Developing a Sustainable Air Hub in Singapore

Report of the International Advisory Panel on Sustainable Air Hub

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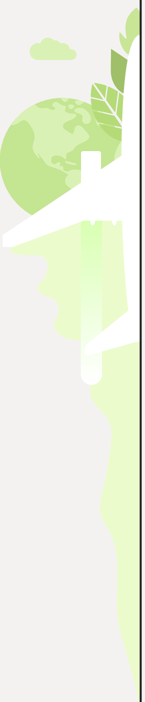


Foreword

Combating climate change is a matter of great urgency and priority, and the status quo is no longer an option. Action against climate change is a task that requires a global joint effort shared across all countries, sectors and vocations. For the aviation sector, firm and decisive actions to decarbonise its operations will contribute to the collective effort.

Aviation sector emissions are inherently challenging to abate, so collective and coordinated efforts by all stakeholders are necessary. To this end, I am honoured to chair the International Advisory Panel (IAP) on Sustainable Air Hub, which brings together leaders and representatives from industry, technology and knowledge partners to provide guidance and recommendations to develop a sustainable air hub in Singapore.

The IAP had its first meeting on February 14, 2022. Over the next five months, we convened four meetings to exchange views on the vision and strategies for Singapore as a sustainable air hub. We also organised six deep dive sessions to canvass ideas from a wider array of interested stakeholders.

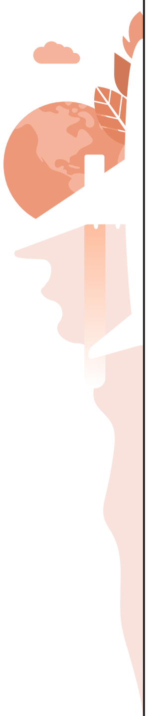
As the Chair of the IAP, I am pleased to submit our report on Developing a Sustainable Air Hub in Singapore. This report captures the discoveries and outcomes of our fruitful and insightful discussions. The IAP has recommended 15 initiatives that the Singapore air hub could embark on as tangible pathways to decarbonise the aviation sector across the key domains of airport, airline and air traffic management. In addition, we have identified four critical enablers for the effective implementation of these initiatives. We hope this report can serve as a useful guide for CAAS in developing its Sustainable Air Hub Blueprint, as well as other stakeholders and international parties pursuing sustainable aviation.

There was active participation, deep discussions, and open sharing of views and insights at every meeting. I would like to thank all IAP members and participants for their invaluable contributions in helping to chart the way forward for the Singapore air hub. I look forward to seeing greater action in advancing aviation sustainability and a sustainable Singapore air hub of the future.

Professor Chong Tow Chong,
Chair of the International Advisory Panel on Sustainable Air Hub

The International Advisory Panel on Sustainable Air Hub

The Civil Aviation Authority of Singapore (CAAS) set up the International Advisory Panel (IAP) on Sustainable Air Hub to support the development of the Singapore Sustainable Air Hub Blueprint. The IAP brings together 20 industry, technology, and knowledge leaders from Singapore and around the world to discuss how international aviation can be made more sustainable and accessible for all, and how Singapore can contribute to this international effort. Singapore's Minister for Transport & Minister-in-charge of Trade Relations, Mr S. Iswaran launched the inaugural meeting held in Singapore on February 14, 2022.



Terms of Reference for the International Advisory Panel:

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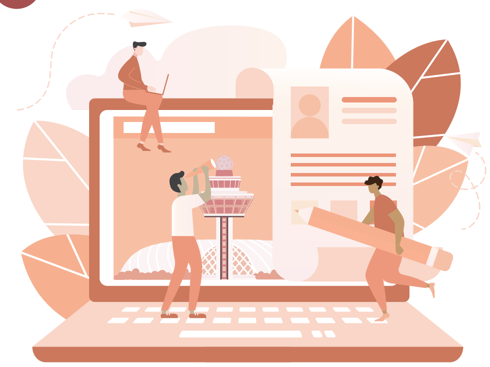


Assess and stocktake the current state of sustainable aviation across the airport, airline and air traffic management domains;

2

Identify potential game-changers and pathways that will help advance sustainable aviation relating to state, corporate and individual actions;

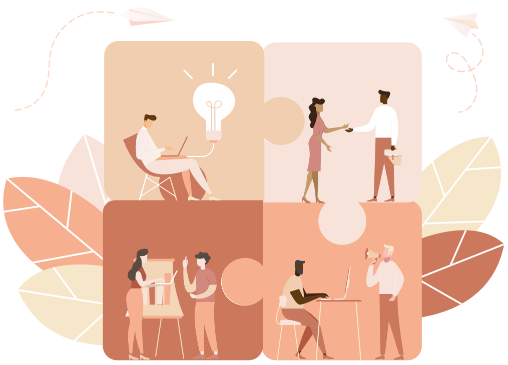
3

Identify strengths, weaknesses, opportunities, and threats for developing a sustainable air hub in Singapore;

4

Propose goals and strategies for developing a sustainable air hub in Singapore; and

5



Identify projects and pilots that Singapore, regional stakeholders and the industry can work on.

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Executive summary

Climate change is an existential problem that causes widespread disruptions and affects the lives of billions around the world. Changes in weather patterns impact air travel directly, affecting critical airport infrastructure and aircraft performance and causing delays and disruptions. The international civil aviation sector must play its part and take firm and decisive actions to decarbonise its operations. No single country or organisation can achieve this on its own; the push for sustainable aviation will require coordinated State actions, cross-sectoral collaboration, public-private partnership and greater climate consciousness amongst corporates and the travelling public.

As an international business, aviation and aerospace hub, Singapore can play an important role as a pathfinder and convenor for the cross-sectoral collaboration and public-private partnership needed to reconfigure the aviation ecosystem to support sustainable operations and make it a commercially viable reality. As an active member of the International Civil Aviation Organization (ICAO) and the international civil aviation community, Singapore can also exercise thought leadership and work with other countries and international organisations to drive and support climate actions globally and regionally.

Singapore has started work on this by voluntarily taking part in the ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) in its pilot phase. Additionally, Singapore is embarking on a one-year pilot to use blended Sustainable Aviation Fuel (SAF) at Changi Airport. It is also actively partnering with other like-minded countries and has inked a Memorandum of Arrangement with New Zealand to establish, amongst other things, a green travel corridor. As a next step, CAAS is developing a Sustainable Air Hub Blueprint to bring together all these efforts and to set a roadmap with clear 2030 and 2050 targets and tangible pathways for achieving them. The Sustainable Air Hub Blueprint is a significant initiative which will help provide thought leadership and further catalyse investments, actions and collaborations with private sector companies and other countries.

The IAP seeks to contribute to the development of the Singapore Sustainable Air Hub Blueprint by proposing specific projects that Singapore can initiate, leveraging its hub position and strong partnerships with international bodies, other countries and private companies. In doing so, the IAP has taken an action-oriented, industry-driven approach, tapping on the experience and expertise of its members, which include senior executives of global aviation bodies and key aviation companies.

Specifically, the IAP has recommended 15 initiatives across the three key domains of airport, airline and air traffic management.

Executive summary

Recommendations of the International Advisory Panel on Sustainable Air Hub

Airport

a. Airfield solar deployment
b. Renewable electricity
c. Building energy efficiency
d. Clean energy airside vehicles
e. System optimisation with digital twin project
f. Resource circularity through on-site waste-to-energy facility

Airline

a. Roadmap to create long-term secured Sustainable Aviation Fuel (SAF) supply ecosystem
b. Corporate Buyers' Club
c. Structural offtake mechanism for SAF
d. Aviation vertical offerings in carbon markets, support ecosystem for and encourage uptake of aviation carbon offsets
e. Technical centre for capability-building in aircraft technology

Air Traffic Management

a. Advanced demand-capacity balancing
b. Performance-based navigation
c. Gate-to-gate trajectory optimisation
d. Trajectory-Based Operations and Free Route Airspace in collaboration with stakeholders and partner Air Navigation Service Providers

Enablers

a. Policy and regulation
b. Industry development
c. Infrastructure planning and provision
d. Workforce transformation

Executive summary

Airport

Airport operations are highly energy intensive. They rely on electricity for air-conditioning airport terminals and to power operational systems, and on fossil fuels for airside vehicles. To reduce carbon footprint, airports must consider ways to reduce electricity usage and switch to renewable energy. This is particularly challenging for Singapore, which has limited access to renewable energy.

To improve the sustainability of airports in Singapore, the IAP recommends that CAAS work with stakeholders on the following initiatives:

a. Deploy solar power on the airfield

Singapore Changi Airport is already tapping on solar energy through solar panels installed on the rooftops of its terminal buildings. There is scope to significantly increase the use of solar energy if solar panels can also be installed on the airfield. The IAP recommends that CAAS conduct a technical study on the feasibility of deploying solar panels on the airfield. This would include assessing their impact on radar signals, pilots and airport and flight operations, energy yields, transmission losses and economic viability. If shown to be viable, CAAS would engage ICAO and other industry bodies on standards and implementation.

b. Secure and increase the use of renewable electricity

The IAP recommends that CAAS work with stakeholders to secure imported low-carbon electricity for Changi Airport and set medium-term 2030 and long-term 2050 targets for the use of renewable electricity.

c. Improve building energy efficiency by reducing the air-conditioning carbon footprint

The air-conditioning system is the largest energy consumer at Changi Airport. The airport has various ongoing initiatives to lower air-conditioning use and reduce the energy used in running the air-conditioning system, to reduce its carbon footprint. The IAP recommends that CAAS work with stakeholders to further improve the energy efficiency of the air-conditioning system through innovative energy-efficient technologies and design concepts. The recommendations include assessing potential alternative cooling methods or technologies to guide the design for Terminal 5 and retrofitting existing terminals to achieve maximum energy savings.

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d. Facilitate the transition of airside vehicles towards clean energy sources

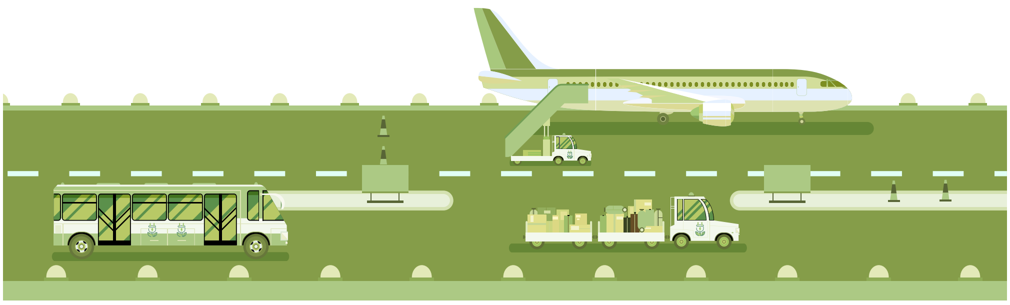
Changi Airport has already started on the electrification of its airside vehicles fleet. The IAP recommends that CAAS work with stakeholders to facilitate the transition of all airside vehicles towards cleaner energy options. This can be achieved through three pathways — electrification of the airside fleet, conversion to hydrogen-powered vehicles and the use of biofuels. A simulation and modelling study, along with technology trials, will facilitate better understanding of the deployment scale, operational challenges, policies and regulations needs for each pathway.

e. Explore system optimisation with a digital twin project

System optimisation at the airport level can improve operational efficiency and reduce carbon emissions systemically. Changi Airport could benefit from developing a digital twin to mirror static and dynamic assets and integrate data from various sources. This can then be presented in a human-centric interface for advanced predictions, simulation and process optimisation. The IAP recommends that CAAS work with stakeholders to study the feasibility of a digital twin modelling process at Changi Airport. The study should include planning, design, and end-to-end optimisation of airport processes to reduce energy consumption and minimise emissions from aircraft and airside vehicle movements.

f. Enhance resource circularity through an on-site waste-to-energy facility

Changi Airport has been adopting circularity practices to reduce the volume of waste generated and consume less external resources. Beyond this, a more direct decarbonisation pathway to reduce energy offtake from the grid would be through an on-site waste-to-energy facility at Changi Airport, which could work by channelling waste as feedstock to generate biofuels or electricity. The IAP recommends that CAAS work with stakeholders to study the potential and feasibility of establishing a waste-to-energy facility in Changi Airport, particularly whether there are sufficient economies of scale for such a facility. If feasible, such a facility can contribute to Changi Airport's carbon reduction efforts through resource recovery and a reduction in energy offtake from the national grid.



Executive summary

Airline

Flight operations account for the bulk of global aviation emissions. The decarbonisation of international civil aviation will require significant climate action in the airline domain.

To improve the sustainability of airlines operating to, from and through Singapore, the IAP recommends that CAAS work with stakeholders on the following initiatives:

a. Develop and implement a roadmap to create a long-term secured SAF supply ecosystem

The global SAF market is still nascent, and the availability and affordability of SAF must be boosted. Likewise, Changi Airport needs to develop a long-term secured supply of SAF to support increased adoption by its airlines. The IAP recommends that CAAS work with stakeholders to develop and implement a roadmap to create a long-term, secured ecosystem for SAF supply in Singapore and the region. This entails building up and strengthening the SAF supply chain and upstream capabilities to establish a SAF ecosystem in Singapore and the region, validating regional feedstock to align with global standards and investing in new SAF pathways.

b. Establish a "Singapore / ASEAN Corporate Buyers' Club" to create demand signals

Long-term demand certainty is required to incentivise SAF suppliers to expand SAF production capacity. There is scope to strengthen the demand signals for SAF in Singapore, to encourage an increase in SAF production. The IAP recommends that CAAS work with stakeholders to establish a buyers' club to encourage early adopters of sustainable air travel to take collective action, thereby aggregating SAF demand and providing stronger demand signals for SAF production and scale-up. As a global business and logistics hub, Singapore has opportunities to tap on business travellers and air cargo users and encourage them to become first movers by joining the corporate buyers' club. Thereafter, there is also the potential of collaborating with regional partners to expand the buyers' club to the broader ASEAN region.

c. **Design and introduce a structural offtake mechanism and create demand signals for secured long-term, lower-cost SAF supply**

To create long-term, predictable SAF demand, Changi Airport needs to introduce and implement a structural mechanism to encourage sustained SAF adoption amongst airlines. The IAP recommends that CAAS work with stakeholders to design and introduce a structural SAF offtake mechanism. It should catalyse a self-sustaining ecosystem and flow of funds for SAF in Singapore to encourage greater adoption of SAF at Changi Airport. The offtake mechanism needs to consider the unique context and characteristics of the air hub, its airlines and passengers, the funding sources, and the metrics used to determine the offtake mechanism.

d. **Innovate to build deep aviation industry vertical offerings in carbon markets, develop a support ecosystem for aviation carbon offsets solutions and encourage uptake among corporates and consumers**

Beyond in-sector measures, carbon offsets are necessary to achieve net-zero emissions. As the carbon offset market is still nascent, there is scope to build up such a market for aviation carbon offsets in Singapore to support the decarbonisation of the aviation sector. The IAP recommends that CAAS work with key players in Singapore's emerging global carbon services hub to build up the market for aviation carbon offsets. This includes products and platform innovations for aviation carbon offsets, developing an enabling ecosystem of carbon support services to improve the reliability, traceability and accountability of aviation industry offsets and exploring the possibility of raising voluntary demand for carbon offsets amongst corporates, passengers and cargo users.

e. **Explore a potential technical centre for capability-building to ensure that Singapore can be an early adopter of aircraft technology**

Singapore would need to remain at the forefront of advancements in aviation technology to reap their full benefits. The IAP recommends that CAAS work with stakeholders to explore setting up a technical centre in Singapore. This entails tapping on Singapore's strong research and development ecosystem and collaborating with aircraft original equipment manufacturers, like-minded aviation partners and stakeholders to strengthen its technical capabilities and position itself for the future. This initiative complements existing efforts to explore the potential use of hydrogen at Changi Airport.

