# Decarbonising gate operations through clean energy solutions

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## Abstract

*Civil aviation authorities, working with their airport, airline and aviation business partners, are developing plans to achieve carbon-neutral aviation growth from 2020. This paper discusses how, in order to meet this goal, the International Civil Aviation Organization (ICAO) Member States have agreed to a basket of measures for reducing carbon dioxide emissions from international aviation. One effective measure identified is replacing aircraft auxiliary power unit emissions with gate electrification systems and solar power as described in the United Nations Clean Development Mechanism small-scale methodology: solar power for domestic aircraft at-gate operations. ICAO, with funding support from international partners, has recently completed three airport pilot projects — in Cameroon, Jamaica and Kenya — that demonstrate how States can implement the solar at-gate measure. Beyond the direct application to auxiliary power units and gate electrification, the solar at-gate concept offers a more general approach as to how other airport electrification conversion projects, including ground support equipment, airport ground transportation and passenger vehicle use, can maximise emission reduction benefits by eliminating fossil-fuel combustion and replacing it with carbon-free electricity. This paper discusses the solar at-gate example, which demonstrates the opportunities associated with maximising airport electrification and supplying the new electricity demand with clean energy for carbon emission reductions consistent with the global efforts to address climate change, and at the same time, accelerating the achievement of the Sustainable Development Goals (SDGs) through innovation for a greener future.*

## Keywords

*environment, climate change, renewable energy, gate electrification*

## INTRODUCTION

Aviation is a catalyst for economic growth, which contributes to national economies by creating jobs and enabling trade and tourism. According to the International Air Transport Association (IATA), international air passenger travel has increased an average of 7 per cent annually since 2013 to 4.3 million in 2018.[1] IATA predicts the number of travellers will double by 2037.[2] While this growth contributes to economic wellbeing, the challenge facing the industry and the governments that regulate it is how to decouple aviation growth from its environmental impact.

According to the International Council on Clean Transportation, $CO_2$ emissions from commercial passenger and freight operations totalled 918 million metric tonnes (Mt) in 2018 or around 2.5 per cent of global energy-related $CO_2$ emissions.[3] Passenger transport accounted for 81 per cent of the total as shown in Figure 1. Emissions from aviation have grown 32 per cent over the past five years. International concern about climate change is increasing, and the aviation sector is expected to find effective ways for responsible and sustainable growth.

To address the impact of aviation on the global climate and promote sustainable growth of aviation, the International Civil Aviation Organization (ICAO) — a United Nations specialised agency — and its Member States adopted a global aspirational goal for the

