TRANSFORMING THE GLOBAL AVIATION SECTOR

Emissions Reduction from International Aviation Assistance Project — Main Outcomes

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Contents

Introduction: ICAO-UNDP-GEF Capacity Building and Assistance Project

In 2014, the International Civil Aviation Organization (ICAO) established a partnership with the United Nations Development Programme (UNDP) to support Member States' requests for assistance in reducing their CO_2 emissions from international civil aviation. Financing for the partnership came from the Global Environment Facility (GEF). The *Transforming the Global Aviation Sector: Emissions Reduction from International Aviation assistance* project, which resulted from this partnership, supports the development and implementation of State Action Plans to reduce CO_2 emission from international civil aviation and to increase States' capacity to advance emission reduction measures. Multiple activities within the project have focused on capacity building to implement emission mitigating technical and operational measures, particularly targeting the needs of developing States and Small Island Developing States (SIDS).

The project contained four primary objectives:

I. Development of guidance documents to facilitate approaches to reduce aviation emissions in developing States and SIDS;
II. Setting up a web-based Low-Carbon Knowledge Sharing Platform;
III. Devising an analytical tool for States' to use when comparing the cost and effectiveness of emission mitigation initiatives; and
IV. Demonstrating an easily replicable, low emission installation by way of a pilot project, which serves as an example for developing States and SIDS.

The deliverables associated with each of these primary objectives are described in more detail within this magazine.

The magazine also summarizes lessons learned and the practical experience that came from planning and implementing the pilot project.

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1 State Action Plans on CO_2 Emissions Reduction Activities for International Aviation

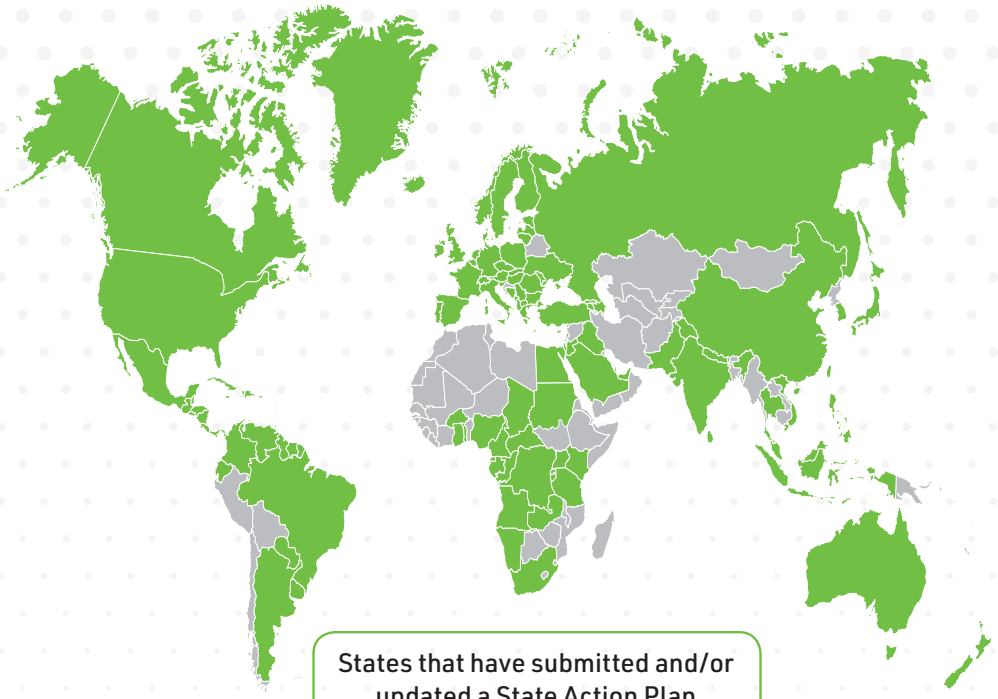
The ICAO State Action Plan initiative on CO_2 Emissions Reduction Activities for International Aviation allows States to establish a medium- to long-term strategy to address international aviation CO_2 emissions, in full cooperation with their national stakeholders. These strategies plot a pathway for achieving aviation emission reductions. State Action Plans identify policies and CO_2 mitigation measures that States, in coordination with other relevant stakeholders, intend to pursue to reduce CO_2 emissions from international aviation. State Action Plans include, inter alia, the State's baseline scenario for future international air traffic, fuel consumption and associated CO_2 emissions. They describe the selected mitigation measures and their expected emission reduction results over time.

The initiative supporting the development of State Action Plans has been very successful and as shown in the figure below, by 1 December 2018, 111 States had developed a State Action Plan and submitted it to ICAO, representing more than 90 per cent of international Revenue Tonne Kilometres (RTK).

ICAO has developed a guidance document on the *Development of States' Action Plans on CO_2 Emissions Reduction Activities* (ICAO Doc 9988), quantification tools, and other resources to support State's efforts to increase the civil aviation authorities' capacity to select and advance the implementation of emissions reduction measures. ICAO also conducts regional workshops and training seminars to support its Member States.

Through work done within the context of the ICAO-UNDP-GEF project, ICAO has developed a number of additional resources to support the implementation of State Action Plans and these resources have been made available on the ICAO website "*Transforming the Global Aviation Sector: Emissions Reductions from International Aviation.*"[1]

The deliverables include four guidance documents which delve into details on regulatory and policy strategies, financing emission reductions, renewable energy, and sustainable aviation fuels. These documents provide a level of detail useful to States and their stakeholders, as they plan their activities to reduce CO_2 emissions. Further details on the four guidance documents can be found in section 2, 3, 4 and 5 of this magazine.



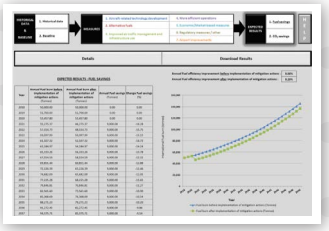
States that have submitted and/or updated a State Action Plan

1 www.icao.int/environmental-protection/Pages/ICAO_UNDP.aspx

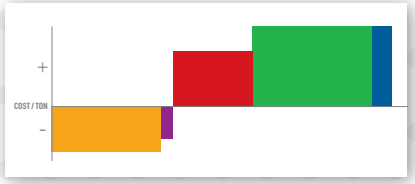
ICAO also produced a Knowledge Sharing Platform, which is an interactive tool through which ICAO Member States can find details on more than 1,000 emissions mitigation measures that have been successfully used across the aviation industry. These measures provide many options for developing States and SIDS to consider, as they select and develop their own emission mitigation strategies. Section 6 of this magazine contains further details on the Knowledge Sharing Platform.

To assess the CO_2 impacts of selected strategies, ICAO has developed a number of technical tools that can be used to compute fuel savings and CO_2 emissions reductions, evaluate environmental benefits, and support an assessment of the combined impact of the strategies and initiatives in a State Action Plan. A Marginal Abatement Cost (MAC) Curve tool was designed under the ICAO-UNDP-GEF project, in conjunction with the ICAO – European Union (EU) Joint Assistance Project,*Capacity building for CO_2 mitigation from international aviation*[2], and this complements an already extensive suite of tools at the disposal of ICAO Member States, namely the Environmental Benefits tool (EBT), ICAO Carbon Emissions calculator, Green Meetings calculator, and the ICAO Fuel Savings Estimation tool (IFSET). The MAC Curve tool is described further in section 7 of the this magazine.