Executive summary

Air Traffic Management (ATM)

Improvements in ATM and operational procedures can help reduce unnecessary emissions and improve environmental performance. Such efforts should be closely aligned with plans and guidance from ICAO, which seek to achieve a global interoperable air navigation system that is safe, efficient and environmentally sustainable.

The IAP has identified the following four short- and medium-term recommendations to optimise ATM for improved environmental performance:

Short-term (2022-2026)

a. Implement advanced demand-capacity balancing

CAAS has been working with stakeholders to enhance the management of air traffic vis-à-vis available capacity, including through the Asia-Pacific Cross-border Multi-Nodal Air Traffic Flow Management (ATFM) Collaboration (AMNAC). The IAP recommends that CAAS work with stakeholders and partner Air Navigation Service Providers (ANSPs) to build on these efforts and introduce advanced demand-capacity balancing initiatives. These include implementing Long Range ATFM to improve coordination and management of longer-haul flights. Additionally, integration between meteorology (MET) and ATM could be strengthened through conducting translational studies of the impact of weather on ATM operations to enhance ATM decision-making and operations.

b. Enhance performance-based navigation

Performance-based navigation initiatives can enable more direct routings and optimise descent profiles for aircraft, thus reducing fuel burn and carbon emissions. CAAS has conducted operational trials for direct route operations for flights arriving at Changi Airport and is facilitating Continuous Descent Operations (CDO) for Changi arrivals when traffic permits. The IAP recommends that CAAS expand on these initiatives. This entails formalising the implementation of direct route operations for Changi arrivals on specific route segments to provide airlines with the flexibility to plan for the most optimal route in terms of flight and fuel efficiency. Additionally, smart tools should be developed to facilitate CDO within Changi Airport for flight profile optimisation and reduction in fuel burn and emissions.

c. Optimise gate-to-gate trajectory

CAAS has been closely following global advancements in ATM that can optimise efficiency during all phases of flight, including Trajectory-Based Operations[1] (TBO) and re-categorisation (RECAT) of aircraft weight categories to reduce the separation between aircraft to optimise runway efficiency. The IAP recommends that CAAS collaborate with stakeholders and partner ANSPs to advance these initiatives to optimise the gate-to-gate trajectory at Changi Airport and increase fuel savings. This includes implementing enablers for TBO, such as Flight and Flow Information for a Collaborative Environment (FF-ICE) and System Wide Information Management (SWIM), and further optimising runway efficiency by extending the implementation of RECAT from arrivals to include departures.

Medium-Term (2027-2032)

d. Implement TBO and free route airspace (FRA) in collaboration with stakeholders and partner ANSPs

TBO and FRA are advanced concepts of operations that could revolutionise ATM, optimising efficiency and reducing carbon emissions from flights. As these would take longer to develop and implement, the IAP recommends that CAAS collaborate with partner ANSPs to further develop the key building blocks for TBO and FRA, such as through demonstrations to refine these advanced concepts of operations.

The IAP believes that the above 15 initiatives, taken together, are transformative and will allow Singapore to distinguish itself as a sustainable air hub. Their effective implementation will require strong government action and close collaboration with the industry. The IAP recommends that CAAS develop and include in its Sustainable Air Hub Blueprint critical enablers in the areas of policy and regulation, industry development, infrastructure planning and provision, and workforce transformation. These enablers are necessary for providing the right conditions to implement these initiatives effectively.

1 TBO represents a fundamental shift in ATM. Instead of relying heavily on tactical air traffic control, flight trajectories can be planned ahead and executed more precisely to improve the management of traffic flows.

1

Stocktake on the Current State of Sustainable Aviation

1.1 A global push towards sustainability

Climate change is an existential problem that affects us all. The global push towards sustainability has gathered momentum over the years, fuelled by several worldwide trends.

First, there is an increasing awareness of the rising environmental impact and cost of global warming. The Intergovernmental Panel on Climate Change (IPCC) report on the impact of global warming of 1.5ºC above pre-industrial levels presented real concerns regarding the actual effects of climate change on the world.[2] The negative impact of climate change can already be felt across the globe, with rising economic and humanitarian costs from adverse weather events, such as unprecedented droughts and floods.

Second, on an international level, significant commitments have been made to climate action. The Paris Agreement was adopted by 196 Parties at the 2015 United Nations Climate Change Conference of the Parties (COP 21) to limit global warming to well below 2ºC, preferably to 1.5ºC, compared to pre-industrial levels.[3] Further to this, during the COP 26 in 2021, countries adopted the Glasgow Climate Pact, whereby they collectively agreed to work to reduce the gap between existing emissions reduction plans and what is required to reduce emissions, to limit the rise in the global average temperature to 1.5ºC per the Paris Agreement.[4] Additionally, the Science Based Targets initiative (SBTi) was established to define and promote best practices in science-based target setting, and provide companies with a clearly-defined path to reduce emissions in line with the Paris Agreement Goals.[5]

Third, there is growing political and social pressure to do more for the environment, and such calls to action resonate across all societal levels and groups. This is especially stark amongst the younger generation, who are becoming increasingly concerned and vocal about the effects of climate change. Governments and corporates face increasing pressure from environmentally conscious consumers and organisations to take firm and concrete climate action. There is also a growing sense that countries have an international obligation to the environment. It is no longer a matter of debate as to whether there is a need for climate action but rather on the means to get there.

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[2] IPCC, "Climate Change 2022: Impacts, Adaptation, and Vulnerability", *Sixth Assessment Report*.

[3] United Nations Framework Convention on Climate Change (UNFCCC), "The Paris Agreement", https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement.

[4] UNFCCC, "The Glasgow Climate Pact — Key Outcomes from COP26", https://unfccc.int/process-and-meetings/the-paris-agreement/the-glasgow-climate-pact-key-outcomes-from-cop26.

[5] SBTi, "About Us", https://sciencebasedtargets.org/about-us.

Fourth, there are opportunities in the emerging global green economy. Many industries and sectors have taken steps towards more sustainable products to distinguish themselves, thus contributing to the growth of new business activities and markets. The emerging global green economy has also supported the growth of green financing, carbon markets and carbon trading services and firms, which help companies find more economically and financially attractive means of achieving their sustainability goals.

1.2 The need for sustainability in the aviation sector

Amidst the global push towards sustainability, the international civil aviation community will need to do its part to decarbonise the aviation sector. Before the COVID-19 pandemic, aviation contributed around 2% of global emissions.[6] If left unaddressed, aviation's contribution is estimated to increase significantly to 22%, while other sectors continue to decarbonise their activities.[7]

Climate change is an existential problem that impacts air travel directly. Changes in weather patterns threaten critical airport infrastructure, affect aircraft performance and cause delays and disruptions.

It is therefore untenable for the aviation sector to remain on its current trajectory. The alternative would be an increased risk of calls to moderate air travel demand. This would then present even greater challenges to the growth of aviation and threaten communities and livelihoods that depend on it.

1.3 Singapore's sustainability goals and implications on the Singapore aviation sector

Singapore's contribution to global emissions is relatively small, at around 0.1% of global greenhouse gas (GHG) emissions.[8] Nevertheless, as a small island nation, Singapore can be disproportionately affected by the impacts of climate change. Rising sea levels and more extreme weather conditions could have significant socio-economic costs. Climate change is thus a critical and existential issue for the country. In 2022, Singapore raised its climate ambition to achieve net-zero emissions by or around the mid-century.[9]

6 Air Transport Action Group (ATAG), "Facts & Figures", https://www.atag.org/facts-figures.html.

7 European Parliament Policy Department A for the Committee on Environment, Public Health and Good Safety, "Emission Reduction Targets for International Aviation and Shipping".

8 National Climate Change Secretariat Strategy Group Prime Minister's Office Singapore, "Speech by Senior Minister and Coordinating Minister for National Security Teo Chee Hean at the Committee of Supply 2021 on "A Considered, Committed and Collective Approach to the Global Climate Crisis"", March 4, 2021.

9 Ministry of Finance, Singapore, "Budget Debate Round-Up Speech by Mr Lawrence Wong, Minister for Finance", March 2, 2022.

The Singapore Green Plan 2030 was published as a whole-of-nation movement to chart ambitious and concrete targets for the national agenda on sustainable development. This strengthens Singapore's commitments under the United Nations 2030 Sustainable Development Agenda and Paris Agreement and positions the country to achieve its long-term net-zero emissions aspirations as soon as viable. Singapore has also launched a GreenGov.SG movement, an initiative for the public sector to attain ambitious sustainability targets in carbon abatement and resource efficiency and be a positive influence on and an enabler of green efforts.

As Singapore seeks to do more in sustainability, the Singapore aviation sector must play its part. In 2019, Singapore's airports contributed to around 0.7% of Singapore's domestic emissions. Singapore does not have domestic air travel, and aviation domestic emissions are mainly attributable to airport operations. On the other hand, Singapore's aircraft operators contributed 1.9% of global aviation emissions. While the aviation sector's contributions are relatively small, the push towards net-zero emissions will require each sector to play its part in achieving the national and global targets.

1.4 Singapore's current efforts in aviation sustainability

Singapore has started on its sustainable aviation journey. It has undertaken a range of efforts and initiatives at the international and domestic levels to reduce its carbon emissions, with support from industry partners and stakeholders. These span across three fronts:

Airport

Changi Airport is progressively performing equipment replacement and improvements across terminals to enhance energy efficiency and reduce its carbon footprint. The Changi Airport Group (CAG) is also designing the upcoming Terminal 5 with sustainability in mind to achieve the highest green building requirements. Electrification of the airside vehicle fleet has also started. To date, around 10% of Changi Airport's airside vehicle fleet is electric, with over 100 charging points available across the terminals.[10]

Changi Airport has around 22 megawatt-peak (MWp) of solar panels installed, equivalent to about 4% of Changi Airport's 2019 energy consumption. The airport will continue to maximise solar deployment to include all remaining terminal rooftops and is studying other possible deployment options in the airport environment, including vertical solar panels.

[10] Changi Airport Group, "Resilience & Sustainability" *Sustainability Report 2019/20,* page 6.

Airline

To address international aviation emissions, Singapore is looking at alternatives to fossil jet fuel. Firstly, Singapore has attracted Neste to set up a Sustainable Aviation Fuel (SAF) production facility in Singapore. When completed by the first quarter of 2023, it will be the world's largest SAF production site, with an annual production capacity of 1 million tonnes. In addition, CAAS, CAG, Singapore Airlines (SIA), Temasek, ExxonMobil and Neste are embarking on a one-year pilot on the use of blended SAF at Changi Airport to scale up its use.[11] Together with Airbus, CAG and Linde, Singapore is also exploring the use of hydrogen in the longer term, through a study on the potential of establishing a future hydrogen hub in Singapore. The study will examine the infrastructure requirements and supply solutions to support hydrogen-powered aircraft and aircraft operations at Changi Airport.

On the international front, Singapore is voluntarily taking part in the pilot phase of the International Civil Aviation Organization's (ICAO) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).[12] Singapore is also providing CORSIA related capacity-building support to other countries through the Assistance, Capacity-building and Training for CORSIA (ACT-CORSIA) programme.

As the largest carrier in Singapore, SIA maintains a young and fuel-efficient passenger fleet, which allows it to reduce fuel burn and emissions.

[11] Under this pilot, blended SAF from ExxonMobil would be used on all Singapore Airlines and Scoot flights starting from the third quarter of 2022, which is expected to reduce about 2,500 tonnes of carbon dioxide emissions. ExxonMobil will blend neat (unmixed or undiluted) SAF produced from used cooking oil and waste animal fats supplied by Neste with refined jet fuel at ExxonMobil's facilities in Singapore and deliver this blended fuel to Changi Airport via the existing fuel hydrant system.

[12] Under CORSIA, airlines will purchase carbon credits and/or use SAF to offset their additional emissions over 15 years from 2021 to 2035 relative to the baseline for all international flights on routes between participating States.

Air Traffic Management (ATM)

Singapore's air navigation service provider (ANSP), CAAS, has been actively trialling operating concepts and technologies. This includes collaboration with other Asia-Pacific ANSPs to optimise flight operations and enhance ATM, reducing fuel consumption and emissions.

Such initiatives include establishing a Distributed Multi-Nodal Air Traffic Flow Management (ATFM) network in the Asia-Pacific region to achieve demand-capacity balancing and reduce air congestion and delays on the ground. CAAS is also deploying performance-based navigation over air routes to increase the precision of flight paths, allowing for optimal route placements and flight levels, and continuous climb and descent operations to facilitate optimal vertical flight profiles for aircraft.

CAAS is also developing the next generation of Air Navigation Services (ANS) systems, which will incorporate advanced technologies to support the implementation of new operating concepts.

