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# Doc 9988

# Guidance on the Development of States' Action Plans on $CO_2$ Emissions Reduction Activities

Third Edition, 2019

Approved by and published under the authority of the Secretary General

INTERNATIONAL CIVIL AVIATION ORGANIZATION

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## Guidance on the Development of States' Action Plans on $CO_2$ Emissions Reduction Activities

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# AMENDMENTS

Amendments are announced in the supplements to the *Products and Services Catalogue;* the Catalogue and its supplements are available on the ICAO website at www.icao.int. The space below is provided to keep a record of such amendments.

## RECORD OF AMENDMENTS AND CORRIGENDA

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# ACRONYMS

| | |
|---|---|
| ACI | Airports Council International |
| A-CDM | Airport collaborative decision-making |
| AEDT | Aviation Environmental Design Tool (United States FAA) |
| AES | Aviation Environmental System |
| AEM | Advanced Emissions Model |
| ANSP | Air navigation services provider |
| APER | Action Plan for Emissions Reduction |
| APU | Auxiliary power unit |
| A-SMGCS | Advanced surface movement guidance and control system |
| ASPIRE | Asia and South Pacific Initiative to Reduce Emissions |
| ASTM | American Society for Testing and Materials |
| ASUR | Alternative surveillance |
| ATAG | Air Transport Action Group |
| CAA | Civil Aviation Authority |
| CAEP | Committee on Aviation Environmental Protection |
| CANSO | Civil Air Navigation Services Organisation |
| CCO | Continuous climb operation |
| CDM | Clean Development Mechanism |
| CDO | Continuous descent operation |
| CNS/ATM | Communications, Navigation and Surveillance/Air Traffic Management |
| CO | Carbon monoxide |
| $CO_2$ | Carbon dioxide |
| $CO_{2e}$ | Carbon dioxide equivalent |
| CORSIA | Carbon Offsetting and Reduction Scheme for International Aviation |
| EBT | Environmental Benefits Tool |
| EEA | European Environment Agency |
| EMEP | European Monitoring and Evaluation Programme |
| EUROCONTROL | European Organisation for the Safety of Air Navigation |
| FAA | Federal Aviation Administration |
| FAST | Future Aviation Scenario Tool (Manchester Metropolitan University) |
| FB | Fuel burn |
| FEGP | Fixed electrical ground power |
| FT | Fischer Tropsch |
| GANP | Global Air Navigation Plan |
| GATMOC | Global Air Traffic Management Operational Concept |
| GFAAF | Global Framework for Aviation Alternative Fuels |
| GHG | Greenhouse gas |
| GIACC | Group on International Aviation and Climate Change |
| GPU | Ground power unit |
| GSE | Ground support equipment |
| HEFA-SPK | Hydroprocessed Esters and Fatty Acids |
| IATA | International Air Transport Association |
| IFSET | ICAO Fuel Savings Estimation Tool |
| IPCC | Intergovernmental Panel on Climate Change |
| LED | Light emitting diode |
| LTO | Landing and take-off |

| | |
|---|---|
| LVP | Low visibility procedures |
| MAC | Marginal abatement cost |
| MBM | Market-based measure |
| MRV | Monitoring, Reporting and Verification |
| PBN | Performance-based navigation |
| PCA | Pre-conditioned air |
| PIRG | Planning and Implementation Regional Group |
| RNP | Required Navigation Performance |
| RTK | Revenue Tonne Kilometre |
| SAF | Sustainable Aviation Fuel |
| SARP | Standard and Recommended Practice |
| SID | Standard instrument departure |
| SKA | Synthetic kerosene with aromatics |
| SPK | Synthetic paraffinic kerosene |
| STAR | Standard instrument arrival |
| SURF | Surface operations |
| UNFCCC | United Nations Framework Convention on Climate Change |

# PUBLICATIONS

*(referred to in this document)*

## 1. ICAO PUBLICATIONS

### Manuals

*Africa-Indian Ocean Regional Traffic Forecasts 2008–2028* (Doc 9939)

*Asia/Pacific Area Traffic Forecasts 2010–2030* (Doc 9961)

*Caribbean/South American Regional Traffic Forecasts 2009–2030* (Doc 9940)

*Global Air Navigation Plan* (Doc 9750)

*Global Air Traffic Management Operational Concept* (Doc 9854)

*Guidance on the Use of Emissions Trading for Aviation* (Doc 9885)

*ICAO's Policies on Charges for Airports and Air Navigation Services* (Doc 9082)

*ICAO's Policies on Taxation in the Field of International Air Transport* (Doc 8632)

*Manual on Air Traffic Forecasting* (Doc 8991)

*Manual on Air Traffic Management System Requirements* (Doc 9882)

*Manual on Global Performance of the Air Navigation System* (Doc 9883)

*Offsetting Emissions from the Aviation Sector* (Doc 9951)

*Operational Opportunities to Reduce Fuel Burn and Emissions* (Doc 10013)

*Procedures for Air Navigation Services — Aircraft Operations* (Doc 8168)

*Report of the Tenth Meeting of the Committee on Aviation Environmental Protection (CAEP/10)* (Doc 10069)

*Report on Voluntary Emissions Trading for Aviation (VETS Report)* (Doc 9950)

### Circulars

*Global Air Transport Outlook to 2030 and trends to 2040* (Circular 333)

### Others

ICAO-EU project: *Feasibility Study on the Use of Sustainable Aviation Fuels — Dominican Republic* (https://www.icao.int/environmental-protection/Documents/FeasabilityStudy_DomRep_ENG_Web.pdf)

ICAO-EU project: *Feasibility Study on the Use of Sustainable Aviation Fuels — Trinidad and Tobago* (https://www.icao.int/environmental-protection/Documents/FeasabilityStudies_TrinidadTobago_Report_Web.pdf)

ICAO-EU project: *Feasibility Study on the Use of Sustainable Aviation Fuels — Burkina Faso* (https://www.icao.int/environmental-protection/Documents/FeasabilityStudy_BurkinaFaso_Report-Web.pdf)

ICAO-EU project: *Feasibility Study on the Use of Sustainable Aviation Fuels — Kenya* (https://www.icao.int/environmental-protection/Documents/FeasabilityStudy_Kenya_Report-Web.pdf)

ICAO-UNDP-GEF project: *Transforming Global Aviation Collection — Financing Aviation Emissions Reductions* (https://www.icao.int/environmental-protection/Pages/ICAO_UNDP_Guidancedocs.aspx)

ICAO-UNDP-GEF project: *Transforming Global Aviation Collection — Regulatory and Organizational Framework to Address Aviation Emissions* (https://www.icao.int/environmental-protection/Pages/ICAO_UNDP_Guidancedocs.aspx)

ICAO-UNDP-GEF project: *Transforming Global Aviation Collection — Renewable Energy for Aviation: Practical Applications to Achieve Carbon Reductions and Cost Savings* (https://www.icao.int/environmental-protection/Pages/ICAO_UNDP_Guidancedocs.aspx)

ICAO-UNDP-GEF project: *Transforming Global Aviation Collection — Sustainable Aviation Fuels Guide* (https://www.icao.int/environmental-protection/Pages/ICAO_UNDP_Guidancedocs.aspx)

### Forms

ICAO Form M — *Fuel Consumption and Traffic — International and Total Services, Commercial Air Carriers* (ICAO Fuel Form)

### Websites

ICAO CORSIA (www.icao.int/corsia)

ICAO Global Framework for Aviation Alternative Fuels (GFAAF) (https://www.icao.int/environmental-protection/GFAAF/Pages/default.aspx)

ICAO-UNDP-GEF project: Environment Knowledge Sharing Platform (KSP) (https://www.icao.int/environmental-protection/knowledge-sharing/Pages/default.aspx)

ICAO-EU project on-line course on State Action Plans developed in cooperation with UNITAR (https://www.unitar.org/event/full-catalog/international-aviation-intro-states-action-plans-reduce-co2-0)

## 2. PUBLICATIONS OF OTHER ORGANIZATIONS

### Alternative fuels

Air Transport Action Group (ATAG)

*Beginner's Guide to Sustainable Aviation Fuel* (https://aviationbenefits.org/media/166152/beginners-guide-to-saf_web.pdf)

International Air Transport Association (IATA)

*IATA 2015 Report on Alternative Fuels* (http://www.iata.org/publications/Pages/alternative-fuels.aspx)

*IATA Guidance Material for Sustainable Aviation Fuel Management* (https://www.iata.org/whatwedo/environment/Documents/IATA%20Guidance%20Material%20for%20SAF.pdf)

Partnership for AiR Transportation Noise and Emissions Reduction. An FAA/NASA/Transport Canada-sponsored Center of Excellence.

*Life Cycle Greenhouse Gas Emissions from Alternative Jet Fuels* (http://web.mit.edu/aeroastro/partner/reports/proj28/partner-proj28-2010-001.pdf)

### Fuel efficiency/emissions reduction

Airbus

*Getting to Grips With Fuel Economy* (https://www.scribd.com/doc/74091544/Getting-to-Grips-With-Fuel-Economy)

Airports Council International (ACI)

*Guidance Manual: Airport Greenhouse Gas Emissions Management* (http://www.aci.aero/Publications/Full-Publications-Listing/Guidance-Manual-Airport-Greenhouse-Gas-Emissions-Management)

Boeing

*Fuel Conservation Strategies* (http://www.boeing.com/commercial/aeromagazine/articles/2015_q1/archive.html)

Civil Air Navigation Services Organisation (CANSO)

*Introduction to Environmental Management Systems for ANSPs* (https://www.canso.org/introduction-environmental-management-systems)

International Air Transport Association (IATA)

*Guidance Material and Best Practices for Fuel and Environmental Management* (https://store.iata.org/IEC_ProductDetails?id=9796-05)

Sustainable Aviation

*Aircraft on the Ground $CO_2$ Reduction Programme* (https://www.sustainableaviation.co.uk/wp-content/uploads/2018/06/Aircraft-On-the-Ground-CO2-Reduction-Programme-Best-Practice-Guidance.pdf)

**Emissions inventory preparation**

United States (U.S.) Federal Aviation Administration

*Aviation Environmental Design Tool (AEDT)* (https://aedt.faa.gov)

European Monitoring and Evaluation Programme (EMEP)/European Environment Agency (EEA)

*EMEP/EEA air pollutant emission inventory guidebook 2016* (http://www.eea.europa.eu/themes/air/emep-eea-air-pollutant-emission-inventory-guidebook)

Intergovernmental Panel on Climate Change (IPCC)

*Guidelines for National Greenhouse Gas Inventories* (http://www.ipcc-nggip.iges.or.jp/public/2006gl/)

U.S. Air Force Research Laboratory

*Propulsion and Power Rapid Response Research and Development (R&D) Support — Delivery Order 0011: Advanced Propulsion Fuels Research and Development-Subtask: Framework and Guidance for Estimating Greenhouse Gas Footprints of Aviation Fuels* (http://caafi.org/information/pdf/AFRL-RZ-WP-TR-2009-2206.pdf)

Argonne National Laboratory

*Greenhouse Gases, Regulated Emissions and Energy Use in Transportation (GREET)* (http://greet.es.anl.gov/)

**Implementation of measures**

Air Transport Action Group (ATAG)

*Aviation Climate Solutions* (https://aviationbenefits.org/media/125796/Aviation-Climate-Solutions_WEB.pdf)

United Kingdom Committee on Climate Change

*Meeting the UK aviation target — Options for reducing emissions to 2050* (http://www.theccc.org.uk/publication/meeting-the-uk-aviation-target-options-for-reducing-emissions-to-2050/)

U.S. Federal Aviation Administration

*Continuous Lower Energy, Emissions, and Noise (CLEEN) Program* (https://www.faa.gov/about/office_org/headquarters_offices/apl/research/aircraft_technology/cleen/)

*NextGen Priorities Joint Implementation Plan 2017-2019* (https://www.faa.gov/nextgen/media/NG_Priorities_Joint_Implementation_Plan.pdf)

## 3. MISCELLANEOUS

Learmount, David

"Lean, Mean Flying," *Flight International* (June 2010)

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# Chapter 1

# INTRODUCTION

### 1.1 BACKGROUND

1.1.1 The 39th Session of the ICAO Assembly, held from 27 September to 7 October 2016, adopted Resolution A39-2: *Consolidated statement of continuing ICAO policies and practices related to environmental protection — Climate change*. Resolution A39-2 reflects the determination of ICAO's Member States to provide continuous leadership to international civil aviation in limiting or reducing its emissions that contribute to global climate change.

1.1.2 The Assembly recognized ICAO's tremendous progress during the 2013 to 2016 triennium, and reaffirmed the collective aspirational goals that were established by the 37th Session of the ICAO Assembly. It agreed on a comprehensive strategy to progress all elements of its "basket of measures", namely: technology and standards, sustainable aviation fuels, operational improvements and market-based measures.

1.1.3 A central element of Resolution A39-2 is for States to voluntarily prepare and submit action plans to ICAO. It also laid out an ambitious work programme for capacity building and assistance to States in the development and implementation of their action plans to reduce emissions, which States were initially invited to submit by the 37th Session of the ICAO Assembly in October 2010. Specifically, Resolution A39-2:

a) "*Further encourages* States to submit voluntary action plans outlining respective policies and actions, and annual reporting on international aviation $CO_2$ emissions to ICAO" (operative clause 10);

b) "*Invites* those States that choose to prepare or update action plans to submit them to ICAO as soon as possible preferably by the end of June 2018 and once every three years thereafter, in order that ICAO can continue to compile the quantified information in relation to achieving the global aspirational goals, and the action plans should include information on the basket of measures considered by States, reflecting respective national capacities and circumstances, quantified information on the expected environmental benefits from the implementation of the measures chosen from the basket, and information on any specific assistance needs" (operative clause 11); and

c) "*Encourages* States that already submitted action plans to share information contained in action plans and build partnerships with other Member States in order to support those States that have not prepared action plans, and to make the submitted action plans available to the public, taking into account the commercial sensitivity of information contained in States' action plans" (operative clause 12).

1.1.4 Furthermore, operative clause 13 of Resolution A39-2 "*Requests* the Council to … continue to provide guidance and other technical assistance for the preparation and update of States' action plans prior to the end of June 2018, in order for States to conduct necessary studies and to voluntarily submit their action plans to ICAO".

1.1.5 Additionally, operative clause 17 b) of Resolution A39-2 requested the Council to:

> Build further partnerships with other international organizations to meet the assistance needs of ICAO's Member States, including through the ICAO Action Plan Buddy Programme, and facilitate access to existing and new financial resources, technology transfer and capacity building, to developing countries and report on results achieved as well as further recommendations, preliminarily by the end of 2018 and at the 40th Session of the Assembly.

1.1.6 In short, action plans give ICAO Member States the ability to establish partnerships, promote cooperation and capacity building, facilitate technology transfer and obtain assistance.

## 1.2 ABOUT THIS GUIDANCE DOCUMENT

1.2.1 This guidance document has been prepared in response to the request referred to in 1.1.4 above. It provides guidance for States to help them prepare or update their action plans and is designed for use by those responsible for the preparation of an action plan.

1.2.2 Specifically, this guidance document aims to:

a) describe how to prepare or update an action plan by providing an overview of the action plan preparation process (i.e. tasks, activities and outputs);

b) help States better understand the objectives and expected outcomes of the action plan preparation process;

c) highlight the need for cooperation and collaboration between and among various stakeholders in the preparation of action plans; and

d) assist States in considering the basket of measures from which they might select their actions.

1.2.3 This document is divided into five chapters, each focusing on a different aspect of an action plan. ICAO has developed an interactive Action Plan on Emissions Reduction (APER) website to facilitate the preparation or update of action plans and their submission to ICAO. Users are encouraged to submit their action plans through the website. Chapter 2, 2.6, provides detailed instructions on accessing the APER website.

1.2.4 This guidance document has been developed with the goal of accommodating the various levels of experience among States in the development of similar national reports. It is expected that in addition to facilitating the preparation or update of an action plan, this guidance document will contribute to improving the reporting of $CO_2$ emissions and the implementation of mitigation projects for international aviation.

1.2.5 Although not specifically mentioned here, there are interrelated issues, such as financial needs, research activities, transfer of technology, capacity building (including education, training and public awareness), and information and networking, which form integral elements of an action plan. These issues will be addressed in the relevant chapters of this guidance document.

## 1.3 CONVENTIONS USED IN THIS DOCUMENT

Recognizing that different conventions for referring to numbers are used throughout the world, this document has been standardized in the North American (English) form. That is, thousands are separated by a comma and the period is used to represent a decimal point (1,500.22 = one thousand five hundred and twenty-two hundredths). In addition, throughout the document reference is made to quantifying fuel consumption and traffic. When required, units for these will be explicitly stated. Furthermore, methods for converting fuel consumption data into $CO_2$ emissions are provided in the relevant sections of this document.

## 1.4 WHAT'S NEW IN THE THIRD EDITION OF DOC 9988

1.4.1 Following the initial invitation by the 37th Session of the ICAO Assembly for States to submit action plans for reducing emissions from international aviation, the Secretariat has worked closely with States to support the development of those plans. The Second Edition of Doc 9988 reflected both the feedback received from States which developed plans based on the First Edition of this document and the feedback from the ICAO Council, as well as observations from the action plans that were submitted to ICAO.

1.4.2 The Third Edition of Doc 9988 aims to accurately reflect the latest changes in ICAO Standards and Recommended Practices applicable to the State Action Plan initiative and to integrate the deliverables and lessons learned from the assistance and capacity-building initiatives undertaken by ICAO. The document has been reorganized to reflect the expected flow of information within each State and contains updated case studies. To this end, the Third Edition should be the reference document for the development or update of State Action Plans.

# Chapter 2

# ACTION PLANS

## 2.1 PURPOSE

2.1.1 In many respects, the development of an action plan resembles the execution of any project, potentially involving activities such as securing resources, assembling a team, and planning and implementing various tasks. This chapter provides generic guidance on some of the key aspects of the development process. It does not prescribe any specific activities, since it is up to individual States to decide upon any arrangements (organizational, legal, procedural, etc.) that they may need to put in place in accordance with their national conditions and circumstances.

2.1.2 The aviation sector often plays a central role in the national economy of a State, affecting numerous economic sectors and contributing to the State's further development. As such, any measures to limit or reduce the impact of international aviation on the environment, pursuant to the global aspirational goals agreed by the 37th Session of the ICAO Assembly, and reaffirmed by the 38th and 39th Sessions of the Assembly, should be an integral part of the broader sustainable development priorities and objectives of a State. This would promote sustainable growth of international aviation while ensuring consistency with any overarching greenhouse gas (GHG) emissions limitation or reduction efforts in the State.

2.1.3 In accordance with operative clauses 10 and 11 of Resolution A39-2: *Consolidated statement of continuing ICAO policies and practices related to environmental protection — Climate change*, an action plan can help:

a) States:

1) to report international aviation $CO_2$ emissions to ICAO;

2) to outline to ICAO their respective policies and actions;

3) to provide information to ICAO on the basket of measures considered, reflecting their respective national capacities and circumstances, and on any specific assistance needs; and

b) ICAO:

1) to compile information in relation to the achievement of the global aspirational goals;

2) to facilitate the dissemination of economic and technical studies and best practices related to aspirational goals;

3) to provide guidance and other technical assistance for the preparation of States' action plans; and

4) to identify and respond to States' needs for technical and financial assistance, with a view to responding appropriately through the development of a process and mechanism for the provision of assistance to States.

2.1.4 It is clear from the above that an action plan is a tool that a State can use to showcase and communicate both at the national and international level, its efforts to address their $CO_2$ emissions from international aviation. In addition, through the development of an action plan, a State could:

a) better understand the share and projections of international aviation $CO_2$ emissions;

b) experience enhanced cooperation between all aviation stakeholders that can positively reflect on their operational areas;

c) identify the most relevant mitigation actions;

d) streamline policies;

e) enhance stakeholders' support and understanding for policy decisions;

f) establish cross-sectoral partnerships;

g) promote capacity building;

h) multiply the environmental effects of mitigation measures;

i) facilitate technology transfer; and

j) identify assistance needs.

## 2.2 SCOPE

2.2.1 In accordance with Resolution A39-2, action plans should incorporate information on activities that aim to address $CO_2$ emissions from international aviation, including national actions, as well as activities implemented regionally or on a global scale as the result of bilateral and regional/multilateral agreements.

2.2.2 It should be noted that most aviation-related mitigation measures affect both domestic and international operations. To the extent possible, States should distinguish between domestic and international aviation data within their State Action Plan. The action plan should focus on international data, however, if a State wishes to highlight the impact of selected measures on domestic aviation, those impacts may be considered a supplemental benefit of ICAO's global aspirational goals.

2.2.3 Examples of supplemental benefits could include emissions from ground support equipment operations and airport-related ground transportation. These are considered domestic emissions and are beyond the scope of Resolution A39-2. However, if a State wishes to consider the aviation sector as a whole, these measures could be listed as relevant supplemental information to help explain their strategies.

## 2.3 CONTENTS: WHAT SHOULD BE INCLUDED IN AN ACTION PLAN?

2.3.1 Every action plan submitted to ICAO should contain, at a minimum, the information described in Box 1. This base set of information will allow States to clearly and consistently communicate their intended actions and the expected results from those actions, and allow ICAO to compile the information into a global picture as requested by the 37th Session of the Assembly, and reaffirmed at the 38th and 39th Sessions of the Assembly. This document describes how to obtain the information necessary to prepare a complete action plan. For a template of a complete action plan, please refer to Appendix B.

**Box 1. Five basic elements of an Action Plan (minimum requirements)**

For action plans to fulfil their purpose in accordance with the provisions of Resolution A39-2, they should contain the following five elements:

1. *Contact information.* The focal point and any other person(s) responsible for the compilation and submission of the action plan should be identified.

2. *Baseline (without action) fuel consumption $CO_2$ emissions and traffic (from the latest available year to 2050).* Annual historic fuel consumption and traffic from international aviation from the latest available year(s) should be submitted. In addition, projected future fuel consumption and traffic to 2030, 2040 and 2050, in the absence of action (i.e. implementation of mitigation measures) should be submitted. Although any available data would be welcome, in order to assess progress towards the global goals, baseline data for the years 2030, 2040 and 2050 should be provided.

3. *Measures to mitigate $CO_2$ emissions.* The measures being proposed to address $CO_2$ emissions from international aviation, distinguishing between those that are already in place and those that are being considered for future implementation, should be listed.

4. *Expected results (fuel consumption, $CO_2$ emissions and traffic with the actions in 3 being taken from the latest available year to 2050).* Similar to 2, in order for ICAO to understand the global effect of the actions being proposed by States, projected fuel consumption and traffic for the same future years provided in 2 that quantify the effect of the actions listed in 3 should be submitted.

5. *Assistance needs.* A description of any specific needs (for example, financial, technological or capacity building) for the implementation of future actions should be described, if applicable.

States are invited to submit this information directly through the Action Plan on Emissions Reduction (APER) website. This website also enables the direct submission of supporting documentation, if desired.

2.3.2 It is recognized that, where the implementation of mitigation measures requires a high level of integration between various national authorities and when the respective $CO_2$ emissions impact of these mitigation measures cannot be attributed to individual States, States may wish to include the supranational measures in their States' Action Plans. These will be considered as quantified data by ICAO, provided that the supranational part of the action plans is adopted by all contributing Member States and that this supranational part can be considered *in lieu* of action plans for those States that would not have directly submitted an action plan to ICAO, until they effectively do so. In this respect, it is of utmost importance that all States are encouraged to provide information on the national implementation of supranational measures or the impact of any additional national measure that would not have been taken into account in the supranational part.

2.3.3 States may provide more detail in their action plans in order to showcase their activities and/or solicit assistance for the future implementation of specific actions. In providing information on ongoing and future actions, a State may indicate which actions are the direct result of policy-making at the government level and which are being driven by other stakeholders (solely or in cooperation with State authorities), such as engine and aircraft manufacturers, air carriers, airport/local authorities and non-governmental organizations. Other action-specific information that may be provided includes:

a) an indication of the type of action (operational, technological, market-based, etc.);

b) time horizon (start date and date of full implementation);

c) anticipated change in fuel consumption and/or $CO_2$ emissions;

d) economic cost and how it may be covered (domestic sources, regional funding, international assistance, etc.);

e) expected supplemental benefits (those benefits that do not directly influence international aviation fuel consumption and/or $CO_2$ emissions, which include domestic aviation, airport-level emissions reduction, air quality improvements, noise reduction, etc.);

f) references to any relevant legislation; and

g) a description of the process used for selecting the mitigation actions.

2.3.4 Furthermore, States may provide additional explanatory information which may highlight the specific conditions of the State (e.g. a general introduction on the role of international aviation in the State).

2.3.5 While States are encouraged to make their action plans available to the public, ICAO will consider all plans submitted as confidential unless otherwise notified by the originating State. To protect confidentiality, the State may elect not to make certain data publicly available, or may aggregate/de-identify the data before including it in the action plan. In the event that confidential data is collected in the development of the action plan (for example, from individual air carriers or on specific international routes), appropriate procedures should be followed by the State for the designation and treatment of such information in accordance with the applicable national legislation and regulations. A State could improve transparency by explaining in its action plan how confidential information has been treated.

2.3.6 Every effort is being made to ensure that the process of reporting action plans to ICAO is as simple and flexible as possible. Once the basic five elements described in Box 1 have been submitted through the APER website, States are encouraged to submit additional information in support of their action plans on assumptions, methods used, etc. in any format they wish. This information will assist ICAO in aggregating the data from different State action plans and could be used by a State to request assistance from ICAO. To ease the process of collecting additional information to be included in the action plan, a template is provided in Appendix B which reflects the format of the APER website.

## 2.4 PROCESS: WHAT ARE THE STEPS TO DEVELOP AN ACTION PLAN?

2.4.1 As described in operative clause 11 of Resolution A39-2, action plans should be prepared and submitted to ICAO by the end of June 2018 and once every three years thereafter. This provides a time horizon against which a plan for the preparation of an action plan can be formulated. However, it is recognized that the work of ICAO Member States might be bound to different timelines, not allowing the completion and submission of their action plan by June every three years. In such cases, it is accepted that a different submission date be defined.

2.4.2 The key steps in the planning process include:

a) establishing the team that will contribute to the development of the action plan;

b) estimating the baseline (without action) international aviation fuel consumption and traffic;

c) selecting the measures to mitigate $CO_2$ emissions and improve fuel efficiency;

d) estimating the expected results from the actions (mitigation measures) selected; and

e) identifying any assistance needed to develop and/or implement the plan.

2.4.3 *Establishing the team*. The first step in developing an action plan is to secure the commitment of all stakeholders involved with civil aviation matters in the State. All relevant stakeholders (from the public and private sectors) should be involved taking into consideration their specific expertise. Depending on the complexity of the aviation sector in a State, small working teams may be established to carry out specific technical tasks or hold discussions on one specific category of mitigation measures. Most States have already employed such a State team approach for the preparation of other national reports in the context of various multilateral agreements under the United Nations (for example, national communications under the United Nations Framework Convention on Climate Change (UNFCCC), national reports in the context of Agenda 21[1], reporting under ICAO Statistical Air Transport Reporting Forms, etc.). It is advised to convene the State Action Plan stakeholders group formally and to develop and share terms of reference for the work of the group and an associated timeline.

2.4.4 One of the key prerequisites for the successful development of an action plan is the establishment of clear roles and responsibilities for each of the stakeholders involved. One of the principal stakeholders at the national level would be an executing body with the overall responsibility (often as mandated by national legislation) to deal with, and coordinate actions on, international aviation and climate change in the State. Examples include, but are not limited to, national authorities (such as the civil aviation authority), departments or ministries (such as the transport or environment ministry) and specialized national agencies. It is important that the appropriate executing body be identified at an early stage of the process because it will make it easier for personnel to be appointed and for specific roles and responsibilities to be allocated. Within this organization, a single person should be identified to serve as the focal point for the action plan. This is the only person who would be authorized to submit the action plan to ICAO through the APER website on behalf of the State and is the primary point of contact between ICAO and the State, including on information related to the organization of training seminars.

2.4.5 In addition, depending on the measures to be included in the action plan, many activities may not be under direct control of the State, and/or may require cooperation with others in order to secure reliable data, including: air carriers, air navigation service providers, airports, fuel providers, airframe/engine manufacturers, etc. States can incorporate information on a point or points of contact in their action plans. Such information would help ICAO clarify any issues that may arise during the compilation of the reported information.

2.4.6 In cases where expertise in specific areas of an action plan is missing or lacking, capacity building and training should be arranged early in the process. This would ensure that all experts have the necessary know-how to carry out their respective tasks in an efficient and timely manner. States that have identified specific capacity-building needs are encouraged to inform ICAO in order for the Organization to explore options for facilitating technical training, as appropriate. The focus of such training would be on the use of available resources (such as GHG inventory guidelines, mitigation models and tools) and would be conducted, preferably, at the national level.

2.4.7 Another equally important element is for all information generated or collected during the action plan process to be documented and archived for future use. Having such a system in place facilitates regular future updates and periodic reporting as suggested in ICAO Assembly Resolution A39-1: *Consolidated statement of continuing ICAO policies and practices related to environmental protection — General provisions, noise and local air quality.*

2.4.8 *Estimating the baseline.* This is a key part of an action plan because it provides the opportunity to determine the historical levels of international aviation fuel consumption and traffic and to project into the future the growth in fuel consumption and traffic in the absence of the actions described in the plan. It provides a reference point against which the State can understand the expected progress of their actions, i.e. implementation of mitigation

1. https://sustainabledevelopment.un.org/outcomedocuments/agenda21

measures, and monitor progress in the future. This information will also assist ICAO in assessing the overall emissions trends and tracking progress towards the achievement of the global aspirational environmental goals. Information about how to develop the baseline is provided in Chapter 3.

2.4.9 *Measures to mitigate $CO_2$ emissions*. An integral element of an action plan is the identification of measures that will be implemented in order to achieve $CO_2$ emissions reductions and/or improve fuel efficiency. Chapter 4 provides more information on how to put together a basket of measures that is suited to a State's circumstances.

2.4.10 *Estimation of expected results*. Along with the selection of measures, Chapter 4 also provides information on how to quantify their effects on $CO_2$ emissions and fuel efficiency. As with the baseline, this information will allow the State to understand the impact that their proposed actions will have on their fuel consumption and $CO_2$ emissions. It also allows ICAO to assess the collective global contribution of States' individual plans toward the achievement of the global aspirational goals.

2.4.11 *Identification of assistance needs*. An often overlooked element of an action plan is the identification of assistance that would further enable the plan's development and implementation. A clearly communicated plan provides a solid basis for requesting assistance from a broad range of sources (see Chapter 5 for more information).

## 2.5 UPDATING AN EXISTING ACTION PLAN

2.5.1 Once action plans have been prepared, States are invited to submit them and subsequently update them every three years preferably on the year prior to the Assembly year. The guidance in this document is equally relevant for updating an existing action plan as for creating a new one. In each of the steps described in this document, recommendations are included for what to consider if a plan is being updated.

2.5.2 Regular updates of the State Action Plan are essential to fully deliver the benefits of the initiative at the national level. Indeed, such updates increase the robustness of the data collection process, the understanding of stakeholders operating needs and constraints, the ownership of the content of the document, the preparedness for the implementation of mitigation measures and the ability to demonstrate progress.

2.5.3 When a State Action Plan is submitted to ICAO, it is reviewed and feedback on the submission is provided to the State Action Plan Focal Point. In order to facilitate this process, ICAO developed a Feedback Form, which is used to provide each State Action Plan Focal Point with an informal analysis of their submitted State Action Plan.