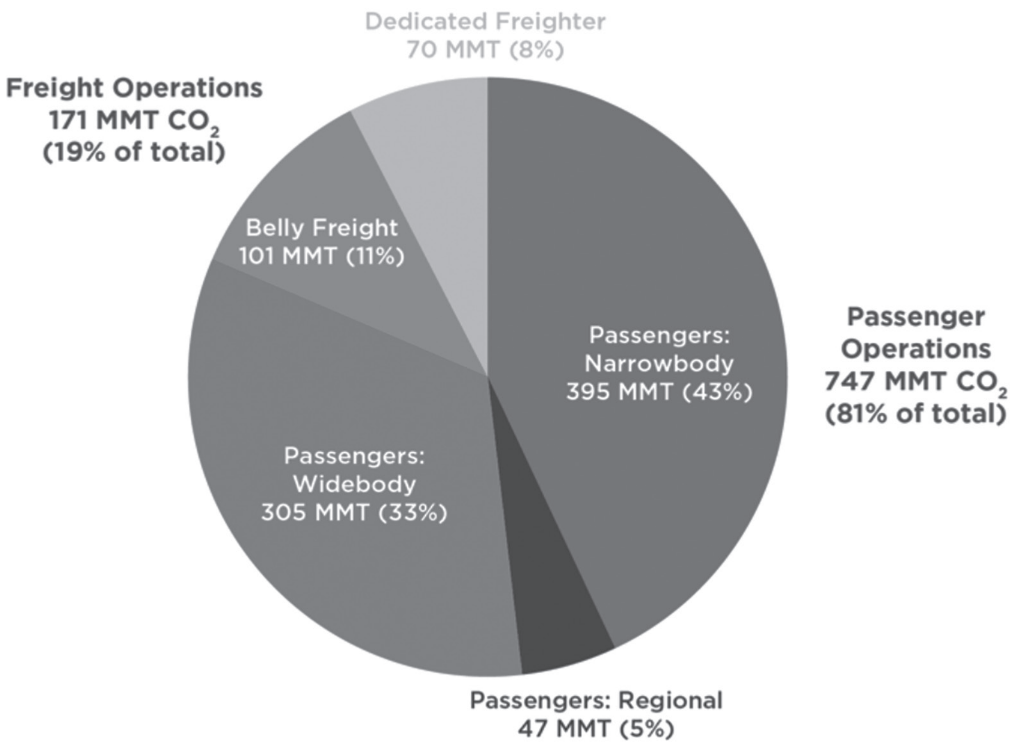


**Figure 1** $CO_2$ emissions in 2018 by operations and aircraft class
Source: Graver, B., Zhang, K. and Rutherford, D. (2019) '$CO_2$ emissions from commercial aviation, 2018', International Council on Clean Transportation, Working Paper 2019-16, available at: https://theicct.org/sites/default/files/publications/ICCT_CO2-commercl-aviation-2018_20190918.pdf (accessed 10th March, 2020).

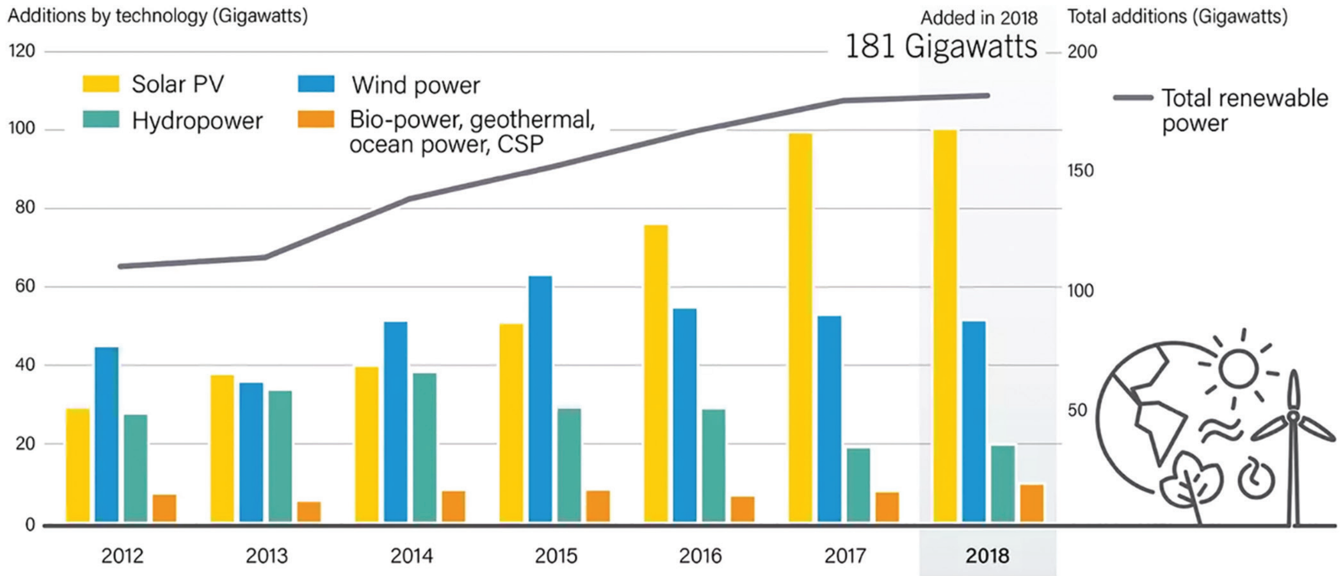


**Figure 2** Annual additions of renewable power capacity, by technology and total, 2012–2018
Notes: CSP, concentrating solar power; PV, photovoltaic.
Source: REN 21. (2019) 'Renewables 2019: Global status report', REN 21: Renewables Now, 10th May, Paris, France, available at: https://www.ren21.net/wp-content/uploads/2019/05/gsr_2019_full_report_en.pdf (accessed 10th March, 2020).

