ICAO

ENVIRONMENT

Air Quality Management at Airports

ECO AIRPORT TOOLKIT

AIR QUALITY MANAGEMENT AT AIRPORTS

Contents

FOREWORD

Aviation stakeholders have been working to reduce their impact on the environment for decades to reduce the environmental impact of aviation operations, including carefully managing their emissions to minimize the effect of their activities on both local air quality conditions and climate change.

Airport infrastructure is the local interface between aviation and non-aviation stakeholders' activities and the communities they serve. Therefore, air quality is one of the most important environmental issues for airport operators. The activities of various stakeholders at and around airports generate many different types of emissions that affect air quality. However, there are actions that airports and aircraft operators, air navigation service providers and other aviation stakeholders can take to avoid, minimize, and otherwise manage emissions and other negative effects on air quality.

Air pollution can negatively impact human health, and for that reason states often have regulations on air quality that airports must adhere to. There are several resources available to support understanding and assessing airport air quality issues. ICAO's *Airport Planning Manual* Part 2 (Doc 9184) describes the emissions to be expected at an airport and basic elements of relevant air quality management. The *Airport Air Quality Guidance Manual* (Doc 9889) provides detailed guidance on assessing airport air quality. The document provides information on types of emissions and their sources at an airport, methods for measuring ambient pollutant concentration and modelling emission dispersion, and it offers some methods for mitigating emissions. The ICAO document *Operational Opportunities to Reduce Fuel Burn and Emissions* (Doc 10013) provides operational procedures that aircraft operators and air navigation service providers (ANSPs) may be able to implement to reduce aircraft emissions. This paper draws on these resources to provide a brief compilation of good practices related to airport air quality management.

Aircraft engines are the largest source of emissions at the airport and are subject to international standards. However, this paper will not discuss aircraft emissions in detail, instead focusing on how airport operators can work with their stakeholders to help them reduce emissions. Emissions of carbon dioxide and other greenhouse gases (GHG's) affecting climate have interdependencies with air quality and will be briefly mentioned[1]. However, this publication will focus only on local air quality.

[1] Airports can use the Airport Carbon and Emissions Reporting Tool (ACERT) to calculate GHG emissions at and around the airport. ACERT generates a comprehensive airport GHG emissions inventory report, highlighting its performance based on emission intensity. It can be downloaded for free at: https://aci.aero/about-aci/priorities/environment/acert/

Air Pollution

ICAO's Airport Planning Manual recognizes that air pollution is a problem in many countries, especially in urban areas.[2] The following list shows the main components of airport air pollutants (but is not exhaustive).

- Carbon monoxide (CO)
- Oxides of nitrogen (NO_x)Volatile organic compounds (VOC)
- Hydrocarbons (HC)
- Non- volatile particulate matter (nvPM), including ultrafine particulates
- Sulphur oxides (SOx)
- Ozone (O3)
- Lead (Pb)
- Hazardous air pollutants (HAPs)

The largest source of these pollutants are aircraft engine emissions. At the airport, however, emissions from fuel combustion can also come from motor vehicles used on the airport and ground transport surrounding the airport. The main gaseous exhaust emissions from jet and diesel engines are hydrocarbons (HC), oxides of nitrogen (NOx), and carbon monoxide (CO).[3] NOx refers collectively to three pollutants, nitric oxide (NO), nitrogen dioxide (NO2), and the nitrate radical (NO3).[4] Jet and diesel engines also produce fine particulate matter. ICAO developed non-volatile Particulate Matter[5] (nvPM) mass and number standards for aircraft engines and the new standards

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[2] See APM Part 2, Section 2.3.3.

[3] Introduction to Local Air Quality (LAQ), by ICAO Secretariat. In *ICAO Environmental Report 2019*, chapter 3, pp. 97-99. Available at: https://www.icao.int/environmental-protection/Documents/EnvironmentalReports/2019/ENVReport2019_pg97-99.pdf

[4] Aviation Emissions and Air Quality Handbook, Version 3, Update 1. US Federal Aviation Administration, January 2015. Available at: https://www.faa.gov/regulations_policies/policy_guidance/envir_policy/airquality_handbook/

[5] During the combustion of hydrocarbon-based fuels, aircraft engines generate gaseous and particulate matter (PM) emissions. At the engine exhaust, particulate emissions consist mainly of ultrafine soot or black carbon emissions. These particles [are] referred

are now approved. This completes ICAO's main environmental Standards for the certification of aircraft and engines, including NOx, HC, CO, and nvPM, leading to improvements in airport air quality from aviation in the coming years. Aircraft all emit CO2, which is of global concern because of its impacts on climate change. In addition to aircraft engines, airside airport emissions impacting air quality also come from ground support vehicles. In some instances, airports may use fossil-fuel powered engines to support lighting, heating and cooling terminals. Tire and break wear can also be a small contributor to particulate emissions on airport, as can fuel handling and storage, airport construction, and other sources.[6]

Ambient Air Quality Regulation

Most states regulate local air quality. A busy airport has many activities from different stakeholders, from flight operations to electrical generation and the handling of fuels, all of which can negatively affect air quality. Airports must be aware of local regulations and operate accordingly. Thresholds for various air pollutants are designed to maintain safe air for the community. Often permits are required from local agencies to conduct certain operations and to store and handle certain products. When new construction is planned, there is often a step in the planning process that calls for modeling air quality impacts of the proposed new infrastructure to determine if safe and legal air quality limits would be exceeded. In some States, there may be different regulations for mobile and stationary sources of emissions.

In some jurisdictions emissions and air quality are regulated by type of emissions. Types may include hazardous air pollutants (HAPs) which are generally gases known to have negative impacts to human health. Other emissions include volatile organic compounds (VOCs). VOCs are the gases that are emitted from human-made chemicals that are used at the airport, including paints, refrigerants, industrial solvents, and fuels. Greenhouse gases (GHGs) are those that exacerbate

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to as "non-volatile" PM (nvPM). ICAO Environment Report 2019, p. 98. https://www.icao.int/environmental-protection/Documents/EnvironmentalReports/2019/ENVReport2019_pg97-99.pdf

[6] See APM section 2.3

global warming, such as carbon dioxide and methane. At the airport, GHGs come primarily from the exhaust of burned fuels.

Reduction Measures by Emissions Sources

Aircraft emissions

Aircraft emissions have some unique considerations. Aircraft are the largest source of emissions at an airport. However, they are not owned or controlled by the airport operator. Aircraft engines must comply with international standards for emissions set by ICAO as noted above. The manufacturers are continuously looking for ways to make engines more efficient, thereby reducing fuel burn and the associated emissions from combustion. These technological advancements have made great progress in reducing emissions from aircraft engines. For example, from 1978 to 2019, U.S. airlines increased fuel efficiency (as measured by RTMs per gallon) by 137%, which has cumulatively saved the U.S. industry more than 5 billion metric tons of CO2.