Furthermore, Singapore actively supports and contributes to ICAO's work on aviation sustainability. In addition to the ACT-CORSIA programme, CAAS recently joined the ACT-SAF programme to develop global capabilities in SAF adoption and deployment. Moreover, Singapore has established international partnerships with like-minded countries to promote and advance aviation sustainability. Its agreement with the United Kingdom (UK) Civil Aviation Authority advances knowledge sharing on emerging sustainable technology and travellers' preferences. Additionally, the Memorandum of Arrangement with New Zealand facilitates collaboration and sharing of information on initiatives to advance sustainable aviation.

As a next step, CAAS is developing a Sustainable Air Hub Blueprint to bring together all these efforts and to set a roadmap with clear 2030 and 2050 targets and tangible pathways for achieving them. The Sustainable Air Hub Blueprint is a significant initiative which will help provide thought leadership and further catalyse investments, actions and collaborations with private sector companies and other countries.

1.5 The future of aviation sustainability for Singapore

The international civil aviation sector must play its part and take firm and decisive actions to decarbonise its operations. No single country or organisation can achieve this on its own; the push for sustainable aviation will require coordinated State actions, cross-sectoral collaboration, public-private partnership and greater climate consciousness amongst corporates and the travelling public.

As an international business, aviation and aerospace hub, Singapore can play an important role as a pathfinder and convenor for the cross-sectoral collaboration and public-private partnership needed to reconfigure the aviation ecosystem to support sustainable operations and make it a commercially viable reality. Singapore is well-positioned to demonstrate its commitment to make aviation more sustainable and encourage similar regional efforts by gathering regional partners and stakeholders to discuss and collaborate on sustainability. As an active member of ICAO and the international civil aviation community, Singapore can also exercise thought leadership and work with other countries and international organisations to drive and support climate actions globally and regionally.

In the same vein, Singapore must set targets for domestic and international aviation emissions to signal its commitment to pursuing sustainable aviation. However, this should be done pragmatically and consider the timing and pacing of global developments, economic costs and potential impact on the Singapore air hub. These efforts must also be supported by the commitments made by aviation stakeholders, such as SIA and CAG, to achieve net-zero emissions by 2050.

2

Game-Changers and Pathways to Advance Sustainable Aviation

This section provides an overview of the key game-changers and trends that shape the future of sustainable aviation and explains how Singapore can chart future pathways for a sustainable air hub.

2.1 International game-changers

As the leading body overseeing aviation, ICAO's decisions and policies are key in shaping the global aviation landscape. To build and drive the momentum of aviation sustainability, ICAO has set the aspirational goals of: (i) 2% annual fuel efficiency improvement through 2050; and (ii) Carbon Neutral Growth from 2020.[13] It has also established a basket of measures to address international aviation emissions, comprising technological and operational improvements, CORSIA, and the development and deployment of SAF.

Of note, ICAO is currently assessing the feasibility of a Long-Term Aspirational Goal (LTAG) for international aviation. More recently, ICAO published its report on the feasibility of a LTAG, developed by the Committee on Aviation Environmental Protection (CAEP). The report highlights the potential for substantial carbon dioxide (CO_2) reductions using in-sector measures such as innovative airframes, new technologies, operational improvements, and alternative fuels.[14] With this, options for a LTAG would be presented and considered at the ICAO 41st Assembly in 2022. If established, the LTAG would serve as a powerful signal of the commitment by ICAO Member States and the international aviation sector towards achieving aviation sustainability. In turn, this would influence behaviours and decisions by governments and corporates within and beyond the aviation sector.

Apart from ICAO, the Air Transport Action Group (ATAG) plays an important role in shaping the industry's response to the challenge of aviation sustainability. The ATAG's adoption of a long-term climate goal of net-zero carbon emissions by 2050 in October 2021 is a significant commitment by the aviation industry towards aviation sustainability, whereby the world's airlines, airports, ANSPs and aircraft and engine manufacturers had pledged to reduce CO_2 emissions in support of the Paris Agreement 1.5°C goal.[15] Moreover, the ATAG published the Waypoint 2050 report, which outlines various pathways and scenarios that can be taken towards the decarbonisation of air transport.[16]

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[13] ICAO, *2019 Environmental Report.*

[14] On LTAG: the CAEP Report foresees the largest overall CO_2 reductions by 2050 coming from fuels and clean energy sources, with decreases in GHG emissions of up to 55% projected. New technology, including advanced traditional and new unconventional airframe configurations, are also expected to contribute to efficiency of up to 21%, and improvements in flight performance of up to 11% through innovations such as formation flying. On SAF: the CAEP agreed on amendments to life-cycle emissions reduction values and a sustainability certification framework. The meeting also agreed on new guidance for States on potential policies and approaches for deploying SAF. ICAO, "Aviation green transition progresses through ICAO CAEP", https://www.icao.int/Newsroom/Pages/Aviation-green-transition-progresses-through-ICAO-CAEP.aspx.

[15] ATAG, "Aviation Industry Adopts 2050 Net-Zero Carbon Goal", https://www.atag.org/component/news/?view=pressrelease&id=125

[16] ATAG, *Waypoint 2050 — Second Edition.*

The World Economic Forum (WEF) Clean Skies for Tomorrow (CST) Coalition's efforts in advancing the deployment of SAF are also noteworthy. The coalition has committed to accelerating the supply and use of SAF technologies to reach 10% of the global jet aviation fuel supply by 2030.[17] The CST SAF Ambassador Group, of which Singapore is a member, developed a SAF Policy Toolkit to help policymakers grow a SAF supply, stimulate demand for such fuels and enable a healthy SAF ecosystem.

2.2 Regional landscapes and efforts

Aviation sustainability ambitions and efforts vary across different regions at present. When setting targets or policies, it is important to consider the specific regional context.

The European Union (EU)[18], United States (US)[19] and UK[20] have all set out their respective visions and strategies to achieve net-zero aviation emissions by 2050. Similarly, the European aviation sector has committed to achieving net-zero CO_2 emissions by 2050 and published a plan laying out its path for meaningful CO_2 emissions reduction efforts in Europe and globally. In the EU, individual countries and the Union have also implemented or are planning to implement SAF mandates.[21] The UK is also exploring mandating the use of SAF.

On the other hand, many countries in the Asia-Pacific region have yet to set targets for aviation emissions. Nonetheless, several airlines in the region, such as Air New Zealand, All Nippon Airways, Japan Airlines, Malaysia Airlines, Qantas Airways, and SIA, have announced their goals to achieve net-zero emissions by 2050, including the use of SAF[22] as one of the key levers. In addition, Japan has set a target for Japanese airlines to adopt a 10% SAF blend by 2030.

[17] World Economic Forum, "Clean Skies for Tomorrow Coalition", https://www.weforum.org/cleanskies.

[18] As part of the Toulouse Declaration launched on February 4, 2022, the EU had committed to supporting the goal of achieving carbon neutrality in the air transport sector by 2050. French Presidency of the Council of the European Union, "European Aviation Summit", https://presidence-francaise.consilium.europa.eu/en/news/european-aviation-summit/.

[19] United States Department of Transportation, Federal Aviation Authority, "US Releases First-Ever Comprehensive Aviation Climate Action Plan to Achieve Net-Zero Emissions by 2050", https://www.faa.gov/newsroom/us-releases-first-ever-comprehensive-aviation-climate-action-plan-achieve-net-zero.

[20] United Kingdom Department for Transport, "Jet zero: our strategy for net zero aviation", https://www.gov.uk/government/consultations/achieving-net-zero-aviation-by-2050.

[21] European Council, "Fit for 55 The EU's plan for a green transition", https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/.

[22] WEF, "Towards a sustainable future for aviation in Asia Pacific", originally published by Thorsten Lange, EVP Sustainable Aviation, Neste, https://www.weforum.org/agenda/2021/08/airlines-flying-asia-pacific-sustainable-aviation-fuel/.

2.3 Key trends that drive and shape aviation sustainability

International aviation is a critical enabler in achieving global connectivity. It is a vital mode of transportation in a globalised world and contributes significantly to the socio-economic progress of a country. This function is even more pertinent for remote countries or small island States that depend on aviation as a bridge to the world and a critical economic contributor. Given the importance of aviation, the answer to achieving sustainability in aviation is not to reduce the number of flights but rather to pursue concrete actions that would make flying inherently more sustainable. This would place the sector on a path towards long-term sustainability, balancing growth and environmental needs.

The aviation sector remains a strong growth industry even as it recovers from the COVID-19 pandemic. This presents both opportunities and challenges in achieving sustainable air travel. The International Air Transport Association (IATA) expects overall traveller numbers to reach 4 billion in 2024, exceeding pre-COVID-19 levels (103% of the 2019 total).[23] The recovery and growth in global air travel will support economic progress and allow more people in developing countries to experience air travel, many for the first time. Accordingly, sustainability efforts and actions must increase in tandem with air traffic growth to meet global and industry net-zero targets. That said, strong demand for air travel provides impetus and much-needed funding for the aviation sector to invest more in decarbonising its operations.

Consumers are becoming increasingly conscious of the environmental impact of air travel. In a McKinsey survey in 2021, around 54% of respondents said aviation should "definitely become carbon neutral" in the future, and more than 30% of respondents have paid to offset their CO_2 emissions from air travel.[24] This shows that there is demand for sustainable air travel products, which is likely to continue increasing. At the same time, there is room to expand public education to raise awareness of and support for climate action in the aviation sector.

[23] IATA, "Air Passenger Numbers to Recover in 2024", March 1, 2022, https://www.iata.org/en/pressroom/2022-releases/2022-03-01-01/.

[24] McKinsey & Company, "Opportunities for industry leaders as new travellers take to the skies", https://www.mckinsey.com/industries/travel-logistics-and-infrastructure/our-insights/opportunities-for-industry-leaders-as-new-travelers-take-to-the-skies.

Governments and corporates worldwide have also been stepping up their investments in SAF production capabilities and technologies. As demand for SAF increases, fuel suppliers have been boosting the production of SAF significantly over the last few years.[25] Aircraft manufacturers have also announced plans and initiatives to explore the use of hydrogen for commercial aviation. Such investments are supported by the growth of green financing and carbon trading services, which can be powerful enablers for the green transition of aviation. Since many projects to improve aviation sustainability may require capital that the sector is hard-pressed to find as it recovers from the COVID-19 pandemic, green financing can potentially increase the availability of capital to fund these projects. The enhancement of carbon trading services can also improve the quality, price transparency and ease of trading carbon credits. The aviation sector can potentially tap on these carbon markets for additional demand for sustainable aviation initiatives.

At the same time, heterogeneous regulations and policies on aviation carbon emissions worldwide can slow the pace and progress of pursuing aviation sustainability. Given the cross-border nature of international air travel, the lack of harmonisation across regulations and policies risks creating market distortions and an uneven playing field within the aviation sector. It may also result in added complexities for corporates and consumers when making decisions on reducing their aviation carbon footprint.

One of the key efforts in facilitating sustainability initiatives is the development of taxonomies to define what is "sustainable". This would help to provide a common language across all sectors and stakeholders, and with greater clarity and alignment, promote investment and efforts in sustainability initiatives. Likewise, the aviation sector would benefit from such taxonomies by a common definition of what would be considered sustainable aviation. Several taxonomies, such as the European Union Taxonomy for sustainable activities, have been developed. In Singapore, the Green Finance Industry Taskforce (GFIT) is developing a green taxonomy for Singapore-based financial institutions to encourage the flow of capital to support the low carbon transition, as well as the environmental objectives of Singapore and the Association of Southeast Asian Nations (ASEAN) nations. This GFIT taxonomy would also cover activities within the aviation sector.

[25] Commercial production of SAF increased from an average of 0.29 million litres per year (2013 – 2015) to 6.45 million litres per year (2016 – 2018), and it is estimated that up to 10.9Mt (13.6 billion litres) per year of SAF production capacity may be available by 2032. ICAO, "SAF Stocktaking", https://www.icao.int/environmental-protection/Pages/SAF_Stocktaking.aspx.

3

Strengths, Weaknesses, Opportunities and Threats for a Sustainable Air Hub in Singapore

We must consider Singapore's unique circumstances in determining the appropriate pathways towards developing a sustainable air hub in Singapore. This section will provide an in-depth look into Singapore's strengths, weaknesses, opportunities and threats in relation to aviation sustainability. This analytical framework can also be useful for other countries in assessing their circumstances.

3.1 Strengths

In Singapore, there is a strong whole-of-government push for sustainability, as well as public-private partnerships and cross-sectoral collaboration that can support the development and implementation of sustainability initiatives. As a vibrant business and financial hub with large corporations and a generally affluent and well-informed travelling public, Singapore can offer a conducive environment for developing and introducing sustainable aviation products. The demand for sustainable air travel is also bolstered by extensive air connectivity and travel demand to countries and regions with strong climate ambitions, such as Europe and the US.

Singapore is a well-established petrochemical hub that can potentially pivot to SAF production. In 2023, Neste, the world's largest producer of renewable diesel and SAF, is expanding its production capacity in Singapore. This gives Singapore a good start. There is also growing interest in the region in building up SAF demand and supply, which allows for more regionalised sourcing of SAF.

In addition, there are moves to develop Singapore as a green financing and carbon trading centre. The launch of Climate Impact X (CIX), which aims to be a global exchange and marketplace for high-quality carbon credits, supports the implementation of its sustainability initiatives.

Singapore has been consistently investing in new aircraft, airport, and ATM technologies, promoting more efficient flights and reducing carbon emissions. There is also a strong research and development (R&D) ecosystem among Singapore's institutes of higher learning and research institutes, which can be leveraged to foster innovation with potential applications in sustainable aviation.

3.2 Weaknesses

Singapore faces inherent land and natural resource constraints, which translate to limited renewable energy options for the country. This presents challenges in decarbonising airport infrastructure, which depends on the wider decarbonisation of the national energy grid. Moreover, the lack of a sizeable domestic market creates constraints for Singapore to pursue sustainability initiatives on its own, given that its airport and airlines are more exposed to international competitive dynamics.

Domestically and across the region, there is also limited availability of acceptable SAF feedstocks. Given that this is a nascent industry, significant investments are required to set up the infrastructure for SAF supply chains. Paired with rising demand and competition for SAF regionally and globally, prices for SAF (currently at two to five times more expensive than fossil jet fuel) are likely to remain high in the coming years.

Although consumers are becoming more environmentally conscious, the proportion of consumers in Singapore who do pay for sustainable air travel, in the form of purchasing carbon offsets or paying for the use of SAF, remains relatively low. This might be due to a lack of understanding of sustainable aviation products offered by airlines and their value and contribution to the environment.

