations, including TBO, would enable ANSPs to work together to jointly plan and optimise flight trajectories from take-off to landing across boundaries and stakeholders.

In mid-2020, CAAS collaborated with ANSPs from Canada, Japan, Thailand, and the United States (US) in a multi-regional TBO project, led by the US FAA, to demonstrate and validate TBO operational values and capabilities. The initial phase of the project involved a lab demonstration trial which tested various scenarios of TBO flights, the negotiation of flight trajectory based on predicted traffic information through flight and flow information exchange, and the identification of operational values and technical capabilities required. Subsequently, CAAS, together with ANSPs from Japan, Thailand, and the US, collaborated with Boeing as the technology partner to successfully conduct the world's first-ever multi-regional TBO demonstration flight in June 2023. The successful demonstration flight validated the technological capabilities that were developed and tested in lab demonstrations during the initial phase, including information exchange, trajectory negotiation, and collaborative decision-making processes during an active flight, utilising onboard capabilities and ground systems.

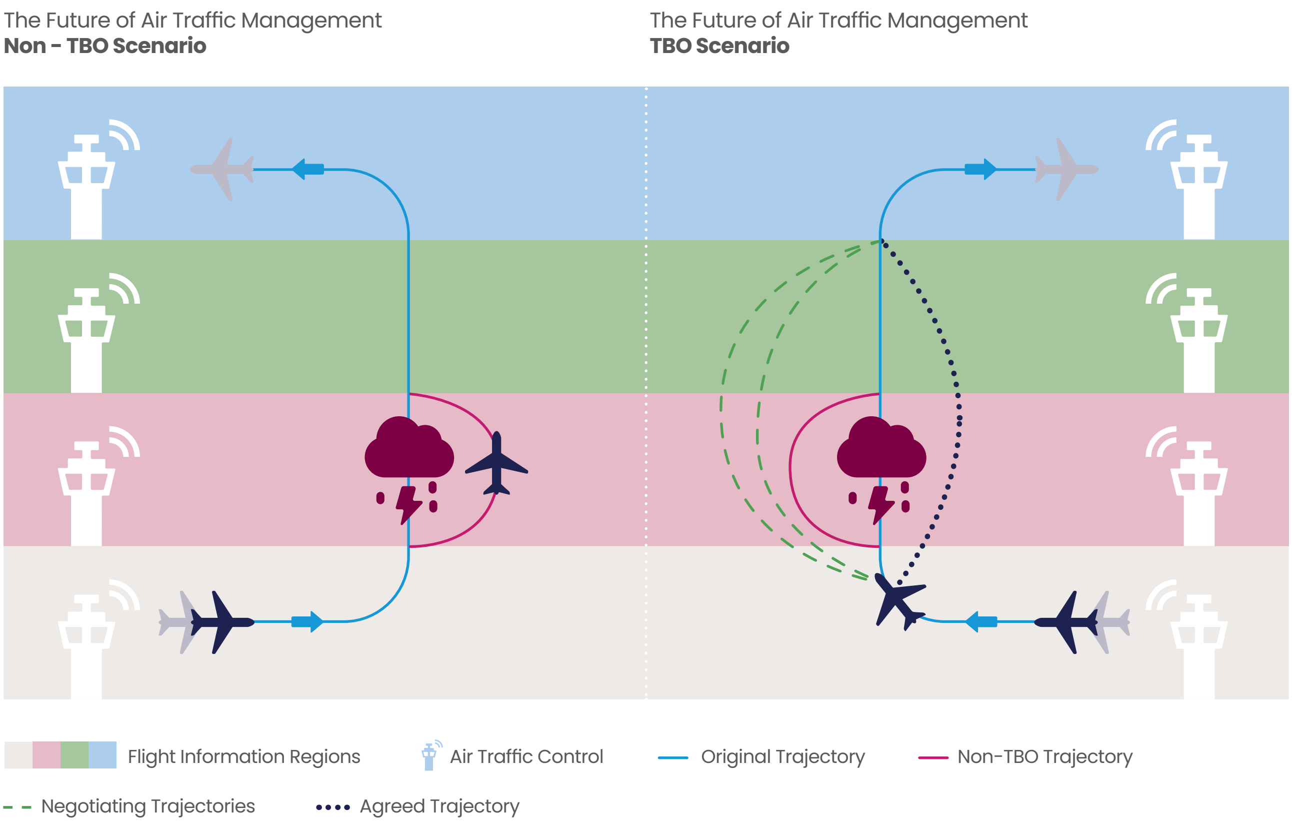
To further advance the development and implementation of TBO in the region, CAAS signed a Letter of Intent on the Asia-Pacific TBO Pathfinder Project in October 2023 with nine other signatories comprising partner ANSPs from China, Indonesia, Japan, New Zealand, the Philippines, Thailand, and the US, the Civil Air Navigation Services Organisation, and IATA, to jointly define, develop, and demonstrate TBO for the Asia-Pacific region within the next few years.