Airports can use simple look-up tables in ICAO Doc 9889 for estimating the emissions from each aircraft LTO cycle based on aircraft type, or more sophisticated calculations methods also provided in ICAO Doc 9889. Zurich Airport has developed the *Aircraft Local Emissions Calculator for Airports (ALECA)*[7], a standalone emission calculation tool for all aircraft related emission sources at an airport, covering the substances NOx, HC, CO, PM (mass) and nvPM (number), SOx and CO2. While outside of the airport's direct control, there are ways that airport operators can encourage air carriers to reduce aircraft emissions by promoting the operation of more efficient aircraft at the airport. For instance, several European airports modulate landing charges to incentivize the use of lower-emission aircraft. These charges focus on local air quality and not

[7] https://www.zurich-airport.com/the-company/noise-policy-and-the-environment/air-quality/

CO_2, and are in line with ICAO document 9884, the *Guidance on Aircraft Emissions Charges Related to Local Air Quality*.[8]

In addition, airport operators can promote efficient airfield operations which reduce the need for ground idling and delays. The design of taxiways and ramps can facilitate smooth transfer of aircraft from runway to terminals.

Aircraft parked at the gate generally need power for instruments and fresh air circulating in the cabin. Installing gate electrification and ground power plugs at the gate, including for overnight parking, allows an aircraft to reduce the use of the aircraft's Auxiliary Power Unit (APU), which decreases fuel burn and emissions.

Aircraft Ground Energy Systems (AGES) can provide both pre-flight electricity (400Hz) and pre-conditioned air (PCA) for aircraft on the ground. Airports can use the ACI AGES-Simulator[9] to evaluate both environmental and economic benefits of substituting the use of the APU by AGES. The tool, available at no cost to airports, calculates the reduction of fuel consumption, providing a snapshot of fuel savings and associated NOx, PM and CO2 emissions reductions, along with expected financial savings for aircraft and airport operators, based on a selected scenario. AGES-S uses the advanced approach of APU emissions calculation methodology in the International Civil Aviation Organization (ICAO)'s Doc 9889 Airport Air Quality Manual, based on aircraft type, turnaround cycle and capacity, PCA needs, and others.[10]

Single Engine Taxiing (SET) is another measure to reduce aircraft engine emissions during surface operations. SET implies a single engine is off during taxiing on a twin-engine aircraft, or one to two engines are off on a four-engine aircraft. Studies suggest potential reductions between 25% -

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[8] Environmental Charges. In the *European Aviation Environmental Report*. EASA, 2021. Available at: https://www.easa.europa.eu/eaer/topics/airports/environmental-charges

[9] https://aci.aero/about-aci/priorities/environment/ages-s/

[10] Aircraft Ground Energy System - Simulator (AGES-S) v.1. ACI World. Available at: https://aci.aero/about-aci/priorities/environment/ages-s/#:~:text=AGES%2DS%20provides%20a%20snapshot,electricity%20and%20PCA%20from%20APU

40% of taxi-out fuel burn.[11] However, SET is not always possible and can be dependent on taxiway and runway configurations, taxi times, weather and maneuverability conditions, airline procedures, pilot decision, and other factors.

Airports can also adopt sustainable taxiing, made possible with all-electric aircraft pushback tug or hybrid-electric tractor attached to the front of the aircraft and controlled by the pilot.[12]

Ground Support Equipment (GSE)

The activities and equipment associated with the handling of aircraft during turnaround or maintenance operations are an important source to consider when looking at airport-related emissions. The term "ground support equipment" refers to the broad category of vehicles and equipment that service aircraft, including those used for towing, maintenance, loading and unloading of passengers and cargo, providing electric power, fuel, and other services to the aircraft. Equipment in this category commonly includes aircraft tractors or tugs, ground power units (GPUs), air conditioning or heating units, baggage tugs, belt loaders, fuel tanker trucks, and de-icing trucks, among many others. Airside vehicles including cars, vans, utilities, and buses also impact local air quality at and around the airport.

Emissions can differ greatly between different GSE. The different types of equipment, as well as the locations in which they operate, will have different emission profiles. Some GSE may operate mainly at the aircraft stand, while other will operate at both the aircraft stand and on service roads. There will also be differences based on the type and location of the stand as well as the type of aircraft that they service. [Doc 9889 *Airport Air Quality Manual*, App 2 to Ch 3 & Doc 10013 *Operational Opportunities to Reduce Fuel Burn and Emissions*, Section 2.5]

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[11] Deonandan, I., and Balakrishnan, H., 2010, "Evaluation of Strategies for Reducing Taxi-out Emissions at Airports," 9th AIAA Aviation Technology, Intergation and Operations (ATIO) conference, pp. 1–14.

[12] Case Study – Sustainable Taxiing, by Aviation Benefits Without Borders, ATAG. Available at: https://aviationbenefits.org/case-studies/sustainable-taxiing/

Environmental impacts should be considered when selecting new vehicles for use at the airport, but there are also steps that can be taken to improve the emission profile of existing GSE, such as various modifications to the engines or to the types of fuel used. Some options are for gasoline or diesel engines to be retrofitted with oxidation catalysts, or for diesel engines to be fitted with particulate traps (though this option may require an ultra-low sulphur fuel). Replacing older engines with new fuel-injected gasoline engines or with diesel engines with a computer-controlled fuel delivery system may also be options. Switching to alternative fuels such as compressed natural gas/liquefied petroleum gas (CNG/LPG), may be an option to consider, although it will often require costly engine or infrastructure improvements [Doc 10013 *Operational Opportunities to Reduce Fuel Burn and Emissions*, Section 2.5]. Electrification or partial electrification (hybrid) of GSE is becoming a common option for addressing emissions related to airport operations. This option can also require substantial investment in infrastructure upgrades but has the potential to achieve significant reductions in air emissions (though ultimate environment benefit will depend on the process through which the electric power is generated.) [Doc 9184 *Airport Planning Manual Part 2*, sections 2.3 and 3.6 & Doc 10013 *Operational Opportunities to Reduce Fuel Burn and Emissions*, Section 2.5]. The availability of renewable energy at the grid to power electric GSE will significantly increase the emission reductions potential.

Beyond modifications to engines or use of alternative fuel types, it is important to keep up with maintenance and perform routine emissions tests to ensure that all equipment is running as efficiently as possible. Reducing the driving distances of ground support vehicles through improved route planning and avoiding unnecessary idling of equipment can also play a role in emissions reductions, as can specific driving behaviors, such as accelerating smoothly or driving at optimum speeds. The emissions savings provided by these measures will depend on the individual situations [Doc 9184 *Airport Planning Manual Part 2*, sections 2.3 and 3.6 & Doc 10013 *Operational Opportunities to Reduce Fuel Burn and Emissions*, Section 2.5].

Stationary Equipment and Airport Infrastructure Activities

Large airports often have their own power and heat generation plants that burn fuel such as natural gas, oils, and coal. Excluding aircraft emissions, these facilities may be the largest airport-owned contributors to airport air quality related emissions. Emissions will vary according to the operating hours, fuel consumption, load factor, installed capacity, etc.

Airports should consider replacing equipment with newer technology when appropriate. For instance, replacing CFC-based refrigeration systems or at a minimum ensuring that leaks of CFCs are minimized. Airports can also reduce energy consumption by improving energy efficiency or implementing other measures such as installing LED lighting on airfield and in terminals and using renewable energy where possible. In fact, the availability of renewable energy at the airport either through the grid or direct onsite generation, will play an essential role to the ability of airport operators to reduce their own emissions, positively impacting local air quality.