Currently, there is also a lower appetite for climate action amongst Southeast Asian countries, and pursuing goals and policies that are hugely disparate compared to the region might result in a first-mover disadvantage.

3.3 Opportunities

As an international business, aviation and aerospace hub, Singapore can differentiate itself by offering sustainable aviation solutions to increase economic output, develop new technology and create new jobs. It can also contribute by playing the role of a pathfinder and convenor for public-private partnerships and cross-sectoral collaboration.

At the same time, as an active member of ICAO and the international civil aviation community, Singapore can spearhead and shape global and regional sustainability efforts. Singapore can also contribute by promoting greater action in the region through exercising thought leadership and driving climate action for sustainable aviation.

Notwithstanding its lack of natural renewable energy sources, Singapore has the opportunity to import low-carbon electricity from other countries, subject to feasibility and compatibility with national energy frameworks.

On SAF, Singapore can build on its local SAF production capabilities to offer competitively priced SAF to airlines passing through Changi Airport and improve its energy resilience by reducing its reliance on fossil fuels. Singapore can also seek to become a frontrunner in new SAF technologies and pioneering next-generation feedstocks. In addition, it can tap on growing regional interest in SAF production to further increase potential SAF supply to Singapore. To complement these supply-side efforts, Singapore can put in place proper accounting frameworks to track and account for SAF usage. Additionally, demand can be boosted by having corporates and the government take the lead in using SAF for business travel.

Furthermore, the Singapore aviation sector can tap into the growing green financing and carbon trading market in Singapore to support its implementation of sustainable aviation initiatives. There is also the potential for Singapore to further expand its green financing efforts to establish a regional green financing network.

Singapore can build on its established R&D ecosystem and strong innovation culture to promote and spearhead sustainable aviation R&D. It can also leverage public-private partnerships to drive ecosystem collaboration and provide a testbed for research outcomes. With the development of Terminal 5 at Changi Airport underway, there are opportunities to incorporate higher energy efficiency measures and trial new sustainable technologies and infrastructure.

Through public education and information campaigns, Singapore can raise awareness and sensitise consumers on the possible need to pay more to travel sustainably. This can then help to generate greater demand and willingness to pay for sustainable aviation initiatives.

3.4 Threats

Future global black swan events that affect international aviation would continue to have an outsized impact on Singapore and its aviation sector, given the lack of a sizeable domestic market for buffer. These events could adversely impact Singapore's economy directly and indirectly, weakening its ability to invest in sustainability initiatives.

As a potential early adopter of sustainability initiatives, Singapore would need to be cautious of possibly compromising the air hub's competitiveness as a result of potential higher costs. For example, high SAF premiums could distort pricing and result in an unlevel playing field vis-à-vis competing hubs that have not adopted SAF. Transfer and transit (T&T) passengers, in particular, are more sensitive to changes in ticket prices, and a price hike could affect Singapore's status as a transfer hub.

Given the lack of natural renewable energy sources, Singapore is highly dependent on imports, such as renewable electricity, to decarbonise the national grid or Changi Airport. This dependence would increase its susceptibility to geopolitical events.

While Singapore can tap on carbon offsets to close the gap with its emissions targets, it needs to be combined with considerable efforts to reduce in-sector emissions. This paired effort will avoid perceptions that the Singapore air hub is "greenwashing" using carbon offsets, which could affect its credibility as a frontrunner in aviation sustainability.

4

Recommendations on Strategies for Developing a Sustainable Air Hub in Singapore

A leading air hub of the future must be connected, competitive and sustainable. Singapore must retain its current strength in connectivity and competitiveness and develop sustainability as a differentiator to carve out a new position as a leading sustainable air hub.

The IAP seeks to contribute to the development of the Singapore Sustainable Air Hub Blueprint by proposing specific projects that Singapore can initiate, leveraging its hub position and strong partnerships with international bodies, other countries and private companies. In doing so, the IAP has taken an action-oriented, industry-driven approach, tapping on the experience and expertise of its members, which include senior executives of global aviation bodies and key aviation companies.

Specifically, the IAP has recommended 15 initiatives across the three key domains of airport, airline and air traffic management.

4.1 Airport

Context

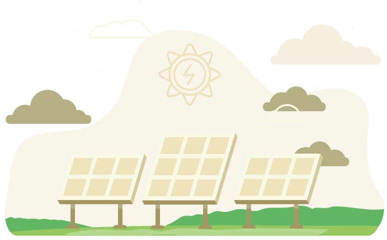
Airports are complex ecosystems of infrastructure, machinery, vehicles and supporting systems, serving as gateways for air travel and connectivity. Airports play a crucial role in tackling overall air hub emissions. Despite only accounting for approximately 2% of global aviation emissions,[26] airport emissions are set to increase in a "business-as-usual" scenario due to growth in air travel demand.

Airport operations are highly energy intensive, relying on electricity for air-conditioning of airport terminals and to power operational systems, and fossil fuels for airside vehicles. To reduce their carbon footprint, airports need to look at ways to reduce electricity usage and switch to renewable energy (e.g., solar deployment and renewable electricity). This is particularly challenging for Singapore, which has limited access to renewable energy.

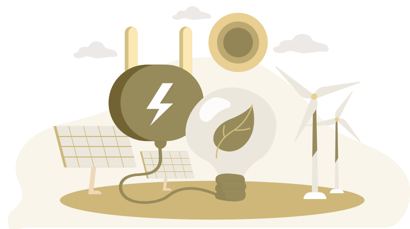
To that end, it is important to take a hierarchical approach to reduce the carbon footprint for terminal and airside operations. This entails looking at measures first to avoid, next to reduce, then to replace emissions and, if necessary, to apply offsets. These measures should be applied to larger airport-wide systems so that any optimisation would result in a greater impact.

Therefore, to improve the sustainability of airports in Singapore, the IAP recommends that CAAS work with stakeholders on the following six initiatives spanning infrastructure, systems, as well as different aspects of airport operations:

26 Airports Council International, *Sustainability Strategy for Airports Worldwide,* page 10.

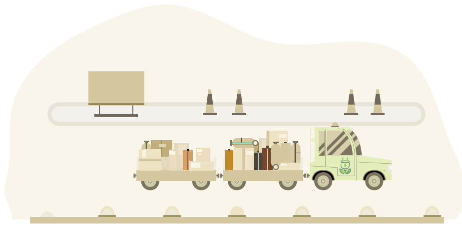


a. **Deploy solar power on the airfield;**

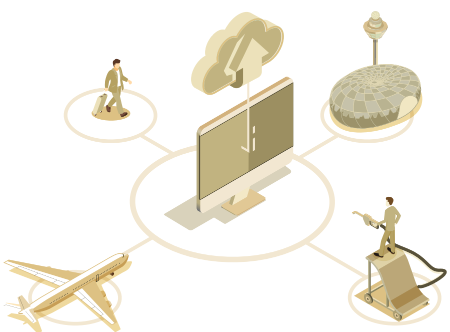


b. **Secure and increase the use of renewable electricity;**

c. **Improve building energy efficiency by reducing the air-conditioning carbon footprint;**



d. **Facilitate the transition of airside vehicles towards clean energy sources;**



e. **Explore system optimisation with a digital twin project; and**

f. **Enhance resource circularity through an on-site waste-to-energy facility.**

Recommendations

a. Deploy solar power on the airfield

Given the high energy intensity of airport operations, Singapore needs to look at more renewable energy sources. For Singapore, solar power is the most immediately viable source of renewable energy, which it should maximise to reduce carbon emissions from power generation. Changi Airport is deploying solar panels to the maximum extent possible, particularly on rooftops, which would cover up to 5%[27] of the airport's existing energy needs.

However, airport land is limited and is already efficiently utilised for operations. The only untapped open spaces are within the airfield, which is designed according to prevailing international regulations and other safety or operational considerations. The use of these open areas for solar panel deployment must be carefully assessed to ascertain the impact on safety and regularity of aircraft operations.

Therefore, the IAP recommends that CAAS work with stakeholders to conduct an airfield solar technical assessment to explore further solar deployment at Changi Airport. This assessment should cover several key considerations, including:

a. Analysis of safety risks to airport and flight operations, including glare or glint impact on air traffic controllers and pilots;
b. Impact on radar signals;
c. Impact on pilots from human factors perspective;
d. Potential energy yields and possible transmission losses, as well as overall economic viability; and
e. Maintainability of the panels and airfield areas where solar panels are deployed.

[27] Calculated based on pre-COVID airport energy consumption.

The IAP recommends looking at all airfield areas within the boundaries of Changi Airport. This would include water bodies, areas surrounding the runways and taxiways, and areas that aircraft fly over just before they reach the runway, i.e., the approach path. Subject to the technical assessment, it is estimated that airfield solar deployment can potentially meet an additional 5%[28] of Changi Airport's existing energy needs, over and above the solar panels deployed on its rooftops.

This detailed airfield solar assessment should involve the relevant regulator(s), the airport operator, and aeronautical safety and solar experts. It is estimated to take two years and may lead to trials on a live airfield or further development of solar panels specifically designed for airfield deployment. If shown to be viable, CAAS would also engage ICAO and other industry bodies on standards and implementation. Given the challenges of deploying solar panels in the airfield, the subsequent implementation could then be carried out in a phased manner as follows:

a. Initial phase — to potentially cover less sensitive areas, such as beyond the approach path and outside of the runway or taxiway strip areas; and
b. Subsequent phase(s) — to extend coverage to more sensitive areas such as within the approach path (including water bodies) and inside the runway or taxiway strip areas.

Following the technical assessment, the installation of new supporting infrastructure would be the key enabler in deploying solar panels in the airfield. The implementation would need to be done in a manner which fully addresses the safety considerations and must subsequently be closely monitored for any adverse safety impact. In addition, the outcome of this solar technical assessment can also extend to Changi East, where Runway 3 and the future Terminal 5 are situated.

[28] Calculated based on pre-COVID airport energy consumption.

b. Secure and increase the use of renewable electricity

Renewable electricity presents a potentially significant lever for the airport to decarbonise, as on-site energy efficiency or reduction initiatives are unlikely to result in full decarbonisation due to natural limits to efficiency improvements.

Renewable electricity import is also crucial for Singapore, where natural resource constraints mean that Singapore is currently limited to solar power as its sole renewable energy source. Land scarcity and heavy cloud cover further limit solar power's contribution to the national energy mix.

The Singapore Energy Market Authority (EMA) has taken steps to plan for future imports of low-carbon electricity[29] from countries in the region.[30] As part of Singapore's plans to import up to 4 gigawatts (GW) of electricity by 2035, EMA has launched the first request for proposal (RFP1) in November 2021. The second request for proposal (RFP2) was launched in July 2022, and RFP1 and RFP2 will be streamlined into a single RFP.[31]

Therefore, the IAP recommends that CAAS work with stakeholders to secure renewable electricity for Changi Airport, starting with imported low-carbon electricity. This recommendation builds upon the earlier one on solar deployment, forming part of a broader strategy to secure green energy for the airport. In the long term, there is also potential to tap on new domestic renewable energy production initiatives such as carbon capture, utilisation and storage, or the use of hydrogen.

The future inflow of low-carbon electricity into Singapore provides two ways that Changi Airport can reduce its carbon emissions. First, it can lower the overall carbon intensity of the grid electricity used at the airport. Second, it provides opportunities for the airport to secure direct contracts with low-carbon electricity retailers for more low-carbon electricity supply to Changi Airport.

Given the value proposition of low-carbon electricity imports, the IAP recommends setting medium-term 2030 and long-term 2050 targets for the Singapore air hub to use renewable electricity. At the same time, there is a need to continue closely monitoring national developments in low-carbon electricity imports.

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29 "Renewable electricity" is the general term referring to electricity produced from renewable sources. More specifically, low-carbon electricity, under EMA's RFP, refers to electricity from low carbon sources with a grid emission factor of below 0.15tCO_2/megawatt-hours (MWh).

30 EMA, "Electricity Imports", https://www.ema.gov.sg/electricity-imports.aspx.

31 EMA, "Second Request for Proposal (RFP2)", http://www.ema.gov.sg/electricity-imports-rfp2.aspx.

The key enablers for this recommendation would include national-level policy and commercial developments in low-carbon electricity imports and government-to-government arrangements and approvals. Decisions on developing imports infrastructure (e.g., construction of interconnectors) would also need to be made commercially and with the source countries. These factors could mean that significant progress may take time to materialise. Based on the current way imported low-carbon electricity contracts are envisaged to be structured, no additional infrastructure is required within the airport boundary to import low-carbon electricity. In the future, low-carbon electricity imports could contribute to Terminal 5's decarbonisation efforts to support national objectives.

c. Improve building energy efficiency by reducing the air-conditioning carbon footprint

The air-conditioning system is the largest energy consumer at Changi Airport, and improving its energy efficiency would significantly reduce the airport's carbon footprint. Changi Airport has been pursuing passive and active strategies to either lower air-conditioning use or reduce the energy used to run the air-conditioning system. An example of a passive initiative, or measure that does not require energy to function, is the trialling of cooling films to reduce heat gain to the terminals. An example of an active initiative, or one that is energy-related, is the regular upgrading of air-conditioning equipment in the terminals to the best-in-class efficiency.

The IAP recommends that CAAS work with stakeholders to further improve the building energy efficiency of Changi Airport by reducing the airport's air-conditioning carbon footprint through innovative energy-efficient technologies and design concepts. While the airport continues undertaking the improvements mentioned above at the existing Terminals 1 to 4, there is potential to achieve further energy savings and carbon reduction with alternative cooling methods or technologies. The IAP recommends progressively assessing these, particularly their viability to be applied in the new Terminal 5.

One such cooling technology under consideration is the distributed district cooling system. With such technology, centralised chiller plants can achieve economies of scale in producing chilled water, which is then delivered to various zones through a network of pipes. As these zones are on the same network, energy is more efficiently utilised to provide cooling than individual standalone systems. Another promising area is to employ space stratification. Catering to the differentiated cooling needs of various zones in the airport will allow for the optimal utilisation of energy to provide just the right amount of cooling to each zone.

The IAP recommends continuing detailed assessments of these potential technologies or methods, including carrying out trials, over the next two years. The outcome of these assessments would guide the incorporation of such features into the design of Terminal 5 to achieve maximum energy savings. This would contribute towards minimally achieving the Singapore Building and Construction Authority's (BCA) Green Mark Platinum Super Low Energy Building certification for Terminal 5.