Environmental Benefits Tool



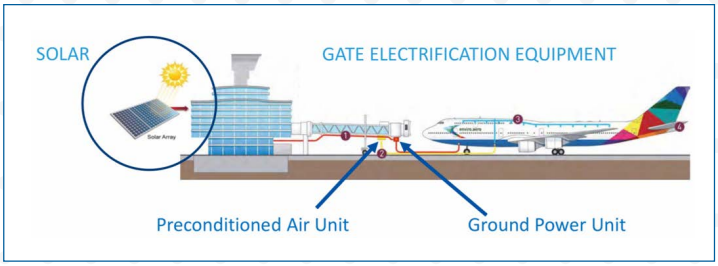
MAC Curve Tool

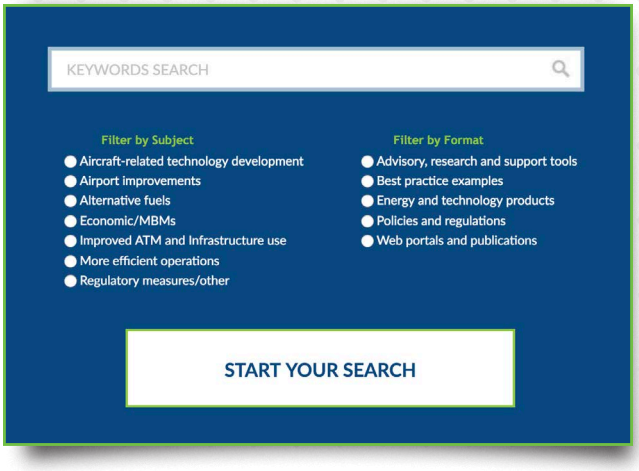


Fuel Savings Estimation Tool

Carbon Emissions Calculator

Finally, ICAO implemented a "solar-at-gate" pilot project at two Jamaican airports to reduce CO_2 emissions from aircraft while they are parked at the gate. This involved the installation of gate electrification equipment with energy supplied by solar power to replace jet fuel-powered Auxiliary Power Units (APUs) and diesel-fuelled Ground Power Units (GPU). This demonstrated the viability of a relatively small project to reduce international aviation emissions and this approach is easily replicable at other airports in developing States and SIDS, with financing from available development and environmental funds. Further details on the solar-at-gate pilot project can be found in section 8 of the this magazine.





2 https://www.icao.int/environmental-protection/Pages/ICAO_EU.aspx

2 Regulatory and Organizational Framework to Address Aviation Emissions

ICAO developed several guidance documents that support the ambitions of States to develop policies and implement measures that will support their emission reduction plans. A number of developing States and SIDS would like to commit to environmental protection measures for international aviation but only have limited human and financial resources to do so. Therefore, under the ICAO-UNDP-GEF project, guidance on *Regulatory and Organizational Framework to Address Aviation Emissions*[3] has been prepared to help ICAO Member States better understand their priorities in terms of environmental policy. Building upon the experience of several States, actions which facilitate synergies between existing and new environmental policies are presented. The guidance document illustrates how a State can structure its civil aviation authority in order to integrate environmental policies in the most cost-effective way, whilst ensuring that the implementation of priority actions is not compromised. In short, the guidance document provides details on why it is important to reduce international aviation emissions, the policy options available, why regulatory and organizational frameworks may be necessary, and the steps States can take to implement the necessary changes.

Many States, through their civil aviation authorities, are beginning to integrate environmental programmes into their planning and development and recognize that a dedicated structure and staff should be put in place to conduct the efforts. In such instances, it is essential to leverage existing policies and expertise within the State and therefore, coordination with other government agencies is a pre-requisite. Some States have realized that establishing or improving the national regulatory and policy frameworks is necessary to encourage low carbon technology deployment, as it can create the conditions for stimulating private sector market activity. Other States would like to benefit from low carbon technologies that are being successfully developed in other parts of the world. Under the circumstances described above, the Guidance Document on *Regulatory and Organizational Framework to Address Aviation Emissions* provides options for States to consider.

On the regulatory side, energy policy and programmes provide opportunities for Member States to expand the availability of clean electricity sources to power aviation activities, including those specific to international aviation. The civil aviation authority can operate in a supporting role, advocating for energy reform and incentive measures and in doing so, it may be able to attract private partners to reduce energy costs, improve supply diversity, and minimize emissions.

The added value provided by the guidance document is to identify policies that can serve as pilot initiatives to create capacity on environmental policies at the level of the civil aviation authorities. For instance, State Action Plans on CO_2 Emissions Reduction require States to estimate their expected international traffic, fuel consumption and CO_2 emissions in the medium to long-term. Then, States can work with all relevant stakeholders through their national State Action Plan team in order to identify a series of CO_2 mitigation measures that are specific to the circumstances of the States, in addition to the mandatory requirements of ICAO Standards and Recommended Practices (SARPS). These consultative groups can support the State in leveraging and establishing the necessary expertise and to define a series of prioritized actions with the objective of forming a coherent and tailored policy on climate change at the State level. In addition, some of the capabilities built

3 www.icao.int/environmental-protection/Documents/ICAO%20UNDP%20GEF%20RegulatoryGuidance.pdf

for the development of the State Action Plans, such as structuring the civil aviation authority for monitoring, reporting, and verifying CO_2 emissions from international civil aviation, also mark the first steps made by the State to prepare for the implementation of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).

The guidance document includes possible steps that States could take to integrate an environmental unit within their administration to achieve aviation-related environmental objectives.

While the focus of ICAO is on international aviation CO_2 emissions reduction activities, adopting policies and procedures appropriate to individual States can also minimize CO_2 from other energy consuming activities at the national level (e.g. at airports), beyond those from international aviation, and help enhance energy policies, thus creating environmental co-benefits. Building internal capacity to address climate change will also enable civil aviation authorities to better respond to the full range of aviation-related environmental issues, including local air quality and noise, as the overall understanding of the environmental impacts and mitigation initiatives increases.

Changes to organizational frameworks are primarily associated with increasing the capacity of the civil aviation authority to address environmental issues, including emissions reduction measures. As much of the environmental programmes and policies are being developed collaboratively by ICAO Member States and are complemented by national actions, it is important that the civil aviation authority builds capacity in its communications with ICAO such that it can facilitate access to technical assistance. This may include an ICAO liaison in order to ensure that the relationship between the State and ICAO on environmental matters is supported and enhanced. This liaison would typically be a member of environmental staff from the civil aviation authority. In the context of the ICAO State Action Plan initiative, this liaison is referred to as the "State Action Plan Focal Point".

Background

Emissions Reductions Organizational Framework

- International
- Regional
- Bilateral
- National
- Emissions Reductions
- Organizational Framework Overview

Environmental Policy

- Policy Objectives
- Policy Options
- Stakeholders
- Examples of Aviation Environmental Policy
- Environmental Policy Overview

Energy Policy

- Policy Objectives
- Incentives to Encourage Energy Alternatives
- Tools to Implement Energy Policy
- Interested Parties
- Examples of Energy Policy
- Energy Policy Overview

Case Studies of Organizational Frameworks

- Generic Model
- Member State Case Studies

Concluding Summary

References

3 Financing Aviation Emissions Reductions

Access to financial resources is considered a significant challenge for the implementation of emissions reduction projects by States, and can limit the ability of a State to deploy a comprehensive climate change strategy. The guidance document on *Financing Aviation Emissions Reductions*[4] provides ICAO Member States with an overview of project financing for low carbon technologies, the role of public and private organizations in providing financing, and a list of financing programmes and policies to help States fund their mitigation measures.

The guidance document also contains a valuable resource for States in search of financial support, as it provides a directory of public financing programmes for mitigating international aviation emissions (contained in Annex A of the document). An analysis of the available funds shows that a significant amount of financial resources are being directed toward programmes associated with climate change mitigation. These programmes are closely tied to public climate financing through the United Nations, multinational development banks, non-governmental organizations, and various private partners and stakeholders.

