An Roinn Iompair,
Turasóireachta agus Spóirt
Department of Transport,
Tourism and Sport

Ireland's Action Plan for Aviation Emissions Reduction

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Principal National Point of Contact

Mr. Brian Smyth

Assistant Principal Officer

Aviation Services Division

Department of Transport, Tourism and Sport

Leeson Lane

Dublin 02 TR60

Ireland.

Telephone: +353 1 604 1120

Email: BrianSmyth@dttas.gov.ie

Alternate Contact

Ms. Laura Cawley

Administrative Officer

Aviation Services Division

Department of Transport, Tourism and Sport

Leeson Lane

Dublin D02 TR60

Ireland.

Telephone: +353 1 604 1547

Email: LauraCawley@dttas.gov.ie

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Common Preamble

a. Ireland is a member of the European Union, 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. Ireland, 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. Ireland 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. This is the action plan of Ireland.

f. Ireland 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,

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

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

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 1 of this Action Plan, where the involvement of Ireland is described, as well as that of other stakeholders.

h. In Ireland a number of actions are undertaken at the national level, including those by stakeholders. These national actions are reported in Section 2 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).

Introduction - Current State of Aviation in Ireland

The Irish aviation and aerospace industry operates within a legislative and regulatory framework established at national, EU and international level. A number of oversight processes exist with the legal system as the overriding entity, including;

- State Obligations under International Conventions and European legislation
- Safety Regulation
- Environmental Regulation
- Economic Regulation
- Planning Regulation
- Company, Financial and Other regulation
- Industry Incentives and the Tax System

The components of the aviation and aerospace industry include:

- Airlines and General Aviation,
- Airports and Air Traffic Management infrastructure
- Maintenance, Repair and Overhaul and ancillary services
- Leasing and International trade
- Banking and Legal Services
- Aviation Services
- Sports aviation

In terms of aviation activity, the following sections provide an overview in respect of:

- Provision of air traffic control services
- Passenger and freight numbers
- Main air routes
- Aircraft registrations
- Main air carriers and fleet characteristics, and
- Employment

Air Traffic Control Service in Ireland

Air navigation services are provided by the Irish Aviation Authority (IAA) on behalf of the State in accordance with international standards laid down by the International Civil Aviation Organisation (ICAO), EUROCONTROL and others.

Three core services are provided:

1. Terminal services at airports;
2. En-route services (the most significant of which relates to Ireland's position as the gateway between Europe and North America); and
3. High Frequency (HF) Communications in the Shanwick Flight Information Region or North Atlantic airspace, which is assigned by ICAO to Ireland and the UK.

Ireland's air traffic controlled airspace comprises 451,000 square kilometres. This airspace lies at the interface between Europe and North America and up to 90% of all aircraft transiting between Europe and North America fly through parts of this area. This equates to approximately 1,400 – 1,500 aircraft every 24 hours during the busy summer months. These are flights that do not land at Irish airports. It is unique en route airspace in the sense that it connects North Atlantic traffic flows (which operate in a non-radar environment) with the European air traffic management (ATM) network (which is a radar environment). In 2018, Shannon air traffic control safely handled over 345,000 flights. The IAA's Free Route Airspace delivers savings of 195,500 minutes of flight time, resulting in savings of 14,800 tonnes of fuel and the saving of 46,800 tonnes of CO_2 each year.

The IAA is responsible for the management of Irish controlled airspace and the safety and security regulation of Irish civil aviation. Air traffic management includes the provision of operational services namely Air Traffic Control (ATC), engineering and communications in airspace controlled by Ireland and the provision of the related air traffic technological infrastructure. The safety and security oversight functions of the IAA reside in the Safety Regulation Division. The IAA ensures that Irish civil aviation operates to safety standards set internationally.

The IAA is responsible for ATM. The ATM Operations & Strategy Directorate of the Irish Aviation Authority provides air traffic management services in airspace controlled by Ireland.

Air traffic management services include:

- Air traffic control
- Flight information
- Alerting
- Aeronautical information
- North Atlantic Communications

In 2018, almost 1,152,000 flights were safely managed by Irish air traffic controllers and radio officers in Irish airspace. This was the busiest year on record for the IAA, with an increase of 1.4% on traffic levels in 2017.

Passenger and Freight Numbers

Airports

Ireland's airport infrastructure consists mainly of three State-owned airports (Dublin, Cork and Shannon) and six designated regional airports (Ireland West Knock, Kerry, Galway, Waterford, Donegal and Sligo). Dublin Airport is Ireland's largest airport with a total of 31,495,604 passengers in 2018, which is an increase of 6% on 2017 passenger numbers. In the 2018 peak season, Dublin Airport had flights to 195 destinations in 42 countries, operated by 56 airlines.

Cork is the second largest State Airport, with 2,392,821 passengers in 2018, followed by Shannon Airport, with a total of 1,751,500 passengers in 2017. Dublin and Cork airports are managed by the Dublin Airport Authority plc. (daa), an airport management company, while Shannon Airport is managed by Shannon Airport Authority DAC.

Table 1 Dublin Airport Total 2018 Traffic Breakdown and State Airports Passengers Numbers (Millions) 2014-2018

Dublin Airport Total 2018 - Traffic Breakdown		
Traffic Breakdown	Passengers (Million's)	Increase
Domestic	.1	18%
Europe (non-UK)	16.3	7%
Other Intl.	1.0	17%
Transatlantic	4.0	16%
UK	10.1	1%
Total Traffic	31.5	
Total Traffic 2014	21.7	
Growth 2018 v 14	45%	

State Airports Passengers Numbers (Millions) 2014 - 2018						
	2014	2015	2016	2017	2018	Growth 2018 v 2017
Dublin	21.7	25	27.9	29.6	31.5	6%
Cork	2.1	2	2.2	2.3	2.4	4%
Shannon	1.6	1.7	1.7	1.7	1.9	12%
Total	25.4	28.7	31.8	33.6	35.8	7%

Since 2012 the number of passengers availing of Ireland's five main airports[2] has increased by 45.5% which equates to an additional 10.8 million passengers. In the third quarter of 2018, over 11.1 million passengers passed through the five main airports, an increase of 5.8% over the same period in 2017. Over 76,000 flights were handled by Ireland's five main airports in the third quarter of 2018. Dublin accounted for 82.5% of all flights (63,032) while Cork handled 8.2% of all flights (6,274).

[2] A main airport is defined as an airport through which in excess of 150,000 passengers fly per annum. The five main airports in Ireland are Dublin, Cork, Shannon, Knock and Kerry.

Table 2 Number of passengers handled by main airports, Quarter 3 2016-2018

Number of passengers handled by main airports, Quarter 3 2016-2018				
	Quarter 3			
Airport	2016	2017	2018	% change 2017-2018
Dublin	8,361,602	8,893,941	9,431,013	+6.0
Cork	706,690	752,138	773,012	+2.8
Shannon	562,727	531,272	561,411	+5.7
Knock	253,870	244,849	251,687	+2.8
Kerry	104,956	102,166	114,010	+11.6
Total	**9,989,845**	**10,524,366**	**11,131,133**	**+5.8**

Regional Airports[3]

The designated regional airports are: Donegal, Ireland West Knock, Kerry, and Waterford. These airports represent access points for both business and tourism.

Freight

Ireland's main airports handled a total of 39,261 tonnes of freight in the third quarter of 2018, the vast majority (93.8%) of which was international freight.

Table 3 Air freight classified by national and international traffic handled by main airports, Quarter 3 2018

Air freight classified by national and international traffic handled by main airports, Quarter 3 2018					
Traffic	Cork	Dublin	Knock	Shannon	Total Tonnes
National freight traffic	0	1,307	0	1,133	2,440
International freight traffic	14	34,499	3	2,304	36,821
All freight	**14**	**35,806**	**3**	**3,437**	**39,261**

Main Air Routes

Ireland's five main airports served 267 scheduled routes in 2017. The UK is the largest market for passengers travelling from Irish airports. London is a particularly vital route for the Irish market with Heathrow, Gatwick and Stansted accounting for 5,842,039 passengers in 2017.

London-Heathrow, London-Gatwick and Amsterdam-Schiphol were the most popular routes for passengers for Dublin airport in 2018. In Cork airport, the top three routes were London-Heathrow, London-Stansted and Malaga. The top route for Shannon was London-Heathrow, the top route for Knock was London-Stansted and the top route for Kerry was

[3] A regional airport is defined as an airport through which less than 150,000 passengers fly per annum.