2.5.4 This Feedback Form is only shared with the State Action Plan Focal Point. This Feedback Form is not used to any other end, is not intended to be a formal document, and is not intended to provide a "grade" or rank of submitted State Action Plans.

2.5.5 The Feedback Form:

a) provides tailored points for consideration when developing future updates of a State Action Plan;

b) ensures that ICAO provides feedback to each State Action Plan Focal Point in a consistent format;

c) encourages States to continue communications with stakeholders following the submission of a State Action Plan; and

d) emphasizes that ICAO is always available for questions related to State Action Plans.

2.5.6 An example of the current version of the Feedback Form is provided in Appendix G. Please note that the Feedback Form may be periodically adjusted in order to reflect comments received by ICAO.

## 2.6 THE APER WEBSITE: HOW TO SUBMIT AN ACTION PLAN

2.6.1 To facilitate the submission of action plans and minimize the burden on States, ICAO has developed an interactive website that can be used to upload and submit action plans electronically. The template in Appendix B will help States to organize the information in the same order that it will be requested on the website. Instructions for online submission, as well as training materials, including a step-by-step guide and examples, can be downloaded from the APER website.

2.6.2 In order to obtain access to the APER website, States' Action Plan Focal Point(s) must create an account on the ICAO Secure Portal. To create a new user account:

a) access the ICAO Portal at the following link: http://portal.icao.int;

b) if you do not have a pre-existing portal username/password, click the **Request an account** option;

c) click the **OK** button on the pop-up message to indicate that this is your first portal account;

d) in the pop-up window **Please enter a group name you wish to subscribe**, enter the group name **APER** (all caps and no spaces);

e) click the **OK** button;

f) enter the necessary information in the **New User Account Application Form**; and

g) click the **Submit Request** button.

When these steps have been completed, you will receive confirmation that you have been granted or denied access (if granted access, the e-mail will include your username and password).

2.6.3 Should the State Action Plan Focal Point(s) already have an ICAO Secure Portal account, instructions for accessing the APER website are as follows:

a) log on to http://portal.icao.int with your secure site login credentials;

b) click on the **PROFILE** link in the top, left-hand corner;

c) in the next window on the left-hand side, click on **Group Subscribe**;

d) under **To Subscribe** enter the group name **APER** (all caps and no spaces) and the **Justification** for your request; and

e) click the **Submit Changes** button.

When these steps have been completed, you will receive an e-mail confirmation that you have been granted or denied access to the group in question.

2.6.4 The APER website allows States to upload their action plans and/or additional supporting documentation as electronic documents. Action plans or supporting documentation submitted in a language other than one of the six official languages of ICAO (Arabic, Chinese, English, French, Russian and Spanish) will not be translated by the ICAO Secretariat. Furthermore, it is emphasized that if a State submits its action plan in a language other than one of the six ICAO official languages, it should use the APER website to provide (at least) the minimum information described above in English. If the State does not do so, the submitted information will not be processed by the ICAO Secretariat.

2.6.5 In addition to providing a secure location to upload a State Action Plan, the APER provides access to resources developed by ICAO in support to States, including this guidance document. Additional resources include the ICAO Environmental Benefits Tool (EBT), the Marginal abatement cost (MAC) curves tool, ICAO Carbon Emissions Calculator for States, additional ICAO guidance documents, useful links, and PowerPoint presentations from past ICAO States' Action Plans Regional Seminars.

## 2.7 HOW ICAO CAN HELP

2.7.1 ICAO generally provides States with assistance related to aviation and the environment on a regular basis under its work programme, including through the organization of meetings at ICAO Headquarters and the regional offices; correspondence with States on specific environmental questions; publication of documents, such as the ICAO Environmental Reports or technical documentation, including the ICAO guidance material; and the development and dissemination of tools to assist States in accounting for aviation related $CO_2$ emissions. These tools support calculating $CO_2$ emissions from air travel (ICAO Carbon Emissions Calculator), estimating fuel and $CO_2$ emissions savings from operational measures (ICAO Fuel Savings Estimation Tool (IFSET)), support the development of the baseline for the action plan (Environmental Benefits Tool (EBT)) and support decision-making in prioritizing mitigation measures (MAC curve tool) and in minimizing $CO_2$ emissions from air travel to attend meetings (ICAO Green Meetings Calculator).

2.7.2 Specific technical assistance was requested by Assembly Resolution A39-2 (operative clause 13) for the preparation and submission of States' action plans on $CO_2$ emissions reduction activities. Significant resources are available to ensure that all States are able to prepare, submit and implement an action plan that reflects their circumstances. In addition to this guidance document, the interactive APER website and regional seminars, the ICAO Secretariat has developed a team for the action plan initiative. This team includes experts at ICAO Headquarters and one focal point in each of the ICAO regional offices who are available to assist States in developing their action plans by providing them with the necessary data and specific technical support; work with States in the development and implementation of their action plans; and answer any questions related to the action plan initiative. The ICAO Secretariat action plan team can be identified at: https://www.icao.int/environmental-protection/Pages/ActionPlan-Questions.aspx.

2.7.3 Since the Second Edition of ICAO Document 9988 was published, the ICAO Secretariat has developed a State Action Plan Feedback Form, based on Box 1 of this chapter. This form provides a streamlined method for the ICAO Secretariat to communicate possible areas of improvements for States in their action plans. This form is an important communication tool to encourage States to continue discussions with their stakeholders, even after the submission of the State Action Plan.

2.7.4 To further support States in the development of their action plans and to encourage cooperation amongst ICAO Member States, ICAO has initiated the ICAO Action Plan Buddy Programme. This programme was given reaffirmed support by Assembly Resolution A39-2 and is in line with the No Country Left Behind initiative. This programme encourages the building of partnerships between States that have already submitted an action plan (Buddy State) and States that wish to develop their action plan, but have not yet done so. The programme is intended as an informal agreement and the level of collaboration is entirely decided upon by the two States. In this context, ICAO can facilitate initial communication between the two States, if desired. Examples of successful Buddy Programme partnerships can be found on the ICAO Environmental Protection (ENV) webpage[2].

2.7.5 ICAO has also engaged in two capacity-building and assistance projects that have delivered guidance material and tools of significant importance for States and their stakeholders in the process of developing or updating a State Action Plan.

2.7.6 ICAO's partnership with the European Union "Capacity Building for $CO_2$ Mitigation from International Aviation", has allowed for support to 14 selected States in the Africa and Caribbean regions in the development of their State Action Plan, the installation of tailor-made $CO_2$ emissions reporting software, the Aviation Environmental System (AES) and the implementation of pilot mitigation measures and feasibility studies. An essential component of the ICAO-EU project is the design and development of guidance material and tools to benefit all ICAO Member States. Thus, ICAO cooperated with the United Nations Institute for Training and Research (UNITAR) to develop an online training course accessible to the State Action Plan Focal Points designated by ICAO Member States. The feasibility studies and case studies from the project are also useful resources that are referenced in the relevant sections of this guidance document and can be found on the ICAO ENV webpage[3].

2.7.7 ICAO has also concluded a partnership with the United Nations Development Programme (UNDP) with financing from the Global Environment Facility (GEF) *Transforming the Global Aviation Sector: Emissions Reduction from International Aviation* in order to support developing States and Small Island Developing States (SIDS) with the implementation of low carbon aviation measures. The key characteristic of all project deliverables is their contribution to the replication of $CO_2$ mitigation measures by States that have limited human and financial resources and that are the most vulnerable to the impacts of climate change. The project is structured around four main objectives:

a) developing guidance documents to facilitate approaches to reduce aviation emissions in developing States and SIDS:

b) setting up a Low-Carbon Knowledge Sharing Platform;

c) devising an analytical tool for States' use in comparing the cost and effectiveness of emission mitigation initiatives; and

d) demonstrating an easily replicable, low emission installation by way of a pilot project which would serve as an example to replicate for developing States and SIDS.

The project deliverables are also referenced in the relevant sections of this guidance document and can be found on the ICAO ENV webpage[4].

2.7.8 Moreover, additional support for States beyond the provision of data or a few days' support may be obtained from the ICAO Technical Cooperation Bureau (TCB) which provides further assistance through consultants/experts selected and hired by TCB.

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2. https://www.icao.int/environmental-protection/Pages/ActionPlan-Questions.aspx
3. https://www.icao.int/environmental-protection/Pages/ICAO_EU.aspx
4. https://www.icao.int/environmental-protection/Pages/ICAO_UNDP.aspx

# Chapter 3

# BASELINE SCENARIO — ACCOUNTING FOR CURRENT AND FUTURE TRAFFIC, FUEL CONSUMPTION AND $CO_2$ EMISSIONS DATA

**(SITUATION WITHOUT ACTION)**

## 3.1 INTRODUCTION

In order to understand the benefits that can be expected from the implementation of a basket of measures, it is useful to quantify both the historic fuel consumption and traffic, as well as to project into the future what would happen in the absence of the measures contained in the action plan. This chapter is intended to help States establish a baseline scenario for their international aviation fuel consumption and traffic. It provides general guidance for the estimation, reporting and verification of $CO_2$ emissions from international aviation.

## 3.2 DIFFERENTIATING BETWEEN INTERNATIONAL AND DOMESTIC EMISSIONS

3.2.1 Multiple definitions exist for differentiating between international and domestic aviation operations. In order to properly interpret the information provided by States, it is important that the definition used is clearly articulated in the action plan. For the purpose of Annex 16 — *Environmental Protection*, Volume IV — *Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)*, international flights are defined (paragraph 1.1.2 refers). To ensure consistency with the mandatory requirements of Annex 16, Volume IV, States that voluntarily develop and submit their action plan to ICAO shall use the following definition of international flight:

> An international flight is defined as the operation of an aircraft from take-off at an aerodrome of a State or its territories, and landing at an aerodrome of another State or its territories. In addition, a domestic flight is defined as the operation of an aircraft from take-off at an aerodrome of a State or its territories, and landing at an aerodrome of the same State or its territories.

3.2.2 Various methodologies exist to account for the $CO_2$ emissions attributed to international flights:

a) ICAO: each State reports the $CO_2$ emissions from the international flights operated by aircraft registered in the State (State of Registry); and

b) IPCC: each State reports the $CO_2$ emissions from the international flights departing from all aerodromes located in the State or its territories (State of Origin).

3.2.3 In light of the Monitoring, Reporting and Verification (MRV) requirements mandated by Annex 16, Volume IV, all States with a registered operator are encouraged follow the ICAO methodology for the accounting of $CO_2$ emissions from international aviation for the purpose of their State Action Plan. However, States that already use the IPCC methodology, or States with no registered air carrier should also be enabled to voluntarily develop and submit an action plan to ICAO, where they could lay down their national strategy for dealing with international aviation $CO_2$ emissions. In those cases, the IPCC methodology for the accounting of international aviation $CO_2$ emissions would be applicable.

## 3.3 COLLECTING OR ESTIMATING HISTORIC AIR TRANSPORT ACTIVITY AND FUEL CONSUMPTION DATA

3.3.1 ICAO requires that States report fuel consumption and traffic through Statistical Air Transport Reporting Form M — *Fuel Consumption and Traffic — International and Total Services, Commercial Air Carriers* on an annual basis. Reporting instructions for this and other forms is provided at http://www.icao.int/staforms. States may wish to leverage this data in creating their historical baseline as it has already been collected.

3.3.2 As indicated in Appendix B, only total fuel consumption and traffic (including of aircraft leased) are required in an action plan. Therefore, the data collected from the various air carriers in the State for the purpose of Form M can be aggregated.

3.3.3 For the purposes of developing a State Action Plan, States are encouraged to aggregate the fuel burn and emissions data submitted by all of their international aeroplane operators for each year. Using this aggregated data, the State Action Plan Focal Point can forecast the future fuel burn and emissions data in order to develop the State Action Plan Baseline Scenario.

3.3.4 The baseline scenario included in the State Action Plan is understood to be an estimation only. The baseline scenario established by each State in their State Action Plan is unrelated to the CORSIA baseline (see Section 4.2). However, the information reported to the State through the CORSIA MRV system (see Box 2) can serve as a basis for collecting fuel consumption and $CO_2$ emissions data in the State.

**Box 2. CORSIA Monitoring, Reporting and Verification (MRV) system**

The first edition of Annex 16, Volume IV was adopted by the ICAO Council at its 214th Session in June 2018. Annex 16, Volume IV contains the Standards and Recommended Practices for the implementation of CORSIA, including CORSIA's MRV system, and is applicable on 1 January 2019.

CORSIA's MRV system consists of three components:

1. **Monitoring** of fuel use on each international flight and calculation of the related $CO_2$ emissions will be either based on a Fuel Use Monitoring Method, or the on use of the simplified ICAO CORSIA $CO_2$ Estimation and Reporting Tool (CERT), which has been made available to aeroplane operators through the ICAO CORSIA website to support the monitoring and reporting of their $CO_2$ emissions. An aeroplane operator is required to describe its approach to $CO_2$ emissions monitoring in an Emissions Monitoring Plan, which the operator will submit for approval by the State. A conversion factor of 3.16 kg of $CO_2$ per 1 kg of Jet-A fuel will be used to convert fuel use into $CO_2$ emissions.

2. **Reporting** of $CO_2$ emissions information between aeroplane operators, States and ICAO through the use of harmonized templates and procedures. ICAO will then consolidate this $CO_2$ emissions data, calculate the Sector's Growth Factor, and then communicate the Growth Factor to States.

3. **Verification** of reported $CO_2$ emissions data to ensure that the data reported by aeroplane operators is accurate and free of errors. A very basic idea of the verification under CORSIA's MRV system is that an accredited third party verification body checks that everything has been done correctly. This is similar to the accounting practices that are performed in the financial world.

As per Annex 16, Volume IV, all aeroplane operators conducting international flights are required to monitor, report, and verify $CO_2$ emissions from these flights from 1 January 2019 until 31 December 2035, unless exempted. It should be noted that the requirement for the MRV of $CO_2$ emissions is independent from participation in CORSIA offsetting.

Annex 16, Volume IV provides exemptions to the applicability of the MRV requirements to the following:

a) An aeroplane operator that produces annual $CO_2$ emissions from international flights less than or equal to 10,000 tonnes;

b) Aeroplane(s) with a maximum certificated take-off mass less than or equal to 5,700 kg; and

c) Humanitarian, medical and firefighting flights, as well as flights preceding or following a humanitarian, medical or firefighting flight, provided that such flights were conducted with the same aeroplane, and were required to accomplish the related humanitarian, medical or firefighting activities or to reposition thereafter the aeroplane for its next activity.

As a part of the CORSIA MRV system, an aeroplane operator is required to submit to the State a verified Emissions Report on an annual basis. The Emissions Report will include information on the previous calendar year's $CO_2$ emissions, and it shall be accompanied by a Verification Report that will be prepared by an accredited third-party verification body. The operator and the verification body shall both independently submit the verified Emissions Report and associated Verification Report to the State Authority.

For example, the $CO_2$ emissions from the calendar year of 2019 shall be reported to the State by 31 May 2020. $CO_2$ emissions from the calendar year of 2020 shall be reported by 31 May 2021. Regarding the $CO_2$ emissions for the period of 2021-2035, the reporting deadline of the previous calendar year's $CO_2$ emissions is 30 April.

After the State has received Emissions Reports from all of its aeroplane operators, the State shall perform an order of magnitude check to the Emissions Report, and submit the required information regarding $CO_2$ emissions to ICAO. Reporting by States will take place by 31 August 2020 for 2019 emissions and by 31 August 2021 for 2020 emissions. Regarding $CO_2$ emissions from 2021-2035, the annual reporting deadline from States to ICAO is 31 July following the calendar year for which the $CO_2$ emissions are being reported.

For CORSIA eligible fuels, an aeroplane operator can report on CORSIA eligible fuels in 2019-2020 as part of its annual Emissions Report. However, the $CO_2$ benefits associated with the use of those fuels will not be claimed from 2021 onwards. In order to claim emissions reductions from the use of such fuels from 2021, the operator will provide supplementary information to the Emissions Report, which includes the details of the CORSIA eligible fuels and associated emissions reductions. The aeroplane operator that intends to claim for emissions reductions from the use of CORSIA eligible fuels during the compliance periods of CORSIA shall use a CORSIA eligible fuel that meets the CORSIA Sustainability Criteria as defined within the ICAO document entitled *CORSIA Sustainability Criteria for CORSIA Eligible Fuels* that is available on the ICAO CORSIA website.

The aeroplane operator that intends to claim for emissions reductions from the use of CORSIA eligible fuels shall only use CORSIA eligible fuels from fuel producers that are certified by an approved Sustainability Certification Scheme included in the ICAO document entitled *CORSIA Approved Sustainability Certification Schemes*, which will become available on the ICAO CORSIA website following approval by the ICAO Council. Such certification schemes meet the requirements included in the ICAO document entitled *CORSIA Eligibility Framework and Requirements for Sustainability Certification Schemes*, also available on the ICAO CORSIA website.

More information on CORSIA is available on the ICAO CORSIA website:
https://www.icao.int/environmental-protection/CORSIA/Pages/default.aspx

3.3.5 *Converting fuel consumption to $CO_2$*. In order to convert from fuel consumption in litres to $CO_2$ emissions in kilogrammes, the fuel consumed must first be converted from volume (litres) to mass (kg). If the average fuel density is known, it should be used; otherwise a conversion factor of 0.8 kg/litre should be assumed. Then, to convert from the mass of fuel to mass of $CO_2$ emissions, a conversion of 3.16 kg $CO_2$/kg fuel should be used for jet fuel. Depending on the methodology used, sustainable aviation fuels may be treated separately (see Section 4.2).

## 3.4 FORECASTING FUTURE BASELINE TRAFFIC AND FUEL CONSUMPTION

3.4.1 The baseline scenario is intended to reasonably represent the fuel consumption and traffic that would occur in the absence of action. This corresponds to the "business as usual" or "do-nothing additional" scenario. States will need to carefully consider how to define their baseline with regard to which elements are and are not included. For example, States may decide to exclude from their baseline any actions or measures already taken, but which will limit or reduce emissions in the future. Alternatively, they may wish to include such actions in the baseline so that the baseline will be used to assess the impacts only of new, additional actions or measures. Whichever approach is chosen, it will be important that States make explicit the assumptions behind the baseline they establish. The time horizon of a baseline scenario is not limited to the present and should correspond to the time horizon (to be) set for the goals.

3.4.2 The establishment of a baseline involves the following steps (see Figure 3-1):

a) *Define the time horizon and intermediate years.* These should include the time horizon and intermediate years set by ICAO for its goals (ideally to 2050, with any other years).

b) *Estimate historical activity data and emissions inventory.* Historical air transport activity data are normally readily available from operators and airport and civil aviation authorities, as described in Section 3.3.

c) *Develop forecasts for air transport activity and for related emissions in the baseline scenario.* Forecasts for air transport activity may be readily available since many States develop such forecasts on a regular basis, while others may have prepared them for other planning purposes. Forecasting emissions may be done using techniques of various levels of complexity. ICAO's *Manual on Air Traffic Forecasting* (Doc 8991) provides guidance on air traffic forecasting techniques and includes some case studies. However, States have the option to select the technique that is suitable to them.


**Figure 3-1. Steps for the establishment of a baseline**

3.4.3 Global and regional (Africa, Asia/Pacific, Europe, Latin America and Caribbean, Middle East, North America) long-term forecasts for passenger and freight traffic are prepared by ICAO on a regular basis. The latest set of these forecasts is contained in Circular 333 — *Global Air Transport Outlook to 2030 and trends to 2040.*

3.4.4 More detailed long-term regional air traffic forecasts are also available: *Asia/Pacific Area Traffic Forecasts 2010–2030* (Doc 9961), *Africa-Indian Ocean Regional Traffic Forecasts 2008–2028* (Doc 9939) and *Caribbean/South American Regional Traffic Forecasts 2009–2030* (Doc 9940).

3.4.5 Fuel consumption and emissions are related to air traffic, but also depend on the fleet in service, air carriers and airport operations, as well as the provision of air navigation services. Consequently, forecasting emissions from civil aviation requires taking these factors into consideration. The three tiers for the estimation of emissions from civil aviation, described in the IPCC 2006 Guidelines, can be used to project emissions based on the available air traffic forecasts.

3.4.6 The approaches to developing a baseline scenario described in this section are all based on the extrapolation of past trend data in order to determine future levels of fuel consumption and traffic. The main assumption made is that past (historic) data on both fuel consumption and traffic are available.

3.4.7 Depending on the availability of historical data, three different methods (depending on the size of the fleet) can be applied for generating a baseline scenario:

a) *Method A.* The State has a current fleet size of no more than ten aircraft.

b) *Method B*. The State has a current fleet size of more than ten aircraft, and has access to data for at least two years.

c) *Method C.* The State has a current fleet size of more than ten aircraft, and has access to data for a single year only.

3.4.8 The Environmental Benefits Tool (EBT) available on the Action Plan for Emissions Reduction (APER) website has been developed to assist in developing the baseline using the methods described above.

### 3.4.9 Method A (fleet size of no more than ten aircraft)

3.4.9.1 Due to the small size of the fleet, this method for calculating the baseline scenario results in step-change increases in traffic, in Revenue Tonne Kilometres (RTKs), and fuel burn (FB) to more realistically reflect the effect of adding aircraft to the fleet when demand exceeds the available capacity.

*Note.— A State can use this method to develop the baseline scenario when the fleet has no more than ten aircraft and then once the fleet size expands beyond ten aircraft, the State can select another method (most likely Method B) to update the baseline scenario.*

Step 1: Estimate fuel burn based on the single year of data

*Note.— In the event that a State has data for multiple years, the fuel burn can be averaged across all of the data available for the period when the fleet size and composition was the same as the most recent year.*

a) obtain historical annual data for fuel consumption (volume of fuel) and RTK for the latest available year ($FB_j$);

b) determine how the RTK will evolve in the future by considering national forecasts (or projections) or by using default regional growth rates (available in ICAO Circular 333); and

c) determine the forecasted (or projected) fuel consumption for the near future assuming the same growth rate as for the RTK as follows:

$$FB_n = FB_{n-1} * (1 + CAGR) \ where \ n \in \{j+1, \dots, N\}$$

where *FB* is the fuel burn, *n* is the current year, *CAGR* is the RTK compound annual growth rate.

Step 2: Estimate average fuel burn per aircraft

a) provide the number of aircraft within the fleet (between one and ten); and

b) estimate average fuel burn per aircraft for the latest available year:

$$\overline{FB} = \frac{FB_j}{k_j}$$

where $\overline{FB}$ is the average fuel burn, *j* is the latest available year (i.e. reference year) and *k* is the number of aircraft in the fleet.

Step 3: Allocate the change in fuel burn to individual aircraft (known as corrected fuel burn (CFB))

a) estimate the CFB for the latest available year (j):

$$CFB_j = FB_j$$

and

b) estimate the CFB for each year (n):

$$CFB_n = \overline{FB} * k_n$$

corrected fuel burn (current year) = average fuel burn × number of aircraft (current year)

where $n \in \{j+1, \dots, N\}$

where $k_n = k_{n-1} \ if \ FB_n - CFB_{n-1} < \overline{FB}$ *(Case 1)*

or $k_{n-1} + 1 \ if \ FB_n - CFB_{n-1} \geq \overline{FB}$ *(Case 2)*

3.4.9.2 The CFB is calculated for each year from the year after the reference year (i.e. when n = j+1) to the last year of the period (i.e. when n = N). We assume a constant average fuel burn across the fleet over the entire period. Up to this point, this is the same technique that is used for operators with larger fleets.

3.4.9.3 In order to more realistically reflect the effects of adding an aircraft to the fleet, the fuel burn needs to be adjusted for each projected year based on one of the two cases that follow:

a) *Case 1* (demand in the given year can be accommodated with the existing fleet). If the amount of fuel burn of the current year minus the amount of corrected fuel burn of the previous year is less than the amount of the average fuel burn, then the number of aircraft within the fleet remains constant ($k_n = k_{n-1}$). The next step is to calculate the corrected fuel burn of the current year by multiplying the number of aircraft (unchanged from the number of aircraft from the previous year) with the average fuel burn.

b) *Case 2* (demand in the given year can only be met with the addition of another aircraft). If the amount of fuel burn of the current year minus the amount of corrected fuel burn of the previous year is greater than or equal to the amount of the average fuel burn, then the number of aircraft within the fleet increases by one ($k_n = k_{n-1}+1$). The next step is to calculate the corrected fuel burn of the current year by multiplying the number of aircraft (number of aircraft in the previous year + 1) with the average fuel burn.

3.4.9.4 *Example.* An operator in the State has the following characteristics for the year of 2014:

a) international fuel burn (tonnes) = 16,000

b) number of aircraft in 2014: 4

c) annual RTK growth rate = 5.8%

d) baseline period for the example: from 2014 to 2025

This translates to the following parameters for the equations described on the previous page:

a) j = 2014 and N = 2025

b) n = {2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025}

c) kj = 4

d) $FB_j = CFB_j = 16{,}000.00$

e) CAGR = 5.8% or 0.058

Step 1: Estimate fuel burn (in tonnes) based on the single year of data from 2014 to 2025

**Table 3-1. Example of outcome of Step 1 of Method A — Estimate of fuel burn (in tonnes) based on the single year of data from 2014 to 2025**

| *Year* | *Fuel burn* | *Details on calculation* |
|---|---|---|
| 2014 | 16,000 | Fuel burn for the latest available year ($FB_j$) |
| 2015 | 16,928 | 16,000 * (1+ 0.058) |
| 2016 | 17,910 | 16,928 * (1+ 0.058) |
| 2017 | 18,949 | 17,910 * (1+ 0.058) |
| 2018 | 20,048 | 18,949 * (1+ 0.058) |
| 2019 | 21,210 | 20,048 * (1+ 0.058) |
| 2020 | 22,441 | 21,210 * (1+ 0.058) |
| 2021 | 23,742 | 22,441 * (1+ 0.058) |
| 2022 | 25,119 | 25,119 * (1+ 0.058) |
| 2023 | 26,576 | 26,576 * (1+ 0.058) |
| 2024 | 28,117 | 28,117 * (1+ 0.058) |
| 2025 | 29,748 | 29,748 * (1+ 0.058) |

Step 2: Estimate average fuel burn per aircraft for the year 2014

$$\overline{FB} = \frac{FB_j}{k_j} = \frac{FB_{2014}}{k_{2014}} = \frac{16{,}000}{4} = 4{,}000$$

Step 3: Allocate the change in fuel burn (in tonnes) to individual aircraft

**Table 3-2. Example of outcome of Step 3 of Method A — Fuel burn versus corrected fuel burn for the period 2014 to 2025**

| *Year* | *Fuel burn* | *Corrected fuel burn (annual tonnes)* | *Number of aircraft (k)* | *Details on calculation* |
|---|---|---|---|---|
| 2014 | 16,000 | 16,000 | 4 | 2014 is the reference year (j)<br>Corrected fuel burn in 2014 = fuel burn in 2014 |
| 2015 | 16,928 | 16,000 | 4 | Fuel burn in 2015 — Corrected fuel burn in 2014 is less than average fuel burn<br>(16,928 – 16,000 < 4,000)<br>The fleet size remains at 4<br>Corrected fuel burn in 2015 = 4,000 * 4 |
| 2016 | 17,910 | 16,000 | 4 | Fuel burn in 2016 — Corrected fuel burn in 2015 is less than average fuel burn<br>(17,910 – 16,000 < 4,000)<br>The fleet size remains at 4<br>Corrected fuel burn in 2016 = 4,000 * 4 |
| 2017 | 18,949 | 16,000 | 4 | Fuel burn in 2017 — Corrected fuel burn in 2016 is less than average fuel burn<br>(18,949 – 16,000 < 4,000)<br>The fleet size remains at 4<br>Corrected fuel burn in 2017 = 4,000 * 4 |
| 2018 | 20,048 | 20,000 | 5 | Fuel burn in 2018 — Corrected fuel burn in 2017 is greater than average fuel burn<br>(20,048 – 16,000 ≥ 4,000)<br>The fleet size increases to 5<br>Corrected fuel burn in 2018 = 4,000 * 5 |
| 2019 | 21,210 | 20,000 | 5 | Fuel burn in 2019 — Corrected fuel burn in 2018 is less than average fuel burn<br>(21,210 – 20,000 < 4,000)<br>The fleet size remains at 5<br>Corrected fuel burn in 2019 = 4,000 * 5 |
| 2020 | 22,441 | 20,000 | 5 | Fuel burn in 2020 — Corrected fuel burn in 2019 is less than average fuel burn<br>(22,441 – 20,000 < 4,000)<br>The fleet size remains at 5<br>Corrected fuel burn in 2020 = 4,000 * 5 |
| 2021 | 23,742 | 20,000 | 5 | Fuel burn in 2021 — Corrected fuel burn in 2020 is less than average fuel burn<br>(23,742 – 20,000 < 4,000)<br>The fleet size remains at 5<br>Corrected fuel burn in 2021 = 4,000 * 5 |

| *Year* | *Fuel burn* | *Corrected fuel burn (annual tonnes)* | *Number of aircraft (k)* | *Details on calculation* |
|---|---|---|---|---|
| 2022 | 25,119 | 24,000 | 6 | Fuel burn in 2022 — Corrected fuel burn in 2021 is greater than average fuel burn<br>(25,119 – 20,000 ≥ 4,000)<br>The fleet size increases to 6<br>Corrected fuel burn in 2022 = 4,000 * 6 |
| 2023 | 26,576 | 24,000 | 6 | Fuel burn in 2023 — Corrected fuel burn in 2022 is less than average fuel burn<br>(26,576 – 24,000 < 4,000)<br>The fleet size remains at 6<br>Corrected fuel burn in 2023 = 4,000 * 6 |
| 2024 | 28,117 | 28,000 | 7 | Fuel burn in 2024 — Corrected fuel burn in 2023 is greater than average fuel burn<br>(28,117 – 24,000 ≥ 4,000)<br>The fleet size increases to 7<br>Corrected fuel burn in 2024 = 4,000 * 7 |
| 2025 | 29,748 | 28,000 | 7 | Fuel burn in 2025 — Corrected fuel burn in 2024 is less than average fuel burn<br>(29,748 – 28,000 < 4,000)<br>The fleet size remains at 7<br>Corrected fuel burn in 2025 = 4,000 * 7 |

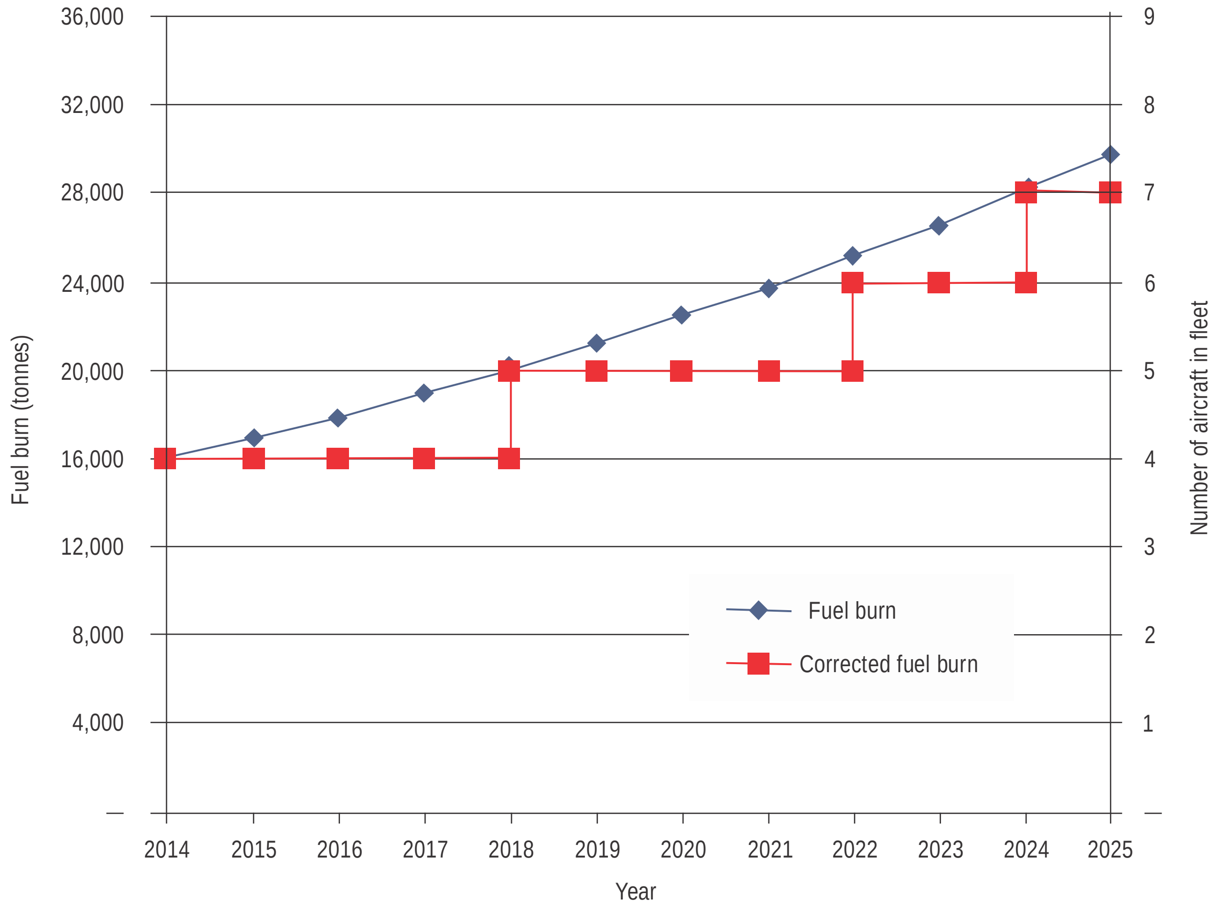


**Figure 3-2. Graphical representation of Table 3-2**

### 3.4.10 Method B (fleet size of more than ten aircraft and data available for at least two years)

3.4.10.1 This method allows the State to consider the past trend in fuel efficiency improvement in their baseline. The specific steps for developing a baseline using Method B are as follows:

Step 1: Obtain historical annual data for fuel consumption (volume of fuel) and RTK.

