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of Transport and
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ICAO State Action Plan for CO_2 Emissions Reduction

– Germany –

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List of Abbreviations

ACARE – Advisory Council for Research and Innovation in Europe

ACARS – Aircraft Communications Addressing and Reporting System

ACA – Airport Carbon Accreditation

ACI – Airports Council International

ADV – Arbeitsgemeinschaft Deutscher Verkehrsflughäfen

AEM – Advanced Emission Model

AFTF – Alternative Fuels Task Force (of ICAO CAEP)

AIRE – The Atlantic Interoperability Initiative to Reduce Emissions

ANA – Administration de la navigation aérienne

ANS – Air Navigation Service

ANSP – Air Navigation Service Provider

AOC – Air Operator Certificate

ATC – Air Traffic Control

ATM – Air Traffic Management

ATT – Air Ticket Tax

BDL – Bundesverband der Deutschen Luftverkehrswirtschaft

CAEP – Committee on Aviation Environmental Protection

CCD – Continuous Climb Departures

CDA – Continuous Descent Approach

CDM – Collaborative Decision Making

CDO – Continuous Descent Operations

CNG – Carbon neutral growth

CORSIA – Carbon Offsetting and Reduction Scheme for International Aviation

CPDLC – Controller-Pilot Data Link Communications

DFS – Deutsche Flugsicherung

DSNA – Direction des Services de la Naviation Aérienne

EAER – European Aviation Environmental Report

EASA – European Aviation Safety Agency

EC – European Commission

ECAC – European Civil Aviation Conference

EEA – European Economic Area

EFTA – European Free Trade Association

ETS – Emissions Trading Scheme

EU – European Union

FAB – Functional Airspace Block

FABEC – Functional Airspace Block Europe Centre

FANS – Future Air Navigation System

FP7 – 7th Framework Programme

GHG – Greenhouse Gas

GMBM – Global Market-based Measure

HVO – Hydro-treated Vegetable Oil

ICAO – International Civil Aviation Organization

IFR – Instrumental Flight Rules

ILUC – Indirect Land Use Change

IPCC – Intergovernmental Panel on Climate Change

IPR – Intellectual Property Right

ITD – Integrated Technology Demonstrator

JTI – Joint Technology Initiative

LTO cycle – Landing/Take-off Cycle

LVNL – Luchtverkeersleiding Nederland

MBM – Market-based Measure

MUAC – Maastricht Upper Area Control Centre

OEM – Original Equipment Manufacturer

RED – Renewable Energy Directive (EU Directive 2009/28/EC)

RNAV – Area Navigation

RNP AR – Required Navigation Performance Authorization Required

RNP STAR – Required Navigation Performance Standard Arrival

RPAS – Remotely Piloted Aircraft

RPK – Revenue Passenger-Kilometres

RTD – Research and Innovation

RTK – Revenue Tonne-Kilometres

SES – Single European Sky

SESAR – Single European Sky ATM Research

SESAR JU – Single European Sky ATM Research Joint Undertaking

SME – Small and medium-sized enterprise

SWAFEA – Sustainable Ways for Alternative Fuels and Energy for Aviation

TMA – Terminal Manoeuvring Area

ToD – Top of Descent

UNEP – United Nations Environmental Programme

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Executive summary

This Action Plan describes measures taken by Germany and collectively by European States in order to limit and reduce CO_2 emissions of international aviation.

The European sections C and D of this action plan, which are common to all European State action plans, present a summary of the actions taken collectively in the 44 States of the European Civil Aviation Conference (ECAC) to reduce CO_2 emissions from the aviation system against a background of increased travel and transport. Additional measures taken at the national level are described in sections B and E.

For over a century, Europe has led the development of new technology, monitoring its impacts and developing new innovations to better meet societies developing needs and concerns. From the dawn of aviation, governments and industry across the region have invested heavily to understand and mitigate the environmental impacts of aviation, initially focussing on noise, then adding air quality and more recently the emissions affecting the global climate and CO_2 from fuel burn in particular. This is all taking place in a sector ever striving to improve safety and security whilst also reducing operating costs and improving fuel efficiency.

Some of these mitigating actions have domestic beginnings that stretch to international aviation whilst others are part of centralised cross-cutting funding such as through the EU Research Framework programmes. The aviation sector has also benefitted from large bespoke programmes such as the EU's Single European Sky ATM Research Initiative (SESAR). This has a vision stretching to 2050, which may turn utopian dreams of flight with seamless end-to-end co-ordination, optimised for efficiency, with minimal environmental impacts and complete safety into reality.

The European common section also includes new innovations being tried and tested in a range of demonstration trials to reduce fuel burn and CO_2 emissions at different stages of different flights, airports or routes. These might not be contributing to measured benefits in day-to-day operations yet, but Europe can anticipate a stream of future implementation actions and additional CO_2 savings.

Aircraft related technology

European members have worked together to best support progress in the ICAO Committee on Aviation Environmental Protection (CAEP). This contribution of resources, analytical capability and leadership has undoubtedly facilitated leaps in global certification standards that has helped drive the markets demand for technology improvements. Developing what became the 2016 ICAO CO_2 standards for newly built aircraft relied on contributions from many across the ECAC States. Airlines now have confidence that fuel efficient aircraft are future proof which may even have generated orders for manufacturers and demonstrates a virtuous circle that efficiency sells. Solutions and technology improvements have already started to go into service and are helping to support demand for ever more ambitious research.

Environmental improvements across the ECAC States is knowledge lead and at the forefront of this is the Clean Sky EU Joint Technology Initiative (JTI) that aims to develop and mature breakthrough "clean technologies". This activity recognises and exploits the interaction between environmental, social and competitiveness aspects with sustainable economic growth. Funding and its motivation is critical to research and the public private partnership model of the EU Framework Programmes underpins much that will contribute to this and future CO_2 action plans across the ECAC region. Evaluations of the work so far under the JTI alone estimate aircraft CO_2 reductions of 32% which, aggregated over the future life of those products, amount to 6bn tonnes of CO_2.

The main efforts under Clean Sky 2 include demonstrating technologies: for both large and regional passenger aircraft, improved performance and versatility of new rotorcraft concepts, innovative airframe structures and materials, radical engine architectures, systems and controls and consideration of how we manage aircraft at the end of their useful life. This represents a rich stream of ideas and concepts that, with continued support, will mature and contribute to achieving the goals on limiting global climate change.

The German national aviation research programme (LuFo) aims at supporting a sustainable and economical air transport system in line with targets laid down in the ACARE "Flightpath 2050". The collaboration of universities, research centres and specialised small and medium-sized enterprises is of central importance within LuFo. Energy-efficiency, environmental compatibility as well as ecologically efficient flying are amongst the main subjects for which national funding is provided.

Alternative fuels

ECAC States are embracing the introduction of sustainable alternative aviation fuels but recognise the many challenges between the current situation and their widespread availability or use. It has been proven fit for purpose and the distribution system has demonstrated its capacity to handle sustainable alternative fuels. Recent actions have focussed on preparing the legal base for recognising a minimum reduction in greenhouse gas emissions and market share targets for such fuels in the transport sector. The greatest challenge to overcome is economic scalability of the production of sustainable fuel and the future actions of the ECAC states are preparing the building blocks towards that goal. The European Commission has proposed specific measures and sub-quotas to promote innovation and the deployment of more advanced sustainable fuels as well as additional incentives to use such fuels in aviation. Public private partnership in the European Advanced Biofuels Flight-path is also continuing to bring down the commercial barriers. In that framework, Europe is progressing towards a 2 million tonne goal for the consumption of sustainably produced paraffinic biofuels by 2020. Europe has progressed from demonstration flights to sustainable biofuel being made available through the hydrant fuelling infrastructure, but recognises that continued action will be required to enable a more large-scale introduction.

In addition to biofuels, CO_2-neutral fuels (including Power-to-Liquid fuels) have recently gained momentum through research projects in Germany. Germany has initiated and continues to support the discussions about Power-to-Liquid fuels for aviation on the ICAO level.

Improved Air Traffic Management

The European Union's Single European Sky (SES) policy aims to transform Air Traffic Management in Europe, tripling capacity, halving ATM costs with 10 times the safety and 10% less environmental impact. Progress is well underway on the road map to achieve these ambitious goals through commitment and investment in the research and technology. Validated ATM solutions alone are capable of 21% more airspace capacity, 14% more airport capacity, a 40% reduction in accident risk, 2.8% less greenhouse emissions and a 6% reduction in flight cost. Steps 2 and 3 of the overall SES plan for the future will deploy 'Trajectory-based Operation' and 'Performance-based Operations' respectively. Much of the research to develop these solutions is underway and published results of the many earlier demonstration actions confirm the challenge but give us confidence that the goals will be achieved in the ECAC region with widespread potential to be replicated in other regions.

DFS Deutsche Flugsicherung GmbH and German airports are working together to ensure an efficient and environmentally friendly air traffic in Germany. Measures in the ATM domain include initiatives for airspace optimisation as well as the successive introduction of Continuous Descent Operations (CDO) and Airport Collaborative Decision Making Procedures (A-CDM).

Economic/Market Based Measures (MBMs)

ECAC members have always been strong supporters of a market-based measure scheme for international aviation to incentivise and reward good investment and operational choices, and so welcomed the agreement on the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). The 31 EEA states in Europe have already implemented the EU Emissions Trading System (ETS), including the aviation sector with around 500 aircraft operators participating in the cap and trade approach to limit CO_2 emissions. It was the first and is the biggest international system capping greenhouse gas emissions. In the period 2012 to 2018 EU ETS has saved an estimated 100 million tonnes of intra-European aviation CO_2 emissions.

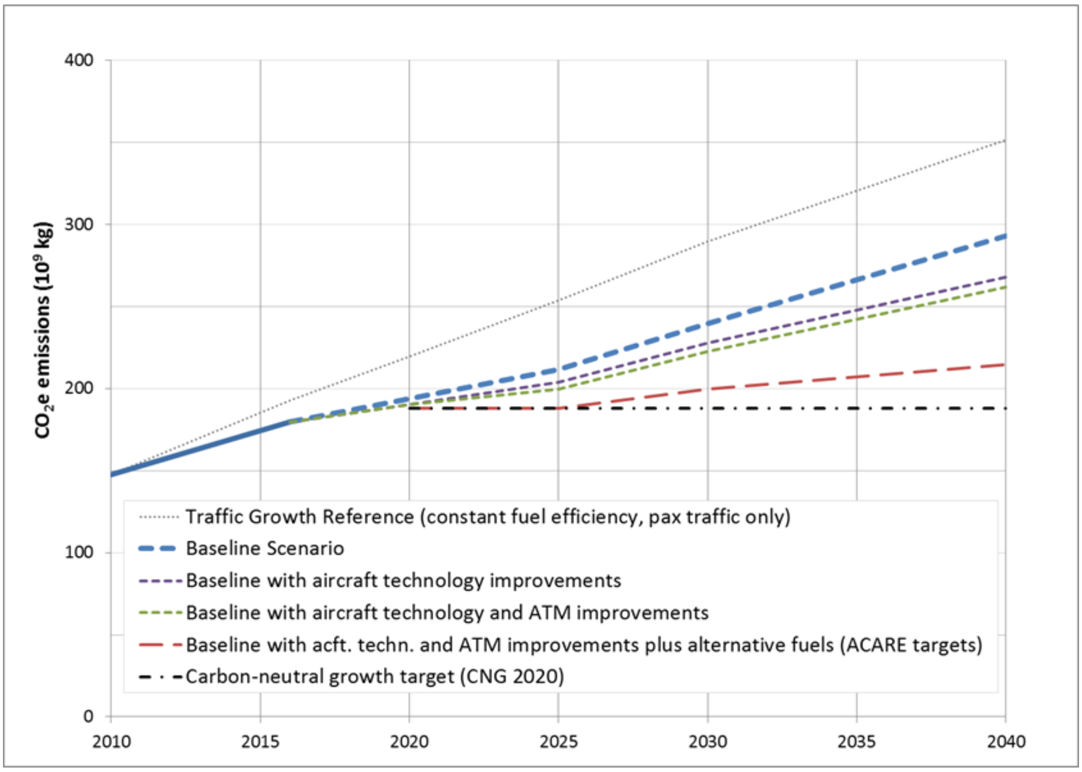
ECAC States, through the Bratislava declaration, have expressed their intention to voluntarily participate in CORSIA from its pilot phase and encourage other States to do likewise and join CORSIA. Subject to preserving the environmental integrity and effectiveness it is expected that the EU ETS legislation will be adapted to implement the CORSIA. A future world with a globally implemented CORSIA aimed at carbon neutral growth of international aviation would significantly reduce emissions.

In 2017, Germany and ICAO have signed a Memorandum of Understanding to test the feasibility and practicality of the CORSIA provisions for Monitoring, Reporting and Verification (MRV) of CO_2 emissions. This so-called Small Scale Implementation Project (SSI) was launched together with six other States and their participating operators. The project could be finalized on time, which enabled the presentation of results during the 2018 ICAO Regional Seminars on CORSIA.

ECAC Scenarios for Traffic and CO_2 Emissions

Aviation traffic continues to grow, develop and diversify in many ways across the ECAC states. Whilst the focus of available data relates to passenger traffic, similar issues and comparable outcomes might be anticipated for cargo traffic both as belly hold freight or in dedicated freighters. Analysis by EUROCONTROL and EASA has identified the most likely scenario of influences on future traffic and modelled these assumptions out to future years. On the basis of this traffic forecast, fuel consumption and CO_2 emissions of aviation have been estimated for both a theoretical baseline scenario (without any mitigation action) and a scenario with implemented mitigation measures that are presented in this action plan. Results are visualised in the below figure.

Figure 1 – Equivalent CO_2 emissions forecast for the baseline and implemented measures scenarios



Under the baseline assumptions of traffic growth and fleet rollover with 2010 technology, CO_2 emissions would almost double for flights departing ECAC airports. Modelling the impact of improved aircraft technology for the scenario with implemented measures indicates an overall 8.5% reduction of fuel consumption and CO_2 emissions in 2040 compared to the baseline. Whilst the data to model the benefits of ATM improvements and sustainable alternative fuels may be less robust, they are nevertheless valuable contributions to reduce emissions further. Overall fuel efficiency, including the effects of new aircraft types and ATM-related measures, is projected to improve by 24% between 2010 and 2040. The potential of sustainable aviation fuels to reduce CO_2 emissions on a lifecycle basis is reflected in Figure 1. Market-based measures and their effects have not been simulated in detail, but will help reach the goal of carbon-neutral growth. As further developments in policy and technology are made, further analysis will improve the modelling of future emissions.

A Introduction

a) The Federal Republic of Germany is a Member of the European Union (EU) and of the European Civil Aviation Conference (ECAC). ECAC is an intergovernmental organisation covering the widest grouping of Member States[1] of any European organisation dealing with civil aviation. It is currently composed of 44 Member States, and was created in 1955.

b) ECAC States share the view that environmental concerns represent a potential constraint on the future development of the international aviation sector. Together they fully support ICAO's on-going efforts to address the full range of these concerns, including the key strategic challenge posed by climate change, for the sustainable development of international air transport.

c) The Federal Republic of Germany, like all of ECAC's forty-four States, is fully committed to and involved in the fight against climate change and works towards a resource-efficient, competitive and sustainable multimodal transport system.

d) The Federal Republic of Germany recognises the value of each State preparing and submitting to ICAO an updated State action plan for CO_2 emissions reductions as an important step towards the achievement of the global collective goals agreed since the 38th Session of the ICAO Assembly in 2013.

e) In that context, it is the intention that all ECAC States submit to ICAO an Action Plan[2]. This is the Action Plan of the Federal Republic of Germany.

f) The Federal Republic of Germany shares the view of all ECAC States that a comprehensive approach to reducing aviation CO_2 emissions is necessary, and that this should include:

   i. emission reductions at source, including European support to CAEP work in this matter (standard setting process),

   ii. research and development on emission reductions technologies, including public-private partnerships,

   iii. development and deployment of low-carbon, sustainable alternative fuels, including research and operational initiatives undertaken jointly with stakeholders,

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[1] Albania, Armenia, Austria, Azerbaijan, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Moldova, Monaco, Montenegro, Netherlands, Norway, Poland, Portugal, Romania, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, The former Yugoslav Republic of Macedonia, Turkey, Ukraine, and the United Kingdom

[2] ICAO Assembly Resolution A38-18 also encourages States to submit an annual reporting on international aviation CO_2 emissions, which is a task different in nature and purpose to that of Action Plans, strategic in their nature. Also this requirement is subject to different deadlines for submission and updates as annual updates are expected. For that reason, the reporting to ICAO on international aviation CO_2 emissions referred to at paragraph 11 of ICAO Resolution A38/18 is not necessarily part of this Action Plan, and may be provided separately, as part of routine provision of data to ICAO, or in future updates of this action plan.

iv. improvement and optimisation of Air Traffic Management and infrastructure use within Europe, in particular through the Single European Sky ATM Research (SESAR), and also beyond European borders, through the Atlantic Initiative for the Reduction of Emissions (AIRE) in cooperation with the US FAA, and

v. Market Based Measures, which allow the sector to continue to grow in a sustainable and efficient manner, recognizing that the measures at (i) to (iv) above cannot, even in aggregate, deliver in time the emissions reductions necessary to meet the global goals. This sustainable growth becomes possible through the purchase of carbon units that foster emission reductions in other sectors of the economy, where abatement costs are lower than within the aviation sector.

g) In Europe, many of the actions which are undertaken within the framework of this comprehensive approach are in practice taken collectively, throughout Europe, most of them led by the European Union. They are reported in Section D of this Action Plan, where the involvement of the Federal Republic of Germany is described, as well as that of other stakeholders.

h) In the Federal Republic of Germany a number of actions are undertaken at the national level, including those by stakeholders. These national actions are reported in Section E of this Plan.

i) In relation to European actions, it is important to note that:

i. The extent of participation will vary from one State to another, reflecting the priorities and circumstances of each State (economic situation, size of its aviation market, historical and institutional context, such as EU/ non EU). The ECAC States are thus involved to different degrees and on different timelines in the delivery of these common actions. When an additional State joins a collective action, including at a later stage, this broadens the effect of the measure, thus increasing the European contribution to meeting the global goals.

ii. Acting together, the ECAC States have undertaken to reduce the region's emissions through a comprehensive approach. Some of the measures, although implemented by some, but not all of ECAC's 44 States, nonetheless yield emission reduction benefits across the whole of the region (for example research, ETS).

B Aviation in the Federal Republic of Germany

B.1 General characteristics of Germany and its aviation sector

Germany is a federal republic in Europe and a Member State of the European Union. It covers an area of 357,021 km^2 and is the Member State with the biggest population (82 million inhabitants) of the European Union. It is the fourth largest economy in the world.

Germany's aviation sector is much diversified and many passenger and cargo airlines are operating from within Germany. Passengers are able to transfer quickly at German airports, and practically every destination in the world can be easily reached for both passengers and cargo.

Frankfurt Airport is Germany's biggest hub for passenger aviation, followed by the airports in Munich, Düsseldorf and Berlin. With regard to cargo transport, Frankfurt, Leipzig and Cologne/Bonn are the biggest airports.

In the framework of the aviation administration the Federal Government of Germany transferred several functions and responsibilities to its federal states, the Laender, for example with respect to the licencing of airfields. Furthermore, the Laender play an important role as the authorities of civil airports in Germany.

B.2 Passenger and cargo air traffic to and from Germany

Table 1 shows the transport performance of commercial air traffic to and from Germany in the past ten years, measured in revenue passenger-kilometres (RPK) and freight/mail tonne-kilometres transported (FTKT) respectively. Also shown in the table are the effectively used total payload capacities in terms of revenue tonne-kilometres (RTK), which include both passenger and cargo transport.

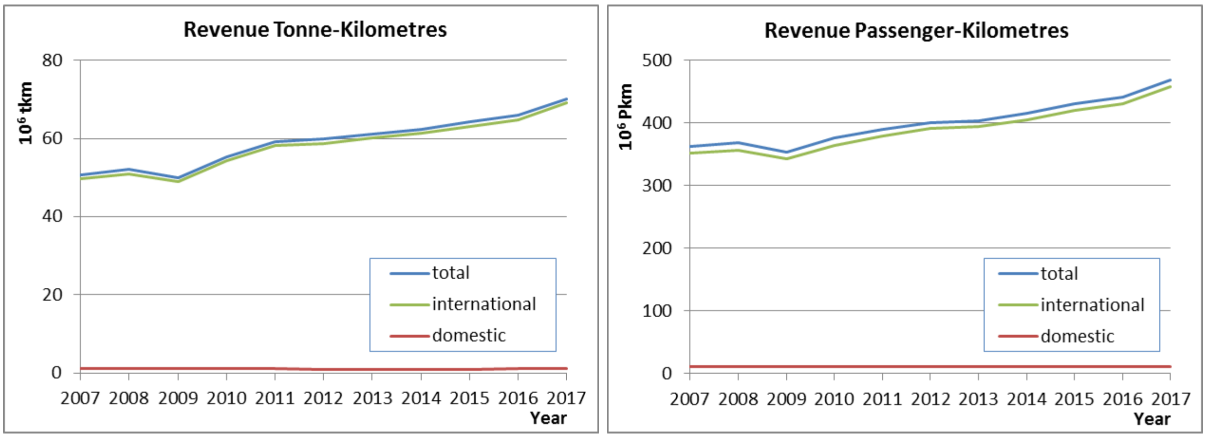
Table 1 – Transport performance of air traffic to and from Germany

	Revenue passenger-kilometres [10^6 Pkm]			Freight/mail tonne-kilometres transported [10^6 tkm]			Revenue tonne-kilometres [10^6 tkm]		
Year	domestic	international	total	domestic	international	total	domestic	international	total
2017	10,361	458,617	468,977	44	22,798	22,842	1,071	69,113	70,184
2016	10,423	431,098	441,521	40	21,329	21,369	1,074	64,841	65,916
2015	10,152	420,491	430,642	38	20,731	20,768	1,046	63,183	64,230
2014	10,020	404,917	414,937	36	20,844	20,881	1,032	61,315	62,346
2013	9,950	393,965	403,915	35	20,443	20,478	1,018	60,093	61,111
2012	10,374	390,710	401,084	35	20,617	20,652	1,064	58,822	59,886
2011	10,742	379,626	390,368	38	21,313	21,352	1,101	58,200	59,301
2010	10,788	364,673	375,461	37	20,300	20,337	1,108	54,298	55,407
2009	10,561	342,954	353,515	37	15,926	15,962	1,086	49,002	50,088
2008	10,950	357,054	368,005	40	16,818	16,858	1,131	50,981	52,765
2007	10,636	351,841	362,477	30	16,419	16,448	1,094	49,671	50,765
Table shows flight-stage data that refers to payload on board of aircraft operating on German airports. Domestic traffic covers flights between German airports (without double counting of passengers or cargo). International traffic includes outgoing and incoming international flights from and to German airports.									

Source: DESTATIS

The development of total transport performance is visualized below in the left diagram of Figure 2. Between 2007 and 2017, revenue tonne-kilometres have increased by 38%, which corresponds to an average annual growth rate of 3.3%. These numbers include both passenger and freight/mail transport. International traffic accounts for 98% of total transport performance, while flights within Germany account for 2%.

Figure 2 – Transport performance of air traffic to and from Germany

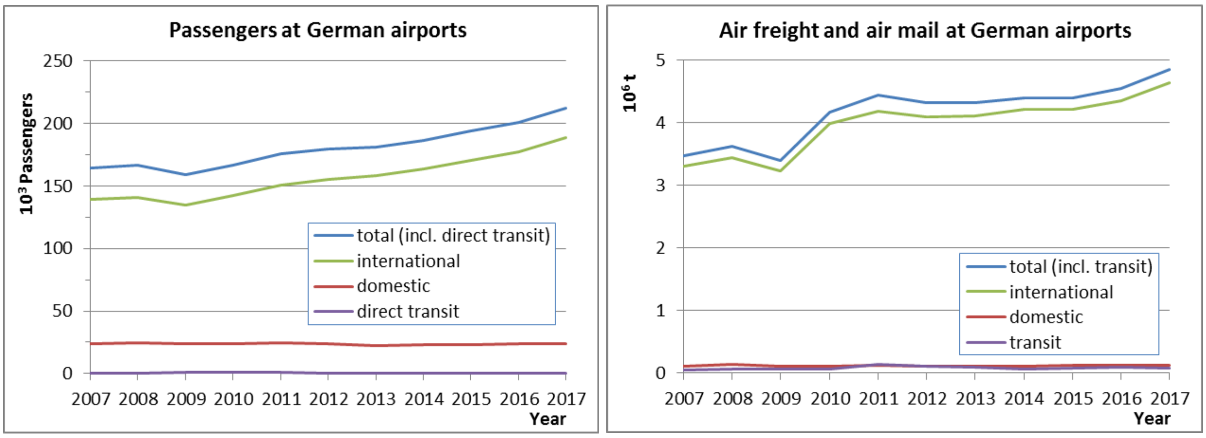


Source: based on DESTATIS data

The transport performance in the passenger segment is shown in the right diagram of Figure 2. Passenger-kilometres have increased by 29% between 2007 and 2017, which corresponds to an average annual growth rate of 2.6%. This growth is attributable to an increase of international traffic only, whereas passenger-kilometres of domestic flights have declined slightly since 2007. Freight and mail tonne-kilometres have increased 39% since 2007, corresponding to an average annual growth rate of 3.3%.

The number of commercial flights, the number of passengers and the amount of freight and mail transported to and from German airports are presented in Table 2. The number of passengers and the freight/mail tonnes transported since 2007 are illustrated in Figure 3.