international aviation sector of keeping net carbon dioxide ($CO_2$) emissions at the same levels from 2020 onwards (ie achieving carbon-neutral growth). ICAO Member States also agreed on a basket of measures for reducing $CO_2$ emissions from aviation, which includes aircraft technology innovations, more efficient operations, the development and use of sustainable aviation fuels and a global market-based measure.[4]

The 2030 Agenda for Sustainable Development directs countries to pursue economic growth that is socially inclusive and environmentally sustainable. Innovation, to transform production, consumption and interaction, is particularly critical to the achievement of the UN sustainable development goals (SDGs). One important opportunity for States to achieve their environmental and carbon emissions-reduction objectives is through expanding use of renewable energy in the aviation sector.

## RENEWABLE ENERGY

Renewable sources of energy accounted for 2,378 gigawatthours (GW) of the global electricity supply, comprising approximately 26 per cent of the world's total electricity generation at the end of 2018.[5] In each year, since 2014, new renewable energy capacity has been greater than new fossil fuel and nuclear power installations combined. The greatest growth has been in the development of solar photovoltaic (PV), which has increased from 30 gigawatts to 100 gigawatts over a six-year period as shown in Figure 2. In 2018, 55 per cent of the new renewable capacity was from solar PV, 28 per cent from wind power and 11 per cent from hydropower. Airports are currently demonstrating the use of bioenergy, geothermal, hydropower, solar and wind as supplemental energy supplies.[6] There are at least 112 airports in the United States alone that have solar power facilities[7] with an additional 60 airports elsewhere in the world hosting solar power.[8] To encourage the adoption of renewable energy at airports, the ICAO published guidance in 2017 titled *Renewable Energy for Aviation: Practical Applications to Achieve Carbon Reductions and Cost Savings*.[9]

While the integration of renewable power into the electricity grid has progressed significantly in recent years, the transport sector has been slow to adopt renewable energy. REN 21, an international policy network dedicated to building a sustainable energy future with renewables, estimates that at the end of 2018, renewable sources represented only 3.3 per cent of the world's transportation fuel, a slight increase from 2017. Transport opportunities are associated with using biofuels, including sustainable aviation fuels, and convert fossil fuel-powered vehicles to electric-powered ones. Airports are increasingly working with airlines, ground handlers and system manufacturers to provide infrastructure for electric ground support equipment (eGSE) to move baggage and cargo between the terminal and aircraft and install gate electrification equipment to electrify aircraft gate operations.[10] While it is clear that electrification removes the fossil fuel emissions from the vehicle at its source, total emissions reductions from vehicle electrification depends on how the electricity obtained from the grid is generated.

## GATE ELECTRIFICATION SYSTEMS

Aircraft undergo a variety of avionics testing and data transfer associated with flight plans and measuring of aircraft performance, which requires on-board electrical power.[11] The interior of the cabin must also be heated or cooled for passenger comfort as well as for the crew working on the plane to get it ready for the next flight. Traditionally, pilots turn off engines on set down with chocks-on at the gate and run the auxiliary power unit (APU), a smaller, jet fuel-fired engine in the tail of the plane designed for use during power loss in the main engines or some other unforeseen power shortage on the aircraft. Running the APU on the ground generates air emissions that affect local air quality, including ingestion of ultra-fine particulates by ground-handling personnel, decreases the life span of the APU, and uses expensive jet fuel for aircraft power needs. These negative consequences led airlines and airports to work together with ground handlers and equipment manufacturers over the past 20 years to install equipment on the gate jet bridge to provide electricity and air conditioning (heating and cooling) to the aircraft as an alternative to running the APU. These units are collectively referred to as gate electrification systems. Many airports around the world, however, have yet to install gate electrification systems, and pilots are still using the APU to power aircraft at the gate between flights.