Step 2: Divide the fuel consumption data by the traffic data to obtain the fuel efficiency (expressed as volume of fuel per RTK) for each past year.

Step 3: Determine the past trend of fuel efficiency.

Step 4: Use the past trend as an approximation of future development of fuel efficiency (in the absence of any additional mitigation measures).

Step 5: Determine how the RTK will evolve in the future either by considering national forecasts (or projections) or by using default regional growth rates (available in ICAO Circular 333).

Step 6: Determine the forecasted (or projected) volume of fuel as follows:

projected volume of fuel = projected fuel efficiency × forecasted RTK.

*Note.— While most changes in the actual development of fuel efficiency over time can be viewed against the efficiency measures taken by a State over time, if a State has more sophisticated techniques (including models) to relate fuel efficiency to other variables such as fleet age and investments, then such techniques and/or models should be applied.*

3.4.10.2 For Step 3, establishing the trend of historical data would require:

a) *Case 1* (if more than 2 years of historical data are available): to determine a best fit (linear, logarithmic or exponential) for all points in the time series available (see Figure 3-3); and

b) *Case 2* (if only two years of historical data are available): to assume a linear fit between the two points available (see Figure 3-4).

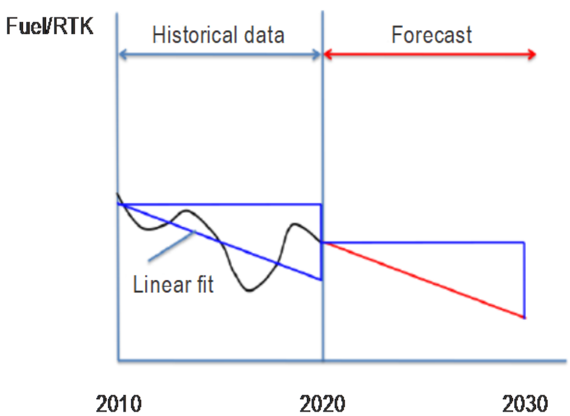


**Figure 3-3. Method B, Case 1 for developing a baseline scenario**

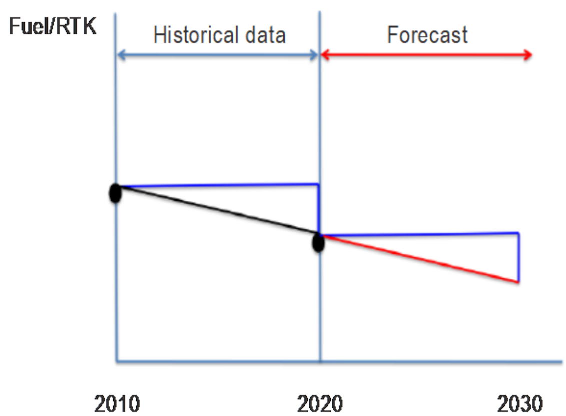


**Figure 3-4. Method B, Case 2 for developing a baseline scenario**

### 3.4.11 Method C (fleet size of more than ten aircraft and data available for a single year only)

3.4.11.1 As Method C is based on a single base year value only, the future fuel efficiency is assumed to be constant. The specific steps for Method C are as follows:

Step 1: Obtain data for fuel consumption (volume of fuel) and RTK for a recent available year.

Step 2: Determine how the RTK will evolve in the future by considering national forecasts (or projections) data or by using default regional growth rates (available in ICAO Circular 333).

Step 3: Determine the forecasted (or projected) volume of fuel for the future (typically 20 years[1] after the base year) assuming the same growth rate as for the RTK as follows:

$$\text{Volume of fuel}_{\text{year n+1}} = \text{volume of fuel}_{\text{year n}} \times (1 + \text{RTK growth}).$$

3.4.11.2 It is important to note that the use of these methods to estimate the baseline scenario assumes that air traffic will continue to grow in a "business as usual" fashion. If the State is aware of plans for exceptional changes to the air traffic in the State, such as with the introduction of new operators or the discontinuation of existing service, those should be specifically accounted for and explained in the action plan.

3.4.11.3 Once complete, the final baseline scenario can be entered into the APER website in the format shown in Table 3-3.

**Table 3-3. Baseline scenario**

| *Year** | *Total RTK (tonne kilometres)* | *Total fuel (litres)* | *Total $CO_2$ emissions (metric tonnes)* | *International RTK* (tonne kilometres)* | *International fuel (litres)** | *International $CO_2$ emissions* (metric tonnes)* |
|---|---|---|---|---|---|---|
| Historic year | | | | | | |
| Historic year | | | | | | |
| Future years | | | | | | |
| 2040 | | | | | | |
| Future years | | | | | | |
| 2050 | | | | | | |
| *Minimum data to be entered. | | | | | | |

3.4.11.4 ***If an existing action plan is being updated***, the State should review the baseline scenario to determine if it remains appropriate. What had been forecast for future years in the previous action plan may now be historic years and the forecast may have been revised. In particular, the implementation of a detailed monitoring system for $CO_2$ emissions from international aviation, such as the MRV system used for CORSIA purposes from 2019, can allow the State to get accurate data on the current level of annual $CO_2$ emissions from international aviation, and to use this information to update the action plan with a more accurate forecast for the baseline scenario. In particular, the implementation of a detailed monitoring system for $CO_2$ emissions from international aviation — such as the one performed using the Aviation Environmental System (AES) described in Appendix C, can allow the State to get more accurate data on the current level of annual $CO_2$ emissions from international aviation, and to use this information to update the action plan with a more accurate forecast for the baseline scenario.

1. For example, if the State has data available for 2010, the near future projections could extend to the period 2011–2030.

## 3.5 VERIFICATION OF EMISSIONS ESTIMATES

3.5.1 It is advisable to conduct an internal verification of the fuel consumption and traffic data prior to both submission to ICAO inclusion in the action plan. Possible verification steps include:

a) comparison of current data to historical activity data or modelled results;

b) review of the share of international and domestic traffic and fuel consumption;

c) review of trends in efficiency indicators such as fuel per RTK; and

d) cross-check of other data sources. For example, fuel uplift could be cross-verified with jet fuel concessionaires at each airport, or departures data could be checked with the airport authorities or with schedules filed with the civil aviation authority of the State. This method is used by the Aviation Environmental System (AES) (see Appendix C for more detail) on a flight-by-flight basis to verify the consistency of the traffic and fuel consumption data submitted for a same flight by two different sources (such as an airline and an airport authority).

3.5.2 In addition, the ICAO Secretariat will review all data submitted and any inconsistencies will be brought to the attention of the submitter.

______________________

# Chapter 4

# SELECTION OF MEASURES AND QUANTIFYING THEIR EXPECTED RESULTS

## 4.1 OBJECTIVE

This chapter provides both examples of measures to select to limit or reduce $CO_2$ emissions from international aviation and guidance on how to quantify the effects that these measures will have once implemented. Many factors contribute to the decision-making associated with the selection of measures, such as safety, infrastructure needs, as well as environmental benefits. The guidance provided in this chapter focuses exclusively on selecting measures and quantifying their benefits from a $CO_2$ emissions reduction/fuel efficiency improvement perspective.

## 4.2 REVIEW OF THE BASKET OF MEASURES, THEIR FEASIBILITY AND EMISSIONS REDUCTION POTENTIAL

4.2.1 Assembly Resolution A39-2: *Consolidated statement of continuing ICAO policies and practices related to environmental protection — Climate change* indicates that: "Action plans should include information on the basket of measures considered by States, reflecting respective national capacities and circumstances, … and information on any specific assistance needs."

4.2.2 Various measures could be taken by States, air carriers, airport authorities and air navigation service providers to reduce $CO_2$ emissions from civil aviation. As noted in Assembly Resolution A37-19, the High-level Meeting on International Aviation and Climate Change (HLM-ENV/09) in October 2009 endorsed the Programme of Action on International Aviation and Climate Change, which included global aspirational goals in the form of fuel efficiency, a basket of measures and the means to measure progress. Since that time, the basket of measures has been further reviewed and updated to reflect the breadth of options available for reducing international aviation $CO_2$ emissions, consistently with the successive Assembly Resolutions on Climate Change. Assembly Resolution A39-2 notes that: "To promote sustainable growth of international aviation and to achieve its global aspirational goals, a comprehensive approach, consisting of a basket of measures including technology and standards, sustainable alternative fuels, operational improvements and market-based measures to reduce emissions is necessary."

4.2.3 The basket of measures is thus classified according to the following categories (see Appendix A for more details):

a) technology and standards;

b) sustainable aviation fuels;

c) operational improvements; and

d) market-based measures.

Reference material that may be relevant to the implementation of these measures is provided in Appendices C, D, E and F.

4.2.4 When considering the feasibility of measures, it is important to consider the practical implications of implementation, such as understanding the steps required, the resources needed, the timing of measures and the entity responsible for carrying out appropriate tasks. States will need to understand how and when they could introduce different measures. For example, measures that require legislation may take longer, may need to be started sooner, and are resourced differently from other measures that could be implemented immediately. These sorts of considerations could have an impact on the choice of certain measures over others and will help States to plan the implementation of the action plan.

4.2.5 In general, emissions reduction/limitation measures can be classified into the four categories listed in 4.2.3 and are discussed in further detail below. For some longer-term measures, it may be difficult to quantify their expected results, but it would nevertheless be valuable for States to include information about them in their action plans.

4.2.6 ***If an existing action plan is being updated***, the State should review whether the same basket of measures will be proposed in the updated plan. If new measures are being added, then the composition of the action plan team may need to differ from the group that developed the original plan in order to have the appropriate stakeholders involved. The updated plan should indicate not only which measures are being added, but also those that have been removed.

4.2.7 It should also be noted that some measures taken to manage international aviation $CO_2$ emissions will also contribute to the management of domestic aviation $CO_2$ emissions. In addition, national aviation stakeholders might wish to report on the adoption of non-aviation specific measures that have an impact on domestic $CO_2$ emissions. Recognizing that these activities also contribute to States' overall strategy against climate change, they could be reported under a dedicated "supplemental benefits for domestic sectors" section. For the purpose of the State Action Plan initiative, these "supplemental benefits for domestic sectors" do not have to be quantified.

### Technology and Standards

4.2.8 This category includes medium-term and long-term measures. Medium-term measures include retrofits and upgrade improvements on existing aircraft, optimizing improvements in aircraft produced in the near- to mid-term. Long-term measures include purchase of new aircraft or the adoption of revolutionary new designs in aircraft/engines and the setting of more ambitious standards.

4.2.9 Most of these measures tend to have a significant emissions reduction potential. However, they are capital intensive and will take time to deliver benefits. Some of the measures such as the purchase of new aircraft cannot be justified on the sole grounds of environmental goals. It is assumed that the fleet plans of most States and/or operators are developed to address anticipated traffic growth and to replace aging aircraft. Nevertheless, such measures may be made more feasible and attractive, should funding and other assistance be made more accessible.

4.2.10 ICAO's Standards are developed to not impose technology advancements. For example, following the work by ICAO's Committee on Aviation Environmental Protection (CAEP), the first-ever certification Standard for aeroplane $CO_2$ emissions was adopted by ICAO in March 2017.

## Sustainable aviation fuels

### Box 3. Definitions of aviation fuels

As per Resolution A39-2, the ICAO Assembly recognized the "technological feasibility of drop-in sustainable alternative fuels for aviation[1]" and acknowledged "the need for such fuels to be developed and deployed in an economically feasible, socially and environmentally acceptable manner". Resolution A39-2 also requested States to recognize that sustainable aviation fuels "should achieve net GHG emissions reduction on a life cycle basis, contribute to local social and economic development; competition with food and water should be avoided".

Following the 39th Session of the ICAO Assembly, the ICAO Council adopted Annex 16, Volume IV (see Box 2), which includes specific definitions related to aviation fuels for use within CORSIA:

> *CORSIA eligible fuel*. A CORSIA sustainable aviation fuel or a CORSIA lower carbon aviation fuel, which an operator may use to reduce their offsetting requirements.
>
> *CORSIA lower carbon aviation fuel*. A fossil-based aviation fuel that meets the CORSIA Sustainability Criteria under this Volume.
>
> *CORSIA sustainable aviation fuel*. A renewable or waste-derived aviation fuel that meets the CORSIA Sustainability Criteria under this Volume.

As the scope of the State Action Plan is different from that of CORSIA (see Section 3.3.4; Box 2; Section 4.2), the discussion of aviation fuels within a State's Action Plan does not need to be limited to the definitions contained in Annex 16, Volume IV. A State Action Plan is intended to be an all-encompassing planning document for a State's aviation sector, so States are therefore encouraged to include any information related to alternative fuel research, including the development of aviation fuels through novel technologies.

However, for the purpose of streamlining the terminology within this guidance document, the generic term Sustainable Aviation Fuel (SAF) is used, in line with the terminology of the 2050 ICAO Vision for Sustainable Aviation Fuels[2], adopted by the ICAO Council in March 2018. For the purpose of this guidance document, the term SAF describes fuels that achieve net GHG emissions reductions on a life cycle basis, in line with Resolution A39-2.

***Background***

4.2.11 The use of SAF is a promising means to reduce aviation emissions. A motivating factor for the deployment of SAF is that the environmental benefits achieved through the implementation of technological and operational mitigation measures will not be sufficient for the international aviation sector to reach its aspirational goal.

1. As defined by the Commercial Aviation Alternative Fuels Initiative (CAAFI), a drop-in jet fuel blend is "a substitute for conventional jet fuel, that is completely interchangeable and compatible with conventional jet fuel when blended with conventional jet fuel. A drop-in fuel blend does not require adaptation of the aircraft/engine fuel system or the fuel distribution network, and can be used "as is" on currently flying turbine-powered aircraft." (http://caafi.org/resources/glossary.html#D)
2. https://www.icao.int/environmental-protection/GFAAF/Pages/ICAO-Vision.aspx

***Benefits***

4.2.12 Unlike the implementation of technological and operational mitigation measures, which provide a reduction of fuel consumption, the deployment of SAF can reduce aviation $CO_2$ emissions on a life cycle basis (i.e., from production to combustion). Due to the characteristics of SAF, environmental benefits can be obtained with existing aircraft and with no investment in fleet renewal. SAF also offers the possibility for a State to diversify their aviation fuel supply.

4.2.13 Typically, the life cycle emissions reductions attributable to SAF are achieved through the use of biomass or waste-based feedstocks for fuel production. The underlying assumption is that, ideally, the amount of $CO_2$ absorbed by the plants (biomass feedstock) used to produce the fuel is equal to the amount of $CO_2$ emitted during the combustion of the fuel. Similarly, for fuels made from wastes, the benefits come from the multiple uses of materials that would otherwise be discarded. However, $CO_2$ emissions are also generated throughout the rest of the SAF life cycle (e.g., feedstock collection, conversion, transportation), and therefore the actual $CO_2$ emissions balance is not zero.

4.2.14 In order to provide a representative view of the progress toward aviation emissions reductions targets, States are invited to submit estimates of the actual life cycle emissions of the SAF they are using or planning to deploy. These estimates should ideally come with information about the methodology and the main assumptions used for the life cycle analysis in order to allow a comparison of the results on an equal basis.

4.2.15 Several methodologies exist in order to estimate the life cycle emissions values attributable to SAF. Within Annex 16, Volume IV, there will be default life cycle emissions values attributed to individual fuel types, as well as a methodology to allow for fuel producers to calculate their actual life cycle emissions values.

4.2.16 For the purpose of the State Action Plan, States may use the CORSIA default life cycle emissions values, the CORSIA methodology for calculating actual life cycle emissions values, or their own methodology for estimating their SAF life cycle emissions values, as long as the methodology used within the action plan is defined. If a State is unable to calculate the life cycle emissions values of their SAF, the State may treat the fuel as zero net emissions for the purpose of the action plan (see rules of thumb in Appendix C).

4.2.17 Some example references that a State may wish to use when estimating life cycle emissions are:

a) *Framework and Guidance for Estimating Greenhouse Gas Footprints of Aviation Fuels* — Air Force Research Laboratory, April 2009 — AFRL-RZ-WP-TR-2009-2206;

b) *Global Assessment and Guidelines for Sustainable Liquid Biofuel Production in Developing Countries* — IFEU, UNEP, Utrecht University, Öko-Institut e.V., February 2012 (a UNEP, FAO, UNIDO GEF targeted research Project);

c) *Using a LCA approach to estimate the net GHG emission of bioenergy* — IEA Bioenergy, October 2011;

d) *The Global Bioenergy Partnership Common Methodological Framework for GHG Lifecycle Analysis of Bioenergy* — Version Zero and One;

e) *Life Cycle Greenhouse Gas Emissions from Alternative Jet Fuels* (http://web.mit.edu/aeroastro/partner/reports/proj28/partner-proj28-2010-001.pdf);

f) ICAO document *CORSIA Sustainability Criteria for CORSIA Eligible Fuels*; (under development and then available on the ICAO CORSIA website https://www.icao.int/environmental-protection/CORSIA/Pages/default.aspx);

g) ICAO document *CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels* (under development); and

h) ICAO document *CORSIA Methodology for Calculating Actual Life Cycle Emissions Values* (under development).

4.2.18 Accounting for emissions reductions from the use of SAF implies tracking the SAF content of the fuel burned during international flights. However, SAF must be mixed with jet fuel before it is used in an aircraft, and from a chemical point of view, cannot be easily distinguished from any other jet fuel. It is, therefore, almost impossible to track SAF use at the level of an individual aircraft. An accounting system based on SAF purchases ("book and claim") is a practical solution to avoid double counting.

4.2.19 States using SAF should describe their methodology for determining the proportion of SAF used for international operations *versus* domestic operations. The description of any benefits related to SAF use in domestic aviation can be included in the State Action Plan as "supplemental benefits for domestic sectors".

***Fuels approved for use in aviation***

4.2.20 Before being introduced to the market, aviation fuels must meet strict safety requirements approved against international standards, such as those of ASTM International, the leading standards organization for aviation fuels. As of 2018, ASTM International has approved six SAF conversion processes.

4.2.21 Through these conversion processes, almost all types of available biomass can be converted into SAF, providing a wide variety of possibilities to adapt to local conditions and available feedstock. However, HEFA-SPK is currently the only conversion process being used on a commercial scale, as it typically requires at least ten years for an aviation fuel to develop from the demonstration phase to commercial production. The deployment of SAF should thus be considered in a medium-term perspective.

4.2.22 While ASTM International has taken a lead role in the approval of aviation fuel standards, these standards are not necessarily directly recognized or applied in all States, some of which may use different systems or require additional regulatory steps to allow the use of a new fuel. Adaptation of local regulation may thus be needed to initiate the deployment of SAF. Recognizing that safety is paramount, any fuel or fuel approval system in a State must provide an equivalent level of quality and reliability. This again ensures the supply of the fuel through the same internationally accepted standards of quality control, all along the logistical steps of the multiple value chains that will be created for SAF.

**Table 4-1. Conversion processes approved by ASTM International**

| | *Annex* | *Conversion Process* | *Abbreviation* | *Possible Feedstocks* | *Blending Ratio by Volume* | *Commercialization Proposals/Projects* |
|---|---|---|---|---|---|---|
| **ASTM D7566** | 1 | Fischer-Tropsch hydroprocessed Synthesized Paraffinic Kerosene | FT-SPK | Coal, natural gas, biomass | 50% | Fulcrum Bioenergy, Red Rock Biofuels, SG Preston, Kaidi, Sasol, Shell, Syntroleum |
| | 2 | Synthesized paraffinic kerosene produced from Hydroprocessed Esters and Fatty Acids | HEFA-SPK | Bio-oils, animal fat, recycled oils | 50% | World Energy, Honeywell UOP, Neste Oil, Dynamic Fuels, EERC |
| | 3 | Synthesized iso-paraffins produced from hydroprocessed fermented sugars | SIP-HFS | Biomass used for sugar production | 10% | Amyris, Total |
| | 4 | Synthesized kerosene with aromatics derived by alkylation of light aromatics from non-petroleum sources | SPK/A | Coal, natural gas, biomass | 50% | Sasol |
| | 5 | Alcohol-to-jet Synthetic Paraffinic Kerosene | ATJ-SPK | Biomass from ethanol or isobutanol production | 50% | Gevo, Cobalt, Honeywell UOP, Lanzatech, Swedish Biofuels, Byogy |
| **ASTM D1655** | Annex | Co-processing | | Fats, oils, and greases (FOG) from petroleum refining | 5% | |

***Challenges***

4.2.23 While the use of SAF minimizes changes and investments in aircraft fleet and aviation infrastructures, its deployment requires significant efforts for the development of the feedstock, production, and conversion industry.

4.2.24 In the short-term, a major hurdle for the deployment of SAF is the initial gap between production costs and aviation fuel pricing. Incentives or compensation mechanisms that account for the environmental benefits of using SAF are required to bridge the price gap and incentivize air carriers to purchase the fuels. A stable and long-term policy is needed to create a market perspective and attract investors.

4.2.25 Policy makers could consider creating a favourable regulatory framework for the development of SAF. The aviation market is in direct competition with road transportation for both the feedstock supply and the allocation of the fuel produced from it. Indeed, technologies for producing jet fuels also produce automotive fuels so that producers may choose to supply only this second market if it is more attractive. Conversely, there may be a synergy between road transport and aviation for the development of production facilities that provide benefits to both sectors, and for which the financial burden can be shared (which is not the case for other measures requiring investments in aircraft renewal).

4.2.26 Sustainable feedstock supply is a critical point in the effort to deploy SAF, as feedstock is, generally, a major contributor to the cost of the fuel. Feedstock, thus, needs to be included in supporting policies as well as in research and development efforts to improve the global efficiency and cost of SAF production.

***Next steps***

4.2.27 States, airports, airlines, and other aviation stakeholders around the world are already involved in sustainable aviation fuel deployment projects, ranging from small scale research projects to commercial scale SAF production facilities. However, despite these successes, SAFs are not yet widely available, and still have the potential for significant evolution in the coming years. Their deployment should be considered from a medium-term perspective as the only solution to physically reduce aviation emissions in tandem with technological progress and operational improvements. When considering the global liquid fuel supply for transport, there are both synergies and competition among the different transportation modes. Beyond the achievement of emissions reductions in the aviation sector, developing SAF can have a strong economic component in States agriculture and industry development. Associated benefits along with sustainability concerns are to be considered in the strategic choice.

4.2.28 More information on SAF is available on the ICAO Global Framework for Aviation Alternative Fuels (GFAAF)[3] website. This publically available online database includes links to recent news articles, details of past and ongoing initiatives, answers to frequently asked questions, and links to additional resources.

4.2.29 Additionally, through the ICAO-EU project (see Section 2.7), ICAO has published four feasibility studies on the use of SAF, as listed below:

a) ICAO-EU project: *Feasibility Study on the use of Sustainable Aviation Fuels — Dominican Republic*[4];

b) ICAO-EU project: *Feasibility Study on the use of Sustainable Aviation Fuels — Trinidad and Tobago*[5];

c) ICAO-EU project: *Feasibility Study on the use of Sustainable Aviation Fuels — Burkina Faso*[6]; and

d) ICAO-EU project: *Feasibility Study on the use of Sustainable Aviation Fuels — Kenya*[7].

These documents can provide guidance to other States that are interested in conducting feasibility studies or establishing SAF supply chains.

4.2.30 Through the ICAO-UNDP-GEF project (see Section 5.3), ICAO also published a document titled *Transforming Global Aviation Collection — Sustainable Aviation Fuels Guide*[8]. The purpose of this guidance is to inform ICAO Member States on how SAF can be deployed to reduce $CO_2$ emissions from international aviation activities, and

3. https://www.icao.int/environmental-protection/GFAAF/Pages/default.aspx
4. https://www.icao.int/environmental-protection/Documents/FeasabilityStudy_DomRep_ENG_Web.pdf
5. https://www.icao.int/environmental-protection/Documents/FeasabilityStudies_TrinidadTobago_Report_Web.pdf
6. https://www.icao.int/environmental-protection/Documents/FeasabilityStudies_TrinidadTobago_Report_Web.pdf
7. https://www.icao.int/environmental-protection/Documents/FeasabilityStudy_Kenya_Report-Web.pdf
8. https://www.icao.int/environmental-protection/Pages/ICAO_UNDP_Guidancedocs.aspx

describes fuel production pathways, usage constraints, environmental and other benefits, and policy perspectives on the use and development of these fuels. Any State interested in developing and deploying SAF is encouraged to explore these resources for more information.

**Operational improvements**

4.2.31 This category reflects changes to air traffic management (ATM) procedures and improvements to infrastructure and operations. This should help States and stakeholders to achieve sustained growth, increased efficiency and responsible environmental stewardship while also improving safety.

4.2.32 The 2016–2030 ICAO *Global Air Navigation Plan* (Doc 9750, Fifth Edition) presents all States with a comprehensive planning tool supporting a harmonized global air navigation system. It identifies all potential performance improvements available, details the next generation of ground and avionics technologies that will be deployed worldwide and provides the investment certainty needed for States to make strategic decisions for their individual planning purposes. In order to facilitate the implementation of air traffic management improvements, the Aviation System Block Upgrade (ASBU) methodology was adopted by ICAO Member States. This methodology is a programmatic and flexible global systems engineering approach that allows all Member States to advance their air navigation capacities based on their specific operational requirements. The block upgrades will enable aviation to realize the global harmonization, increased capacity and improved environmental efficiency that modern air traffic growth now demands in every region around the world.

4.2.33 A detailed analysis of the Block 0 and Block 1 modules was carried out in order to identify those modules that bring immediate and significant emissions reduction. For Block 0, these modules and associated benefits are displayed in the table below:

| *Block 0 Module* | *Benefits* |
|---|---|
| Improved Flexibility and Efficiency in Descent Profiles — Continuous Descent Operations **(B0-CDO)** | Fuel efficient descent profiles. |
| Improved Operations through Enhanced En-route Trajectories — Free-route Operations **(B0-FRTO)** | Greater routing possibilities, reducing potential congestion on trunk routes and busy crossing points resulting in reduced flight lengths and fuel burn. |
| Improved Traffic Flow through Sequencing — Runway Sequencing **(B0-RSEQ)** | Reduced holding and low level vectoring has a positive effect on fuel usage. |
| Improved Flexibility and Efficiency in Departure Profiles — Continuous Climb Operations **(B0-CCO)** | Fuel efficient climb profiles. |
| Improved Flow Performance through Planning based on a Network-wide View — Network Operations **(B0-NOPS)** | Reduced fuel burn when delays are absorbed on the ground with shut engines; rerouting generally increases flight distance, but this is generally compensated by other airline operational benefits. |
| Improved Safety and Efficiency through the Initial Application of Data Link En-route — Trajectory-based Operations **(B0-TBO)** | Routes/tracks and flights can be separated by reduced minima, allowing flexible routings and vertical profiles closer to the ones preferred by the users. |
| Increased Runway Throughput through Optimized Wake Turbulence Separation **(B0-WAKE)** | Reduced delays and associated fuel consumption. |
| Improved Airport Operations through Airport Collaborative Decision-Making **(B0-A-CDM)** | Reduced taxi time; reduced fuel burn and carbon emissions; shorter aircraft engine run time. |
| Initial Capability for Ground Surveillance — Alternative Surveillance **(B0-ASUR)** | Availability of optimum flight levels. |
| Improved access to Optimum Flight Levels through Climb/Descent Procedures using ADS-B **(B0-OPFL)** | Reduced emissions due to access to optimum flight levels. |

For Block 1, these modules and associated benefits are displayed in the table below:

| *Block 1 Module* | *Benefits* |
|---|---|
| Remote Air Traffic Services — Radar Analysis and Test System **(B1-RATS)** | Digital enhancements can be used to maintain throughout in low visibility, and may reduce fuel burn. |
| Remotely Piloted Aircraft Systems **(B1-RPAS)** | Implementation of basic procedures for operating RPAS in non-segregated airspace including detect and avoid. |
| Meteorological information supporting enhanced operational efficiency and safety — Aeronautical Meteorology **(B1-AMET)** | Less fuel burn due to fewer ground hold/delay actions and environmentally optimized routing. |
| Free-Route Operations **(B1-FRTO)** | Reduction in fuel burn due to the availability of a greater set of routing possibilities and the reduction of potential congestion on trunk routes and at busy crossing points. |
| Trajectory-based Operations **(B1-TBO)** | More environmentally friendly trajectories through the absorption of some delays. |
| Flight and flow information for the collaborative environment **(B1-FICE)** | Better knowledge of aircraft capabilities allows trajectories closer to airspace user preferred trajectories, reducing fuel burn. |
| Continuous descent operations **(B1-CDO)** | Enhanced vertical flight path precision allows for reduced aircraft level-offs, resulting in a decrease in fuel burn. |
| Airborne separation **(B1-ASEP)** | Early speed advisories provided by an interval management system reduce controller interaction and remove the requirement for later path-lengthening, leading to reduced fuel burn. |
| Network Operations **(B1-NOPS)** | Decrease in fuel burn due to the better use of airspace and ATM network. |
| Airport Accessibility **(B1-APTA)** | Reduced fuel burn through enhanced reliability and predictability of approaches to runways. |
| Wake Turbulence Separation **(B1-WAKE)** | Better cross-wind knowledge through precise measurement will optimize the use of more environmental-friendly departure procedures and departure runways. |
| Service improvement through integration of all digital ATM information **(B1-DATM)** | Increased ability for the system to create new applications through the availability of standardized data, including meteorological information, leading to reduced inefficiencies and associated fuel burn. |
| Runway Sequencing **(B1-RSEQ)** | Reduction in fuel burn through the reduction in airborne delay/holding. |
| Surface Operations **(B1-SURF)** | Reduced fuel burn through enhanced surface situational awareness. |
| Airport Collaborative Decision-Making **(B1-A-CDM)** | Through collaborative procedures, comprehensive planning and proactive action to foreseeable problems, a major reduction in on-ground and in-air holding is expected thereby reducing fuel consumption. |

4.2.34 Specific rules of thumb have been developed in order to support States in estimating the fuel and $CO_2$ emissions reduction resulting from the implementation of these operational improvements (Appendix C, Table C-2).