Figure 3 – Passengers and freight/mail tonnes at German airports



Source: based on DESTATIS data

Table 2 – Flights, passengers and freight/mail transported to and from German airports

	Number of flights [1000]			Number of passengers [1000]			Freight/mail [1000 t]		
Year	domestic	international	total	domestic	international	total[1]	domestic	international	total[1]
2017	299	1,545	1,845	23,738	188,556	212,547	125	4,646	4,847
2016	310	1,497	1,806	23,736	165,912	200,930	119	4,345	4,546
2015	300	1,458	1,758	23,081	170,780	194,165	113	4,209	4,401
2014	307	1,429	1,736	22,732	163,657	186,689	111	4,219	4,396
2013	321	1,421	1,742	22,578	158,165	181,142	108	4,114	4,315
2012	352	1,450	1,802	23,347	155,089	179,199	111	4,094	4,317
2011	374	1,465	1,838	24,351	150,898	175,965	116	4,182	4,436
2010	361	1,411	1,772	24,021	141,966	166,803	105	3,993	4,163
2009	358	1,403	1,760	23,598	134,422	158,855	110	3,232	3,398
2008	389	1,493	1,882	24,724	140,912	166,291	129	3,439	3,621
2007	377	1,471	1,848	24,079	139,466	164,150	106	3,312	3,469

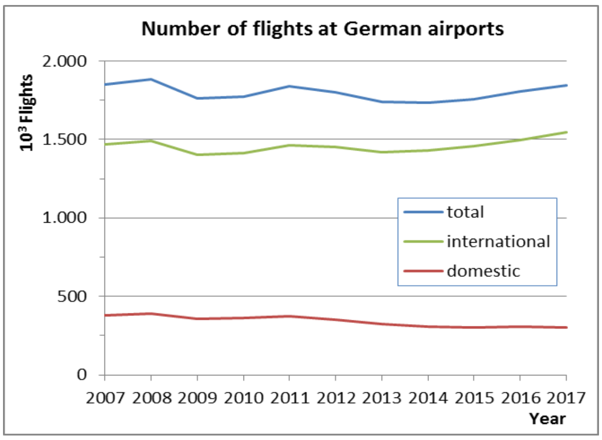
Passenger and freight/mail data is on-flight origin and destination (OFOD) data.
Domestic traffic covers traffic between German airports (without double counting of passengers or cargo).
International traffic includes outgoing and incoming international traffic from and to German airports.
[1] Including domestic, international and direct transit services.

Source: DESTATIS

The number of passengers on international connections has increased by an average 3.1% per annum in the past ten years, while the number of passengers within Germany remained nearly constant. In total, passenger numbers have increased by 2.6% annually since 2007. Similar trends can be observed for the freight and mail tonnes transported, where international traffic has increased by 3.4% annually since 2007. Domestic cargo tonnes show a slight increase of 1.7% annually at a comparably low level, resulting in a growth of total freight and mail tonnes (domestic and international) of also 3.4% per annum.

The number of flights at German airports is visualized in Figure 4. It remained approximately constant since 2007. As passenger numbers and transported cargo have grown stronger than the number of flights, this indicates that the average payload capacity of aircraft operating at German airports has increased.

Figure 4 – Number of flights at German airports



Source: based on DESTATIS data

B.3 CO_2 emissions of flights from German airports

Germany reports the greenhouse gas emissions of its civil aviation to the United Nations Framework Convention on Climate Change (UNFCCC). Respective emissions data is calculated in accordance with guidelines of the International Panel on Climate Change (IPCC) and based on the amount of fuel delivered to German airports. This includes both Jet fuel and aviation fuel quantities. An overview of fuel consumption and CO_2 emissions of aviation is shown in Table 3.

Table 3 – Fuel consumption and CO_2 emissions of flights from German airports based on IPCC guidelines

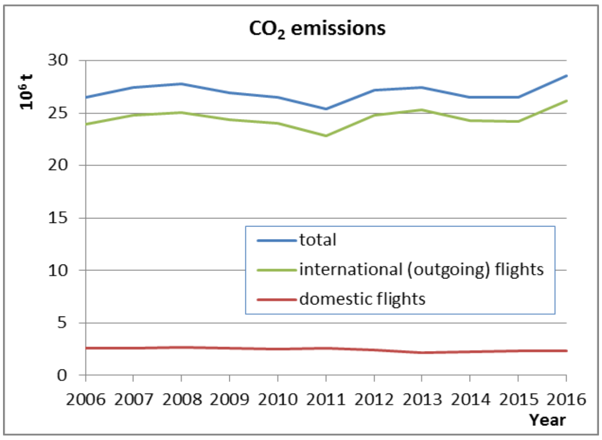
	Fuel consumption [1000 t]			CO_2 emissions [1000 t]		
Year	domestic	international[1]	total	domestic	international[1]	total
2016	752	8,347	9,099	2,357	26,170	28,527
2015	741	7,722	8,463	2,321	24,211	26,532
2014	708	7,758	8,465	2,218	24,324	26,542
2013	698	8,067	8,765	2,188	25,293	27,482
2012	773	7,897	8,671	2,424	24,761	27,185
2011	824	7,277	8,101	2,581	22,817	25,398
2010	813	7,652	8,465	2,548	23,992	26,540
2009	817	7,777	8,594	2,562	24,382	26,944
2008	855	8,000	8,855	2,679	25,081	27,761
2007	843	7,919	8,762	2,642	24,830	27,472
2006	826	7,629	8,455	2,587	23,921	26,508

[1] Values for intern. flights cover flights from Germany to abroad (i.e. outgoing traffic only).

Source: Umweltbundesamt

The development of CO_2 emissions since 2006 is visualized in Figure 5. CO_2 emissions of flights from German airports have grown by 7.6% between 2006 and 2016, which corresponds to an average annual growth rate of 0.7%. Since 2006, CO_2 emissions of international flights have grown by 9.4%, while emissions of domestic flights have decreased by 8.9%. Further action is required in order to reduce CO_2 emissions and aviation's impact on climate.

Figure 5 – CO_2 emissions of flights from German airports



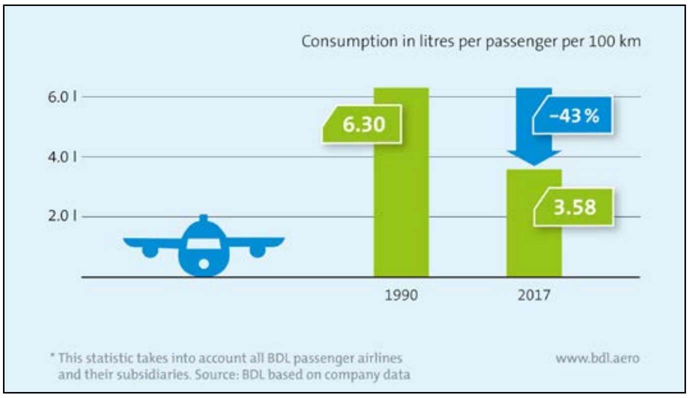
Source: based on data from Umweltbundesamt

The transport performance of outgoing flights from Germany is contained in Table 19 within Annex 1. As CO_2 emissions and transport performance originate from different sources, they are not directly comparable. It can be noted, however, that growth rates for CO_2 emissions since 2006 are considerably lower than respective growth rates for transport performance in revenue tonne-kilometres (RTK). This indicates an improvement of fuel efficiency, amongst other factors due to the introduction of more modern aircraft and improved load factors.

B.4 Efficiency improvements by German airlines and airports

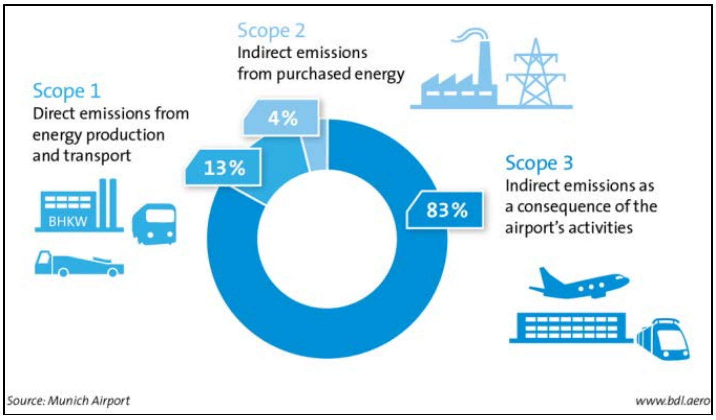
Since 1990, German airlines have reduced their fuel consumption per revenue passenger-kilometre by 42%. In 1990, an aircraft on average consumed 6.3 litres of fuel per 100 passenger-kilometres. In 2017, German airlines on average consumed 3.58 litres of fuel per 100 Pkm (see Figure 6). This can mostly be attributed to the introduction of more modern and more fuel-efficient aircraft and, amongst other measures, a continuous improvement of load factors. In 2017, the German aviation industry achieved a passenger load factor of 82.1%, which is above the global average.

Figure 6 – Average fuel consumption of the German air fleet*



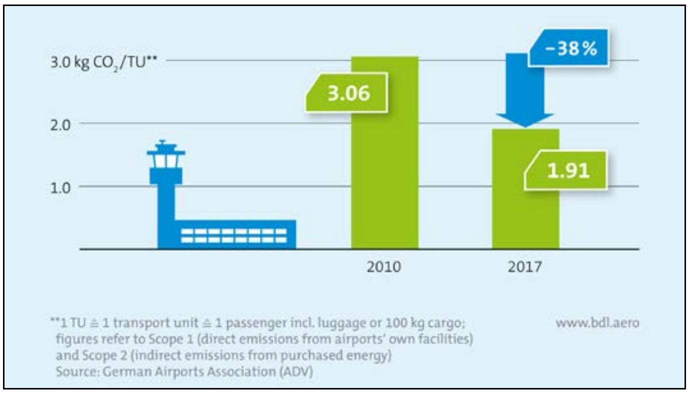
German airports are aware of their CO_2 footprint. CO_2 emissions from airport operation are assessed for all major airports on a regular basis. Assessments take into account the heating of the building, ground handling operations as well as aircraft emissions during take-off, landing and when operating on the ground. As shown in Figure 7, the CO_2 assessments for German airports are divided into three categories (called scopes) in line with the Greenhouse Gas Protocol.

Figure 7 – Airport carbon footprint



Between 2010 and 2017, German airports managed to reduce their specific CO_2 emissions by 32%, to 1.92 kg of CO_2 per transport unit (TU)[3] for scopes 1 and 2. This is primarily due to measures falling under Scope 1, including the optimization of ground operations and the use of innovative technologies to run buildings and installations, such as modern heating controls and the use of alternative vehicle propulsion systems.

Figure 8 – CO_2 emissions of German airports per transport unit (Scopes 1 and 2)



[3] 1 TU = 1 transport unit = 1 passenger including luggage or 100 kg cargo.

C Aviation in Europe, ECAC Baseline Scenario and Benefits of Implemented Measures

C.1 Aviation in Europe, European Aviation Environmental Report

The aviation sector brings significant benefits to the European countries, including Germany, as it creates jobs and facilitates trade as well as tourism. On the other hand, negative effects of aircraft include among others noise as well as gaseous and particulate emissions.

An overview of the environmental performance of the European aviation system can be found in the European Aviation Environmental Report (EAER)[4]. The EAER, which was published in 2016, was prepared by EASA, EUROCONTROL and the European Environment Agency (EEA). The next release of this report is scheduled for January 2019. According to the current EAER, the number of flights from or to airports in the European Union (EU) and the European Free Trade Association (EFTA) has increased by 80% between 1990 and 2014, and the environmental impacts of European aviation have also grown. Compared to 1990, CO_2 emissions of European aviation have increased by about 80%, while NO_x emissions have doubled. The report also states that emissions and noise exposure in 2014 were around 2005 levels, amongst other factors due to technological improvements and the 2008 economic downturn. Until 2035, on the other hand, a further increase of aviation's environmental impacts is expected, and requires a set of measures to address this challenge. The current action plan can be regarded as a contribution towards this requirement.

C.2 ECAC Baseline Scenario

The baseline scenario is intended to serve as a reference scenario for CO_2 emissions of European aviation in the absence of any of the mitigation actions described later in this document. The following sets of data (2010, 2016) and forecasts (for 2020, 2030 and 2040) were provided by EUROCONTROL for this purpose:

- European air traffic (includes all commercial and international flights departing from ECAC airports, in number of flights, revenue passenger kilometres (RPK) and revenue tonne-kilometres (RTK)),
- its associated aggregated fuel consumption,
- its associated CO_2 emissions.

The sets of forecasts correspond to projected traffic volumes in a scenario of "Regulation and Growth", while corresponding fuel consumption and CO_2 emissions assume the technology level of the year 2010 (i.e. without considering reductions of emissions by further aircraft related technology improvements, improved ATM and operations, alternative fuels or market based measures).

[4] Available online, see https://www.easa.europa.eu/eaer/

C.2.1 Traffic Scenario "Regulation and Growth"

As in all forecasts produced by EUROCONTROL, various scenarios are built with a specific storyline and a mix of characteristics. The aim is to improve the understanding of factors that will influence future traffic growth and the risks that lie ahead. In the 20 year forecasts published by EUROCONTROL the scenario called 'Regulation and Growth' is constructed as the 'most likely' or 'baseline' scenario for traffic, most closely following the current trends. It considers a moderate economic growth, with some regulation particularly regarding the social and economic demands.

Amongst the models applied by EUROCONTROL for the forecast the passenger traffic sub-model is the most developed and is structured around five main group of factors that are taken into account:

- **Global economy** factors represent the key economic developments driving the demand for air transport.
- Factors characterizing the **passengers** and their travel preferences change patterns in travel demand and travel destinations.
- **Price of tickets** set by the airlines to cover their operating costs influences passengers' travel decisions and their choice of transport.
- More hub-and-spoke or point-to-point **networks** may alter the number of connections and flights needed to travel from origin to destination.
- **Market structure** describes size of aircraft used to satisfy the passenger demand (modelled via the Aircraft Assignment Tool).

Table 4 on page 23 presents a summary of the social, economic and air traffic related characteristics of three different scenarios developed by EUROCONTROL. The year 2016 serves as the baseline year of the 20-year forecast results[5] updated in 2018 by EUROCONTROL and presented here. Historical data for the year 2010 are also shown later for reference.

C.2.2 Further assumptions and results for the baseline scenario

The ECAC baseline scenario was generated by EUROCONTROL for all ECAC States. It covers all commercial international passenger flights departing from ECAC airports, as forecasted in the aforementioned traffic scenario. The number of passengers per flight is derived from Eurostat data.

EUROCONTROL also generates a number of all-cargo flights in its baseline scenario. However, no information about the freight tonnes carried is available. Hence, historical and forecasted cargo traffic have been extracted from another source (ICAO[6]). This data, which is presented below, includes both belly cargo transported on passenger flights and freight transported on dedicated all-cargo flights.

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[5] Challenges of Growth 2018: Flight forecast, EUROCONTROL, September 2018

[6] ICAO Long-Term Traffic Forecasts, Passenger and Cargo, July 2016.

Table 4 – Summary characteristics of EUROCONTROL scenarios

	Global Growth	*Regulation and Growth*	*Fragmenting World*
2023 traffic growth	High ↗	Base →	Low ↘
Passenger Demographics (Population)	Aging UN Medium-fertility variant	Aging UN Medium-fertility variant	Aging UN Zero-migration variant
Routes and Destinations	Long-haul ↗	No Change →	Long-haul ↘
Open Skies	EU enlargement later +Far & Middle-East	EU enlargement Earliest	EU enlargement Latest
High-speed rail (new & improved connections)	20 city-pairs faster implementation	20 city-pairs	20 city-pairs later implementation.
Economic conditions GDP growth	Stronger ↗	Moderate →	Weaker ↘↘
EU Enlargement	+5 States, Later	+5 States, Earliest	+5 States, Latest
Free Trade	Global, faster	Limited, later	None
Price of travel Operating cost	Decreasing ↘↘	Decreasing ↘	No change →
Price of CO_2 in Emission Trading Scheme	Moderate	Lowest	Highest
Price of oil/barrel	Low	Lowest	High
Change in other charges	Noise: ↗ Security: ↘	Noise: ↗ Security: →	Noise: → Security: ↗
Structure Network	Hubs: Mid-East ↗↗ Europe ↘ Turkey↗ Pt-to-pt: N-Atlant.↗↗	Hubs: Mid-East ↗↗ Europe&Turkey ↗ Pt-to-pt: N-Atlant.↗	No change →
Market Structure	Industry fleet forecast + STATFOR assumptions	Industry fleet forecast + STATFOR assumptions	Industry fleet forecast + STATFOR assumptions

Historical fuel burn and emission calculations are based on the actual flight plans from the PRISME data warehouse used by EUROCONTROL, including the actual flight distance and the cruise altitude by airport pair. These calculations were made for 98% of the passenger flights; the remaining flights in the flight plans had information missing. Determination of the fuel burn and CO_2 emissions for historical years is built up as the aggregation of fuel burn and emissions for each aircraft of the associated traffic sample. Fuel burn and CO_2 emission results consider each aircraft's fuel burn in its ground and airborne phases of flight and are obtained by use of the EUROCONTROL IMPACT environmental model. While historical traffic data is used for the year 2016, the baseline fuel burn and emissions in 2016 and the forecast years (until 2040) are modelled in a simplified approach on the basis of the historical/forecasted traffic and assume the technology level of the year 2010.

The following tables and figures show the results for this baseline scenario, which is intended to serve as a reference case by approximating fuel consumption and CO_2 emissions of European aviation in the absence of mitigation actions.

Table 5 – Baseline forecast for international traffic departing from ECAC airports

Year	Passenger Traffic (IFR movements) (million)	Revenue Passenger Kilometres[7] RPK (billion)	All-Cargo Traffic (IFR movements) (million)	Freight Tonne Kilometres transported[8] FTKT (billion)	Total Revenue Tonne Kilometres[8,9] RTK (billion)
2010	4.6	1,218	0.20	45.4	167.2
2016	5.2	1,601	0.21	45.3	205.4
2020	5.6	1,825	0.25	49.4	231.9
2030	7.0	2,406	0.35	63.8	304.4
2040	8.4	2,919	0.45	79.4	371.2

Table 6 – Fuel burn and CO_2 emissions forecast for the baseline scenario

Year	Fuel Consumption (10^9 kg)	CO_2 emissions (10^9 kg)	Fuel efficiency (kg/RPK)	Fuel efficiency (kg/RTK)
2010	37.98	120.00	0.0310	0.310
2016	46.28	146.26	0.0287	0.287
2020	49.95	157.85	0.0274	0.274
2030	61.75	195.13	0.0256	0.256
2040	75.44	238.38	0.0259	0.259
For reasons of data availability, results shown in this table do not include cargo/freight traffic.				

[7] Calculated based on 98% of the passenger traffic.

[8] Includes passenger and freight transport (on all-cargo and passenger flights).

[9] A value of 100 kg has been used as the average mass of a passenger incl. baggage (ref: ICAO).

Figure 9 – Forecasted traffic until 2040
(assumed both for the baseline and implemented measures scenarios)

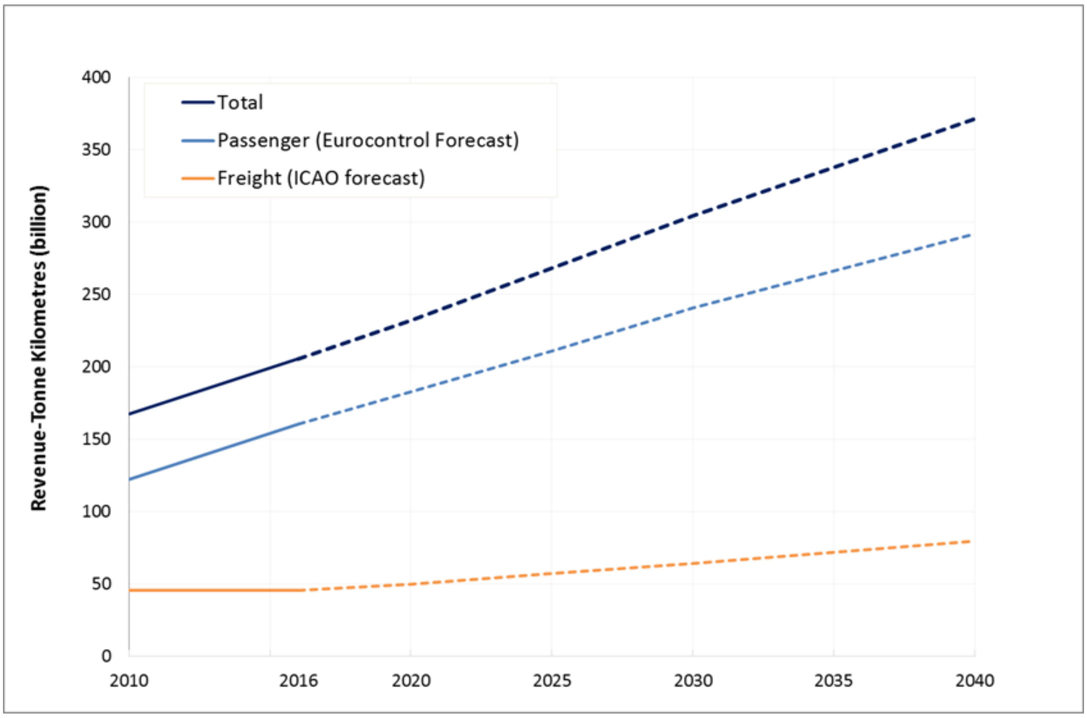
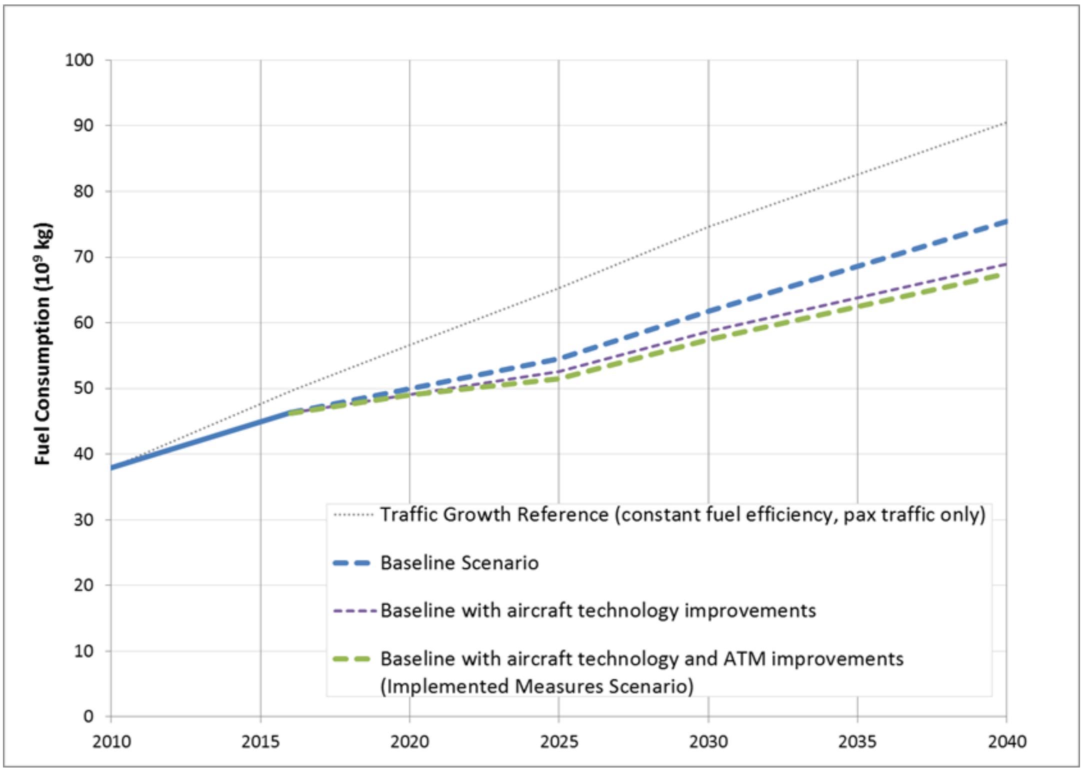


Figure 10 – Fuel consumption forecast for the baseline and implemented measures scenarios (international passenger flights departing from ECAC airports)



C.3 ECAC Scenario with Implemented Measures, Estimated Benefits of Measures

In order to improve fuel efficiency and to reduce future air traffic emissions beyond the projections in the baseline scenario, ECAC States have taken further action. Assumptions for a top-down assessment of effects of mitigation actions are presented here, based on modelling results by EUROCONTROL and EASA. Measures to reduce aviation's fuel consumption and emissions will be described in the following chapters.

For reasons of simplicity, the scenario with implemented measures is based on the same traffic volumes as the baseline case, i.e. EUROCONTROL's 'Regulation and Growth' scenario described earlier. Unlike in the baseline scenario, the effects of aircraft related technology development, improvements in ATM/operations and alternative fuels are considered here for a projection of fuel consumption and CO_2 emissions up to the year 2040.

Effects of **improved aircraft technology** are captured by simulating fleet roll-over and considering the fuel efficiency improvements of new aircraft types of the latest generation (e.g. Airbus A320NEO, Boeing 737MAX, Airbus A350XWB etc.). The simulated future fleet of aircraft has been generated using the Aircraft Assignment Tool (AAT) developed collaboratively by EUROCONTROL, EASA and the European Commission. The retirement process of the Aircraft Assignment Tool is performed year by year, allowing the determination of the amount of new aircraft required each year. In addition to the fleet rollover, a constant annual improvement of fuel efficiency of 0.96% per annum is assumed to aircraft deliveries during the last 10 years of the forecast (2030-2040). This rate of improvement corresponds to the 'medium' fuel technology scenario used by CAEP to generate the fuel trends for the Assembly.

The effects of **improved ATM efficiency** are captured in the Implemented Measures Scenario on the basis of efficiency analyses from the SESAR project. Regarding SESAR effects, baseline deployment improvements of 0.2% in terms of fuel efficiency are assumed to be included in the base year fuel consumption for 2010. This improvement is assumed to rise to 0.3% in 2016 while additional improvements of 2.06% are targeted for the time period from 2025 onwards[10]. Further non-SESAR related fuel savings have been estimated to amount to 1.2% until the year 2010, and are already included in the baseline calculations[11].

Regarding the **introduction of sustainable alternative fuels**, the European ACARE roadmap targets described in section D.2.1 of this document are assumed for the implemented measures case. These targets include an increase of alternative fuel quantities to 2% of aviation's total fuel consumption in the year 2020, rising linearly to 25% in 2035 and 40% in 2050. An average 60% reduction of lifecycle CO_2 emissions compared to crude-oil based JET fuel was assumed for sustainable aviation fuels, which is in line with requirements from Article 17 of the EU's Renewable Energy Directive (Directive 2009/28/EC)[12]. The resulting emission savings are shown in Table 9 and Figure 11 in units of

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10 See SESAR1 D72 "Updated Performance Assessment in 2016" document, November 2016, project B05, project manager: ENAIRE.