The full implementation of TBO is a long-term endeavour. As an interim step, several fundamental technological building blocks can enable the sharing of information among all stakeholders involved. These include Flight and Flow Information for a Collaborative Environment (FF-ICE) and System Wide Information Management (SWIM).

CAAS is working with stakeholders in ASEAN, the Asia-Pacific region, and at the global ICAO level to adopt a phased implementation of the key building blocks for TBO. For FF-ICE, the focus is on pre-departure negotiation for flight trajectory optimisation, starting with the implementation of filing and flight data request services by 2026. Beyond 2026, CAAS will explore the implementation of other elements of FF-ICE, which will enable post-departure "In-The-Air" information exchange and negotiation of flight trajectory optimisation.

For SWIM, CAAS has completed an operational trial with multi-nodal ATFM as the first use case and has collaborated with partner ANSPs to form an ICAO APAC SWIM Implementation Pioneer Group to develop the timelines for SWIM services testing and provisioning, with the implementation timeframe for SWIM in APAC before 2030.

Figure 8: ATM transformation: Optimise end-to-end flight trajectories



Critical Enablers

06

The effective implementation of sustainability initiatives across the three domains will require strong government action and close collaboration with the industry. As such, key enablers are necessary for providing the right conditions for success. They are policy and regulation, industry development, infrastructure planning and provision, workforce transformation, and international partnerships and collaborations.

Policy and regulation

Policies and regulations are key instruments for the government to set the sustainability ambition for the aviation sector. The role of policy and regulations is especially important in relatively nascent areas and where some level of standardisation or harmonisation will be required. This also includes situations where the industry, when acting alone, may not be able to achieve the intended outcomes.

CAAS will introduce several policies to drive tangible actions. This includes setting domestic aviation emissions reduction targets to spur collective action amongst the Singapore aviation community, and the introduction of a national SAF target to encourage SAF production and kickstart adoption in Singapore and the region.

Another policy support tool is the development of a taxonomy for green financing. A well-designed taxonomy provides a clear, transparent, and credible framework for financiers to assess projects for green financing and for implementers to identify projects that qualify. The Monetary Authority of Singapore (MAS) launched the Singapore-Asia Taxonomy for Sustainable Finance in December 2023.

The taxonomy sets out detailed thresholds and criteria for defining green and transition activities that contribute to climate change mitigation across eight focus sectors, including aviation under the transport sector. CAAS worked closely with MAS to ensure that the taxonomy accurately reflects the considerations of the aviation sector and its initiatives.

Industry development

Singapore will require concerted efforts from the aviation industry and collaboration amongst multiple stakeholders to achieve our targets. Cross-sectoral partnerships are therefore important as many aviation decarbonisation pathways involve a diverse range of stakeholders from across the value chain. CAAS has put in place two key industry development programmes to foster collaboration, cooperation, and capability-building amongst stakeholders.

a) Aviation Sustainability Programme

CAAS has set up a S$50 million ASP to support decarbonisation efforts. It demonstrates CAAS's commitment to drive sustainable aviation and support the development of innovative solutions through defraying investment cost and accelerating industry-led projects.

As of November 2023, CAAS has supported several sustainability projects. These include the feasibility study for the deployment of solar panels on the airfield, a simulation and modelling study for the electrification of airside vehicles, and trials for the use of renewable diesel for ground handling equipment and vehicles.

CAAS will continue to leverage the ASP to support our industry's sustainability efforts that will contribute towards our 2030 and 2050 targets, such as electric and hydrogen power trials under the clean energy airside vehicles programme, as well as feasibility studies for waste-to-energy conversion.

b) International Centre for Aviation Innovation

As air travel recovers from the pandemic, innovation is another focus for international aviation. Innovation allows the aviation sector to leverage technology to transform travel experience, enhance productivity, safety, and achieve sustainability goals.