This recommendation could have potential synergies with system optimisation efforts (see recommendation e. Explore system optimisation with a digital twin project). The measures and technologies could be integrated into an intelligent building management system that could holistically optimise energy use for the terminal buildings. For example, a smart energy management system could be used to control the air-conditioning system by gathering real-time information from sensors within the terminal spaces, so that cooling can be provided optimally to spaces only when needed.

The key enablers for this recommendation would include infrastructure changes, as well as the creation of jobs and skills in the green technology field to design and implement these energy efficiency measures. Highly skilled consultants, engineers and designers will be needed to develop the systems, while trained technicians will be needed to implement and operate these systems.

d. Facilitate the transition of airside vehicles towards clean energy sources

Today, airside vehicles generate pollutive carbon emissions from burning fossil fuels. We can reduce the carbon footprint by switching the existing airside vehicle fleet to cleaner energy options. The potential pathways include electrification of the airside fleet, conversion to hydrogen-powered vehicles, or the use of biofuels. While there are multiple cleaner energy pathways available, there is also a need to consider the maturity of the pathways and the potential challenges of implementing these pathways in the local context. The challenges could be as follows:

Electrification

a. Upfront costs — Costs would be incurred to switch existing vehicles to electric variants, install the charging infrastructure and upgrade the electrical grid;
b. Grid adequacy — The existing electrical grid at the airport might not be able to cope with the electricity demand from full-scale electrification;
c. Space limitations — There might be limited space at the airside to deploy an adequate network of charging points; and
d. Technology limitations — Certain airside vehicles might not have viable electric variants (e.g., those requiring high torque).

Hydrogen-powered vehicles

a. Safety concerns — Due to the highly combustible nature of hydrogen, there is a need to ensure the safe transport, storage and use of hydrogen at the airside;
b. Upfront costs — Costs would be incurred to switch vehicles to hydrogen fuel cell variants and to install storage and refuelling infrastructure; and
c. Technology limitations — Certain airside vehicles might not have viable hydrogen-powered variants, as technology is still nascent.

Use of biofuels

a. Compatibility issues — Engines of certain airside vehicles might not be compatible with some biofuels[32] and might require further examination on the appropriate blend of biofuels and conventional fossil fuels; and
b. Cost concerns — Currently, biofuels are more expensive than conventional fuels in Singapore, leading to higher operating costs.

Additionally, airports need to ensure that critical airside operations can continue in disruptions, such as a blackout or shortage in fuel supply. A mixed pathway approach could provide airports with the necessary operational resilience.

In view of the above, the IAP recommends that CAAS work with stakeholders to facilitate the transition of airside vehicles from running on conventional fossil fuels to cleaner energy options. This should pursue multiple pathways to harness different carbon abatement technologies to reduce the carbon footprint of airside activities. This approach would bolster operational resilience should black swan events arise and reduce the peak load on the electrical grid. Three main pathways should undergird this effort: electrification, hydrogen, and biofuels. The following four projects should be pursued to facilitate a better understanding of the deployment scale, concept of operations, challenges, policies and regulations for each pathway.

32 Renewable diesel is a drop-in fuel that can be used 100% in vehicles without blending with conventional diesel. Some other biofuels, such as Fatty Acid Methyl Esters (FAME), are chemically different from conventional diesel. Prolonged usage of such biofuels in high concentrations can cause problems to the fuel systems or engines. Neste, "What is the difference between renewable diesel and traditional biodiesel if any", https://www.neste.com/what-difference-between-renewable-diesel-and-traditional-biodiesel-if-any.

Simulation and modelling study

First, to better understand the changes needed to pursue electrification of the airside fleet, the IAP recommends that CAAS work with A*STAR, the airport operator and Ground Handling Agents (GHAs). Other partners to work with may include research institutes and institutes of higher learning to model and simulate electricity-related needs at varying levels of electrification and the required charging infrastructure. This study should model and produce a high-fidelity simulation of the behaviours, movement patterns, and expected charging requirements of airside vehicles. It will then be able to quantify the resulting impact of different electrification levels on the grid infrastructure. The study should also provide recommendations regarding the management of electric vehicles' (EVs) 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 EVs and facilitate broader decision-making on the scale of deployment for each pathway.

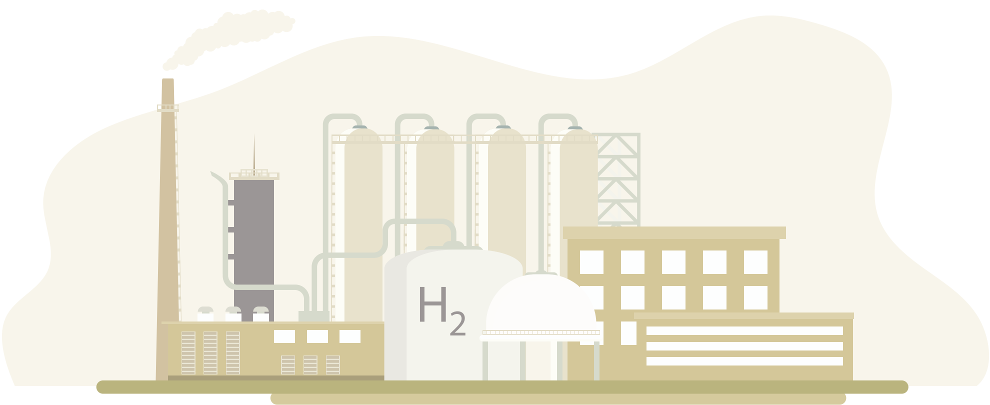
Energy storage system trial

Second, the IAP recommends an energy storage system trial to facilitate cost-effective charging throughout the day and reduce peak grid loads. As the number of EVs in the airside fleet increases, the aggregate demand for electricity and peak load on the grid will rise in tandem. This might challenge the adequacy of the airport's electrical grid. It could also increase electricity costs, especially if these vehicles are charged during times of day with high electricity prices. To address this, an energy storage system could be charged during off-peak hours with lower electricity prices for subsequent usage during peak hours.

In addition, this system could have potential synergies with the deployment of solar panels at the airport, as it could also store energy generated from renewable sources. Such energy can be stored for subsequent use, further reducing costs. By augmenting the capacity of the airport's electrical grid and improving EV charging cost-effectiveness, this system can facilitate and support the electrification of the airside vehicle fleet at scale.

Hydrogen-powered vehicles trial

Third, given that the use of hydrogen at the airside is relatively nascent, the IAP recommends piloting the use of hydrogen-powered airside vehicles in Singapore's context to determine its feasibility. As opposed to traditional vehicles that are fitted with internal combustion engines, hydrogen-powered fuel cell electric vehicles (FCEVs) have no tailpipe emissions, with water vapour being the only by-product. FCEVs would have to be brought into an airport environment, and relevant refuelling infrastructure would need to be installed, to understand how hydrogen can be used at the airside. This trial will then facilitate the development of the concept of operations, as well as policies and regulations to ensure the safe and efficient use of hydrogen-powered airside vehicles in the airport's unique operational context.



Renewable diesel trial

Fourth, under the biofuels pathway, the IAP recommends trialling the use of renewable diesel for the existing airside fleet. Renewable diesel generates lower emissions compared to conventional diesel, making it a cleaner energy option, particularly for airside vehicles that do not have viable electric or hydrogen variants. Renewable diesel can provide near-term potential for carbon abatement because it can be used in diesel engines with minimal adjustments. Furthermore, it could be compatible with existing diesel transportation, storage, and distribution infrastructure. To ascertain this, GHAs and the relevant vehicle original equipment manufacturers (OEMs) will need to be consulted before actual trials with existing airside vehicles. Findings from this trial regarding the feasibility, cost, and operational nuances will inform the Changi Airport community on the best approach to the possible large-scale adoption of renewable diesel for the airside fleet.

Overall, the IAP recommends pursuing the four projects to facilitate better understanding of the deployment scale, operational challenges, policies and regulations needs for each of the three pathways — electrification, the use of hydrogen and biofuels. The overarching aim is to reduce the carbon footprint of airside operations while ensuring operational resilience. The simulation and modelling study will serve as the foundation to understand the amount of electrification the airport's current infrastructure can support. By extension, it can then facilitate decision-making on the scale of deployment for each of the pathways. Concurrently, the other three projects will delve deeper into the implementation aspects of the respective pathways to understand how each can be scaled up. The four projects are estimated to be completed by end-2025 to facilitate a timely transition to 100% cleaner energy vehicles at the airside. Thereafter, the next milestone should be that all new airside vehicles should run on cleaner energy by 2030, unless no viable cleaner energy option is available.

The key enablers for this recommendation would include policies and regulations to support, encourage, and harmonise the implementation of these three pathways, particularly for the hydrogen pathway. CAAS can reference similar efforts by other airports to develop policies and regulations that can effectively facilitate the transition to cleaner energy airside processes locally. There are also opportunities to build synergies between these four projects and other initiatives under the airport domain, such as solar deployment and renewable energy imports. Specific to the development of Terminal 5, there would need to be sufficient electrical grid capacity and space provisions to support a mixed pathway approach for viable cleaner energy options.

e. Explore system optimisation with a digital twin project

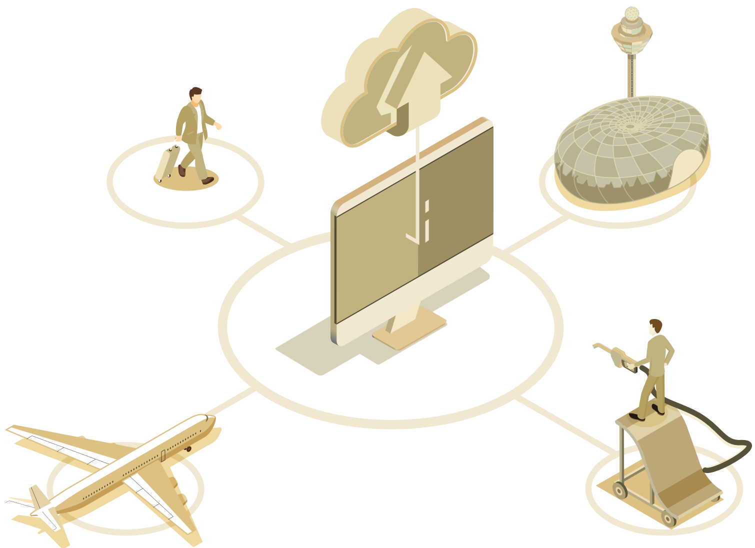
In recent years, airports have been tapping on the potential of digital technology to improve operational efficiencies and, in turn, reduce carbon footprint. System optimisation at the airport level can help significantly reduce aircraft turnaround times, optimise airside vehicle movements, and enhance overall airport collaborative decision-making. This would consequently improve operational efficiency and reduce carbon emissions systemically.

The IAP therefore recommends that CAAS work with stakeholders to study the feasibility of a digital twin modelling process at Changi Airport to reduce energy consumption and minimise emissions from aircraft and airside vehicle movements. Changi Airport could greatly benefit from developing a digital twin to mirror static and dynamic airport assets. A digital twin would help integrate and unify data from various sources to form a virtual replica. This can then be visualised in a human-centric interface for advanced predictions, simulation of future airport developments and process optimisation.

Using predictive analysis, the digital twin can also provide alerts to airport operators to improve resource deployment, reduce carbon footprint and enable cost savings. The digital twin would also optimise real-time monitoring and control, with artificial intelligence and machine learning, and serve as a method for improving systems and designs over time.

As a first step, a feasibility study should be conducted over the next two years to provide a clear and comprehensive framework comprising the planning, design, and end-to-end optimisation of airport processes.

Following this feasibility study, the development of the airport digital twin modelling process would require the involvement of the airport community, system integrators, service providers and regulators. The outcome of this study and potential trials would also guide the digital twin modelling process of Changi East and Terminal 5.



f. Enhance resource circularity through an on-site waste-to-energy facility

Large airports produce considerable amounts of waste. Carbon emissions could be reduced by holistically managing airport waste to extract maximum value through resource recovery. Changi Airport has been incorporating some of these circularity practices by reducing the volume of waste and consuming less external resources. This includes recycling concrete aggregates for re-paving aircraft parking bays and collecting condensate water from the terminal's air-conditioning system for use in cooling towers. However, the carbon reduction benefits to the airport from these measures are largely indirect. Beyond these circularity practices, a more direct decarbonisation pathway to reduce energy offtake from the grid would be through an on-site waste-to-energy facility.

Therefore, the IAP recommends that CAAS work with stakeholders in studying the potential and feasibility of establishing a waste-to-energy facility in Changi Airport. This facility could work by utilising waste as feedstock to generate biofuels, electricity, heating or even cooling for the airport through a tri-generation process. An example of a potential pathway is through an anaerobic digestion process that converts food or organic waste to biogas, which can be used as a form of fuel. However, the viability of such a facility depends on having sufficient waste, visibility on the available types of waste with recoverable energy content, changes to Changi Airport's carbon emissions, fire safety and explosion risks, and pollution impacts. Some of these wastes may also be mixed and would require sorting or segregation for a more effective waste-to-energy process. The siting of such facilities within the airport would need to be carefully assessed to avoid (i) conflicts with airport operations and (ii) deterioration of ambient air quality or generation of disamenities such as odour, noise and dust nuisance. Hence, an airport waste-to-energy study would need to be conducted. This is to determine the type and quantity of viable waste, assess if there are economies of scale and, if so, the most effective waste-to-energy pathway to pursue. The study should also take into account the appropriate pollution control and nuisance mitigation measures to be implemented, where necessary. This could also inform on the feasibility of having an on-site facility while surfacing any potential safety, operational, environmental, disamenities and economic challenges. If feasible, such a facility can contribute to Changi Airport's carbon reduction efforts through resource recovery and a reduction in energy offtake from the national grid.

This waste-to-energy feasibility study would involve the whole airport community, local waste-to-energy experts, and waste management consultants. This study should be carried out within two years and incorporate findings of any ongoing waste-to-energy trials conducted by airport stakeholders.

Following the completion of this study, the key enabler for this waste-to-energy facility would be the construction of new dedicated infrastructure at the airport, which would likely come with considerable costs. It would also require land, which is already a scarce resource. Subject to the outcomes of the study, site provisions might need to be made at Changi East for such a potential facility in the future if found to be feasible.