11 See SESAR1 D107 "Updated Step 1 validation targets – aligned with dataset 13", project B.04.01, December 2014, project manager: NATS.

12 According to article 17 of the EU RED (Directive 2009/28/EC), GHG emission savings of at least 60% are required for biofuels produced in new installations in which production started on or after 1 January 2017.

equivalent CO_2 emissions on a well-to-wake basis. Well-to-wake emissions include all GHG emissions throughout the fuel lifecycle, including emissions from feedstock extraction or cultivation (including land-use change), feedstock processing and transportation, fuel production at conversion facilities as well as distribution and combustion[13].

For simplicity, effects of market-based measures including the EU Emissions Trading Scheme (ETS) and ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) on aviation's CO_2 emissions have not been modelled explicitly in the top-down assessment of the implemented measures scenario presented here. CORSIA aims for carbon-neutral growth of aviation from 2020 onwards, and this target is therefore shown in Figure 11[14].

Tables 7-9 and Figures 10-11 summarize the results for the scenario with implemented measures. It should be noted that Table 7 shows direct combustion emissions of CO_2 (assuming 3.16 kg CO_2 per kg fuel), whereas Table 9 and Figure 11 present equivalent CO_2 emissions on a well-to-wake basis. More detailed tabulated results are found in Annex 2.

Table 7 – Fuel burn and CO_2 emissions forecast for the Implemented Measures Scenario (new aircraft technology and ATM improvements only)

Year	Fuel Consumption (10^9 kg)	CO_2 emissions (10^9 kg)	Fuel efficiency (kg/RPK)	Fuel efficiency (kg/RTK)
2010	37.98	120.00	0.0310	0.310
2016	46.24	146.11	0.0286	0.286
2020	49.03	154.93	0.0245	0.245
2030	57.38	181.33	0.0242	0.242
2040	67.50	213.30	0.0237	0.237
For reasons of data availability, results shown in this table do not include cargo/freight traffic.				

Table 8 – Average annual fuel efficiency improvement for the Implemented Measures Scenario (new aircraft technology and ATM improvements only)

Period	Average annual fuel efficiency improvement (%)
2010-2016	-1.36%
2016-2020	-1.40%
2020-2030	-1.11%
2030-2040	-0.21%

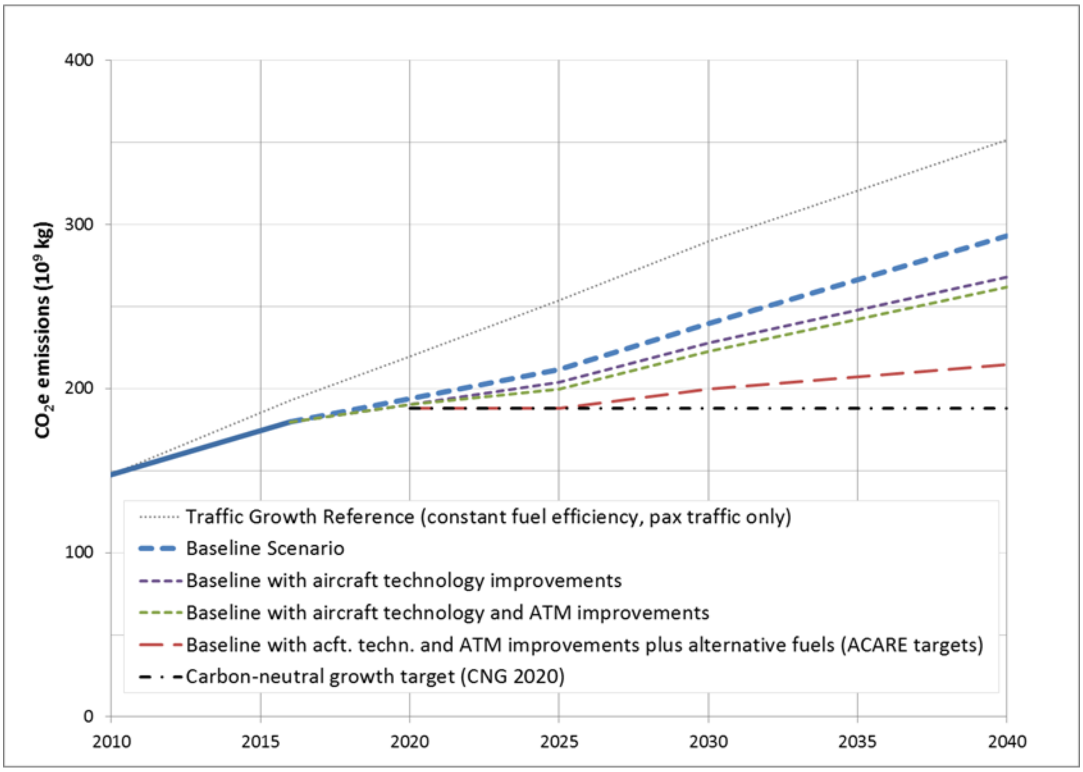
13 Well-to-wake CO_2e emissions of fossil-based JET fuel are calculated by assuming an emission index of 3.88 kg CO_2e per kg fuel (see DIN e.V., "Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers)", German version EN 16258:2012), which is in accordance with 89 g CO_2e per MJ suggested by ICAO CAEP AFTF.

14 Note that in a strict sense the CORSIA target of CNG is aimed to be achieved globally (and hence not necessarily in each world region).

Table 9 – Equivalent (well-to-wake) CO_2e emissions for the scenarios described in this chapter

Year	Well-to-wake CO_2e emissions (10^9 kg)				% improvement by Implemented Measures (full scope)
	Baseline Scenario	Implemented Measures Scenario			
		Aircraft techn. improvements only	Aircraft techn. and ATM improvements	Acft. techn. and ATM impr. + alternative fuels	
2010	147.3				NA
2016	179.6	*179.6*	*179.4*	179.4	-0.1%
2020	193.8	*190.4*	*190.2*	187.9	-3.0%
2030	239.6	*227.6*	*222.6*	199.5	-16.7%
2040	292.7	*267.7*	*261.9*	214.8	-26.6%
For reasons of data availability, results shown in this table do not include cargo/freight traffic. Note that fuel consumption is assumed to be unaffected by the use of alternative fuels.					

Figure 11 – Equivalent (well-to-wake) CO_2 emissions forecast for the baseline and implemented measures scenarios



As shown in Figures 10-11, the impact of improved aircraft technology indicates an overall 8.5% reduction of fuel consumption and CO_2 emissions in 2040 compared to the baseline scenario. Whilst the data to model the benefits of ATM improvements and sustainable alternative fuels shown in Figure 11 may be less robust, they are nevertheless valuable contributions to reduce emissions further. Overall fuel efficiency, including the effects of new aircraft types and ATM-related measures, is projected to improve by 24% between 2010 and 2040.

Under the currently assumed aircraft and ATM improvement scenarios, the rate of fuel efficiency improvement is expected to slow down progressively until 2040. Aircraft technology and ATM improvements alone will not be sufficient to meet the post-2020 carbon neutral growth objective of aviation, nor will the use of alternative fuels even if Europe's ambitious targets for alternative fuels are met. This confirms that additional action, particularly market-based measures, are required to fill the gap.

D Actions Taken Collectively Throughout Europe

D.1 Aircraft-related technology development

D.1.1 Aircraft emissions standards – Europe's contribution to the development of the aeroplane CO_2 standard

European Member States fully supported the work achieved in ICAO’s Committee on Aviation Environmental Protection (CAEP), which resulted in an agreement on the new aeroplane CO_2 Standard at CAEP/10 meeting in February 2016, applicable to new aeroplane type designs from 2020 and to aeroplane type designs that are already in-production in 2023. Europe significantly contributed to this task, notably through the European Aviation Safety Agency (EASA) which co-led the CO_2 Task Group within CAEP’s Working Group 3, and which provided extensive technical and analytical support.

The assessment of the benefits provided by this measure in terms of reduction in European emissions is not provided in this action plan. Nonetheless, elements of assessment of the overall contribution of the CO_2 standard towards the global aspirational goals are available in CAEP.

D.1.2 Research and development

Clean Sky is an EU Joint Technology Initiative (JTI) that aims to develop and mature breakthrough “clean technologies” for air transport globally. By accelerating their deployment, the JTI will contribute to Europe’s strategic environmental and social priorities, and simultaneously promote competitiveness and sustainable economic growth.

Joint Technology Initiatives are specific large-scale EU research projects created by the European Commission within the 7th Framework Programme (FP7) and continued within the Horizon 2020 Framework Programme. Set up as a Public Private Partnership between the European Commission and the European aeronautical industry, Clean Sky pulls together the research and technology resources of the European Union in a coherent programme that contributes significantly to the ’greening’ of global aviation.

The first Clean Sky programme (**Clean Sky 1** - 2011-2017) has a budget of €1.6 billion, equally shared between the European Commission and the aeronautics industry. It aims to develop environmental friendly technologies impacting all flying-segments of commercial aviation. The objectives are to reduce aircraft CO_2 emissions by 20-40%, NO_x by around 60% and noise by up to 10dB compared to year 2000 aircraft.

What has the current JTI achieved so far?

It is estimated that Clean Sky resulted in a reduction of aviation CO_2 emissions by more than 32% with respect to baseline levels (in 2000), which represents an **aggregate of up to 6 billion tonnes of CO_2 over the next 35 years.**

This was followed up with a second programme (**Clean Sky 2** – 2014-2024) with the objective to reduce aircraft emissions and noise by 20 to 30% with respect to the latest technologies entering into service in 2014. The current budget for the programme is approximately €4 billion.

The two Interim Evaluations of Clean Sky in 2011 and 2013 acknowledged that the programme is successfully stimulating developments towards environmental targets. These preliminary assessments confirm the capability of achieving the overall targets at completion of the programme.

Main remaining areas for RTD efforts under Clean Sky 2 are:

- **Large Passenger Aircraft:** demonstration of best technologies to achieve the environmental goals whilst fulfilling future market needs and improving the competitiveness of future products.
- **Regional Aircraft:** demonstrating and validating key technologies that will enable a 90-seat class turboprop aircraft to deliver breakthrough economic and environmental performance and a superior passenger experience.
- **Fast Rotorcraft:** demonstrating new rotorcraft concepts (tilt-rotor and compound helicopters) technologies to deliver superior vehicle versatility and performance.
- **Airframe:** demonstrating the benefits of advanced and innovative airframe structures (like a more efficient wing with natural laminar flow, optimised control surfaces, control systems and embedded systems, highly integrated in metallic and advanced composites structures). In addition, novel engine integration strategies and innovative fuselage structures will be investigated and tested.
- **Engines:** validating advanced and more radical engine architectures.
- **Systems:** demonstrating the advantages of applying new technologies in major areas such as power management, cockpit, wing, landing gear, to address the needs of a future generation of aircraft in terms of maturation, demonstration and Innovation.
- **Small Air Transport:** demonstrating the advantages of applying key technologies on small aircraft demonstrators to revitalise an important segment of the aeronautics sector that can bring key new mobility solutions
- **Eco-Design:** coordinating research geared towards high eco-compliance in air vehicles over their product life and heightening the stewardship with intelligent Re-use, Recycling and advanced services.

In addition, the **Technology Evaluator** will continue to be upgraded to assess technological progress routinely and evaluate the performance potential of Clean Sky 2 technologies at both vehicle and aggregate levels (airports and air traffic systems). More details on Clean Sky can be found at the following link: http://www.cleansky.eu/

D.2 Alternative fuels

D.2.1 European Advanced Biofuels Flightpath

Within the European Union, Directive 2009/28/EC on the promotion of the use of energy from renewable sources ("the Renewable Energy Directive" – RED) established mandatory targets to be achieved by 2020 for a 20% overall share of renewable energy in the EU and a 10% share for renewable energy in the transport sector. Furthermore, sustainability criteria for biofuels to be counted towards that target were established[15]. Directive 2009/28/EC of the European Parliament and of the Council of 23/04/2009 on the promotion of the use of energy from renewable sources, details in its Article 17 that 'with effect from 1 January 2017, the greenhouse gas emission saving from the use of biofuels and bioliquids taken into account for the purposes referred to in points (a), (b) and (c) of paragraph 1 shall be at least 50 %. From 1 January 2018 that greenhouse gas emission saving shall be at least 60 % for biofuels and bioliquids produced in installations in which production started on or after 1 January 2017'.

In November 30, 2016, the European Commission (EC) presented a proposal to the EU Council and the European Parliament for a recast of the Renewable Energy Directive for 2030. To promote the deployment and development of low carbon fuels, such as advanced biofuels, it is proposed to introduce after 2020 an obligation requiring fuel suppliers to sell a gradually increasing share of renewable and low-emission fuels, including advanced biofuels and renewable electricity (at least 1.5% in 2021 increasing to at least 6.8% by 2030). To promote innovation the obligation includes a specific sub-quota for advanced biofuels, increasing from 0.5% in 2021 to at least 3.6% in 2030. Advanced biofuels are defined as biofuels that are based on a list of feedstocks; mostly lignocellulosic material, wastes and residues.

Aviation and marine sectors are explicitly covered in the proposal. In fact, it is proposed that advanced alternative fuels used for aviation and maritime sectors can be counted 1.2 times towards the 6.8% renewable energy mandate. This would provide an additional incentive to develop and deploy alternative fuels in the aviation sector.

In February 2009, the European Commission's Directorate General for Energy and Transport initiated the SWAFEA (Sustainable Ways for Alternative Fuels and Energy for Aviation) study to investigate the feasibility and the impact of the use of alternative fuels in aviation. The SWAFEA final report was published in July 2011[16]. It provides a comprehensive analysis on the prospects for alternative fuels in aviation, including an integrated analysis of the technical feasibility, environmental sustainability (based on the sustainability criteria of the EU Directive on renewable energy[17]) and economic aspects. It includes a number of recommendations on the steps that should be taken to promote the take-up of sustainable biofuels for aviation in Europe.

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[15] Directive 2009/28/EC of the European Parliament and of the Council of 23/04/2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, Article 17 Sustainability criteria for biofuels and bioliquids, at pp. EU Official Journal L140/36-L140/38

[16] http://www.icao.int/environmental-protection/GFAAF/Documents/SW_WP9_D.9.1%20Final%20report_released%20July2011.pdf

[17] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

In March 2011, the European Commission published a White Paper on transport[18] . In the context of an overall goal of achieving a reduction of at least 60% in greenhouse gas emissions from transport by 2050 with respect to 1990, the White Paper established a goal of low-carbon sustainable fuels in aviation reaching 40% by 2050.

ACARE Roadmap targets regarding share of alternative sustainable fuels:

Aviation to use:

- **at minimum 2%** sustainable alternative fuels **in 2020**;
- **at minimum 25%** sustainable alternative fuels **in 2035**;
- **at minimum 40%** sustainable alternative fuels **in 2050**.

(Source: ACARE Strategic Research and Innovation Agenda, Volume 2)

As a first step towards delivering this goal, in June 2011 the European Commission, in close coordination with Airbus, leading European airlines (Lufthansa, Air France/KLM, & British Airways) and key European biofuel producers (Choren Industries, Neste Oil, Biomass Technology Group and UOP), launched the **European Advanced Biofuels Flight-path**. This industry-wide initiative aims to speed up the commercialisation of aviation biofuels in Europe, with the objective of achieving the commercialisation of sustainably produced paraffinic biofuels in the aviation sector by reaching an aggregated 2 million tonnes consumption by 2020.

This initiative is a shared and voluntary commitment by its members to support and promote the production, storage and distribution of sustainably produced drop-in biofuels for use in aviation. It also targets establishing appropriate financial mechanisms to support the construction of industrial "first of a kind" advanced biofuel production plants. The Biofuels Flight path is explained in a technical paper, which sets out in more detail the challenges and required actions[19]. More specifically, the initiative focuses on the following:

1. Facilitating the development of standards for drop-in biofuels and their certification for use in commercial aircraft,
2. Working together across the full supply chain to further develop worldwide accepted sustainability certification frameworks,
3. Agree biofuel take-off arrangements over a defined period of time and at a reasonable cost,
4. Promote appropriate public and private actions to ensure the market uptake of paraffinic biofuels by the aviation sector,
5. Establish financing structures to facilitate the realisation of 2nd Generation biofuel projects,
6. Accelerate targeted research and innovation for advanced biofuel technologies, and especially algae, and
7. Take concrete actions to inform the European citizen of the benefits of replacing kerosene with certified sustainable biofuels.

[18] Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, COM (2011) 144 final

[19] https://ec.europa.eu/energy/sites/ener/files/20130911_a_performing_biofuels_supply_chain.pdf

When the Flightpath 2020 initiative began in 2010, only one production pathway was approved for aviation use; renewable kerosene had only been produced at very small scale and only a handful of test and demonstration flights had been conducted using it. Since then, worldwide technical and operational progress in the industry has been remarkable. Four different pathways for the production of renewable kerosene are now approved and several more are expected to be certified soon. A significant number of flights using renewable kerosene have been conducted, most of them revenue flights carrying passengers. Production has been demonstrated at up to industrial scale for some of the pathways. Distribution of renewable kerosene through an airport hydrant system was also demonstrated in Oslo in 2015.

In 2016 the European commission tendered support and secretariat functions for the Flightpath 2020, which had so far depended on the initiative of the individual members. This €1.5m tender was won by a consortium run by SENASA, which started the work supporting the Flightpath at the end of 2016.

Performed flights using bio-kerosene

IATA:	2000 flights worldwide using bio-kerosene blends performed by 22 airlines between June 2011 and December 2015
Lufthansa:	1189 Frankfurt-Hamburg flights using 800 tonnes of bio-kerosene (during 6 months June/December 2011)
KLM:	a series of 200 Amsterdam-Paris flights from September 2011 to December 2014, 26 flights New York-Amsterdam in 2013, and 20 flights Amsterdam-Aruba in 2014 using bio-kerosene
Air France:	A series of 50 Paris – Toulouse flights evaluating SIP kerosene in 2014/2015

Since late 2015, bio kerosene is regularly available as a fuel blend at Oslo airport. Total throughput so far can be approximatively estimated at 2000 tonnes. Attribution to individual flights is no longer possible except on an accounting basis as the fuel is commingled in the normal hydrant fuelling infrastructure of the airport.

Production (EU)

Neste (Finland): by batches

- Frankfurt-Hamburg (6 months) 1 189 flights operated by Lufthansa: 800 tonnes of bio-kerosene - Itaka: €10m EU funding (2012-2015): ca. 1 000 tonnes

Biorefly: €13.7m EU funding: 2000 tonnes per year – BioChemtex (Italy)

BSFJ Swedish Biofuels: €27.8m EU funding (2014-2019)

D.2.2 Research and Development projects on alternative fuels in aviation

In the time frame 2011-2016, 3 projects have been funded by the FP7 Research and Innovation program of the EU.

ITAKA: €10m EU funding (2012-2015) with the aim of assessing the potential of a specific crop (camelina) for providing jet fuel. The project aims entailed testing the whole chain from field to fly and assessing the potential beyond the data gathered in lab experiments, gathering experiences on related certification, distribution and economic aspects. For a feedstock, ITAKA targeted European camelina oil and used cooking oil in order to meet a minimum of 60% GHG emissions savings compared to the fossil fuel Jet-A1.

SOLAR-JET: This project has demonstrated the possibility of producing jet-fuel from CO_2 and water. This was done by coupling a two-step solar thermochemical cycle based on non-stoichiometric ceria redox reactions with the Fischer-Tropsch process. This successful demonstration is further complemented by assessments of the chemical suitability of the solar kerosene, identification of technological gaps, and determination of the technological and economical potentials.

Core-JetFuel: €1.2m EU funding (2013-2017) this action evaluated the research and innovation "landscape" in order to develop and implement a strategy for sharing information, for coordinating initiatives, projects and results and to identify needs in research, standardisation, innovation/deployment and policy measures at European level. Bottlenecks of research and innovation will be identified and, where appropriate, recommendations for the European Commission will be made with respect to the priorities in the funding strategy. The consortium covers the entire alternative fuel production chain in four domains: Feedstock and sustainability; conversion technologies and radical concepts; technical compatibility, certification and deployment; policies, incentives and regulation. CORE-Jet Fuel ensures cooperation with other European, international and national initiatives and with the key stakeholders. The expected benefits are enhanced knowledge amongst decision makers, support for maintaining coherent research policies and the promotion of a better understanding of future investments in aviation fuel research and innovation.

In 2015, the European Commission launched projects under the Horizon 2020 research programme with production capacities of the order of several thousand tonnes per year

In addition, in 2013 the Commission tendered the **HBBA study** (High Biofuel Blends in Aviation). This study analysed in detail the blending behaviour of fossil kerosene with bio kerosene produced by the various pathways either already approved or undergoing the technical approval process. It also analysed the impact of bio kerosene on various types of aircraft fuel seals, plus the effect of different bio-kerosenes on aircraft emissions. The final report on this research was published in early 2017 and is available at:

https://ec.europa.eu/energy/sites/ener/files/documents/final_report_for_publication.pdf.

D.3 Improved Air Traffic Management and Infrastructure Use

D.3.1 The EU's Single European Sky Initiative and SESAR

The European Union's Single European Sky (SES) policy aims to reform Air Traffic Management (ATM) in Europe in order to enhance its performance in terms of its capacity to manage larger volumes of flights in a safer, more cost-efficient and environmental friendly manner.

The initial SES aims with respect to the 2005 performance were to:

- Triple capacity of ATM systems,
- Reduce ATM costs by 50%,
- Increase safety by a factor of 10, and
- Reduce the environmental impact by 10% per flight.

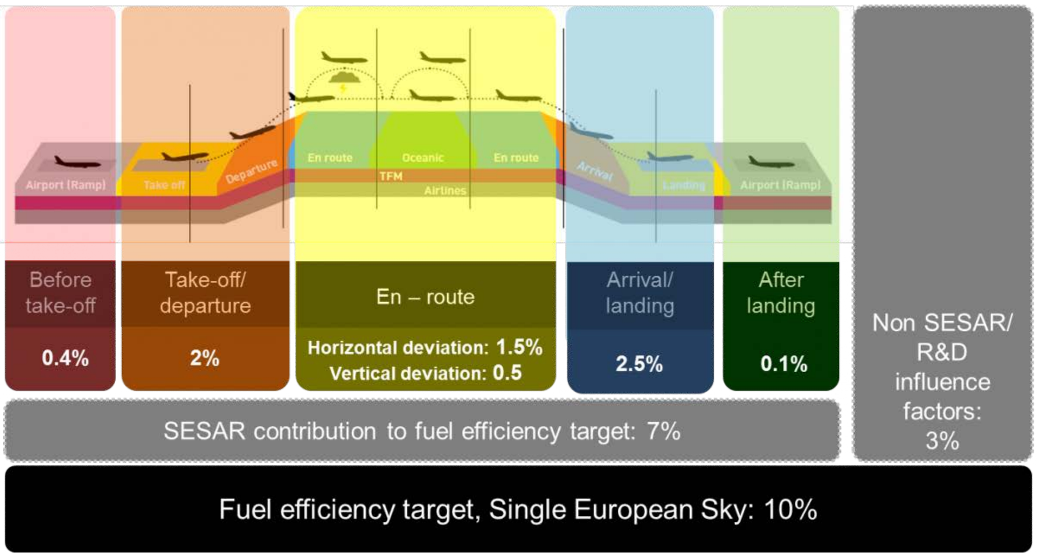
SESAR, the technology pillar of the Single European Sky, contributes to the Single Sky's performance targets by defining, developing, validating and deploying innovative technological and operational solutions for managing air traffic in a more efficient manner.

Guided by the European ATM Master Plan, the SESAR Joint Undertaking (JU) is responsible for defining, developing, validating and delivering technical and operation solutions to modernise Europe's air traffic management system and deliver benefits to Europe and its citizens. The SESAR JU research programme has been split into 2 phases, SESAR 1 (from 2008 to 2016) and SESAR 2020 (starting in 2016). It is delivering solutions in four key areas, namely airport operations, network operations, air traffic services and technology enablers.

The SESAR contribution to the SES high-level goals set by the Commission are continuously reviewed by the SESAR JU and are kept up to date in the ATM Master Plan.

Concerning the environmental impact, the estimated potential total fuel and CO_2 emission savings per flight are depicted below by flight segment:

Figure 12 – Contributions to SES and SESAR fuel efficiency targets



By the end of SESAR 1, the validation exercises conducted showed that the solutions identified could provide by 2024 (as compared to the 2005 baseline) 2.36% reduction per flight in gate-to-gate greenhouse gas emissions.

D.3.2 SESAR Research Projects (environmental focus)

During SESAR 1, environmental aspects were mainly addressed under two types of project: Environmental research projects, which were considered as a transversal activity and therefore primarily supported the projects validating the SESAR solutions, and secondly SESAR validation and demonstration projects, which were pre-implementation activities. Environment aspects, in particular fuel efficiency, were also a core objective of approximately 80% of SESAR 1's primary projects.

Environmental Research Projects:

Four Environmental research projects are have been completed:

- Project 16.03.01 dealt with the "Development of the Environment validation framework (Models and Tools)";
- Project 16.03.02 addressed the "Development of environmental metrics";
- Project 16.03.03 dealt with the "Development of a framework to establish interdependencies and trade-off with other performance areas";
- Project 16.03.07 considered "Future regulatory scenarios and risks".

In the context of **Project 16.03.01**, a first version of the IMPACT tool was developed by EUROCONTROL providing SESAR primary projects with the means to conduct fuel efficiency, aircraft emissions and noise assessments, from a web-based platform, using the same aircraft performance assumptions. IMPACT successfully passed the verification and validation process of the ICAO Committee on Aviation Environmental Protection (CAEP) Modelling and Database Group (MDG). Project 16.06.03 also ensured the continuous development/maintenance of other tools covering aircraft greenhouse gas (GHG) assessment (AEM), and local air quality issues (Open-ALAQS). It should be noted that these tools were developed to cover the research and the future deployment phase of SESAR, as well as to support European states and agencies in conducting environmental impact assessments for operational or regulatory purposes.