CAAS has set up the ICAI to drive innovation initiatives across all aspects of aviation including air traffic management, airport operations, advanced air mobility, and aviation sustainability. In line with the IAP's recommendation for Singapore to develop a digital twin to mirror static and dynamic assets and integrate data from various sources, ICAI will set up an innovation lab in the next few years to simulate and validate new concepts of operations for advanced predictions, simulation, and process optimisation across all aspects of aviation.

The first use case for such a digital twin capability would be in the reduction of energy consumption and emissions from aircraft and airside vehicle movements.

CAAS has engaged ICAI to manage Stage 1 of Singapore's Aviation Transformation Programme 2.0. ICAI will work with local research institutes and Institutes of Higher Learning, including the Aviation Studies Institute, Air Traffic Management Research Institute, Aviation Innovation Research Lab, MITRE Asia Pacific Singapore, and the Institute for Infocomm Research.

Infrastructure planning and provision

Proper planning and provisions for supporting infrastructure are necessary for the aviation sustainability initiatives to be implemented smoothly.

a) Future infrastructure

The Singapore air hub is also looking ahead to ensure necessary provisions are made to achieve high sustainability standards for future developments. Terminal 5 is being designed and developed to achieve BCA's Green Mark Platinum Super Low Energy standard, a significant goal given the airport's huge energy requirements. Key strategies include ensuring high efficiency of the cooling systems through district cooling and maximising on-site solar energy production.

Image credit: CAG

b) Hydrogen

In February 2022, CAAS signed a Cooperation Agreement with Airbus, CAG, and Linde to study the technical feasibility of hydrogen adoption and infrastructure requirements for aviation. Under the Cooperation Agreement, the four parties will collaborate to conduct market analysis on the projected aviation demand and supply for liquid hydrogen, as well as regional readiness and commercial feasibility for the adoption of liquid hydrogen operated aircraft. The parties will also evaluate the safety considerations, regulatory challenges, operational impact as well as infrastructure requirements for hydrogen adoption in an airport to complement the electrification of airport operations.

Workforce transformation

Sustainability will not just create new career opportunities, it will also eventually impact every aviation worker's job. CAAS is developing initiatives to support greater awareness of aviation sustainability, in the form of e-modules and bite-sized videos, to share with the aviation workforce, new entrants, and potential job-seekers.

To support existing aviation workers, we will embark on a tripartite partnership to identify new and emerging sustainability-related job roles, accompanied by upskilling and job redesign efforts offered by NTUC's Company Training Committees, relevant lifelong learning and skills-upgrading initiatives under SSG, and WSG's Career Conversion Programme. The next generation of aviation professionals joining the industry from local schools will also need a strong understanding of aviation sustainability. CAAS will work closely with our Institutes of Higher Learning to develop and refresh their curriculum to offer aviation sustainability modules and stimulate interest through curated sustainability-linked internships and learning journeys.

Through these efforts, the aim is to make sustainability, like aviation safety, a way of life for our aviation workers.

Image credit: CAAS

International Partnerships and Collaborations

There is a need for strong international partnerships and collaboration across governments, industry, and academia to enable international aviation to grow sustainably and continue to play a vital role in global economic and social development. Singapore is committed to participate in partnerships and collaborations across various levels to advance sustainable aviation.

Image credit: Ministry of Transport

a) ICAO

Singapore participates actively in environment discussions at ICAO through our representatives and experts in the ICAO Council, the Climate and Environment Committee, the Technical Advisory Body, and the Committee on Aviation Environmental Protection.

Singapore is also participating in ICAO's capacity-building initiatives. In 2022, Singapore entered an agreement with ICAO for Assistance, Capacity-building, and Training on SAF initiative (ACT-SAF), where we provide capacity-building and technical assistance to other countries. We have also been providing training and support on CORSIA to our partner States in the Pacific Islands through the ACT-CORSIA initiative since 2019.

b) Asia-Pacific sustainable aviation centre

Given the differences in circumstances, operating contexts, and readiness across regions, a varied pace of sustainable aviation policy implementation can be seen across the world. In the Asia-Pacific region, which is one of the largest aviation markets with more than a third of global travel pre-pandemic, aviation is a critical enabler for many economies and is expected to continue growing. The types of available SAF feedstocks and difference in technology options also set this region apart from others.