4.2.35 Other manuals can provide relevant information. The *Global Air Traffic Management Operational Concept* (Doc 9854) sets out the parameters for an integrated, harmonized and globally interoperable ATM system planned to 2025 and beyond. It can serve to guide the implementation of CNS/ATM technology by providing a description of how the emerging and future ATM system should operate. The *Manual on Air Traffic Management System Requirements* (Doc 9882) is used by PIRGs as well as States as they develop transition strategies and plans. It defines the high-level ATM system requirements to be applied when developing Standards and Recommended Practices (SARPs) to support the Global Air Traffic Management Operational Concept (GATMOC). Finally, the *Manual on Global Performance of the Air Navigation System* (Doc 9883) is aimed at personnel responsible for designing, implementing and managing performance activities. It provides organizations with the tools to develop an approach to performance management suited to their local conditions.

4.2.36 In contrast to the improved air traffic management and infrastructure use category, operational measures reflect changes to how aircraft are loaded and operated. Emissions reduction from this broad category can be achieved in the short-term and with minimum investment. Improvements can be introduced in pre-flight procedures (centre of gravity, take-off mass, flight planning, taxiing, auxiliary power unit (APU)) as well as in-flight procedures (take-off and climb, cruise, descent, holding and approach) and post-flight maintenance procedures (airframe and engine maintenance and aerodynamic deterioration).

4.2.37 Guidance is provided in ICAO's *Procedures for Air Navigation Services — Aircraft Operations* (Doc 8168), *Operational Opportunities to Reduce Fuel Burn and Emissions* (Doc 10013), Airbus' *Getting to Grips with Fuel Economy*[9] (and technical documentation and guidance) and Boeing's *Fuel Conservation Strategies: Descent and Approach*[10] (and technical documentation and guidance).

4.2.38 Weight reduction presents an opportunity to reduce fuel consumption immediately. This can be achieved through such measures as reducing the amount of potable water uploaded, using plastic beverage bottles instead of glass, reducing the number of duty-free items carried, using lighter serving ware, removing galley components, reducing the number of in-flight magazines and using lighter safety equipment.

4.2.39 Minimizing the use of reverse thrust on landing, reduced engine taxi and reduced engine idling time can all result in fuel reduction.

4.2.40 Some of the largest penalties in terms of excess fuel consumption are caused by increased drag resulting from poor airframe condition. Excessive gap tolerances, badly fitting hatches and covers, faring deterioration and the incomplete retraction of moving surfaces are all potential sources of additional fuel consumption. Bumps, dents and scratches must also be taken into account when considering aerodynamic cleanliness. Even surface dirt, on all parts of the airframe, can considerably increase drag. The fuel burn penalty incurred from drag-inducing items is largely dependent upon their location and extent, with different areas of the airframe being more sensitive to alterations of their optimum aerodynamic shape or smoothness.

4.2.41 Attention may be given to the rigging and seal condition of doors since substantial fuel penalties can occur. A misrigged door will not only give rise to a step on the airframe surface which spoils clean airflow, but also may imply badly fitting pressure seals and consequent air leakage.

9. https://www.scribd.com/doc/74091544/Getting-to-Grips-With-Fuel-Economy
10. http://www.boeing.com/commercial/aeromagazine/articles/2015_q1/archive.html

4.2.42 Design features that provide for long-term clearance control, leakage control and erosion resistance are included in modern engines. The major cause of deterioration of specific fuel consumption in modern turbofan engines is erosion which can change airfoil contours and surface finishes. Some fan surface degradation may be recoverable by washing.

4.2.43 Within the business and safety constraints placed on a flight, the pilot will endeavour to fly the aircraft at an optimum cruise speed and altitude to reduce fuel burn and emissions. Aircraft mass and weather conditions (wind) are the key factors in the flight's fuel efficiency. For current aircraft designs, flying at speeds or altitudes other than the optimum can significantly increase fuel burn and emissions. For example, a representative heavy wide-body aircraft could burn 400 kg of extra fuel on a typical flight when flying 4,000 ft. below the optimum altitude. The optimum altitude is based on a number of complex variables, but the primary ones are aircraft weight, wind, ambient temperature and speed. These will already have been taken into account in the flight planning stage. While in flight, operational stakeholders should make every effort to improve the aircraft's trajectory, for example, by making use of route re-planning on long distance flights, short-cut vectors and step climbs. However, such tactical optimization may not deliver its full potential where constraints later in the flight, such as a night noise curfew or stand non-availability, cause holding or routing on a non-optimal trajectory. Therefore, where possible it is recommended to collaboratively identify such opportunities or constraints and plan the flight's operation accordingly.

4.2.44 For long-haul flights, generally there is a relatively limited opportunity to optimize cruise speed because operators already tend to fly at or close to the optimum. However, in some airspace, cruise airspeed/Mach number must be closely controlled (assigned by the controlling agency) to maintain safe (reduced) separation and thereby maximize airspace capacity. On balance, the increased route capacity results in more aircraft being able to fly more optimum (shorter) routings and this more than offsets the incremental fuel burned due to the non-optimum speed. As a rule of thumb and driven by the cost index, fuel efficiency at presently used speeds is typically only around 0.5% worse than maximum-range cruise speed. However, even a fraction of 0.5% is a valuable improvement.

4.2.45 Most air carrier aircraft have flight management systems (FMS) with a cost index input that is vital in selecting the most cost-efficient speed and altitude, particularly above 10,000 ft where speed restrictions and other constraints are not as frequent. The cost index is the cost of time divided by the cost of fuel. The cost index generally flown by commercial aircraft will tend towards the most fuel efficient profile; however, the commercial costs of missed connections for passengers and crew and other factors may be more significant beyond a certain threshold. Minimum fuel use would result from a cost index of 0. The cost index determination is typically done in the flight and route planning stage before take-off and can be route specific. However, it remains for the pilot to update some of the input data (en-route winds) and to fly, to the extent possible, according to the output from the FMS. This cost-indexed trajectory is embedded in the flight plan for a specific flight and its achievement depends on the plan being facilitated by air traffic control and on the ability to update the cost index according to changes to the plan. It is important that all of the operational stakeholders involved in facilitating a flight understand the generic implications of variance from plan according to cost index and take this into account in their decision making.

4.2.46 At the airport level, improvements that result in reduced taxi time, thereby reducing fuel consumption by aircraft main engines, and improvements that result in reduced APU use lower international aviation emissions and should be reflected in the "expected results" portion of the action plan. Providing 400 Hz fixed electrical ground power (FEGP) and, where necessary, pre-conditioned air (PCA) at gates and maintenance areas, and encouraging their use, can substantially reduce APU usage. This ground power can be provided from renewable sources, such as through a combination of solar panels and wind-based grid power. In this scenario, the airport electrical system feeding the energy needs of the aircraft at the gate would be powered by both solar power and grid power. All the remaining renewable energy would be fed into the airport's electrical system, generating co-benefits.

4.2.47 For long-term planning, site selection for new airports allows for the optimization of regional transit access, operating constraints due to weather, etc. Providing an efficient runway, taxiway and apron layout minimizes taxiing and congestion. This, in turn, facilitates more efficient ground movements. Low-visibility take-off and landing capabilities, supported by surface movement guidance and control systems (SMGCS), can be improved. This reduces congestion and delay in bad weather and can reduce the need for diversions to other airfields.

**Market-based measures**

4.2.48 Market-based measures (MBMs) are policy tools that are designed to achieve environmental goals at a lower cost and in a more flexible manner than traditional regulatory measures. Examples of MBMs include levies, emissions trading systems, and carbon offsetting.

4.2.49 Emissions-related levies generally refer to charges or taxes designed to address emissions. While they cannot guarantee a specific environmental outcome, they have potential advantages compared to other MBMs, in terms of simplicity for administration, quickness for implementation, and low transaction costs. *ICAO's Policies on Charges for Airports and Air Navigation Services* (Doc 9082) make a conceptual distinction between a "charge" and a "tax", in that a charge is a levy that is designed and applied specifically to recover the costs of providing facilities and services for civil aviation, and a tax is a levy that is designed to raise national or local government revenues, which are generally not applied to civil aviation in their entirety or on a cost-specific basis. The ICAO Council adopted, on 9 December 1996, a policy statement, in the form of a resolution, wherein the Council strongly recommended that any emissions-related levies be in the form of charges rather than taxes, and that the funds collected should be applied in the first instance to mitigating the environmental impact of aircraft engine emissions.

4.2.50 Emissions trading is a system whereby the total amount of $CO_2$ (or GHG) emissions from participants in the system is capped. Allowances, in the form of permits to emit $CO_2$, are allocated or auctioned to participants in the system for all emissions under the cap. Participants are then free to buy and sell the allowances. At the end of each compliance period, participants are required to surrender allowances to account for their actual emissions. Participants can emit above the cap by buying allowances from the market. Conversely, an installation that emits less than the cap can sell its surplus allowances. This emissions trading between participants in the scheme enables reductions to be achieved at least cost because those sectors where abatement opportunities are cheapest are incentivized to reduce emissions in order to sell their surplus allowances to other sectors where abatement is more costly, such as aviation.

4.2.51 Emissions offsetting involves compensating for the emissions resulting from operation with an equivalent amount of emissions reductions or removal from specific mitigation projects outside of the operation. The accurate estimation of emissions from air travel is essential to identify the amount of emissions to be offset. With a view to providing appropriate and harmonized information on $CO_2$ emissions from air travel and thus avoiding the proliferation of various different methodologies, ICAO developed a globally accepted Carbon Emissions Calculator, which is available on the ICAO website (www.icao.int). ICAO also examined the potential for emissions offsetting for aviation, and the study report *Offsetting Emissions from the Aviation Sector* (Doc 9951) was published in 2011.

4.2.52 The 39th Session of the ICAO Assembly reached a historic agreement on the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), which was adopted through Assembly Resolution A39-3: *Consolidated statement of continuing ICAO policies and practices related to environmental protection — Global Market-based Measure (MBM) scheme*. CORSIA is the first global MBM scheme for any industry sector, and complements a broader basket of measures to achieve the global aspirational goal, without imposing inappropriate economic burden on international aviation. Following the Assembly, the ICAO Council endorsed the overall plan of preparatory activities for the CORSIA implementation, including development of the CORSIA-related draft Standards and Recommended Practices (SARPs) and guidance by CAEP. CAEP developed the SARPs for CORSIA which were adopted by the Council in June 2018 resulting in the First Edition of Annex 16, Volume IV.

4.2.53 The participation in CORSIA offsetting can act as one measure from 2021 to address $CO_2$ emissions in a States' Action Plan. In addition, MRV requirements under CORSIA for States with registered aeroplane operators can support the data collection for the baseline scenario of a States' Action Plan.

4.2.54 CORSIA will be implemented in three phases: a pilot phase (2021-2023); a first phase (2024-2026); and a second phase (2027-2035). The difference between the phases is that the participation of States in the offsetting portion of CORSIA is voluntary for the pilot and first phases, whereas the second phase applies to all ICAO Member States, if not specifically exempted. States that voluntarily decide to participate in CORSIA offsetting may join the scheme from the beginning of a given year, and should notify ICAO of their decision to join by 30 June of the preceding year.

4.2.55 The coverage of offsetting in CORSIA is determined through a "route-based approach" (see Figure 4-1). Specifically: a route is covered by CORSIA offsetting if both States connecting the route participate in the CORSIA offsetting; and a route is not covered by CORSIA offsetting if one or both States connecting the route do not participate in the CORSIA offsetting.

4.2.56 When an aeroplane operator calculates its $CO_2$ emissions covered by the CORSIA offsetting in a given year, it needs to take into consideration emissions from its operations on all the routes covered by CORSIA offsetting. It should be noted that the coverage of CORSIA offsetting requirements and the coverage of CORSIA monitoring, reporting and verification (MRV) requirements are not the same; all international flights are covered by the MRV requirements starting on 1 January 2019.

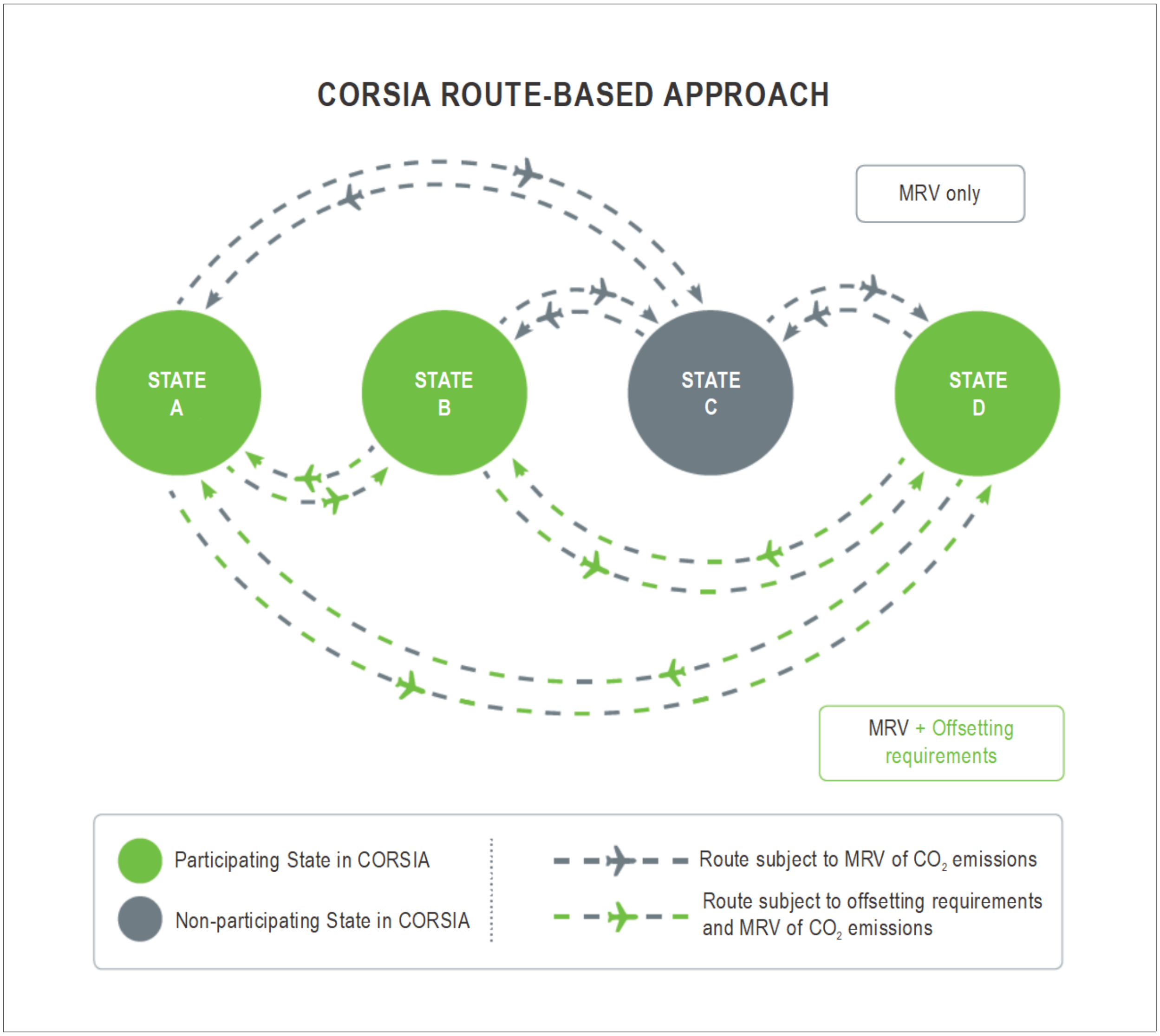


**Figure 4-1. CORSIA route-based approach**

4.2.57 In order to calculate the entire sector's offsetting requirements for a given year, the total emissions covered by CORSIA offsetting in that year will be compared against a CORSIA baseline level of $CO_2$ emissions. The CORSIA baseline is defined as the average of total $CO_2$ emissions for the years 2019 and 2020 on the routes covered by CORSIA offsetting requirements in a given year, from 2021 onwards. It should be noted that the CORSIA baseline can change, depending on the changes in the coverage of CORSIA offsetting requirements. The CORSIA MRV system becomes applicable on 1 January 2019.

4.2.58 Distribution of the total amount of $CO_2$ emissions to be offset in a given year between aeroplane operators is determined through a dynamic approach for the distribution of offsetting requirements, which takes into account:

a) The Sector's Growth Factor, which represents the international aviation sector's global average growth of emissions in a given year. It will be applied as a common factor for all individual operators participating in the scheme for the calculation of their offsetting requirements. ICAO will calculate the Sector's Growth Factor every year based on the reported $CO_2$ emissions data from States to ICAO; and

b) The individual operator's growth factor, which represents an individual operator's Growth Factor of emissions in a given year. This variable will start to be used from 2030 together with the Sector's Growth Factor. It will increase gradually to represent more of an operator's offsetting requirement.

4.2.59 Once ICAO has calculated and shared the Sector's Growth Factor (and the State has calculated the individual operator's Growth Factor, if applicable) for a given year, the State will calculate an operator's $CO_2$ offsetting requirements by multiplying the operator's annual emissions covered by CORSIA offsetting by the Growth Factor. The result of this calculation is the operator's offsetting requirements for a given year. For each three-year compliance period, the State will sum up the offsetting requirements for each year within that compliance period, and the result will be the operator's total offsetting requirement for that compliance period.

4.2.60 Regarding technical exemptions, CORSIA does not apply to aeroplane operators with annual $CO_2$ emissions less than or equal to 10,000 tonnes. Additionally, humanitarian, medical and firefighting operations, as well as aeroplanes of less than or equal to 5,700 kg of maximum take-off mass (MTOM), are exempted from CORSIA requirements.

4.2.61 A new entrant aeroplane operator is exempted from the application of the CORSIA offsetting for three years or until the year in which its annual emissions exceed 0.1% of total emissions in 2020, whichever occurs earlier. From the subsequent year, the new entrant is included in the scheme and treated in the same way as the other aeroplane operators.

4.2.62 Assembly Resolution A39-3 includes a provision stating that the ICAO Council will conduct a review of the implementation of the CORSIA every three years, starting in 2022. This review will include an assessment of the impact of CORSIA on the growth of international aviation. The results of this assessment will serve as an important basis for the Council to consider adjustments and make recommendations to the Assembly for decisions about the next implementation phase or compliance period, as appropriate. Regarding the implementation mechanisms of CORSIA, the Assembly requested the Council, with the technical contribution of CAEP, to develop SARPs and related guidance material for the implementation of the Monitoring, Reporting and Verification (MRV) system under CORSIA, and for Emissions Unit Criteria (EUC) to support the purchase of appropriate emissions units by aircraft operators under the scheme, taking into account relevant developments in the United Nations Framework Convention on Climate Change (UNFCCC) and Article 6 of the Paris Agreement; as well as policies and related guidance material to support the establishment of registries under the CORSIA.

4.2.63 Following the Assembly, the 209th Session of the Council endorsed the overall plan of preparatory activities for the CORSIA implementation, including development of the CORSIA-related draft SARPs and guidance by CAEP. The CAEP developed SARPs for CORSIA which were adopted by the Council at its 214th Session in June 2018 resulting in the First Edition of Annex 16, Volume IV for applicability on 1 January 2019.

**Supplemental benefits for domestic sectors**

4.2.64 The development of States' Action Plans can generate supplemental benefits for domestic aviation through the implementation of mitigation measures that can have both an impact on international aviation $CO_2$ emissions and on domestic aviation $CO_2$ emissions (e.g. some air traffic management changes).

4.2.65 In addition, the development of States' Action Plans can encourage national aviation stakeholders to adopt and showcase comprehensive climate change strategies. These strategies can include measures that would only trigger $CO_2$ emissions reduction for domestic sectors. For instance, airport improvements include changes made to the airfield, the sources of energy used, ground support equipment (GSE), and transportation infrastructure. Each of these areas can offer significant potential for emissions reduction; however, not all of those changes will directly affect international aviation emissions as defined in this guidance document. Improvements that result in reduced taxi time, thereby reducing fuel consumption by aircraft main engines, and improvements that result in reduced APU use, lower international aviation emissions and should be reflected in the "expected results" portion of the action plan. As other airport improvements can result in important environmental improvements, States are encouraged to include them in their action plans as well, while differentiating between those that will contribute to reduced fuel consumption by aircraft flying internationally and those that offer supplemental benefits, including the reductions in fuel used by domestic aviation, SAF use in domestic aviation operations and the reduction of emissions from airport-related ground-based sources.

4.2.66 While States are invited to use their State Action Plan to showcase these supplemental benefits for domestic sectors, their quantified impacts should not be reported within the context of the international baseline scenario or the international expected results, which are required as a part of the State Action Plan. ICAO Member States can quantify the supplemental benefits for domestic sectors as part of their reporting obligations under the UNFCCC.

4.2.67 Airport emissions and electricity use can be reduced by the following wide range of measures:

a) modernization of the power, heating and cooling plants;

b) generation, use or purchase of electricity and heating from renewable sources, including wind, solar, hydroelectric, geothermal and biomass sources;

c) the design, inclusion or retrofitting of "smart" and energy efficient buildings and component technologies, including double glazing, window tinting, variable shading, natural lighting, light emitting diode (LED) lighting, absorption-cycle refrigeration, heat recovery power generation and the like;

d) modernization of fleet vehicles and use of alternative fuels for buses, cars and other air and land side vehicles, including compressed natural gas, hydrogen, electric, compressed air and hybrid vehicles;

e) providing the infrastructure for alternative fuels for airport and tenant vehicles; and

f) driver education on fuel conserving driving techniques including a no-idling policy.

4.2.68 The emissions and energy use from other airport-related activities can also be reduced with the following measures:

a) providing public transport and rapid transit to and from the airport including buses, coaches, light rail and trains;

b) educational campaigns (or using by-laws) to reduce vehicle idling, taxi dead-heading (one way trips), and individual passenger drop-off and pick-up;

c) hotel and rental car agency shuttle bus consolidation;

d) encouraging alternative fuel or hybrid taxis, rental and other cars using incentives such as priority queuing, parking cost reduction and priority parking areas; and

e) providing infrastructure to fuel and power low-emission vehicles including recharging stations.

## 4.3 PRIORITIZATION AND SELECTION OF MITIGATION MEASURES

4.3.1 When selecting measures for inclusion in an action plan, the objective for the State is to describe how $CO_2$ emissions reductions from international aviation will be achieved. However, the State may or may not have a predetermined benefit threshold. The schematic in Figure 4-2 provides an indicative sequence of steps that may be taken for selecting measures. The top-down approach illustrates the process for selecting measures when trying to attain a specific environmental objective. The bottom-up approach quantifies the benefits of the measures that are ultimately selected. In both cases, the process is iterative and can be refined based on experience gained with the implementation of the individual measures.

4.3.2 Depending on the State, prioritization/ranking may or may not be a prerequisite to the selection of measures. This may be an initial step in the decision process, the final outcome of which may depend on other considerations.

4.3.3 Prioritization can be performed for individual measures or for scenarios (a combination of two or more measures). Prioritization of individual measures or scenarios is done by ranking them and establishing a priority list according to certain criteria such as their cost-effectiveness or cost-benefit ratios (see Figure 4-3). Typically, this criteria or metric would be the average cost associated with the reduction of a unit of emissions (for example, dollars per tonne of $CO_2$). Marginal Abatement Cost (MAC) curves can help compare $CO_2$ mitigation projects on a common basis, in terms of the cost per tonne of emissions reduced, while highlighting the total potential reductions. By plotting multiple projects, using locally available data on emissions reductions and project implementation costs, a State can readily compare and prioritize projects. As part of the capacity-building and assistance project implemented by ICAO in cooperation with the United Nations Development Programme (UNDP) with financing from the Global Environment Facility (GEF), a global MAC curve has been updated and includes information related to twenty selected mitigation measures (see Appendix F). A MAC curve tool was also developed for use by developing States and SIDS 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 tool is available on the APER website.

4.3.4 A cost-effectiveness or cost-benefit analysis may be performed prior to the prioritization exercise (see Appendix F). There are two possible approaches to select measures:

a) *Progressive approach.* Measures are ranked individually and added progressively to achieve the goal(s):

   1) prioritize individual measures;

   2) start with the measure having the highest priority (more cost-effective, for example);

   3) assess whether the goal would be achieved; if yes go to 5;

   4) add the next measure on the priority list and go back to 3; and

   5) prepare a summary of all measures retained, their emissions reduction potential and their costs.

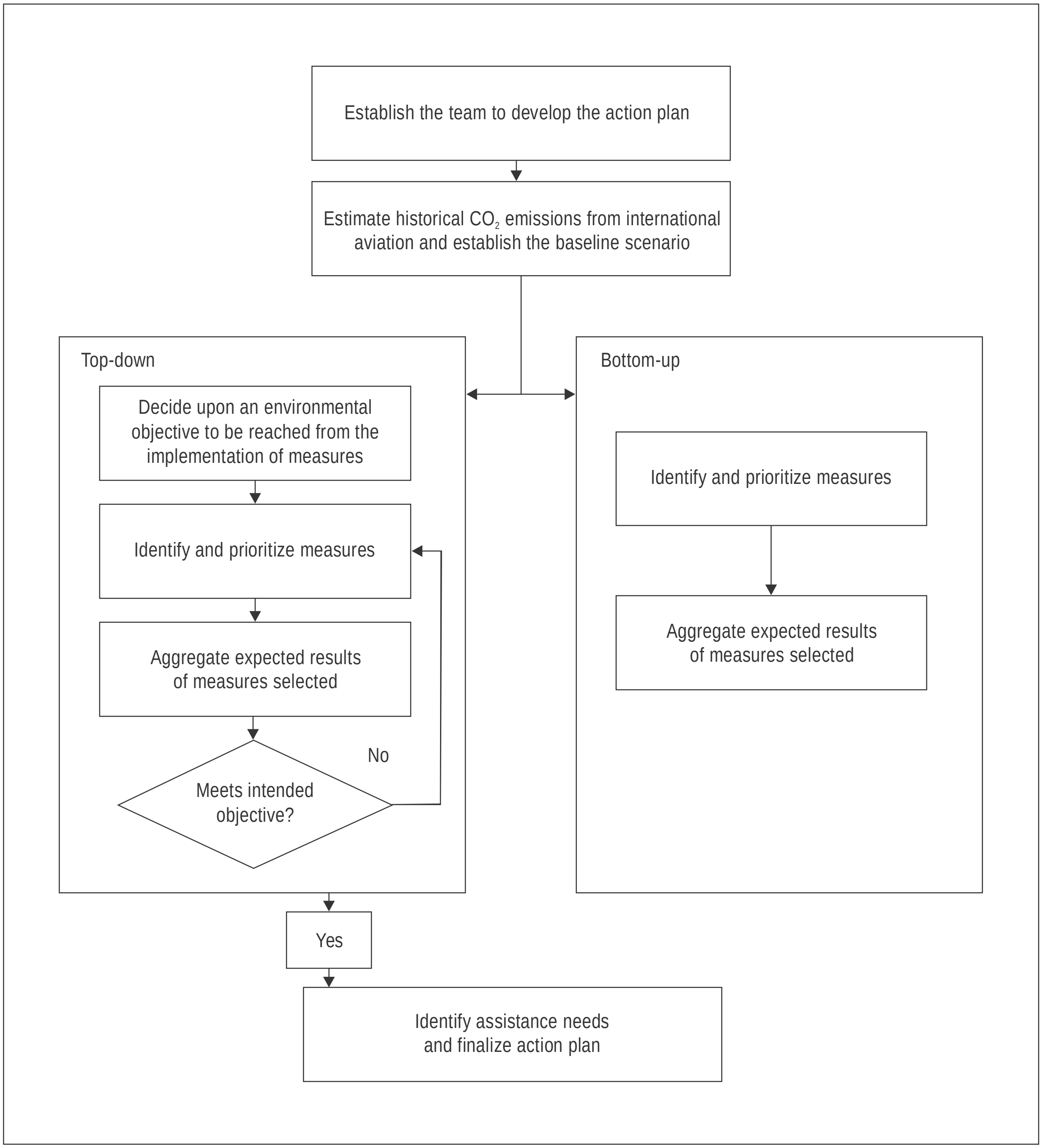


**Figure 4-2. Indicative sequence of steps for developing an action plan**

b) *Scenario approach.* Measures are combined in scenarios and ranked in combination:

1) define scenarios by combining two or more measures;

2) prioritize scenarios;

3) prepare a comparison table of all scenarios that achieve the goal(s), summarizing their costs and benefits and impact on stakeholders;

4) rank the various scenarios according to certain criteria; and

5) select the best scenario.

4.3.5 In some cases, measures being implemented at the regional level may encompass more than one State's airspace. Such "supranational" measures should be reflected in a State's individual action plan as well in order to give a comprehensive view of the action being taken.