4.2 Airline

Context

Flight operations account for the bulk of global aviation emissions. The decarbonisation of international civil aviation will require significant climate action in the airline domain.

Emissions from aircraft operations are inherently hard to abate. The use of SAF is a critical lever that could account for the bulk of possible emissions reduction from flight operations. SAF is also available today as a drop-in solution.[33] However, its adoption remains low and there remain significant hurdles in terms of higher costs compared to fossil jet fuel (at two to five times) and the need for feedstock diversification through new SAF production pathways for longer-term SAF scale up.[34] Aircraft technology has been steadily improving over the years, bringing about higher operational efficiencies and fuel savings. Nonetheless, game-changing technological bounds that could drastically reduce emissions (e.g., hydrogen-powered aircraft) will still require decades to develop. As a global industry, it is also crucial for actions to be harmonised regionally and around the world to minimise competitive distortions or asymmetrical requirements. Such harmonisation requires collaboration amongst governments and stakeholders, which might have different starting points in their climate goals and plans.

Recognising these challenges in decarbonising the air transport sector, it is widely accepted in the industry that a basket of measures would be required. The ATAG Waypoint 2050 report identified four decarbonisation pathways for the global air transport sector to meet net-zero carbon emissions by 2050: SAF, Operations and Infrastructure, Technology and Market-based Measures.[35]

Taking reference from these four pathways, to improve the sustainability of airlines operating to, from and through Singapore, the IAP recommends that CAAS work with stakeholders on the following initiatives:

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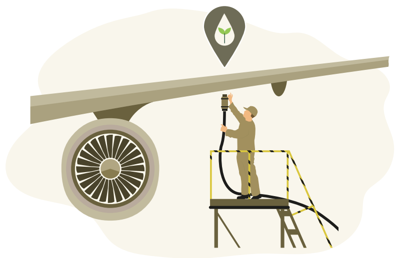
[33] SAF can be mixed into fossil fuel to reduce emissions, with no changes needed to the aircraft or infrastructure.

[34] It is noteworthy that feedstock availability is not of immediate concern currently for the Hydroprocessed Esters and Fatty Acids (HEFA) pathway.

[35] ATAG, *Waypoint 2050 — Second Edition.*

a. **Develop and implement a roadmap to create a long-term secured SAF supply ecosystem;**

b. **Establish a "Singapore / ASEAN Corporate Buyers' Club" to create demand signals;**



c. **Design and introduce a structural offtake mechanism and create demand signals for secured long-term, lower-cost SAF supply;**

d. **Innovate to build deep aviation industry vertical offerings in carbon markets, develop a support ecosystem for aviation carbon offsets solutions and encourage uptake among corporates and consumers; and**

e. **Explore a potential technical centre for capability-building to ensure that Singapore can be an early adopter of aircraft technology.**

In particular, the recommendations take into consideration Singapore's unique context: its susceptibility to first mover disadvantage given the intense competition from other air hubs; the significant share of T&T passengers who tend to be more price sensitive; current limited regional consensus on sustainability goals and plans for SAF adoption; and the lack of a domestic aviation market to serve as a buffer.

Recommendations

a. Sustainable Aviation Fuel — Develop and implement a roadmap to create a long-term secured SAF supply ecosystem

The global SAF market is still in its nascent stage. It is critical for airlines and air hubs to develop a long-term secured supply of SAF by boosting its availability and affordability, as the growth of SAF demand is expected to outpace supply readiness. Based on preliminary estimates, by 2050, the global SAF production capacity would need to ramp up by more than 40 times of current planned 2030 capacity to provide sufficient supply to support net-zero goals for the air transport sector.[36] Therefore, there is a great need and opportunity to establish a SAF ecosystem both in Singapore as well as the region.

Thus, the IAP recommends that CAAS work with stakeholders to develop and implement a roadmap to create a long-term, secured ecosystem for SAF supply in Singapore and the region. This entails building up and strengthening the SAF supply chain and upstream capabilities by putting key enablers in place. There are three key thrusts: to establish a SAF ecosystem in Singapore and the region; validate regional feedstock to align with global standards; and invest in new technological pathways for SAF.

Establish a SAF ecosystem in Singapore and the region

First, Singapore can build upon its existing petrochemical industry to establish a SAF ecosystem in Singapore. Locally, this entails leveraging and repurposing existing petrochemical infrastructure to produce sustainable fuels. In addition, CAAS could work with relevant agencies to explore further supporting mechanisms to expand SAF production. It could also collaborate with regional partners to establish and secure a network of regional feedstock sources and production, as well as facilitate trade and distribution of feedstock and SAF. This could be achieved by spearheading regional cooperation agreements to enable security and free cross-border movement of regional feedstock and SAF.

[36] Boston Consulting Group analysis for the 3rd Meeting of the International Advisory Panel on Sustainable Air Hub.

Validate regional feedstock to align with global standards

Second, as another key thrust of the SAF supply roadmap, the IAP recommends that CAAS work with stakeholders to validate regional feedstocks to align with global standards. At present, some abundant feedstocks in the region are not as widely accepted in certain parts of the world due to the perception of higher environmental risks. For example, palm fatty acid distillate (PFAD) and palm oil mill effluent (POME) are both listed as eligible fuels under the ICAO CORSIA regime. However, these feedstocks have lower acceptability due to potential concerns that they might indirectly result in deforestation and the degradation of rainforest habitats in producer countries. Nonetheless, palm oil residues are one of the feedstocks with the highest potential in the region. This is due to its abundance and relative efficiency compared to other vegetable oils in terms of yield and use of fertiliser per hectare. Moreover, many global producers of these feedstocks have established supply chains that have been proven and certified as sustainable.[37]

Therefore, recognising the importance of transparency and traceability in regional feedstocks, the IAP recommends that CAAS work with stakeholders to convene a technical body to develop a scientific fact base on the sustainability of regional feedstock. This could include conducting life cycle assessments of regional feedstock supply chains. The technical body could also undertake dialogue with international bodies (e.g., the Roundtable on Sustainable Biomaterials (RSB) and the International Sustainability and Carbon Certification (ISCC)) to provide feedback on existing global sustainability criteria to better reflect regional conditions and processes. It could also collaborate with stakeholders in Singapore's carbon services hub to set up a neutral and credible sustainability traceability and certification regime for regional feedstocks.

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[37] This would include: the IOI Group, whereby 100% of its operations in Malaysia are currently RSPO (Roundtable on Sustainable Palm Oil)- and MSPO (Malaysian Sustainable Palm Oil)-certified; PT Hindoli, which is the first palm plantation in Indonesia to be RSPO-certified; and Wilmar International, where 90% of its palm oil and lauric volumes have declared a group-level commitment to no deforestation. IOI Group, "Palm Oil Dashboard & Traceability", https://www.ioigroup.com/Content/S/S_Dashboard; Cargill Indonesia, "PT Hindoli plantation and mills", https://www.cargill.co.id/en/pt-hindoli-plantation-and-mills; and Wilmar International, "No Deforestation, No Peat, No Exploitation Policy", https://www.wilmar-international.com/docs/default-source/default-document-library/sustainability/policies/wilmar-ndpe-policy---2019.pdf?sfvrsn=7870af13_2.

Invest in new technological pathways for SAF

Third, the IAP recommends that CAAS work with stakeholders to invest in new technological pathways for SAF. Currently, the Hydroprocessed Esters and Fatty Acids (HEFA) pathway is the most widely commercialised and viable SAF production option. Other SAF production pathways and technologies are more nascent but might provide higher emissions reductions and become economically viable in the future. For example, Alcohol to Jet (ATJ) and Gasification Fischer-Tropsch (GFT) pathways are possible medium-term options. In contrast, Power to Liquids (PtL) could serve as a long-term option with the lowest environmental footprint. At this early stage, where the SAF production market is still developmental, Singapore should future-proof its capabilities to become an early adopter of new SAF technologies. This could take the form of partnering with leading players or countries in the R&D for SAF and exploring the possibility of scaling up nascent technologies.

The key enablers for this recommendation would include policy and regulations, as well as industry development efforts to support and promote the ramping up of SAF production. There is also a need to build up jobs and skills for both the energy and aviation sectors, including the certification of sustainable feedstocks and SAF pathways. In addition, regional cooperation would also be key when it comes to sourcing and facilitating the transport of feedstocks and SAF.

b. Sustainable Aviation Fuel — Establish a "Singapore / ASEAN Corporate Buyers' Club" to create demand signals

Both demand and supply side enablers are required to support the growth of the emerging SAF market. Production of SAF requires heavy upfront capital investments. Long-term demand certainty is needed to incentivise SAF suppliers to expand SAF production capacity, which is necessary to lower the cost of SAF. There is scope to strengthen the demand signals for SAF in Singapore, to encourage an increase in SAF production. **Therefore, the IAP recommends that CAAS work with stakeholders to establish a buyers' club as an immediate, no-regret move to create stronger demand signals, first in Singapore, before potentially extending it to the broader ASEAN region.**

The buyers' club encourages potential early adopters of sustainable air travel, such as government organisations or large corporates that have higher sustainability ambitions at present, to take collective action. For Singapore, as a global business and logistics hub, there is an opportunity to tap on business travellers and air cargo users and encourage them to become first movers in joining the corporate buyers' club. After government organisations and large corporates in Singapore have come on board as the initial members, the buyers' club can then be expanded to attract small and medium enterprises, and even beyond Singapore to large companies in the Asia-Pacific region.

A corporate buyers' club can create value for both SAF buyers and producers. By aggregating demand, the buyers' club provides demand certainty for SAF suppliers, encouraging them to invest and scale up their SAF production. At the same time, demand aggregation avails high volumes of SAF at competitive prices to the SAF buyers. It enables corporates to reduce their environmental footprint from business travel or cargo transportation.

The key enablers for this recommendation would include the development of SAF production and trading capabilities in the industry. Digital infrastructure is also required to facilitate the aggregation of group purchases and delivery of either physical or virtual SAF. It would also be necessary to have robust frameworks to ensure that high-integrity SAF is purchased through the buyers' club. Additionally, a transparent accounting approach would prevent double counting. Eventually, regional cooperation would also be required to extend the buyers' club outside of Singapore.

c. Sustainable Aviation Fuel — Design and introduce a structural offtake mechanism and create demand signals for secured long-term, lower-cost SAF supply

The IAP's next recommendation to create long-term, predictable SAF demand is to design and introduce a structural SAF offtake mechanism at Changi Airport. It is unlikely that voluntary demand alone can scale SAF use beyond certain levels or provide sufficient and sustained demand certainty to enable capital-intensive investments in SAF production facilities. Thus, such a structural mechanism aims to catalyse a self-sustaining ecosystem and flow of funds for SAF in Singapore to encourage greater adoption of SAF at Changi Airport. In turn, this provides the necessary demand signals for SAF suppliers to ramp up their production to drive down the price of SAF.

As a vibrant air hub, Singapore needs to take a proactive stance in adopting offtake mechanisms to promote the use of SAF. That said, aviation is a global business and policy harmonisation is important to reduce market distortions among airports. While Singapore considers a SAF offtake mechanism for Changi Airport, it should also engage the region to advocate the need for a regional approach towards SAF. In the long run, there is a need to take a regional or even global view in implementing such policies.

Different offtake models are being explored or implemented around the world. Some airlines, such as Air France–KLM, have introduced intrinsic surcharges to ticket prices to fund the extra cost of using SAF. Others like Lufthansa have introduced voluntary carbon offset programmes for customers to pay extra to compensate for their CO_2 emissions. Some countries have introduced or are planning to introduce mandates at the air hub level. For example, Norway has started with a 0.5% advanced biofuels blend in 2020, and is targeting to increase this to 30% in 2030.[38] Sweden[39] and France[40] have also started with mandates of 0.8% GHG reduction for aviation fuels from 2021 and 1% SAF blend from 2022 respectively. The European Parliament has recently adopted its position to propose that the EU adopt a 2% SAF blend mandate by 2025, followed by a 37% mandate by 2040 and 85% mandate by 2050.[41] On the other hand, the United States has implemented financial incentives for SAF on both the demand and supply side.[42]

A non-exhaustive list of the key design options for a SAF offtake mechanism is presented below. Beyond these broad options, there is also a need to define second-order details, such as further breaking down each option (e.g., defining Origin-Destination (OD) versus T&T passengers) and introducing initiatives in a phased and progressive manner.

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[38] Reuters, "Airlines get ready for jet biofuel take-off in Norway", https://www.reuters.com/article/us-norway-airplane-biofuels-idUSKBN1XV1TQ.

[39] Neste, "Sweden becomes a frontrunner in sustainable aviation", https://www.neste.com/releases-and-news/aviation/neste-sweden-becomes-frontrunner-sustainable-aviation.

[40] ExxonMobil, "ExxonMobil and Neste to Supply Sustainable Aviation Fuel in France", https://www.exxonmobil.com/en/aviation/knowledge-library/resources/sustainable-aviation-fuel-france.

[41] European Parliament, "Texts adopted - Sustainable aviation fuels (ReFuelEU Aviation Initiative)", https://www.europarl.europa.eu/doceo/document/TA-9-2022-0297_EN.html.

[42] United States Department of Transportation, Federal Aviation Administration, "U.S. Releases First-Ever Comprehensive Aviation Climate Action Plan to Achieve Net-Zero Emissions by 2050".

1 What are the participation options for driving structural SAF offtake?	Voluntary	Mandatory	Mixed/Hybrid
2 What should be the scope of offtake mechanism?	Airline	Air hub	Select routes
3 Who funds or pays for it?	Passengers/ cargo users	Airline	Mixed/Hybrid e.g transitional support from govt
4 How should mechanism be applied	By carbon emissions	By volume/ distance	By flat surcharge

Source: BCG

Assessing the design of the SAF offtake mechanism would require careful consideration based on each country's unique context. The sustainability benefits must be balanced with the potential economic impact on passengers, airlines and the air hub.

One of the fundamental design features of a SAF offtake mechanism is whether participation is voluntary (e.g., paying extra for green flights and incentives) or mandatory (e.g., SAF blend mandate). An example of a voluntary option is to offer incentives for the use of SAF. However, such incentives are usually transitional to assist companies in tiding over the initial high-cost barriers of adopting SAF. These incentives could be expensive and challenging to sustain in the long run. On the other hand, SAF mandates could provide long-term demand certainty since fuel suppliers would be obligated to purchase a certain amount of SAF for their sales to airlines to meet the targets. The blend ratio could also be adjusted to chart out a progressive adoption of SAF over time. Nonetheless, mandates could distort competition with other airports with less ambitious or even no mandates, resulting in an uneven playing field. That said, these options are not binary, and a combination of these could be utilised to achieve optimal benefits.