The guidance document presents an introduction to CO_2 emissions reduction financing instruments with an emphasis on how these programmes incentivize private investment, and how they may offer opportunities for States to implement CO_2 emissions reduction measures. It is shown that new financing models, where the combination of public and private capital delivers the highest multiplier effects, are becoming more frequent. Experiences from developed States have been drawn upon, where targeted public policies have encouraged private investment in low carbon projects, like those associated with the renewable energy industry, creating markets where such alternatives compete with energy generated from fossil fuels. While private financiers are examining new and emerging markets in which to make investments and expand their businesses, it is clear that public finance programmes and policies are critical to reducing risks to private sector investment, and will provide new opportunities specifically for the aviation sector.

It is worth noting that in the area of international aviation, the State Action Plans on CO_2 Emissions Reduction Activities provide the opportunity for States to establish their medium- to long-term climate change strategy, in full cooperation with their national stakeholders. ICAO Member States are invited to assess the future international air traffic and associated fuel consumption and CO_2 emissions in the absence of any mitigation measures. The State Action Plan also encourages States to identify a combination of mitigation measures, taking into account the regulatory requirements and voluntary initiatives. For each measure, the expected CO_2 benefits and the implementation costs should be indicated. Therefore, when States consider the implementation of the measures included in their action plan, they can build upon the information already collected and the buy-in of national aviation stakeholders to submit a robust business case to secure financing. They can demonstrate that these measures are part of a wider and long-term strategy on climate change and that they can create supplemental benefits for other sectors (for example: energy, social, economy).

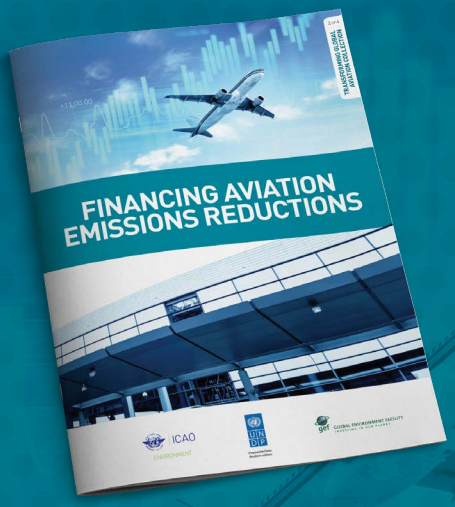
The guidance document is an attempt to provide a simple and schematic approach to a complex network of public financing programmes. These programmes are building capacity by

4 www.icao.int/environmental-protection/Documents/ICAO_UNDP_GEF_FinancingLowCarbonAirportGuidance.pdf

informing existing government institutions about climate challenges and opportunities, providing information on new regulatory and legal frameworks, and connecting staff with other stakeholders that can help advance climate programmes. A few recommendations can be drawn to facilitate States' initiatives with the aim of securing funding for low emissions aviation projects:

- Project financing can be complex and may require that the civil aviation authority coordinate with other national stakeholders to access specific information and expertise;
- Financial instruments long used in international development have been modified to benefit climate financing. They provide great opportunity for developing States, but depend on close cooperation with international agencies;
- Public financing to reform the energy sector and incentivize low carbon energy, which must be developed within the State, is critical to attracting private investment;
- State Action Plans developed using ICAO Doc 9988, *Guidance on the Development of States' Action Plans on CO_2 Emissions Reduction Activities*, can be a good starting point for financing projects to reduce international aviation emissions; and
- Using internationally approved plans and methodologies as the basis to assess potential CO_2 benefits from projects can highly facilitate the approval of green financing for selected aviation projects.

While each State has different challenges and opportunities, the guidance document on *Financing Aviation Emissions Reductions* provides the reader with insight into public climate financing programmes and how they may be accessed to provide long-term sustainable growth in the international aviation sector.



4 Renewable Energy for Aviation

Aircraft entering airlines' fleet today emit 80 per cent less CO_2 emissions than the first jet aircraft. Despite tremendous progress in aircraft technology development, aeroplanes remain the primary source of CO_2 emissions on the airport site, during the landing and take-off phase. ICAO has considered the possibility to implement clean, renewable energy sources to perform some aircraft operations while on the ground and has identified that solar energy could be used to feed the electricity needs of aircraft parked at the gate, in place of the kerosene used by the aircraft Auxiliary Power Unit (APU).

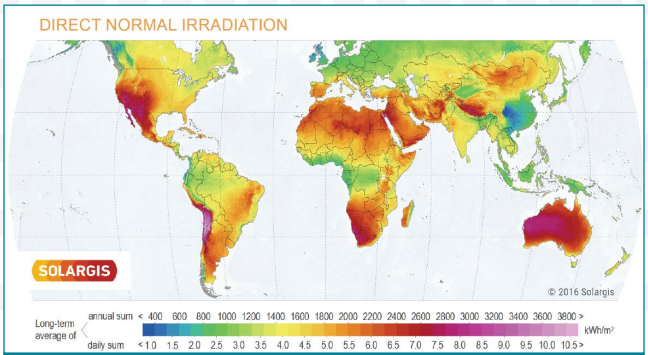
In its 2016 Medium-Term Report on Renewable Energy, the IEA stated that renewable power accounted for more than half of the world's additional electricity capacity in 2015 as the result of supportive government policies and sharp cost reductions. Pioneering airports across the globe have participated in this growth through the successful deployment of renewable energy at airports. As renewable energy systems have become increasingly economical to deploy, and airports and their stakeholders have become more aware of the economic, environmental and social benefits that renewable energy provides, this growth in the deployment renewable energy has continued. The demonstration of solar at-gate projects in ICAO's assistance projects participant States (Cameroon, Jamaica, and Kenya) are important pilot projects that can be replicated in other States and provides a clear step towards ICAO's environmental objective of reducing emissions from international aviation. The experience presented throughout the guidance demonstrates that renewable energy projects can be successful and easily replicable.

The purpose of the guidance on *Renewable Energy for Aviation: Practical Applications to Achieve Carbon Reductions and Cost Savings*[5] is to inform ICAO Member States on how renewable energy can be deployed to reduce CO_2 emissions from international aviation activities at and around airports. While ICAO's focus is on international aviation CO_2 emissions reduction activities, developing airport renewable energy projects can also minimize CO_2 from many energy consuming activities at airports beyond those that relate to international civil aviation

The guidance document increases the understanding of energy usage in relation to

Seymour Airport, operated by the Argentinian company Ecogal S.A., is believed to be the only airport in the world working exclusively on wind and solar energy. (Source: Ecogal S.A)

5 www.icao.int/environmental-protection/Documents/ICAO_UNDP_GEF_RenewableEnergyGuidance.pdf



The amount of electricity that can be generated on a given surface area in a given time varies by geography and climate. The amount of potential electricity generation from solar per day across the world is shown. (Source: DNI Solar Map © 2016 Solargis)

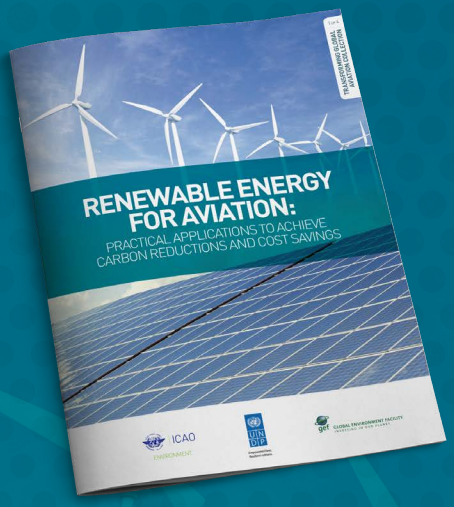
aviation activities, including electricity, heating and passenger mobility. It explores the close link between climate change and energy policies and emphasizes the necessity to create synergies between both policies, so that their impacts are maximized.