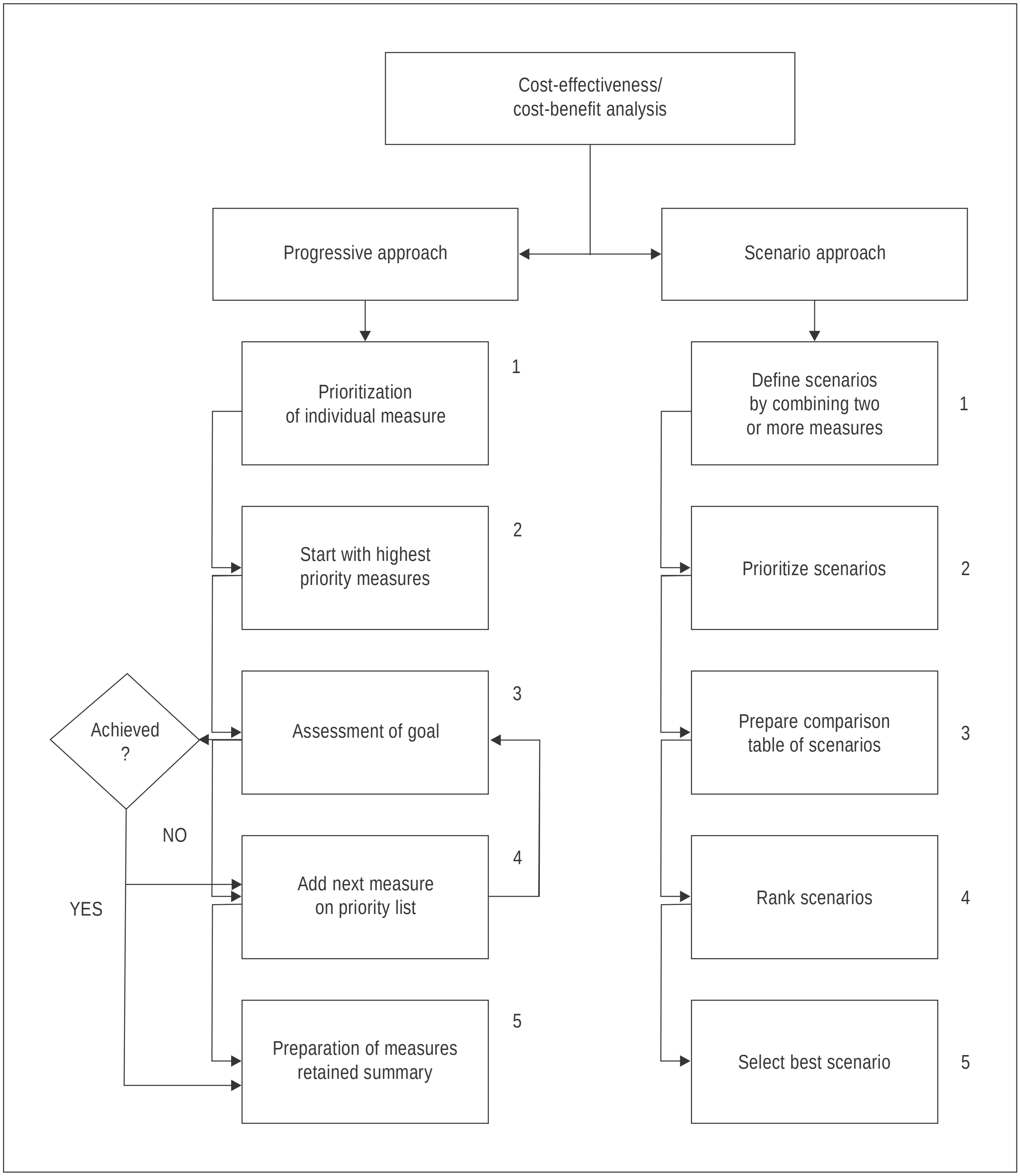


**Figure 4-3. Indicative sequence of steps for a cost-effectiveness or cost-benefit analysis**

## 4.4 QUANTIFYING THE EFFECTS ON FUEL CONSUMPTION AND $CO_2$ EMISSIONS FROM THE MEASURES SELECTED

4.4.1 Expected results represent the projected fuel consumption and $CO_2$ emissions after the implementation of the measures selected. The quantification of expected results from the implementation of an action plan is an essential element, as it is the means by which ICAO can understand the expected global progress to be achieved toward the environmental aspirational goals established by the Assembly. A consultative process with stakeholders associated with particular measures can be an effective means of obtaining information on the potential benefits from the implementation of the measure. Appendix C identifies many of the stakeholders that may be involved with the implementation of specific measures. Appendix C also provides a description of tools available along with a set of rules of thumb for estimating the expected benefits for each of the measures listed in Appendix A. These rules of thumb can be used in the event that the State does not have access to more detailed information about the expected results of a specific measure. In addition, example costs and benefits of individual measures are provided in Appendix E.

4.4.2 In some cases, the implementation of one measure may enable the benefits associated with another. An example would be with the equipage of new avionics. The avionics alone may not deliver any fuel savings; however, when combined with new procedures that require that equipment, the benefit is realized. For this reason, the quantification of benefits for each measure identified in the action plan is not required. However, to facilitate the assessment of the action plan by ICAO, States are invited to provide the expected benefits of each selected mitigation measures, even if only the end result of the implementation of the entire plan needs to be submitted, as shown in Table 4-2. The expected results submitted should include the effect of supranational measures on the individual State in addition to measures being implemented exclusively in the State. The APER website facilitates the development of this table by allowing the user to enter benefits associated with each measure identified, as desired. States are encouraged to submit additional information in support of their action plans on assumptions, methods used, etc. that will help the ICAO Secretariat to better interpret the plan. This information can be provided in any format the submitter wishes.

4.4.3 ***If an existing action plan is being updated***, the expected results should be updated as well. In all cases, if a change is made to any element of the action plan, whether to the baseline or the measures selected, it will result in a change to the expected results table as well.

**Table 4-2. Expected action plan results**

| *Year** | *Total RTK (tonne kilometres)* | *Total fuel (litres)* | *Total $CO_2$ emissions (metric tonnes)* | *International RTK* (tonne kilometres)* | *International fuel (litres)** | *International $CO_2$ emissions* (metric tonnes)* |
|---|---|---|---|---|---|---|
| Historic year | | | | | | |
| Historic year | | | | | | |
| Future years | | | | | | |
| 2040 | | | | | | |
| Future years | | | | | | |
| 2050 | | | | | | |

*Minimum data to be entered.

*Note 1.— The future years should match the baseline's future years.*

*Note 2.— The traffic data (in RTK) may not be identical to the baseline. Some measures may enable an increase in traffic or aim to reduce demand.*

# Chapter 5

# IMPLEMENTATION AND ASSISTANCE

## 5.1 IMPLEMENTATION CONSIDERATIONS

5.1.1 The development and submission of an action plan is not the end goal, but the beginning of a multi-year effort to reduce the impact of international aviation on the global climate while ensuring that aviation continues to grow in a sustainable manner. After the action plan has been finalized, a State will need to set in motion a process to implement the relevant measures in the action plan either directly or by working with and through stakeholders.

5.1.2 Various stakeholders will be involved in, and actively contribute to, the implementation of the selected measures. Continuous consultation and coordination between the various stakeholders will be essential to the successful implementation of the action plan.

5.1.3 The State will need to monitor the implementation of all activities. At the same time, the State will need to continue to work through ICAO to ensure that the needs identified by the State are met, in accordance with the practices and policies of the Organization, for the successful implementation of mitigation actions for which additional action at the international level would be necessary. Areas in which such assistance could be provided include gaining access to financial resources, building national capacities and receiving technological or technical assistance.

## 5.2 IDENTIFICATION OF ASSISTANCE NEEDS

5.2.1 The voluntary preparation of States' action plans will assist States in identifying their basket of measures to limit or reduce $CO_2$ emissions from international aviation, as well as the specific assistance needs to implement such measures, including financing, technical assistance and training/capacity building. In turn, it will allow ICAO to address States' specific needs in terms of facilitating access to the required assistance.

5.2.2 The financial information contained in the action plan provides an excellent forecast of when funding will be required. Funding may come from internal or external sources. Funding for the required investment may come in various forms, such as accumulated profits, government contributions, commercial debt financing (including loans and leasing), bond issues and equity financing. External sources of financing for environmental initiatives and actions to mitigate climate change exist and are expanding.

5.2.3 ***If an existing action plan is being updated***, the State should clearly indicate what assistance is needed in order to implement its updated action plan.

## 5.3 ACTION PLANS AS A SOURCE OF ASSISTANCE

5.3.1 Action plans create the possibility of partnerships, cooperation, capacity building, technology transfer and assistance. Stakeholders in States recognize the value in clearly communicating a strategy for achieving a specific objective. Many external organizations are creating potential funding opportunities for action on climate change from the aviation sector. To this end, States can build upon their action plan to demonstrate their commitment to the implementation of climate change policies and mitigation measures, even if resources are not readily available. The information requested for the development of State action plans bears the potential to create a comprehensive business case for States wishing to request implementation support.

5.3.2 The ICAO public website on financing and assistance[1] provides up-to-date descriptions of climate change financing mechanisms and possibilities of financing for the international aviation sector. The guidance document on *Financing Aviation Emissions Reductions*[2] developed in the framework of the ICAO-UNDP-GEF capacity-building and assistance project also provides invaluable information on the financing options for low carbon aviation measures. In addition, a list of climate funds can be found at www.climatefundsupdate.org, with information also available on the World Bank website, www.climatefinanceoptions.org. The information presented therein is for information purposes only. Material provided by the websites is provided "as is", without warranty of any kind, either express or implied, including, without limitation, warranties of merchantability, fitness for a particular purpose and non-infringement. The Organization accepts no responsibility or liability whether direct or indirect, as to the accuracy, completeness or quality of the information, or for any consequence of its use.

5.3.3 ICAO will continue to play a pivotal role in providing assistance to its Member States through the dissemination of the latest information on best practices and the provision of guidance and other technical assistance to enhance capacity building and technology transfer, including through the ICAO Technical Cooperation Bureau.

5.3.4 Moreover, ICAO will continue to initiate specific measures to assist developing States as well as to facilitate access to financial resources, technology transfer and capacity building. ICAO's partnerships with the European Union, and UNDP with financing from GEF, are testimonials to the Organization's commitment to support its Member States, in the spirit of the No Country Left Behind initiative.

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1. http://www.icao.int/environmental-protection/Pages/financing.aspx
2. https://www.icao.int/environmental-protection/Documents/ICAO_UNDP_GEF_FinancingLowCarbonAirportGuidance.pdf

# Appendix A

## BASKET OF MEASURES TO LIMIT OR REDUCE $CO_2$ EMISSIONS FROM INTERNATIONAL CIVIL AVIATION

This appendix summarizes all measures to limit or reduce $CO_2$ emissions from international civil aviation. All measures listed below can also be found on the Action Plan for Emissions Reduction (APER) website. These measures have been developed by the Group on International Aviation and Climate Change (GIACC) and subsequently approved by the High Level Meeting on Climate Change in November 2009. This list has since been updated in line with the basket of measures defined by Assembly Resolution A39-2.

The list below is deconstructed into four categories, which are subdivided into measures (a, b, c, etc.) and subsequently into actions (i, ii, etc.).

1. Technology and Standards

    a) aircraft fuel efficiency standards

    b) purchase of new aircraft

    c) retrofitting and upgrade improvements on existing aircraft

        i) improve fuel efficiency through development of modification (wingtip fence, blended winglet/sharklets, raked wingtip, etc., drag reduction, turbulent flow drag coatings, high power light emitting diode (LED) lighting, wireless/optical connections)

        ii) replacement of engines

        iii) replacement or modification of avionics

    d) optimizing improvements in aircraft produced in the near- to mid-term

        i) maximizing contribution of lightweight materials in aircraft planned for the near future

        ii) maximizing contribution of engine technology in aircraft planned for the near future

        iii) maximizing contribution of auxiliary power sources in aircraft planned for the near future

    e) avionics

    f) adoption of revolutionary new designs in aircraft/engines

        i) open rotor

        ii) blended wing body

iii) improved laminar flow

2. Sustainable aviation fuels (SAF)

a) development of aviation fuels with lower life cycle $CO_2$ emissions

b) standards/requirements for SAF use

3. Operational improvements

3.1 Air Traffic Management (ATM)

a) more efficient ATM planning, ground operations, terminal operations (departure, approach and arrivals), en-route operations, airspace design and usage, aircraft capabilities

i) measures to improve pre-departure planning and arrival planning (departure management (DMAN) and arrival management (AMAN))

ii) measures to improve ground operations

iii) measures to improve airport collaborative decision-making (A-CDM)

iv) measures to improve the use of optimum flight levels

v) measures to improve the use of optimum routings

vi) measures to improve flexible tracks

vii) measures to improve fuel efficient departure and approach procedures (PBN STAR, CCO, CDO, etc.)

viii) measures to fully utilize RNAV/RNP capabilities

ix) measures to improve flexible use of civil-military airspace

b) more efficient use and planning of airport capacities

i) measures to improve taxiing

ii) measures to improve parking

iii) measures to enhance terminal support facilities

iv) measures to plan new capacity when bottlenecks cause environmental problems

v) enhancing weather forecasting services

c) collaborative research endeavours

3.2 Operations

a) best practices in operations (Doc 10013 — *Operational Opportunities to Reduce Fuel Burn and Emissions*)

i) minimizing weight

ii) minimizing flaps (take-off and landing)

iii) minimizing reversers use

iv) single engine taxi

v) E-Taxi (only for A320 and B737)

vi) improving load factors

vii) reduced speed

viii) improved ground operations

ix) training pilots

4. Market-based measures

a) Voluntary inclusion of a State in the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)

b) Incorporation of emissions from international aviation into regional or national market-based measures, in accordance with relevant international Standards and instruments

c) Emissions charges or modulation of landing and take-off (LTO) charges, in accordance with relevant international instruments

i) $NO_x$ charges

ii) Fuel charges

iii) other

d) accredited offsetting schemes

Supplemental benefits for domestic sectors

Market-based measures

Airport improvements

a) airfield improvements

i) installation of LED lighting instead of classic lighting

b) reduced energy demand and preferred cleaner energy sources

  i) use cleaner alternative sources of power generation (photovoltaic panels, wind generators)

  ii) use cleaner heater/cooler equipment and/or minimize heater/cooler utilization

  iii) reduce electrical demand (switch off unnecessary lights, promote stairs instead of lifts, etc.)

c) enhanced ground support equipment (GSE) management

  i) reduce distance travelled

  ii) avoid unnecessary idling of equipment

d) conversion of GSE to cleaner fuels

  i) electrical operated ground vehicles

  ii) gas operated ground vehicles

  iii) alternative fuel operated ground vehicles

e) improved transportation to and from airport

  i) improved public transport access

  ii) improved employee transportation

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# Appendix B

## TEMPLATE FOR STATES' ACTION PLANS ON $CO_2$ EMISSIONS REDUCTION ACTIVITIES

1. This template has been developed to assist States intending to prepare and submit to ICAO an action plan outlining their policies and actions for addressing $CO_2$ emissions from international aviation. An action plan is a tool that a State can use to showcase and communicate, both at the national and international level, its efforts to address $CO_2$ emissions from international aviation.

2. In many respects, the development of an action plan resembles the execution of any project potentially involving activities such as securing resources, assembling a team, and planning and implementing various tasks. The structure of the action plan is intentionally simple in order to facilitate straightforward communication of the actions that a State intends to take and their expected results.

3. This template is generic and can be used for all types of action plans, ranging from simple compilations of data to elaborate reports. The level of information presented should be sufficient to clearly demonstrate the effectiveness of the actions implemented by a State and for ICAO to determine the anticipated global benefits from these actions.

4. ICAO has developed an interactive Action Plan for Emissions Reduction (APER) website that follows this template to simplify the submission of an action plan. This is the preferred method for submitting an action plan, and instructions for accessing the APER website are presented in Chapter 2, 2.6. Alternatively, if you are unable to access the website, you may fill out the template and submit it by e-mail to actionplan@icao.int.

5. This template is divided into five sections:

Section 1 — Contact information

Section 2 — Baseline scenario

Section 3 — Measures to mitigate $CO_2$ emissions

Section 4 — Expected results

Section 5 — Assistance needs

6. Per Assembly Resolution A39-2: *Consolidated statement of continuing ICAO policies and practices related to environmental protection — Climate change*, States are encouraged to share information contained in their action plans. Focal points would need to inform the ICAO Secretariat action plan team (actionplan@icao.int) if they want their entire action plan or any part of it to be made publicly available on the ICAO public website.

## SECTION 1 — CONTACT INFORMATION

For more information, please refer to Chapter 2 of this guidance document.

### 1.1 Contact information

Please provide below the contact information for the focal points within your State for your action plan. Please note that the first point of contact entered should be the individual responsible for submitting the action plan to ICAO.

Name of the Authority: ………………………………………………………………………………………..

Point of contact: ……………………………………………………………………………………..….

Street address: ………………………………………………………………………………………..

Country: ………………………………………………………………………………………..

State/Province: ………………………………………………………………………………………..

City: ………………………………………………………………………………………..

Telephone number: ………………………………………………………………………………………..

Fax number: ………………………………………………………………………………………..

E-mail address: ………………………………………………………………………………………..

Please note that you can provide as many contacts as necessary and one individual per mitigation measure, if desired.

## SECTION 2 — BASELINE SCENARIO

In order to understand the benefits that can be expected from the implementation of a basket of measures, it is useful to quantify both the historic fuel consumption and traffic, as well as to project into the future what would happen in the absence of the action plan.

For more information, refer to Chapter 3 of this document.

### 2.1 Baseline scenario

In the table below, describe the estimated baseline of fuel consumption and $CO_2$ emissions for international aviation within your State.

| | *Data required in order for an action plan to be considered complete by ICAO* | | | *Optional Data* | | |
|---|---|---|---|---|---|---|
| *Year* | ***International RTK (tonne kilometres)*** | ***International fuel (litres)*** | ***International $CO_2$ emissions (metric tonnes)*** | *Total RTK (tonne kilometres)* | *Total fuel (litres)* | *Total $CO_2$ emissions (metric tonnes)* |
| Historic year | | | | | | |
| Historic year | | | | | | |
| Future year | | | | | | |
| 2040 | | | | | | |
| Future year | | | | | | |
| 2050 | | | | | | |

Please indicate by checking the box below how your State accounts for $CO_2$ emissions from international traffic:

☐ All international flights operated by all air carriers registered in your State (ICAO methodology — State of registration)

☐ All international flights that depart from your State (IPCC methodology — State of departure)

## SECTION 3 — MEASURES TO MITIGATE $CO_2$ EMISSIONS

Various measures could be taken by States, air carriers, airports and air navigation service providers to reduce $CO_2$ emissions from civil aviation. Different categories constituting the basket of measures have been identified, including:

a) technology and standards;

b) sustainable aviation fuels;

c) operational improvements; and

d) market-based measures, including CORSIA.

For more information, refer to Chapter 4 of this document.

### 3.1 Description of the measures to mitigate $CO_2$ emissions

In the table below, enter the measure to mitigate $CO_2$ emissions, selected from among the basket of measures, for inclusion in your action plan. For each action identified, you may optionally provide information regarding its schedule for implementation and its associated incremental improvements/benefits.

For each new measure, start by entering the name of the measure as it is known in your State (title) and provide a brief description. Then, identify the type of measure by first selecting the category of the measure, then the type and subtype. (if applicable), per the tree given in Appendix A. Please note that for each action, the following information (if applicable and available) can be provided:

a) a description of the action and an indication of its type (operational, technological, market-based, etc.);

b) time horizon (start date and date of full implementation);

c) anticipated change in fuel consumption and/or $CO_2$ emissions;

d) economic cost and how it will be covered (domestic sources, regional funding, international assistance, etc.);

e) supplemental benefits for domestic sectors (mainly for domestic aviation, but others could also be reported, if appropriate);

f) reference to any relevant legislation;

g) identification of any barriers to implementation and any assistance needed; and

h) list of stakeholders involved.

| | |
|---|---|
| Title | |
| Description | |
| Category | |
| Measure | |
| Action | |
| Start date | |
| Date of full implementation | (when there are benefits from the measures) |
| Implemented by | |
| Economic cost | |
| Currency | |
| Reference to existing legislation | |
| Legislation is proposed | |
| Compliance | — voluntary<br>— mandatory<br>— N/A |
| Assistance needed | |
| Assistance needed<br>(check more than one) | — finance<br>— technology<br>— technical support<br>— education<br>— research<br>— other |
| Currency for financial assistance | |
| List of stakeholders involved | |
| Point of contact | |

### 3.2 Incremental improvements/benefits of each measure

This information is not required, but may be helpful in preparing the input for the Expected Results portion (Section 4). Please inscribe below the anticipated improvements/benefits associated with each specific measure. A measure can have several anticipated improvements for different years.

| Year | | | |
|---|---|---|---|
| Improvement in total fuel consumption (litres) | | | |
| Improvement in total $CO_2$ emissions (kg) | | | |
| Improvement in international fuel consumption (litres) | | | |
| Improvement in international $CO_2$ emissions (kg) | | | |
| Anticipated supplemental benefits for domestic sectors | | | |

### 3.3 Additional information

### 3.4 Point of contact for this measure

## SECTION 4 — EXPECTED RESULTS

In the table below, enter the projected fuel consumption and $CO_2$ emissions and traffic (i.e. after implementation of mitigation actions) that your State envisages to reach. Please note that this year-by-year description of the projected RTK, fuel consumption, and $CO_2$ emissions can be done consecutively or periodically.

| | *Data required in order for an action plan to be considered complete by ICAO* | | *Optional Data* | |
|---|---|---|---|---|
| *Year* | *International fuel (litres)* | *International $CO_2$ emissions (metric tonnes)* | *Total fuel (litres)* | *Total $CO_2$ emissions (metric tonnes)* |
| Historic year | | | | |
| Historic year | | | | |
| Future year | | | | |
| 2040 | | | | |
| Future year | | | | |
| 2050 | | | | |

## SECTION 5 — ASSISTANCE NEEDS

If applicable, the State can identify any assistance that is required either with the preparation of the action plan or its implementation. Through the tables provided in Section 3, assistance required for specific measures can either be identified there, or as a statement to be included in this section.

**— END OF ACTION PLAN —**

Templates presenting a step-by step guide and set of examples to assist States in the preparation of the action plan are available on the APER website. Instructions for accessing this website are given in Chapter 2, 2.6.

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# Appendix C

# KEY STAKEHOLDERS, ANALYSIS METHODS AND TOOLS

## 1. KEY STAKEHOLDERS

The development of an action plan that can be successfully implemented depends on the engagement and coordination with relevant stakeholders. Table C-1 provides a list of the main stakeholders typically involved with many of the measures. These stakeholders can support the decision-making process regarding the selection of measures, contribute to the analysis and assist with the implementation of the plan.

**Table C-1. Stakeholders typically involved with the implementation of measures**

| *Category* | *Measure* | *Air carriers* | *Other stakeholders*[1] | *Airports* | *ANSPs* | *Manufacturers* |
|---|---|---|---|---|---|---|
| Technology and Standards | Aircraft fuel efficiency standards | Yes | | | | Yes |
| | Purchase of new aircraft | Yes | Yes | Yes | | Yes |
| | Retrofitting and upgrade improvements on existing aircraft | Yes | | | | Yes |
| | Optimizing improvements in aircraft produced in the near- to mid-term | Yes | | | | Yes |
| | Avionics | Yes | Yes | | Yes | Yes |
| | Adoption of revolutionary new designs in aircraft/engines | Yes | | | | Yes |
| Sustainable aviation fuels | Development of fuels with lower $CO_2$ emissions on a life cycle basis, and associated standards | Yes | Yes | Yes | | Yes |

1. Other stakeholders include passengers, governments and other airspace users.

| *Category* | *Measure* | *Air carriers* | *Other stakeholders*[1] | *Airports* | *ANSPs* | *Manufacturers* |
|---|---|---|---|---|---|---|
| Operational improvements | More efficient ATM planning, ground operations, terminal operations (departure, approach and arrivals), en-route operations, airspace design and usage, aircraft air navigation capabilities | Yes | Yes | Yes | Yes | Yes |
| | More efficient use and planning of airport capacities | Yes | Yes | Yes | Yes | |
| | Conversion of airport infra-structure and ground support equipment to cleaner fuels | Yes | | Yes | | |
| | Construction of additional runways to relieve congestion | Yes | Yes | Yes | Yes | |
| | Enhanced terminal support facilities | Yes | | Yes | | |
| | Improved public transportation access | | | Yes | | |
| | Collaborative research endeavours | Yes | Yes | Yes | Yes | Yes |
| | Best practices in operations | Yes | | Yes | Yes | Yes |
| | Optimized aircraft maintenance (including jet engine cleaning/washing) | Yes | | | | Yes |
| | Selecting aircraft best suited to the mission | Yes | Yes | | | |
| Market-based measures | Voluntary inclusion of the aviation sector in market-based measures | Yes | Yes | Yes | Yes | Yes |
| | Incorporation of emissions from international aviation into regional or national market-based measures, in accordance with relevant international instruments | Yes | Yes | | | |

| *Category* | *Measure* | *Air carriers* | *Other stakeholders*[1] | *Airports* | *ANSPs* | *Manufacturers* |
|---|---|---|---|---|---|---|
| Market-based measures *(continued)* | Establishment of a multilateral emissions trading scheme for aviation which allows trading permits with other sectors, in accordance with relevant international instruments | Yes | Yes | Yes | Yes | Yes |
| | Establishment of a framework for linking existing emissions trading schemes and providing for their extension to international aviation, in accordance with relevant international instruments | Yes | | Yes | Yes | Yes |
| | Emissions charges or modulation of LTO charges, in accordance with relevant international instruments | Yes | Yes | Yes | Yes | Yes |
| | Positive economic stimulation by regulator: research programmes, special consideration and government programmes/ legislation and accelerated depreciation of aircraft | Yes | Yes | Yes | Yes | Yes |
| | Accredited offset schemes | Yes | Yes | Yes | Yes | Yes |
| | Explore extension of Clean Development Mechanism (CDM) | Yes | Yes | Yes | Yes | Yes |
| | Taxation of aviation fuel | Yes | Yes | Yes | Yes | Yes |
| | CORSIA | Yes | Yes | | | |

## 2. TOOLS AVAILABLE TO ASSIST IN QUANTIFYING FUEL CONSUMPTION AND $CO_2$ EMISSIONS FROM AVIATION

ICAO has developed tools to assist States in quantifying fuel consumption and $CO_2$ emissions from existing and planned operations. The objective of these tools is to allow all States to develop quantified baseline and expected results sections in their action plans. The tools require minimal data to be entered and are easy to use.

### 2.1 ICAO Carbon Emissions Calculator

ICAO has developed a methodology to calculate the $CO_2$ emissions from air travel for use in offset programmes. The methodology applies the best publicly available industry data to account for various factors such as aircraft types, route specific data, passenger load factors and cargo carried. An interactive Action Plan on Emissions Reduction (APER) website to support the development of action plans is available to allow a State to enter their flight schedule by airport pair and aircraft type to generate a $CO_2$ emissions inventory for the State. Instructions for accessing the APER website are given in Chapter 2, 2.6.

### 2.2 ICAO Fuel Savings Estimation Tool

(http://www.icao.int/environmental-protection/Pages/Tools.aspx)

The ICAO Fuel Savings Estimation Tool (IFSET) has been developed to assist the States to estimate fuel savings from operational changes in a manner consistent with the models approved by ICAO's Committee on Aviation Environmental Protection (CAEP) and aligned with the Global Air Navigation Plan (GANP). The IFSET is not intended to replace the use of detailed measurement or modelling of fuel savings where those capabilities exist. Rather, it is provided to assist those States without such facilities to estimate the benefits from operational improvements in a harmonized way.

### 2.3 ICAO Environmental Benefits Tool

The Environmental Benefits Tool (EBT) has been developed by ICAO to assist States' focal points in order to generate the baseline, estimate the benefits from the selected mitigation measures using the rules of thumb (described in Table C-2 below) and also generate the expected results which automatically compute the benefits from the mitigation measures with respect to the baseline. In addition, the EBT has been developed to offer the possibility to the focal points to use their own fuel savings methodologies when available, or to use the rules of thumb which generate a high-level estimate of benefits. The EBT is available on the APER website.

### 2.4 ICAO Aviation Environmental System

The Aviation Environmental System (AES) has been developed by ICAO in the scope of the ICAO-European Union Project Capacity Building for $CO_2$ Mitigation from International Aviation. The AES is an integrated system which allows Civil Aviation Authorities to monitor fuel consumption and $CO_2$ emissions on a flight-by-flight basis and report aggregated results on $CO_2$ emissions from international aviation to ICAO. A dedicated, uniform format called Form ENV1 has been developed to facilitate the reporting of relevant flight data from the airlines to their Civil Aviation Authority. Following the installation of the AES in their premises, several Civil Aviation Authorities have enforced a national regulation requesting their national airlines to report $CO_2$ emissions data monthly on Form ENV1. These forms can then be imported in the AES by the Civil Aviation Authority to populate a flight database, used to export aggregated results and report them to ICAO in various formats automatically generated by the AES, such as monthly or annual $CO_2$ reports, or ICAO Form M. The AES also performs validity checks on the imported data and can verify, through a cross-checking process, the consistency of RTK and fuel consumption data of identical flights imported by two different sources. As of 2017, the AES has only been implemented in the selected States of the ICAO-European Union Project, but may be upgraded in the future for compatibility with CORSIA, and distributed to a wider group of States.

## 3. RULES OF THUMB FOR ESTIMATING BENEFITS

3.1 While the previous section of this appendix described tools available to compute the benefits from the measures listed in Appendix A, the rules of thumb presented in Table C-2 can be applied if the data or resources are not available to use a more advanced technique. The objective of the rules of thumb is to provide a reasonable approximation of the benefits associated with a specific measure, thereby allowing all action plans to include a quantified expected results section. The rules of thumb provided in this appendix are suitable for generating a high-level estimate of benefits in support of the development of an action plan. However, a more detailed analysis may be warranted if the results are to be applied in support of an investment decision or cost-benefit analysis.

3.2 Table C-2 also includes a brief example to illustrate how to apply each rule of thumb. It is important to note that the expected results table (see Table 4-2) should include the expected fuel consumption as a result of applying the measures, not the fuel savings. Therefore, the fuel savings computed using these rules of thumb should be subtracted from the baseline fuel consumption to arrive at the expected results.

3.3 Table C-2 is followed by a legend, a list of references used in formulating the rules of thumb, and information on the reference data used in some of the example calculations.

3.4 More examples on the estimation of fuel consumption from more efficient operations can be found in ICAO Doc 10013 — *Operational Opportunities to Reduce Fuel Burn and Emissions*.