Gate electrification systems are comprised of a ground power unit (GPU) frequency converter and a pre-conditioned air (PCA) unit as illustrated in Figure 3. Because aircraft require electricity in a different form than what is available from grid-compatible buildings like the airport terminal, a GPU frequency converter is required. The unit, which is typically located either under the jet bridge adjacent to the aircraft or as a mobile unit that can serve multiple gates, converts terminal power from 50 or 60 Hz to the 400 Hz required for aircraft operation. The mobile 400 Hz frequency converter is small enough that it can be readily pulled into position

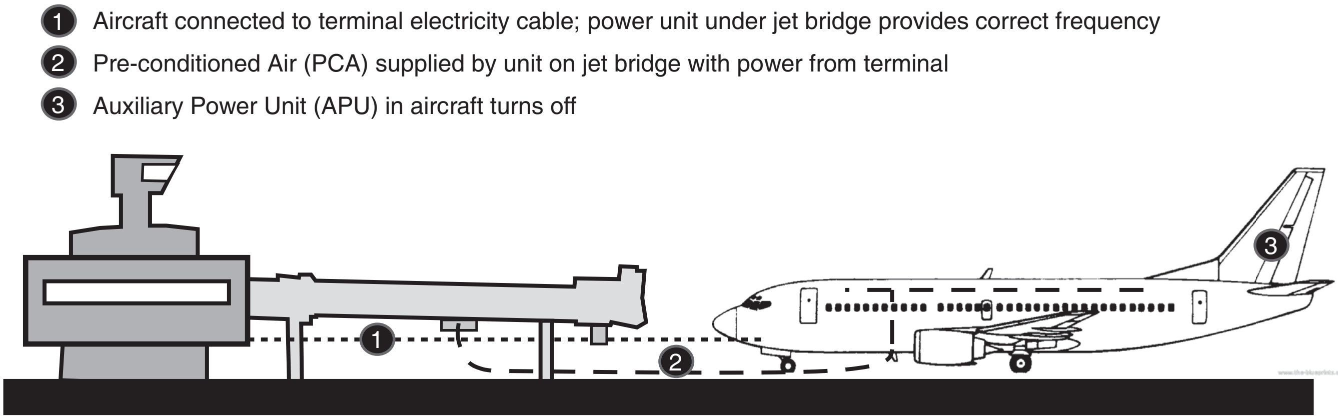


**Figure 3** Airport gate electrification systems
Source: Air Transport Action Group (ATAG). (2015) 'Aviation climate solutions', available at: https://aviationbenefits.org/media/125796/Aviation-Climate-Solutions_WEB.pdf (accessed 10th March, 2020).

by the ground crew. Mobile versions should not be confused with mobile diesel-powered GPUs, which also allow the aircraft APU to cease operation by providing power from a GPU, although with no on-site air emission–reduction benefits.

To provide heating and cooling functions, jet bridges can also be retrofitted with PCA units powered electrically from the terminal. PCAs generate heated or cooled air for the aircraft cabin. These units are larger than the 400 Hz GPU frequency converters, although they can also be mounted to the underside of the jet bridge, mounted on the ground near the jet bridge, or operated as a mobile unit. To be fully emissions-free, mobile PCA units need to be moved by a tug electrified with power from a renewable source.

Installing gate electrification systems increases the airport's demand for electricity necessary to replace the power previously provided by the APU. Airports draw power from regional electricity grids managed by the regional utility and generated by large regional power plants. The pollution characteristics associated with airport electricity use depend on how the power from the grid is generated.

As reported by REN 21 in its *Renewables 2019 Global Status Report*, 26 per cent of global electricity generation is coming from renewable sources, which means, on average, 74 per cent of the electricity mix is non-renewable.[12] The amount of renewable energy use, however, varies widely among States, from Iceland, which generates all of its electricity by hydropower and geothermal, to 35 other countries/territories with less than 5 MW of renewable energy capacity.[13,14] In most locations, using the gate electrification systems removes the pollution source from the airport, but it does not mitigate all of the emissions associated with the power.