There is a need to carefully assess the scope of the offtake mechanism based on the unique context and characteristics of the air hub, its airlines and passengers. An airline-level offtake mechanism could be limited in impact while compromising the airline's competitiveness. A route level mechanism or "green corridor", which could arise from direct government-to-government or airline-to-airline arrangements, would likewise have limited impact due to its reduced scale. Comparatively, an airport-level mechanism has the highest potential for reducing carbon emissions while ensuring a level playing field among all airlines operating at that airport.

Given the high cost of SAF at present, determining the source of funding for the offtake mechanism would be a key consideration. Broadly, three main groups of stakeholders could contribute: passengers (through higher ticket prices or SAF offsets), airlines (in the form of higher operating costs), and the government (through possible incentives or other transitional funding support). All stakeholders would likely have to co-share the cost of adopting SAF, considering the current substantive price difference between SAF and fossil jet fuel. There is also the possibility of differentiating between passenger groups. For Changi Airport, its competitiveness is closely linked to its status as a transfer hub. Therefore, imposing a lower share of cost on transfer passengers could help to moderate the impact on competitiveness.

Lastly, the metrics used to determine the offtake mechanism could also differ. This could include measuring by the amount of carbon emissions (i.e., direct carbon pricing) or by volume. Using carbon emissions could be more direct and incentivise higher reductions but it is more challenging to implement and verify. A volume-based mechanism would be more straightforward to implement as it is measurable and easily understood by the public and stakeholders.

A preliminary analysis of the implications of different combinations of offtake options for Singapore is presented below. This is by no means exhaustive and serves to present a possible matrix for assessing the different options.

		Airline		Air hub		Select routes
		Intrinsic pricing (Embedded SAF premium)	**Voluntary option** (Pay extra for green flights)	**Mandatory** (For all airlines)	**Voluntary** (Usually linked to incentives)	**Mandatory**
Competitiveness	Impact on airline	Could impact price competitiveness, esp for short haul, price sensitive segments	No impact on profitability of airlines	Similar impact across all airlines flying into hub	Similar options/benefits for all airlines	Similar impact on the same route
	Impact on air hub	Could impact the hub carrier	No impact to air hub	Impact can be moderated if T&T[1] passengers are excluded	Enhance attractiveness as SAF air hub	Limited impact on direct flights
	Impact on SG as destination	Limited impact, as other airline options	No impact to Singapore's tourism	SG is already a higher cost destination. Higher cost could have neutral or limited negative impact	Minimal impact to Singapore's tourism	Limited impact on direct flights
Sust. Impact	Impact on sustainability outcomes	SAF uptake linked to airline commitments	Depends on uptake rate from customers	Higher SAF uptake, lower emissions	Depends on uptake rate from airlines	SAF uptake only on selected routes
	Effectiveness *In ensuring level playing field and driving impact*	**Low:** Intrinsic pricing might impact airline competitiveness, and limited impact on outcomes from voluntary options		**High:** Mandatory interventions at air hub level can potentially level playing field — can also be further supported with voluntary measures		**Moderate:** Impacts only selected routes, requires bilateral effort

Legend: Relatively Good/High · Relatively Moderate · Relatively Poor

1. Transfer & Transit

Source: BCG

The IAP recommends that CAAS work with stakeholders to design and introduce a SAF offtake mechanism, considering all the above factors and incorporating feedback from affected stakeholders. This would build on the existing efforts by Singapore in promoting SAF adoption, such as the SAF pilot at Changi Airport and the corresponding selling of SAF credits.

The key enablers for this recommendation would include the development of policy and regulations for the SAF offtake mechanism, as well as the involvement of the entire industry (e.g., governments, SAF producers, airport stakeholders, corporates and individual travellers), which is crucial for the mechanism to work. Regional cooperation would also be key in promoting common approaches at the regional and global levels.

d. Carbon offsetting — Innovate to build deep aviation industry vertical offerings in carbon markets, develop a support ecosystem for aviation carbon offsets solutions and encourage uptake among corporates and consumers

Beyond in-sector measures, the ATAG Waypoint 2050 report projected that carbon offsets are necessary for the aviation sector to achieve net-zero emissions by 2050. As the carbon offset market is still nascent, there is scope to build up such a market for aviation carbon offsets in Singapore to support the decarbonisation of the aviation sector. There are opportunities for innovation to address the availability, quality and pricing of offsets. Moreover, the demand for offsets in the aviation industry is expected to increase over the coming years, fuelled by CORSIA and other regulatory requirements. Several challenges exist in the carbon offset market, such as inconsistent standards and criteria for defining carbon offset quality across registries, a lack of transparency in the pricing of carbon offsets, and a limited supply of high-quality carbon offset projects. At the same time, the uptake of voluntary carbon offset by corporates and individual passengers for air travel can also be improved.

Therefore, the IAP recommends that CAAS work with key players in Singapore's emerging global carbon services hub to build up the market for aviation carbon offsets and encourage uptake among corporates and air transport users. First, they could innovate on the products and platforms for aviation carbon offsets to address issues relating to availability, liquidity and transparency and create a broad portfolio of aviation-specific products (e.g., CORSIA-eligible offsets or progressive offsets with varying SAF components). Such opportunities may require work to ensure the reportability of emissions reductions for corporate buyers are in line with recognised reporting frameworks (e.g., SBTi). Second, CAAS could work with stakeholders to develop an enabling ecosystem of carbon support services to improve the reliability, traceability and accountability of aviation industry offsets. This can be done by using advanced accounting and registry tools and technologies and bringing onboard more Measurement, Reporting and Verification (MRV) players.

Third, the IAP further recommends exploring the possibility of raising voluntary demand for carbon offsets amongst corporates, individual passengers and cargo users. This could be done through developing an alliance model for group purchase of aviation carbon offsets by corporates (which could tie in with the earlier recommendation on a SAF corporate buyers' club). At the same time, there could be efforts to raise public awareness to educate consumers about buying offsets when they travel and improve willingness to pay among individual travellers by highlighting the value of such initiatives.

Collaborations are already ongoing between aviation industry stakeholders and players in Singapore's carbon services, and such synergies can continue to deepen through the recommended initiatives. One example is the collaboration between CIX and aviation stakeholders to launch the sale of SAF credits as part of the SAF Pilot at Changi Airport. The key enablers to support this recommendation would include the overall development of industries for aviation sustainability solutions and carbon trading services in Singapore. In addition, software or digital infrastructure, as well as related jobs and skills, might be required to construct the supporting ecosystem for aviation carbon offset trading.

e. New and emerging aircraft technology — Explore a potential technical centre for capability-building to ensure that Singapore can be an early adopter of aircraft technology

The advancement of aircraft technologies will be an important pathway in supporting the global air transport sector in meeting its net-zero by 2050 ambition. Singapore would need to remain at the forefront of advancements in aviation technology to reap their full benefits. To do so, Singapore should work closely with like-minded aviation partners to strengthen its technical capabilities and position itself for the future. **Therefore, the IAP recommends that CAAS work with stakeholders to explore the opportunity of setting up a technical centre in Singapore.**

The proposed technical centre for sustainable aviation will play a central role in pushing the boundaries of aviation sustainability technology research with research institutes and delivering solutions with aviation partners. A key focus is to develop technical capabilities to support new aircraft technologies by aircraft OEMs and ensure that Singapore can be an early adopter. The centre would also catalyse and boost Singapore's sustainability commitment and promote strong public-private sector collaboration, strengthening the growth and competitiveness in this area. Singapore can continue to strengthen its innovation ecosystem to attract companies to anchor their innovation and R&D activities here amidst the rapid advancement of aviation technologies.

In particular, the technical centre could look into developing capabilities in possible design changes to improve efficiency and new emerging disruptive propulsion technologies (e.g., hydrogen technology and hybrid electrical system). This initiative complements existing efforts to explore the potential use of hydrogen at Changi Airport.

Several key considerations would need to be addressed to establish a technical centre for sustainable aviation in Singapore, including its governance and operationalisation plans, types of R&D projects and strategic partnerships. The key enablers for this recommendation would include the overall development of the industry for aviation technologies in Singapore, as well as supporting technology and R&D jobs and skills. The technical centre will then further promote the uptake of new R&D jobs and strengthen the talent and resource pool in Singapore.

4.3 Air Traffic Management

Context

ATM operations include planning activities that happen even before loading passengers and cargo and managing the aircraft throughout all phases of the flight, from take-off to landing. Improvements in ATM and operational procedures can help reduce unnecessary emissions and improve environmental performance.

Efforts to optimise ATM for improved environmental performance should be closely aligned with plans and guidance from ICAO. ICAO has developed the Global Air Navigation Plan (GANP)[43] 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. An analysis by ICAO found that implementing some fundamental initiatives[44] by 2025 would yield global fuel and CO_2 savings of between 1.6 – 3.0%.[45] To enhance regional collaboration in ATM, ICAO has also developed regional plans, including the Asia-Pacific Seamless ANS Plan, which takes guidance from the GANP.

New ATM technologies and improved operations and procedures present a vast potential for increasing capacity, improving efficiency and enhancing environmental performance. Other factors, in particular, aviation safety, system-wide efficiency, suitability for local airports and airspace, and close collaboration and cooperation with aviation stakeholders, including ANSPs and airlines, are also important to ensure the success of the initiatives.

Accordingly, the IAP has identified the following four short- and medium-term recommendations to optimise ATM for improved environmental performance:

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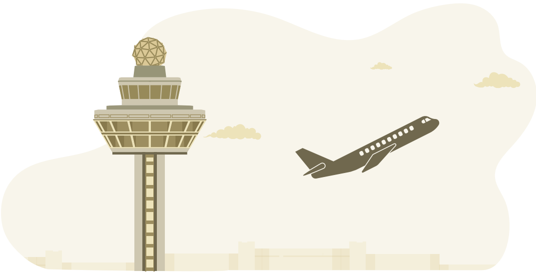
[43] The GANP serves as a worldwide reference to transform air navigation systems and is a worldwide collaborative effort by all stakeholders (industry, international organisations, R&D organisations, manufacturers). The GANP consists of four levels: (i) the global strategic level, which provides high-level strategic directions; (ii) the global technical level, which includes the ASBUs; (iii) the regional level to address regional and sub-regional needs aligned with the global objectives; and (iv) the national level developed by States and aligned with regional and global plans.

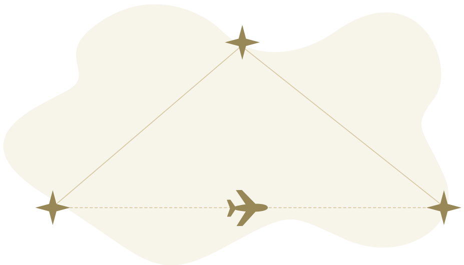
[44] This refers to the implementation of ASBU Block 0 and 1 modules.

[45] ICAO, *2019 Environmental Report*.

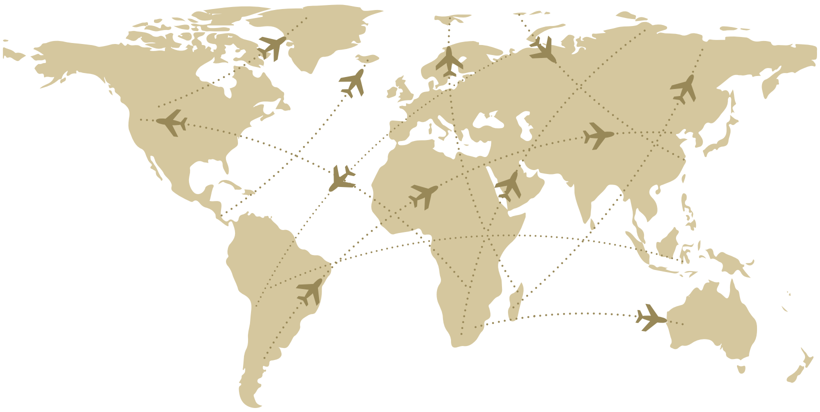
Short-term recommendations (2022 – 2026)



a. **Implement advanced demand-capacity balancing;**

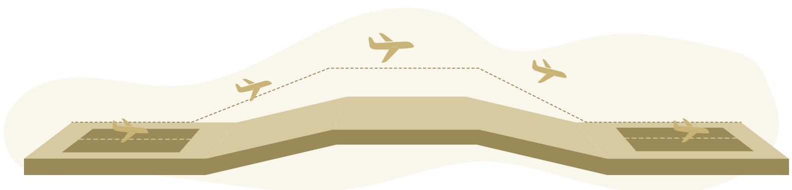


b. **Enhance performance-based navigation;**



c. **Optimise gate-to-gate trajectory; and**

Medium-term recommendations (2027 – 2032)



d. **Implement trajectory-based operations and free route airspace in collaboration with stakeholders and partner ANSPs.**

Short-term recommendations

a. Implement advanced demand-capacity balancing

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

CAAS and partner ANSPs within the Asia-Pacific region[46] have implemented a Distributed Multi-Nodal ATFM network, termed as the Asia-Pacific Cross-border Multi-Nodal ATFM Collaboration (AMNAC). This enables 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 (GDPs) regulate the departure timings of flights in anticipation of a period of projected demand-capacity imbalance during their arrival phase at the destination airport. The affected flights depart as guided by calculated take-off times issued by ATFM units within the AMNAC network to avoid the anticipated congestion while in the air. The AMNAC has been effective in optimising traffic flows, increasing predictability of flights, and reducing holding in the air and hence, unnecessary fuel burn and carbon emissions.

As the existing ATFM measures only apply to flights within the AMNAC network, the IAP recommends that CAAS work with stakeholders to expand the suite of ATFM solutions and implement LR-ATFM, so that longer haul flights can also reap these benefits. With the introduction of LR-ATFM, longer-haul flights can be sped up or slowed down while en route to the destination to mitigate arrival demands that the destination cannot accommodate. As a result, arrival delays arising from unnecessary holding and vectoring can be avoided, and unnecessary fuel burn will be minimised.