As such, there is a need to build sustainable aviation policy research capabilities and develop policies that reflect Asia-Pacific's unique circumstances and development needs. To this end, CAAS will work with key industry partners to establish a regional sustainable aviation centre. This centre will develop capabilities for sustainable aviation policy research specific to the needs of the Asia-Pacific region, such as policy development to balance sustainability and development outcomes and build deeper scientific understanding of regional SAF feedstocks. The centre will validate prevailing policy recommendations against the Asia-Pacific context and add new perspectives to these discussions. It will also provide capacity-building activities to support aviation decarbonisation efforts for the region, building upon Singapore's current contributions through ICAO's capacity-building programmes.

c) Multilateral and bilateral partnerships

Singapore entered into bilateral sustainable aviation agreements with Australia, Japan, New Zealand, the United Kingdom, and the US in recent years. Through these agreements, we will exchange information on key developments and work together to scale up the adoption of SAF. For example, Singapore is working with Japan and the United States to develop a novel Aviation Green Lane concept shown in Figure 9, as an end-to-end model, bringing together stakeholders across the value chain to collaborate and make flying more sustainable. We aim to expand our network of partners over time.

In ASEAN, Singapore forged agreement on the ASAAP (Figure 10), during our two-year chairmanship of the ASEAN Air Transport Working Group in 2022-2023. This 10-year action plan details milestones and activities including an ASEAN roadmap to drive sustainable aviation growth in the region. CAAS is working closely with ASEAN Member States and dialogue partners to deliver the ASAAP.

In addition, CAAS has collaborated with multiple ANSPs to advance ATM initiatives to enhance the safety, efficiency, and sustainability of aviation. This includes the Asia-Pacific TBO Pathfinder Project to further advance the development and implementation of TBO in the region, as well as the South-East Asia – Oceania Implementation of Free Route Operations (FRTO) Project to identify applicable city pairs and flights, and validate the use of FRTO between defined cities. The two initiatives are early products of the Asia-Pacific ANSP Committee (AAC) which was set up in April 2023 to enhance collaboration between ANSPs and drive regional ATM collaboration, including in seamless ATM operations and technologies. The AAC is chaired by the Director-General of CAAS.

Figure 10: ASAAP terms of reference

ASEAN Sustainble Aviation Action Plan Objectives:

- **Share best practice on aviation decarbonisation to support capability building.**
- **Facilitate information exchange to advance the region's aviation sustainability and decarbonisation efforts.**
- **Collaborate among ASEAN Member States, dialogue and experts to develop an ASEAN Sustainable Aviation Roadmap.**
- **Support the efforts and objectives on sustainble transport under the Kuala Lumpur Transport Strategic Plan 2016-2025 and the subsequent Post-2025 Vision Roadmap for ASEAN Transport Cooperation.**

Figure 9: Aviation green lane concept

Initiatives could include:

- **Sustainable aviation fuel use**
- **Fuel-efficient aircraft**
- **Optimised air traffic management**
- **Sustainability measures in airports**
- **Use of high-integrity carbon offsets**

Aviation green lane serves as a potential approach to implement ICAO's basket of measures (technology and operational improvements, aviation cleaner energy use, and CORSIA). Through an end-to-end concept, it seeks to foster value chain collaboration, ensure credibility, and provide transparency to consumers.

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International Advisory Panel members

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President, Singapore University of Technology and Design

Mr Han Kok Juan
Director-General, Civil Aviation Authority of Singapore

Mr Luis Felipe de Oliveira
Director General, Airports Council International World

Mr Simon Hocquard
Director General, Civil Air Navigation Services Organization

Mr Willie Walsh
Director General, International Air Transport Association

Professor Peter Jackson
Director, Aviation Studies Institute

Professor Lam Khin Yong
Co-Chair, Air Traffic Management Research Institute

Mr Jeffrey Chua
Chairman, Boston Consulting Group Singapore

Mr Kaushik Das
Senior Partner and Managing Partner for Southeast Asia, McKinsey & Company

Mr Pedro Gómez
Head, Climate; Member of Executive Committee, World Economic Forum