In the context of **Project 16.03.02**, a set of metrics for assessing GHG emissions, noise, and airport local air quality were documented. The metrics identified by Project 16.03.02 will be gradually implemented in IMPACT.

Project 16.03.03 produced a comprehensive analysis of the issues related to environmental impact interdependencies and trade-offs.

Project 16.03.07 conducted a review of the then current environmental regulatory measures as applicable to ATM and SESAR deployment, and another report presenting an analysis of environmental regulatory and physical risk scenarios in the form of user guidance. It identifies both those concept of operations and Key Performance Areas which are most likely to be affected by these risks and the future operational solutions that can contribute to mitigating them. It also provides a gap analysis identifying knowledge gaps or uncertainties which require further monitoring, research or analysis.

Project 16.06.03 was the SESAR Environment support and coordination project which ensured the coordination and facilitation of all the Environmental research project activities whilst supporting the SESAR/AIRE/DEMO projects in the application of the material produced by the research projects. In particular, this project delivered an Environment Impact Assessment methodology providing guidance on how to conduct an assessment, which metrics to use, and dos and don'ts for each type of validation exercise with a specific emphasis on flight trials.

The above-mentioned SESAR 1 environmental project deliverables constitute the reference material that SESAR2020 should be using.

SESAR demonstration projects:

In addition to its core activities, the SESAR JU co-financed projects where ATM stakeholders worked collaboratively to perform integrated flight trials and demonstrations of solutions. These aimed to reduce CO_2 emissions for surface, terminal and oceanic operations and substantially accelerate the pace of change. Between 2009 and 2012, the SESAR JU co-financed a total of 33 "green" projects in collaboration with global partners, under the **Atlantic Interoperability Initiative to Reduce Emissions (AIRE)**.

A total of 15 767 flight trials were conducted under AIRE, involving more than 100 stakeholders, demonstrating savings ranging from 20 to 1 000kg of fuel per flight (or 63 kg to 3 150 kg of CO_2), and improvements in day-to-day operations. Another nine demonstration projects took place from 2012 to 2014, also focusing on the environment, and during 2015/2016 the SESAR JU co-financed fifteen additional large-scale demonstration projects, which were more ambitious in geographic scale and technology. More information can be found at http://www.sesarju.eu.

A key feature leading to the success of AIRE is that it focused strongly on operational and procedural techniques rather than new technologies. AIRE trials used technology that was already in place, but until the relevant AIRE project came along, air traffic controllers and other users hadn't necessarily thought deeply about how to make best use of that technology operationally. For example, because of the AIRE initiative and the good cooperation between NAV Portugal and FAA, in New York and St Maria oceanic airspace lateral separation optimisation is given for any flight that requests it.

Specific trials were carried for the following improvement areas/solutions as part of the AIRE initiative:

a. Use of GDL/DMAN systems (pre-departure sequencing system / Departure Manager) in Amsterdam, Paris and Zurich;

b. Issue of Target-Off Block time (TOBT), calculation of variable taxiout time and issue of Target-Start-up Arrival Time (TSAT) in Vienna;

c. Continuous Descent Operations (CDOs or CDAs) in Amsterdam, Brussels, Cologne, Madrid, New York, Paris, Prague, Pointe-à-Pitre, Toulouse, and Zurich;

d. CDOs in Stockholm, Gothenburg, Riga, La Palma; Budapest and Palma de Majorca airports using RNP-AR procedures;

e. Lateral and vertical flight profile changes in the NAT taking benefit of the implementation of Automatic Dependent Surveillance-Broadcast (ADS-B) surveillance in the North Atlantic;

f. Calculation of Estimated Times of Arrival (ETA) allowing time based operations in Amsterdam;

g. Precision Area Navigation - Global Navigation Satellite System (PRNAV GNSS) Approaches in Sweden;

h. Free route in Lisbon and Casablanca, over Germany, Belgium, Luxembourg, Netherlands in the EURO-SAM corridor, France, and Italy;

i. Global information sharing and exchange of actual position and updated meteorological data between the ATM system and Airline AOCs for the vertical and lateral optimisation of oceanic flights using a new interface;

The **AIRE 1 campaign** (2008-2009) demonstrated, with 1 152 trials performed, that significant savings can already be achieved using existing technology (see Table 10). CO_2 savings per flight ranged from 90kg to 1 250kg and the accumulated savings during the trials were equivalent to 400 tonnes of CO_2. This first set of trials represented not only substantial improvements for the greening of air transport, but generated further motivation and commitment of the teams involved creating momentum to continue to make progress on reducing aviation emissions.

Table 10 – Summary of AIRE 1 projects

Domain	Location	Trials performed	CO_2 benefit per flight (kg)
Surface	Paris, France	353	190-1200
Terminal	Paris, France	82	100-1250
	Stockholm, Sweden	11	450-950
	Madrid, Spain	620	250-800
Oceanic	Santa Maria, Portugal	48	90-650
	Reykjavik, Iceland	48	250-1050
	Total	**1 152**	

The **AIRE 2 campaign** (2010-2011) showed a doubling in demand for projects and a high transition rate from R&D to day-to-day operations. 18 projects involving 40 airlines, airports, ANSPs and industry partners were conducted in which surface, terminal, oceanic and gate-to-gate operations were tackled. 9 416 flight trials took place. Table 11 summarises AIRE 2 projects operational aims and results.

CDOs were demonstrated in busy and complex TMAs although some operational measures to maintain safety, efficiency, and capacity at an acceptable level had to be developed.

Table 11 – Summary of AIRE 2 projects

Project name	Location	Operation	Objective	CO_2 (kg) and Noise benefits per flight	Number of flights
CDM at Vienna Airport	Austria	CDM notably pre-departure sequence	CO_2 & Ground Operational efficiency	54	208
Greener airport operations under adverse conditions	France	CDM notably pre-departure sequence	CO_2 & Ground Operational efficiency	79	1 800
B3	Belgium	CDO in a complex radar vectoring environment	Noise & CO_2	160-315; -2dB (between 10 to 25 Nm from touchdown)	3 094
DoWo - Down Wind Optimisation	France	Green STAR & Green IA in busy TMA	CO_2	158-315	219
REACT-CR	Czech republic	CDO	CO_2	205-302	204
Flight Trials for less CO_2 emission during transition from en-route to final approach	Germany	Arrival vertical profile optimisation in high density traffic	CO_2	110-650	362
RETA-CDA2	Spain	CDO from ToD	CO_2	250-800	210
DORIS	Spain	Oceanic: Flight optimisation with ATC coordination & Data link (ACARS, FANS CPDLC)	CO_2	3 134	110
ONATAP	Portugal	Free and Direct Routes	CO_2	526	999
ENGAGE	UK	Optimisation of cruise altitude and/or Mach number	CO_2	1 310	23
RlongSM (Reduced longitudinal Separation Minima)	UK	Optimisation of cruise altitude profiles	CO_2	441	533
Gate to gate Green Shuttle	France	Optimisation of cruise altitude profile & CDO from ToD	CO_2	788	221
Transatlantic green flight PPTP	France	Optimisation of oceanic trajectory (vertical and lateral) & approach	CO_2	2 090+ 1 050	93
Greener Wave	Switzerland	Optimisation of holding time through 4D slot allocation	CO_2	504	1 700
VINGA	Sweden	CDO from ToD with RNP STAR and RNP AR.	CO_2 & noise	70-285; negligible change to noise contours	189
AIRE Green Connections	Sweden	Optimised arrivals and approaches based on RNP AR & Data link. 4D trajectory exercise	CO_2 & noise	220	25
Trajectory based night time	The Netherlands	CDO with pre-planning	CO_2 + noise	TBC	124
A380 Transatlantic Green Flights	France	Optimisation of taxiing and cruise altitude profile	CO_2	1 200+ 1 900	19
				Total	**9 416**

The **AIRE 3 campaign** comprised 9 projects (2012-2014) and 5199 trials summarised in Table 12.

Table 12 – Summary of AIRE 3 projects

Project name	Location	Operation	Benefits per flight	Number of Trials
AMBER	Riga International Airport	Turboprop aircraft to fly tailored Required Navigation Performance – Authorisation Required (RNP-AR) approaches together with Continuous Descent Operations (CDO),	230 kg reduction in CO_2 emissions per approach; A reduction in noise impact of 0.6 decibels (dBA).	124
CANARIAS	La Palma and Lanzarote airports	CCDs and CDOs	Area Navigation-Standard Terminal Arrival Route (RNAV STAR) and RNP-AR approaches 34-38 NM and 292-313 kg of fuel for La Palma and 14 NM and 100 kg of fuel for Lanzarote saved.	8
OPTA-IN	Palma de Mallorca Airport	CDOs	Potential reduction of 7-12% in fuel burn and related CO_2 emissions	101
REACT plus	Budapest Airport	CDOs and CCOs	102 kg of fuel conserved during each CDO	4 113
ENGAGE Phase II	North Atlantic – between Canada & Europe	Optimisation of cruise altitude and/or Mach number	200-400 litres of fuel savings; An average of 1-2% of fuel burn	210
SATISFIED	EUR-SAM Oceanic corridor	Free routing	1.58 t CO_2 emissions	165
SMART	Lisbon flight information region (FIR), New York Oceanic and Santa Maria FIR	Oceanic: Flight optimisation	3.13 t CO_2 per flight	250
WE-FREE	Paris CDG, Venice, Verona, Milano Linate, Pisa, Bologna, Torino, Genoa airports	Free routing	693 kg CO_2 for CDG-Roma Fiumicino; 504 kg CO_2 for CDG Milano Linate	128
MAGGO	Santa Maria FIR and TMA	Several enablers	The MAGGO project couldn't be concluded	100
			Total	**5 199**

D.3.3 SESAR2020 Environmental Performance Assessment

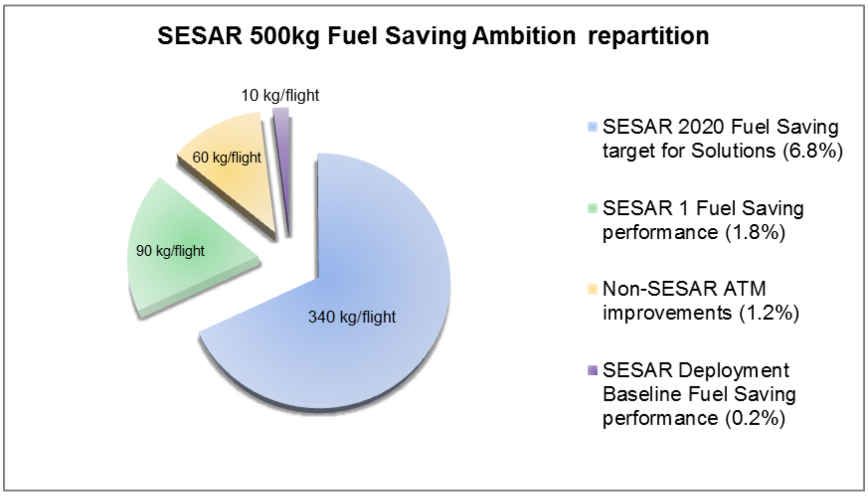
SESAR2020 builds upon the expectations of SESAR1 and of the deployment baseline.

It is estimated that around 50.0m MT of fuel per year will be burned by 2025, ECAC wide, by around 10m flights. The SESAR2020 Fuel Saving Ambition (10%) equate to 500kg of fuel savings per flight (or around 1.6 t CO_2 per flight), including:

- SESAR2020 Fuel Saving target for Solutions (6.8%) = 340kg/flight or 1 t CO_2/flight,
- SESAR 1 Fuel Saving performance (1.8%) = 90kg/flight or 283kg of CO_2/flight,
- SESAR Deployment Baseline Fuel Saving performance (0.2%) = 10kg/flight or 31kg of CO_2/flight,

It has to be noted that, while the SESAR 1 baseline was 2005, the SESAR2020 baseline is 2012.

Figure 13 – SESAR Fuel Saving Ambition



SESAR2020 has put in place a methodology that should allow a close monitoring of the expected fuel saving performance of each Solution, and of the overall programme. But, at this point of the SESAR2020 programme, it is too early to assess with a good level of confidence the gap between the expected fuel-saving benefit of each SESAR Solution and its demonstrated potential from the results of the validation exercises.

However, 30 out of the 85 SESAR2020 Solutions have the potential to generate fuel savings. Table 13 provides the Top 10 Solutions with the biggest expected fuel saving potential.

Table 13 – Summary of SESAR2020 projects offering the greatest potential fuel savings

Solution	Short description + Fuel saving rational	Operational environment (OE/ Sub-OEs) benefitting
PJ.07-01 Airspace User Processes for Trajectory Definition	This Solution refers to the development of processes related to the Flight Operation Centre (FOC) aimed at managing and updating the shared business trajectory, and fully integrating FOCs in the ATM Network processes. These processes respond to the need to accommodate individual airspace users' business needs and priorities without compromising the performance of the overall ATM system or the performance of other stakeholders. This will also ensure continuity in the Collaborative Decision Making process throughout the trajectory lifecycle. The benefits will come through anticipation and choice of the optimal route and reduction of vertical inefficiencies, which will reduce costs and fuel burn. No real impact on airport is expected.	Mainly for: Terminal Very High Complexity En-route Very High Complexity Some benefit but much lower for: Terminal High, Medium, Low Complexity En-route High, Medium Complexity
PJ.10-01C Collaborative Control	This Solution refers to coordination by exception rather than coordination by procedure and is facilitated by advanced controller tools, reducing the need for coordination agreements, fewer boundary constraints and the ability to combine sectors into multisector planner teams. The existence of clear procedures for collaborative control reduces the need for coordination and results in a more streamlined method of operation close to a sector boundary. This may bring a reduction in the number of level-offs and, thus, bring a partial improvement in fuel efficiency.	Mainly for: Terminal Very High Complexity En-route Very High Complexity Some benefit but much lower for: Terminal High, Medium, Low Complexity En Route High, Medium Complexity
PJ.10-02b Advanced Separation Management	This Solution aims to further improve the quality of services of separation management in the en-route and TMA operational environments by introducing automation mechanisms and integrating additional information (ATC intent, aircraft intent). Controller tools will enable earlier and more precise detection and resolution of conflicts. This will reduce the need for vectoring and enable de-confliction actions to be taken earlier and through the usage of closed clearances. Those will be managed more proactively on-board, and benefit fuel efficiency. Clearances issued by the ATCOs may, in some situations, take into account aircraft derived data related to airline preferences, bringing an improvement in fuel efficiency.	Mainly for: Terminal Very High Complexity En-route Very High Complexity Some benefit but much lower: Terminal High, Medium, Low Complexity En-route High, Medium Complexity
PJ.09-03 Collaborative Network Management Functions	This Solution allows for network management based on transparency, performance targets and agreed control mechanisms. The work enables a real-time visualisation of the evolving Airport Operation Plan (AOP) and Network Operating Plan (NOP) planning environment (such as demand pattern and capacity bottlenecks) to support airspace user and local planning activities. Thanks to this Solution, the increased efficiency of the performance of the system due to more optimised trajectory with airlines preference will result in fuel burn reductions.	Mainly for: En-route Very High Complexity Some benefit but much lower for: Terminal very High, High, Medium Complexity En-route High, Medium Complexity Airport very large, large, medium
PJ.01-02 Use of Arrival and Departure Management Information for Traffic Optimisation within the TMA	This Solution brings near real time traffic management to the TMA, taking advantage of predicted demand information provided by arrival and departure management systems from one or multiple airports. This will allow the identification and resolution of complex interacting traffic flows in the TMA and on the runway, through the use of AMAN and DMAN flow adjustments and ground holdings. Traffic optimisation obtained thanks to this Solution will reduce the need for tactical interventions and will result in more efficient flights, and increased flight efficiency will save fuel.	Mainly for: Terminal Very High Complexity En-route Very High Complexity Some benefit but much lower for: Terminal very High, High, Medium, Low Complexity En-route High, Medium Complexity

<table>
<tr><td>PJ2-01
Wake turbulence separation optimization</td><td>This Solution refers to the use of downlinked information from aircraft to predict wake vortex and determine appropriate wake-vortex minima dynamically, thereby optimising runway delivery.
Wake turbulence separation optimization should reduce airborne delays due to arrival capacity limitations linked to wake separations.
For major airports that are today constrained in peak hours, the use of:
- optimised wake category scheme or pairwise separations can either be translated into added capacity (as described above) or additional resilience in case of perturbation.
- time based separation will reduce the effect of a headwind on the arrival flow rate and thus increase the predictability of the scheduling process.
On less constrained airports, significant improvement can also be observed by employing reduced separation applied on a time based separation basis in the specific runway configuration or wind conditions responsible for a large part of the airport delay. This increases the flexibility for Controllers to manage the arrival traffic due to the separation minima reduction.
The weather dependant reduction of wake separation, considering the allowable increase of throughput, is expected to be a major mitigation of delay and to provide for an increase in the flexibility for Controllers to manage the arrival traffic due to the reduction in the required wake separations.
The reduction of delay will generate fuel saving.</td><td>Mainly for:
Airports and TMAs with High and Medium complexity.
• Any runway configuration.
• Airports with mainly strong headwinds.
• Capacity constrained airports or airports with observed delay.</td></tr>
<tr><td>PJ.09-02
Integrated local DCB processes</td><td>This Solution sees the seamless integration of local network management with extended air traffic control planning and arrival management activities in short-term and execution phases. The work will improve the efficiency of ATM resource management, as well as the effectiveness of complexity resolutions by closing the gap between local network management and extended ATC planning.
The increased efficiency of the performance of the system due to more optimised trajectory with airlines preference will result in fuel burn reductions.</td><td>Mainly for:
Airport Very large

Some benefit but much lower for:
Terminal very High, High, Medium Complexity
En-route very High, High, Medium Complexity
Airport large, medium</td></tr>
<tr><td>PJ.01-03
Dynamic and Enhanced Routes and Airspace</td><td>This Solution brings together vertical and lateral profile issues in both the en-route and TMA phases of flight, with a view to creating an end-to-end optimised profile and ensuring transition between free route and fixed route airspace. The Solution will be supported by new controller tools and enhanced airborne functionalities.
Significant fuel efficiency benefits are expected from Continuous Descent (CDO) / Continuous Climb Operations (CCO) in high density operations.
CDO / CCO permit closer correlation of the actual with optimal vertical profile, to take into account the preference of the Airspace User for the most efficient climb / descent profile for the flight. Implementation of enhanced conformance monitoring / alerting by both ground and airborne systems reduce the likelihood of ATCO intervention in the climb / descent, so reducing the potential for tactical level offs.</td><td>Mainly for:
Terminal Very High Complexity

Some benefit but much lower for:
Terminal High, Medium Complexity</td></tr>
</table>

PJ.02-08 Traffic optimisation on single and multiple runway airports	This Solution refers to a system that enables tower and approach controllers to optimise runway operations arrival and/or departure spacing and make the best use of minimum separations, runway occupancy, runway capacity and airport capacity. Imbalances known more than 3 hours ahead allow to re-planning inbound traffic from the originating airport or reconsider Airport Transit View (ATV) on behalf of airlines reducing delays due to airport constraints up to 20%. Planning runway closures or runway changes in the optimum periods of the day will minimize the time spent re-routing air and ground traffic during the execution phase. Sharing this information with the different actors will provide the NOP with more accurate forecasts for arrival and departure time in order to coordinate the subsequent target times. There should be some fuel gains as a direct consequence of improved predictability, both for departures and arrivals (less variability => less path stretching, holdings ...).	Mainly for: Terminal Very High Complexity • Single and Multiple runways • Preferably Congested large and medium size airports
PJ.08-01 Management of Dynamic Airspace configurations	This Solution refers to the development of the process, procedures and tools related to Dynamic Airspace Configuration (DAC), supporting Dynamic Mobile Areas of Type 1 and Type 2. It consists of the activation of Airspace configurations through an integrated collaborative decision making process, at national, sub-regional and regional levels; a seamless and coordinated approach to airspace configuration, from planning to execution phases, allowing the Network to continuously adapt to demand pattern changes in a free route environment) and ATC sector configurations adapted to dynamic TMA boundaries and both fixed and dynamic elements. This solution increased efficiency enabling optimised flight trajectories and profiles with the end result being reduced fuel burn, noise and CO_2 emissions. Advanced Airspace Management should decrease Airspace Users fuel consumption and reduce flight time. Optimised trajectory and a more direct route as a result of enhanced situation awareness through real airspace status update and seamless civil-military coordination by AFUA application.	Mainly for: En-route Very High Complexity Some benefit but much lower for: En-route High, Medium Complexity

D.4 Economic / market-based measures

ECAC members have always been strong supporters of a market-based measure scheme for international aviation to incentivise and reward good investment and operational choices, and so welcomed the agreement on the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). The 31 EEA states in Europe have already implemented the EU Emissions Trading System (ETS), including the aviation sector with around 500 aircraft operators participating in the cap and trade approach to limit CO_2 emissions. It was the first and is the biggest international system capping greenhouse gas emissions. In the period 2012 to 2018 EU ETS has saved an estimated 100 million tonnes of intra-European aviation CO_2 emissions.

D.4.1 The EU Emissions Trading System

The EU Emissions Trading System (EU ETS) is the cornerstone of the European Union's policy to tackle climate change, and a key tool for reducing greenhouse gas emissions cost-effectively, including from the aviation sector. It operates in 31 countries: the 28 EU Member States, Iceland, Liechtenstein and Norway. The EU ETS is the first and so far the biggest international system capping greenhouse gas emissions; it currently covers half of the EU's CO_2 emissions, encompassing those from around 12 000 power stations and industrial plants in 31 countries, and, under its current scope, around 500 commercial and non-commercial aircraft operators that fly between airports in the European Economic Area (EEA). The EU ETS Directive has recently been revised in line with the European Council Conclusions of October 2014[20] that confirmed that the EU ETS will be the main European instrument to achieve the EU's binding 2030 target of an at least 40% domestic reduction of greenhouse gases compared to 1990[21].

The EU ETS began operation in 2005; a series of important changes to the way it works took effect in 2013, strengthening the system. The EU ETS works on the "cap and trade" principle. This means there is a "cap", or limit, on the total amount of certain greenhouse gases that can be emitted by the factories, power plants, other installations and aircraft operators in the system. Within this cap, companies can sell to or buy emission allowances from one another. The limit on allowances available provides certainty that the environmental objective is achieved and gives allowances a market value. For aviation, the cap is calculated based on the average emissions from the years 2004-2006. Aircraft Operators are entitled to free allocation based on an efficiency benchmark, but this might not cover the totality of emissions. The remaining allowances need to be purchased from auctions or from the secondary market. The system allows aircraft operators to use aviation allowances or general (stationary installations) allowances to cover their emissions.

By 30th April each year, companies, including aircraft operators, have to surrender allowances to cover their emissions from the previous calendar year. If a company reduces its emissions, it can keep the spare allowances to cover its future needs or sell them to another company that is short of allowances. The flexibility that trading brings ensures that emissions are cut where it costs least to do so. The number of allowances reduces over time so that total emissions fall.

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20 http://www.consilium.europa.eu/en/meetings/european-council/2014/10/23-24/

21 Directive (EU) 2018/410 of the European Parliament and of the Council of 14 March 2018 amending Directive 2003/87/EC to enhance cost-effective emission reductions and low-carbon investments, and Decision (EU) 2015/1814, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32018L0410

As regards aviation, legislation to include aviation in the EU ETS was adopted in 2008 by the European Parliament and the Council[22]. The 2006 proposal to include aviation in the EU ETS, in line with the resolution of the 2004 ICAO Assembly deciding not to develop a global measure but to favour the inclusion of aviation in open regional systems, was accompanied by a detailed impact assessment[23]. After careful analysis of the different options, it was concluded that this was the most cost-efficient and environmentally effective option for addressing aviation emissions.

In October 2013, the Assembly of the International Civil Aviation Organisation (ICAO) decided to develop a global market-based mechanism (MBM) for international aviation emissions. Following this agreement the EU decided to limit the scope of the EU ETS to flights between airports located in the European Economic Area (EEA) for the period 2013-2016 (Regulation 421/2014), and to carry out a new revision in the light of the outcome of the 2016 ICAO Assembly. The temporary limitation follows on from the April 2013 'stop the clock' decision[24] adopted to promote progress on global action at the 2013 ICAO Assembly.

The European Commission assessed the outcome of the 39th ICAO Assembly and, in that light, made a new legislative proposal on the scope of the EU ETS. Following the EU legislative process, this Regulation was adopted in December 2017[25].

The legislation maintains the scope of the EU ETS for aviation limited to intra-EEA flights. It foresees that once there is clarity on the nature and content of the legal instruments adopted by ICAO for the implementation of CORSIA, as well as about the intentions of other states regarding its implementation, a further assessment should take place and a report be presented to the European Parliament and to the Council considering how to implement CORSIA in Union law through a revision of the EU ETS Directive. This should be accompanied, where appropriate, by a proposal to the European Parliament and to the Council to revise the EU ETS Directive that is consistent with the Union economy-wide greenhouse gas emission reduction commitment for 2030 with the aim of preserving the environmental integrity and effectiveness of Union climate action.

The Regulation also sets out the basis for the implementation of CORSIA. It provides for European legislation on the monitoring, reporting and verification rules that avoid any distortion of competition for the purpose of implementing CORSIA in European Union law. This will be undertaken through a delegated act under the EU ETS Directive.

The EU ETS has been effectively implemented over recent years on intra-EEA flights, and has ensured a level playing field with a very high level of compliance[26]. It will continue to be a central element of the EU policy to address aviation CO_2 emissions in the coming years.

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[22] Directive 2008/101/EC of the European Parliament and of the Council of 19 November 2008 amending Directive 2003/87/EC so as to include aviation activities in the scheme for greenhouse gas emission allowance trading within the Community, http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0101

[23] http://ec.europa.eu/clima/policies/transport/aviation/documentation_en.htm

[24] Decision No. 377/2013/EU derogating temporarily from Directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading within the Community, http://eur-lex.europa.eu/LexUriServLexUriServ.do?uri=CELEX:32013D0377:EN:NOT

[25] Regulation (EU) 2017/2392 of the European Parliament and of the Council of 13 December 2017 amending Directive 2003/87/EC to continue current limitations of scope for aviation activities and to prepare to implement a global market-based measure from 2021, http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2017.350.01.0007.01.ENG&toc=OJ:L:2017:350:TOC

The complete, consistent, transparent and accurate monitoring, reporting and verification of greenhouse gas emissions remains fundamental for the effective operation of the EU ETS. Aviation operators, verifiers and competent authorities have already gained wide experience with monitoring and reporting; detailed rules are prescribed by Regulations (EU) N°600/2012[27] and 601/2012[28].