Construction activities also contribute to air pollution with the emissions from combustion engines and the release of PM, such as dust. Airports should consider these emissions in the design, approval, and implementation of construction projects, including the equipment, vehicles, demolition, storage, and handling procedures.

Airports should also take measures to reduce and mitigate the emissions from other stationary sources including emergency generators, liquid and fuel storage tanks, incinerators, fire training facilities, airport maintenance activities (cleaning agents, building maintenance and repairs as well as maintenance of the greeneries), as well as consider sources of emissions outside of its direct control, such as aircraft maintenance facilities and engine test runs; these can be controlled through the use of test cells equipped with afterburners and catalytic converters.[13]

[13] ICAO Airport Planning Manual, Part 2, Section 3.3.3

Ground Access Vehicles

Ground transportation to access the airport is the major contributor to landside emissions. This includes road access for passengers, employees, visitors, contractors, nearby businesses such as hotels, air cargo traffic, service deliveries, etc. This is also not under the control of airports. However, airports can work with municipalities, public transport authorities, tenants, and others to identify opportunities to reduce these emissions. For instance, providing employees with discounts to use public transport or incentives for ridesharing, providing adequate and safe pedestrian and bicycling infrastructure, promoting electric taxis with priority queuing or incentive on annual license fees. Airport car parks can also be equipped with charging stations for electric vehicles and car park roof can be fitted with solar panels to generate green electricity for the airport.

Air Quality Management Plans

Airports generally need to assess and manage their emissions. As mentioned above, local municipalities may require reporting on air quality measurements to understand ground-level hazards. When new projects are considered, like a runway extension, there is usually a need to understand how the emissions will change as a result. Also, many airports want to reduce their environmental impact by reducing emissions and improving overall air quality around the airport. All of these processes, from strategic management goals to planning new development, involve air quality issues at some level.

Air quality management planning is carried out by airports in different ways. An airport may have a specific Air Quality Management Plan that guides how they handle these matters. An air quality management plan is a distinct document that provides data on emissions and outlines the actions to be taken to reduce them. Alternatively, plans for managing air quality issues may be combined into other airport processes, such as a Master Plan, an Environmental Management System, or standard operating procedures, as well as into staff training courses, and more. Regardless of the format, the goals of air quality planning are generally similar in that they aim to improve efficiency and effectiveness in both airfield operations and how staff manages processes and complies with regulations and reporting. There are many components of airport operations tied to emissions and air quality, including airfield operations, equipment purchases, reporting and regulatory compliance, and sustainability goals. A systematic plan for managing air quality issues allows these different aspects to be considered and aligned in a well-organized way to ensure successful implementation.

Emissions inventory

To understand the impact that airport activities have on air quality, it is necessary to have data on emissions. Conducting an inventory of emission sources, types, and amounts is a vital first step to gather data. Such an inventory may be needed for proposed development projects, to report on local air quality measurements to local authorities, or to achieve sustainability objectives. A busy urban airport will likely need to do all of the above and will be best served with a comprehensive emissions inventory that looks at all possible emissions sources at the airport, and links them to an air quality management plan. A full inventory of emission sources at a facility provides the information to systematically plan new facilities, report to authorities as needed, and set goals and objectives for how to manage the airport. An inventory is a quantitative assessment of pollutants, and an accurate compilation of this information requires use of technical models and tools. Consequently, airports may choose to engage external experts with air quality expertise to conduct analysis of emissions. For reference, information on developing inventories can be found in ICAO doc 9889, *Airport Air Quality Manual*. As mentioned previously, airports can also use the emissions calculation tool ALECA. An inventory works as a management tool. When an airport has a full inventory of emissions it becomes easier to plan how to minimize and mitigate emissions.

Some airports' emissions reduction actions require more specific data, and forecast of pollutants, which can be complex and technical in nature. Airports can consult the local agencies or organizations responsible for collecting data on air quality and modelling, in order to assist them in this task. Pollutants are mostly gases or fine particles which are airborne and disperse over space and over time. Stationary instruments can measure ambient air quality at a point in time, and that is valuable for understanding the general air quality environment. In many cases an airport would like to predict or model what emissions would be expected before an action is decided or taken, for example when considering alternatives for expanding airport capacity. This kind of modeling of potential emission scenarios is a technical process that requires specialized tools. The process is especially complicated when aircraft operations must be modeled and measured. Adding to all of this is the fact that air pollutants are not static. The health risks posed by pollutant emissions is based on the concentration of emissions, and modeling emissions dispersion at the airport requires climatological factors such as wind and precipitation be considered. Specialized models are used to assess emission dispersion and predict when air quality issues might be problematic. An overall airport emissions inventory does not necessarily have to do all of these things. An inventory of emissions showing the sources, types and amounts of pollutants will show what equipment and processes at the airport are generating the largest amounts of emissions. With that information, the airport operator can make effective environmental decisions that avoid, minimize, or reduce emissions at the airport.

Mitigation measures

Potential actions to reduce emissions may include upgrading technology, such as ground support equipment or terminal heating systems. Emissions will mostly come from aircraft operations and minimizing them may require changes to airfield operational procedures, and the use of more efficient and less pollutant aircraft engines.

Air quality management plans, and the emissions inventories within, should describe the type of pollutants measured, the indicators used (e.g., AGE-S and ALECA calculators, airport operational activities, evolution in time, etc.), the pollutant thresholds, the frequency of measurement and their procedures, etc. This will allow the airport to analyze the data against options for mitigating pollutants. A mitigation plan will usually try to resolve the biggest or easiest issues first and consider the steps and costs necessary to carry out further mitigation. Local circumstances may inform some of the mitigation options to be included in a mitigation plan. Working with other stakeholders to reduce their own emissions, particularly emissions from aircraft operations, is necessary.

Nature can also contribute to the regulation of air quality. Urban vegetation can help reduce and prevent particulate matter and gaseous pollutants emissions, as there are potential benefits of vegetation in changing dispersion and deposition processes, along with protecting bare lands and reducing the local air temperature. However, potential issues and even degradation of air quality, might also arise.

Dispersion. Planting of trees may enhance or reduce dispersion locally, which redistributes pollution but does not remove it. Vegetation acts as a barrier close to a source of emissions, thereby immediately decreasing the concentrations behind the barrier.

Deposition. Nature improves air quality through the retention and detoxification of pollutants, though these processes (such as acidic deposition) may affect terrestrial and aquatic ecosystems. Plants can help reduce air pollutants concentration by trapping fine particulate matter on leaves, branches and trunks, and facilitate the activity of microbes that degrade particulates.

Bio-emissions. It is important to note that Biogenic Volatile Organic Compounds (BVOC) released in the air by some species of plants, like pollen, fern spores, and fungal spores, can be harmful to people and contribute to fine particulate matter emissions.

Land. Vegetation also protects soils and can prevent dust emissions from bare lands. The sustainable management of ecosystems and land at and around airports may thus prevent the emissions of air pollutants.