London-Luton. In 2016, the Dublin-London-Heathrow route was the 12th busiest route in Europe, with 1,751,689 passengers travelling on that route. In 2018, the Dublin–London air route was the busiest air route in Europe, and the 2nd busiest international route in the world, carrying just over 5 million passengers.

In the first quarter of 2018, more than eight out of every ten passengers (83.8%) on international flights in the five main airports were travelling to or from Europe. The two most popular countries of origin/destination were the United Kingdom and Spain. Outside of Europe, the United States of America was the most popular country of origin/destination in the third quarter of 2018.

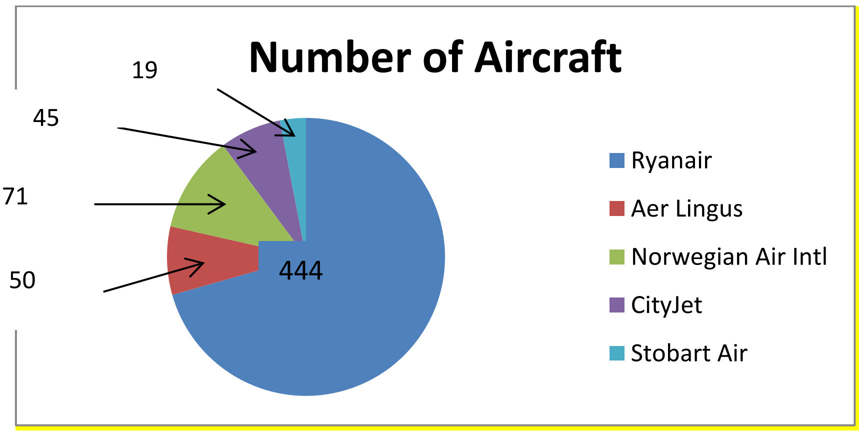
Irish Aircraft Registrations

The rapid growth in aviation activity over the past 20 years in Ireland is reflected in the increase of organisations active in the sector with increasingly influential players in a highly complex sector. This upsurge is also reflected in the growth of the Irish Aircraft Register. In September 2018, there were 1,422 aircraft registered in Ireland.

Main Irish Air Carriers and Fleet Characteristics

Irish air carriers continue to grow and increase their presence in both European and International markets. The 5 main carriers (Ryanair, Aer Lingus, Norwegian Air International, Cityjet and Stobart Air) account for a total of 629 aircraft and a further total of 175 aircraft to be delivered by 2024.

Figure 1 Number of Aircraft



In terms of Air Operator Certificates (AOC) on the Irish register, Ryanair is by far the largest Irish carrier, and 2nd largest in Europe in terms of passengers carried. As of September 2018, Ryanair have over 450 Boeing 737 aircraft in its fleet, with orders for 115 new Boeing 737 aircraft and a further 110 new Boeing 737 MAX 200.

Aer Lingus operate circa 50 aircraft; predominantly a mixture of Airbus A320, Airbus A321 (narrow body short-haul operations) and A330 (twin-aisle wide body aircraft for long and short-haul operations). Aer Lingus partner, ASL operates the Boeing 757 on a number of transatlantic routes, Ireland to North America East Coast. In addition, Aer Lingus currently lease 2 RJ-85 aircraft from CityJet.

Norwegian Air International, a subsidiary of Norwegian Air Shuttle, is the newest Irish carrier, founded in 2014 with a fleet of 65 aircraft comprising of B737-800 and B737 MAX 8 aircraft.

Cityjet predominantly operates wet-lease arrangements for other airlines. Its fleet includes Avro RJ85s and Bombardier CRJ900 aircraft which are operated by SAS Airlines.

Stobart Air operates franchise, wet-lease (ACMI) and charter flights. It has a fleet of 17 ATR aircraft operating regional flights within Ireland, as well as flights to the UK and north-western France under the Aer Lingus Regional banner. Fleet includes 4 Embraer E190 and E195 aircraft.

Aviation and Employment

Aviation plays a critical role in economic activity in Ireland. As an island nation with a focus on export trade, access to overseas markets is central to economic success overall. Ireland's tourism industry is heavily dependent on aviation and it is estimated to employ in excess of 220,000. In 2017, 34.4 million passengers travelled through Ireland's main airports.

Ireland's main airports[4] employ 143,747 people; 21,635 of whom are directly employed by these airports. These airports contribute €10.2 billion to the Irish economy; reflecting 5.1% of Ireland's GNI[5] and 3.5% of GDP[6].

Ireland is the aircraft leasing capital of the world, with Irish aviation leasing industries contributing €541 million to the Irish economy, whilst supporting up to 5,000 jobs. The Maintenance, Repair and Overhaul and related aerospace sector supports in excess of 2600 jobs.

Aviation Emissions in Ireland

Ireland has fully supported European and global efforts to reduce the environmental impact of aviation activities. As a peripheral island State, we are more dependent on air links for business and tourism than countries with land connections to their markets. In this regard, Ireland has always been keen to reduce emissions while ensuring that no competitive distortions arise from any measures introduced that would disproportionately impact on peripheral States such as ours.

Aviation emissions are included in the EU-wide commitment to reduce emissions by 20% in 2020 from 1990 levels, and the EU supports a comprehensive approach to reducing aviation emissions, encompassing progress on technology and standards, operational measures, and market based measures.

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[4] Dublin, Cork, Shannon, Knock and Kerry.

[5] Gross National Input

[6] Gross Domestic Product

Domestic and International Aviation Emissions

The figure for CO_2 emissions associated with Domestic aviation in Ireland was 9.8 kt of CO_2 in 2016. This is about 0.1% of overall transport emissions in Ireland. This figure has been reducing steadily since the mid-2000's.

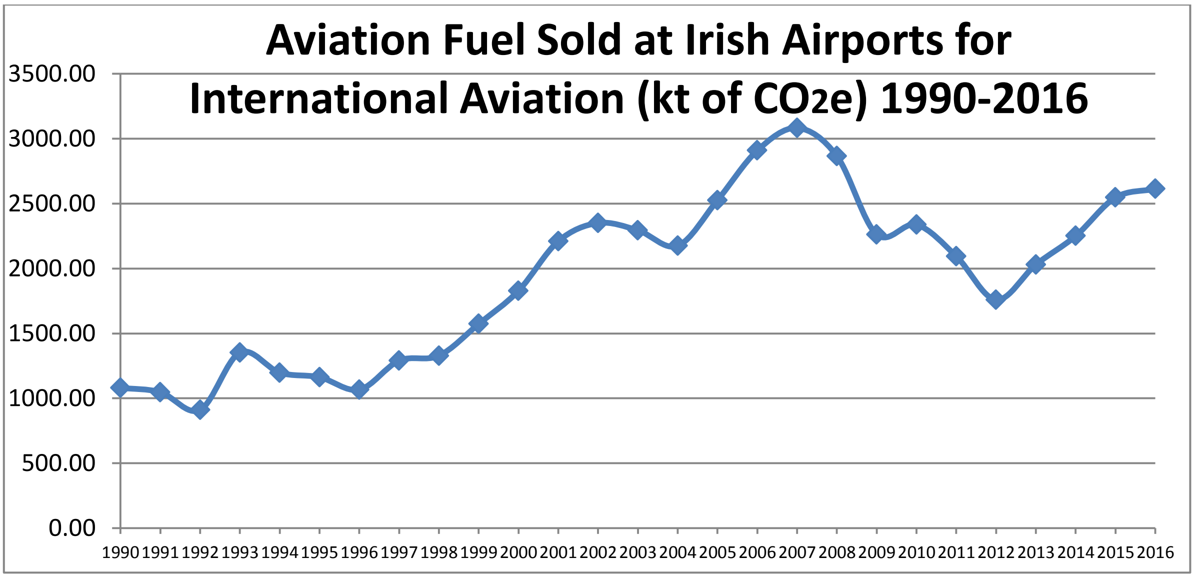
Kerosene jet fuel sold at Irish Airports for International Aviation accounted for almost 21% of all energy used in the transport sector in Ireland (in 2016). The level of aviation emissions peaked in 2007, with over 3,000 kt of CO_2 emitted by Irish airlines following a steady increase from 1996. The peak in aviation emissions in 2007 was largely in line with increased aviation traffic generally. The table and figure below reflect this correlation. Nevertheless, aviation emissions' percentage share of overall transport emissions in Ireland has remained relatively constant since 1990 at around 20%. The anticipated increase in emissions is expected to be less than the actual volume of air traffic due to improving aircraft technology and the significant increase in the acquisition by Irish operators of newer and more environmentally friendly aircraft. Overall, without any intervention, it is expected that the emissions will grow significantly in the future.