## SOLAR AT-GATE CONCEPT

In 2016, the United Nations approved a new Clean Development Mechanism (CDM) small-scale methodology: solar power for domestic aircraft at-gate operations.[15] The methodology describes how States can install gate electrification systems for aircraft use at the gate and develop solar projects to provide

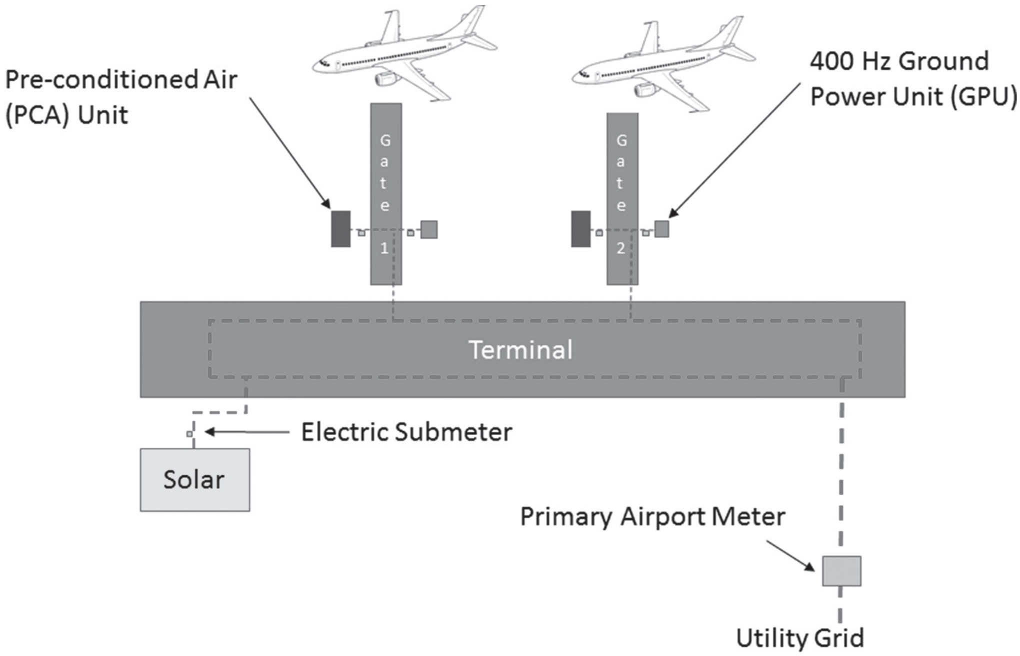


**Figure 4** Solar at-gate concept
Source: Stephen Barrett.

the additional required power from a renewable source and eliminate all emissions originating from the aircraft's APU. The components of the project are included in Figure 4. The concept recognises that gate electrification units must be connected to the airport terminal to obtain reliable power. It also recognises that airports are large consumers of electricity that draw power from the grid and consume any locally generated power on-site. Under these conditions, the airport's internal grid serves to store power generated in the airport, which then is consumed by various airport functions from lighting to powering airport systems (eg buildings, computers, security).

The objective of the solar at-gate concept is to eliminate global emissions from the APU when the aircraft is at the gate. To achieve this, the components of the solar at-gate system must be accurately designed and sized to accommodate the functions of the aircraft served. The gate units are designed to serve aircraft sizes in general categories referred to as narrow body, wide body and regional jets. Single or multiple units can be employed depending on aircraft size and whether the gate units are fixed or mobile.

Once the correct sizing of the 400 Hz GPUs and PCAs has been determined, the increased electricity demand from the units can be estimated. The calculation of electricity use is dependent on the turnaround time (or turn time), which is the time that aircraft are parked at the gate. On average, shorter, more frequent routes have shorter turn times and longer, less frequent trips have longer turn times.[16] It is most accurate if the airport can use actual turn times observed and recorded for the airport's specific use and operations activities. Average turn times representative of typical airports, however, can be used for planning purposes.[17]

Once the number of gate electrification units and their annual compounded run-time is known, the amount of additional electricity necessary to power the units can be calculated. Manufacturers can provide hourly power demand for each unit.