## Table C-2. Rules of thumb for estimating expected results by measure

| *Category* | *Sub-category* | *Measure (References)* | *Rule of thumb* | *Example* |
|---|---|---|---|---|
| Technology and Standards | Purchase of new aircraft | Purchase of new aircraft<br><br>(Air Navigation Report 2014) | FS = [0.9% to 1.05%] * a/c' age (year) * old a/c' fuel burn | An airline has 5 narrow-body aircraft that are 10 years old with an average fuel consumption of 2.411 tonnes per hour and 5 wide-body aircraft that are 12 years old with an average fuel consumption of 12.183 tonnes per hour. All 10 aircraft will be replaced with new aircraft.<br><br>Each aircraft in the narrow-body fleet operates for an average of 2,700 hours per year, and each aircraft in the wide-body fleet operates for an average of 3,800 hours per year.<br><br>The annual fuel savings can be estimated as:<br><br>— narrow-body: 0.009 * 10 * 5 * 2.411 * 2,700 = 2,929 tonnes of fuel<br><br>— wide-body: 0.009 * 12 * 5 * 12.183 * 3,800 = 25,000 tonnes of fuel<br><br>Total: 27,929 tonnes of fuel saved per year (low end of range) |
| | Retrofitting and upgrade improvements on existing aircraft | Improve fuel efficiency through development of modification:<br><br>*Wingtip fence*<br><br>(IATA) | FS = [1% to 3%] * FB | An airline has 5 aircraft with an average fuel consumption of 2.411 tonnes per hour that are used, on average, 2,700 hours per year. The airline intends to install wingtip fences on all 5 of these aircraft.<br><br>The annual fuel savings can be estimated as:<br><br>0.01 * 5 * 2.411 * 2,700 = 325.5 tonnes of fuel saved per year (low end of range) |
| | | Improve fuel efficiency through development of modification:<br><br>*Blended winglet/ sharklets*<br><br>(IATA) | FS = [3% to 6%] * FB | An airline has 5 aircraft with an average fuel consumption of 2.411 tonnes per hour that are used, on average, 2,700 hours per year. The airline intends to install blended winglets on all 5 of these aircraft.<br><br>The annual fuel savings can be estimated as:<br><br>0.03 * 5 * 2.411 * 2,700 = 976.5 tonnes of fuel saved per year (low end of range) |
| | | Improve fuel efficiency through development of modification:<br><br>*Raked wingtip*<br><br>(IATA) | FS = [3% to 6%] * FB | An airline has 5 aircraft with an average fuel consumption of 2.411 tonnes per hour that are used, on average, 2,700 hours per year. The airline intends to install raked wingtips on all 5 of these aircraft.<br><br>The annual fuel savings can be estimated as:<br><br>0.03 * 5 * 2.411 * 2,700 = 976.5 tonnes of fuel saved per year (low end of range) |

| *Category* | *Sub-category* | *Measure (References)* | *Rule of thumb* | *Example* |
|---|---|---|---|---|
| Technology and Standards *(continued)* | Retrofitting and upgrade improvements on existing aircraft *(continued)* | Improve fuel efficiency through development of modification:<br><br>*Split winglets with scimitar tips*<br><br>(IATA) | FS = [2% to 6%] * FB | An airline has 5 aircraft with an average fuel consumption of 2.411 tonnes per hour that are used, on average, 2,700 hours per year. The airline intends to install split winglets on all 5 of these aircraft.<br><br>The annual fuel savings can be estimated as:<br><br>0.02 * 5 * 2.411 * 2,700 = 651 tonnes of fuel saved per year (low end of range) |
| | | Improve fuel efficiency through development of modification:<br><br>*Drag reduction coatings*<br><br>(IATA) | FS = [1%] * FB | An airline has 5 aircraft with an average fuel consumption of 2.411 tonnes per hour that are used, on average, 2,700 hours per year. The airline intends to apply drag reduction coatings to all 5 of these aircraft.<br><br>The annual fuel savings can be estimated as:<br><br>0.01 * 5 * 2.411 * 2,700 = 325.5 tonnes of fuel saved per year |
| | | Improve fuel efficiency through development of modification:<br><br>*Turbulent flow drag coatings (riblets)*<br><br>(IATA) | FS = [1%] * FB | An airline has 5 aircraft with an average fuel consumption of 2.411 tonnes per hour that are used, on average, 2,700 hours per year. The airline intends to install riblets on all 5 of these aircraft.<br><br>The annual fuel savings can be estimated as:<br><br>0.01 * 5 * 2.411 * 2,700 = 325.5 tonnes of fuel saved per year |
| | | Improve fuel efficiency through development of modification:<br><br>*Aircraft graphic films*<br><br>(IATA) | FS = [1%] * FB | An airline has 5 aircraft with an average fuel consumption of 2.411 tonnes per hour that are used, on average, 2,700 hours per year. The airline intends to apply drag reducing films to all 5 of these aircraft.<br><br>The annual fuel savings can be estimated as:<br><br>0.01 * 5 * 2.411 * 2,700 = 325.5 tonnes of fuel saved per year |
| | | Improve fuel efficiency through development of modification:<br><br>*High power LEDs for cabin lighting*<br><br>(IATA) | FS = [0.5%] * FB | An airline has 5 aircraft with an average fuel consumption of 2.411 tonnes per hour that are used, on average, 2,700 hours per year. The airline intends to install LED cabin lighting in all 5 of these aircraft.<br><br>The annual fuel savings can be estimated as:<br><br>0.005 * 5 * 2.411 * 2,700 = 162.7 tonnes of fuel saved per year |

| *Category* | *Sub-category* | *Measure (References)* | *Rule of thumb* | *Example* |
|---|---|---|---|---|
| Technology and Standards *(continued)* | Retrofitting and upgrade improvements on existing aircraft *(continued)* | Improve fuel efficiency through development of modification:<br><br>*Wireless/optical connections for in-flight entertainment*<br><br>(IATA) | FS = [0.5%] * FB | An airline has 5 aircraft with an average fuel consumption of 2.411 tonnes per hour that are used, on average, 2,700 hours per year. The airline intends to replace its in-flight entertainment systems with wireless systems in all 5 of these aircraft.<br><br>The annual fuel savings can be estimated as:<br><br>0.005 * 5 * 2.411 * 2,700 = 162.7 tonnes of fuel saved per year |
| Sustainable Aviation Fuels (SAF) | Standards/ requirements for SAF use | Use SAF<br><br>(ICAO Secretariat) | $CO_2$ savings = utilization (%) * FB * 3.16<br>(until international agreement is reached regarding life-cycle analysis) | An airline has 5 aircraft with an average fuel consumption of 2.411 tonnes per hour that are used, on average, 2,700 hours per year. The airline intends to use a 20% blend of SAF in all operations.<br><br>The $CO_2$ savings can be estimated as:<br><br>0.2 * 5 * 2.411 * 2,700 * 3.16 = 20,551 tonnes of $CO_2$ saved per year<br><br>***Note.— This measure only reduces net $CO_2$ emissions, not fuel.*** |
| Operational improvements | More efficient ATM planning, ground operations, terminal operations, en-route operations, airspace design and usage, aircraft air navigation capabilities | Measures to improve fuel-efficient departure and approach procedures:<br><br>*CDO*<br><br>(CAEP/10 Report 2016) | Use IFSET<br><br>or<br><br>FS = 60 kg (0.06 tonnes) of fuel * number of CDOs | A State averages 1,000,000 flights per year. Currently, 10 of its airports offer CDO which accounts for approximately 4,800,000 arrival movements. Expert judgement estimates that CDO at these airports is performed 100% in off-peak hours which accounts for approximately 35% or 1,680,000 traffic movements.<br><br>The annual fuel savings can be estimated as:<br><br>0.06 * 1,680,000 = 100,800 tonnes of fuel saved |
| | | Measures to improve fuel efficient departure and approach procedures:<br><br>*PBN STAR*<br><br>(CAEP/10 Report 2016) | Use IFSET<br><br>or<br><br>FS = 20 kg to 50 kg of fuel (.02 to .05 tonnes) * number of arrivals on PBN STAR | A State averages 1,000,000 flights per year. Currently, 50 of its airports have implemented PBN STAR which is estimated to be used by 250,000 arrival movements. Expert judgement is that 100% of these arrivals fly the PBN STAR.<br><br>The annual fuel savings can be estimated as:<br><br>— 0.02 * 250,000 = 5,000 tonnes of fuel saved (low end of range)<br><br>— 0.05 * 250,000 = 12,500 tonnes of fuel saved (high end of range) |

| *Category* | *Sub-category* | *Measure (References)* | *Rule of thumb* | *Example* |
|---|---|---|---|---|
| Operational improvements *(continued)* | More efficient ATM planning, ground operations, terminal operations, en-route operations, airspace design and usage, aircraft air navigation capabilities *(continued)* | Measures to improve fuel efficient departure and approach procedures:<br><br>*CCO*<br><br>(CAEP/10 Report 2016) | Use IFSET<br><br>or<br><br>FS = 90-150 kg (0.09-0.15 tonnes) of fuel * number of CCOs | A State averages 2,000,000 flights per year. Currently, 50 of its airports offer CCO which accounts for approximately 200,000 departure movements. Expert judgement estimates that CCO is performed by 80% of the departures, a total of 160,000 departure movements.<br><br>The annual fuel savings can be estimated as:<br><br>— 0.09 * 160,000 = 14,400 tonnes of fuel saved (low end of range)<br><br>— 0.15 * 160,000 = 24,000 tonnes of fuel saved (high end of range) |
| | | Measures to improve fuel efficient departure and approach procedures:<br><br>*PBN SID*<br><br>(CAEP/10 Report 2016) | Use IFSET<br><br>or<br><br>FS = 0 kg to 30 kg of fuel (0 to .03 tonnes) * number of departure movements on PBN SID | A State averages 1,000,000 flights per year. Currently, 50 of its airports have implemented PBN SID which is estimated to be used by 200,000 departure movements. Expert judgement is that 100% of these departures fly the PBN SID.<br><br>The annual fuel savings can be estimated as:<br><br>— 0.0 * 200,000 = 0 tonnes of fuel saved (low end of range)<br><br>— 0.03 * 200,000 = 6,000 tonnes of fuel saved (high end of range) |
| | | Measures to improve collaborative decision making:<br><br>*A-CDM (non-U.S. version)* | Use IFSET<br><br>or<br><br>FS = time savings (1 to 3 min) * number of movements | An airport with an average of 100,000 movements (both departures and arrivals) annually is implementing A-CDM. On average, aircraft at the airport burn 12 kg (0.012 tonnes) per minute during taxi. The benefit of A-CDM (non-U.S. version) is achieved during the total taxi phase (taxi-in and taxi-out).<br><br>The annual fuel savings can be estimated as:<br><br>— 1 * 0.012 * 100,000 = 1,200 tonnes of fuel saved (low end of range)<br><br>— 3 * 0.012 * 100,000 = 3,600 tonnes of fuel saved (high end of range) |
| | | Measures to improve collaborative decision making:<br><br>*A-CDM (U.S. version)* | Use IFSET<br>or<br><br>FS = time savings (1 to 2 min) * number of departure movements | An airport with an average of 50,000 departure movements annually is implementing A-CDM. On average, aircraft at the airport burn 12 kg (0.012 tonnes) per minute during taxi. The benefit of A-CDM (U.S. version) is achieved only during the taxi-out phase.<br><br>The annual fuel savings can be estimated as:<br><br>— 1 * 0.012 * 50,000 = 600 tonnes of fuel saved (low end of range)<br><br>— 2 * 0.012 * 50,000 = 1,200 tonnes of fuel saved (high end of range) |

| *Category* | *Sub-category* | *Measure (References)* | *Rule of thumb* | *Example* |
|---|---|---|---|---|
| Operational improvements *(continued)* | More efficient ATM planning, ground operations, terminal operations, en-route operations, airspace design and usage, aircraft air navigation capabilities *(continued)* | Measures to improve fuel efficient departure and approach procedures:<br><br>*WAKE-RECAT (departures)*<br><br>(CAEP/10 Report 2016) | Use IFSET<br><br>or<br><br>FS = time (fuel) savings (21-32 seconds (4.2-6.4 kg)) * number of departure movements * 0.35 | An airport with an average of 100,000 departure movements annually is implementing WAKE-RECAT. It is assumed that 35% of departure traffic will fly in peak hours when the benefit from RECAT will be realized (35,000 departure movements). The benefit from RECAT is estimated to be between 21-32 seconds of taxi time savings per aircraft. On average, aircraft at the airport burn 12 kg (0.012 tonnes) per minute during taxi, so 21-32 seconds can be equal to 4.2-6.4 kg of fuel.<br><br>The annual fuel savings can be estimated as:<br><br>— 4.2 * 100,000 * 0.35 = 147 tonnes of fuel saved (low end of range)<br><br>— 6.4 * 100,000 * 0.35 = 224 tonnes of fuel saved (high end of range) |
| | | Measures to improve fuel efficient departure and approach procedures:<br><br>*WAKE-RECAT (arrivals)* | Use IFSET<br><br>or<br><br>FS = time (fuel) savings (7-12 kg) * number of arrival movements * 0.35 | An airport with an average of 100,000 arrival movements annually is implementing WAKE-RECAT. It is assumed that 35% of arrival traffic will fly in peak hours when the benefit from RECAT will be realized (35,000 arrival movements).The benefit of RECAT is estimated to be between 7-12 kg fuel savings per flight.<br><br>The annual fuel savings can be estimated as:<br><br>— 7 kg * 100,000 * 0.35 = 245 tonnes of fuel saved (low end of range)<br><br>— 12 kg * 100,000 * 0.35 = 420 tonnes of fuel saved (high end of range) |
| | | Measures to improve fuel efficient departure and approach procedures:<br><br>*AMAN/(RSEQ)*<br><br>(CAEP/10 Report 2016) | Use IFSET<br><br>or<br><br>FS = fuel savings (50-100 kg) * number of arrival movements* 0.35 | An airport with an average of 200,000 arrival movements annually is implementing AMAN. It is assumed that 35% of arrival traffic will fly in peak hours when the benefit from AMAN will be realized (70,000 arrival movements). The benefit from AMAN is estimated to be between 50-100 kg fuel savings per aircraft.<br><br>The annual fuel savings can be estimated as:<br><br>— 0.05 * 200,000 * 0.35 = 3,500 tonnes of fuel saved (low end of range)<br><br>— 0.1 * 200,000 * 0.35 = 7,000 tonnes of fuel saved (high end of range) |

| *Category* | *Sub-category* | *Measure (References)* | *Rule of thumb* | *Example* |
|---|---|---|---|---|
| Operational improvements *(continued)* | More efficient ATM planning, ground operations, terminal operations, en-route operations, airspace design and usage, aircraft air navigation capabilities *(continued)* | Measures to fully utilize ADS-B surveillance<br><br>(CAEP/10 Report 2016) | Use IFSET<br><br>or<br><br>FS = number of flights in unsurveilled airspace * equipage rate (70%) * average flight time (hours) * fuel burn (per hour) * number of climbs to optimal level (1-2) * fuel savings (1% to 2%) | A State's non-RADAR airspace typically handles 10,000 aircraft per year. Each aircraft spends, on average, 4 hours in unsurveilled airspace, burning 12.183 tonnes of fuel per hour.<br><br>Estimated ADS-B equipage of the aircraft in unsurveilled airspace is 70%. It is assumed that an aircraft can benefit by approximately 1-2% fuel reduction for each 1,000 feet of altitude toward the optimal en-route altitude and that between 1-2 climbs of 1,000 feet can be made in the airspace using ADS-B surveillance.<br><br>The annual fuel savings from the implementation of alternative surveillance (ASUR) can be estimated as:<br><br>— 10,000 * 0.7 * 4 * 12.183 * 1 * 0.01 = 3,411 tonnes of fuel saved (low end of range)<br><br>— 10,000 * 0.7 * 4 * 12.183 * 2 * 0.02 = 13,645 tonnes of fuel saved (high end of range) |
| | | Implementation of radius to fix PBN procedures | Use IFSET<br><br>or<br><br>FS = ∑[(Total movements * 0.1 * fuel savings for small aircraft (11-40 kg)) + (total movements * 0.8 * fuel savings for medium aircraft (62-121 kg)) + total movements * 0.1 * fuel savings for heavy aircraft (95-187 kg))] * 0.5 | An airport with 100,000 arrival movements is planning to implement radius to fix PBN procedures. It is assumed that 50% of arrivals to this airport will fly this approach procedure. The breakdown of traffic at this airport is estimated to be 10% : 80% : 10% in relation to small : medium : heavy aircraft.<br><br>The annual fuel savings can be estimated as:<br><br>— ((100,000 * 0.1 * 11 kg) + (100,000 * 0.8 * 62 kg) + (100,000 * 0.1 * 95 kg)) * 0.5 = 3,010 tonnes of fuel saved (low end of range)<br><br>— ((100,000 * 0.1 * 40 kg) + (100,000 * 0.8 * 121 kg) + (100,000 * 0.1 * 187 kg)) * 0.5 = 11,950 tonnes of fuel saved (high end of range) |

| *Category* | *Sub-category* | *Measure (References)* | *Rule of thumb* | *Example* |
|---|---|---|---|---|
| Operational improvements *(continued)* | More efficient ATM planning, ground operations, terminal operations, en-route operations, airspace design and usage, aircraft air navigation capabilities *(continued)* | Implementation of RNP AR APCH procedures for reducing approach minima and the possibilities of missed approach/diversion | Use IFSET<br><br>or<br><br>FS = total arrival movements * 0.5 * 0.005 * fuel savings (381-471 kg) | An airport with 100,000 arrival movements is planning to implement an RNP AR APCH procedure. It is assumed that 50% of arrivals to this airport will fly this approach procedure. It is estimated that in the event of a missed approach or diversion the average extra fuel burn used ranges from 381-470 kg. It is assumed that the minima are sufficiently reduced to require an aircraft to carry out a missed approach or diversion in 0.005 operations.<br><br>The annual fuel savings can be estimated as:<br><br>— 100,000 * 0.5 * 0.005 * 381 kg = 95.25 tonnes of fuel saved (low end of range)<br><br>— 100,000 * 0.5 * 0.005 * 470 kg = 117.5 tonnes of fuel saved (high end of range) |
| | | Implementation of A-SMGCS surface operations (SURF) during peak periods | Use IFSET<br><br>or<br><br>FS = fuel savings (0.012-0.024) * number of departure movements * 0.35 | An airport with an average of 200,000 departure movements annually is implementing A-SMGCS. On average, aircraft at the airport burn 12 kg (0.012 tonnes) per minute during taxi. It is assumed that 35% of departure traffic will fly in peak hours when the benefit from A-SMGCS will be realized (35,000 departure movements). The benefit of A-SMGCS is estimated to be a taxi-out time reduction in peak hours of between 1-2 minutes.<br><br>The annual fuel savings can be estimated as:<br><br>— 1 * 0.012 * 200,000 * 0.35 = 840 tonnes of fuel saved (low end of range)<br><br>— 2 * 0.012 * 200,000 * 0.35 = 1,680 tonnes of fuel saved (high end of range) |
| | | Implementation of A-SMGCS surface operations (SURF) during periods of low visibility | Use IFSET<br><br>or<br><br>FS = fuel savings (0.012-0.024) * number of departure movements * 0.04 | An airport with an average of 200,000 departure movements annually is implementing A-SMGCS. On average, aircraft at the airport burn 12 kg (0.012 tonnes) per minute during taxi. The benefit of A-SMGCS is estimated to be a taxi-out time reduction during low visibility procedures (LVPs) of between 1-2 minutes. It is assumed that LVPs occur in time periods that affect 0.4% of movements.<br><br>The annual fuel savings can be estimated as:<br><br>— 1 * 0.012 * 200,000 * 0.04 = 96 tonnes of fuel saved (low end of range)<br><br>— 2 * 0.012 * 200,000 * 0.04 = 192 tonnes of fuel saved (high end of range) |

| *Category* | *Sub-category* | *Measure (References)* | *Rule of thumb* | *Example* |
|---|---|---|---|---|
| Operational improvements *(continued)* | More efficient ATM planning, ground operations, terminal operations, en-route operations, airspace design and usage, aircraft air navigation capabilities *(continued)* | Implementation of A-SMGCS (SURF) during night operations | Use IFSET<br><br>or<br><br>FS = fuel savings (0.0038-0.0077) * number of departure movements * 0.1 | An airport with an average of 200,000 departure movements annually is implementing A-SMGCS. On average, aircraft at the airport burn 12 kg (0.012 tonnes) per minute during taxi. The benefit of A-SMGCS is estimated to be a taxi-out time reduction during “night time” of between 23-64 seconds. This is equivalent to 3.8-7.7 kg fuel. It is assumed that operations during “night time” are equivalent to 10% of movements.<br><br>The annual fuel savings can be estimated as:<br><br>— 1 * 0.0038 * 200,000 * 0.1 = 240 tonnes of fuel saved (low end of range)<br><br>— 2 * 0.0077 * 200,000 * 0.1 = 480 tonnes of fuel saved (high end of range) |
| | Best practices in operations | Minimizing weight – TP<br><br>(IATA’s guidance) | FS = weight reduction * flight time * 1.95% | An airline has 5 aircraft that are used, on average, 2,700 hours per year. The airline intends to reduce weight by 20 kg (0.02 tonnes) on all 5 of these aircraft.<br><br>The annual fuel savings can be estimated as:<br><br>5 * 0.02 * 2,700 * 0.0195 = 5.25 tonnes of fuel saved |
| | | Minimizing weight – NB<br><br>(IATA’s guidance) | FS = weight reduction * flight time * 3.35% | An airline has 5 aircraft that are used, on average, 2,700 hours per year. The airline intends to reduce weight by 20 kg (0.02 tonnes) on all 5 of these aircraft.<br><br>The annual fuel savings can be estimated as:<br><br>5 * 0.02 * 2,700 * 0.0335 = 9.0 tonnes of fuel saved |
| | | Minimizing weight – WB<br><br>(IATA’s guidance) | FS = weight reduction * flight time * 3.87% | An airline has 5 aircraft that are used, on average, 3,800 hours per year. The airline intends to reduce weight by 20 kg (0.02 tonnes) on all 5 of these aircraft.<br><br>The annual fuel savings can be estimated as:<br><br>5 * 0.02 * 3,800 * 0.0387 = 14.7 tonnes of fuel saved |

| *Category* | *Sub-category* | *Measure (References)* | *Rule of thumb* | *Example* |
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| Operational improvements *(continued)* | Best practices in operations *(continued)* | Minimizing flaps (take-off) – NB<br><br>(Boeing) | FS = 1.7% * departure FB (BAU) | An aircraft with 3,000 departures per year typically burns 1.7 tonnes of fuel on take-off.<br><br>The annual fuel savings can be estimated as:<br><br>0.017 * 1.7 * 3,000 = 86.7 tonnes of fuel saved |
| | | Minimizing flaps (take-off) – WB<br><br>(Boeing) | FS = 1.4% to 3.4% * departure FB (BAU) | An aircraft with 3,000 departures per year typically burns 4.5 tonnes of fuel on take-off.<br><br>The annual fuel savings can be estimated as:<br><br>0.014 * 4.5 * 3,000 = 189 tonnes of fuel saved |
| | | Minimizing flaps (landing) – NB<br><br>(Boeing) | FS = 1.4% * approach FB (BAU) | An aircraft with 3,000 arrivals per year typically burns 0.6 tonnes of fuel on landing.<br><br>The annual fuel savings can be estimated as:<br><br>0.014 * 0.6 * 3,000 = 25.2 tonnes of fuel saved |
| | | Minimizing flaps (landing) – WB<br><br>(Boeing) | FS = 3.2% to 7.6% * approach FB (BAU) | An aircraft with 3,000 arrivals per year typically burns 1.8 tonnes of fuel on landing.<br><br>The annual fuel savings can be estimated as:<br><br>0.032 * 1.8 * 3,000 = 172.8 tonnes of fuel saved |
| | | Minimizing reversers use<br><br>(ICAO Secretariat) | FS for NB = 26.01 kg/landing<br><br>FS for WB (2 engines) = 73.14 kg/landing<br><br>FS for WB (4 engines) = 100.15 kg/landing | An airline has 5 narrow-body aircraft with 2,000 landings per year, per aircraft and 10 wide-body aircraft (2 engines) with 900 landings per year, per aircraft.<br><br>The annual fuel savings can be estimated as:<br><br>— for NB: 5 * 0.02601 * 2,000 = 260.1 tonnes of fuel saved<br><br>— for WB: 10 * 0.07314 * 900 = 658.3 tonnes of fuel saved<br><br>Total = 918.4 tonnes of fuel saved |

| *Category* | *Sub-category* | *Measure (References)* | *Rule of thumb* | *Example* |
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| Operational improvements *(continued)* | Best practices in operations *(continued)* | E-taxi (only for B737 and A320)<br><br>(ICAO Secretariat) | FS = 10.41 kg (0.01041 tonnes) of fuel/min * time (min) | An aircraft with 3,000 operations per year typically spends a total of 26 minutes taxiing per operation. It will use E-taxi for approximately 20 minutes per operation.<br><br>The annual fuel savings can be estimated as:<br><br>0.01041 * 20 * 3,000 = 624 tonnes of fuel saved |
| | | Single engine taxi – NB<br><br>(ICAO Secretariat) | FS = ∑[28% * $FB_i$/min (idle) * time with 1 engine off (min)], where *i* is the a/c type | An aircraft with 3,000 operations per year typically spends a total of 26 minutes taxiing per operation. All-engine taxi requires 12 kg (0.012 tonnes) per minute. It will spend 20 minutes taxiing single-engine per operation.<br><br>The annual fuel savings can be estimated as:<br><br>0.28 * 0.012 * 20 * 3,000 = 201.6 tonnes of fuel saved |
| | | Single engine – WB (2 engines)<br><br>(ICAO Secretariat) | FS = ∑[28% * $FB_i$/min (idle) * time with 1 engine off (min)], where *i* is the a/c type | An aircraft with 3,000 operations per year typically spends a total of 26 minutes taxiing per operation. All-engine taxi requires 33 kg (0.033 tonnes) per minute. It will spend 20 minutes taxiing single-engine per operation.<br><br>The annual fuel savings can be estimated as:<br><br>0.28 * 0.033 * 20 * 3,000 = 554.4 tonnes of fuel saved |
| | | Double engine – WB (4 engines)<br><br>(ICAO Secretariat) | FS = ∑[28% * $FB_i$/min (idle) * time with 2 engines off (min)], where *i* is the a/c type | An aircraft with 3,000 operations per year typically spends a total of 26 minutes taxiing per operation. All-engine taxi requires 54 kg (0.054 tonnes) per minute. It will spend 20 minutes taxiing two-engine per operation.<br><br>The annual fuel savings can be estimated as:<br><br>0.28 * 0.054 * 20 * 3,000 = 907.2 tonnes of fuel saved |
| | Optimized aircraft maintenance | Engine wash<br><br>(IATA) | FS = [1%] * FB | An airline has 5 aircraft with an average fuel consumption of 2.411 tonnes per hour that are used, on average, 2,700 hours per year. The airline intends to conduct an engine wash on all 5 of these aircraft.<br><br>The annual fuel savings can be estimated as:<br><br>0.01 * 5 * 2.411 * 2,700 = 325.5 tonnes of fuel saved per year |

| *Category* | *Sub-category* | *Measure (References)* | *Rule of thumb* | *Example* |
|---|---|---|---|---|
| Operational improvements *(continued)* | Optimized aircraft maintenance *(continued)* | Zonal dryer<br><br>(IATA) | FS = [1%] * FB | An airline has 5 aircraft with an average fuel consumption of 2.411 tonnes per hour that are used, on average, 2,700 hours per year. The airline intends to apply a zonal dryer to all 5 of these aircraft.<br><br>The annual fuel savings can be estimated as:<br><br>0.01 * 5 * 2.411 * 2,700 = 325.5 tonnes of fuel saved per year |
| | Selecting aircraft best suited to the mission | Selecting aircraft best suited to the mission<br><br>(ICAO Secretariat) | FS = $\sum$[$FB_i$ (BAU) – $FB_h$ (OPTIMUM)], where *h* represents optimal aircraft | An airline currently operates an aircraft that burns 12.183 tonnes of fuel per hour on routes that total 2,700 hours per year. The optimum aircraft for that mission would burn 2.411 tonnes per hour.<br><br>The annual fuel savings can be estimated as:<br><br>[12.183 * 2,700] – [2.411 * 2,700] = 26,384 tonnes of fuel saved per year |
| | Airfield improvements | Construction of runways<br><br>(ICAO Secretariat) | Use IFSET<br><br>or<br><br>FS = $\sum$[time $savings_i$ (min) * $FB_i$ /min] | An airport with an average of 100,000 arrivals and 100,000 departures annually is building an additional runway. On average, aircraft are expected to save 3 minutes on arrival and 5 minutes on departure from the additional runway. Arriving aircraft typically burn 35 kg (0.035 tonnes) per minute and departing aircraft burn 12 kg (0.012 tonnes) per minute during taxi.<br><br>The annual fuel savings can be estimated as:<br><br>— arrivals: 3 * 0.035 * 100,000 = 10,500 tonnes of fuel saved<br><br>— departures: 5 * 0.012 * 100,000 = 6,000 tonnes of fuel saved<br><br>Total: 16,500 tonnes of fuel saved |

| *Category* | *Sub-category* | *Measure (References)* | *Rule of thumb* | *Example* |
|---|---|---|---|---|
| Operational improvements *(continued)* | Airfield improvements *(continued)* | Construction of taxiways<br><br>(ICAO Secretariat) | Use IFSET<br><br>or<br><br>FS = ∑[time savings (min) * $FB_i$ (idle)/min] | An airport with an average of 100,000 arrivals and 100,000 departures annually is building additional taxiways. On average, aircraft are expected to save 3 minutes on arrival and 5 minutes on departure. Aircraft typically burn 12 kg (0.012 tonnes) per minute during taxi.<br><br>The annual fuel savings can be estimated as:<br><br>— arrivals: 3 * 0.012 * 100,000 = 3,600 tonnes of fuel saved<br><br>— departures: 5 * 0.012 * 100,000 = 6,000 tonnes of fuel saved<br><br>Total: 9,600 tonnes of fuel saved |
| | | Construction of additional taxiway-exits and/or speed-exit<br><br>(ICAO Secretariat) | Use IFSET<br><br>or<br><br>FS = ∑[time savings (min) * $FB_i$ (idle)/min] | An airport with an average of 100,000 arrivals and 100,000 departures annually is building additional taxiways. On average, aircraft are expected to save 3 minutes on arrival. Aircraft typically burn 12 kg (0.012 tonnes) per minute during taxi.<br><br>The annual fuel savings can be estimated as:<br><br>3 * 0.012 * 100,000 = 3,600 tonnes of fuel saved |
| | | Installation of fixed electrical ground power and pre-conditioned air allow aircraft APU switch-off:<br><br>*GPU and PCA – NB*<br><br>(ICAO Secretariat) | Fuel savings = [time with APU off (hour) * 106 kg (0.106 tonnes) of fuel per hour] | An airport with an average of 100,000 narrow-body departures annually plans to install GPU and PCA that will reduce APU operating times by 0.5 hours per departure.<br><br>The annual fuel savings can be estimated as:<br><br>0.5 * 0.106 * 100,000 = 5,300 tonnes of fuel saved |
| | | Installation of fixed electrical ground power and pre-conditioned air allow aircraft APU switch-off:<br><br>*GPU and PCA – WB*<br><br>(ICAO Secretariat) | Fuel savings = [time with APU off (hour) * 240 kg (0.24 tonnes) of fuel per hour] | An airport with an average of 100,000 wide-body departures annually plans to install GPU and PCA that will reduce APU operating times by 0.5 hours per departure.<br><br>The annual fuel savings can be estimated as:<br><br>0.5 * 0.24 * 100,000 = 12,000 tonnes of fuel saved |

| *Category* | *Sub-category* | *Measure (References)* | *Rule of thumb* | *Example* |
|---|---|---|---|---|
| Supplemental benefits for domestic sectors<br><br>*Note.— These fuel savings are not from the aircraft or aircraft international operations and should not be included in the expected results table of the action plan.* | Airfield improvements | Installation of LED instead of classic light<br><br>(ICAO Secretariat) | $CO_2$ savings = 0.4 * kWh * kg of $CO_2/kWh_j$ | An airport uses 600,000 kWh per year for light. $CO_2$ released per 1 kWh produced is 0.3 kg (0.0003 tonnes)<br><br>The annual $CO_2$ savings can be estimated as:<br><br>0.4 * 600,000 * 0.0003 = 72 tonnes of $CO_2$ saved |
| | Reduced energy demand and preferred cleaner energy sources | Use cleaner alternative sources of power generation<br><br>(ICAO Secretariat) | $CO_2$ savings = number of kWh produced * kg of $CO_2/kWh_j$ | An airport produces 20 million kWh per year with solar panels. The $CO_2$ released per 1 kWh produced is 0.3 kg (0.0003 tonnes).<br><br>The annual $CO_2$ savings can be estimated as:<br><br>20,000,000 * 0.0003 = 6,000 tonnes of $CO_2$ |
| | | Reduce electrical demand<br><br>(ICAO Secretariat) | $CO_2$ savings = number of kWh reduced * kg of $CO_2/kWh_j$ | An airport plans to reduce its electrical demand by 200,000 kWh per year. $CO_2$ released per 1 kWh produced is 0.3 kg (0.0003 tonnes).<br><br>The annual $CO_2$ savings can be estimated as:<br><br>200,000 * 0.0003 = 60 tonnes of $CO_2$ |
| | Enhanced GSE management | Reduce distance travelled<br><br>(ICAO Secretariat) | FS = ∑[Time savings (hr) * FB/hr of $GSE_k$], where *k* is the type of GSE | An airport has a diesel-powered loader that burns 18,250 tonnes of fuel per year. With operating improvements it will burn 12,250 tonnes of fuel per year.<br><br>The annual fuel savings can be estimated as:<br><br>18,250 – 12,250 = 6,000 tonnes of fuel saved per year |
| | Conversion of GSE to cleaner fuels | Electrical operated ground vehicles<br><br>(ICAO Secretariat) | FS = ∑[$implementation_k$ (%) * FB of $GSE_k$], where *k* is the type of GSE | An airport has a diesel-powered tug that burns 18,250 tonnes of fuel per year. It will be replaced with an electric tug that receives power from a renewable source.<br><br>The annual fuel savings can be estimated as:<br><br>1 * 18,250 = 18,250 tonnes of fuel saved<br><br>***Note.— These fuel savings are not from the aircraft and should not be included in the expected results table of the action plan.*** |

| *Category* | *Sub-category* | *Measure (References)* | *Rule of thumb* | *Example* |
|---|---|---|---|---|
| Supplemental benefits for domestic sectors *(continued)* | Conversion of GSE to cleaner fuels *(continued)* | Alternative fuel operated ground vehicles<br><br>(ICAO Secretariat) | FS = utilization (%) * FB * 3.16 [if powered by jet fuel]<br>(until international agreement is reached regarding life-cycle analysis) | An airport has a Jet-A-powered loader that burns 18.25 tonnes of fuel per year. It will be fuelled exclusively with alternative fuel.<br><br>The annual fuel savings from the implementation of alternative surveillance (ASUR) can be estimated as:<br><br>1 * 18.25 * 3.16 = 57.67 tonnes of $CO_2$ saved<br><br>***Note.— These fuel savings are not from the aircraft and should not be included in the expected results table of the action plan.*** |

Legend:

| | |
|---|---|
| a/c | aircraft |
| apch | approach |
| BAU | business as usual |
| FB | fuel burn |
| FBI | fuel burn index |
| FS | fuel savings |
| GSE | ground support equipment |
| i | type of aircraft |
| j | State or region |
| NB | narrow-body aircraft |
| TP | turboprop and small jet aircraft |
| WB | wide-body aircraft |

References:

— Boeing, *Fuel Conservation Strategies: Descent and Approach,* 2010

— Boeing, *Fuel Conservation Strategies: Takeoff and Climb,* 2008

— IATA, *Guidance Material and Best Practices for Fuel and Environmental Management*

— IATA, *Technology Roadmap,* 2013

— ICAO, *Report of the Tenth Meeting of the Committee on Aviation Environmental Protection* (Doc 10069), 2016

Rules of thumb developed by ICAO Secretariat are based on the following references:

— GSE FB provided by Energy and Environmental Analysis Inc. for EPA

— E-Taxi and single-engine information from EGTS and WheelTug

— LED efficiency from Philips (40% pessimistic estimate) [Ex: Christchurch Airport efficiency is 60%]

— Fuel burn estimates are based on the ICAO engine exhaust emissions data bank (data available on the EASA website). Based on the most common aircraft, an average fuel burn was estimated for all LTO cycles for NB, WB and TP aircraft. A power setting of 7% was used for taxi, 30% for approach, 85% for climb and 100% for take-off. Fuel burn estimates for cruise are based on three different sources: ICAO, EUROCONTROL and Corinair and speed assumptions were 420 knots for NB and WB aircraft, and 300 knots TP aircraft.