Table 4 Irish International Aviation CO_2 Emissions (1990-2014)

Year	CO_2 Emissions (kt CO_2)
1990	1080.55
1991	1047.38
1992	911.28
1993	1352.36
1994	1197.86
1995	1162.56
1996	1066.88
1997	1290.35
1998	1328.53
1999	1573.02
2000	1828.63
2001	2210.77
2002	2350.69
2003	2294.55

2004	2175.30
2005	2526.76
2006	2909.80
2007	3082.87
2008	2866.43
2009	2262.65
2010	2337.80
2011	2094.65
2012	1758.93
2013	2030.52
2014	2250.99

Figure 2 Aviation Fuel Sold at Irish Airports for International Aviation (kt CO_2e) 1990-2016



Section I: ECAC/EU Common Measures

Executive Summary

The European Section of this action plan, which is common to all European State action plans, presents 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.

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.

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.

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.

Economic/Market Based Measures (MBMs)

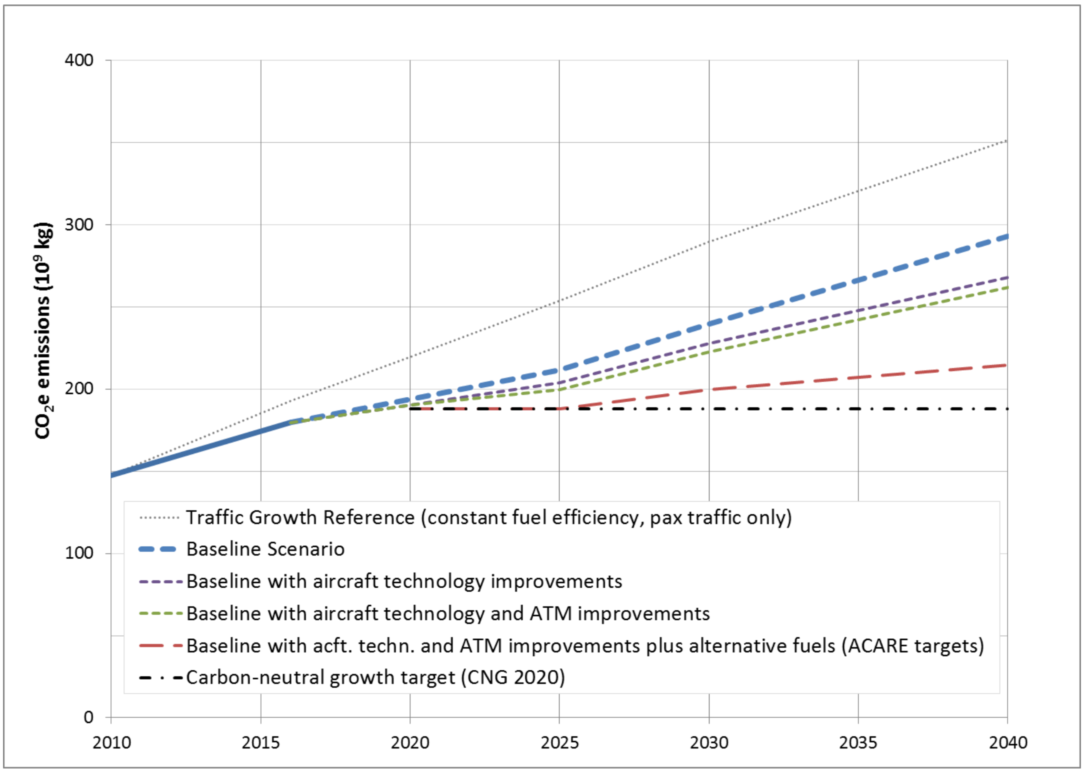
ECAC members have always been strong supporters of a market-based measure scheme for international aviation to incentivise and reward good investment and operational choices, and so welcomed the agreement on the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). The 31 EEA states 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.

ECAC Scenarios for Traffic and CO_2 Emissions

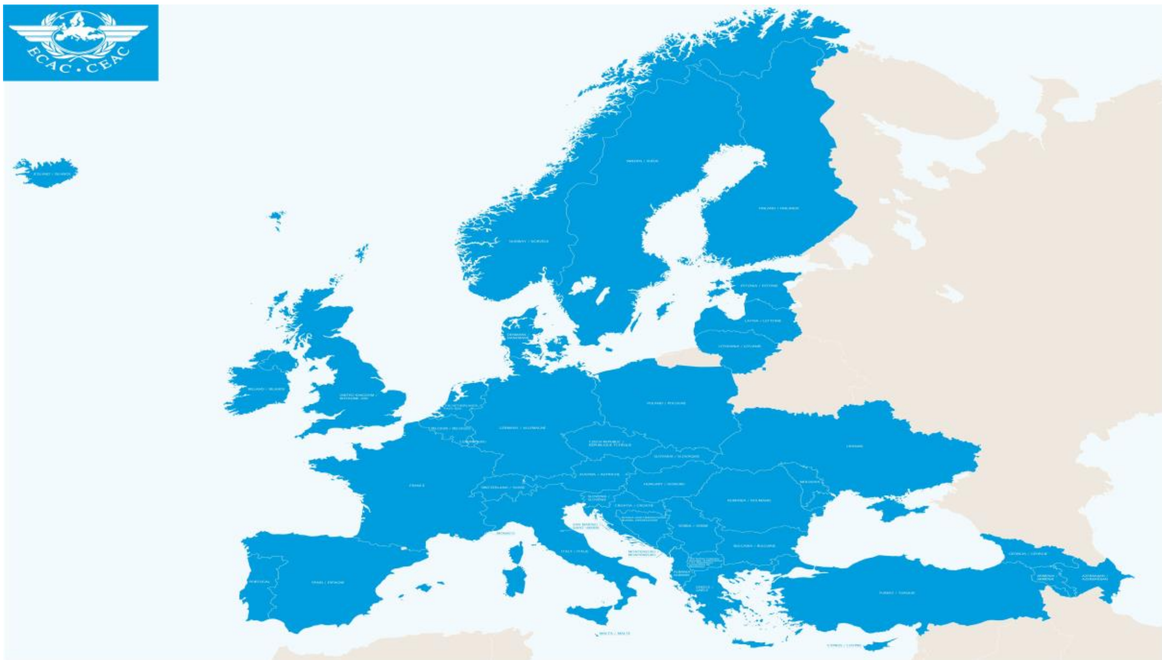
Aviation traffic continues to grow, develop and diversify in many ways across the ECAC states. Whilst the focus of available data relates to passenger traffic, similar issues and comparable outcomes might be anticipated for cargo traffic both as belly hold freight or in dedicated freighters. Analysis 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 3 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 3. 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. ECAC Baseline Scenario



ECAC Baseline Scenario and Estimated Benefits of Implemented Measures

1. 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 levels 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).

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 groups of factors that are taken into account:

- **Global economy** factors represent the key economic developments driving the demand for air transport
- Factors characterising 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 5 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[7] updated in 2018 by EUROCONTROL and presented here. Historical data for the year 2010 are also shown later for reference.

Table 5 Summary characteristics of EUROCONTROL scenarios

[7] Challenges of Growth 2018: Flight forecast, EUROCONTROL September 2018 (to be published)

	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 ➘	Hubs: Mid-East ➚➚ Europe&Turkey ➚	No change ➔

	Turkey↗ Pt-to-pt: N-Atlant.↗↗	Pt-to-pt: N-Atlant.↗	
Market Structure	Industry fleet forecast + STATFOR assumptions	Industry fleet forecast + STATFOR assumptions	Industry fleet forecast + STATFOR assumptions

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[8]). This data, which is presented below, includes both belly cargo transported on passenger flights and freight transported on dedicated all-cargo flights.

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.

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

Table 6 Baseline forecast for international traffic departing from ECAC airports

Year	Passenger Traffic (IFR movement) (million)	Revenue Passenger Kilometres[9] RPK (billion)	All-Cargo Traffic (IFR movements) (million)	Freight Tonne Kilometres transported[10] FTKT (billion)	Total Revenue Tonne Kilometres[14, 11] 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 7 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.				