Temperature. Vegetation cover affects the local meteorology, helps to reduce the heat island effect and the local air temperature. Reducing local air temperature from trees can improve air quality because the emission of many pollutants, ozone-forming chemicals and ozone is temperature dependent.

Ecosystems. Loss of biodiversity and ecosystem function, resulting from air pollution and other drivers, may compromise nature‘s contributions to moderating air pollution.

In addition, nature also contributes to regulate Green House Gazes emissions and mitigate climate change, in particular by directly absorbing CO2 emissions through plants, but also by preventing the release of additional emissions by keeping them in soils and oceans.

Vegetation can therefore help improve the air quality at and around airports - among other co-benefits - if it is carefully planned.

Land use planning

Air Quality Management plans can also play a role in communicating with the community on land use around airports (*ref. Doc 9889*). Depending on the location, airport air quality can have an impact on land use options that become available around an airport and adequate planning can reduce the negative impacts of emissions on human health. For example, at some airports, engines run-ups are conducted in specific areas at the airport where the local air quality (and noise) is monitored. These areas are normally away from housing to avoid additional exposure to the local communities around the airport. The data collected is communicated to the local communities, municipalities, and/or States, to ensure transparency.

Innovation Solutions

Innovation and technology are important enablers to mitigate environmental impact for any organization and this is no different of airports and other aviation stakeholders. Working in collaboration with aviation and non-aviation partners to identify opportunities to reduce emissions and improve local air quality are important to achieve results that have a broader impact. Another point to consider are the interdependencies with other topics such as GHG emissions reductions. Proposing solutions that have knock-on benefit impacts beyond local air quality are a win-win and can support granting buy-in from different stakeholders.

An approach an airport can take is to use what is called a 'smart airport design', which helps to optimize the use of infrastructure through technology adoption. An example is airport terminal energy optimization, which results in emission reduction from the energy intensive systems such as Heating, Ventilation, and Air Conditioning (HVAC) systems. Similarly, smart airports facilitate the adoption of innovative wastewater treatment technologies that require only a quarter of the area taken by a conventional facility. These are energy efficient and can reduce up to 50% of energy consumption, resulting in emission reduction.

Another example of innovative approach is the use of lighting as a service, used by Schiphol Airport, to increase efficiency of energy consumption as part of the circular economy concept. This innovative business model, called servitization, has the potential to facilitate the implementation of different environmentally friendly solutions for different stakeholders. Airport operators and stakeholders operating at and around the airports can benefit from these improvements in efficiency, operational costs reduction, and optimization of infrastructure and aircraft fleet at the terminal and airside operations, including ground surface access to the airport.

San Diego International Airport (SAN) has taken the concept of innovation even further. SAN has established an Innovation Lab to encourage and promote new solutions to aviation issues that airports face. The Lab was initially developed in a decommissioned Commuter Terminal which provided a space to conduct real-life testing for airport innovations.13 SAN has included environmental-related topics in the Innovation Lab efforts, some of which have implications for air quality and emissions. The Lab is currently soliciting solutions for electric powered 'autonomous solutions.' They expect proposals for this topic could include autonomous pushback solutions, Artificial Intelligence (AI)-based smart assistants, intra-campus transportation services, and options to move people throughout the airport within the terminal space. The Lab has had submittals in past years focused on vehicle-to-grid electric charging products (I.e., bidirectional). Such a specific focus on finding creative new solutions to airport environmental challenges will help improve aviation into the future.

More information on other airport infrastructure sources such as waste management and aircraft ground energy systems, can be found in the Eco-Airport Toolkit e-collection.[14]

Examples of Action

Ankara Esenboga Airport (Turkey)

A series of energy efficiency projects have been implemented at Ankara Esenboga Airport Terminal Building and its auxiliaries operated by TAV Airports in order to reduce greenhouse gas emissions and improve local air quality. TAV has been receiving annual certificates from ACI/ACA organization since the year 2010 and as of the beginning of 2014, it increased up to the level of **Neutralization** which is referred to as "LEVEL 3+". In addition, TAV has also been getting ISO 50001 Energy Management System in order to follow the energy figures in a most efficient route.

Below is a description and summary of a series of measures taken.

Automatic Meter Reading System: Unmeasurable data cannot be controlled; a significant number of meters have therefore been installed and integrated into a wide field by creating an Automatic Meter Reading System in order to monitor the consumption of consumers, with as much details as possible. This provides instant data tracking and control of each consumption source, and facilitates reduction actions that can be taken for energy efficiency planning.

Building Management System of Lighting and Mechanical Automation: Terminal-wide lights are connected to an automation system. Via this system, all lighting zones are under the control of a supervisor. In addition, daylight sensors are connected to the system and the external lighting is controlled automatically by these sensors, to ensure maximum efficiency. Likewise, to efficiently manage HVAC (Heating Cooling and Ventilation), the equipment is controlled by an integrated

[14] ICAO Environment. Eco-Airport Toolkit e-collection. 2019. Available at: https://www.icao.int/environmental-protection/pages/ecoairports.aspx

automation system, in order to optimize usage with actual needs, by setting the system's operational parameters. This leads to less energy consumption in terms of air conditioning activities.

PBB, 400 Hz and PCA Systems: As 400 Hz (Ground Power Units) and PCA (Pre-conditioned Air) systems are installed at PBB's (Passenger Boarding Bridges), almost all aircraft which are docking to the bridges are utilizing 400 Hz and PCA for their power and air-conditioning needs instead of running APU's.

LED (Light Emitting Diode) Lighting: A remarkable energy consumption reduction and energy efficiency are achieved by using new types of LED lighting instead of old-style lighting. The conversion was first initiated with lights that are switched on for 24 hours a day to be able to gain as much reduction as possible. Subsequently, the work plan was extended to all other lights. This project leads also to great cost savings.

Thermal Measures: In the terminal area, thermal screening cameras are placed at possible non-isolated areas where thermal energy losses occur, in order to detect all leakages and reinforce the isolation conditions. Furthermore, wind breakers are built to create indoor isolated zones around the doors, in order to prevent thermal losses due to opening of the doors as passengers flow.

Tri-Generation Plant: There is a tri-generation plant integrated to the power network in use to feed the terminal building. It also contributes to heating and cooling needs. Electricity is generated from the running of natural gas motors located in the plant. In addition, exhaust at high temperature produces hot water in wintertime for heating purposes. In the summer period, it contributes to the cooling by means of the absorption chiller installed in the plant. This energy recovery prevents a large amount of emissions.

Energy Efficiency and GHG Reduction Trainings: The importance of energy efficiency and carbon reduction trainings are given to all personnel involved, including staff and stakeholders. In addition, in orientation trainings which are given by the HR department, new staff are informed and trained within this context of full awareness.

Waste Management System: A project launched by government authorities named "Zero Waste Project" is being implemented at the airport in Esenboga. Accordingly, all waste generated by the terminal operations are collected and segregated by type at the first point of collection, to be processed for recycling; this includes domestic wastes as they have been put into composting devices to be converted to fertilizer to be reused within the agriculture field. Those actions are performed together with all stakeholders in the airport.

Forestation Projects: TAV is involved in "planting trees" projects every year and plants at least 10.000Pcs of pine trees every year.