— Annual flight times are based on the Airbus study *Getting hands-on experience with aerodynamic deterioration*

## 4. IPCC METHODOLOGIES FOR ESTIMATING GREENHOUSE GAS EMISSIONS FROM AVIATION

4.1 The 2006 IPCC Guidelines provide three methodological tiers for estimating $CO_2$ emissions from international aviation. All tiers distinguish between domestic and international flights, which are defined using criteria (see Table C-3) that apply irrespective of the nationality of the carrier.

**Table C-3. IPCC criteria for defining international and domestic aviation**
(apply to individual legs of journeys with more than one take-off and landing)

| *Journey type between two airports* | *Domestic* | *International* |
|---|---|---|
| Departs and arrives in same State | Yes | No |
| Departs from one State and arrives in another | No | Yes |

*Source: 2006 IPCC Guidelines*
(http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf)

4.2 The choice of methodology depends on the type of fuel, the data available and the relative importance of aircraft emissions. All tiers can be used for operations using jet fuel because relevant emission factors are available for this fuel type. The data requirements for the different tiers are summarized below:

a) Tier 1 is based on an aggregate quantity of fuel consumption data (no distinction is made between the LTO and cruise phase) multiplied by the average emission factor.

b) Tier 2 is based on the number of LTOs and fuel use. A distinction is made between emissions generated during the LTO and cruise phases of flight. Default or nationally-specific emission factors for $CO_2$ can be used.

c) Tier 3 methods are based on actual flight movement data, either for Tier 3A origin and destination data or for Tier 3B full-flight trajectory information.

4.3 The resource demand for the various tiers depends in part on the number of air traffic movements. Tier 1 should not be resource intensive. Tier 2, based on individual aircraft, and Tier 3A, based on origin and destination pairs, would use incrementally more resources. Tier 3B, which involves the use of sophisticated models, requires the most resources.

4.4 Emissions estimates for the cruise phase become more accurate when using Tier 3A methodology or Tier 3B models (such as the CAEP-approved models AEDT, AEM III, AERO2k and FAST or other national models). Moreover, because Tier 3 methods use flight movement data instead of fuel use, they provide a more accurate separation between domestic and international flights.

# Appendix D

# REFERENCE MATERIAL RELEVANT TO THE IMPLEMENTATION OF MITIGATION MEASURES

Reference material that may be relevant to the implementation of most mitigation measures is available from various sources. This appendix presents some of this material that States may use in the identification and selection of measures.

In 2014, ICAO established a partnership with the United Nations Development Programme (UNDP) with financing from the Global Environmental Facility (GEF) to support Member States' requests for assistance to reduce $CO_2$ emissions from international aviation.

The Transforming the Global Aviation Sector: Emissions Reduction from International Aviation capacity-building assistance project builds upon the ICAO State Action Plans initiative and supports States' efforts to advance $CO_2$ emissions reduction measures. The project has focused on developing guidance documents, tools and on implementing a pilot project, taking into account the needs of developing States and SIDS.

The project was structured around the four following initiatives:

1. Developing guidance documents to facilitate approaches to reduce aviation emissions in developing States and SIDS.

    a) *Renewable Energy for Aviation: Practical applications to achieve carbon reductions and cost savings* (https://www.icao.int/environmental-protection/Documents/ICAO_UNDP_GEF_RenewableEnergyGuidance.pdf).

    b) *Financing Aviation Emissions Reductions* (https://www.icao.int/environmental-protection/Documents/ICAO_UNDP_GEF_FinancingLowCarbonAirportGuidance.pdf).

    c) *Regulatory and Organizational Framework to Address Aviation Emissions* (https://www.icao.int/environmental-protection/Documents/ICAO%20UNDP%20GEF%20RegulatoryGuidance.pdf).

    d) *Sustainable Aviation Fuels Guide* (https://www.icao.int/environmental-protection/knowledge-sharing/Docs/Sustainable%20Aviation%20Fuels%20Guide_vf.pdf).

2. Setting up a Low-Carbon Knowledge Sharing Platform (https://www.icao.int/environmental-protection/knowledge-sharing/Pages/default.aspx).

3. Devising an analytical tool for States' use in comparing the cost and effectiveness of emission mitigation initiatives, the Marginal Abatement Cost (MAC) curve (Appendix F).

4. Demonstrating an easily replicable, low emission installation by way of a pilot project, which serves as an example for developing States and SIDS.

## 1. TECHNOLOGY AND STANDARDS

1.1 In 2009, IATA produced, with a number of industry experts, the *IATA Technology Roadmap*[1], which provides a summary and assessment of technological opportunities for future aircraft. This document looks at technologies that will reduce, neutralize and eventually eliminate the carbon footprint of aviation. The fourth edition of the roadmap was published in 2013, focusing on airframe and engine technologies.

1.2 In November 2010, the Air Transport Action Group (ATAG) published the *Beginner's Guide to Aviation Efficiency*[2] explaining, in simple words, the various measures to reduce aircraft engine emissions including aircraft design, engine design and aircraft operations in the air and on the ground. ATAG also published, in May 2009, the *Beginner's Guide to Aviation Biofuels* whose third edition, published in 2017, broadened its scope from biofuel to other sustainable-sourced alternative fuels, under the title *Beginner's Guide to Sustainable Aviation Fuel*[3]*.* It analyses the opportunities and challenges in developing sustainable aviation fuels.

1.3 The United Kingdom Committee on Climate Change published, in December 2009, a policy document entitled *Meeting the UK aviation target — Options for reducing emissions to 2050*[4]. The document explores various options including improvement in fleet fuel efficiency through technology innovation and the use of biofuels and hydrogen in aviation.

1.4 The Royal Aeronautical Society's Greener by Design[5] is an initiative whose aim is to limit aviation's environmental impact by providing advice to governments and industry in operational, technological, economic and regulatory aspects. The *Annual Report 2017-2018* provides information on SAF and technology development, including programmes being developed by other bodies such as Boeing and NASA.

1.5 In July 2017, the Aerospace Technology Institute published the *Emerging technologies in Commercial Aircraft systems*[6]. This document identifies technological trends and their application in aircraft technology.

## 2. SUSTAINABLE AVIATION FUELS

2.1 The ICAO Global Framework for Aviation Alternative Fuels (GFAAF) website is recognized as the source for information related to SAF use in the aviation industry. As of 2018, this website includes over 600 news articles dating back to 2005, details of 35 past and on-going initiatives, answers to frequently asked questions, facts and figures, and an aviation live feed that allows users to view, in real-time, aircraft involved in on-going alternative fuel purchase agreements. It also includes a section providing other resources, such as reports and publications related to SAF, feasibility studies performed in different States, and publications related to policy development and sustainability.

2.1.1 ICAO has established two partnerships to support its Member States with the development of their action plans and the implementation of identified mitigation measures. In the context of ICAO's partnership with the European Union, a series of feasibility studies on the use of sustainable aviation fuels in Burkina Faso, the Dominican Republic, Kenya, and Trinidad and Tobago have been developed and published. ICAO's partnership with the UNDP and the GEF has led to the publication of a guidance document on SAF. All of these materials are available from the ICAO Global Framework for Aviation Alternative Fuels Other Resources section[7] of the ICAO website.

1. http://www.iata.org/publications/Pages/technology-roadmap.aspx
2. https://www.atag.org/our-publications/latest-publications.html
3. https://www.atag.org/our-publications/latest-publications.html
4. http://www.theccc.org.uk/publication/meeting-the-uk-aviation-target-options-for-reducing-emissions-to-2050/
5. https://www.aerosociety.com/get-involved/specialist-groups/air-transport/greener-by-design/
6. https://www.ati.org.uk/resources/publications/#insight
7. https://www.icao.int/environmental-protection/GFAAF/Pages/Other-Resources.aspx

2.2 The IATA website includes a section dedicated to SAF[8]. It acknowledges the role of SAF in achieving emission reduction goals. The webpage provides information on IATA's own path for SAF and a section with Key Documents, such as the *IATA Guidance Material for Sustainable Aviation Fuel Management* and the *IATA Sustainable Aviation Fuel Roadmap.*

2.2.1 The Air Transport Action Group (ATAG), affiliated with IATA, also maintains a webpage dedicated to SAF. This webpage includes a downloadable publication titled *The Beginner's Guide to Sustainable Aviation Fuel* and a daily counter of commercial flights that have been operated using SAF since 2011.

2.3 In March 2017, the International Council on Clean Transportation published a white paper titled *Mitigating International Aviation Emissions — Risks and Opportunities for Alternative Jet Fuels*[9]. The paper assesses the sustainability, cost, and constraints to deployment of SAF.

2.4 In 2015, Sustainable Aviation (SA)[10], an initiative from a coalition of industry partners in the United Kingdom, published the *Sustainable Fuels UK Road-Map*. The objective of this report is to identify and predict the potential of SAF production to 2050, taking into account the environmental, economic and governmental aspects to fulfil this objective.

2.5 An initiative of Boeing, Embraer and FAPESP, called The Sustainable Aviation Biofuels for Brazil Project, published in 2014 the *Roadmap for Sustainable Aviation Biofuels for Brazil — A Flightpath to Aviation Biofuels in Brazil*[11]. The document establishes a technology roadmap with the drivers, barriers and strategies for its development.

## 3. OPERATIONAL IMPROVEMENTS

3.1 The 2016–2030 ICAO *Global Air Navigation Plan* (Doc 9750) presents States with a comprehensive planning tool supporting a harmonized global air navigation system.

3.2 The *Global Air Traffic Management Operational Concept* (Doc 9854) sets out the parameters for an integrated, harmonized and globally interoperable air traffic management (ATM) system planned up to 2025 and beyond. It can serve to guide the implementation of Communications, Navigation and Surveillance/Air Traffic Management (CNS/ATM) technology by providing a description of how the emerging and future ATM system should operate.

3.3 The *Manual on Air Traffic Management System Requirements* (Doc 9882) is used by ICAO Planning and Implementation Regional Groups (PIRGs) as well as by States as they develop transition strategies and plans. It defines the high-level ATM system requirements to be applied when developing Standards and Recommended Practices (SARPs) to support the Global Air Traffic Management Operational Concept (GATMOC).

3.4 The *Manual on Global Performance of the Air Navigation System* (Doc 9883) is aimed at personnel responsible for designing, implementing and managing performance activities. It provides organizations with the tools to develop an approach to performance management suited to their local conditions.

3.5 The *Guidance on Environmental Assessment of Proposed Air Traffic Management Operational Changes* (Doc 10031), published in 2014, provides guidance for decision-making when considering ATM operational changes.

8. https://www.iata.org/whatwedo/environment/Pages/sustainable-alternative-jet-fuels.aspx
9. https://www.theicct.org/publications
10. https://www.sustainableaviation.co.uk/goals/climate-change/
11. http://pdf.blucher.com.br.s3-sa-east-1.amazonaws.com/openaccess/roadmap-aviation/completo.pdf

3.6 In 2016 a document titled *Airport Collaborative Decision-Making: Optimisation through Collaboration* was published by the Civil Air Navigation Services Organisation (CANSO). The guide assists on the implementation of airport collaborative decision-making (A-CDM) with the aim of supporting ANSPs to improve the efficiency of air transport. Other relevant documents can be found on CANSO's website, such as the *Accelerating Air Traffic Management Efficiency: A Call to Industry* and the *Air Navigation Service Provider Carbon Footprinting: A Best Practice Guide*[12].

3.7 States may wish to gather more information and monitor the progress in the implementation of these programmes since they encompass a variety of projects and activities that they may select to include in their own action plans.

3.8 Airports Council International (ACI) published the *Guidance Manual: Airport Greenhouse Gas Emissions Management*[13] in November 2009. While airport emissions are part of States' national inventories, their reduction may be a co-benefit of action plans to reduce greenhouse gas (GHG) emissions. ACI provides a free calculation tool, the Airport Carbon and Emissions Reporting Tool (ACERT) for conducting inventories of airport and airport-related GHG emission[14]. Airport Carbon Accreditation is an ACI programme for independently certifying the progress of GHG management at airports[15].

3.9 ICAO Doc 10013 — *Operational Opportunities to Reduce Fuel Burn and Emissions* includes information on aircraft ground level and in-flight operations, as well as ground service equipment and auxiliary power units.

3.10 A similar publication, *Guidance Material and Best Practices for Fuel and Environmental Management,* was released by IATA in 2004, which has since been updated to the fifth edition[16] .

3.11 In October 2004, Airbus published a document entitled *Getting to Grips with Fuel Economy*, the purpose of which is "to examine the influence of flight operations on fuel conservation with a view towards providing recommendations to enhance fuel economy". It applies to Airbus aircraft and provides guidelines for pre-flight procedures, take-off and initial climb, climb, cruise, descent, holding and approach.

3.12 In a series of four articles, published in 2007 and 2008, Boeing outlines fuel conservation strategies applying to Boeing aircraft which cover the appropriate use of the cost index, an improved understanding of cruise flight, efficient take-off and climb and improved approach and descent.

3.13 In December 2008, Sustainable Aviation (SA), an initiative from a coalition of industry partners in the United Kingdom, published a $CO_2$ roadmap for civil aviation in the United Kingdom covering various measures, whose latest version was published in December 2016. SA also published the best practice document *Aircraft on the Ground $CO_2$ Reduction Programme* for the United Kingdom. Other SA reference material includes an industry code of practice for taxi operations and the use of fixed electrical power.

3.14 Sabre Airline Solution published a brochure entitled *Efficient Operations — Efficient Airlines Capitalize on Integrated Solutions and Processes.* This document highlights the economic benefits of efficient operations[17].

12. https://www.canso.org/publications
13. http://www.aci.aero/Publications/Full-Publications-Listing/Guidance-Manual-Airport-Greenhouse-Gas-Emissions-Management
14. http://www.aci.aero/About-ACI/Priorities/Environment/ACERT
15. www.airportcarbonaccreditation.org
16. http://www.iata.org/publications/store/Pages/fuel-efficiency-guidelines.aspx
17. https://www.sabreairlinesolutions.com/images/uploads/Efficient_Operations_Brochure.pdf

3.15 As part of its partnership with the UNDP and GEF, ICAO implemented a solar-at-gate pilot project at two international airports in Jamaica. Aircraft conventionally use on-board auxiliary power units (APU) powered with kerozene and diesel-run ground power units (GPU) to provide electricity and cabin climate control while aircraft are 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 Norman Manley Airport sized to supply the new electricity demand to operate the gate electrification equipment[18] .

## 4. MARKET-BASED MEASURES

Related ICAO guidance documents and resources include:

a) *Guidance on the Use of Emissions Trading for Aviation* (Doc 9885);

b) *ICAO's Policies on Charges for Airports and Air Navigation Services* (Doc 9082);

c) *ICAO's Policies on Taxation in the Field of International Air Transport* (Doc 8632);

d) *Report on Voluntary Emissions Trading for Aviation (VETS Report)* (Doc 9950);

e) Assembly Resolution A39-3: *Consolidated statement of continuing ICAO policies and practices related to environmental protection — Global Market-based Measure (MBM) scheme*;

f) Annex 16 — *Environmental Protection*, Volume IV — *Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)* contains the SARPs related to the Carbon Offsetting and Reduction Scheme for International Aviation;

g) *Environmental Technical Manual*, Volume IV — *Procedures for demonstrating compliance with the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)* (Doc 9501);

h) *Offsetting Emissions from the Aviation Sector* (Doc 9951);

i) *ICAO Environmental Report 2016*, Chapter 4, Section3 — *Market-based measures*; and

j) The CORSIA webpage[19] .

18. https://www.icao.int/environmental-protection/Documents/ICAO%20ENVIRO%20Magazine-Web.pdf
19. https://www.icao.int/environmental-protection/CORSIA/Pages/default.aspx

# Appendix E

# EXAMPLES OF MEASURES SELECTED IN ACTION PLANS

This appendix contains extracts from States' action plans submitted to ICAO. States' action plans that are publicly available can be found on the ICAO public website: http://www.icao.int/environmental-protection/Pages/action-plan.aspx.

## 1. TECHNOLOGY AND STANDARDS

### 1.1 Purchase of new aircraft

List of stakeholders: air carriers, aircraft manufacturers, States (Cape Town Convention).

> Malaysia — From 2012, Malaysia Airlines has replaced its Boeing B747-400s to Airbus A380s. From 2017 to 2018, the air carrier has introduced Airbus A350-900s and used Airbus A330-200s to its fleet. The air carrier is planning to introduce new Boeing B737-MAX 8s in 2020 as a replacement to the current existing B737-800s.
>
> In 2017 and 2018, the air carrier made fuel improvements of 3-4% on its routes. In 2020, the Boeing B737-MAX 8s are estimated to contribute reduction of overall fuel consumption to the air carrier. The air carrier estimates a 10% overall fleet fuel improvement on its routes with the introduction of Boeing B737-MAX 8s alongside the existing fleet of Airbus A330-200s, A330-300s, A330-200F, A350-900s and Boeing B737-800s.

### 1.2 Retrofitting and upgrade improvements on existing aircraft

List of stakeholders: air carriers, aircraft manufacturers.

> *From action plan*
>
> Germany — The wing tips of the B737 (-700/-800) fleet were retrofitted with Blended Wings. This measure increases the aspect ratio of the wing, thus reducing lift-induced drag and increasing performance. Improvement in total fuels is estimated at 3% per flight.

## 2. SUSTAINABLE AVIATION FUELS

List of stakeholders: airports, air carriers, engine manufacturers, private R&D companies, States.

### 2.1 Development of biofuels

*From action plan*

Argentina — Every year, commercial aviation uses more than 200 million tonnes of fuel per year, which corresponds to around 3% of world consumption. These data allow us to see just how important it is to come up with new sustainable fuel alternatives.

Even if industry has recently started research into alternative biomass improvements, processes to be used and scaling up of production, the objectives are nevertheless ambitious, given that international organizations are putting forward as a possible objective that 1% of fuel used should be of plant origin within five years. It is likewise being estimated that this figure should reach 5% by 2020.

It is within this context that a multidisciplinary group has been set up in Argentina with participants from government authorities, regulatory agencies, technological and agricultural institutes, oil companies, air operators and chambers, in order to find the best alternative, which enables the production of Argentinian bio-jet in line with international quality standards.

### 2.2 Standards/requirement for alternative fuel use

*From action plan*

Indonesia — The utilization of bio-jet fuel has been mandated through the Ministry of Energy and Mineral Resources Decree No. 12 Year 2015 which initiated with 2% blending in 2016, 3% in 2020 and 5% in 2025. By the end of 2013, some actions have been performed to support the implementation of bio-jet fuels. Starting with the establishment of a Memorandum of Understanding (MoU) between the Ministry of Transportation and the Ministry of Energy and Mineral Resources at the end of 2013, and continuing with the establishment of the Aviation Biofuels and Renewable Energy Task Force by mid-2014. However, some challenges still exist. The State Oil Company is still waiting for government support in terms of policy and incentives in order to reduce the investment cost, create business certainty and commercial viability. As there is no global bio-jet fuel mandate, it causes uncertainty for Indonesian bio-jet fuel producers to do their business calculation.

The second subject regarding utilization Biofuel relates to Ground Support Equipment (GSE) and mobile vehicles for airport support operations. The government has set a mandate of a partial use of 10% Biodiesel for GSE and mobile vehicles since September 2013 and has continued with a partial use of 15% Biodiesel since April 2015. The bio blend percentage is planned to be increased up to 20% at the end of 2018. In accordance with Indonesia's plans to implement 7.5 MW renewable energy for the operation of non-commercial airports during the period 2013-2020, approximately 5.4 MW renewable energy (solar) has been installed up to mid-2018. During the 39th ICAO Assembly in September 2016, DGCA Indonesia and Airbus signed a MoU concerning Promotion of Aviation Environmental Protection Measures and Operational Improvement. This is following the previous cooperation signed between Indonesia DGCA and the United States FAA under a MoU on Promotion of Sustainable Aviation Alternative Fuels and Renewable Energy.

### 2.2 Standards/requirement for alternative fuel use
*(continued)*

*From action plan*

United States — The United States Government (USG) has taken significant steps since 2006 to facilitate the development and deployment of "drop-in" alternative jet fuels. "Drop-in" jet fuel can be used without changes to aircraft systems or fueling infrastructure; it may also reduce aircraft emissions and enhance U.S. energy security.

The Commercial Aviation Alternative Fuels Initiative (CAAFI) — a public-private partnership between the USG, airlines, aircraft manufacturers, airports, and fuel producers — has led efforts in research and development; environmental assessment; fuel testing; and demonstration and commercialization of alternative aviation fuels. CAAFI efforts contributed to the creation of testing protocols and new alternative fuel specifications that have enabled approvals for aviation to use new fuels in commercial service. This is paving the way to large-scale production and use of these fuels. This leadership has also helped make aviation a major target market for the alternative fuels sector.

The USG is taking a multidisciplinary and multi-agency approach to support the development and deployment of alternative jet fuels. The U.S. Departments of Agriculture (USDA), Commerce (DOC), Energy (DOE), Defense (DOD), the Environmental Protection Agency (EPA), the FAA, NASA, and the National Science Foundation (NSF) have all made investments to support alternative jet fuel research, development, and production. Aviation is a key strategic target, partner, and market for accomplishing USG goals of promoting bioenergy production, enhancing sustainability and supporting economic development and innovation.

### 2.3 "Solar-at-Gate"

Kenya — A pilot project in Kenya consisting of a ground-mounted 500 kW solar power generation facility and mobile airport gate electric equipment was launched on 12 December 2018 at Moi International Airport in Mombasa, Kenya.

By providing pre-conditioned air and compatible electricity that runs on solar energy to aircraft during ground operations, this new solar-at-gate project will eliminate carbon dioxide emissions from aircraft parked at the gate. To run on-board systems and cooling before departing for their next flight, aircraft at Moi International Airport currently use their auxiliary power unit (APU) powered by aviation fuel or airport ground power units (GPU) operated by diesel.

The solar facility will generate 820,000 kWh per year and will avoid at least 1,300 tonnes of $CO_2$ every year, while the airport gate equipment will serve more than 2,500 flights per year, demonstrating a concrete solution to reduce aviation carbon emissions.

This pilot project at Moi International Airport is implemented as part of a € 6.5 million initiative, entitled *"Capacity Building for $CO_2$ Mitigation from International Aviation"*, which targets 14 States — 12 from the African region and two from the Caribbean region — to address carbon emissions in the aviation sector. This initiative is implemented by ICAO and funded by the European Union.

### 2.4 Other

*From action plan*

Brazil — Notwithstanding the advances in research, development and certification of aviation biofuels, the commercial use of the product faces the challenges of economics feasibility. The final biokerosene for aviation price is considerably higher than the conventional kerosene price. Taking into account the airlines lower profit margin and the high percentage that the fuels represent in the air carriers total costs (above 30%), it is not likely that biofuels are going to be used in large scale as long as the price is not competitive.

Thus, public and private players in Brazil have studied mechanisms to reduce biofuels production costs, such as: research on abundant raw materials and with lower costs, analysis of refinery methods, more efficient production and transportation logistics, among others. In this sense, Brazil and the United States signed a Memorandum of Understanding for cooperation on biofuels for aviation development. The Brazilian government believes that this partnership can be very useful for technology and information sharing aiming at the development of aviation biofuels.

## 3. OPERATIONAL IMPROVEMENTS

### 3.1 More efficient ATM planning, ground operations, terminal operations (departure, approach and arrivals), en-route operations, airspace design and usage, aircraft air navigation capabilities

3.1.1 Measures to improve arrival management — AMAN

List of stakeholders: air carriers, airports, ANSPs.

*From action plan*

Switzerland — Working within the SESAR (AIRE) framework, SWISS Int. Air Lines, Skyguide and Zurich Airport have developed an innovative approach procedure that significantly reduces $CO_2$ emissions. Like many other airports around the world, Zurich Airport is subject to a night curfew. The first aircraft to arrive in the morning is permitted to land from 6.04 a.m. The long-haul flights on approach to Zurich have historically done so on a 'first come, first served' basis, which is the standard (hitherto uncontested) procedure at airports around the world. Cockpit crews are thereby motivated to fly as fast as they can in order to arrive as early as possible. The result, however, is often a backlog of flights in the early morning sky over Zurich — which entails unnecessary noise and $CO_2$ emissions.

3.1.1 Measures to improve arrival management — AMAN *(continued)*

> *From action plan*
>
> Switzerland *(continued)* — To tackle this problem, SWISS Int. Air Lines have introduced in corporation with Zurich Airport and Skyguide an alternative approach system defined as "Greener Wave" — a system coordinated by all partners whereby a specific time slot is assigned for arrival at Zurich Airport[1]. This means that every aircraft of SWISS Int. Air Lines involved in the first wave of arrivals between 6.10 and 6.30 a.m. is assigned a Tactical Time of Arrival (TTA) in the form of a three-minute arrival time window. This new method allows pilots to modify the flight in accordance with operational conditions — by timing their take-off time and adjusting the speed of the flight. By flying at a slower speed and scheduling their arrival to avoid being backlogged on arrival and subsequently having to fly a holding pattern ahead of landing, the cockpit crew can reduce $CO_2$ emissions substantially. The analysis of some 10,000 flights has determined that the Greener Wave system reduces by approximately one tonne the amount of $CO_2$ emissions per flight during the first morning wave of incoming air traffic. In total this is a reduction of 1800 t $CO_2$ per year.

3.1.2 Measures to improve fuel efficient departure and approach procedures — CDO

Continuous descent operation (CDO) is an operation, enabled by airspace design, procedure design and ATC facilitation, in which an arriving aircraft descends continuously to the greatest possible extent, by employing minimum engine thrust, ideally in a low drag configuration, prior to the final approach fix[2].

List of stakeholders: airports, ANSPs.

> *From action plan*
>
> Sweden — *Reduced and harmonized descent speeds:* By reducing descent speed and descent angle, arriving flights can leave the cruise level somewhat earlier and thereby save fuel and reduce emissions. This can also make the descent and speed profiles of the arriving traffic flow more harmonized, which in turn can make ATC sequencing more efficient. Actual fuel data and model calculations for both Airbus321 and Boeing737 show that a reduction of descent speed by 20 kt will save approximately 20 kg of fuel. In turn the flight will be extended by 45 seconds, but an increasing number of airlines want to make this trade-off between fuel and time by getting their pilots to use lower descent speed.
>
> LFV is currently examining if it is possible to publish a harmonized descent speed for all airports in Sweden.

1. SWISS Int. Air Lines 2011: Greener Wave; http://www.youtube.com/watch?v=br5bJ-KSi0o
2. EUROCONTROL, http://www.eurocontrol.int/articles/continuous-descent-operations-cdo

3.1.3 Measures to improve the use of optimum routings — shorter flight courses

ANSPs can provide new flight paths by shortening existing flight paths. By using RNAV or RNP routes instead of conventional routes, distance saving could be significant.

List of stakeholders: air carriers, airports, ANSPs.

*From action plan*

Portugal — The ONATAP consortium, working in the framework of the AIRE programme and cosponsored by the SESAR Joint Undertaking, involving two Air Navigation Service Providers — NAV Portugal and ONDA (Office National Des Aéroports), from Morocco - and a major airline — TAP Portugal - concluded recently the implementation and evaluation of shorter flight courses from a combination of "free route" airspace at Lisboa FIR and direct route creation at Casablanca FIR.

New flight paths lead to an average time saving of 2:32 minutes per flight and a reduction of 167 kg in fuel consumption, with consequent decrease of 526 kg in $CO_2$ emissions. This represents an average saving of about 285USD/213€ for each flight.

Those trials are a culmination of one year of collaboration between the different partners, with a flight trial period of five months, from June to October. Demonstrations were performed with TAP Portugal medium- and long-range aircraft, A319, A320, A321, A330 and A340, operating across Lisboa and Casablanca FIRs, departing from Portugal (Lisbon) to Africa (Dakar, Bissau, Bamako, Accra, Luanda and Maputo).

In order to accomplish the proposed objective, the consortium identified three key points: to take advantage of the flexibility of the Lisbon free route airspace (FRAL), the creation of a new significant point on the Lisboa/Casablanca FIRs common border and the implementation of two new direct routes in the Casablanca FIR. Considering the key points it was possible to fly an almost direct course from the main airports in the Lisbon FIR to the south boundary of the Casablanca FIR.

In addition to environmental benefits, regional stakeholders concluded that the increased collaboration and exchange of information raised the situational awareness of traffic and may foster future developments on the flights operation.

The free route has enabled time and fuel savings vital to the preservation of the environment and the survival of airlines.

NAV Portugal decided to implement on 7 May 2009 the 'free route concept' in the Lisbon FIR (FRAL). This initiative received praise from the entire international aviation community, contributing to NAV Portugal's status as a reference provider of air navigation services. Furthermore, from an economic perspective, even though there was a decrease in the number of movements in the Lisbon FIR, the FRAL project enabled a reduction of 1.3 million nautical miles, representing fuel savings of more than 8,783 tonnes and an operational benefit to companies of more than 12 million. In terms of environmental benefits, this saving of nautical miles/fuel represents a decrease in $CO_2$ emissions of more than 27,000 tonnes.