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

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

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

Figure 4 Forecasted traffic until 2040 (assumed both for the baseline and implemented measures scenarios)

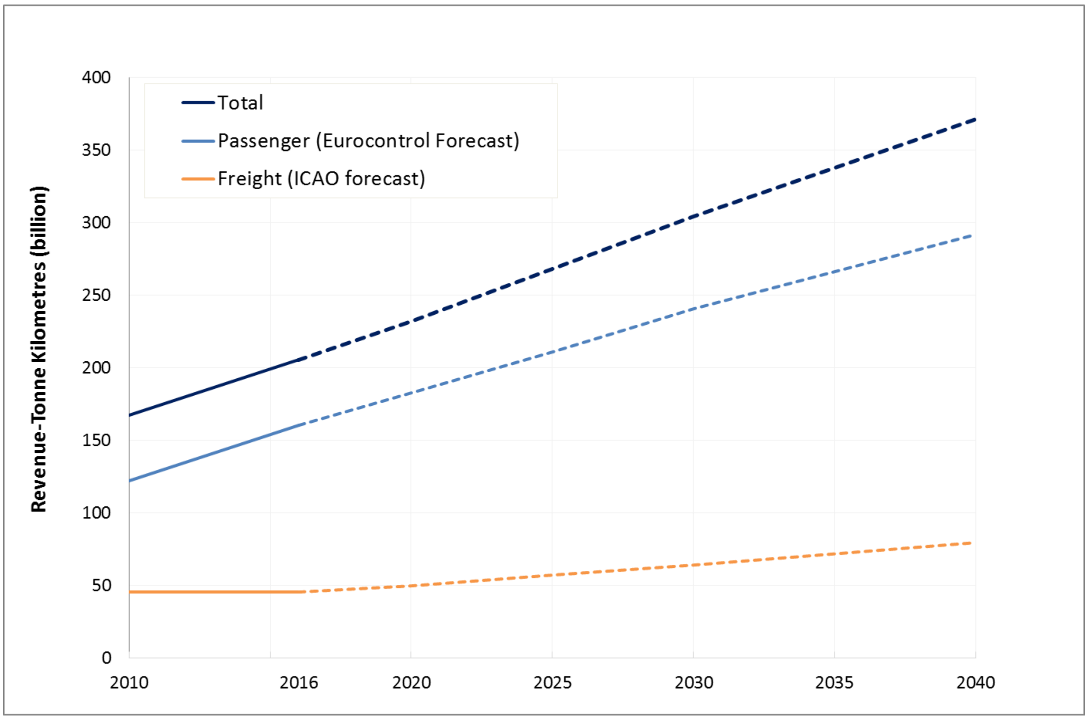
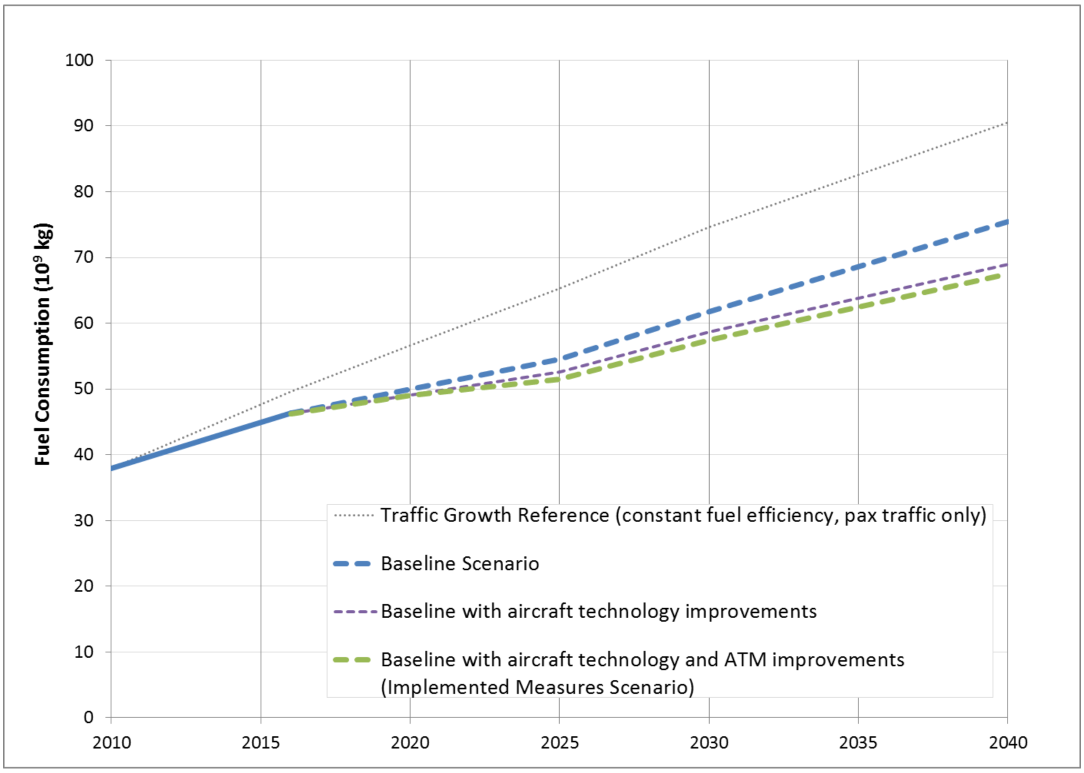


Figure 5 Fuel consumption forecast for the baseline and implemented measures scenarios (international passenger flights departing from ECAC airports)



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[12]. 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[13].

Regarding the **introduction of sustainable alternative fuels,** the European ACARE roadmap targets described in section B chapter 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)[14]. The resulting emission savings are

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

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

[14] 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.

shown in Table 10 and Figure 6 in units of 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[15].

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 (CNG) of aviation, and this target is therefore shown in Figure 6[16].

Tables 8-10 and Figures 5-6 summarize the results for the scenario with implemented measures. It should be noted that Table 8 shows direct combustion emissions of CO_2 (assuming 3.16 kg CO_2 per kg fuel), whereas Table 10 and Figure 6 present equivalent CO_2 emissions on a well-to-wake basis. More detailed tabulated results are found in Appendix A.

Table 8 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.				

15 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.

16 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).

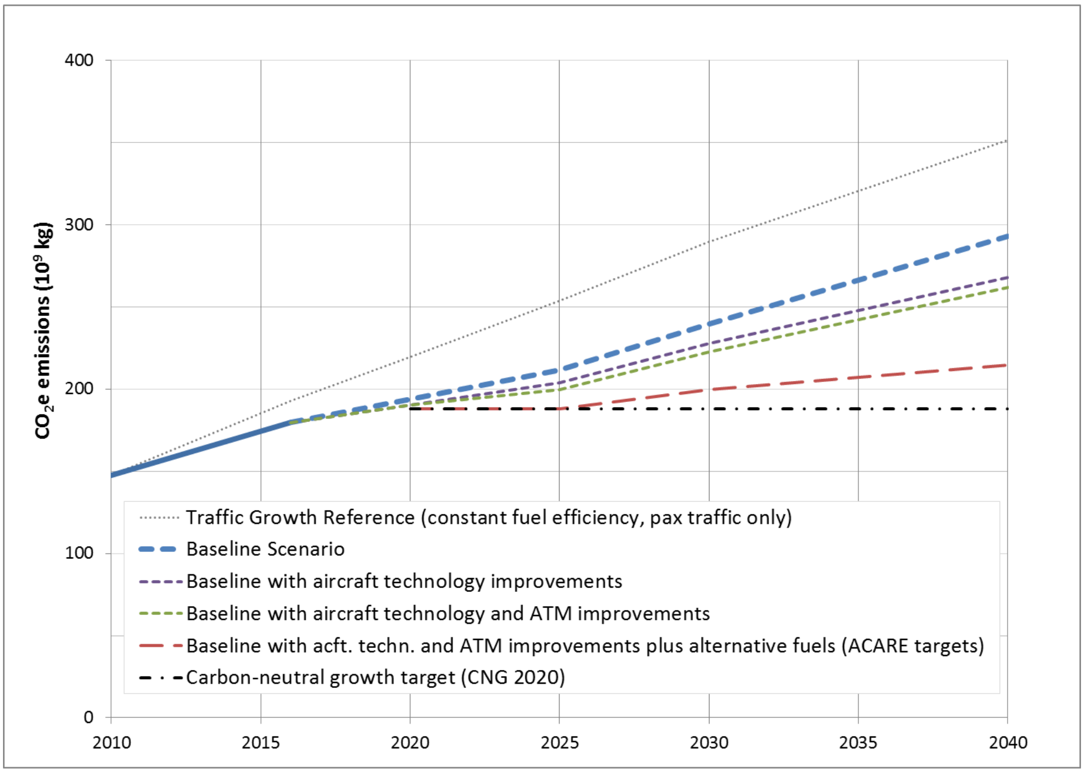
Table 9 Average annual fuel efficiency improvement for the Implemented Measures Scenario (new aircraft technology and ATM improvements only)

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

Table 10 Equivalent (well-to-wake) CO_2e emissions forecasts 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 improvements + 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 6 Equivalent (well-to-wake) CO_2 emissions forecast for the baseline and implemented measures scenarios



As shown in Figures 5-6, 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 6 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.