The document provides unique guidance on the technical, environmental, economic and financing characteristics associated with the implementation of various renewable energy sources (solar PV, wind, hydro geothermal, geothermal heat pump, solar thermal and biomass). It also provides recommendations on the fundamental steps for planning and developing a renewable energy project, and a summary of several project examples from existing airports worldwide.

These examples demonstrate that renewable energy can also be a key component of facility modernization and economic development.

The guidelines provided to developing States and SIDS on the implementation of renewable energy projects at airports should facilitate the replication of such projects.

Airports around the world have deployed renewable energy to generate on-site power. Reductions in CO_2 emissions are most frequently identified as a primary factor for developing such projects. Beyond that overarching driver, airports have pursued project development influenced by geography, available resources, and opportunity. Renewable energy case studies provide an insight into what individual airports have accomplished.



Background

Introduction

Energy and Climate Change

- Aviation Energy Reduction Opportunities
- Parties Involved with Aviation Energy Reduction
- ICAO-UNDP Assistance Project
- ICAO-European Union (EU) Assistance

Renewable Energy and Airports

- Airport Energy Use
- Renewable Electricity
- Renewable Thermal Energy
- Microgrids

Project Conceptualization

- Defining Project Objectives
- Identifying Regulatory Barriers and Opportunities
- Assessing Project Feasibility

Project Financing

- Airport Owned, Net-metered
- Third Party Owned, Grid Purchased
- Third Party Owned, Airport Purchased

Example of How to Plan an Airport Solar Project

- Plan the Project
- Issue a Tender
- Construct the Project
- Commission and Monitor

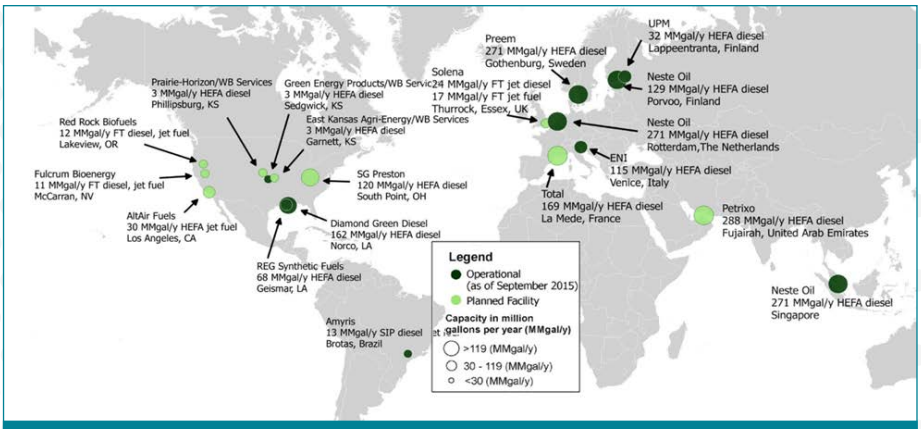
Airport Renewable Energy Case Studies

Concluding Summary

References

5 Sustainable Aviation Fuels Guide

During the 37th Session of the ICAO Assembly, ICAO Member States adopted two aspiration goals for international aviation of 2 per cent annual fuel efficiency improvement and carbon neutral growth from 2020. A basket of measures was also defined, including technology and standards, operations, sustainable aviation fuels (SAF) and a global market-based measure. Since then ICAO has been working with its Member States to make progress on each element of the basket of measures.



The operational and planned facilities with the capability to produce SAF is shown and as of 2015, these facilities summed up to a production capability of 6.2 million tonnes of SAF/year. (Source: adapted from Radich, 2015)

Since SAF were accepted as a CO_2 emissions mitigation measure for international aviation, significant progress has been made with regard to the production, certification and commercial use of SAF and as of December 2018, six production pathways have been certified and more than 150,000 flights have been operated with a blend of SAF and conventional aviation fuel.

The *Sustainable Aviation Fuels Guide*[6] takes stock of the initiatives carried out by ICAO to design the framework that States and international aviation stakeholders need to further the development of SAF. The document also clarifies important concepts related to the use of SAF, such as the concept of "drop-in" fuels and looks into the roles and responsibilities of each stakeholder for the development of SAF. The requirement that a fuel be "drop-in" is essential for the aviation industry because a drop-in SAF would not need to be handled separately from current aviation fuel.

The document provides practical guidance on the national conditions to be met to develop a SAF market, highlighting that "one size does not fit all" and that thorough feasibility studies are a pre-requisite to the further consideration of a SAF supply chain. It also details the technical characteristics linked to the processing routes for the production of SAF and introduces schemes for sustainability certification.

While the combustion of SAF emits similar quantities of CO_2 to the combustion of current aviation fuels, SAF provide an environmental benefit on a life cycle basis. The guidance document provides details on the fuel life cycle, showing that it is made up of multiple steps from the feedstock to the final use in an aircraft engine.

As shown throughout the guidance document, States, airports, airlines, and other aviation stakeholders around the world are already involved in SAF deployment projects, ranging from small scale research projects to commercial scale SAF production facilities. There is a multitude of feedstocks and conversion processes available for

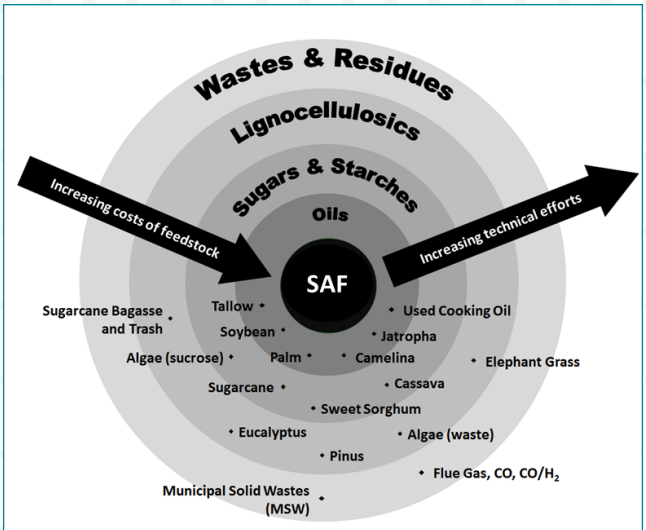
6 www.icao.int/environmental-protection/knowledge sharing/Docs/Sustainable%20Aviation%20Fuels%20Guide_vf.pdf

SAF production, which allow flexibility for setting up SAF supply chains tailored to the particular characteristics of each State.

The SAF Guide addresses the practical and operational considerations related to the development and deployment of SAF, including how to improve their economic competitiveness and how to ensure an appropriate system for transport, distribution and storage of these fuels. These aspects are crucial to ensure a robust market for SAF. The SAF Guide also presents some guidelines on setting a national programme for promoting SAF.

The *Sustainable Aviation Fuels* Guide is a one-stop shop for States and aviation stakeholders that wish to contemplate the opportunity to engage in the production, commercialization and use of SAF, supported by practical case studies.

In addition to contributing to the ICAO global aspirational goal of carbon neutral growth, the development and deployment of SAF can advance the social and economic development associated with the UN Sustainable Development Goals (SDGs).