The EU legislation establishes exemptions and simplifications to avoid excessive administrative burden for the smallest operators of aircraft. Since the EU ETS for aviation took effect in 2012 a *de minimis* exemption for commercial operators – with either fewer than 243 flights per period for three consecutive four-month periods or flights with total annual emissions lower than 10 000 tonnes CO_2 per year applies. This means that many aircraft operators from developing countries are exempted from the EU ETS. Indeed, over 90 States have no commercial aircraft operators included in the scope of the EU ETS. In addition, from 2013 flights by non-commercial aircraft operators with total annual emissions lower than 1 000 tonnes CO_2 per year are excluded from the EU ETS. A further administrative simplification applies to small aircraft operators emitting less than 25 000 tonnes of CO_2 per year, who can choose to use the small emitters' tool rather than independent verification of their emissions. In addition, small emitter aircraft operators can use the simplified reporting procedures under the existing legislation. The recent amendment to extend the intra-EEA scope after 2016 includes a new simplification, allowing aircraft operators emitting less than 3 000 tCO_2 per year on intra-EEA flights to use the small emitters' tool.

The EU legislation foresees that, where a third country takes measures to reduce the climate change impact of flights departing from its airports, the EU will consider options available in order to provide for optimal interaction between the EU scheme and that country's measures. In such a case, flights arriving from the third country could be excluded from the scope of the EU ETS. This will be the case between the EU and Switzerland following the agreement to link their respective emissions trading systems, which was signed on 23rd November 2017. The EU therefore encourages other countries to adopt measures of their own and is ready to engage in bilateral discussions with any country that has done so. The legislation also makes it clear that if there is agreement on global measures, the EU shall consider whether amendments to the EU legislation regarding aviation under the EU ETS are necessary.

Impact on fuel consumption and/or CO_2 emissions

The environmental outcome of an emissions trading system is determined by the emissions cap. Aircraft operators are able to use allowances from outside the aviation sector to cover their emissions. The absolute level of CO_2 emissions from the aviation sector itself can exceed the number of allowances allocated to it, as the increase is offset by CO_2 emissions reductions in other sectors of the economy covered by the EU ETS.

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[26] Report on the functioning of the European carbon market, COM(2017) 693 final, https://ec.europa.eu/commission/sites/beta.../report-functioning-carbon-market_en.pdf

[27] Commission Regulation (EU) No 600/2012 of 21 June 2012 on the verification of greenhouse gas emission reports and tonne-kilometre reports and the accreditation of verifiers pursuant to Directive 2003/87/EC of the European Parliament and of the Council, http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012R0600&from=EN

[28] Regulation (EU) No 601/2012 of the European Parliament and of the Council of 21 June 2012 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council, http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32012R0601

With the inclusion of intra-European flights in the EU ETS it has delivered around 100 MT of CO_2 reductions/offsets between 2012 and 2018. The total amount of annual allowances to be issued will be around 38 million, whilst verified CO_2 emissions from aviation activities carried out between aerodromes located in the EEA has fluctuated between 53.5 MT CO_2 in 2013 and 61MT in 2016. This means that the EU ETS is now contributing more than 23 MT CO_2 of emission reductions annually[29], or around 100 MT CO_2 over 2012-2018, partly within the sector (airlines reduce their emissions to avoid paying for additional units) or in other sectors (airlines purchase units from other ETS sectors, which would have to reduce their emissions consistently). While some reductions are likely to be within the aviation sector, encouraged by the EU ETS's economic incentive for limiting emissions or use of aviation biofuels, the majority of reductions are expected to occur in other sectors.

Putting a price on greenhouse gas emissions is important to harness market forces and achieve cost-effective emission reductions. In parallel to providing a carbon price which incentivises emission reductions, the EU ETS also supports the reduction of greenhouse gas emissions through €2.1bn fund for the deployment of innovative renewables and carbon capture and storage. This funding has been raised from the sale of 300 million emission allowances from the New Entrants' Reserve of the third phase of the EU ETS. This includes over €900m for supporting bioenergy projects, including advanced biofuels.

In addition, through Member States' use of EU ETS auction revenue in 2015, over €3.5bn has been reported by them as being used to address climate change. The purposes for which revenues from allowances should be used encompass mitigation of greenhouse gas emissions and adaptation to the inevitable impacts of climate change in the EU and third countries. These will reduce emissions through: low-emission transport; funding research and development, including in particular in the field of aeronautics and air transport; providing contributions to the Global Energy Efficiency and Renewable Energy Fund, and measures to avoid deforestation.

In terms of its contribution towards the ICAO global goals, the states implementing the EU ETS have delivered, in "net" terms, a reduction of around 100 MT of aviation CO_2 emissions over 2012-2018 for the scope that is covered, and this reduction will continue to increase in the future under the new legislation. Other emission reduction measures taken, either collectively throughout Europe or by any of the 31 individual states implementing the EU ETS, will also contribute towards the ICAO global goals. Such measures are likely to moderate the anticipated growth in aviation emissions.

Table 14 – Estimated emissions reductions resulting from the EU-ETS

Year	Reduction in CO_2 emissions
2012-2018	100 MT

The above table presents projected benefits of the EU-ETS based on the current scope (intra-European flights).

29 Report on the functioning of the European carbon market, COM(2017) 693 final, https://ec.europa.eu/commission/sites/beta.../report-functioning-carbon-market_en.pdf

D.4.2 The Carbon Offsetting and Reduction Scheme for International Aviation

In October 2016, the ICAO Assembly confirmed the objective of targeting CO_2-neutral growth as of 2020, and for this purpose to introduce a global market-based measure for compensating CO_2 emissions above that level, namely Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). The corresponding resolution is A39-3: Consolidated statement of continuing ICAO policies and practices related to environmental protection – Global Market-based Measure (MBM) scheme.

According to the Assembly Resolution, the average level of CO_2 emissions from international aviation covered by the scheme between 2019 and 2020 represents the basis for carbon neutral growth from 2020, against which emissions in future years are compared. In any year from 2021 when international aviation CO_2 emissions covered by the scheme exceed the average baseline emissions of 2019 and 2020, this difference represents the sector's offsetting requirements for that year.

CORSIA is divided into 3 phases[30]: There is a pilot phase (2021-2023), a first phase (2024-2026) and a second phase (2027-2035). During CORSIA's pilot phase and the first phase, participation from states is voluntary. The second phase applies to all ICAO Member States.

CORSIA Implementation Plan Brochure (© ICAO)

Exempted are States with individual share of international aviation activities in RTKs, in year 2018 below 0.5 per cent of total RTKs and States that are not part of the list of States that account for 90 per cent of total RTKs when sorted from the highest to the lowest amount of individual RTKs. Additionally Least Developed Countries (LDCs), Small Island Developing States (SIDS) and Landlocked Developing Countries are exempted as well.

CORSIA operates on a route-based approach. The offsetting obligations of CORSIA shall apply to all aircraft operators on the same route between States, both of which are included in the CORSA. Exempted are a) emissions form aircraft operators emitting less than 10 000 tCO_2 emissions from international aviation per year, b) emissions from aircraft whose Maximum Take Off Mass (MTOM) is less than 5 700 kg, and c) emissions from humanitarian, medical and firefighting operations.

According to the "Bratislava Declaration" from September 3rd 2016 the Directors General of Civil Aviation Authorities of the 44 ECAC Member States declared their intention to implement CORSIA from the start of the pilot phase, provided certain conditions were met. This shows the full commitment of the EU, its Member States and the other Member States of ECAC to counter the expected in-sector growth of total CO_2 emissions from air transport and to achieving overall carbon neutral growth.

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[30] Further information on https://www.icao.int/environmental-protection/Pages/market-based-measures.aspx

D.5 EU Initiatives in Third Countries

Multilateral projects

At the end of 2013 the European Commission launched a project with a total budget of €6.5 million under the name "Capacity building for CO_2 mitigation from international aviation". The 42-month project, implemented by the ICAO, boosts less developed countries' ability to track, manage and reduce their aviation emissions. In line with the call from the 2013 ICAO Assembly, beneficiary countries will submit meaningful State action plans for reducing aviation emissions. They then and received assistance to establish emissions inventories and pilot new ways of reducing fuel consumption. Through the wide range of activities in these countries, the project contributes to international, regional and national efforts to address growing emissions from international aviation. The beneficiary countries are the following:

- **Africa**: Burkina Faso, Kenya and Economic Community of Central African States (ECCAS) Member States: Angola, Burundi, Cameroon, Central African Republic, Chad, Republic of Congo, Democratic Republic of Congo, Equatorial Guinea, Gabon, Sao Tome and Principe.
- **Caribbean**: Dominican Republic and Trinidad and Tobago.

Preceding the ICAO Assembly of October 2016 sealing the decision to create a global MBM scheme, a declaration of intent was signed between Transport Commissioner Violeta Bulc and ICAO Secretary General Dr Fang Liu, announcing their common intention to continue cooperation to address climate change towards the implementation of the ICAO Global Market Based Measures. On adoption of a decision by the ICAO Assembly on a GMBM, the parties intended to jointly examine the most effective mechanisms to upgrade the existing support mechanism and also to continue similar assistance, including cooperation and knowledge sharing with other international organisations, with the aim of starting in 2019.

The "Capacity building for CO_2 mitigation from international aviation" has been of enormous value to the beneficiary countries. A second project has been initiated by the European Commission aimed at assisting a new set of countries on their way to implementing the CORSIA. Further details will be published upon signature of the contract with the different parties.

Additionally, initiatives providing ASEAN Member States with technical assistance on implementing CORSIA have been initiated in 2018 and will possibly be extended further in 2019. The ARISE plus project dedicates an activity under result 3 - 'strengthened national capabilities of individual ASEAN Members States and aligned measures with ICAO SARPs'. To achieve this, the project will support workshops in 2018 on capacity building and technical assistance, especially for the development or enhancement of actions plans. This will provide a genuine opportunity to pave the way for the effective implementation of further potential assistance and foster States readiness for their first national aviation emission report at the end of 2019.

EASA is also implementing Aviation Partnership Projects (APPs) in China, South Asia and Latin America (including the Caribbean) as well as projects funded by DG NEAR and DG DEVCO in other regions. This can enable the EU to form a holistic view of progress on CORSIA implementation worldwide.

In terms of synergies, the South Asia and South East Asia environmental workshops could engage with key regional stakeholders (ICAO Asia Pacific office, regulatory authorities, airline operators, verification bodies), and thereby assess the level of readiness for CORSIA on wider scale in the Asia Pacific region. This preparatory work would help focus the subsequent FPI CORSIA project and create economies of scale in order to maximise the benefits of the project, which needs to be implemented within an ambitious timescale.

D.6 Support to voluntary actions

ACI Airport Carbon Accreditation

This is a certification programme for carbon management at airports, based on carbon mapping and management standards specifically designed for the airport industry. It was launched in 2009 by ACI EUROPE, the trade association for European airports.

The underlying aim of the programme is to encourage and enable airports to implement best practice carbon and energy management processes and to gain public recognition of their achievements. It requires airports to measure their CO_2 emissions in accordance with the World Resources Institute and World Business Council for Sustainable Development GHG Protocol and to get their emissions inventory assured by an independent third party.

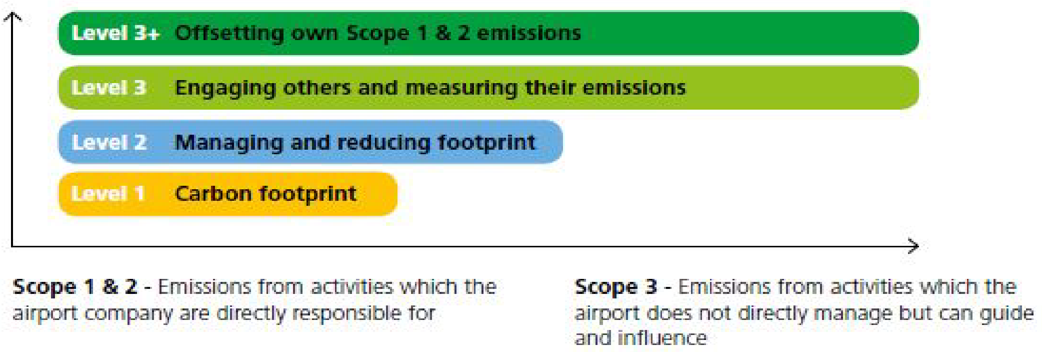
This industry-driven initiative was officially endorsed by EUROCONTROL and the European Civil Aviation Conference (ECAC). It is also officially supported by the United Nations Environmental Programme (UNEP). The programme is overseen by an independent Advisory Board.

At the beginning of this reporting year (May 2016) there were 156 airports in the programme. Since then, a further 36 airports have joined and 3 have withdrawn, bringing the total number of airports at the end of this reporting year (May 2017) to 189 covering 38.1 % of global air passenger traffic.

In 2017, for the first time, airports outside Europe achieved the highest accreditation status: 1 airport in North America, 5 in Asia-Pacific and 1 in Africa have been recognised as carbon neutral. European airports doubled their pledge and set the bar at 100 European airports becoming carbon neutral by 2030 from the 34 currently assessed to be carbon neutral.

Airport Carbon Accreditation is a four-step programme (see Figure 14), from carbon mapping to carbon neutrality. The four steps of certification are: Level 1 "Mapping", Level 2 "Reduction", Level 3 "Optimisation", and Level 3+ "Carbon Neutrality".

Figure 14 – Four steps of Airport Carbon Accreditation



Levels of certification (ACA Annual Report 2016-2017)

One of its essential requirements is the verification by external and independent auditors of the data provided by airports. Aggregated data are included in the Airport Carbon Accreditation Annual Report thus ensuring transparent and accurate carbon reporting. At level 2 of the programme and above (Reduction, Optimisation and Carbon Neutrality), airport operators are required to demonstrate CO_2 reductions associated with the activities they control.

For historical reasons European airports remain at the forefront of airport actions to voluntarily mitigate and reduce their impact on climate change. The strong growth momentum was maintained for the reporting year which ended with 116 airports in the programme. These airports account for 64.8% of European passenger traffic and 61% of all accredited airports in the programme this year.

Anticipated benefits

The Administrator of the programme has been collecting CO_2 data from participating airports over the past five years. This has allowed the absolute CO_2 reduction from the participation in the programme to be quantified, as shown in the following tables.

Table 15 – Emissions reduction highlights for the European region

	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017
Total aggregate scope 1 & 2 reduction ($ktCO_2$)	51.7	54.6	48.7	140	130	169	156	155
Total aggregate scope 3 reduction ($ktCO_2$)	360	675	366	30.2	224	551	142	899

Table 16 – Emissions offset for the European region

	2015-2016	2016-2017
Aggregate emissions offset, Level 3+ ($ktCO_2$)	222	252

The above table presents the aggregate emissions offset by airports accredited at Level 3+ of the programme. The programme requires airports at Level 3+ to offset their residual Scope 1 & 2 emissions as well as Scope 3 emissions from staff business travel.

The programme's main immediate environmental co-benefit is the improvement of local air quality.

Costs for the design, development and implementation of Airport Carbon Accreditation have been borne by ACI EUROPE. Airport Carbon Accreditation is a non-for-profit initiative, with participation fees set at a level aimed at allowing for the recovery of the aforementioned costs.

The scope of Airport Carbon Accreditation, i.e. emissions that an airport operator can control, guide and influence, implies that aircraft emissions in the LTO cycle are also covered. Thus, airlines can benefit from the gains made by more efficient airport operations to see a decrease in their emissions during the LTO cycle. This is consistent with the objective of including aviation in the EU ETS as of 1 January 2012 (Directive 2008/101/EC) and can support the efforts of airlines to reduce these emissions.

Table 17 – Summary of Emissions under airports' direct control

Variable	2013 -2014		2014-2015	
	Emissions	Number of airports	Emissions	Number of airports
Aggregate carbon footprint for 'year 0'[31] for emissions under airports' direct control (all airports)	22.04 MT CO_2	85	2.09 MT CO_2	92
Carbon footprint per passenger	2.01 kg CO_2		1,89 kg CO_2	
Aggregate reduction in emissions from sources under airports' direct control (Level 2 and above)[32]	87.4 ktonnes CO_2	56	139 ktonnes CO_2	71
Carbon footprint reduction per passenger	0.11 kg CO_2		0.15 kg CO_2	
Total carbon footprint for 'year 0' for emissions sources which an airport may guide or influence (level 3 and above)[33]	12.8 MT CO_2	31	14.0 MT CO_2	36
Aggregate reductions from emissions sources which an airport may guide or influence	224 ktonnes CO_2		551 ktonnes CO_2	
Total emissions offset (Level 3+)	181 ktonnes CO_2	16	294 ktonnes CO_2	20

31 'Year 0' refers to the 12 month period for which an individual airport's carbon footprint refers to, which according to the Airport Carbon Accreditation requirements must have been within 12 months of the application date.

32 This figure includes increases in CO_2 emissions at airports that have used a relative emissions benchmark in order to demonstrate a reduction.

33 These emissions sources are those detailed in the guidance document, plus any other sources that an airport may wish to include.

E National actions in the Federal Republic of Germany

E.1 Aircraft-related technology development

E.1.1 Overview

The aviation industry in Germany and Europe is oriented in research, technology and innovation towards targets which have been coordinated Europe-wide. They were formulated for the first time in the European strategy paper “Vision 2020” and were last updated in “Flightpath 2050”.

The aviation industry enterprises in Germany are at the top of and in cooperation with European and global supply chains. The gains in efficiency of newly available aircraft stem from the overall and partial system architecture and from the synergy of many innovations in technical detail along the supply chain. Investments into research, technology and innovation with the aim of improving the ecological balance of the aviation product for the enterprises at the same time mean investments into their own competitiveness, since ecological benefit in aviation in most cases also entails economic benefits for the aircraft operator.

A quantification of the contributions to ecological efficiency of the systems and components from Germany is not possible because of the large numbers of influence factors, for example the individual success of the technologies in the market and the fleet policy of the airlines.

Nevertheless, the influence of technological innovations from Germany must not be underestimated. Especially innovations stemming from the German engine industry enable global Original Equipment Manufacturers (OEMs) like Rolls-Royce and Pratt & Whitney to provide more competitive and fuel saving engines. New engines typically deliver a double-digit percentage in CO_2 reductions compared to their predecessors, e.g. the new engine options for the Airbus A320neo and A330neo as well as the engines of the A350 XWB.

Thanks to technological innovations in the fields of engine, airframe and systems technology, the latest generation of aircraft ordered by German airlines now use 3 litres of fuel per 100 passenger-kilometres.

E.1.2 National aviation research programme

Objectives

In principle, the purpose of the promotional measures is to improve the technological basis and the economic and technical situation of the aviation industry and of air transport. Strengthening the innovative power and the competencies in research, development and production at the economic site Germany is the main aim. In this way the aviation industry is to be enabled in the framework of effective network structures to achieve the targets laid down in the ACARE Flightpath 2050. The long term aim is to achieve a sustainable and economical air transport system. The innovative power of the German aviation industry is essentially based on a research network which is continuously consolidated and growing. The collaboration of the universities, the relevant research centres and the specialised small and medium-sized enterprises is of central importance here. With the help of this network the aviation industry at the economic site Germany has succeeded in recent years to defend and extend its position in promising development and production programmes in international competition. This success is clearly reflected in the positive developments of the number of jobs and the turnover in the civil aviation industry.

Further growth in global aviation is only possible if innovative and internationally competitive technologies can be offered which allow a further optimisation of civil aircraft. The focus is placed especially on improvements and increases in efficiency in the research and technology fields listed below. This also includes aspects of an efficient and resource-saving manufacture and production of sustainable technologies.

Subject of the funding - Research and technology projects

The research promotion is based on the goals of ACARE (Advisory Council for Aeronautic Research in Europe) Flightpath 2050 and it will be oriented towards the challenges which can be recognised today.

<u>Production, maintenance and repair</u>

The important thing is to introduce the high competency of the aviation industry at the site Germany in the area of innovative production procedures, processes und machines into the international market for production, maintenance and repair. This is also the basis from which it is planned to develop flexible and customer-oriented value-creation processes with the further development of this competency it will be possible to cover all phases of the life cycle, from development through production to maintenance and repair including modification and retrofitting, at national level. This takes account of the increased importance of this sector. To further increase the sustainability of the entire value-creation chain particularly subjects of innovative, environment-friendly and resource-saving manufacturing and production procedures and processes are promoted. The further reduction of the weight of (printed) structures, particularly through innovative construction methods and material selection is a current research subject.

<u>Environmentally compatible air transport</u>

The social challenges regarding the environment require a sustainable restriction of negative external effects of air transport. In order to achieve the goals of ACARE Flightpath 2050 for an environmentally compatible air transport, innovative technologies for the reduction of noise and harmful pollutants are necessary. Active and passive technological measures at propulsion systems and in the field of flight physics are applied in an effort to reduce external noise by 65%. In particular the noise burden in the neighbourhood of airports is to be reduced. Endeavours are also made to achieve a further reduction of fuel consumption and thereby of the CO_2 emissions into the atmosphere by approximately 75% and also of nitrogen oxides by 90%. Up-to-date propulsion concepts and aerodynamic systems in the low-speed area as well as measures to reduce the flow resistance during cruise are to make special contributions to this goal.

Increase of the transport performance, infrastructure and processes in civil aviation have to be coordinated and integrated in a way which achieves the expected increase of the transport performance in a safe, reliable and highly flexible manner while at the same time reducing the aircraft accident rate by 80%, in accordance with the objective set by ACARE in the European framework. This requires measures in the areas flight guidance, all-weather capability and automation.

Efficient aircraft

More stringent emission constraints and performance requirements demand a continuous evolutionary and revolutionary development of modern aircraft. In order to achieve a decrease in environmental pollution efficient aviation systems have to be developed which reduce the consumption and operational costs of individual aircraft and of fleet operation. Research is focused on efforts to further reduce energy consumption and to optimise use and provision of energy for consumers. And increasing efficiency of existing and new systems in aircraft, especially through the reduction of weight and in the production of energy (e.g. fuel cells), as well as the inclusion and integration of these factors into the overall system are also subjects of technology issues which need to be resolved.

Integrated technology projects

In addition to the technology fields mentioned individual technologies which are known in principle, but still isolated, should be optimised and validated in a more comprehensive system context. Apart from individual technologies the system context also includes procedures for their production and manufacturing concepts at the level of the overall system. The aim is to examine, in addition to technologies in the system context, also the related manufacturing concepts as to their industrial applicability. The issue is to focus integrated technology projects on the provision of technologies for the next generation of wide-body aircraft for short and medium distances. Projects in the framework of the integrated technology projects are to concern the following areas:

- Configuration and integration at the level of the entire aircraft
- progressive fuselage construction methods and fuselage manufacturing concepts
- energy efficient systems
- modular concepts for cabins and cabin assembly
- environmentally sound and efficient propulsion concepts

The aim is to improve the capabilities for the development of complex aircraft and sub-systems, which especially includes the multi-disciplinary optimisation of the entire aircraft. The projects should, if possible, be controlled by the system leaders.

Ecologically efficient flying

The long-term goal of research in the field of civil aviation is the further implementation of a sustainable air transport system. Some aspects of this are: a zero-emission aircraft regarding pollutant emissions and noise, and efficient flight guidance structures for more capacity and safety in aviation. A further technological foundation and protection of such a sustainable air transport system requires the academic research of technologies with an application period from 2030 to 2050. To achieve the aim of a zero-emission aviation system it is necessary to examine fundamentally new solutions and technologies. For this purpose a number of different individual technologies have to be optimised for new overall concepts.

In the framework of the funding line “Ecologically efficient flying” the Federal Ministry of Economic Affairs and Energy promotes joint initiatives of science and industry for aviation in the years 2030 and after. Basic research projects in this context can be applied for in the funding programmes of the German Research Foundation (DFG). In view of the very long product cycles and life cycles in aviation and the connected early orientation required, the research of promising technologies is necessary already now. Especially subjects concerning the further reduction of the so-called “environmental footprint” of aviation and of aircraft are funded. Special attention in this context is given to projects with great environmental potential and recognisable potential for implementation. Promoted are subjects across the whole range of the aviation system and of civil aircraft. The precondition for the funding is that it is not the evolution of a technology which, in principle, is known, but rather of new innovative technologies and incentives.

The energetic optimisation of individual components of the system, taking account of the impact on the overall system, allows well-founded starting points. Especially the better use of residual and waste energy, (nano)materials, propulsion concepts with alternative thermo-dynamic processes, innovative aero-dynamic solutions, effective flight guidance systems as well as ecologically acceptable concepts for “post oil” energy sources offer very promising potentials. Depending on the objective of the projects they can be submitted either in the aviation research programme (LuFo) or to DFG. The potential funding is effected according to the regulations in force either of LuFo or of DFG. The selection by the funding donor should comply with the primary character of the research project and the funding instrument.

The technology developments expected in the framework of the programme have to take up the challenges and fields of action mentioned in a holistic approach according to the concept of a demand-oriented air transport system. The primary aim is to serve the growing demand for air transport capacity in a way which takes account in equal measure of the social and economic as well as the ecological requirements of the society.

Research and technology projects are funded for the following programme lines:

- *Eco-efficient flight:*

  For initiatives and projects of universities to carry out technology research for the 2030 – 2050 application period. The programme line covers all topics and disciplines of the air transportation system and civil aircraft.

- *Small and medium-sized enterprises (SMEs):*

  SMEs can apply for R&D funding for all aviation related technologies. They are given the opportunity to become active in product segments that are of interest to them. If research alliances are formed with other SMEs and scientific institutions, one SME is expected to take the lead.

- *Technology:*

  Funding for industrial research projects can go towards issues like passenger-friendly and eco-efficient cabins, efficient, safe and economical systems, quiet and efficient engines, innovative structures for aircrafts, flight physics, aviation-specific aspects of Industry 4.0 in development, production and maintenance, and safe, efficient and environmentally compatible aviation processes and flight guidance.