B. Actions Taken at the Supranational Level

1. Aircraft – Related Technology Development

1.1 Aircraft emissions standards (Europe's contribution to the development of the aeroplane CO_2 standard in CAEP)

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.

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 environmentally 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/

2. Alternative Fuels

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[17]. 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*'.

On 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

[17] 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

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[18]. 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[19]) 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.

In March 2011, the European Commission published a White Paper on transport[20]. 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 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

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

19 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

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

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[21].

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
7. Take concrete actions to inform the European citizen of the benefits of replacing kerosene with certified sustainable biofuels

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.

21 https://ec.europa.eu/energy/sites/ener/files/20130911_a_performing_biofuels_supply_chain.pdf

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: 1 189 Frankfurt-Hamburg flights using 800 tonnes of bio-kerosene (during 6 months period 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 approximately 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)*

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 jetA1.

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

3. The EU's Single European Sky Initiative and SESAR

3.1 SESAR Project

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
- 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.

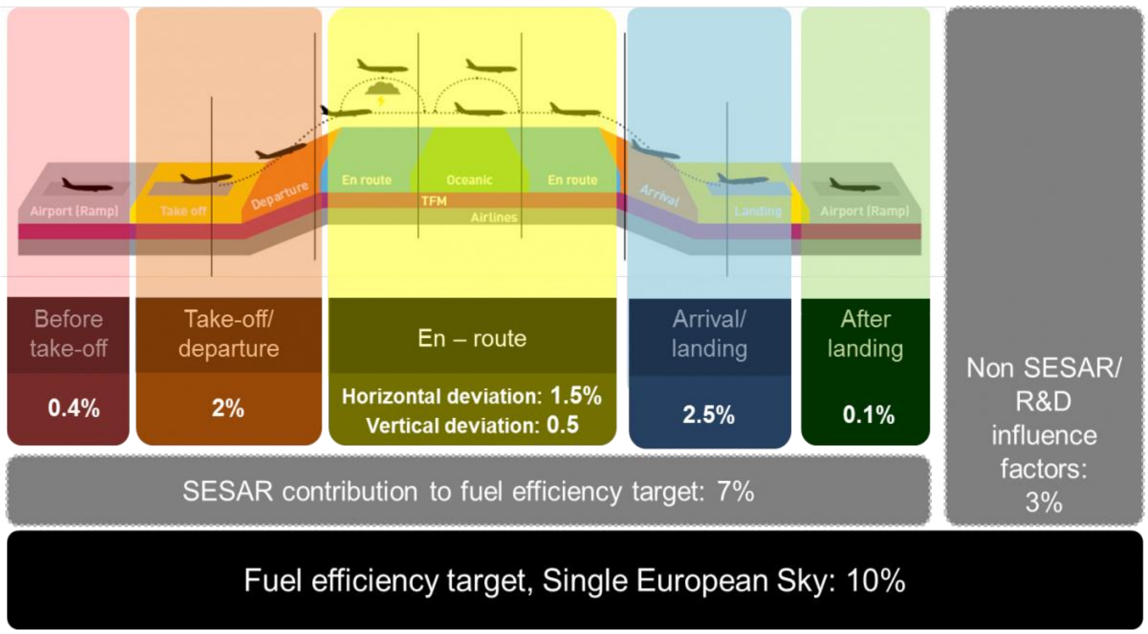
Guided by the European ATM Master Plan, the SESAR Joint Undertaking (JU) is responsible for defining, developing, validating and delivering technical and operation solutions to modernise Europe's air traffic management system and deliver benefits to Europe and its citizens. The SESAR JU research programme 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 7 Environmental Impact



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.

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

The four Environmental research projects 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 Modelling and Database Group CAEP. 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 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 the best operationally use of that technology. 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. 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 11 Summary of AIRE 1 projects

Domain	Location	Trials performed	CO_2 benefit/flight
Surface	Paris, France	353	190-1 200 kg
Terminal	Paris, France	82	100-1 250 kg
	Stockholm, Sweden	11	450-950 kg
	Madrid, Spain	620	250-800 kg
Oceanic	Santa Maria, Portugal	48	90-650 kg
	Reykjavik, Iceland	48	250-1 050 kg
	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 12 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 12 Summary of AIRE 2 projects

Project name	Location	Operation	Objective	CO_2 and Noise benefits per flight (kg)	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 13.

Table 13 Summary of AIRE 3 projects

Project name	Location	Operation	Number of Trials	Benefits per flight
AMBER	Riga International Airport	Turboprop aircraft to fly tailored Required Navigation Performance – Authorisation Required (RNP-AR) approaches together with Continuous Descent Operations (CDO),	124	230 kg reduction in CO_2 emissions per approach; A reduction in noise impact of 0.6 decibels (dBA).
CANARIAS	La Palma and Lanzarote	CCDs and CDOs	8	Area Navigation-Standard Terminal Arrival Route (RNAV

	airports			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.
OPTA-IN	Palma de Mallorca Airport	CDOs	101	Potential reduction of 7-12% in fuel burn and related CO_2 emissions
REACT plus	Budapest Airport	CDOs and CCOs	4 113	102 kg of fuel conserved during each CDO
ENGAGE Phase II	North Atlantic – between Canada & Europe	Optimisation of cruise altitude and/or Mach number	210	200-400 litres of fuel savings; An average of 1-2% of fuel burn
SATISFIED	EUR-SAM Oceanic corridor	Free routing	165	1.58 t CO_2 emissions
SMART	Lisbon flight information region (FIR), New York Oceanic and Santa Maria FIR	Oceanic: Flight optimisation	250	3.13 t CO_2 per flight
WE-FREE	Paris CDG, Venice, Verona, Milano Linate, Pisa, Bologna, Torino, Genoa airports	Free routing	128	693 kg CO_2 for CDG-Roma Fiumicino; 504 kg CO_2 for CDG Milano Linate
MAGGO	Santa Maria FIR and TMA	Several enablers	100	The MAGGO project couldn't be concluded

3.3 SESAR2020 Environmental Performance Assessment

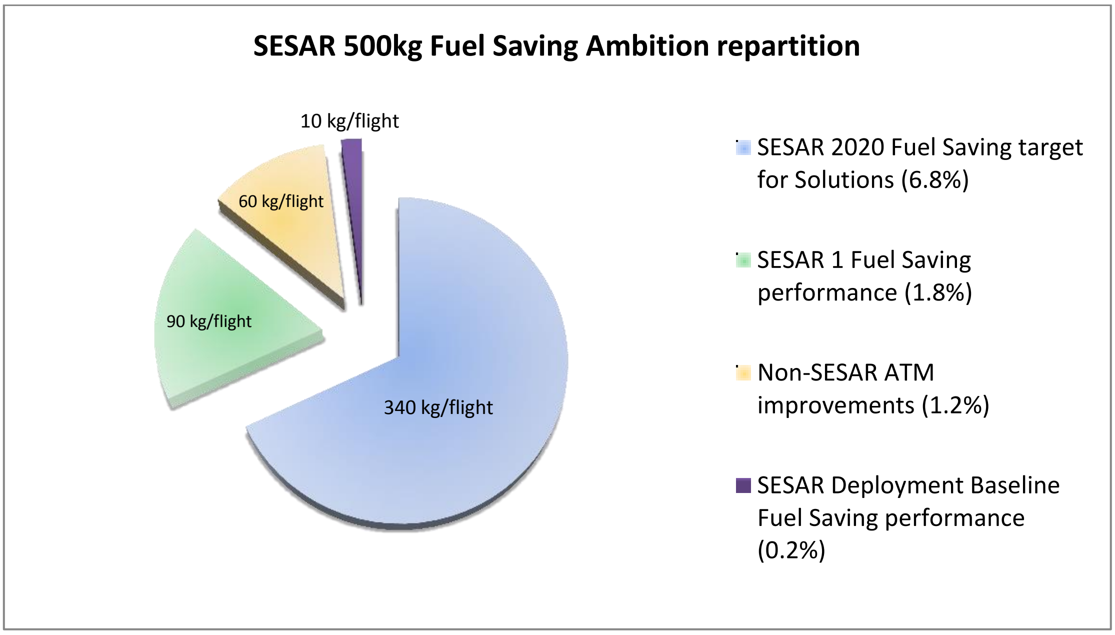
SESAR2020 builds upon the expectations of SESAR1 and of the deployment baseline.