3.1.3 Measures to improve the use of optimum routings — shorter flight courses *(continued)*

*From action plan*

Sweden — *Extended Free Route Airspace — NEFRA and Borealis:* The NEFRA Programme has been a cooperative effort by technical and operational experts from six air navigation service providers in neighbouring Danish/Swedish and North European FABs — Avinor, EANS, Finavia (now ANS Finland), LGS, LFV, and Naviair. It originated from regional FAB-wide FRA initiatives in DK/SE FAB and NEFAB, setting cross border free route operations as the ultimate goal for ensuring the most cost effective and fuel efficient flights in the whole area.

The final NEFRA's milestone was successfully accomplished on 25 May 2017 by connecting the Free Route Airspace (FRA) in Norway with the seamless FRA area already available across Denmark, Estonia, Finland, Latvia and Sweden. This has expanded the area where aircraft operators can fly their preferred trajectories as if in one airspace, marking completion of the four-year programme.

*EcoFly — structured environmental cooperation between stakeholders:* In EcoFly, LFV and Swedavia quarterly meet representatives from five airlines (SAS, Norwegian, BRA, TUI and Novair) in order to continuously analyse airspace, procedures and working methods for pilots and air traffic controllers to find common areas of improvements and environmental gains.

EcoFly is an important forum to gather knowledge and enhance the understanding between airlines, pilots, airports and LFV. The cooperation has also resulted in a lot of modifications to working methods at LFV, such as enhanced methods for providing predictability for approach planning, enabling CDO, providing distance-to-go during approach vectoring, more fuel efficient ways to use speed control, etc.

## 3.2 Collaborative research endeavours

3.2.1 ASPIRE

*From action plan*

Singapore — The Asia Pacific Initiative to Reduce Emissions (ASPIRE) is a partnership started in 2008 among Air Navigation Service Providers (Singapore, Australia, Japan, New Zealand, Thailand, and the United States) to promote best practices to reduce aviation emissions and improve efficiency of the overall air traffic system. CAAS joined the ASPIRE partnership in February 2010. The ASPIRE-Daily City Pair concept was conceived in mid-2010 with the objective of delivering ATM best practices in gate-to-gate air navigation efficiency measures between selected airport-city pairs to reduce fuel burn and carbon emissions in all phases of the flight. These ATM best practices employed include: Network Optimisation, User-Preferred Routes (UPRs), Dynamic Airborne Reroute Procedure (DARP), Required Navigation Performance (RNP4), 30NM/30NM Reduced Oceanic Separation, Time-Based Arrivals Management, Arrivals Optimisation, Departure Optimisation and Surface Movement Optimisation.

Singapore is participating in the ASPIRE-Daily for the following city pairs: (i) Los Angeles to Singapore (ii) Singapore to Melbourne, (iii) Melbourne to Singapore, (iv) Singapore to Sydney, and (v) Sydney to Singapore, (vi) Auckland to Singapore, (vii) Singapore to Auckland, (viii) Christchurch to Singapore, (ix) Singapore to Christchurch, (x) Brisbane to Singapore, (xi) Singapore to Brisbane, (xii) Wellington-Canberra-Singapore, (xiii) Singapore-Canberra-Wellington. The average savings for a city-pair flight amount to 4% in fuel and up to 15,000 kg in carbon emissions.

## 3.3 Best practices in operations, ICAO Doc 10013 — *Operational Opportunities to Reduce Fuel Burn and Emissions*

### 3.3.1 Minimizing weight

Weight reduction can take different forms as using lighter unit load devices, lighter seat, etc. The following examples provide an idea how much fuel savings is possible.

List of stakeholders: air carriers, manufacturers.

> *From action plan*
>
> Switzerland — Airline operators are continuously optimizing the interior of their aircraft in terms of weight gain. A weight reduction can be achieved by installing lighter materials such as new seats, lighter freight/baggage containers or lighter on-board equipment. Calculations of $CO_2$ reduction due to weight gain were carried out by some Swiss operators. The installation of new seats led to an estimated reduction of 2400 t $CO_2$ per year in comparison with 2009. The replacement of freight/baggage containers with lighter models will remove about 3000 t $CO_2$ per year starting in 2014. Started in 2011, lighter on-board equipment has been installed and is reducing 800 t $CO_2$ per year.
>
> Germany — In 2008, German airlines started to implement different measures aiming to reduce aircraft weight. The German action plan lists some of them: new lighter seat, light weight containers, light weight trolley, omission towing loop, omission fuel expansion tanks, reduction of paper maps on board, etc.

### 3.3.2 Single engine taxi

Based on ICAO's landing/take-off (LTO) cycle, taxi time is around 26 minutes. Excluding 6 minutes in total (3 minutes for engine's warming up and 3 minutes for engine's cooling), there is around 20 minutes remaining. If conditions are appropriate, taxiing on a single engine is efficient in terms of fuel savings.

List of stakeholders: air carriers, pilots.

> *From action plan*
>
> Korea — When an aircraft is taxiing-in or taxiing-out, it can save fuel by shutting down one or two engines. The annual average rates of engine-out taxiing-in per flight by airlines and aircraft type were surveyed for 2017. Based on the surveyed rates, appropriate target rates were set by consultations with airlines' staff. The fuel saving was estimated, based on the difference of implementation rates between the target years and 2017. Engine-out taxiing-out was not considered, because it is hardly implemented in the field.

### 3.4 Airfield improvements

3.4.1 Installation of fixed electrical ground power and pre-conditioned air to allow aircraft auxiliary power unit (APU) switch off

By using Ground power units (GPUs) (ground power units) instead of APUs, fuel savings by air carriers are significant.

List of stakeholders: airports, air carriers, manufacturers.

*From action plan*

Japan — Aircraft needs electric power for cabin lighting and air conditioning even after arriving at destination airports and shutting down engines. For this purpose, an on-board equipment names auxiliary power unit (APU) which is powered by jet fuels supplies the electric power. It is possible to reduce jet fuel consumption, $CO_2$ emissions and noise, if ground power unit (GPU), one of airport facilities, is used to supply electric power to aircraft instead of an APU. In view of this, Japan will continue to promote the use of GPU.

*From action plan*

China — In order to carry out the thought of ecological civilization in the new era put forward by President Xi Jinping, the CAAC formulated policies which required that since October 1, 2018, new energy equipment/vehicles must account for not less than 50% of newly added or updated equipment/vehicles in airports and that the newly-added or updated petrol and diesel equipment/vehicles in the field must meet CHINA stage IV and above standards for emission of pollutants from motor vehicles. Besides, petrol and diesel equipment/vehicles being used in China now which cannot reach CHINA stage III or lower standards shall achieve 100% exhaust standard transformation. At the same time, from 1 January 2019, when the planes stop at the airport corridor bridge, they shall actively use APU replacement facilities in accordance with the principle of “as possible as practical”.

*From action plan*

Switzerland — Both national airports Zurich and Geneva have aircraft positions with pre-conditioned air (PCA) and electricity (400Hz). In Zurich Airport all terminal stands are equipped with 400 Hz and PCA, many open stands are equipped with 400Hz systems. The use of the system is mandatory and is regulated in the AIP ZRH. The airport of Zurich estimates a reduction of 42 000 t $CO_2$ per year from their aircraft stands.

Geneva Airport has equipped 30 aircraft positions with fixed 400 Hz and pre-conditioned air installation. The use of these facilities has been made mandatory at equipped positions. Simultaneously, the use of aircrafts APU is prohibited. In 2017, five new aircraft positions have been opened with 400 Hz energy. It is estimated that the use of these systems instead of the APU saves about 31 800 t $CO_2$ and 62 t of $NO_x$ annually.

3.4.2 Construction of taxiways

List of stakeholders: airports

*From action plan*

Mauritius — Prior to 2012, when an aircraft landed, it has to roll to the end of the runway, then backtrack to exit via Taxiway C. With the construction of a parallel taxiway and an additional exit taxiways, there is no need for landing aircraft to proceed to the end of the runway and backtrack. This considerably reduced the runway occupancy time, thus decreasing: holding time of aircraft in the air where applicable and holding time of departing traffic.

With the opening of new taxiways, there is an opportunity to optimize the use of reverses on landing and reduce fuel engine burn during landing rollout. With the opening of parallel taxiway and exit TWY Delta from runway 14, there is potential for reduced taxi in time for heavy jets.

The benefit is a reduction of expected approaching time between two successive arrivals during peak periods from 9 minutes to 7 minutes. In other words, by improving the landing phase by 2 minutes and also reducing holding during peak traffic, Mauritius expects an international fuels improvement of approximately 0.2%.

3.4.3 Construction of runways

*From action plan*

Sri Lanka — Use of Mattala Rajapakse International Airport (HRI) as an in-country alternate airport for aircraft operations to Sri Lanka. Mattala Rajapakse International Airport was opened in March 2013, as a category 4F International Airport. It is available as an alternate airport for three international aircraft operators in Sri Lanka (as well as for foreign air operators). This will allow airlines to carry less contingency fuel which reduces fuel consumption, thus reducing the $CO_2$ emissions level in Sri Lanka.

## 3.5 Enhancing weather forecasting services

List of stakeholders: air carriers, airports, ANSPs, States.

Tanzania — Tanzania is working on real time updates of current weather and wind conditions that allow the flight crew to modify their flight. By applying this measure, Tanzania expects to improve international fuel burn and $CO_2$ emissions by up to 1.2%.

## 4. MARKET-BASED MEASURES

### 4.1 Voluntary inclusion of the aviation sector in market-based measures

Air carriers can offer to their passengers the choice to offset their own emissions. With funds from offsetting, air carriers will sponsor different projects aiming to reduce $CO_2$ emissions.
List of stakeholders: air carriers, passengers, providers of voluntary carbon offsetting, States.

*From action plan*

Australia — In Australia, Virgin Australia, Qantas and Jetstar provide passengers with the opportunity to purchase carbon offsets for their individual travel. When launched in 2007, Virgin's carbon offset program was the world's first government certified airline offset program. On average, Virgin customers offset around 2% of the airlines total annual carbon emissions with a total of 54,462 tonnes $CO_2$-e being offset in 2012-13.

The Qantas Group (Qantas and Jetstar Airlines) also launched its voluntary carbon offset program, Fly Carbon Neutral, in 2007. The program has continued to be successful with around 5 per cent of customers per year choosing to offset through Qantas' online booking system. To demonstrate commitment to this initiative, the company also offsets all employee work-related travel and ground vehicle tailpipe emissions. Since its launch in 2007, approximately 300,000 tonnes of $CO_2$-e has been offset per year.

### 4.2 Explore extension of Clean Development Mechanism (CDM)

*From action plan*

Central American Action Plan for Emission Reduction from International Civil Aviation (CAAPER) — The CAAPER contemplates the compensation measures as part of a set of measures to reduce $CO_2$ emissions. The compensation measures are an important alternative strategy because they facilitate access to financial resources and guide efforts toward strategic objectives.

This strategy promotes a plan to exchange with other sectors in accordance with existing international instruments. It also considers the possibility of including the clean development mechanism (CDM) as part of this compensation and providing aircraft operators accredited compensation plans appropriate to their respective capabilities, among others.

## 5. SUPPLEMENTAL BENEFITS FOR DOMESTIC SECTORS

### 5.1 Reduced energy demand and preferred cleaner energy sources

5.1.1 Use of cleaner alternative sources of power generation (photovoltaic panel, wind generators)

By using electricity from photovoltaic panels instead of regular providers, there is an impact on airports' $CO_2$ emissions.

List of stakeholders: airports, photovoltaic manufacturers.

*From action plan*

Germany — In 2011, Dusseldorf Airport has installed a new photovoltaic system. It generates about 2 million of kilowatt hours of energy per annual. This system is one of the biggest photovoltaic systems in North Rhine-Westphalia. By using photovoltaic systems for power generation, Dusseldorf Airport is able to save about 1000 tons of $CO_2$ emissions per year.

### 5.2 Enhancing and conversion of GSE

*From action plan*

Italy — To improve the GSEs performances in terms of emissions, in addition to the renewal of vehicles and equipment serving aircraft with the purchase of environmentally friendly vehicles, a series of measures can be applied, such as reducing distance traveled within airport areas and engine shut down as soon as possible, use of alternative fuels or electric motors, as widely reported in the ENAC document "*Guidelines to minimize fuel use and reduce greenhouse gases*" published in 2009. Given that environmental performance of these vehicles can improve up to 90% emissions reduction, ENAC will introduce modernization of the GSEs as a mandatory airport handlers environmental standard. From 2005 to 2010 tons of $CO_2$ generated from the use of airport vehicles fell from 47,817 to 42,295. The trend in emissions from 2007 to 2009 finds its cause in the economic downturn. From 2011 to 2014 ENAC assumes that with an annual replacement of 10% of old vehicles with other more technologically and eco-friendly advanced models, even with a passenger and cargo traffic growth, it is possible a reduction of 2,198 $CO_2$ tons, that is significant compared to the scope of reference. This result, estimated at between 7 and 8% per annum compared to the total vehicle fleet can be obtained by optimizing the use of airport vehicles and a renewal with Euro 4 standard motors.

# Appendix F

## COSTS AND BENEFITS RELATED TO THE BASKET OF MEASURES

1. In considering which measures should be taken to reduce $CO_2$ emissions from international civil aviation, and in what order, one important criterion is the cost-effectiveness of each measure. Marginal abatement cost (MAC) curves are a graphical means of showing the measures that can reduce $CO_2$ emissions in order of their cost-effectiveness. In the chart in Figure F-1, the most cost-effective measures are on the left and the most expensive on the right. The vertical axis shows the net cost in USD of the measure for each tonne of $CO_2$ reduced by it. The horizontal axis shows the quantity of $CO_2$ in millions of tonnes that can be saved by the measures. This MAC curve is not cumulative because each measure has been considered in isolation and as such it may not be directly comparable with cumulative MAC curves in other sectors.

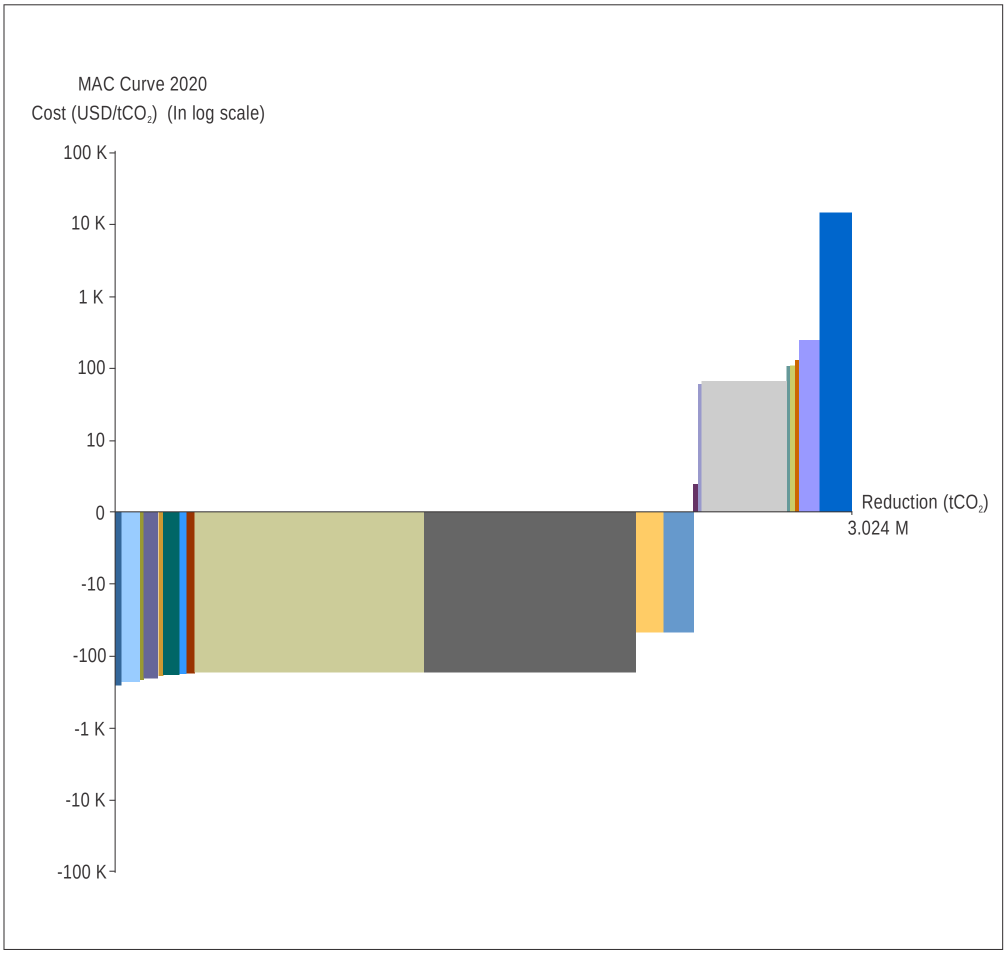


**Figure F-1. $CO_2$ marginal abatement cost curve in 2020 for global commercial airline fuel burn**

| | Measure | Cost ($USD/tCO_2$) | Reduction ($tCO_2$) |
|---|---|---|---|
| | Installation of fixed electrical ground power and pre-conditioned air to allow APU switch-off | -254 | 26,082.11 |
| | Measures to improve airport collaborative decision-making (A-CDM) | -226 | 73,208.66 |
| | Minimizing reverser use | -211 | 12,135.11 |
| | Engine wash and zonal dryers | -199 | 65,167.54 |
| | Minimizing flaps | -184 | 3,005.53 |
| | Selecting aircraft best suited to the mission | -182 | 70,918.01 |
| | Measures to improve departure management (DMAN) and arrival management (AMAN) | -175 | 29,225.21 |
| | Measures to improve taxiing | -170 | 37,749.56 |
| | Measures to increase fuel efficiency of departure and approach procedures | -166 | 964,285.04 |
| | Measures to introduce CCO and CDO | -165 | 892,351.94 |
| | Improve fuel efficiency through modifications | -46 | 117,192.07 |
| | Minimizing weight | -45 | 124,516.26 |
| | Reduced speed | 2 | 9,553.61 |
| | Measures to improve ATM in non-RADAR airspace | 60 | 1,470.39 |
| | Airport infrastructure (runways, taxiways, highspeed turnoffs) | 65 | 356,285.60 |
| | Measures to improve aircraft guidance on apron | 105 | 15,280.61 |
| | Replacement of engines | 107 | 1,105.77 |
| | Use cleaner alternative sources of power generation | 131 | 1,133.23 |
| | Development of biofuels | 241 | 87,716.49 |
| | Purchase new aircraft | 14,411 | 135,946.99 |

**Figure F-2. $CO_2$ marginal abatement cost legend in 2020 for global commercial airline fuel burn**

2. The chart is made up of individual abatement measures, a mixture of infrastructure, operations and technology options. The width of each bar shows the total $CO_2$ that has been estimated to be feasible to abate worldwide using this measure. The height of the bar shows its net cost in USD for each tonne of $CO_2$ abated (its relative cost-effectiveness).

3. This net cost includes the (amortized) capital cost and any operating costs of implementing the measure minus any resulting cost savings from reduced fuel use or operational savings. The bars on the left, mostly infrastructure efficiency improvements, show negative net costs. This means that the fuel and other savings resulting from the implementation of the measure exceed its (amortized) capital and operating costs. These are often called "no regrets" measures, i.e. they bring a financial as well as environmental benefit. Usually the barrier to implementation is political rather than economic. Sometimes the barrier is a lack of information or awareness. These are the measures that would be sensible to implement first to reduce $CO_2$ emissions from air transport. At the right end of the chart, measures such as re-engining existing aircraft have high net costs. Some of these measures can be implemented only at a cost of more than 1,000 USD for each tonne of $CO_2$ saved. These are very expensive ways of reducing $CO_2$.

4. The chart is a summary of the analysis by McKinsey in the context of the ICAO-UNDP-GEF capacity-building and assistance project and suggests what is feasible in the year specified for each of the measures. The quantity of $CO_2$ abated by each measure is what could be saved in that year relative to a baseline of where emissions would be without such additional measures and in the absence of any concurrent measures. In this case the baseline was dependent on traffic growth and the "normal" replacement of the fleet based on the same survivor curves (a plot of the per cent of aircraft fleet remaining in service as a function of aircraft age. It usually takes the shape of an S curve reversed) used in ICAO's Committee on Aviation Environmental Protection (CAEP) analyses. Many of the measures depend on the size of the fleet or the flow of traffic. As a result, the size of $CO_2$ reductions from these measures will depend on the year in which the snapshot is taken.

5. The chart in Figure F-1 and the data portrayed in Figure F-2 show that, beyond a certain point, it is not cost-effective to abate $CO_2$ emissions from international civil aviation. The MAC curve rises steeply towards the right of the chart, after a certain quantity of $CO_2$ has been abated by the measures specified. Comparing the MAC curve with the cost of reducing $CO_2$ in other industries (through, for example, carbon offsets or tradable emission allowances) shows the point at which it becomes cost-ineffective to reduce $CO_2$ emissions from international civil aviation.

6. The work carried out in the framework of the ICAO-UNFDP-GEF capacity-building and assistance project enables the design of a unique MAC curve tool, allowing developing States and SIDS 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 MAC curve tool is accessible on the APER website.

7. *Relative costs and benefits*

7.1 While the MAC curve shown in Figure F-1 provides information on costs to mitigate a tonne of $CO_2$ emissions for specific measures, it is not comprehensive.

7.2 The following tables provide relative cost and benefit information for many of the measures to help guide States in their selection of measures to include in their action plans.

**Table F-1. Aircraft-related technology development**

| *Measure* | *Benefit/cost* | |
|---|---|---|
| Aircraft fuel efficiency standards | Benefit: | Reduced $CO_2$ emissions |
| | Relative potential gains: | Medium to high |
| | Supplemental benefits: | More efficient fuel burn (increased cost efficiency)<br>Possible offset carbon credits<br>Reduced maintenance cost (new aircraft/engine) |
| | Cost: | Manufacturers:<br>• research and development, retooling and cost of new production processes<br><br>Operators:<br>• purchase of new aircraft<br>• cost of additional training if required<br>• re-engining existing aircraft<br>• possible aircraft downtime cost<br>• loss of resale value of existing aircraft |
| | Cost range: | Medium to high |
| | Additional metric(s): | Proportion of fleet that is compliant |
| Purchase of new aircraft | Benefit: | Reduced $CO_2$ emissions |
| | Relative potential gains: | Very high |
| | Supplemental benefits: | More efficient fuel burn (increased cost efficiency)<br>Possible offset carbon credits<br>Reduced maintenance cost (new aircraft/engine) |
| | Cost: | Purchase of new aircraft<br>Cost of additional training if required |
| | Cost range: | High |
| | Additional metric(s): | Average age<br>Proportion of fleet below a certain age |

| *Measure* | *Benefit/cost* | |
|---|---|---|
| Retrofitting and upgrade improvements on existing aircraft | Benefit: | Reduced $CO_2$ emissions |
| | Relative potential gains: | Low to high |
| | Supplemental benefits: | More efficient fuel burn (increased cost efficiency)<br>Possible offset carbon credits<br>Possible reduced maintenance cost<br>Possible gain in resale value |
| | Cost: | Cost of retrofit and upgrade<br>Possible aircraft downtime cost |
| | Cost range: | Low to medium |
| | Additional metric(s): | Proportion of fleet retrofitted |
| Optimizing improvements in aircraft produced in the near- to mid-term | Benefit: | Reduced $CO_2$ emissions |
| | Relative potential gains: | Low to medium |
| | Supplemental benefits: | More efficient fuel burn (increased cost efficiency)<br>Possible offset carbon credits |
| | Cost: | Manufacturers:<br>• Research and development, retooling and cost of new production processes<br><br>Operators:<br>• purchase of new aircraft<br>• cost of additional training if required<br>• re-engining existing aircraft<br>• possible aircraft downtime cost<br>• loss of resale value of existing aircraft |
| | Cost range: | Medium |
| | Additional metric(s): | N/A |

| *Measure* | *Benefit/cost* | |
|---|---|---|
| Avionics | Benefit: | Reduced $CO_2$ emissions |
| | Relative potential gains: | Low to medium |
| | Supplemental benefits: | More efficient fuel burn (increased cost efficiency)<br>Possible offset carbon credits |
| | Cost: | Cost of avionics and installation<br>Possible aircraft downtime cost |
| | Cost range: | Medium |
| | Additional metric(s): | Proportion of fleet retrofitted |
| Adoption of revolutionary new designs in aircraft/engines | Benefit: | Reduced $CO_2$ emissions |
| | Relative potential gains: | High to very high |
| | Supplemental benefits: | More efficient fuel burn (increased cost efficiency)<br>Possible offset carbon credits |
| | Cost: | Manufacturers:<br>• Research and development, retooling and cost of new production processes<br><br>Operators:<br>• purchase of new aircraft<br>• cost of additional training if required<br>• re-engining existing aircraft<br>• possible aircraft downtime cost<br>• loss of resale value of existing aircraft |
| | Cost range: | High |
| | Additional metric(s): | N/A |

**Table F-2. Alternative fuels**

| *Measure* | *Benefit/cost* | |
|---|---|---|
| Sustainable aviation fuels | Benefit: | Reduced $CO_2$ emissions |
| | Relative potential gains: | Medium to high |
| | Supplemental benefits: | Possible improvement of air quality (depends on fuels)<br><br>Development of national/regional agriculture<br>Employment |
| | Cost: | States<br>• Research and development in process, biomass production and logistics<br>• Development of biomass production and associated required infrastructure<br>• Education, training to new agricultural practices<br>• Incentive mechanism to compensate the initial price gap with conventional fuels<br><br>Fuel producers<br>• Research and development in process, biomass production and logistics<br>• Investments in new facilities and equipment<br>• Reduction of production costs<br><br>Operators:<br>• Management/compensation of potentially increased fuel cost (at least in the initial development phase) |
| | Cost range: | High in the initial period, with potential decrease |
| | Risks: | Environmental, social and economic impacts need to be assessed, mitigated and controlled |
| | Additional metric(s): | N/A |

**Table F-3. Operational improvements**

| *Measure* | *Benefit/cost* | |
|---|---|---|
| More efficient ATM planning, ground operations, terminal operations (departure, approach and arrival) en-route operations, airspace design and usage, aircraft air navigation capabilities | Benefit: | Reduced $CO_2$ emissions |
| | Relative potential gains: | Low to medium |
| | Supplemental benefits: | More efficient fuel burn (increased cost efficiency)<br>Possible offset carbon credits |
| | Cost: | N/A |
| | Cost range: | Medium to high |
| | Additional metric(s): | N/A |
| More efficient use and planning of airport capacities | Benefit: | Reduced $CO_2$ emissions |
| | Relative potential gains: | Low |
| | Supplemental benefits: | More efficient fuel burn (increased cost efficiency)<br>Possible offset carbon credits |
| | Cost: | N/A |
| | Cost range: | Medium to high |
| | Additional metric(s): | N/A |
| Construction of additional runways to relieve congestion | Benefit: | Reduced $CO_2$ emissions through reduced congestion/delays |
| | Relative potential gains: | Low to high |
| | Supplemental benefits: | More efficient fuel burn (increased cost efficiency)<br>Possible offset carbon credits |
| | Cost: | N/A |
| | Cost range: | High |
| | Additional metric(s): | N/A |

| *Measure* | *Benefit/cost* | |
|---|---|---|
| Enhanced terminal support facilities | Benefit: | Reduced $CO_2$ emissions through reduced congestion/delays |
| | Relative potential gains: | Low |
| | Supplemental benefits: | More efficient fuel burn (increased cost efficiency)<br>Possible offset carbon credits |
| | Cost: | N/A |
| | Cost range: | Low to medium |
| | Additional metric(s): | N/A |
| Collaborative research endeavours | Benefit: | N/A |
| | Relative potential gains: | Low |
| | Supplemental benefits: | N/A |
| | Cost: | N/A |
| | Cost range: | Low to medium |
| | Additional metric(s): | N/A |

**Table F-4. More efficient operations**

| *Measure* | *Benefit/cost* | |
|---|---|---|
| Best practices in operations | Benefit: | Reduced $CO_2$ emissions |
| | Relative potential gains: | Low to medium |
| | Supplemental benefits: | More efficient fuel burn (increased cost efficiency)<br>Possible offset carbon credits |
| | Cost: | Procedures design and implementation<br>Training costs |
| | Cost range: | Low |
| | Additional metric(s): | N/A |
| Optimized aircraft maintenance (including jet engine cleaning/washing) | Benefit: | Reduced $CO_2$ emissions |
| | Relative potential gains: | Low |
| | Supplemental benefits: | More efficient fuel burn (increased cost efficiency)<br>Possible offset carbon credits |
| | Cost: | Possible additional maintenance costs |
| | Cost range: | Low |
| | Additional metric(s): | N/A |
| Selecting aircraft best suited to the mission | Benefit: | Reduced $CO_2$ emissions |
| | Relative potential gains: | Low to medium |
| | Supplemental benefits: | More efficient fuel burn (increased cost efficiency)<br>Possible offset carbon credits<br>Better aircraft utilization<br>Better use of crews |
| | Cost: | N/A |
| | Cost range: | Medium |
| | Additional metric(s): | N/A |

# Appendix G

# FEEDBACK FORM TEMPLATE FOR THE ANALYSIS OF STATES' ACTION PLANS

**ICAO STATE ACTION PLAN FEEDBACK FORM**

| | | | |
|---|---|---|---|
| *State:* | | *ICAO Region:* | |
| SAP Submission Date: | [dd-mmm-yyyy] | Notes: | |
| Previous Submissions: | [dd-mmm-yyyy] | | |
| | [dd-mmm-yyyy] | | |
| | [dd-mmm-yyyy] | | |

**Overview**

| | |
|---|---|
| **Preliminary requirement for the development of a State Action Plan** | |
| Has the State nominated a State Action Plan Focal Point? | [Yes / No] |
| **State Action Plan Minimum Requirements (from ICAO Doc 9988, Box 1)** | **Included?** |
| Baseline scenario (without action) fuel consumption, $CO_2$ emissions, and RTK | [Yes / Partially / No] |
| Measures to mitigate $CO_2$ emissions | [Yes / No] |
| Expected results (estimated impact of selected mitigation measures on the baseline scenario, including fuel consumption, $CO_2$ emissions) | [Yes / Partially / No] |
| **Other** | |
| Does the State Action Plan request assistance? | [Yes / No] |
| | |
| Notes: | |

**Baseline Scenario**

| Elements of a State Action Plan | Included? | Notes |
|---|---|---|
| Historical data | [Yes / No] | |
| Baseline scenario | [Yes / Partially / No] | |
| ↳ from (first year) | [Year] | |
| ↳ to (last year) | [Year] | |
| ↳ data on annual basis | [Yes / No] | |
| → if no, provide step used | [Number] | |
| ↳ RTK CAGR* | [Percentage(s)] | |
| ↳ Fuel efficiency improvement | [Percentage(s)] | |

* CAGR: Compound Annual Growth Rate

___ **Fully Quantified** ___ **Partially Quantified** ___ **Not Quantified**

**Mitigation Measures**

| Elements of a State Action Plan | Included? | Notes |
|---|---|---|
| Measures evaluated | [Fully / Partially / No] | |
| ↳ data on annual basis | [Yes / No] | |
| → if no, provide step used | [Number] | |

___ **Fully Quantified** ___ **Partially Quantified** ___ **Not Quantified**

**Expected Results**

| **Elements of a State Action Plan** | **Included?** | **Notes** |
|---|---|---|
| Expected results data | [Yes / Partially / No] | |
| ↳ from (starting date) | [Year] | |
| ↳ to (ending date) | [Year] | |
| ↳ data on annual basis | [Yes / No] | |
| → if no, provide step used | [Number] | |

___ **Fully Quantified** ___ **Partially Quantified** ___ **Not Quantified**

| **Additional Notes:** |
|---|
| |

**— END —**

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