- *Demonstration:*

  Projects bridging the gap between technology and product development are supported. These include the integration of individual technologies to create a system or a relevant subsystem and the strengthening and development of capabilities and skills at the overall system level.

E.2 Alternative fuels

Since its foundation in 2011 aireg – **Aviation Initiative for Renewable Energy in Germany e.V.** – has been facilitating development and deployment of sustainable alternative fuels in Germany. Through workshops, conferences, research projects and policy support aireg focused on raising awareness about the opportunities associated with sustainable fuels. As a network of partners from the entire value chain, the initiative has enabled a deeper understanding of e.g. feedstock options and their availability, the technological and economic details of current and future production pathways, the infrastructural and regulatory prerequisites, as well as issues relating to fuel quality, certification and overall sustainability. Some of the most prominent current projects are included in Annex 3.

With the ambitious "Energiewende" underway in Germany, which also includes the transport sector, aviation is part of several policy initiatives for a reduction in carbon intensity. With regards to alternative aviation fuels, the **Mobility and Fuels Strategy** of the German Federal Government, which was adopted in 2013, entails several measures for a market deployment. As part of a National Development Plan Alternative Aviation Fuels, a "10,000 mt programme" is to be established. Furthermore, the Federal Ministry of Transport and Digital Infrastructure supports research and demonstration projects regarding sustainable aviation fuels, including the "DEMO-SPK" project on the use of renewable Jet fuel at Leipzig/Halle Airport.

In addition to bio-based alternative fuels, **CO_2-neutral fuels** have recently gained momentum through research projects. SOLAR-JET was a project to demonstrate the direct conversion of sunlight and water to a synthesis gas and the subsequent fuel production via the Fischer-Tropsch process. Sunfire, another pathway for carbon-free fuels, has demonstrated the conversion of renewable electricity to synthetic fuels (Power-to-Liquid, PtL). Also hybridization, e.g. the use of battery power for propulsion in combination with a fuel-powered back-up engine, is under investigation by OEMs. Within ICAO, Germany has initiated and continues to support the discussions about PtL fuels for aviation, e.g. in the course of ICAO's Second Conference on Alternative Aviation Fuels (CAAF/2) in 2017[34]. and the corresponding development of an ICAO Vision on Sustainable Alternative Aviation Fuels. The German federal government has announced its intention to promote further research regarding the production and use of sustainable aviation fuels, including PtL fuels, in its coalition agreement for the 19th election period (from 2017 onwards).

[34] See WP 7 from CAAF/2 by Germany: "Power-to-Liquids (PtL): Sustainable Alternative Fuels Produced from Renewable Electricity", https://www.icao.int/Meetings/CAAF2/Documents/CAAF.2.WP.015.1.en.pdf

E.3 Improved Air Traffic Management and infrastructure use

E.3.1 Essential projects for airspace optimisation in the framework of FABEC

The Functional Airspace Block Europe Central (FABEC) covers the lower and upper airspace of six European States (Belgium, France, Germany, Luxembourg, the Netherlands and Switzerland). In the course of the FABEC airspace optimisation several projects have the objective of increasing capacity and at the same time establish more direct or shorter flight paths. In all these projects DFS, which is responsible for air traffic control in Germany, is active in a leading function or in the framework of the project management.

The FABEC area of responsibility is one of the busiest and most complex in the world. Most major European airports, major civil airways and military training areas are located in this area. FABEC airspace covers 1.7 million km² and handles about 5.5 million flights per year – 55% of European air traffic. The seven civil air navigation service providers (ANSP) are ANA (Luxembourg), Belgocontrol (Belgium), DFS (Germany), DSNA (France), LVNL (Netherlands), MUAC (EUROCONTROL) and skyguide (Switzerland).

The multitude of participants – 6 Member States, 7 civil ANSPs and the military partners – as well as the geographical location turn FABEC into a unique partnership. On the one hand, it has the leverage to contribute substantially to the establishment of the single European Sky and the modernisation of European ATM, while on the other hand it faces a complex decision-making process, in which it also involves its stakeholders. Activities are not only focussed on the FABEC level, but in many cases local or bilateral initiatives which finally contribute to FABEC performance.

Analysis of radar data shows that FABEC ANSPs have consistently provided almost optimal horizontal flight profiles to airspace users. In 2017, horizontal flight profiles were close to the optimum as actual trajectories converged at 96.77 percent (2016: 96.45 percent) of the great circle distance. This is an excellent value, which allows for only marginal improvements in the future. Controllers have been providing the shortest routings on average to airspace users since the start of the second reference period in 2014. And this has been achieved despite the strong growth in traffic and often unexpected and volatile variations in volume.

<u>Free Route Airspace (FRA)</u>

The Free Route Airspace (FRA) project, launched in 2012, contributes to the overall FABEC performance targets and objectives of increasing flight efficiency whilst ensuring military mission effectiveness and safety. The final objective of the FRA project is to define an airspace within which users may freely plan a route between a defined entry point and a defined exit point, with the possibility to route via intermediate (published or unpublished) waypoints, without reference to the ATS route network.

The FRA project aims at delivering benefits to both airspace users and ANSPs, by improving:

- Horizontal flight efficiency thus reducing fuel burn and environmental emissions,
- Flexibility for airspace users and ANSPs by increasing the number of routing options,
- Availability of economical routings through making increased use of special use airspace,
- Predictability through better compliance to the flight plan.

The project also aims at offering national and cross-border direct routings and enhance the inbound and outbound flows with the regional and adjacent airports.

Leadership: DSNA

Results: Several implementations took place at national level. In the area of responsibility of DFS, a first implementation step took place in November 2017. The annual potential benefits of this step, assuming that all eligible flights would file the shortest available FRA routing option, were calculated for 2017 as follows:

Annual Route Length Reduction:	981 720 NM;	Gain per flight: 3.12 NM
Annual fuel saving (1NM ≙ 6kg):	5 890 318 kg	
Annual CO_2 saving (1NM ≙ 20 kg):	19 634 392 kg	

<u>XMAN/AMAN</u>

The system XMAN is the cross-border version of the AMAN (Arrival Manager) already in operation. The FABEC XMAN (cross-centre arrival management) project is a multi-stakeholder project, conducted by ANSPs of the European core area (Belgocontrol, DFS, DSNA, MUAC, LVNL, skyguide) to ensure a harmonized and coordinated implementation of extended arrival management.

The overall objective of the XMAN project is to develop, to validate and to implement cross-centre and cross-border arrival management procedures and techniques that enable an optimised traffic flow into the major airports within and close to the FABEC airspace. As such, the project aims to generate a considerable improvement in various performance categories such as environment (CO_2 and fuel-burn reduction), safety (reduction in stack holding) and capacity (reduction in traffic bunching/workload).

Leadership: DFS

Results: First trials in Australia and New Zealand with comparable systems resulted in fuel savings of 50 to 100 kg per flight.

E.3.2 Successive introduction of CDO-procedures at German airports

Continuous Descent Operations (CDO), also known as Continuous Descent Approach (CDA), should lead to greater noise abatement and fuel saving. CDO is an aircraft operating technique aided by appropriate airspace and procedure design and appropriate ATC clearances enabling the execution of a flight profile optimized for the operating capability of the aircraft, with low engine thrust settings and, where possible, a low drag configuration, thereby reducing fuel burn and emissions during descent. The optimum vertical profile takes the form of a continuously descending path, with a minimum of level flight segments.

CDO is being introduced in Germany progressively in three steps and is supposed to result in “CDO on the basis of Instrument Flight procedure Design (Transition and Profile)”.

The status of CDO introduction at German Airports as of May 2015 can be summarized as follows:

1. CDO on a tactical basis during the en-route phase of flight. Airports:
    a. Hannover
    b. Frankfurt/Main
    c. München

2. CDO on a tactical basis in the terminal area. Airports:
    a. Frankfurt/Main
3. CDO on the basis of Instrument Flight Procedure Design (Transition and Profile). Airports:
    a. Hamburg
    b. Hannover
    c. Braunschweig-Wolfsburg
    d. Leipzig/Halle
    e. Köln/Bonn
    f. Nürnberg
    g. München
    h. Stuttgart
    i. Düsseldorf
    j. Berlin-Tegel

E.3.3 Introduction of A-CDM at German airports

The new procedure **A-CDM (Airport Collaborative Decision Making)** is to make the turnaround process of aircraft at the airports smoother: The planners hope to achieve in this way among other things shorter operating times of the engines and a reduction of the waiting times at the runway, but mainly a better feasibility of planning the operational processes.

The core idea of the concept is the introduction of a “Target Off-Block Time” (TOBT) for every flight that is a target time for the moment when the aircraft has finished its handling on the ground. This target time is laid down by the airline which reports it to the system. The TOBT automatically generates a latest point in time for the start of the engines, the so-called Target Start-up Approval Time (TSAT), which is transparent for all the parties concerned – airlines, airport operators, air traffic control, ground handling and Network Manager Operations Centre (NMOC). If formerly it was an ad-hoc decision of the controller as to which aircraft he cleared at what time, this is now defined as early as forty minutes before the planned end of the handling. This can avoid congestion at the runway and unnecessary engine operating times and hence CO_2 emissions.

The status of implementation at German airports can be summarized as follows:

1. On 7 June 2007 the trial operation “Airport CDM at Munich Airport” was transferred into regular operation and thus implemented as standard procedure at the first airport in Europe. The project partners FMG Munich Airport GmbH and DFS Deutsche Flugsicherung GmbH are responsible for the execution of the project.

    Essential results at Munich Airport:

    - It has been possible to shorten the waiting times at the runways by one minute on average to approximately 3.4 minutes.
    - For more than 50% of the flights it was possible to reduce the delay in take-off compared to the delay in arrival or to compensate it completely.
    - Improvement of the comparison airport slot (SOBT) und ATC flight plan (EOBT)
    - Improvement of the process of the allocation of positions in case of overlap of positions.

- In all cases the values of the target times (CTOT) achieved a better quality than the Estimated Take-off Time (ETOT) based only on ATC flight plan data.

<u>Leadership:</u> DFS Deutsche Flugsicherung GmbH, FMG Flughafen München GmbH

<u>Partner/stakeholder:</u> All airlines, Ground Handling agents, Eurocontrol (NMOC)

2. In February 2011 the trial operation "Airport CDM at Frankfurt Airport" was transferred into regular operation and thus implemented as standard procedure at the Second CDM airport in Germany and the forth in Europe. The project partners Fraport AG and DFS Deutsche Flugsicherung GmbH were responsible for the execution of the project.

   <u>Leadership:</u> DFS Deutsche Flugsicherung GmbH, Fraport AG

   <u>Partner/stakeholder:</u> All airlines, Ground Handling agents, Eurocontrol (NMOC)

3. In April 2013 the trial operation "Airport CDM at Düsseldorf Airport" was transferred into regular operation and thus implemented as standard procedure at the third CDM airport in Germany. The project partners Flughafen Düsseldorf GmbH and DFS Deutsche Flugsicherung GmbH were responsible for the execution of the project.

   <u>Leadership:</u> DFS Deutsche Flugsicherung GmbH, FDG GmbH

   <u>Partner/stakeholder:</u> All airlines, Ground Handling agents, Eurocontrol (NMOC)

4. In May 2014 the trial operation "Airport CDM at Berlin-Schoenefeld Airport" was transferred into regular operation and thus implemented as standard procedure at the fourth CDM airport in Germany. The project partners Flughafen Berlin-Brandenburg GmbH and DFS Deutsche Flugsicherung GmbH were responsible for the execution of the project. The Berlin-Schoenefeld Airport CDM implementation ensures a seamless transfer of Airport CDM for the future opening of Berlin-Brandenburg international airport.

   <u>Leadership:</u> DFS Deutsche Flugsicherung GmbH, FBB Gmbh

   <u>Partner/stakeholder:</u> All airlines, Ground Handling agents, Eurocontrol (NMOC)

5. In October 2014 the trial operation "Airport CDM at Stuttgart Airport" was transferred into regular operation and thus implemented as standard procedure at the fifth CDM airport in Germany. The project partners Flughafen Stuttgart GmbH and DFS Deutsche Flugsicherung GmbH were responsible for the execution of the project.

   <u>Leadership:</u> DFS Deutsche Flugsicherung GmbH, FSG GmbH

   <u>Partner/stakeholder:</u> All airlines, Ground Handling agents, Eurocontrol (NMOC)

6. In August 2017 the trial operation "Airport CDM at Hamburg Airport" was transferred into regular operation and implemented as standard procedure at the sixth CDM airport in Germany.

   The project partners Flughafen Hamburg GmbH and DFS Deutsche Flugsicherung GmbH were responsible for the execution of the project.

   <u>Leadership:</u> DFS Deutsche Flugsicherung GmbH, FHG GmbH

   <u>Partner/stakeholder:</u> All airlines, Ground Handling agents, Eurocontrol (NMOC)

Furthermore, an initative on harmonisation of Airport CDM in Germany was established in January 2010. A Letter of Intent is signed by DFS and the Airport operation companies, FMG Munich, Fraport Frankfurt, FBB Berlin, FDG Düsseldorf, FSG Stuttgart, FHG Hamburg.

The objectives of this initiative are:

- Exchange of information and best practices between the different German CDM airports (regardless if fully implemented or project);
- To achieve a common understanding of Airport CDM in Germany and represent this understanding to the European Airport CDM process;
- In the interest of the customers (AO) it is necessary to harmonize the use and consequences of several aspects of the Airport CDM process.

E.4 Economic / market-based measures

This section describes market-based and economic measures in the German air transport sector including emission-based landing charges at airports and emissions trading.

Emissions-based landing charges have been introduced at the airports of Frankfurt, Munich, Cologne/Bonn, Hamburg, Düsseldorf, Hannover and Stuttgart. More recently, the airports in Bremen and Dortmund have also introduced such emission-based charges. Engine emissions of nitrogen oxide (NO_x) and hydrocarbons (HC), which are main contributors to combustion-related local air pollution, are in the focus of these measures. Emissions-based landing charges at airports aim at setting economic incentives to accelerate the introduction of environmentally friendly aircraft engine technology with lower emissions during a standardized landing and take-off (LTO) cycle. Despite their focus on local air quality, these measures may positively influence global air traffic emissions, as modern engines with low-NO_x combustion technology are often also more fuel-efficient.

Aircraft engine emissions of CO_2 are covered by the **EU Emission Trading Scheme (ETS)**, whose scope is temporarily limited to intra-European flights (see section D.4.1). On the global level, Germany supports the development of the **Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)** of the International Civil Aviation Organization (ICAO). Throughout the development of CORSIA, German experts contribute to the Global Market Based Measures Technical Task Force (GMTF) and further working groups of the ICAO Committee of Aviation Environmental Protection (CAEP). In August 2017, Germany and ICAO signed a Memorandum of Understanding to test the feasibility and practicality of the CORSIA provisions for Monitoring, Reporting and Verification (MRV) of CO_2 emissions of aeroplane operators on international flights. This so-called *Small Scale Implementation Project (SSI)* was launched together with six other States and their participating operators. Staffing for this project was provided by the German Environment Agency in cooperation with the Ministry of Environment and Ministry of Transport. The objective of the project was to test the MRV process in a small scale, but real life environment, and to also assess the relevant administrative duties for States in order to derive "lessons learned" for the upcoming implementation of the CORSIA SARPs. The project was finalized on time which enabled the presentation of results during the 2018 ICAO Regional Seminars on CORSIA. During the project, no significant findings were identified which would prevent the implementation of the MRV provisions of CORSIA. The "lessons learned" will be used to create and refine FAQs and future guidance material.

Since 2011, passenger flights departing from Germany and operated by commercial airlines are subject to an **Air Ticket Tax (ATT)**. Thus air traffic is included in the mobility taxation and incentives for environmentally friendly behavior are provided. The amount of tax to be paid for each passenger depends on the final destination. According to law the Federal Ministry of Finance adapts the tax rates each year depending on the annual revenues from the EU Emission Trading System.

E.5 Support to voluntary actions: ACI Airport Carbon Accreditation

Airport Carbon Accreditation is an independent, voluntary programme administered by WSP Environment & Energy, an international consultancy appointed by ACI EUROPE to enforce the accreditation criteria for airports on an annual basis. Details on the programme and the four levels of accreditation are found in section D.6.

There are currently 5 accredited airports in Germany:

- Hamburg (level 3)
- Frankfurt (level 3)
- Munich (level 3)
- Düsseldorf (level 3)
- Stuttgart (level 3)

F Conclusion

This Action Plan provided an overview about measures taken by the Federal Republic of Germany and its aviation sector in order to limit aviation's emissions. Both national actions and the measures initiated on the European level are covered by this document. The measures described in the previous chapters cover a broad range of subjects, including aircraft-related technology development, support for alternative fuels, improved Air Traffic Management, and economic measures. Furthermore, details about a selection of best practice examples in Germany are found in Annex 3 of this report.

It should be noted that those sections, which cover aviation in Germany and the national actions, were finalised in September 2018. The sections covering measures taken collectively in Europe were finalised in July 2018. The contents of the action plan shall be considered as subject to update after those dates.

Annexes

Annex 1 Statistical data

Table 18 – General transport data for Germany

		2010	2013	2014	2015	2016	2017
Goods transport		Transport quantity (in million t)					
	Rail transport	355.7	373.7	365.0	367.3	363.5	348.6
	Road transport[1)]	2,734.1	2,938.2	3,052.1	3,035.3	3,111.8	3,161.8
	Aviation	4.2	4.3	4.4	4.4	4.5	4.8
	Pipelines: crude oil[2)]	88.8	87.3	87.7	90.7	92.2	90.9
	Maritime transport	272.9	294.0	300.1	291.8	292.0	294.9
	Inland waterway transport	229.6	226.9	228.5	221.4	221.3	222.7
		Domestic transport performance (in billion tkm)					
	Rail transport	107.3	112.6	112.6	116.6	116.2	112.2
	Road transport[1)3)]	313.1	305.8	310.1	314.8	315.8	313.1
	Pipelines: crude oil[2)]	16.3	18.2	17.5	17.7	18.8	18.2
	Inland waterway transport	62.3	60.1	59.1	55.3	54.3	55.5
Passenger transport		Passengers carried (in millions)					
	Aviation	167	181	187	194	201	213
	Public road transport	8,984	9,193	9,222	9,255	9,393	*not yet available*
	→ Scheduled services	8,904	9,120	9,146	9,173	9,312	
	→ Occasional services	79	73	76	82	81	
	Rail transport	2,370	2,601	2,650	2,650	2,767	
	→ Short-distance transport	2,244	2,469	2,521	2,518	2,628	
	→ Long-distance transport	126	131	129	131	138	142

Source: DESTATIS

1) Sources: Bundesamt für Güterverkehr, Köln; Kraftfahrt-Bundesamt, Flensburg; only domestic lorries.

2) Source: Bundesamt für Wirtschaft und Ausfuhrkontrolle, Eschborn.

3) Including tkm abroad.

Table 19 – Transport performance of air traffic departing from German airports

	Revenue passenger-kilometres [10^6 Pkm]			Freight/mail tonne-kilometres transported [10^6 tkm]			Revenue tonne-kilometres [10^6 tkm]		
Year	domestic	international	total	domestic	international	total	domestic	international	total
2017	10,361	228,808	239.168	44	12,133	12,177	1,071	35,411	36,482
2016	10,423	215,399	225,822	40	11,400	11,440	1,074	33,324	34,399
2015	10,152	210,011	220.163	38	11,088	11,126	1,046	32,521	33,567
2014	10,020	202,095	212.116	36	11,032	11,068	1,032	31,598	32,630
2013	9,950	196,869	206,819	35	11,014	11,049	1,018	30,991	32,009
2012	10,374	195,069	205,444	35	10,999	11,034	1,064	30,314	31,378
2011	10,742	189,735	200,478	38	10,318	11,356	1,101	30,034	31,135
2010	10,788	182,146	192,934	37	10,486	10,522	1,108	27,453	28,561
2009	10,561	171,231	181,792	37	8,025	8,062	1,086	24,672	25,758
2008	10,950	178,215	189,165	40	8,368	8,408	1,131	25,557	26,688
2007	10,636	175,605	186,805	30	8,318	8,348	1,094	25,019	26,113
	Table shows flight-stage data that refers to payload on board of aircraft operating on German airports. Domestic traffic covers flights between German airports. International traffic includes outgoing international flights from German airports.								

Source: DESTATIS

Table 20 – Aircraft Fleet in the Federal Republic of Germany

Categories	2009	2010	2011	2012	2013	2014	2015	2016	2017
A Aircraft > 20 t	757	772	770	767	758	751	751	777	753
B Aircraft 14 to 20 t	43	40	38	30	34	33	34	35	37
C Aircraft 5.7 to 14 t	231	228	236	217	199	207	191	211	219
E Single-engine aircraft below 2 t	6,752	6,801	6,744	6,757	6,733	6,689	6,596	6,553	6,527
F Single-engine aircraft 2 to 5.7 t	144	153	155	150	155	149	147	160	174
G Multi-engined aircraft below 2 t	241	242	243	239	240	228	229	221	219
I Multi-engined aircraft 2 to 5.7 t	445	444	428	414	403	393	371	381	391
H Rotorcraft (helicopters)	780	811	773	774	769	745	747	733	729
K Powered gliders	3,022	3,081	3,122	3,185	3,263	3,357	3,403	3,456	3,528
L Airships	3	4	3	5	3	3	3	3	3
O Balloons	1,261	1,260	1,257	1,215	1,201	1,183	1,164	1,124	1,102
Gliders	7,891	7,867	7,834	7,793	7,704	7,657	7,567	7,450	7,383
Aircraft in total	**21.570**	**21.703**	**21,603**	**21,546**	**21,462**	**21,395**	**21,213**	**21,104**	**21,065**

Source: Luftfahrt-Bundesamt

Table 21 – Number of airlines with active operating licence

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Number of airlines	171	163	165	170	169	158	147	138	137	128	126

Source: Luftfahrt-Bundesamt

Table 22 – International RTK of air operators registered in Germany based on ICAO definitions

	Scheduled international RTK [10^6 tkm]								
State of AOC	2007	2008	2009	2010	2011	2012	2013	2014	2015
Germany	28,696	27,070	25,262	26,464	28,033	27,576	28,308	28,815	30,507

Source: ICAO APER website

Annex 2 Detailed Results for ECAC Scenarios from Section C

1. Baseline Scenario (technology freeze in 2010)

a) International passenger and cargo traffic departing from ECAC airports

Year	Passenger Traffic (IFR movements) (million)	Revenue Passenger Kilometres[35] RPK (billion)	All-Cargo Traffic (IFR movements) (million)	Freight Tonne Kilometres transported[36] FTKT (billion)	Total Revenue Tonne Kilometres[36, 37] RTK (billion)
2010	4.6	1,218	0.20	45.4	167.2
2016	5.2	1,601	0.21	45.3	205.4
2020	5.6	1,825	0.25	49.4	231.9
2030	7.0	2,406	0.35	63.8	304.4
2040	8.4	2,919	0.45	79.4	371.2

Note that the traffic scenario shown in the table is assumed for both the baseline and implemented measures scenarios.

b) Fuel consumption and CO_2 emissions of international passenger traffic departing from ECAC airports

Year	Fuel Consumption (10^9 kg)	CO_2 emissions (10^9 kg)	Well-to-wake CO_2e emissions (10^9 kg)	Fuel efficiency (kg/RPK)	Fuel efficiency (kg/RTK)
2010	37.98	120.00	147.3	0.0310	0.310
2016	46.28	146.26	179.6	0.0287	0.287
2020	49.95	157.85	193.8	0.0274	0.274
2030	61.75	195.13	239.6	0.0256	0.256
2040	75.44	238.38	292.7	0.0259	0.259
For reasons of data availability, results shown in this table do not include cargo/freight traffic.					

[35] Calculated based on 98% of the passenger traffic for which sufficient data is available.

[36] Includes passenger and freight transport (on all-cargo and passenger flights).

[37] A value of 100 kg has been used as the average mass of a passenger incl. baggage (ref: ICAO).

2. Implemented Measures Scenario

a) Effects of Aircraft Technology Improvement after 2010

Fuel consumption and CO_2 emissions of international passenger traffic departing from ECAC airports, with aircraft technology improvements after 2010 included:

Year	Fuel Consumption (10^9 kg)	CO_2 emissions (10^9 kg)	Well-to-wake CO_2e emissions (10^9 kg)	Fuel efficiency (kg/RPK)	Fuel efficiency (kg/RTK)
2010	37.98	120.00	147.3	0.0310	0.310
2016	46.28	146.26	179.6	0.0286	0.286
2020	49.08	155.08	190.4	0.0270	0.245
2030	58.65	185.34	227.6	0.0247	0.247
2040	68.99	218.01	267.7	0.0242	0.242
For reasons of data availability, results shown in this table do not include cargo/freight traffic.					

b) Effects of Aircraft Technology and ATM Improvements after 2010

Fuel consumption and CO_2 emissions of international passenger traffic departing from ECAC airports, with aircraft technology and ATM improvements after 2010:

Year	Fuel Consumption (10^9 kg)	CO_2 emissions (10^9 kg)	Well-to-wake CO_2e emissions (10^9 kg)	Fuel efficiency (kg/RPK)	Fuel efficiency (kg/RTK)
2010	37.98	120.00	147.3	0.0310	0.310
2016	46.24	146.11	179.4	0.0286	0.286
2020	49.03	154.93	190.2	0.0245	0.245
2030	57.38	181.33	222.6	0.0242	0.242
2040	67.50	213.30	261.9	0.0237	0.237
For reasons of data availability, results shown in this table do not include cargo/freight traffic.					

c) Effects of Aircraft Technology and ATM Improvements and Alternative Fuels

Fuel consumption and CO_2 emissions of international passenger traffic departing from ECAC airports, with aircraft technology and ATM improvements as well as alternative fuel effects included:

Year	Fuel Consumption (10^9 kg)	CO_2 emissions (10^9 kg)	Well-to-wake CO_2e emissions (10^9 kg)	Fuel efficiency (kg/RPK)	Fuel efficiency (kg/RTK)
2010	37.98	120.00	147.3	0.0310	0.310
2016	46.24	146.11	179.4	0.0286	0.286
2020	49.03	154.93	187.9	0.0245	0.245
2030	57.38	181.33	199.5	0.0242	0.242
2040	67.50	213.30	214.8	0.0237	0.237
For reasons of data availability, results shown in this table do not include cargo/freight traffic. *Note that fuel consumption is assumed to be unaffected by the use of alternative fuels.*					

Annex 3 Best practice examples – Measures to mitigate CO_2 emissions

In order to facilitate the compilation of a comprehensive German Action Plan contributing to ICAO´s Action Plan on Emissions Reduction, aireg and the German Aviation Association (BDL) are providing the following outline of measures to the Federal Ministry of Transport and Digital Infrastructure. This is to summarize the major national existing and intended actions towards a large-scale introduction of alternative fuels in aviation.