The key enablers for this recommendation include collaboration with multiple stakeholders and the development of the concept of operations and software infrastructure to support the implementation of LR-ATFM. The IAP notes that CAAS has started collaborating with Airways New Zealand and NATS UK to develop the concept of operations for LR-ATFM in the Asia-Pacific region. LR-ATFM trials have also been conducted with SIA. To further this initiative, the IAP recommends that CAAS continue developing the operational requirements for integrating the LR-ATFM concept into the existing ATFM system and engaging stakeholders and partner ANSPs to refine the LR-ATFM concept of operations, with the implementation of LR-ATFM operations planned for 2026.

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

Strengthen integration between Meteorology (MET) and ATM

Weather can significantly affect air traffic operations and adversely impact efficiency and capacity. For example, rain may impede visibility at or around an airport, resulting in pilots opting to hold in the air due to poor landing conditions. Increased spacing between arrivals may be required due to higher runway occupancy time in the event of wet runways and weather cells around the final approach path. These result in increased delays and additional fuel burn and emissions.

The convective nature of weather in the region accounts for most weather events at Changi Airport that affect operations. Disruptive weather conditions, such as thunderstorms with possible wind shears, occur abruptly, in short periods of not more than an hour, and are difficult to predict. As such, accurate and timely MET information is important to support ATM operations. The IAP notes that CAAS has been working with stakeholders on improving MET information for ATM decision-making.

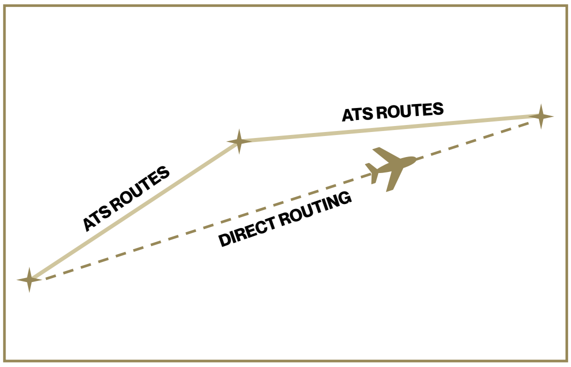
The IAP recommends that CAAS build on these relationships with stakeholders and partners to conduct translational studies of the impact of weather on ATM operations to enhance ATM decision-making and operations. This should include translating MET information into constraints and impact on capacity, determining the decision threshold for implementing ATFM solutions to achieve the optimal mitigating effect, and identifying other suitable ATFM solutions based on MET information. The intended outcome should be to improve the reliability, timeliness and accuracy of weather information provided to pilots and ATC, to support better decision-making for ATFM, thereby optimising traffic flows and reducing unnecessary fuel burn and emissions.

The IAP expects CAAS to finalise the scope of the weather impact translation studies by 2022, which sets the stage for R&D efforts in 2023. In addition to collaboration with stakeholders, the key enablers for this recommendation include the subsequent phased development of predictive and decision support tools to improve the reliability and timeliness of weather forecasts for ATM operations between 2024 to 2026.

b. Enhance performance-based navigation

Implement Free Route Airspace (FRA) – Direct Route Operations (DRO)

Free Route Operations (FRTO) is one of the ASBU threads in the GANP that will bring about optimised capacity and flexible flights. It enables the most direct route between two points and provides flexibility for airlines to plan for the most optimal route in terms of flight and fuel efficiency.



CAAS has already conducted operational trials with SIA flights for DRO, a building block of FRTO. The trials facilitated direct point-to-point routings for specific route segments to improve flight efficiency and reduce fuel burn.

Given the positive outcomes from the trials, the IAP recommends that CAAS proceed to formalise the implementation of DRO for arrivals at Changi Airport on specific route segments by 2023. In line with this, the IAP also recommends that CAAS explore collaboration with partner ANSPs in the region to implement DRO on a wider scale.

Develop smart tools to facilitate Continuous Descent Operations (CDO)

CAAS has been facilitating CDO for Changi arrivals when traffic permits so that aircraft can descend continuously with minimum engine thrust, reducing fuel burn and emissions. Nonetheless, the existing ATC operations for the conduct of CDO pose several challenges which limit its effectiveness. These include the lack of awareness of the optimal top of descent (TOD) for all aircraft, high traffic density and a complex operational environment.

Therefore, the IAP recommends that solutions to support ATC in conducting CDO, such as pre-identifying suitable aircraft for CDO and raising ATC's awareness of CDO opportunities and optimal TOD profile for the aircraft, could be developed to increase the confidence for ATC to issue and successfully carry out CDO. This will then contribute to better optimisation of flight profiles and reduction in fuel burn and emissions.

The key enabler for this recommendation is collaboration with stakeholders to develop tools to support ATC in conducting CDO. The IAP expects a smart advisory tool to facilitate CDO to be ready for operational trials by 2022 and operationalisation within Changi Airport by 2023. Beyond this, the IAP recommends that CAAS continue to explore the development of other smart tools to support the optimisation of ATM operations (e.g., through Continuous Climb Operations).

c. Optimise gate-to-gate trajectory

Implement enablers for Trajectory-Based Operations (TBO)

TBO represents a fundamental shift in ATM. Instead of relying heavily on tactical ATC, flight trajectories can be planned ahead and executed more precisely to improve the management of traffic flows. TBO presents significant benefits for sustainability in ATM given the enhanced predictability of flight trajectory, which balances capacity with demand. This will optimise flight efficiency, minimise delays and therefore, reduce fuel burn and emissions.

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

The IAP recommends that CAAS work with stakeholders to adopt a phased implementation of the key building blocks for TBO in collaboration with partner ANSPs in Asia-Pacific. For FF-ICE, the IAP recommends focusing on pre-departure negotiation for flight trajectory optimisation, starting with the implementation of filing and flight data request services by 2026. Beyond 2026, the IAP recommends that CAAS 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, the IAP notes that CAAS has identified multi-nodal ATFM as the first use case for operational trial on SWIM in the second half of 2022.

The key enablers for this requirement include collaboration with stakeholders and necessary software and hardware infrastructure for the implementation of key TBO building blocks, such as FF-ICE and SWIM.

Optimise runway efficiency

Runway throughput is determined by several factors, including the required minimum wake turbulence separation between aircraft. ICAO's wake turbulence separation rules are based on aircraft weight. There were previously only four weight categories which led to wider separation between aircraft. The re-categorisation (RECAT) of aircraft weight to seven weight categories at ICAO has enabled a reduction in separation between aircraft, thus improving the overall arrival or departure throughput efficiency, increasing runway capacity, and reducing delays and fuel burn.

CAAS has implemented arrival RECAT within Changi Airport since 2022 to reduce separation between arrival flights. This is facilitated by an Approach Spacing Tool, a decision support tool providing guidance to controllers.

To further optimise runway efficiency and increase fuel savings, the IAP recommends that CAAS extend the same initiative to departures. The key enabler for this recommendation is a software tool to support RECAT for departures. CAAS should complete the scoping for a Departure RECAT tool for departures by 2023, complete software testing and integration by 2025, and operationalise the Departure RECAT tool by 2026.

Estimated fuel reduction for short-term recommendations

The IAP notes that based on CAAS' assessment, the overall fuel emissions for 2030 will rise well above the 30% projected growth rate should operations remain business as usual, due to excessive track miles taken to accommodate the greater traffic.[47]

Therefore, the IAP recommends that CAAS implement these short-term recommendations to reduce the average track miles and allow aircraft to operate closer to their optimal altitudes. These recommendations are estimated to bring about a 10% reduction in additional fuel burn and emissions, with the potential for further reduction if airlines adopt SAF and enhanced aircraft technologies.

[47] Using 2019 traffic data as baseline figures, with considerations for traffic growth projection of 30% in 2030.

Medium-term recommendations

d. Implement TBO and FRA in collaboration with stakeholders and partner ANSPs

In the medium term, the IAP recommends that CAAS further develop the key building blocks for TBO and FRA in collaboration with stakeholders and partner ANSPs, such as through demonstrations to refine these advanced concepts of operations.

For TBO, the IAP notes that CAAS has collaborated with Canada, Japan, Thailand, and the US in a multi-regional TBO lab demonstration trial in 2022, led by the US FAA. The lab demonstration trial involved various scenarios of flights on TBO, negotiation of flight trajectory based on predicted traffic information through flight and flow information exchange and identified operational values and technical capabilities required. The lessons learnt from the trial have been shared with ICAO.

For FRA, the IAP recommends that CAAS continue collaborating with partner ANSPs to further assess, simulate and explore the implementation of FRA across contiguous volumes of airspace. This will allow for greater flexibility to operate on optimal routings and efficient flight profiles, thus reducing track miles and fuel burn.

4.4 Key Enablers

The IAP believes that the above 15 initiatives, taken together, are transformative and will allow Singapore to distinguish itself as a sustainable air hub. Their effective implementation will require strong government action and close collaboration with the industry. As such, certain key enablers are necessary for providing the right conditions for effectively implementing the airport, airline and ATM initiatives.

Therefore, the IAP recommends that CAAS, together with the rest of the Singapore aviation sector and other stakeholders, develop and include four critical enablers in its Sustainable Air Hub Blueprint — policy and regulation, industry development, infrastructure planning and provision, and workforce transformation. In addition to the specific enablers stated under each initiative above, the IAP would like to add the following perspectives:

Policy and Regulation

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

Overall international and national policies and regulations on sustainability and aviation sustainability play an important role in framing the overall ambition. With the broad goal and direction set, it would trickle down to all stakeholders in the aviation sector and help to align and guide everyone's efforts. This should include the development of a taxonomy that can align and guide all parties' understanding of what would be considered sustainable aviation. A consistent taxonomy would need to be applied within the aviation sector and beyond, given that such taxonomies are typically used to assess green financing.

Industry Development

Given the wide scope and extent of aviation sustainability, standalone efforts by individuals are unlikely to succeed on their own. Singapore needs sector-wide efforts and collaboration amongst multiple stakeholders to achieve the intended sustainability goals and objectives. In certain cases, this might require reconfiguration of existing ecosystems or construction of entirely new ecosystems. The formation of strong private and public-private partnerships is also required. Moreover, since many aviation decarbonisation pathways involve stakeholders from other industries (e.g., energy, petrochemical, technology and research) upstream and downstream, cross-sectoral partnerships are also crucial. Therefore, industry development to foster collaboration, cooperation, and capability-building amongst stakeholders is a key enabler to facilitate the implementation of the recommendations.

Infrastructure Planning and Provision

Aviation sustainability initiatives can vary in their level of infrastructure requirements. While some might require heavy upfront infrastructure investments, others might only have minimal infrastructure needs. Correspondingly, the extent and readiness of infrastructure required would play a role in determining the timelines for initiatives. To implement the initiatives successfully, proper planning and provisions for supporting infrastructure are necessary.

Workforce Transformation

As the aviation sector transits towards being more sustainable, sustainability should be integrated into all job functions and roles across the Singapore aviation sector, not unlike how aviation safety considerations permeate the sector currently. Accordingly, efforts by all aviation stakeholders are required to raise awareness in their organisations and redesign job roles and training programmes. Sustainability should also be a core part of training for all workers. Greater consciousness amongst the aviation workforce regarding the environmental impact of their daily work would serve as a powerful catapult for greater action on sustainability.

At the same time, this transition would create new jobs with a deeper focus on aviation sustainability. Correspondingly, it is critical to develop a workforce with the necessary skills to support the implementation of initiatives in this field.

To achieve this, there needs to be a careful look at the entire pipeline of workforce development. Starting with education, Singapore could begin by instilling the importance and value of sustainability, including in aviation, among young students. At higher education levels, the sector could work with institutes of higher learning to design and offer aviation sustainability modules for various courses. These would be able to equip students with the necessary knowledge and skills to enter aviation sustainability jobs in the future. Companies with sustainability roles could also design internships to introduce students to this area of work early on. As for existing aviation workers, there could also be opportunities and programmes offered for them to reskill towards taking on sustainability-related jobs. Overall, Singapore should aim to build an aviation workforce that imbues sustainability as part of everyday work.

5

Conclusions and the Way Forward

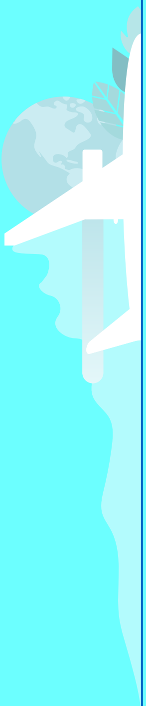
Decarbonisation will remain a key priority for the Singapore air hub for the years to come. As a vibrant air hub, Singapore must take on ambitious yet pragmatic and measured goals to demonstrate the twin goals of a sustainable and growing air hub. The Singapore air hub is well-positioned to harness the opportunities and overcome the challenges in the transition towards sustainable aviation.

The recommendations of the IAP in this report outline the key pathways that the Singapore air hub can take to decarbonise its airport, airline and ATM operations. Standalone initiatives on their own would not be sufficient — a combination of these would be required to help the Singapore air hub achieve its intended decarbonisation goals. These initiatives must be built upon key enablers of policy and regulation, industry development, infrastructure planning and provision, as well as workforce transformation. This would be no easy feat. The transition towards becoming a sustainable air hub would require reshaping existing ecosystems or creating new ones. For this reason, the collective efforts of all relevant government agencies, industry stakeholders, technology experts and knowledge partners would be critical in this process.

The IAP's recommendations should guide CAAS in developing the Singapore Sustainable Air Hub Blueprint. The Blueprint, targeted for release in 2023, must set a roadmap with medium-term and long-term targets and identify tangible pathways for achieving them. This initiative will help provide thought leadership and further catalyse investments, actions and collaborations with private sector companies and other countries.

The IAP further hopes that this report can provide a useful reference for aviation partners in advancing their sustainability and decarbonisation efforts.

The IAP looks forward to the implementation of its recommendations by CAAS, together with the support and active participation of all stakeholders and partners, to bring the Singapore air hub and international aviation to greater heights.



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Contributors to the IAP Deep Dives

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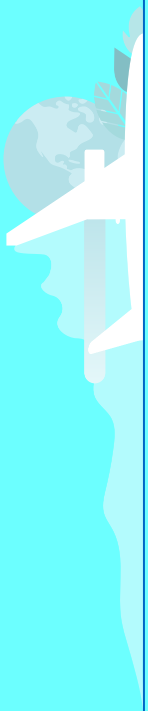

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