With the gate equipment power demand calculated, the compatibility of the solar project design and the capacity of the solar power facility necessary to supply the required power can be estimated. One of the siting advantages of solar is its modular construction, allowing the solar panels to be integrated into the airport landscape, either on building rooftops, in larger farms over unused airfield land, or elevated on canopy structures above surface car parks. Solar facilities can, however, impinge into airspace if located too close to runways or block radar signals when located near such facilities. In addition, the smooth surface of solar panels can also produce glare impacts on aviation sensitive receptors, such as control towers and aircraft, when landing.[18] The US Federal Aviation Administration's Solar Policy provides guidance on evaluating potential glare from solar PV projects and standards for determining impacts.[19]

In considering the size of a proposed solar facility, online tools are available from government sources to estimate electricity production and ensure that a sufficient amount of electricity will be supplied.[20] These tools use weather data for the project location often collected from long-term datasets at airport weather stations used for aviation purpose, which consider variations in latitude and cloud cover, to estimate electricity production from a solar facility with specific design characteristics. For example, the user can input a fixed solar PV system with a tilt angle, which optimally would be facing due south in the northern hemisphere or due north in the southern hemisphere to maximise electricity generation. Design constraints, such as roof orientation and tilt angle, however, may require adjustments to the prescribed facility design based on location. Tracking systems, which follow the path of the sun, can further optimise electricity production if space and operational needs can be met. After inputting information on a specific project design at a geographic location, the solar power-estimating tool will produce a reliable estimate of annual electricity generation expected for project planning.

Emission reductions associated with the project can be estimated using guidance included in the CDM methodology. A monitoring methodology is also included for verifying actual system performance, which is required for projects seeking to obtain CDM approval.

## SOLAR AT-GATE PILOT PROJECTS

As part of its capacity building and assistance strategy on environment, and to support States to meet the ambitious aspirational goals on environmental protection, ICAO developed three pilot projects, which consisted of the installation of airport gate electric equipment powered by solar PV facilities at three airports in Africa and the Caribbean. These projects aimed at demonstrating an innovative solution for a low-carbon air transport sector, which could be easily replicated by other States and directly contribute to the achievement of the UN SDGs, in particular, Goal 7: Affordable and Clean Energy, Goal 12: Responsible Consumption and Production, and Goal 13: Climate Action.

Participating States were identified based on completion of State action plans

**Figure 5** Solar PV project at Norman Manley International Airport, Kingston, Jamaica
Note: PV, photovoltaic.
Source: Stephen Barrett.

on emissions reduction and identification of renewable energy as a preferred activity of the Country to offset emissions from international aviation. The first project, funded by the Global Environment Facility (GEF) and the United Nations Development Programme (UNDP), proposed to install gate equipment at a single gate supported by a 100-kW solar PV array to supply the required power at Norman Manley International Airport in Kingston, Jamaica. The solar facility, inaugurated in April 2018, was comprised of a canopy structure in the parking lot, topped by solar panels to generate electricity and provide shaded parking. Along with its emission reduction capacity, one of the hallmarks of the project was incorporating new design elements for climate adaptation from lessons learned from Hurricane Maria in Puerto Rico such that the solar facility would withstand the force of a Category V hurricane. Figure 5 shows the solar canopy structure.

The second project funded by the European Union included two project sites in Africa: one at Douala International Airport, Cameroon; and a second at Moi International Airport in Mombasa, Kenya. While the pilot project in Jamaica focused on a single gate and enough solar power to address the additional electricity demand, these two projects in Africa considered emissions from aircraft parked at multiple gates, requiring larger solar PV facilities (1,200 kW and 500 kW, respectively) in ground-mounted arrays to supply adequate power. The Mombasa Project included mobile PCA and 400 Hz GPUs to allow aircraft parked at three fixed gates and three remote gates to receive electrification services. Figure 6 shows the mobile gate electrification equipment.