There is an economic trade-off observed when selecting pathways for SAF production. Moving towards the centre of the diagram, the feedstocks typically become more expensive, but the conversion technology is simpler or less costly. (Source: Boeing and others, 2013)

Background

Introduction

- The work of ICAO on Environmental impacts and Climate Change
- The work of ICAO on Sustainable Aviation Fuels
- The work of ICAO on a Global Market-Based Measure

Sustainable Aviation Fuels

- The growing interest in SAF
- The essential "drop-in" concept
- Emissions reductions from SAF
- Drivers to develop SAF

Conditions for promoting SAF

- Stakeholders' roles and responsibilities
- National conditions to develop a SAF market

How to produce SAF

- Approved conversion processes
- Feedstock options
- Processing routes
- Sustainability of aviation fuels
- Schemes for sustainability certification

How to promote the use of SAF

- Economic considerations
- Supporting measures for SAF industry
- Logistics of aviation fuels
- Quality certification of SAF
- Developing a national SAF programme

Case studies and best practices

Conclusions

Bibliography

Annex A Sustainability concepts – Life Cycle Assessment and Land Use Changes

6 Knowledge Sharing Platform

Among the many products and guidance materials that ICAO has developed to support States' strategies for reducing their CO_2 emissions is the ICAO Knowledge Sharing Platform. It is a ready-to-use reference to proven strategies and projects that have been implemented by international aviation stakeholders, worldwide. The ICAO Knowledge Sharing Platform brings together the latest and most relevant information on climate mitigation efforts, as well as other environmental issues, in the air transport section. It can be used to build-up a State's Action Plan or identify a low carbon emission strategy for an individual airport. It creates a space for the aviation community to share and discuss its experiences implementing low-emissions measures. By sharing and combining this collective knowledge, the ICAO Knowledge Sharing Platform aims to assist those who are the most vulnerable to climate change.

The ICAO Knowledge Sharing Platform compiles and disseminates a wide range of informative materials and best practice examples relevant to low emission aviation measures. The information used to populate the database was drawn from a variety of ICAO internal resources, as well publicly available third party sources. The platform comprises over 1,000 examples of low emission aviation measures from different States across all ICAO regions.

A search of the platform returns many results that may include projects, policies, guidance documents, tools, and outreach initiatives. From the list of search results, individual initiatives can be selected to learn more about that measure and whether it would apply to a State's or stakeholder's circumstances. Individual searches result in extensive details on a specific project, tool, or other resource.

The measures collected are classified according to seven main categories of measures, consistent with the ICAO Basket of Measures:

1) Aircraft-related technology development
2) Airport Improvements
3) Alternative fuels
4) Economic/market-based measures
5) Improved air traffic management and infrastructure use
6) More efficient operations
7) Regulatory measures/other

The database further distinguishes five formats to group the identified measures:

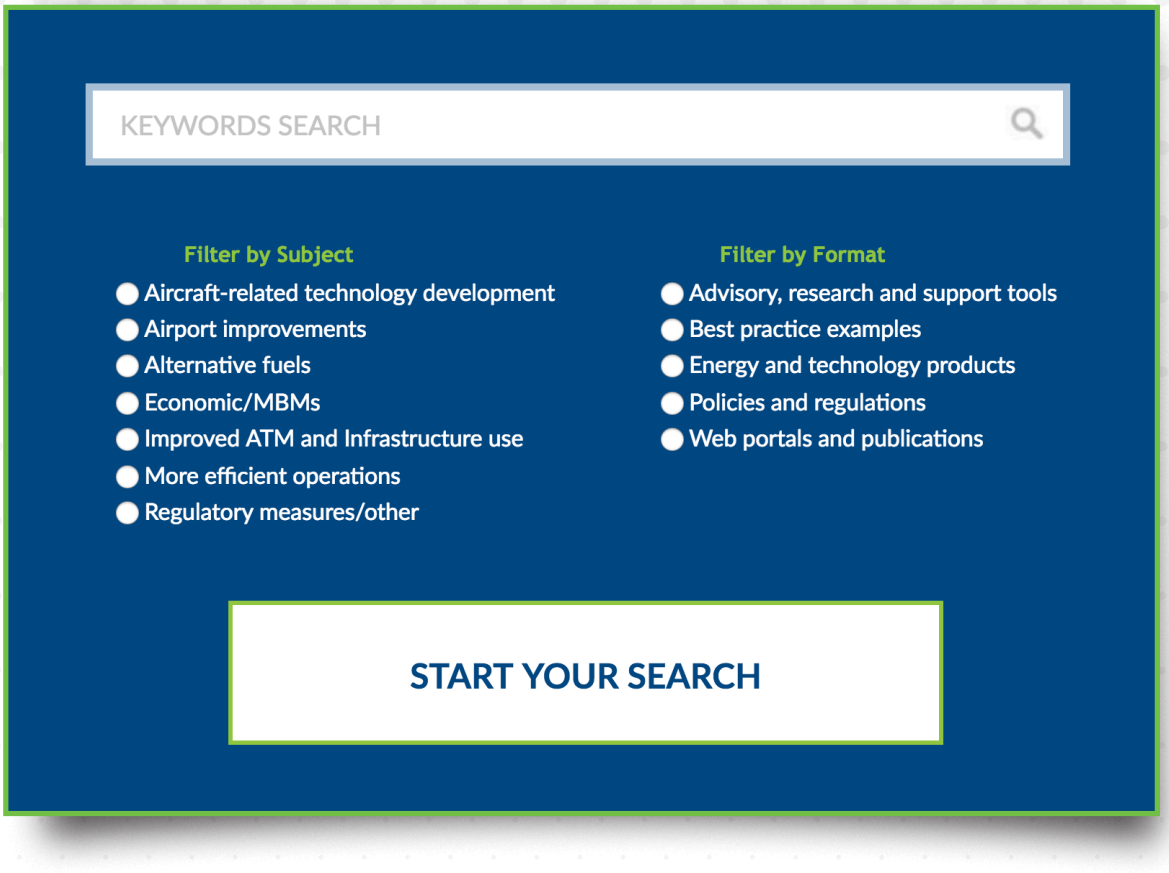
1) energy and technology products
2) policies and regulations
3) web portals and publications
4) advisory, research and support tools
5) best practice examples

Other relevant descriptors used within the database include the name, type, and location of the entity from which the example was taken, the relevant ICAO Region, as well as, in some cases, the year in which the specific measure was implemented.

In addition to the searchable database, the host website contains specific sections with selected videos on aviation and environment, materials and tutorials, as well as a document library where users can access relevant ICAO guidance materials.

Finally, a major asset of the platform is the ability to generate live interactions between users and ICAO. It introduces an "Expert Community", where stakeholders and interested parties can submit specific questions regarding the various aspects surrounding the use and implementation of low emission aviation measures. Responses to questions will be posted by relevant experts at ICAO and their responses, together with the original questions, will be shared online for everyone's benefit.

Specifically, the aim is to strengthen national capacities, processes, and mechanisms to reduce CO_2 emissions from international aviation, particularly in developing States and SIDS. The information gathered on the various mitigation options available to the aviation community can fuel the discussions held at national level by ICAO Member States, while they are in the process of developing or updating their State Action Plan.



7 Project Planning Using Marginal Abatement Costs

Numerous measures are available to States and their aviation stakeholders seeking to reduce CO_2 emissions from international aviation. Limited financial and technical resources represent a challenge for the implementation of these measures and make prioritizing a necessity. In this context, the ICAO-UNDP-GEF project, in conjunction with the ICAO – European Union (EU) Joint Assistance Project, has enabled the development of a tool supporting States and their stakeholders in their discussions on the prioritization of the implementation of CO_2 mitigation measures for international aviation.

This tool is based on the Marginal Abatement Cost (MAC) curve concept. MAC curves illustrate the relative CO_2 emissions reductions from possible measures on a comparative cost basis. They provide a simple, quantitative way to directly compare the costs and amount of CO_2 emission reductions associated with numerous projects.