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 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
- Non-SESAR ATM improvements (1.2%) = 60kg/flight or 189Kg of CO_2/flight

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

Figure 8 SESAR 500kg Fuel Saving Ambition repartition



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 14 provides the Top 10 Solutions with the biggest expected fuel saving potential:

Table 14 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	This Solution aims to further improve the quality of services of separation management in the en-route and TMA operational environments by introducing automation	Mainly for: Terminal Very High Complexity

Management	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.	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
PJ2-01 Wake turbulence separation optimization	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.	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.
PJ.09-02 Integrated local	This Solution sees the seamless integration of local network management with extended air traffic control planning and arrival management	Mainly for: Airport Very large

DCB processes	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.	Some benefit but much lower for: Terminal very High, High, Medium Complexity En-route very High, High, Medium Complexity Airport large, medium
PJ.01-03 Dynamic and Enhanced Routes and Airspace	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.	Mainly for: Terminal Very High Complexity Some benefit but much lower for: Terminal High, Medium Complexity
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	Mainly for: Terminal Very High Complexity • Single and Multiple runways • Preferably Congested large and medium size airports

	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 patch stretching, holdings ...).	
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

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.

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[22] 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[23].

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.

As regards aviation, legislation to include aviation in the EU ETS was adopted in 2008 by the European Parliament and the Council[24]. 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[25]. 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

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

23 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

24 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

25 http://ec.europa.eu/clima/policies/transport/aviation/documentation_en.htm

temporary limitation follows on from the April 2013 'stop the clock' decision[26] 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[27].

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[28]. It will continue to be a central element of the EU policy to address aviation CO_2 emissions in the coming years.

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[29] and 601/2012.[30]

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[26] 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

[27] 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

[28] 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

[29] 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

[30] 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

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.

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[31], 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

[31] 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

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 15 Summary of estimated EU-ETS emission reductions

Year	Reduction in CO_2 emissions
2012-2018	100 MT

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

4.2 The Carbon Offsetting and Reduction Scheme for International Aviation

In October 2016, the Assembly of ICAO 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 the 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[32]: 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.

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

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.

5. EU Initiatives in Third Countries

5.1 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 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.

6. Support to Voluntary Actions

6.1 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.

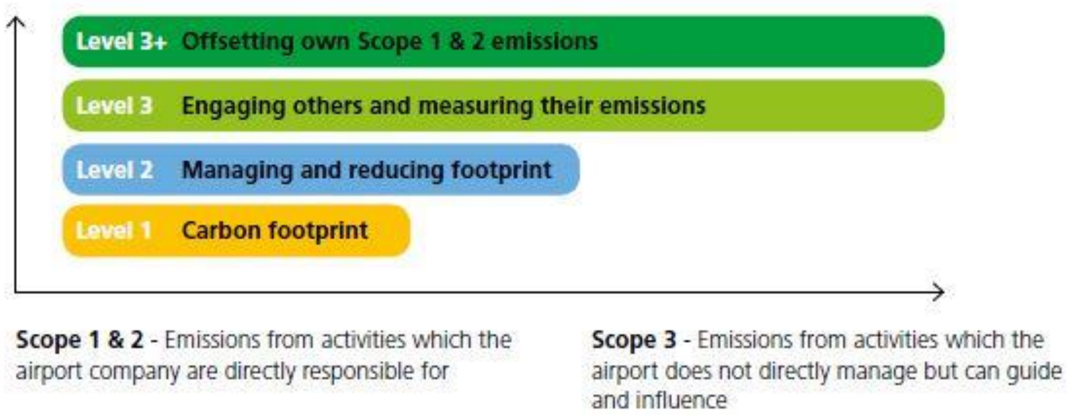
This industry-driven initiative was officially endorsed by EUROCONTROL and the European Civil Aviation Conference (ECAC). It is also officially supported by the United Nations Environmental Programme (UNEP). The programme is overseen by an independent Advisory Board.

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, 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 9 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.

Table 16 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 17 Emissions offset for the European region

	2015-2016	2016-2017
Aggregate emissions offset, Level 3+ (tCO_2)	222	252 218

The table above 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.

Table 18 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'[33] for emissions under airports' direct control (all airports)	22.04 MT CO_2	85	2.09 MT CO_2	92

[33] '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.

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)[34]	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)[35]	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

Its 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.

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

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

Section II: National Actions in Ireland

Introduction

The transport sector has been the fastest growing source of greenhouse gas emissions between 1990 and 2015, representing 27.5% of Ireland's non-ETS emissions in 2015. The transport share of overall national greenhouse gas emissions has increased from 9% in 1990 to almost 20% in 2005 and remains now at that 20% level[36]. Given the strong relationship between growth in transport emissions and the economy, it is reasonable to assume that as the economy improves, transport emissions will increase unless there is sustained policy action and further intervention.

Sustainable transport is central to Ireland's transport policy and is in line with EU flagship initiatives on energy efficiency. Nationally, the Government's policy approach to sustainable transport is set out in the 'Smarter Travel – a Sustainable Transport Future', which is an Irish policy document and aims to reverse unsustainable transport and travel patterns between 2009-2020. Some of the key goals of the strategy include maximising the efficiency of the transport system; minimising the negative impacts of transport on the local and global environments and improving security of energy supply by reducing dependency on imported fossil fuels. The policy requires action from a wide range of Government Departments, agencies and local authorities throughout Ireland.

According to recent analysis, changes in Ireland's climate are in line with global trends. Climate change is already having diverse and wide ranging impacts on Ireland's environment, society, economic and natural resources. Future impacts are predicted to include sea level rise; more intense storms and rainfall; increased likelihood and magnitude of river and coastal flooding; water shortages in summer; increased risk of new pests and diseases; adverse impacts on water quality; and changes in the distribution and time of lifecycle events of plant and animal species on land and in the oceans[37]. Against this background, strategies must be devised to reduce and manage climate change risks through a combination of mitigation and adaptation responses. This reality must be factored into planning and investment choices. The vulnerability of existing systems and infrastructure must be assessed and the necessary measures, systems and tools to enable the effective management of these impacts put in place. Accordingly, further cost-effective actions are required to be identified, assessed, adopted and implemented to reduce GHG emissions in the short-term.

The trends in aviation emissions in Ireland between 1990 and 2014 indicate that since 1996 there has been a steady increase in emissions, peaking in 2007 to just over 3000 kt of C02e and reducing sharply to coincide with the reduced traffic levels as a result of the economic downturn. As the economy recovers, evidence shows increasing traffic. This may not necessarily mean that there will be a corresponding increase in emissions. For example, Irish air operators have developed and continue to develop improved aircraft efficiencies and technological advances. In addition, Ireland also continues to make improvements in the provision of its air navigation services such as improved operational efficiency leading to lower emissions. The figure for CO_2

[36] "National Mitigation Plan", 2017, Department of Communications, Climate Action and Environment, pp. 96.
[37] "National Mitigation Plan", 2017, Department of Communications, Climate Action and Environment, pp. 7.

emissions associated with domestic aviation in Ireland was 9.8 kt of CO_2 in 2016. This is about 0.1% of overall transport emissions in Ireland.

Ireland is committed to working with its European and international partners to mitigate the impacts of aviation on the environment and will facilitate the sustainable growth of the sector.

Overall, Ireland requires a combination of a long-term strategy as well as specific actions geared towards short and medium-term goals in order to enable a successful transition to a low-emission, climate resilient, sustainable economy.

Please see Table 21 for progress made on Ireland's national measures since the 2015-2019 Action Plan.