It also included an uninterrupted power system (UPS) and a lithium ion battery storage system to ensure that aircraft attached to the system would not experience any interruption in power


**Figure 6** Gate electrification equipment at Moi International Airport, Mombasa, Kenya
Source: Stephen Barrett.

should the grid power temporarily cease operation. This project component was critical because the airport regularly loses power for brief moments when the grid power goes down and before its on-site emergency power generator is engaged. If aircraft are connected to electric power and experience power loss for less than a second, a variety of avionics procedures would be discontinued requiring restart and potential delay in turnaround time. Battery storage systems also provide the airport with operational flexibility whereby electricity generated by renewable energy systems can be stored on-site for use at a later time. The ability to control when renewable energy is consumed may allow the airport to avoid purchasing power from the electric grid during peak consumption periods when prices are high, providing an economic advantage.[21] Renewables and battery storage can also be part of a long-term planning effort at building an airport microgrid, which would enable the airport to operate at times when there is failure in the regional electricity grid as the result of a natural disaster, terrorism or ageing equipment.[22] Installations of the Douala and Mombasa solar at-gate projects were completed in spring of 2019.

Ownership of the equipment associated with the projects was transferred formally by ICAO to the civil aviation authority in each country. Project contracts required the company that installed the equipment to conduct operations and maintenance for a five-year period to ensure that any glitches in operations could be addressed in the early years. Carbon emission reduction estimates for the projects range from 532 metric tons of $CO_2$ per year (MT/year) for the Jamaica Project to 1,287 MT/year for the Kenya project to 2,575 MT/year for the project in Cameroon.

## CONCLUSION

The approval of the CDM small scale methodology: solar power for domestic aircraft at-gate operations established a verifiable way for civil aviation authorities and their airport, airline and aviation business partners to reduce emissions from on the ground aviation activities. ICAO administered three demonstration projects to show ICAO Member States how these emission reduction projects could be implemented. As ICAO is responsible for international aviation, the projects were directed towards international flights (from/to different countries). The presence of the equipment, however, will result in emission reductions from all flights using it regardless of destination as cobenefits. It is expected that the success of these demonstration projects will result in the scale-up and replication at the national and international levels and can even catalyse a more expansive approach to reducing numerous carbon-generating activities associated with air travel.

One of the inherent challenges with gate equipment is that it requires a change in airport operations.[23] When aircraft operate their APU to provide on-board power, decision-making is centralised with the pilot based on guidance from the airline and in the context of airport rules. The use of the gate electrification equipment requires the airline's ground handlers to operate the equipment, which includes hooking up the 400 Hz GPU cable to the front of the aircraft and the hose associated with the PCA to the underside of the plane. The crew must be trained in how to deploy the new equipment. The equipment can easily be damaged if run over or not properly stored, which creates inefficiencies and increases maintenance costs. With these considerations, airlines may be reluctant to change ground handling procedures, which, in turn, would require leadership from the civil aviation authority to support new electrification practices. Some airports, like Zurich, mandate that airlines use the gate electrification equipment to decrease noise and air emissions.[24] There is, however, often collective agreement that use of gate electrification equipment may be impractical for short turn times although greater use of the equipment has led to higher frequency of use in all types of operations.[25]

In addition, hundreds of airports around the world have already installed gate electrification equipment, which has resulted in a reduction in emissions through the elimination of the APU with replacement power supplied by grid-sourced electricity.[26] Airports can take the next step and install solar power within the airport's local electricity grid and offset the grid power consumed by the gate electrification system to achieve a complete carbon-neutral solution for ground operations. Alternatively, they can use the same concept to offset a variety of other activities where grid power is consumed, resulting in air emissions associated with a regional plant that generates power to supply the grid. For example, solar power could be paired with a project to convert GSE to electric to provide carbon-free GSE operations. It could also be paired with a people-moving system or airfield lighting or electric ground transportation from shuttle buses. In each case, the new electrification project is increasing demand for grid power, which can be offset with solar power, creating an emissions-free package that maximises carbon reductions. As with the solar at-gate concept, the solar power is generated on-site at a capacity to meet the increased demand of the new electrification project and the airport's grid serves as temporary storage. The expected decrease in the cost of lithium-ion battery storage and its increase of use as a stationary storage facility and for powering vehicles (both on-road and off-road) will energise this transformation. Airports should consider how they can generate clean electricity on airport and convert fossil fuel combustion to electricity. The solar at-gate example demonstrates the opportunities associated with maximising airport electrification and supplying the new electricity demand with clean energy for carbon emission reductions consistent with the global efforts to address climate change, and at the same time, accelerating the achievement of the SDGs through innovation for a greener future.

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