Marginal Abatement Costs

Any single emissions mitigation project has a limit on the maximum possible CO_2 emissions reductions and similarly each proposed measure requires a specific investment to achieve these reductions. MAC curves are a way to compare projects on a common basis. By evaluating projects in terms of the cost to reduce one ton of emissions analysts can readily compare various projects. MAC curves plotted according to $/ton of CO_2 reduced compare multiple project costs while highlighting the total potential emissions reductions.

Since some projects reduce energy use or other operating costs over current operations, they can actually have a negative $/ton of CO_2 reduction, saving money for the project sponsors. By plotting multiple projects sponsors can compare and prioritize them.

ICAO analyzed emissions mitigation measures, using expert knowledge and the information included in the State Action Plans submitted by its Member States. Using this data, ICAO developed global MAC curves, which can be used to simplify the process of calculating the emission reduction costs for specific projects and so putting the amount of emission reductions in priority order. The Global MAC curves for 2020, 2030, 2040 and 2050 can be found on the ICAO website[7]. Using the MAC Curve Tool as a focal point for their analysis, States can input local data to create MAC charts specific to their conditions to prioritize and estimate needed investment to achieve their CO_2 emission reduction goals.

MAC Curve Tool

The MAC Curve Tool allows States to conduct a dedicated and tailor-made cost-benefit analysis of the most popular mitigation measures included in the ICAO basket of measures to reduce CO_2 emissions from international aviation. It is simple to use and requires a limited amount of information from the user, adjusting to the specific circumstances of States.

The results of the analysis performed by the tool will guide civil aviation authorities and the national stakeholder teams who develop the State Action Plan, as they select and prioritize mitigation measures to be included in the plan. The tool provides a brief overview of potential emission reductions for a given scenario. The MAC Curve Tool allows the MAC curves to be tailored to the individual reality of States, allowing them to input their local data, create MAC charts specific to their

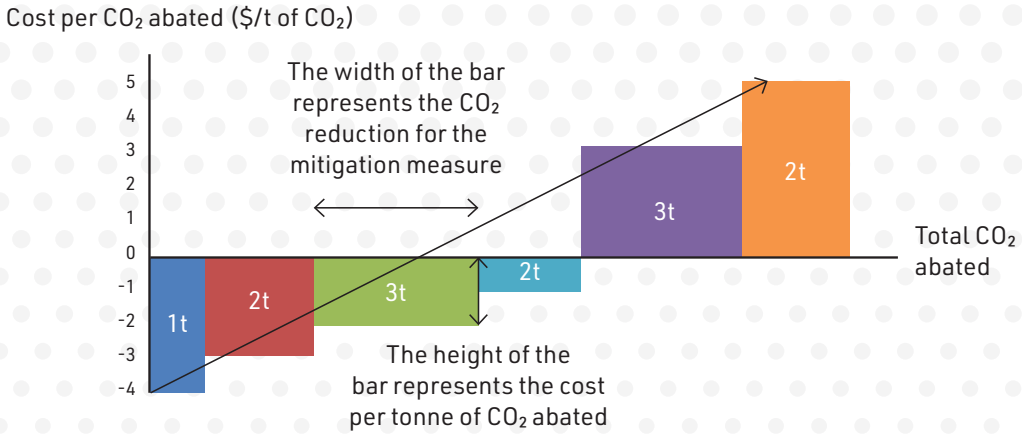
7 https://www.icao.int/environmental-protection/Pages/ICAO_UNDP.aspx

conditions at various time horizons, and prioritize the measures to be implemented in light of their own circumstances.

The ICAO-UNDP-GEF project, in conjunction with the ICAO – European Union (EU) Joint Assistance Project, enabled the development of a global MAC curve, showing the global abatement potential for 20 CO_2 mitigation measures identified by ICAO (shown in the box to the right). It ranks these measures by cost-effectiveness and the width of every bar is an approximate visualization of the measure's CO_2 emissions reduction potential.

Using the ICAO resources helps States obtain essential information on the financial costs and CO_2 emission reduction benefits associated with the various measures. The approach provides technical support and practical guidance enabling the user to identify feasible emissions reduction measures and allows them to make informed decisions about implementing CO_2 mitigation measures.

How to read a MAC curve

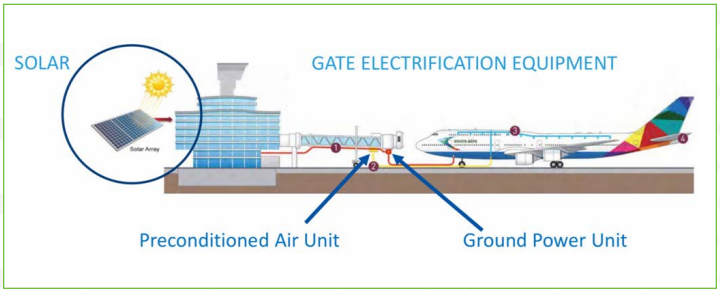


MAC Curve Tool – Available Mitigation Methods

- Purchase new aircraft
- Improve fuel efficiency through development or modification
- Replace engines
- Develop sustainable aviation fuel (SAF)
- Improve pre-departure planning (DMAN) and arrival planning (AMAN)
- Improve collaborative decision-making (A-CDM)
- Improve air traffic management in non-radar airspace
- Improve fuel efficiency of departure and approach procedures
- Introduce continuous climb and descent procedures
- Improve aircraft guidance on apron
- Improve taxiing
- Minimise weight
- Minimise flaps (takeoff and landing)
- Minimise reverser use
- Reduce speed
- Optimise aircraft maintenance (engine washing and zonal drying)
- Select aircraft best suited to the mission
- Install fixed electrical ground power and preconditioned air to enable auxiliary power unit switch-off
- Use cleaner alternative sources of power generation (for fixed electrical GPU and PCA)
- Construct taxiways and speed exits

8 Management of the Solar-at-Gate Project

One of the main deliverables under the ICAO-UNDP-GEF project was a small-scale project that could be easily replicated, and which would illustrate both the use of clean energy and the associated CO_2 emissions reductions for international aviation operations. Following the assessment of several potential measures, a solar-at-gate pilot project was selected to be implemented in Jamaica.



ICAO implemented the pilot project at two Jamaican airports to demonstrate how SIDS could use renewable energy at an airport to reduce CO_2 emissions from ground operations while an aircraft is parked at the gate. Aircraft conventionally use on-board auxiliary power units (APU) and ground power units (GPU) to provide electricity and cabin climate control while an aircraft is parked at the gate. Electric equipment, comprised of a pre-conditioned air (PCA) unit and a 400 Hz ground power frequency converter, was installed at airport gates used for international flights at Norman Manley International Airport in Kingston and Sangster International Airport in Montego Bay.

A photovoltaic solar power facility was installed at Normal Manley Airport, sized to supply the power demand to operate the gate electrification equipment in order to supply renewable electricity to an aircraft during gate operations. At Sangster Airport, one airport gate servicing international flights was electrified, with the aim of encouraging the investment in the solar power facility from a private supplier to be identified by the airport, thus illustrating the possibility to combine public and private financing sources. The combination of electricity generated by photovoltaic cells and gate electrification equipment, in lieu of equipment using fossil fuels, completely eliminates the CO_2 and local air quality emissions from gate operations. In the case of Norman Manley Airport, the avoided emissions at one gate are equivalent to permanently removing 40 cars from the road. To support the public education and outreach component of the project, a display showing real-time electricity generation from the solar-at-gate project is included in the airport terminal and this shows the practical emission reduction benefits, presented in cars removed from the road or trees planted.

While focusing the pilot project on the reality of SIDS and the reduction of CO_2 emissions from international aviation, this climate change mitigation action also embeds a climate change adaptation measure, as it was designed to withstand a Category 5 Hurricane.