Information Tags: Information tags are located in the terminal areas to remind of energy efficiency and CO2 emission reduction.

Brisbane Airport (Australia)

Brisbane Airport Electric Bus Fleet and Charging Station (Jun 2019)

Brisbane Airport boasts a diverse property portfolio spanning retail, commercial and industrial developments across the airport precinct. Many passengers and staff choose to park at Brisbane Airport due to the wide variety of parking options, competitive pricing, and car parking spaces available. Dedicated bus services are required to convey passengers and staff to and from remote car parks; between the domestic and international terminals, and to and from the terminals and Skygate shopping precinct. Brisbane Airport's landside bussing contract was due for renewal in 2017 which was the trigger to upgrade the older, diesel bus fleet.

The electric bus fleet operates landside servicing the whole airport precinct. The tender panel included representatives from BAC's Parking and Transport, Customer Experience, Environment and Sustainability, and Finance teams. Each of the 12 electric buses were built new and funded through operational expenditure as part of the bus services contract, whereas the construction of the dedicated facility for bus charging, parking, and maintenance was funded through capital expenditure, all of which is privately funded by BAC.

The BYD TORO is the world's most modern and technologically advanced electric bus. Developed jointly by Carbridge and electric vehicle manufacturer BYD, the TORO is helping to reduce carbon emissions, improve local air quality, lower noise levels, and reduce waste fluids.

Real time data is generated for each electric bus and monitored via the ViriCiti dashboard, an all-in-one platform for electric fleet management. The dashboard provides a vast array of information to optimize the fleet's operations including temporal metrics (e.g. time charging/time driving), performance metrics (e.g. C02/pollutants, mileage driven), energy metrics (e.g. energy consumed/regenerated driving) and state of charge metrics. ViriCiti has recorded the following data for the bus fleet's operation to date (February 2018 to 18 November 2020):

- 1,049,922 km have been driven

- 1,223,000 L of diesel fuel has been saved
- 1,952,561 kwh of energy has been consumed in charging

Grid electricity emissions are offset by a 1.8MWp solar PV array located in the same precinct as the bus charging station (Brisbane International Terminal rooftop array). However, without including the emissions offset by renewable energy, ViriCiti calculates the following emission savings have occurred from using the electric bus fleet since operations commenced:

Emission type	Emission Factors	Total Savings	Per Year Savings
C02 (tonnes)	0.5925 kg/kWh and 2.642 kg/L	1,025.8	341.93
PM (particles) (kg)	0.005 g/ kWh and 0.111 g/L	15.2	5.06
N0x saved (kg)	0.2 g/kWh and 4.44 g/L	608	202.66

Other assumptions:

- Emissions produced from the grid (0% renewable energy) – not including 1.8MWp solar
- Non-electric (diesel) bus consumption = 35 L / 100 km
- Per year savings divide 3 full years of operation by the emission types and are conservative due to a reduction in service due to COVID-19 from April – November 2020

Electric bus charging station
Credit: Brisbane Airport Corporation

ViriCiti dashboard showing fleet position and status, 19 November 2020

Chhatrapati Shivaji Maharaj International Airport (India)

Enhancement in Ambient Air Quality (Dec 2019)

Chhatrapati Shivaji Maharaj International Airport (CSMIA) is located in the heart of the capital city Mumbai and is the second largest airport in the country. Though CSMIA is situated at the centre of the city and surrounded by highway and an industrial belt, it has always put efforts to safeguard ambient air quality levels. The airport continuously monitors ambient air quality levels for Sulphur dioxide (SO2), NOx, CO, Ozone (O3), Total hydrocarbon (THC), Lead (Pb), PM2.5 and PM10, etc. It has recently conducted a project of enhancement of air quality, executed simultaneously via two initiatives: the installation of fixed electrical ground power (FEGP) and pre-conditioned air (PCA) systems at all the aerobridges of the terminal buildings, and the use of Airport Collaborative Decision Making (A-CDM). The total cost of this project was approximately 12.5 million INR. Both these initiatives were a retrofitting project to achieve maximum landing and take offs in an hour. Both these projects were simultaneously implemented between the years 2016 to 2019.

Fixed electrical ground power (FEGP) : To reduce fuel burn emissions while aircraft are parked, FEGP units were installed at 70 aerobridges between Terminals 1 and 2 (72 GPU and 58 PCA units). At some aerobridges in terminal 2, both GPU and PCA units were fitted. The diesel consumption of power units used before the installation of FEGP is now non-existent, as diesel-based GPUs were completely replaced with FEGP.

Airport Collaborative Decision Making (A-CDM): To effectively utilize slots and minimize taxiing time for aircraft, the A-CDM application was developed in collaboration with the Airport Authority of India (AAI) for all aircraft landing and take-offs. A-CDM takes into consideration the Expected Time of Arrival (ETA), Target off Block Times (TOBT) of departures, runway in use, and the handling capacity of runway to determine the arrival and departure sequence. Based on the sequence and the parking position, it calculates the Target Take Off times (TTOT) and Target Start up Approval Times (TSAT) of departures and Target in Block Times for arrivals. The airport was able to reduce aircraft taxiing time, which resulted in drastic reduction in fuel consumption and aircraft emissions on taxiways.

The airport also installed Continuous Ambient Air Quality Monitoring Stations (CAAQMS) at two different locations, covering the landside and airside areas of CSMIA. The parameters monitored at these stations are as per the National Ambient Air Quality Monitoring Standard (NAAQS), 2009. These stations were installed in year 2016 and 2018. The reducing trend of the Air Quality Index (AQI) for 2018, 2019 and 2020 (until March) shows reduction in emissions including gaseous and particulate matter.

Chart 1: Air Quality Index of CSMIA for 3 consecutive years.

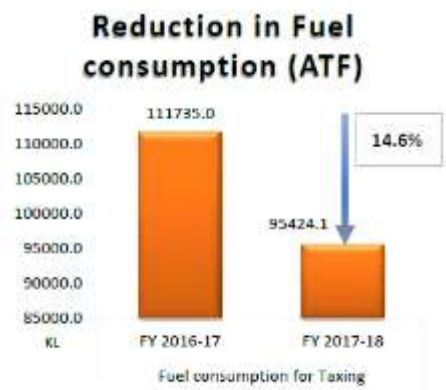


Chart 2: Reduction in fuel consumption after A-CDM application installation.

Pic 1: Continuous Ambient Air Quality Monitoring Station installed at airside near R/W 09 end.

Darwin International Airport (Australia)

Bushfire Mitigation Project (Nov 2020)

The Rapid Creek Bushfire Mitigation Project was developed from air quality and biodiversity impacts experienced as a result of three wildfires that occurred in late 2019 at the Rapid Creek Reserve at Darwin International Airport (DIA). The fires lit by arsonists in late 2019 coincided with extremely hot and dry conditions causing wildfires to develop. Wildfires at this time have an impact on the biodiversity of natural areas and generate thick smoke that negatively impacts airside operations and the health and safety of airport users. The project focused on Rapid Creek Reserve, which is a landside reserve area on airport land. Areas benefiting from the project include airside areas, the entire airport precinct and the wider community, and involved several stakeholders (firefighting services, federal police, government, rangers and airport staff).