Aircraft Related Technology

Ireland, as a member of the ICAO Council, contributed to the development and adoption of the carbon dioxide emissions standard for new aircraft to be applicable to new aircraft designs as of 2020 and to designs already in production as of 2023. Irish airline operators continue to invest in next generation aircraft and engine technologies and implement operational changes to minimise the environmental impact of their operations. These measures are leading to greater fuel efficiency and consequently reduced emissions.

As aviation activity increases in parallel to an improving European economy, the pressure on aircraft operators, airports and air traffic management to increase capacity is intensifying the debate on the environmental impact of aviation.

Ireland is committed to reducing climate-effecting emissions and the adverse impact of aircraft noise emissions and implementing initiatives to conserve energy in the Irish aviation sector. Like cars, planes vary in fuel efficiency. Engine technology, aerodynamics, size and other factors affect the amount of fuel required to haul a kilogram of cargo one mile.

Technical advancements that can improve the fuel consumption and hence CO_2 emissions of an aircraft generally fall into two categories: airframe improvements, i.e. weight and drag of the airplane; and improvements in engine efficiency. Between 1950 and 1997 a 70% improvement in overall fuel efficiency has been observed in Irish registered aircraft.

Since the lifetime of an airplane is 25-35 years, any technological changes will require a significant period of time before a substantial reduction of emissions is noticed from the fleet. Considering the time required for technology implementation and stock turnover, potential reductions in energy intensity are roughly 25% to 40% by 2030.

Ireland's registered airlines are fully committed to reducing emissions and noise through investments in "next generation" aircraft and engine technologies and the implementation of certain operational decisions to minimise the environmental impact of their operations. For example, Aer Lingus has entered into an agreement to lease 8 A321NEO long range aircraft with the first deliveries starting in 2019, and Ryanair will have new Boeing 737-MAX-200 arriving in spring 2019. daa (the Dublin Airport Authority with responsibility for Dublin and Cork airports) is also focussing on the development of measures to promote the use of more energy efficient aircraft among its client airlines at both Dublin Airport (31.5 million passengers in 2018) and Cork Airport (2.4 million passengers in 2018).

Operational Improvements

Aireon System

The Aireon system is a revolutionary space-based air traffic surveillance system. The Irish Aviation Authority is a partner in Aireon LLC, along with Iridium (USA) and the air navigation service providers NAV CANADA (Canada), ENAV (Italy), Naviair (Denmark) and NATS (UK). Aireon's vision is that space-based surveillance will provide surveillance coverage over parts of the globe where there is no radar coverage at present (e.g. oceanic and remote areas) and can also be used to supplement ground-based radar services.

The Aireon system uses Automatic Dependent Surveillance Broadcast (ADS-B) technology installed on a network of 66 'Iridium NEXT' satellites to receive and send aircraft positional tracking data, making it possible to extend next-generation coverage across the entire planet and establishing Aireon as the first truly global air transport traffic management and surveillance system.

With this technology, Air Navigation Service Providers (ANSPs) will be able to access surveillance data on flights over any part of the globe. This will allow for ANSPs to provide for more efficient separation between flights in many areas, whilst also enhancing safety. The IAA will participate in the trial implementation of Advanced Surveillance-Enhanced Procedural Separation (ASEPS) using ADS-B on the North Atlantic planned for the 28th of March 2019 or soon thereafter. It is a technological step change which will offer airlines substantial fuel savings and efficiencies on the North Atlantic alone. The footprint of terrestrial surveillance sources may also be reduced with the use of this technology.

Aireon will offer a space-based air traffic surveillance system to track flights in emergency situations as a free, public service to the global aviation community. Known as Aircraft Locating and Emergency Response (ALERT), the system will allow rescue agencies around the globe to request the location and last flight track of any suitably equipped aircraft flying anywhere in the world. The Aireon ALERT service will be managed from the IAA's North Atlantic Communications Centre in Ballygirreen, Co Clare, and has a scheduled operational date of the 30th of April 2019.

Point Merge

Placing aircraft in holding patterns prior to landing at airports traditionally results in those aircraft continuing to burn fuel while in the hold as well as contributing to noise pollution in those areas in proximity to the hold. However hold patterns are often necessary to ensure the safe and efficient landing of aircraft, particularly where there are capacity constraints at the airport or if certain aircraft have to be given priority to land or take off for safety or other reasons.

Point Merge was first implemented on Runway 28 at Dublin Airport in December 2012; Runway 28 handles approx. 79% of the total air traffic at Dublin Airport. It streamlines the way in which aircraft are sequenced to land at Dublin Airport and uses new techniques to assist airlines to fly in Continuous Descent Approaches (CDAs) to the main runway. Point Merge is a different and more advanced system compared to the traditional air traffic control techniques, which are employed at airports throughout the world. Rather than using traditional "race track pattern" holding stacks, Point Merge places arriving aircraft onto defined arcs or tracks, every point on which is equidistant from the runway. From these arcs, the aircraft make one single turn and fly a continuous descent to the runway. This results in a reduction in aircraft manoeuvring at low levels and overall track miles flown and means that in effect, aircraft get more efficient and direct approach to the runway. CDAs permit the aircraft to reduce their fuel burn by up to 250kg per flight depending on the aircraft size.

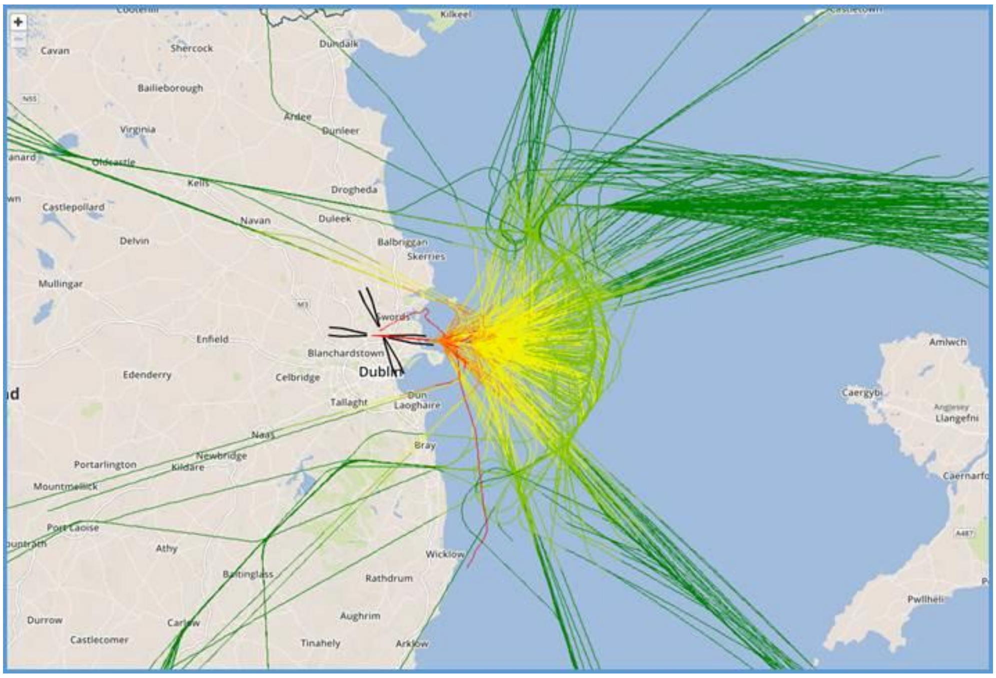
After the proven success of the introduction of Point Merge on Runway 28, the IAA introduced Point Merge to Runway 10 in April 2015, which handles approx. 17% of the total air traffic at Dublin Airport. The system lists among its benefits reduction in track mileage flown with consequent fuel saving, enhanced use of airborne avionics and continuous descent approaches and associated environmental benefits. The Runway 10 version differs from the Runway 28 system in that features individual sequence legs, positioned on the ideal track to final approach for Runway 10.

The implementation of Point Merge at both of the main runways at Dublin Airport has significantly reduced the need to put aircraft into traditional circular holding patterns, thereby providing savings to airlines by reducing their fuel burn, providing increased environmental benefits by cutting CO_2 emissions, reducing the noise footprint on approach to the airport and reducing delays to passengers. It benefits both air traffic controllers and pilots by harnessing the capabilities of the technology of the ATM and flight control systems to reduce workload and improve situational awareness thereby enhancing safety.

The graphic below reflects the Point Merge concept in the real time, data taken on Sunday 22nd April 2018 showing approx. 700 aircraft movements. The Point Merge will also be an integral part of parallel runway airspace changes in the coming years[38].