We are convinced that whereas improvements in technology, air traffic management and operations will lead to a sizable emissions reduction, the industry`s ambitious goals (ACARE Vision for 2020, Flightpath 2050, IATA Global Approach to Reducing Aviation Emissions) will only be met with a significant contribution of alternative fuels. Therefore we emphasize that regulatory and public financial support for alternative fuels has to be a priority. Adequate support will enable achieving the potential benefits described in the measures below.

Category A:

Alternative aviation fuel measures in Germany that are ongoing or whose financing will be secured in the short to medium term

A.1 aireg – Aviation Initiative for Renewable Energy in Germany e.V.

Title	**aireg – Aviation Initiative for Renewable Energy in Germany e.V.**
Description	Multi-stakeholder initiative to establish sustainable aviation fuels value chains in Germany
Category	Organizational
Measure	Enable market deployment of alternative aviation fuels
Action	Foster relationships among stakeholders; garner regulatory, organizational, scientific and business support and thus securing supply for aviation and contributing to carbon-reduction goals
Start Date	June 2011
Date of full implementation	October 2011
Economic Cost in €	provided through membership contributions
Assistance needed in €	variable costs according to project scope to be provided by external public or private institutions
List of stakeholders involved	• Airbus Group • Austrian Airlines • Aviation Fuel Projects Consulting • Bauhaus Luftfahrt e.V. • Boeing International Corporation • CCP Technology GmbH • Clean Carbon Solutions • Condor Flugdienst GmbH • Deutsche Lufthansa AG • Deutsche Post DHL • Deutsche Shell Holding GmbH • DLR (Deutsches Zentrum für Luft-und Raumfahrt) • DVB Bank SE • Flughafen München GmbH • Forschungszentrum Jülich GmbH • Fraunhofer-Institut für Bauphysik • Global Bioenergies • ISCC System GmbH • Jatro Green S.A.R.L • Karlsruher Institut für Technologie (KIT) • Leibniz-Institut für Katalyse e.V. (LIKAT) • MTU Aero Engines AG • Neste Oil • OMV Refining + Marketing GmbH • Petrixo Oil & Gas • Schleswig-Holstein – Ministerium für Wirtschaft, Arbeit, Verkehr und Technologie • Technische Universität Hamburg-Harburg – Institut für Umwelttechnik und Energiewirtschaft • Total Deutschland GmbH • TU Bergakademie Freiberg • TU München • WIWeB
Contact for this measure	Melanie Form, Acting Managing Director, Director Political & Public Affairs, aireg e.V., Bundesratufer 10, 10555 Berlin, Germany Phone: +49 178 1843041, Mail: melanie.form@aireg.de, Web: www.aireg.de

A.2 AUFWIND – Algenproduktion und Umwandlung in Flugzeugtreibstoffe: Wirtschaftlichkeit, Nachhaltigkeit, Demonstration

Title	**AUFWIND** Algenproduktion und Umwandlung in Flugzeugtreibstoffe: Wirtschaftlichkeit, Nachhaltigkeit, Demonstration
Description	Alternative fuels research project with focus on algae to jetfuel
Category	Scientific
Measure	Investigate the economic and ecological feasibility of individual process steps and of the overall chain for using micro algae as sustainable feedstock for aviation biofuels under Central European conditions.
Action	• Investigating of the value chain from algae to jetfuel • Life-Cycle-Analysis of the whole value chain • Determination of the ecological footprint • Out of lab-scale (3x500m²) cultivation of micro-algae for further processing • Investigation of additional products and side streams from algae
Start Date	June 2013
Date of full implementation	Summer 2014 and 2015
Economic Cost in €	8.1 Mio. €
Assistance needed in €	6.85 Mio. € (provided by BMEL through FNR)
List of stakeholders involved	• Federal Ministry of Food and Agriculture (BMEL) • Fachagentur nachwachsende Rohstoffe (FNR) • Forschungszentrum Jülich • Airbus Defence and Space • DBFZ • Novagreen • Phytolutions • BTU • OMV • RWTH Aachen • TU München • Fraunhofer UMSICHT • VERBIO • VTS
Contact for this measure	Dr. Christine Schreiber Institute für Pflanzenwissenschaften (IBG-2) Forschungszentrum Jülich GmbH 52425 Jülich Tel: +49 2461 61 3207 Mail: c.schreiber@fz-juelich.de

A.3 KIT – Link of Lignocellulose-based fuel synthesis with Power-to-Jetfuel concept based on Fischer-Tropsch Technology

Title	**Link of Lignocellulose-based fuel synthesis with Power-to-Jetfuel concept based on Fischer-Tropsch Technology**
Description	Alternative fuels research project with focus on BtL
Category	Scientific
Measure	Jetfuel obtained by linking BtL based on lignocellulosic biomass as a carbon source with Power-to-Fuels/Liquids using electrolysis-derived hydrogen. Demonstration of process integration in kg/h-scale as research platform of the Helmholtz Association.
Action	• Tuning the existing bioliq pilot plant and adapting the synthesis parameters to produce components for jet fuel (paraffinic and aromatic compounds). • Implementing a demo-unit based on microstructured reactors and water electrolysis for turning electrical power into Jetfuel. • Process integration with software and hardware solutions of the Energy Lab 2.0 • Demonstration and systems evaluation of integrated value chains.
Start Date	November 2014
Date of full implementation	2020
Economic Cost in €	Investment in Infrastructures at KIT (bioliq + Energy Lab 2.0)
Assistance needed in €	Additional Investment needed: 2 Mio. € Additional Operating Costs: ca. 2.5 Mio. € over 5 years in order to be able to supply technical quantities for engine tests
List of stakeholders involved	Partners of the bioliq project: • Air Liquide (industry partner for gasification stage) • CAC Chemieanlagenbau Chemnitz (industry partner for MTG-Unit, which could supply aromatic compounds for JF) • Ineratec (startup focusing on modular syngas conversion plants, especially FT synthesis) • Helmholtz Association
Contact for this measure	Prof. Dr. Jörg Sauer Karlsruher Institut für Technologie KIT Institut für Katalyseforschung und Technologie Hermann-von-Helmholtz-Platz 1 76344 Eggenstein-Leopoldshafen Tel.: +49 721 608 22400 Mail: j.sauer@kit.edu

A.4 TU Hamburg-Harburg – Biokerosine from Alcohols

Title	**Biokerosine from Alcohols**
Description	Alternative fuels research project with focus on alcohol to jetfuel
Category	Scientific
Measure	Evaluation of different pathways of Kerosene provision from alcohols
Action	• Identification of most promising provision pathway for alternative aviation fuel from alcohol • Evaluation based on technical, economic and environmental aspects • Assessment of raw material potentials, conversion routes and maturity of technologies / processes
Start Date	April 2015
Date of full implementation	October 2015
Economic Cost in €	Several 10 k€
Assistance needed in €	Assistance of industry partners
List of stakeholders involved	• Hamburg University of Technology (TUHH) – Institute of Environmental Technology and Energy Economics (IUE) • Airbus Operations GmbH • Deutsche Lufthansa AG • Linde AG • OMV AG • TOTAL New Energies • Amyris Inc.
Contact for this measure	Prof. Dr.-Ing. Martin Kaltschmitt Hamburg University of Technology (TUHH) Institute of Environmental Technology and Energy Economics (IUE) Eissendorfer Str. 40 D-21073 Hamburg Tel.: +49 40 42 878 3008 Fax: +49 40 42 878 2315 Mail: kaltschmitt@tuhh.de

A.5 TU Hamburg-Harburg – InnoTreib

Title	**Innovative Treibstoffe der Zukunft – InnoTreib**
Description	Alternative fuels research project
Category	Scientific
Measure	Evaluation of different pathways of biofuel provision
Action	• Characterize and model pathways for the production of alternative fuels, with feedback based on performance-optimized fuel formulation • Evaluation based on technical, economic and environmental aspects • Investigate experimentally the effect of fuel composition on combustion performance and emissions in a generic spray burner. • Model and validate fuel composition's effect on selected combustion-relevant sub-processes. • Develop optimization methods to determine fuel compositions, such as enhanced combustor performance, minimized emissions and reduced environmental impact and economical production costs
Start Date	January 2014
Date of full implementation	December 2016
Economic Cost in €	675 t € granted by the Federal Ministry for Economic Affairs and Energy, 34 t € by Rolls-Royce and MTU
Assistance needed in €	n/a
List of stakeholders involved	• Hamburg University of Technology (TUHH) - Institute of Environmental Technology and Energy Economics (IUE) • DLR VT – Institute of Combustion Technology • University of Stuttgart – Institute of Combustion Technology for Aerospace Engineering • Rolls Royce Ltd. & Co. KG • MTU Aero Engines AG
Contact for this measure	Prof. Dr.-Ing. Martin Kaltschmitt Hamburg University of Technology (TUHH) Institute of Environmental Technology and Energy Economics (IUE) Eissendorfer Str. 40 D-21073 Hamburg Tel.: +49 40 42 878 3008 Fax: +49 40 42 878 2315 Mail: kaltschmitt@tu-harburg.de

A.6 TU Hamburg-Harburg – Climate protection options for international air transport

Title	**Climate protection options for international air transport**
Description	Alternative fuels research project
Category	Scientific
Measure	Assessment of different options to mitigate the CO_2 emissions of international aviation
Action	• Identification of suitable options in the field of technology, operation, alternative fuels and carbon offsets • Modeling of different mitigation scenarios based on (i) a fuel demand model (representing technology and operations) and (ii) an emissions model (representing fossil and renewable fuels as well as carbon offsets). • Evaluation of options and identification of trends • Recommendations
Start Date	November 2016
Date of full implementation	September 2018
Economic Cost in €	>100 k€, provided by the Federal Ministry of Transport and Digital Infrastructure (BMVI)
Assistance needed in €	n/a
List of stakeholders involved	• Hamburg University of Technology (TUHH) – Institute of Environmental Technology and Energy Economics (IUE) • Fraunhofer Institute for Systems and Innovation Research ISI • Fraunhofer Institute for Material Flow and Logistics IML • M-Five GmbH
Contact for this measure	Prof. Dr.-Ing. Martin Kaltschmitt Hamburg University of Technology (TUHH) Institute of Environmental Technology and Energy Economics (IUE) Eissendorfer Str. 40 D-21073 Hamburg Tel.: +49 40 42 878 3008 Fax: +49 40 42 878 2315 Mail: kaltschmitt@tuhh.de

A.7 DBFZ – Research and Demonstration Project on the Use of Renewable Jet fuel at Leipzig/Halle Airport (DEMO-SPK)

Title	**Research and Demonstration Project on the Use of Renewable Jet fuel at the Airport Leipzig/Halle (DEMO-SPK)**
Description	Alternative fuels research project
Category	Scientific
Measure	Scientific monitoring and demonstration of the use of multi-blends of different sustainable aviation fuels under realistic conditions at Leipzig/Halle Airport.
Action	• Blending of different sustainable aviation fuels (so-called multi-blends) • Assessment of storage characteristics of renewable Jet fuel multiblends • Use of multiblends via the fuel infrastructure at Leipzig/Halle Airport • Life cycle analysis of renewable Jet fuel multiblends, covering costs and emissions • Development and practice validation of an operational methodology for the recognition of Jet fuel blends in market-based systems, e.g. EU-ETS or CORSIA
Start Date	November 2016
Date of full implementation	April 2019
Economic Cost in €	4.2 Mio. €, provided by the Federal Ministry of Transport and Digital Infrastructure
Assistance needed in €	n/a
List of stakeholders involved	• Deutsches Biomasseforschungszentrum (DBFZ) gGmbH • Hamburg University of Technology (TUHH) – Institute of Environmental Technology and Energy Economics (IUE) • MEO Carbon Solutions GmbH • Aviation Initiative for Renewable Energy in Germany e.V. (aireg) • IFOK GmbH
Contact for this measure	Dr.-Ing. Franziska Müller-Langer Head of Department Biorefineries DBFZ Deutsches Biomasseforschungszentrum gGmbH Torgauer Straße 116 D-04347 Leipzig Tel.: +49 341 2434 423 Fax: +49 341 2434 133 Mail: franziska.mueller-langer@dbfz.de

A.8 TU Hamburg-Harburg – Short Study „Power to Liquid"-Kerosene

Title	**Short Study „Power to Liquid" – Kerosene (Concepts, Resources, Processes, Assessment)**
Description	Alternative fuels research project with focus on Power-to-Liquid
Category	Scientific
Measure	Evaluation of different pathways of Kerosene provision via Power-to-Liquid
Action	• Identification of most promising provision pathway for alternative aviation fuel via Power to Liquid • Evaluation based on technical, economic and environmental aspects • Assessment of raw material potentials, conversion routes and maturity of technologies / processes
Start Date	August 2017
Date of full implementation	March 2018
Economic Cost in €	Several 10 k€
Assistance needed in €	Assistance of industry partners
List of stakeholders involved	• Hamburg University of Technology (TUHH) – Institute of Environmental Technology and Energy Economics (IUE) • Airbus Operations GmbH • Deutsche Lufthansa AG • OMV AG • Shell AG
Contact for this measure	Prof. Dr.-Ing. Martin Kaltschmitt Hamburg University of Technology (TUHH) Institute of Environmental Technology and Energy Economics (IUE) Eissendorfer Str. 40 D-21073 Hamburg Tel.: +49 40 42 878 3008 Fax: +49 40 42 878 2315 Mail: kaltschmitt@tuhh.de

A.9 DLR – German Aerospace Center – ECLIF

Title	**Emission and Climate Impact of Alternative Fuels - ECLIF**
Description	Alternative fuels research project with focus on emission and climate impact
Category	Scientific
Measure	Investigate, understand and model how fuel composition affects combustion systems' emissions and thereby contrails, cirrus, and climate.
Action	• Investigate experimentally the effect of fuel composition on combustion performance and emissions in a generic spray burner. • Model and validate fuel composition's effect on all combustion-relevant sub-processes. Investigate numerically fuel effect on the emissions of a jet engine single sector under relevant conditions. • Thermodynamics simulation of jet engine conditions to provide boundary conditions for CFD and lab-scale experiment. Model alternative fuels effect on airline fleet emissions balance. • Measure fuel's composition effect on triple sector (HOTS-rig) performance and emissions under real conditions. • Measure emissions in the immediate wake of a jet engine (V2500, on the DLR A320 ATRA Aircraft) to investigate fuel effects on aircraft cruise emissions, specifically concentrations of soot and ice particles and gaseous particle precursors. • Investigate and model the further effect of emissions on ice crystal formation in contrails, the impact on cirrus formation and global radiation balance.
Start Date	April 2014
Date of full implementation	2014 through 2018
Economic Cost in €	6.5 mio. € DLR internal funding
Assistance needed in €	n/a
List of stakeholders involved	• Collaboration with NASA (USA) that deployed its DC-8 for in-flight measurements in Jan-Feb 2018, • NRC-CRC (Canada), • Aerodyne Research (USA), • University of Oslo (Norway) that participated in the ground tests, • collaboration in kind from SASOL Plc (ZA) and BP Europe (Hamburg) regarding alternative fuels sourcing and logistics. • DLR Institutes involved: Institute of Combustion Technology (VT), Institute of Atmospheric Physics (PA), Institute of Propulsion Technology (AT) and Flight Experiment (FX).
Contact for this measure	Patrick Le Clercq DLR – Deutsches Zentrum für Luft- und Raumfahrt Institute of Combustion Technology Pfaffenwaldring 38-40 70569 Stuttgart Tel.: +49 711 6862 441 Mail: Patrick.LeClercq@dlr.de

A.10 Breeding programme of Jatropha - global

Title	**Breeding programme of Jatropha - global**
Description	Long-term breeding programme of Jatropha for conversion into alternative fuels
Category	Scientific/Economic
Measure	Development of Jatropha cultivars with superior oil yield and quality for conversion into Biofuels.
Action	• Recombination of promising Jatropha varieties by means of classical plant breeding • Evaluation of Jatropha varieties under realistic field conditions across multiple years and locations • Selection of Jatropha varieties for increased oil yield, oil quality and low production costs • Commercialization of elite Jatropha cultivars and supply of high quality seeding and planting material • Provision of agronomic consultancy for successful Jatropha cultivation
First Results	Since 2014 first high yielding cultivars are on the market
Start Date	2009
Date of full implementation	2011
Economic Cost in €	Depending on project scale
Assistance needed in €	Public financial R&D support needed
List of stakeholders involved	• JatroSolutions GmbH • EnBW
Contact for this measure	Sebastian Held Managing Director JatroSolutions GmbH Echterdingerstr. 30 70599 Stuttgart Tel.: +49 711 459 99 760 Mail: office@jatrosolutions.com Web: www.jatrosolutions.com

A.11 Establishment of a Jatropha-Demo-Farm

Title	**Establishment of a Jatropha-Demo-Farm**
Description	Research project about the establishment of a Jatropha-Demo-Farm and proving economy of Jatropha Oil production
Category	Scientific/Economic
Measure	Cultivation and management of a 400 ha Jatropha Farm up to commercialization of products Jatropha-oil
Action	• Evidence of profitability of the first jatropha cultivars • Realistic representation of a Jatropha farm from management up to the end product Jatropha-oil • Presentation of a long-term economically operating (cost-efficiency) agricultural business (Jatropha – Farm) • Commercialization of Jatropha products on local markets • Increase of knowledge in all parts beginning by cultivation up to sales market
Start Date	End of 2015 / Beginning of 2016
Date of full implementation	Peak yield to be reached from 2021 on (depends on climatic condition of chosen region)
Economic Cost in €	About 4 Mio. €
Assistance needed in €	Financial R&D support needed
List of stakeholders involved	• Jatro Green S.A.R.L
Contact for this measure	Jochen Benz Managing Director, Jatro Green S.A.R.L EnBW Baden-Württemberg GmbH Durchlacher Allee 93 76131 Karlsruhe Tel.: +49 721 86 17886 Fax: +49 721 86 17888 Mail: j.benz@enbw.com Web: www.enbw.com

A.12 Power-to-Liquids - Potentials and Perspectives for the Future Supply of Renewable Aviation Fuel

Title	**Power-to-Liquids – Potentials and Perspectives for the Future Supply of Renewable Aviation Fuel**
Description	The German Environment Agency (UBA) initiated and published a study on the potential and perspectives of alternative and environment-friendly fuels for aviation. In particular, the study deals with the manufacturing process of fuel made from renewable energy (Power-to-Liquid, PtL).
Category	Alternative fuels research project
Measure	Investigate the PtL manufacturing process
Action	• The study gives an introduction into the novel concept of producing renewable jet fuel using renewable electricity, so-called Power-to-Liquids (PtL) for the sector of aviation. • The PtL production pathways and the drop-in capability of the resulting jet fuel are explained and their comparative performances are discussed in terms of greenhouse gas emissions, energy efficiencies, costs, water demand and land requirement.
Publishing Date	2016
Economic Cost in €	n/a
Assistance needed in €	n/a
List of stakeholders involved	• Umweltbundesamt (German Environment Agency) • LBST – Ludwig-Bölkow-Systemtechnik GmbH
Contact for this measure	Download-Link to study: Download Study Mail: info@umweltbundesamt.de

A.13 Climate Paths for Germany

Title	**Climate Paths for Germany**
Description	This study was published by BDI e.V. in 2018. The aim of the study is to identify economically cost efficient ways of achieving Germany's emission reduction targets.
Category	Research study
Measure	Identify economically cost-efficient ways of achieving Germany's emission reduction targets.
Action	• The study shows economically cost efficient strategies for a GHG reduction of 80 to 95 percent by 2050. • For air traffic, the use of PtL, which is imported into Germany, is found to achieve the climate protection targets.
Publishing Date	2018
Economic Cost in €	n/a
Assistance needed in €	n/a
List of stakeholders involved	• Bundesverband der Deutschen Industrie e.V. (BDI)
Contact for this measure	Download-Link to study: Download Study Summary Mail: info@bdi.eu

Category B:

Alternative fuel and propulsion measures that are in the stage of early development and bear a significant long-term potential of emissions reduction

B.1 Jatropha: Sustainable oil production method and detoxification of sludge material

Title	**Jatropha: Sustainable oil production method and detoxification of sludge material**
Description	Research project about sustainable production of Jatrohpa oil in combination with detoxification of sludge material for production of protein
Category	Scientific/Economic
Measure	Evaluation and demonstration of Jatropha-oil production as base for bio-kerosene in combination with use of by-products like protein
Action	• Phase 1: Production of Jatropha oil by aqueous extraction as base for bio-kerosene • Phase 2: Detoxification of by-products aqueous sludge (Jatropha kernel meal) by Methanol – Extraction • Phase 3: Detoxification of Jatropha Oil and re-use for detoxification of Sludge (JKM) • Phase 4: Test of different drying methods
Start Date	2015
Date of full implementation	2016
Economic Cost in €	100.000 €
Assistance needed in €	Public financial R&D support needed
List of stakeholders involved	• JatroSolutions GmbH • EnBW • GEA-Westfalia • Mühle Ebert Dielheim
Contact for this measure	Sebastian Herld Managing Director JatroSolutions GmbH Echterdingerstr. 30 70599 Stuttgart Tel.: +49 711 459 99 760 Mail: office@jatrosolutions.com Web: www.jatrosolutions.com

B.2 TELOS – Thermo-electrically optimized aircraft propulsion systems

Title	**Thermo-electrically optimised aircraft propulsion systems - TELOS**
Description	Complementary research project to Airbus Group overall project concerning reduction of emissions to reach the Flight Path 2050 requirements (- 50% CO_2, - 90 % NO_x and - 65% Noise). Development of the technological basis for a hybrid electric propulsion system on an appropriate power level (high power class).
Category	Scientific/Economic
Measure	Demonstration of propulsion system for passenger aircraft with significantly reduced block energy demand for certain missions and reduction of carbon fuel by implementation of hybrid energy source. Target applications are regional range aircraft in a first step and short range aircraft in a second step (100-200 Passengers).
Action	• Research and development of electrical high voltage / power aviation network supporting electrical energy transport from different energy sources to electric propulsion units. • Investigations and assessment of different systems architectures and impacts on aircraft topologies for different power classes, and missions. • Alternative energy sources and energy management for hybrid configurations for different aircraft missions. • Impacts, synergies and new requirements for other aircraft systems and aircraft operation.
Start Date	2016
Date of full implementation	End of 2019
Economic Cost in €	23 M€
Assistance needed in €	11 M€
List of stakeholders involved	• Airbus Group Innovations, München • Airbus Operations, Hamburg • Siemens AG, Erlangen • Karlsruhe Institute of Technology • Neue Materialien Bayreuth • Technische Universität München
Contact for this measure	Martin Nüßeler Head of E-Aircraft Systems Airbus Group, Corporate Technical Office (CTO) 81663 Munich Tel.: +49 89 607 35999 Mail: martin.nuesseler@airbus.com Web: www.airbus.com

Category C:

Measures of airlines and airports in Germany

C.1 Improved aerodynamical performance

Title	**Improved aerodynamical performance**
Description	Operations & fuel efficiency improvement
Category	Technical performance improvement
Measure	Optimised aerodynamical performance of the aircraft
Action	Riblet / Shark Skin Shark Skin Coating is able to improve flow quality. Due to the special structure of the coating the usual turbulent flow properties can be influenced towards laminar ones. Compared to turbulent flow, a benefit of laminar flow is reduced drag, hence reduced fuel consumption. Vortex Control Finlets VCT (Vortex Control Technologies) is proposing to install vortex control finlets at the rear lower part of the aircraft fuselage. Aerodynamical improvements are expected by reducing the pressure drag area. Theoretical evaluation of the promised effect is planned for 2015.
Start Date	2014
Date of full implementation	2017
Economic Cost	n/a
List of Stakeholders involved	Riblet / Shark Skin • BWM • Fraunhofer IPT • Airbus (Riblet) • Lufthansa Technik Vortex Control Finlets • Vortex Control Technologies for Boeing aircraft • Lufthansa Technik

Incremental improvements / benefits for each measure

YEAR	n/a
Improvement in Total Fuel and CO_2	Riblet / Shark Skin Reduced fuel consumption of 0.5% – 0.75% Vortex Control Finlets Reduced fuel consumption up to 2%
Anticipated co-benefits	n/a

Point of contact for this measure
Deutsche Lufthansa AG, www.lufthansa.com
Bernhard Dietrich, Head of Environmental Issues, Bernhard.Dietrich@dlh.de

C.2 Retrofit of aircraft with Winglets - Update

Title	**Retrofit of aircraft with winglets**
Description	Technological/Aerodynamic improvement
Category	Aircraft-related Technology Development
Measure	Retrofitting and upgrade improvements on existing aircraft
Action	• The wing tips of airberlin's Boeing B73N fleet [B737(-700/-800)] were retrofitted with Blended Winglets. • This measure increases the aspect ratio of the wing, thus reducing lift-induced drag and increasing performance. • Fuel consumption of the aircraft drops by 3% net. Saves 270t fuel per year/per Boeing aircraft. Annual reduction of 790t CO_2 per year per aircraft. • All new A320/321 aircraft on order are equipped with Sharklets. The measure is expected to achieve a reduction in CO_2 emissions of around 800t per year, per aircraft. • All 9 of Condor's Boeing B767-300ER aircraft and all 13 Boeing B757-300 aircraft have been retrofitted with winglets to improve the fuel efficiency of the fleet.
Start Date	Varies
Date of full implementation	Varies
Economic Cost	Moderate investment volume (678,000 € for airberlin)
List of Stakeholders involved	• airberlin, airberlin Technik • Boeing • Condor