Mr Thorsten Lange
Executive Vice President for Renewable Aviation, Neste (former). IAP member until April 2023

Dr Steve Howard
Vice Chairman, Sustainability, Temasek

Dr Sabine Klauke
Chief Technical Officer, Airbus

Dr Naveed Hussain
Vice President and Chief Engineer, Boeing Defense, Space and Security. IAP Member from Feb-Apr 2022

Dr Todd Citron
Chief Technology Officer, The Boeing Company. IAP Member from Apr 2022

Mr Lee Seow Hiang
Chief Executive Officer, Changi Airport Group

Ms Grazia Vittadini
Special Advisor, Rolls Royce

Mr Kerry Mok
President and Chief Executive Officer, SATS

Ms Aw Kah Peng
Chairperson, Shell Companies in Singapore

Mr Goh Choon Phong
Chief Executive Officer, Singapore Airlines

Mr Philippe Keryer
Executive Vice President for Strategy, Research, and Technology, Thales

Contributors to IAP deep dives

Airport

Airbus
Airports Council International
The Boeing Company
Boston Consulting Group Singapore
Changi Airport Group
DHL
dnata
McKinsey & Company
Neste
Netherlands Airport Consultants
Rolls-Royce
SATS
Singapore Airlines
SIA Engineering Company
Singapore Technologies Engineering
Singapore University of Technology and Design
Solar Energy Research Institute of Singapore
Temasek
World Economic Forum

Airline

Airports Council International
Boston Consulting Group Singapore
All Nippon Airways
Airbus
The Boeing Company
Changi Airport Group
Climate Impact X
Economic Development Board Singapore
ExxonMobil
FedEx
International Air Transport Association
Louis Vuitton Moët Hennessy
Neste
Rolls-Royce
Sembcorp
Qantas
Shell Companies in Singapore
Singapore Airlines
Singapore University of Technology and Design
SkyNRG
Sustainable Aviation Buyers Alliance
Temasek
United Airlines
United Parcel Service
World Economic Forum

Air Traffic Management

Aeronautical Radio of Thailand
Airbus
Aviation Studies Institute
Air Traffic Management Research Institute
The Boeing Company
Changi Airport Group
German Aerospace Center
International Air Transport Association
International Civil Aviation Organization Asia-Pacific Regional Office

Glossary

ACT-CORSIA	Assistance, Capacity-building and Training on Carbon Offsetting and Reduction Scheme for International Aviation
ACT-SAF	Assistance, Capacity-building and Training for Sustainable Aviation Fuels
Air-SITEM	Air-Singapore Integrated Transport & Energy Model
AMNAC	Asia-Pacific Cross-border Multi Nodal ATFM Collaboration
ANS	Air Navigation Services
ANSP	Air Navigation Service Provider
ASAAP	ASEAN Sustainable Aviation Action Plan
ASBU	Aviation System Block Upgrade
ASEAN	Association of South-East Asian Nations
ASP	Aviation Sustainability Programme
ATAG	Air Transport Action Group
ATC	Air Traffic Control
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
BAU	Business as Usual
BCA	Building and Construction Authority
CAAS	Civil Aviation Authority of Singapore
CAG	Changi Airport Group
CCO	Continuous Climb Operation
CDO	Continuous Descent Operation
CO2	Carbon Dioxide
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
COVID	Coronavirus Disease
CWIF	Convective Weather Impact Forecast
EE	Energy efficiency
EMA	Energy Market Authority
FF-ICE	Flight and Flow Information for a Collaborative Environment
GEF	Grid Emission Factor
GW	Gigawatts
HFCV	Hydrogen Fuel Cell Vehicle
IAP	International Advisory Panel
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
LR-AFTM	Long Range - Air Traffic Flow Management
LTAG	Long Term Aspirational Goal
MAS	Monetary Authority of Singapore
MET	Meteorology
NTUC	National Trade Union Congress
PV	Photovoltaic
RD	Renewable Diesel
RECAT	Re-categorisation
SAF	Sustainable Aviation Fuel
SSG	SkillsFuture Singapore
SWIM	System Wide Information Management
TBO	Trajectory Based Operations
TOD	Top of Descent
WSG	Workforce Singapore

Singapore Sustainable Air Hub Blueprint