The project was driven through the airport's Environment and Sustainability Department who collaborated with other department managers including:

- Head of Security & Contingency Planning – coordinated liaison with the Australian Federal Police
- Airside Operations Manager - provided feedback on the updated bushfire response procedure after liaison with Airside Operations Officers and Airport Duty Managers.

The project was low cost and funded under the environment operational budget. A project grant from IFM investors that supported the Larrakia Rangers working within Rapid Creek Reserve kick started the liaison and additional fire risk management tasks undertaken by the Rangers at the reserve.

The project was primarily a series of meetings with various project stakeholders followed up by additional land management activities, new bushfire response procedures and providing resources to Northern Territory Fire service to best undertake bushfire response.

Main achievements:

- Improved response by emergency services and DIA staff in the event of a wildfire: Updated DIA bushfire management procedures and stakeholder workshops to trouble shoot issues related to efficient bushfire response.
- Increased fire management tasks: More detailed DIA fire management plans that include areas and timing for where cool season burns will occur.
- A more educated and connected community: Resources and information sessions provided to the Northern Territory Fire Service including detailed maps of airport land within each fire truck and training sessions with firefighters about the biodiversity value of Rapid Creek.
- A closer relationship with the Australian Federal Police for bushfire response and understanding the arson risk along Rapid Creek Reserve.
- Greater engagement activities with the Larrakia Rangers.
- Greater understanding of wildfire risks and effective wildfire response across department managers within DIA.
- Liaising with other landowners and managers along Rapid Creek about fire response issues.

In 2020 there were two fires that were lit by arsonists, but neither events developed into wildfires, with improved coordination and response in fire management by emergency services and DIA. There were no interruptions to airside operations as a result of fires and the likelihood of wildfire and associated air pollution that poses safety, environmental and health risks to the airport and its stakeholders has been reduced. Rapid Creek Reserve continues to regenerate after the 2019 fires and an updated land management plan for the reserve now includes cool season burns that will be undertaken with the Larrakia Rangers.

		
Caption 1, Thick smoke from wildfire threatening airside operations at Darwin International Airport, October 2019.	Caption 2, Poor visibility and air quality across the airport, October 2019	Caption 3, Stakeholder engagement event with the Northern Territory Fire Service

Hong Kong International Airport (Hong Kong, China)

Ground Services Equipment (Jul 2018)

With a view to improving operating efficiency and reducing air emissions, AAHK rolled out a new Ground Service Equipment (GSE) Pooling Scheme at HKIA in July 2018. Initially implemented as Phase 1 at Midfield Apron, the Scheme enables ramp handling operators (RHOs) serving client airlines to rent critical GSE, of which 95% are electric-powered, from AAHK. Phases 2 and 3 of the Scheme are planned and when fully implemented in 2024, AAHK will own 1,000 units of GSE.

The scheme was first conceived when AAHK initiated a review of aircraft ramp handling processes, which included an in-depth analysis of arrival baggage delivery performance in 2016. The findings revealed timely provision of GSE is one of the most important factors affecting HKIA’s service standards. Likewise, the deployment of GSE from flight to flight across the apron increasingly led to traffic congestion peak periods throughout the day. This not only affected the on-time performance of arriving baggage and departing flights, but also led to increased air emissions, especially when the RHOs have been using many aged diesel-powered GSE.

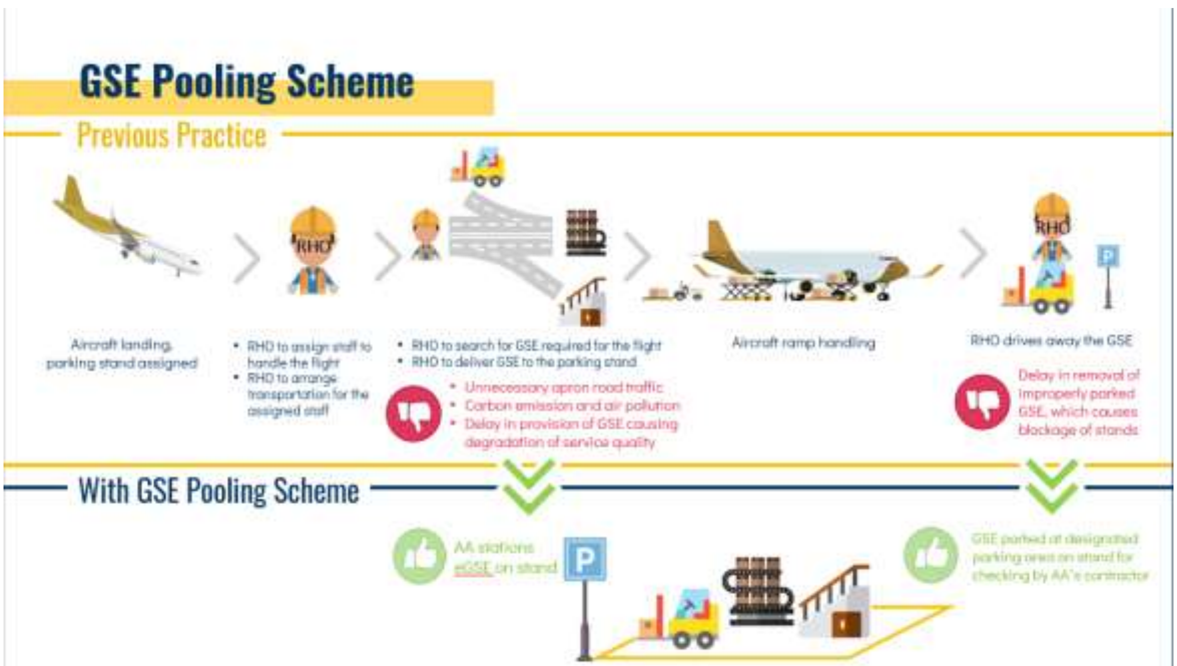
Under the new AAHK's ownership model, all critical GSE are standing by at every parking stand and the need for mobilizing GSE is minimized. This not only brings benefits in terms of reduced emissions and energy use, but also reduced unnecessary traffic on apron road and traffic congestion. Moreover, with 95% of GSE being electric-powered, exposures of workers and other receptors to NOx, particulates and other pollutants are significantly reduced. In addition to spending over HK$300 million to procure the GSE, AAHK also funded installation of chargers, established two GSE maintenance workshops, provided training, and developed detailed operations process to include in its handbook[15].

Through early engagement of RHOs and other relevant stakeholders in planning of the scheme, AAHK demonstrated the power of proactive, collaborative stakeholder engagement. The scheme is well received by all stakeholders including the RHOs, as it promotes resources sharing with guaranteed GSE availability at a lowered operating cost. The scheme allowed optimized use of GSE and at the same time reduced the total GSE fleet size needed at HKIA. Through centralized provision, management and maintenance of all critical GSE, the overall investment and operational cost are reduced while safe operation of GSE are also enhanced via relevant training provided to RHOs. The provision of on-stand GSE also helped RHOs to meet prescribed performance level and avoided aircraft ground delays caused by lateness or insufficient provision of GSE. From available statistics for Q4 2019, the key performance indicators for baggage delivery performance have consistently surpassed 97% with a daily throughput exceeding 127K bags on average, which demonstrated overall enhancement of the RHOs' operation efficiency.