This small-scale demonstration project now serves as a model for other airports to follow as an emission mitigation strategy. Many experiences were gained during the design and implementation of the solar-at-gate project and the following describes the steps involved from conceptualization to full operation:

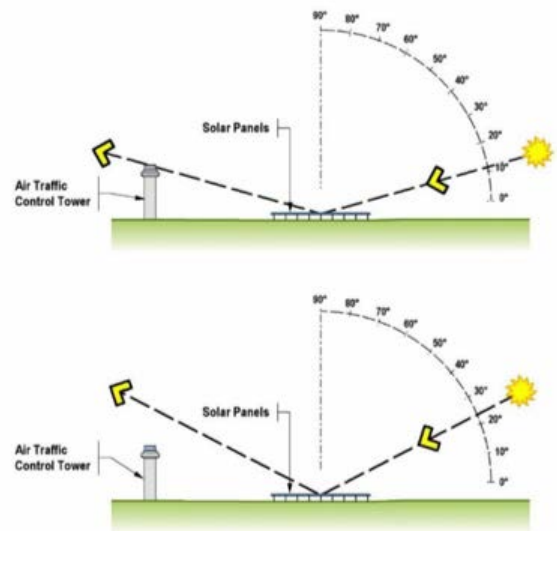
- Develop the concept with local partners
- Conduct a risk analysis
- Secure funding
- Prepare a tender
- Hold a bidders' conference
- Review bids and select a contractor
- Design, construct and install the solar and gate components
- Commission the equipment
- Begin operations

Develop the concept with local partners

Jamaica had developed a thorough State Action Plan for reducing the State's CO_2 emissions from international civil aviation and Jamaica was interested in working with ICAO on an emissions reduction project. As the project was being planned, ICAO and UNDP contacted the Jamaica Civil Aviation Authority (JCAA) regarding an opportunity to demonstrate an emissions reduction measure. The JCAA and local airport authorities showed significant leadership and interest to participate. As a result of their preparedness and willingness to engage in such a project, ICAO chose to work with Jamaica to install a complete solar-at-gate project at Normal Manley International Airport in Kingston and to install similar gate electrification equipment at Sangster International Airport in Montego Bay. The solar component of the project at Montego Bay is to be installed at a later time, relying on a private partner, to be selected by the airport.

Conduct a risk analysis

A full risk assessment was carried out at the beginning, and periodically during the the project development and installation. This covered project management, technical and operational aspects of the solar-at-gate installation.



Glare Analysis

One important risk consideration was the expected maximum wind conditions. Initially the wind specification was to accommodate a Category 3 hurricane, that is 178 km/hr, which was the maximum wind specification that solar manufacturers could accommodate according to the Jamaican solar industry. Following both Hurricanes Irma and Maria the Category 5 Hurricanes which tracked through the Caribbean area during the Autumnof 2017, the wind speed specification of the solar panel array was upgraded to Category 5, meaning that it can withstand wind speeds of up to 252 km/hr. This required adding additional clips to make the attachment of the solar cells to the supporting structure more robust.

Another operating concern with solar installations near airports is reflectivity where sunlight is reflected from the solar panel surface. Impacts of this reflection include glint and glare, which can cause a brief loss of vision. This can be annoying at best and potentially dangerous at worst if it effects the vision of pilots or air traffic controllers. Conducting a glare analysis has been standard practice for major solar installations for several years and in Jamaica, modelling tools were used to ensure no adverse impacts would occur on aircraft operations.

Another project risk was the expected lifetime of the project. In light of the operating environment, unfamiliarity of the technology, and the need for system interoperability, the project planners did not want to simply walk away from the facilities following startup. To address this concern the tender specified that the selected contractor would stay involved with the operation and maintenance of the equipment for two years. This helped airport staff learn the details of the operation, define the need for spare parts, and integrate the overall project into the regular airport operations and maintenance practices.

Developing a proper outreach and communication strategy for the project is essential in managing the risk associated with a misunderstanding of the project objectives and deliverables, which could result in a lack of support for the solar-at-gate projects replicability. Fully communicating

the successes and promoting the replicability of the solar-at-gate project is important, not only for the further local development of the installation but also for the outreach of the initiative globally. The outreach for this project involved many activities during the various stages of its development. It included leaflets describing the project and its deliverables during the launch of the work, seminars to communicate the progress and results, and the promotion of the work at other events around the world. It also included material such as the development of this magazine and a website containing all the project details.[8] The public education objectives of the project were also important to consider, and the project scope required the contractor to provide a digital education display in the terminal building capable of presenting real-time electricity generation information from the solar-at-gate project at Norman Manley International Airport. In addition, a static information sign was designed and included at the site of the solar project to provide travellers with simple information about the project. Overall, the communication and outreach component of the project was aimed at a target audience of ICAO Member States, aviation stakeholders, financial institutions and the general public.

Secure funding

The scope of the project in Kingston included the 400 Hz ground power frequency converter, an electric preconditioned air unit, and a 100 kW solar panel array on a nearby parking lot canopy. In defining the project scope, a detailed financial estimate was developed in addition to calculating the expected CO_2 emission reductions.

This project was consistent with the available financial resources committed by ICAO and no outside funding was secured to install both the gate electrification equipment and the solar panel array at Normal Manley International Airport in Kingston. For Sangster International Airport in Montego Bay sufficient funding was secured to install the gate electrification equipment and the solar component is to be installed at a later time, relying on a private partner, to be selected by the airport. This approach allowed the project to demonstrate two different funding models.

Over the course of the project, ICAO, UNDP, JCAA, Normal Manley airport management and staff attracted other interested stakeholders who played essential roles in ensuring the success of the project. This included representatives from the local UNDP office, local solar developers, environmental organizations, representatives of the local township and parishes as well as airlines and ground handling companies who serve the airport.

Prepare a tender

Following the development of the project scope, a project tender was developed over several months. Detailed equipment specifications were a major part of the tender. Example issues that were evaluated during this period included:

- The technical specification of the project, including energy needs and the size of the solar array;
- Identifying the international electrical codes and standards that would be applicable; and
- Reviewing local environmental conditions to specify operating limits for temperature, humidity, salt tolerance, and similar factors.