Incremental improvements / benefits for each measure

YEAR	n/a
Improvement in Total Fuel (t)	250 t / aircraft p.a. (airberlin)
Improvement in Total Fuel (%)	ca. 3,5 % / Flight
Improvement in Total CO_2 Emissions (t)	790 t / aircraft p.a. (airberlin)
Improvement in Total CO_2 Emissions (%)	3,5 % / Flight
Anticipated co-benefits	• Better climb performance • Noise reduction by about 6.5 % • 4.8 Mio € DOC effect for Condor

Point of contact for this measure
Condor Flugdienst GmbH, www.condor.com
Walter Emmerling, Head of Flight Operations, walter.emmerling@condor.com

C.3 Modifying of current aircraft engines

Title	**Modifying of current aircraft engines**
Description	Technological improvement
Category	Aircraft Technology Development
Measure	Installation of optimized components
Action	The Trent 500 engines of the aircraft type Airbus A340 are to be modified by the installation of optimized components. Expected annual CO_2 savings in metric tonnes: 34,062. Project duration: 2012-2020. The Trent 700 engines of the aircraft type Airbus A330 are to be modified by the installation of optimized components. Expected annual CO_2 savings in metric tonnes: 13,227. Project duration: 2012-2019.
Start Date	2012
Date of full implementation	2020
Economic Cost	n/a
List of Stakeholders involved	Lufthansa

Incremental improvements / benefits for each measure

YEAR	n/a
Improvement in Total Fuel (t)	15,012t fuel p.a.
Improvement in Total Fuel (%)	n/a
Improvement in Total CO_2 Emissions (t)	47,289t CO_2 p.a.
Improvement in Total CO_2 Emissions (%)	n/a

Point of contact for this measure
Deutsche Lufthansa AG, www.lufthansa.com
Bernhard Dietrich, Head of Environmental Issues, Bernhard.Dietrich@dlh.de

C.4 Software OMEGA "Tracks"

Title	**Software OMEGA "Tracks"**
Description	Optimizing flight routes
Category	Analysing in-flight data
Measure	Visualization of historical flight routes
Action	The OMEGA software helps pilots find the shortest route by analysing flight tracks stored in the flight data recorder. The tracks thus generated for the current flight are fed back into the pilots' briefing. The pilots see these on the electronic navigation map in the cockpit. Thanks to the displayed shortcuts from previous flights, pilots can actively request such tracks from air traffic control, if appropriate.
Start Date	2015
Date of full implementation	2017
Economic Cost	n/a
List of Stakeholders involved	• Lufthansa • Honeywell

Incremental improvements / benefits for each measure

YEAR	n/a
Improvement in Total Fuel (t)	8,551t fuel p.a.
Improvement in Total Fuel (%)	n/a
Improvement in Total CO_2 Emissions (t)	26,937t CO_2 p.a.
Improvement in Total CO_2 Emissions (%)	n/a
Anticipated co-benefits	

Point of contact for this measure

Deutsche Lufthansa AG, www.lufthansa.com
Bernhard Dietrich, Head of Environmental Issues, Bernhard.Dietrich@dlh.de

C.5 Reduction of Aircraft Weight - Update

Title	**Reduction of Aircraft Weight**
Description	Technological improvement
Category	Aircraft-related Technology Development
Measure	Retrofitting and upgrade improvements on existing aircraft
Action	• New Recaro seats on short/medium haul fleet at AB The new Recaro seat saves 1.5kg related to the previous model (saves 575 kg per flight) • Implementation Light Weight Containers LD3 After successfully testing 1,000 light weight LD3 containers, the implementation of ACS Aerobox and DoKaSch containers is prepared. 16 kg weight can be saved per utilized container. • Light Weight Trolley Interkont With the 38 light-weight trolleys which are needed to serve passengers on an Airbus, airberlin saves more than 225 kg compared to the trolleys used previously. • Lightweight Container for Condor Jettainer will make available and manage about 1,800 ULDs for Thomas Cook Group Airlines. The extremely light AKE and DQF containers provide a significant reduction in flying weight, as they weigh only 58 and 99 kilograms respectively; this reduces fuel consumption, costs and emissions. The first new lightweight units have been in operation for Condor since spring of 2015 and they are gradually replacing the older items. • Reduction of Paper Maps on Board All airberlin aircraft are equipped with special computers which display both the onboard library and the flight charts. This reduces the weight of each aircraft by more than 50 kilogrammes and corresponds to an emissions saving of more than 1,900 tonnes of CO_2 a year. • Light components produced by a 3D Printing In an Airbus A320, a wall that divides kitchen and passenger area was made by a 3D printer. Its weighs just as half as much as the original (35 kilograms). • Reduction of cable Wireless networks on board replace the heavy cabling of passenger seats. By eliminating many kilometres of cable and other components the aircraft becomes much lighter: An Airbus A340-600 can save about 900 kilograms.
Start Date	2010
Date of full implementation	-
Economic Cost	Moderate investment volume
List of Stakeholders involved	• Air Berlin PLC & Co. Luftverkehrs KG • Condor Flugdienst GmbH • Lufthansa Group • TUIfly GmbH

Incremental improvements / benefits for each measure

YEAR	n/a
Improvement in Total Fuel	Improvement depends on type of aircraft, weight and distance: • e.g. on a flight from Berlin to Tenerife (5 h) with a Boeing 737 with 100 kg less weight, fuel savings are 14 litres • 1 kg less weight on e.g. all aircraft of Lufthansa Passage saves 29 t fuel per year

Point of contact for this measure

Bundesverband der Deutschen Luftverkehrswirtschaft (BDL) - German Aviation Association
www.bdl.aero
Uta Maria Pfeiffer, Head of Sustainability, uta-maria.pfeiffer@bdl.aero

C.6 Airberlin fuel coaches

Title	**Airberlin fuel coaches**
Description	More efficient operations
Category	Best Practice in Operations
Measure	Training Pilots
Action	airberlin trains its pilots in eco-efficient flying techniques by means of a special advanced training programme. Equipped with their specialist expertise, the 60 trained Fuel Coaches use even less fuel on airberlin flights. It is not a question of filling up less fuel, however, but of using less of the fuel which is available in the tank. If there are unforeseen changes to the flight route this can even increase passenger safety. Once the Fuel Coaches have completed their advanced training, they pass on their expertise to other pilots on coaching flights, known as Fuel Efficiency Flights.
Start Date	2012
Date of full implementation	-
Economic Cost	Moderate investment volume
List of Stakeholders involved	• Air Berlin PLC & Co. Luftverkehrs KG

Incremental improvements / benefits for each measure

YEAR	2014
Improvement in Total Fuel	1000 t fuel/a

C.7 Lufthansa “Fuel Order Model”

Title	**Lufthansa “Fuel Order Model”**
Description	More efficient operations
Category	Innovation and digitalization
Measure	Enhancing fuel order process
Action	The project Fuel Order Model is to support pilots on the basis of comprehensive information and an improved user interface in calculating the optimum quantity of reserve fuel while taking safety and economic aspects into account. An important consideration is to make the empirical values available after a flight to other pilots for the benefit of their future fuel decisions.
Start Date	2018
Date of full implementation	-
Economic Cost	Low six-digit amount of euro
List of Stakeholders involved	• Lufthansa Technik • Lufthansa Systems • Honeywell

Incremental improvements / benefits for each measure

YEAR	n/a
Improvement in Total Fuel (t)	
Improvement in Total Fuel (%)	n/a
Improvement in Total CO_2 Emissions (t)	4,500t CO_2 p.a.
Improvement in Total CO_2 Emissions (%)	n/a

Point of contact for this measure

Deutsche Lufthansa AG, www.lufthansa.com
Bernhard Dietrich, Head of Environmental Issues, Bernhard.Dietrich@dlh.de

C.8 Use of alternative drive technologies at Fraport AG (Frankfurt Airport)

Title	**Use of alternative drive technologies at Fraport AG (Frankfurt Airport)**
Description	Technological Improvement
Category	Alternative Fuels at Airports
Measure	Operations with alternative fuels
Action	Potential CO_2 savings were identified in the company fleet totaling around 1,900 t CO_2 p.a. in 2020, nearly 6 percent of the total CO_2 emissions (Scope 1 GHG) of Fraport AG. Gradual implementation is planned until 2020. Previously deployed: • 11 electric pallet loader • 1 electric container pallet transporter • 6 serial hybrid tow tractors in baggage handling • 10 electric tow tractors in baggage handling • 30 small electric tow tractors • 7 electric conveyor-belts • 1 electric passenger stair • 14 electric cars • 15 plug in hybrid cars • 5 electric minibuses • 9 e-bikes About 240 tons CO_2-reduction implemented (31.12.2017)
Start Date	2010
Date of full implementation	2020
Economic Cost	n/a
List of Stakeholders involved	Producer of vehicles

Incremental improvements / benefits for each measure

YEAR	2010 – 2020
Improvement in Total CO2 Emissions (t)	1,900 t CO_2 p.a.
Anticipated co-benefits	• no engine noise • improvement of air quality • less fuel costs

Point of contact for this measure

Fraport AG, www.fraport.de

Dr. Wolfgang Scholze, Head of Environmental Management, w.scholze@fraport.de

C.9 Energy-optimized planning of Terminal 3 at Fraport AG (Frankfurt Airport)

Title	**Energy-optimized construction of Terminal 3 at Frankfurt Airport**
Description	Technological Improvement
Category	Alternative Fuels at Airports and improved Infrastructure Use
Measure	Operations with alternative fuels and more efficient terminal operations
Action	Terminal 3 is currently in planning stage. Several measures are planned to minimize energy consumption and CO_2 emissions: • Highly thermal-insulated façade • External sunscreen • Free-cooling system to cover 30 percent of the demand (cooling fins installed on the roof) • Use of lost heat from baggage transport system for heating purposes • Efficient use of daylight and LED lighting
Start Date	2018 (start of construction)
Date of full implementation	2022
Economic Cost	Additional costs for the high energy efficiency cannot be separated from the construction costs.
List of Stakeholders involved	Fraport AG

Incremental improvements / benefits for each measure

YEAR	2022
Improvement in Total CO_2 Emissions (kg)	Not yet calculated
Anticipated co-benefits	• less costs for heating and cooling • electricity savings for lighting and air-conditioning units

Point of contact for this measure
Fraport AG, www.fraport.de
Dr. Wolfgang Scholze, Head of Environmental Management, w.scholze@fraport.de

C.10 Energy optimization of Terminals 1 and 2 at Frankfurt Airport (Fraport AG)

Title	**Energy optimization of Terminals 1 and 2 at Frankfurt Airport (Fraport AG)**
Description	Technological and Operational Improvement
Category	Improved Infrastructure Use
Measure	More efficient terminal operations
Action	Potential CO_2 savings were identified totaling around 41,000 t CO_2 p.a. between 2005 and 2020. The savings split in • Refurbishment of defined ventilation control centers: - total potential about 7,100 t CO_2, - 3,300 t CO_2 have been implemented (31.12.2017), - a further 3,800 t CO_2 to be implemented. • Advanced Energy Management of HCV-centers: - Potential about 28,300 t CO_2 - 12,600 t CO_2 have been implemented (31.12.2017) - a further 15,700 t CO_2 to be implemented • Replacement of lightning bulbs by LED - total potential about 6,000 t CO_2, - 1,500 t CO_2 have been implemented (31.12.2017), - a further 4,500 t CO_2 to be implemented.
Start Date	2005
Date of full implementation	2020
Economic Cost	n/a
List of Stakeholders involved	n/a

Incremental improvements / benefits for each measure

YEAR	2005 – 2020
Improvement in Total CO_2 Emissions (t)	41,000 t CO_2 p.a.
Anticipated co-benefits	less costs for heating and cooling

Point of contact for this measure
Fraport AG, www.fraport.de
Dr. Wolfgang Scholze, Head of Environmental Management, w.scholze@fraport.de

C.11 Energy optimization of Service Buildings at Frankfurt Airport (Fraport AG)

Title	**Energy optimization of Service Buildings at Frankfurt Airport (Fraport AG)**
Description	Technological and Operational Improvement
Category	Improved Infrastructure Use
Measure	More efficient operations
Action	Potential CO_2 savings were identified in the existing service and administration buildings totaling around 4,900 t CO_2 p.a. between 2005 and 2020. The savings split in • Refurbishment of ventilation control centers: - total potential about 4,600 t CO_2, - 2,000 t CO_2 have been implemented (31.12.2017), - a further 2,600 t CO_2 to be implemented. • Replacement of lightning bulbs by LED - total potential about 260 t CO_2, - 160 t CO_2 have been implemented (31.12.2017), - a further 100 t CO_2 to be implemented.
Start Date	2005
Date of full implementation	2020
Economic Cost	Not for public disclosure
List of Stakeholders involved	n/a

Incremental improvements / benefits for each measure

YEAR	2005 – 2020
Improvement in Total CO2 Emissions (t)	4,900 t CO_2 p.a.
Anticipated co-benefits	less costs for heating and cooling

Point of contact for this measure

Fraport AG, www.fraport.de

Dr. Wolfgang Scholze, Head of Environmental Management, w.scholze@fraport.de

C.12 Reduced energy consumption within the Baggage Handling System at Fraport AG (Frankfurt Airport)

Title	**Reduced energy consumption within the Baggage Handling System (BHS) at Fraport AG (Frankfurt Airport)**
Description	Technological Improvement
Category	Improved Infrastructure Use
Measure	Downsizing of conveyor drives of the BHS
Action	Potential CO_2 savings were identified by means of replacing about 2,500 drives (IE1 standard) with more efficient and downsized conveyor drives in IE4 standard. The replacement is implemented step-by-step, while the BHS is in full operation. Replaced are drives in heavily used sections like early bag stores and main distribution lines, mostly running 20 hours per day continuously. The potential savings amount to 3,900 t CO_2 p.a. About 1,500 tons CO_2-reduction implemented (2017)
Start Date	2015
Date of full implementation	2020
Economic Cost	Not for public disclosure
List of Stakeholders involved	n/a

Incremental improvements / benefits for each measure

YEAR	2015 – 2020
Improvement in Total CO_2 Emissions (t)	3,900 t CO_2 p.a.
Anticipated co-benefits	Less wear and tear of conveyors

Point of contact for this measure
Fraport AG, www.fraport.de
Dr. Wolfgang Scholze, Head of Environmental Management, w.scholze@fraport.de

C.13 Energy optimization of Parking Garages at Frankfurt Airport (Fraport AG)

Title	**Energy optimization of Parking Garages at Frankfurt Airport (Fraport AG)**
Description	Technological and Operational Improvement
Category	Improved Infrastructure Use
Measure	More efficient operations
Action	The savings derive from the replacement of lightning bulbs by LED. Potential CO_2 savings were identified in the existing parking garages totaling around 2,700 t CO_2 p.a. between 2015 and 2020. 400 t CO_2 have been implemented (31.12.2017), a further 2,300 t CO_2 to be implemented.
Start Date	2015
Date of full implementation	2020
Economic Cost	n/a
List of Stakeholders involved	n/a

Incremental improvements / benefits for each measure

YEAR	2015 – 2020
Improvement in Total CO2 Emissions (t)	2,700 t CO_2 p.a.
Anticipated co-benefits	less costs for electricity

Point of contact for this measure
Fraport AG, www.fraport.de
Dr. Wolfgang Scholze, Head of Environmental Management, w.scholze@fraport.de

C.14 Reduced Energy consumption in the apron at Frankfurt Airport (Fraport AG)

Title	**Reduced energy consumption in the apron at Frankfurt Airport (Fraport AG)**
Description	Technological and Operational Improvement
Category	Improved Infrastructure Use
Measure	More efficient operations
Action	The savings derive from the replacement of lightning bulbs by LED. Potential CO_2 savings were identified totaling around 1,900 t CO_2 p.a. between 2015 and 2025. 900 t CO_2 have been implemented (31.12.2017), a further 1,000 t CO_2 to be implemented.
Start Date	2015
Date of full implementation	2025
Economic Cost	Not for public disclosure
List of Stakeholders involved	n/a

Incremental improvements / benefits for each measure

YEAR	2015 – 2025
Improvement in Total CO2 Emissions (t)	1,900 t CO_2 p.a.
Anticipated co-benefits	less costs for electricity

Point of contact for this measure
Fraport AG, www.fraport.de

Dr. Wolfgang Scholze, Head of Environmental Management, w.scholze@fraport.de

C.15 Energy Efficient lighting at Munich Airport

Title	**Energy Efficient lighting at Munich Airport**
Description	Technological improvement
Category	Energy efficiency at Airports
Measure	Changing to energy-saving LED technology for lighting
Action	In order to increase energy efficiency and reduce CO_2-emissions, Munich Airport replaced apron, road, building and park deck lighting with highly efficient LED-technology. In contrast to sodium-high-pressure-lamps, this saves up to 50% of energy and reduces costs of maintenance and operating. In addition the light of the LEDs is more natural as the orange tinted light of the sodium-high-pressure-lamps, this providing a safer working environment for night shifts. The replacement of fluorescent or other lighting by LED systems saves about 2,600 t of CO_2 per year at aprons, where 185,000 LEDs have been installed. The savings at roads, inside the buildings or park decks are 10,600 t of CO_2 per year. The annual savings from reduced electricity costs amount to € 3 Mio.
Start Date	2009
Date of full implementation	n/a
Economic Cost	Total costs of a few million Euro
List of Stakeholders involved	Munich Airport

Incremental improvements / benefits for each measure

YEAR	n/a
Improvement in CO_2 Emissions (t)	Saving about 13,000 t CO_2 per year
Anticipated co-benefits	The more natural light colour of LEDs has proven very acceptable for employees working in night shifts. Employees show fewer signs of fatigue, the colour recognition is improved and apron safety and productivity are increased.

Point of contact for this measure

Flughafen München GmbH, www.munich-airport.de
Günter Sellmeier, guenter.sellmeier@munich-airport.de

C.16 Pre-conditioned air at Munich Airport

Title	**Pre-conditioned air at Munich Airport**
Description	Technological and operational improvement
Category	Best practice at Airports
Measure	Using pre-conditioned-air systems for air conditioning of aircraft on the ground
Action	Innovative systems for the air conditioning of aircraft on the ground, so-called pre-conditioned-air systems (PCA) have been installed at Munich Airport. All near parking positions at Terminal 1, Terminal 2 and at the satellite are equipped with PCA – 64 systems in total. Unlike the technology used so far, where the less effective auxiliary power units (APU) of the aircraft provided the energy for the air conditioning, the aircraft in their parking positions are supplied in addition to power with the pre-conditioned air which has been generated in a highly efficient manner by the Airport. Airlines are advised to use PCA in the parking position instead of their auxiliary engines for the air conditioning on board. This is induced by a PCA-fee, which has to be paid to the airport operator when parking at a PCA equipped position – even if the airline denies its use.
Start Date	Project study in 2009 and start of tender process in 2012
Date of full implementation	End of 2016
Economic Cost	Total costs of about € 32 Mio.
List of Stakeholders involved	• Flughafen München GmbH (FMG) • Terminal 2 Gesellschaft mbH & Co oHG • Flughafen München Baugesellschaft mbH

Incremental improvements / benefits for each measure

YEAR	n/a
Improvement in CO_2 Emissions (t)	Savings potential of 23,500 t CO_2 per year
Anticipated co-benefits	Noise reduction, saving kerosene and significant reduction in nitrogen oxide without using the auxiliary power unit (APU)

Point of contact for this measure

Flughafen München GmbH, www.munich-airport.de
Maximilian Hartwig, maximilian.hartwig@munich-airport.de

C.17 Use of alternative drive technologies at Flughafen München GmbH (Munich Airport)

Title	**Use of alternative drive technologies at Flughafen München GmbH (Munich Airport)**
Description	Technological Improvement
Category	Alternative Fuels at Airports
Measure	Operations with alternative fuels
Action	• Already in operation: - 186 electric airside vehicles: ➢ 53 Airport tractor ➢ 66 luggage conveyor belt ➢ 25 draggable passenger stairs ➢ 36 self-driving passenger stairs ➢ 6 lifting platforms - 82 hybrid equipment tractors - 30 natural gas vehicles • Invest in electric vehicles (government-sponsored) → Substitution of 121 conventional cars with EVs (25 running, 30 ordered) • Implementing "CARE-Diesel" for chosen vehicle types: Fuel from renewable raw materials and fat residues. Replaces conventional fossil diesel and can be used by all airside vehicles. CO_2-Reduction of up to 100%.
Start Date	2017
Date of full implementation	2019
List of Stakeholders involved	Producer of vehicles and CARE-Diesel supplier

Incremental improvements / benefits for each measure

YEAR	2017 – 2019
Improvement in Total CO_2 Emissions (t)	2,500 t CO_2 p.a.
Anticipated co-benefits	• No engine noise (EV) • Less fuel costs (EV) • Improvement of air quality (EV and CARE-Diesel)

Point of contact for this measure

Flughafen München GmbH, www.munich-airport.de
Günther Schmitz, Head of Fleet Management, guenther.schmitz@munich-airport.de

C.18 BDL-Forum »energy efficiency and climate protection in aviation«

Title	**BDL-Forum »energy efficiency and climate protection in aviation«**
Description	Communicative Improvement
Category	Regulatory measures / Other
Measure	Conferences / workshops
Action	Air transport has many issues that reach far into the society. As part of the BDL-Forum, a new series of the German Aviation Association is ideal for a broad dialogue on their topics. The first event was held in June 2012 in cooperation with the German Energy Agency GmbH (dena). About 120 guests from politics and administration, business and science, but also from environmental organizations, the media and interested public discussed in Berlin. The second event on climate protection in aviation took place in 2016. The aim of this BDL Forum was to inform 160 participants on a wide variety of issues relating to climate protection in the industry. The spectrum ranged from the climate impact of air traffic to ICAO's global market-based climate protection measures as well as future concepts in aviation.
Start Date	2012
List of Stakeholders involved	• Bundesverband der Deutschen Luftverkehrswirtschaft (BDL) - German Aviation Association • Deutsche Energieagentur GmbH (dena) - German Energy Agency GmbH Representatives of • German Parliament • German Federal Ministry of Transport and Digital Infrastructure • Public authorities • NGOs • Science • Transport associations • Aviation industry

Additional information
Further information: https://www.bdl.aero/de/veranstaltungen/bdl-foren/klimaschutz-im-luftverkehr/

Point of contact for this measure
Bundesverband der Deutschen Luftverkehrswirtschaft (BDL) - German Aviation Association, www.bdl.aero
Uta Maria Pfeiffer, Head of Sustainability, uta-maria.pfeiffer@bdl.aero

C.19 BDL-report »energy efficiency and climate protection in aviation«

Title	**BDL-report »energy efficiency and climate protection in aviation«**
Description	Communicative Improvement
Category	Regulatory measures / Other
Measure	Annual Report
Action	In the Aviation Energy Efficiency and Climate Protection Report, the German Aviation Association (BDL) presents the key indicators as well as the strategies and measures that lead to improved energy efficiency and climate protection.
Start Date	2012
List of Stakeholders involved	Bundesverband der Deutschen Luftverkehrswirtschaft (BDL) - German Aviation Association Representatives of • German Parliament • Public authorities • NGOs • Science • Transport associations • Aviation industry

Additional information
Further information: https://www.bdl.aero/de/veroffentlichungen/klimaschutzreport_2017/

Point of contact for this measure
Bundesverband der Deutschen Luftverkehrswirtschaft (BDL) - German Aviation Association
www.bdl.aero
Uta Maria Pfeiffer, Head of Sustainability, uta-maria.pfeiffer@bdl.aero

Category D:

Examples of research funded by the National Aviation Research Programme (LuFo)

D.1 Development of an improved oil system for a power gearbox for large aeroengines

Title	**Development of an improved oil system for a power gearbox for large aeroengines**
Description	Improved oil system of an engine with high-performance transmission: Simulation, Architecture and Technologies
Category	Propulsion System
Measure	Improvement of the oil system for power gearbox
Action	The oil system is one of the safety critical components in a geared turbofan. It equally determines propulsive efficiency. The project addresses the generation of knowledge about heat generation in high performance gearboxes (gear and bearing friction, wind age etc.) and the development of a model for heat flux propagation and efficient heat dissipation mechanisms.
Start Date	2018
Date of full implementation	2020
List of Stakeholders involved	Rolls-Royce Deutschland Ltd & Co KG

Incremental improvements / benefits for each measure

YEAR	2018 – 2020
Improvement in Total CO_2 Emissions (t)	Rolls-Royce UltraFan aiming at SFC reduction of 30% at aircraft level
Anticipated co-benefits	Rolls-Royce UltraFan aiming at noise reduction of 15 dB

Point of contact for this measure
Rolls-Royce Deutschland Ltd & Co KG, 15827 Blankenfelde-Mahlow, www.rolls-royce.com

D.2 Use of improved planning and realization of flight trajectories with minimal ecological foot print

Title	**Use of improved planning and realization of flight trajectories with minimal ecological foot print**
Description	Integration of calculation methods for the determination of ecological optimized trajectories in of airlines flight-planning-tools and their realization in the cockpit
Category	Ecologically efficient flying
Measure	New flight-planning-tools and their realization in the cockpit
Action	The project's goal is the further reduction of emissions and kerosene consumption and thus an additional increase in efficiency of aircraft as a mean of transport through the implementation and use of innovative processes and systems. An effective way to reduce the environmental footprint of aviation is to optimize the flight path. At the outset, flight profiles are calculated in advance with the stated objective and transmitted to systems in the aircraft. On-board, existing pilot interfaces are specifically provided with this information to provide an intuitive picture of the quality of compliance with the previously calculated profiles.
Start Date	2017
Date of full implementation	2020
Economic Cost	Not to be published
List of Stakeholders involved	Jeppesen GmbH GfL Gesellschaft für Luftverkehrsforschung mbH Technische Universität Dresden

Incremental improvements / benefits for each measure

YEAR	2017 – 2020
Improvement in Total CO_2 Emissions (t)	n/a – depending on flight route, aircraft model, traffic and weather conditions
Anticipated co-benefits	Reduction of condensation trails

Point of contact for this measure

Jeppesen GmbH, Frankfurter Str. 233, 63262 Neu-Isenburg, www.jeppesen.com