[15] HKIA GSE Pooling Scheme Operations Handbook. 24 February 2020, version 3. Available at: https://extranetapps.hongkongairport.com/iwov_extra/OpenFile/GSE+Pooling+Scheme+Handbook+Ver3.pdf

eGSE Chargers installed by AAHK at parking stands

Enhanced ramp handling process enabled via new HKIA's GSE Pooling Scheme



Indira Gandhi International Airport (Delhi, India)

Green Taxing at IGI Airport (Oct 2019)

Local air quality management at Indira Gandhi International Airport (IGI) is one of the important environmental and key materiality aspects of Delhi International Airport Limited (DIAL)'s business sustainability. DIAL and its stakeholders always believe that the air quality at the airport has a major influence on its business, since the region of Delhi experiences bad air quality during winter seasons. To exemplify the air quality improvement in the region, DIAL and its stakeholders have taken numerous initiatives. One of the most recent and promising projects implemented at Delhi Airport is the use of TaxiBot for aircraft taxiing.

TaxiBot is a semi-autonomous vehicle that enables airplane taxiing without engines running, controlled by the pilot and without shortening the nose landing gear (NLG) lifetime. In a conventional aircraft taxi process, an aircraft is tugged by a ground vehicle to the Tug Detach Point (TDP). Following this, the aircraft switches on its engines and taxies to the runway. Starting the engines early means the aircraft is using more aviation turbine fuel (ATF), and it also leads to air pollution in the form of NOx, CO, HC, SO2, PM and CO_2 emissions.

The use of TaxiBots helps in delaying the operation of aircraft engines and avoids the burning of AFT. This benefits DIAL and its stakeholders both environmentally and economically, as well as the region's local air quality. Airlines in Delhi Airport have achieved the following benefits (calculated using ICAO Aircraft Engine Emissions Databank), from more than 450 TaxiBot missions completed till now:

- Saved more than 52,463 liters of ATF (the actual benefits are much higher than the presented values).
- Local air quality benefits:
  - Total NOx saving- 723 kg
  - Total CO saving- 5,814 kg
  - Total HC saving- 1,342 kg

Additional benefits from the 450 mission include:

- 31.5 hours of aircraft ground time saved
- 58.5 hours of engine life saved
- Training and knowledge sharing on operational procedures with stakeholders
- Increased operational efficiency by reducing turnaround time and throughput at airport gates
- Significant financial benefit to airlines to the tune of two million INR in terms of fuel cost savings.

Currently, two TaxiBots are deployed at Delhi Airport, which can handle 30-40 aircraft/day. In addition, DIAL is planning to add 15 more TaxiBots in the next three years, which will further multiply the local air quality benefits in the region. Following the success of Delhi Airport, a number of Indian airports as well as few global airports are planning to adopt TaxiBot to support the business sustainability. DIAL continuously studies the local air quality at the airport and in the region. The airport has two monitoring stations within its boundary and there are also many monitoring stations installed by the government around the airport that compare air quality data with the airport's data.

Fig 4: Air Quality Monitoring Stations in IGI Airport and neighboring area, within a radius of 5 KM (yellow mark) and 10 KM (blue mark). The yellow points are monitoring stations within IGIA, blue points are monitoring stations in neighboring area

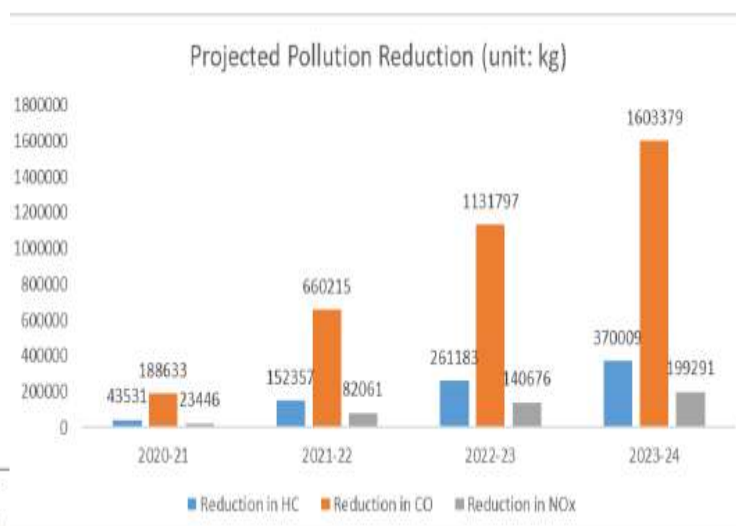


Fig 2: Projected pollution reduction with planned implementation of 17 TaxBots at Delhi Airport

Rajiv Gandhi International Airport (Hyderabad, India)

Sustainable Airport Operation for effective Airport Air Quality Management (2016-2020)

To reduce air emissions as well as operating costs, GMR Hyderabad International Airport Limited (GHIAL) has adopted a wide array of eco-friendly technology, infrastructure, and practices in collaboration with their stakeholders. These efforts have been implemented throughout the entire airport area, involved a multitude of stakeholders (airlines, ground support departments, airside operations, Air Traffic Control tower, GMR-Transport, landscaping and environmental teams, cargo, concessionaires, etc.), and have resulted in minimizing the air emissions and maintaining good air quality at the airport and its surroundings. RGIA's green initiatives are also aligned with ICAO's Environmental Goal *to limit or reduce the impact of aviation emissions on local air quality*, and the UN Sustainable Development Goal 3: Ensure Healthy lives & promote well-being for all at all ages. In 2019, World Environment Day was observed with the Theme of Beat Air Pollution at RGIA.

More concretely, these sustainable airport operations have resulted in significant reduction in fossil fuel consumption and air emissions at the airport:

Sustainable LTO cycle of aircraft(s) and ground support operations, single engine taxiing: ATC and the airlines practiced Continuous Descent Approach and continuous Climb Operations for landing and departing aircraft to reduce aircraft fuel burn. Single engine taxiing of aircraft avoided 40-50% of aviation turbine fuel (ATF) fuel burn per air traffic movement, or approximately 4,382 kl of ATF saving in a year. Indigo airline contributes to 40% of total ATMs of the airport. The airline in co-ordination with the airport operator implemented aircraft single engine taxiing and used the FEGP in place of the APU since 2016. Also, short taxi routing and intersection take-off reduced aircraft emissions.

Fixed Electric Ground Power Unit (FEGP): During 2017-2019, 1,596,190 kWh of electricity used which in turn avoided ATF of 152,749 litres from aircraft APU.

Solar powered ground support equipment: In 2019, Air India SATS developed a prototype of solar ground support equipment (GSE) - baggage flight loader (BFL), and step ladder in place of diesel equipment. This avoided 102,209 litres of diesel and emissions NOx: 1672 kg; CO: 965 kg; PM: 190 kg every year in the airside. GHIAL's 10 MW solar power plant also reduces the thermal electricity use.