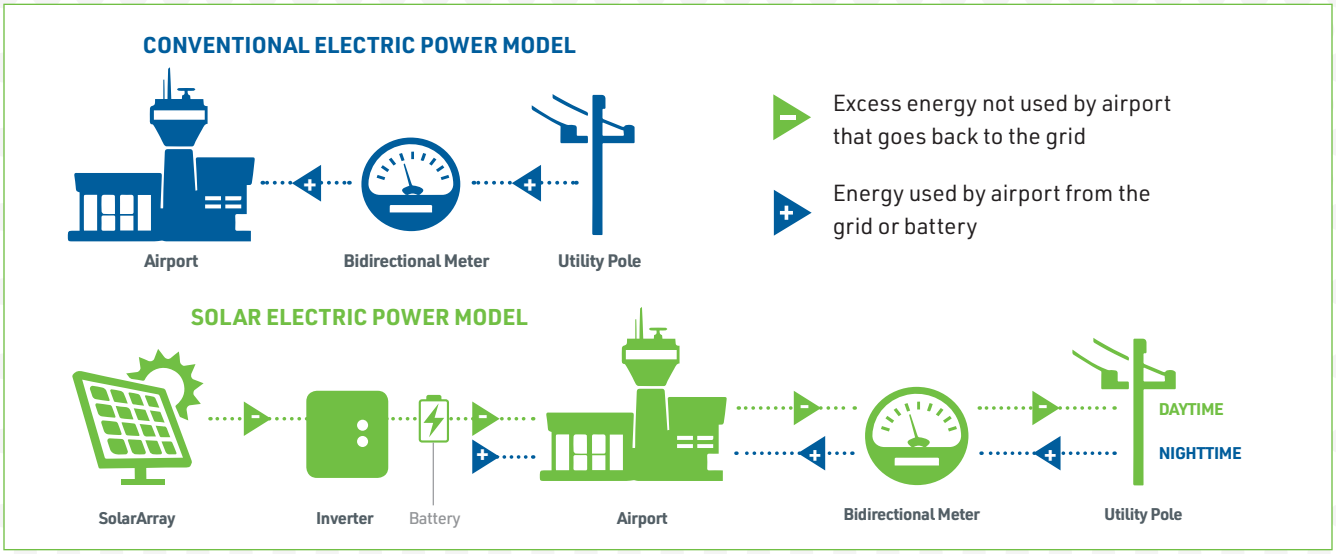
Hold a bidders' conference

As the tender was being developed, the project team notified solar developers of the upcoming opportunity and invited them attend a bidders' conference. Mostly local installers were attracted to participate. All project components, design requirements, and proposed project schedule were discussed at the bidders conference.

Review bids and select a contractor

All of the project requirements were included in a single tender, including power interconnections, solar panel installation, preconditioned air supply, and power conversion from the grid to 400 Hz and while this made for a comprehensive and complex

8 www.icao.int/environmental-protection/Pages/ICAO_UNDP.aspx



tender document, it resulted in a reasonably simple project management structure, led by one contractor with experience and expertise in the field of solar panel array design and installation. Having one single counterpart responsible for the project highly facilitated the work and communication with ICAO and other stakeholders. Bids from several project teams were evaluated for compliance with the project scope and technical requirements, prior experience, estimated cost, and project delivery schedule. Following the bid review, a qualified and experienced contractor was selected.

Design, construct and install the solar and gate components

During the project installation and construction phase regular weekly status calls were held with the contractor, ICAO project managers, airport staff, and other stakeholders. Scheduling issues were among the most frequent topics. Other issues included design details, equipment specifications, construction considerations, and electrical interconnections. The project structure enabled the team to respond quickly and efficiently to issues, such as upgrading the solar panel array to account for Category 5 Hurricanes.

Commission the equipment

Another requirement of the tender was that equipment commissioning was the responsibility of the contractor. A site acceptance test was conducted during which the project management team reviewed the commissioning procedures, inspected the equipment, verified all training responsibilities were met, and appropriate spare parts were listed and on hand where appropriate. Upon successfully passing the site acceptance test, the ownership of the equipment was transferred from ICAO to JCAA.

Begin operations

Once the facilities were installed and operations had begun, the project team was able to confirm that the actual CO_2 emissions reductions conformed to expectations. In addition to the direct emission savings, the project had several indirect benefits including:

1) the solar energy produced by the photocells enhances the airport's power stability and adds resilience to the overall system;
2) ramp workers who service the aircraft at the gate are exposed to fewer unhealthy air pollutants since the equipment emissions are gone; and
3) the traveling public learns about efforts to reduce emissions from international aviation activities.

These positive aspects of the project make for good public relations with the nearby community and demonstrate the airport's leadership in reducing carbon emissions. Another factor that is a benefit to potentially many other airports is that this project design, equipment specifications, and project tender can all be used to educate other airports that may want to undertake similar projects.

9 Lessons Learned: Key Elements for Successful Project Management

The Jamaican Solar-at-Gate project is an example of a small-scale yet complex project, installed at an operating commercial airport, designed to reduce carbon emissions from international aviation. Planning the project and managing its installation were both critical in ensuring the delivery of a successful project. This section describes the most important project management guidelines and decisions that ensured this project's successful outcomes.

Defining the Project

Clearly defining the objectives of the project from the very beginning is essential for establishing a solid foundation on which to proceed. Key stakeholders and other interested parties must be identified to ensure effective communication and to weigh important benefits and trade-offs.

Measurable goals should be enumerated to clarify the desired project outcome. Defining goals for both early stage communications and to evaluate results throughout construction and during operation following completion is necessary.

To ensure the project benefits are communicated to interested parties and the broader public an educational component should be included. For the Solar-at-Gate project at Norman Manley Airport, a computer display showing real-time electricity generation from the solar project and the practical emission reduction benefits, represented by cars removed or trees planted, is included in the airport terminal. This confirms the benefits of the current project and garners support for future carbon reduction projects.

Structuring the Team

To ensure a strong team dedicated to the project's success it is essential to have a dedicated, hands-on project manager who has appropriate experience leading a multidisciplinary team, preferably someone with local experience. The project management team should also include representatives from the finance department, engineering or technical department, and operations department. The team will also require strong executive-level support to ensure the project receives organization-wide prioritization.

The project team must also be staffed to address both construction and operational project phases and, in particular, staff should be designated to follow-up on any technical issue arising from the project after its entry into service.

Stakeholder Consultation

It is critical to involve all relevant stakeholders from the inception of the project to ensure their views are duly considered during the project design and to minimize any adverse impact on their regular operations. For the Solar-at-Gate project stakeholders included the airport administration, civil aviation authority, aircraft operators, ground handling services companies, and the local electric utility. Stakeholders could also include airport neighbours, local politicians, and environmental regulators.

Part of the stakeholder's consultation involves a discussion on the tariffs for the use of the new gate equipment, management of the gate equipment in the case where the airport is not the provider of ground handling services, and the compatibility of the new gate equipment with the aircraft serving that airport. Agreements resulting from this consultation should be formalized in an official document (e.g. Memorandum of Understanding).

Establishing the Project Context

To set the stage for a successful project, it is important to develop a project plan to guide the project management cycle. A clear and robust project management cycle should underpin the implementation of the project. An example project management cycle is Plan-Do-Check-Act, which drives continuous improvements.

Prior to the project launch, appropriate studies should be undertaken to understand the legal and operational framework.

On the legal framework, as a minimum the following should be considered:

- regulated versus liberalized energy market;
- ability to send extra power back to the grid;
- obligation to sell all the power to the grid; and
- environmental impact assessments as appropriate

On the operational framework it would be essential to understand the existence of:

- stable or unstable grid power that will have an impact on the equipment retained;
- the financing and ownership options; and
- the stakeholders in the market who should be informed of the project.

Project implementation requires regular and structured team meetings to review project progress and schedule including: project status, plan for critical path tasks, and status of stakeholder communications.

Defining the Project Sustainability

Implementing the operational programme is essential to ensuring long-term sustainability of the project. A post-implementation mechanism should be created to account for the direct and indirect benefits accrued from the implementation of the project including financial, social, and environmental benefits. Identified benefits can serve as the basis for initiating a similar project, securing funding for other initiatives, or adopting lessons learned in other applications.

Finally, it is essential to communicate the direct and indirect benefits measured by the project management team to stakeholders and the general public to promote the understanding of the project sustainability.

Improving the environmental performance of aviation is a challenge ICAO takes very seriously. In fulfilling its responsibilities, the Organization has developed a range of Standards, policies and guidance material for the application of integrated measures to limit and reduce CO_2 emissions. Through ICAO's *Transforming the global aviation sector: emissions reductions from international aviation* joint assistance project with the UNDP, financed by GEF, ICAO is supporting developing States and SIDS in their efforts to reduce CO_2 emissions from international aviation. This project successfully delivered results to assist States, through the development of guidance material, tools and practical mitigation measures, and shows the commitment of ICAO and its Member States, in the context of its *No Country Left Behind* initiative,* to limit and reduce CO_2 emissions from international aviation.

* www.icao.int/about-icao/NCLB/Pages/default.aspx

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