Electric ground transportation: GHIAL and GSDs introduced five electric coaches and 12 e-tugs and cars. The airport has collaborated with the State Road Transport Corporation in introducing 40 electric buses in 2019 for the passengers' commute. Electric buses and cars in the city side of the airport prevented 4,567 litres of diesel and emissions savings: NOx: 38,105 kg; CO: 22,874 kg; PM: 1,750 kg in 2019.

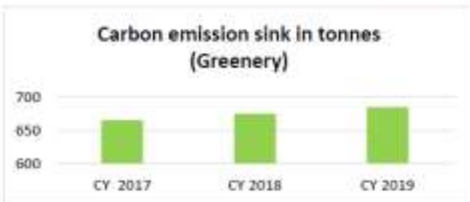
Green belt: 693 acres of developed greenery and more than 2,000 acres of natural vegetation absorb 685 tonnes of CO_2 in the premises of the airport.

Ambient air quality monitoring station: GHIAL installed a monitoring station that measures NOx, CO, PM 10 & PM 2.5, SO_2, O_3, and HCs. The real-time monitoring data is transfered to the State Pollution Control Board's website on a 24-hours, 7-days a week basis. The airport's air quality parameters are recorded well within the stipulated norms.

Dust mitigation from the airport expansion activities.

The savings from all these measures are to the tune of INR 150-195 million every year.

GHIAL organized on-site briefing sessions to nearly 1,500 cab drivers, ground support departments and the employees on the maintenance of the vehicles, and periodical emission quality checks in line with the emission norms. Senior management reviews the effectiveness of the air pollution control measures regularly. With these efforts, GHIAL has maintained good air quality environment at the Airport for the wellbeing of all the airport stakeholders and the local communities.



Caption 3: Forty electric bus fleet introduced for city side passengers commute between the Airport and Hyderabad City.

Caption 2: Vehicle charging point provided by the airport for GSD equipment to avoid diesel equipment

Taoyuan International Airport Corporation Ltd. (Chinese Taipei)

Air Pollutant Reduction Plan (Aug 2020)

To strengthen the management and operation performance of environmental protection, Taoyuan International Airport introduced in 2019 an ISO 14001 environmental management system and identified incinerators and fuel vehicles as the main contributors to air pollution. Through continuous improvement, stationary pollution sources and mobile pollution sources from the airside and landside, including incinerators, baggage consignment, and taxi scheduling, as well as other fuel vehicles and others, are now monitored. With the integration of third-party resources and the provision of complete educational training and other measures, the partners have helped to promote an integrated gaseous and particulate pollutants reduction plan, containing three sub-projects, described below. TIAC has invited ground handlers, maintenance vendors, engineering consultants, and other airport partners to participate in these projects, with the general manager acting as the chief supervisor. At least one meeting is held every quarter to establish beneficial communication channels and ensure the effective reduction of air pollutants. Personnel is appointed to be responsible for identifying air pollutants, as well as for planning, implementing, reviewing, and revising various reduction projects. They also work closely with environmental protection authorities, external experts, and contractors to ensure these projects are well-implemented.

Reduction projects Electrification for airside operation vehicles: Through a pass-review mechanism, fuel vehicles were gradually prohibited from using airside areas, and 148 fuel luggage trailers have been replaced, helping to cut down air pollutant emissions: 1.4 tons of NOx and 1.8 tons of CO.

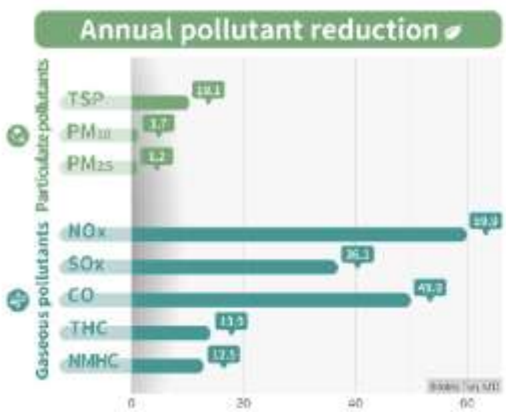
Incinerator upgrade: Introduced a remote intelligent monitoring system to improve the proper availability rate of equipment, strengthening the efficiency of waste incineration and waste gas treatment, and comprehensively improving the efficiency of incineration plants, further reducing all kinds of air pollutants such as TSP, SOx, NOx, CO, and others, to levels lower than 10% of the national emission standards.

Cloud-smart scheduling APP for taxis: Developed a scheduling application and cloud software to reduce emissions from landside taxis. It helped 600 vehicles to apply passenger services through the app. The system proactively notifies the drivers about passengers' journey times, reduced fuel consumption and CO emissions, and reduced fuel costs by NT$21.6 million every year.

Results

After the implementation of the plan in 2019, the annual environmental performance includes a reduction of 10.1 metric tons of TSP, 1.7 metric tons of PM10, 1.2 metric tons of PM2.5, 59.9 metric tons of NOx, 36.1 metric tons of SOx, 49.9 metric tons of CO, 13.9 metric tons of Total hydrocarbon (THC), and 12.5 metric tons of Non-Methane Hydrocarbon (NMHC).

Pollutant (MT) / Project Name	TSP	PM_{10}	$PM_{2.5}$	NOx	SOx	CO	THC	NMHC
1. Electrification for airside operation vehicles	0.4	0.3	0.2	1.4	-	1.8	0.2	0.2
2. Incinerator upgrade	7.2	-	-	55.2	36.1	23.8	-	-
3. Cloud-smart scheduling APP for taxis	2.5	1.4	1.0	3.3	-	24.3	13.7	12.3
Total	**10.1**	**1.7**	**1.2**	**59.9**	**36.1**	**49.9**	**13.9**	**12.5**



Annual environmental performances

Continuous Emission Monitoring Systems

RESOURCES

Below is a list of useful resources for the users of this Eco-Airport Toolkit on air quality management, including a brief description for each document.

ICAO Airport Air Quality Guidance Manual (Doc 9889): provides detailed information on air quality standards, conducting airport emissions inventories, aircraft and other emissions calculations, dispersion modelling and monitoring and measuring air quality.

ICAO Airport Planning Manual (Doc 9184), Part 2, Land Use and Environmental Control: provides information on means of reducing emissions and improving fuel efficiency and encourages the use of environmental management systems at airports.

ICAO Operational Opportunities to Reduce Fuel Burn and Emissions (Doc 10013): provides operational procedures that aircraft operators and air navigation service providers (ANSPs) may be able to implement to reduce aircraft emissions

Aviation Emissions and Air Quality Handbook, Version 3 (US FAA, 2014): insert short description

US Environment Protection Authority AP-42 released by the US Environmental Protection Agency (EPA): it is the primary compilation of EPA's emissions factor information and contains emissions factors and process information for more than 200 air pollution source categories.

EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016 (European Environment Agency, 2016): provides guidance on estimating emissions from both anthropogenic and natural emission sources.

ACRP Guidance for Estimating Airport Construction Emissions (TRB, Report 102, 2016): provides guidance and an interactive electronic tool (Airport Construction Emissions Inventory Tool) to assist airports and other stakeholders to better understand and quantify airport construction emissions and also to bring consistency to airport construction emissions inventories.

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