38 As part of the airspace changes associated with the development of parallel runway operations, the IAA will consider the application of PBN based procedures (PBN – performance based navigation), including RNP-1 where appropriate (RNP - required navigation performance). PBN based procedures will deliver more efficient flight procedures.

Figure 10 Point Merge real time data



The IAA engaged NATS to conduct a study, using the 3Di environmental efficiency tool, to compare performance parameters measured in Dublin airspace for the three months prior to and the three months following -TMA2012 (Point Merge) implementation at Dublin. The results of this study were received by the IAA at the end of July 2013.

This study sought to provide an independent assessment of how the IAA TMA2012 (Point Merge) project has delivered tangible benefits to its customer airlines.

NATS 3Di Metric

The 3Di 'tool' is a method which estimates the difference between an ideal flight trajectory (i.e. without airspace constraints) with achieved profiles (gathered from actual radar data). The ideal trajectory is allocated a 3Di score of 'zero'. The score for actual flight trajectories is the sum of the combined horizontal (extra track miles flown) and vertical (deviation from the preferred airline trajectory) efficiencies of measured flights - with maximum inefficiency defined as '100'. Therefore, the closer the score is to zero, the better the performance.

Dublin Airspace 3Di Study Results

In the Dublin airspace case, over 18,000 flights (pre-Point Merge) and nearly 20,000 flights (post-Point Merge) formed the basis of the 3Di scores. The flights were also analysed for fuel burn as well as the average track distances flown within Dublin airspace.

Table 19 Dublin Airspace 3Di study results

DUBLIN AIRSPACE	3Di SCORE (0-100)	AVERAGE FUEL BURN (kg)	AVERAGE TRACK DISTANCE (NM)
Pre-Point Merge	34.6	668.5	67.0
Post-Point Merge	28.5	540.9	55.7
PERCENTAGE IMPROVEMENT	17.6%	19.1%	20.3%

Conclusions

The implementation of TMA2012 (Point Merge) has had a significant positive effect on the performance of flights, based on the calculated 3Di scores. Moreover, the demonstrated savings on fuel burn and track distances show that the introduction by the IAA of the new airspace arrangements comprising TMA2012 (Point Merge) confirms the Authority's on-going commitment to provide enhanced, cost-efficient measures for its customer airlines.

Point Merge continues to provide fuel, emissions and time saving benefits to the Aircraft operators using Dublin Airport. It remains a core strategy for ATM operations and will be central to accommodating the extra demand expected when the second runway comes into service in 2021.

Nonetheless, Point Merge can be further enhanced by the use of emerging technology such as Enhanced Arrival Management and Time-Based-Separation. The IAA ANSP is actively engaged in the development and resultant implementation of these innovative techniques which are aimed at reducing airborne delay and holding still further.

Reduced Departure Intervals (RDI) and High Intensity Runway Operations (HIRO)

Continuous Descent Approach is a more efficient descent method by which aircraft approach airports prior to landing. It is designed to reduce fuel consumption and emissions when compared with a conventional approach and involves maintaining a consistent descent profile from top of descent until landing. Instead of approaching an airport in a stepped fashion which requires continuous adjustment of engine power as the aircraft starts and stops descending, CDA allows for a smooth, constant-angle descent to landing, thereby reducing fuel burn and emissions.

CDA was implemented at Dublin Airport as part of the Point Merge project in 2012, and is being considered for both Cork and Shannon Airports. Currently, the aircraft coming into Cork and Shannon Airports get a CDA equivalent service due to lower volumes of air traffic.

As part of its on-going initiative to enhance the efficiency of single runway operations on the two main runways, R10 and R28 at Dublin Airport, the IAA reduced the interval between successive departing aircraft of the same category to 1NM. This measure, termed initially as Reduced Departure Intervals (RDI), has proved that an appropriate level of safety has been maintained, without infringement of existing minimum radar separation (3NM). The Dublin Tower Controllers are therefore permitted to issue take-off clearance to a succeeding aircraft once the preceding aircraft has reached 1NM from the departure end of the runway.

The next stage is the commencement of an Operational Trial to support a robust justification of reducing the distance from the departure end of the runway (from 1NM initially to 0.85NM), at which the Tower Controller can issue take off clearance and in consequence increase runway throughput rates. This procedure will be known as Refined Reduced Departure Intervals (RRDI) and is expected to be implemented on an operational trial basis in the second part of 2019. The potential environmental benefits of this new procedure will be primarily fuel burn and ground noise reduction, both being a result of reduced aircraft taxi times due to runway throughput increase.

HIROs are used to minimise runway occupancy time for both arriving and departing aircraft and to increase runway capacity. Expeditious exit from the landing runway allows air traffic control (ATC) to separate aircraft with the appropriate radar separation minimum during final approach.

Arrival spacing is adjusted in accordance with demand to make most efficient use of the runway and to reduce departure delays. ATC considers every aircraft at the holding point as able to commence line up and take-off roll immediately after clearance issued.

HIRO provides environmental savings to airspace users in the form of reduced fuel burn and CO_2 emissions, and reduced ground noise. This is based on reduced airborne arrivals times and delays, and reduced taxi times as runway throughput increases. The HIRO initiative is complementary to the A-CDM process, which was introduced on a 24hr basis in January 2019 (see later section)

On-going weekly/monthly statistics from HIRO looking at movements on the runway are being published and will include ADA (Arrival - Departure – Arrival) spacing in late 2018. This will allow the IAA Operations Manager and the Station Managers to actively monitor efficiencies of aircraft spacing.

UK/Ireland Functional Airspace Block (FAB)

Another key area in creating and delivering operational efficiencies is through the Single European Sky initiative (SES).

One of the cornerstones of the SES legislation is the creation of Functional Airspace Blocks (FABs), defined as an "airspace block based on operational requirements, reflecting the need to ensure more integrated management of the airspace regardless of existing boundaries". The UK-Ireland Functional Airspace Block (FAB) was the first FAB to be established in 2008. The FAB covers the airspace in the Shannon, London and Scottish FIRs, controlled by the IAA and NATS (En route services).

By focusing on operational efficiency, the FAB enables the airspace users to utilise the optimum flight profiles for their aircraft, which in turn helps them to reduce their fuel costs and CO_2 emissions.

A number of initiatives have been completed under the umbrella of the UK-Ireland FAB:

- *Dynamic Sectorisation of Airspace Trials (DSOT)*

In September 2014, the UK-Ireland FAB successfully completed the first-ever operational trial to test new ways of delivering air traffic control services to airlines and gather information on efficiencies that could be gained through the SESAR concept of 'dynamic sectorisation' – the tactical switching of air traffic services between providers.

The trial involved enhanced cooperation between the ANSP FAB Partners, IAA and UK NATS, under which the IAA delivered, on a trial basis, air traffic control services in airspace over Northern Ireland and further north.

- *Cross Border Arrivals Management (XMAN)*

Since April 2014, the IAA has been cooperating with NATS in a Heathrow XMAN project. When delays in the Heathrow holding stacks begin to build, the IAA's en-route air traffic controllers together with their colleagues in the Netherlands, France and Scotland are asked to slow down aircraft up to 350 miles away from London to help minimise aircraft holding on arrival, with the aim of cutting average Heathrow holding times by at least a quarter from the current time of just under 8 minutes. This reduction in holding times delivers UK-Ireland FAB environmental benefits through reduction in fuel burn and CO_2 emissions.

In conjunction with NATS, the Heathrow XMAN initiative has been successfully implemented and a permanent procedure put in place for the IAA in early 2017. The new air traffic management system functionality on the IAA COOPANS system is now delivering information on Heathrow delays directly to radar screens in the IAA's Shannon en-route control centre. IAA air traffic controllers can then easily identify when delays are forecast and pro-actively coordinate the inbound traffic to Heathrow, thereby reducing or avoiding delays.

Delays are minimised by reducing aircraft speed in the cruise phase, therefore reducing the time aircraft spend in fuel-intensive holding stacks at Heathrow.This saves fuel, reduces CO_2 emissions and delivers a better arrival experience for travelling passengers. Since its initial introduction on a trial basis in 2014, over 4,700 tonnes of fuel savings have been enabled per annum, which delivers approximately £2.5 million savings for airlines per year. These savings are expected to rise as air traffic levels increase in the coming years.

- *Single European Sky Performance Scheme*

The Single European Sky also requires States to put in place a performance plan for five year periods. RP2, the current performance period runs from 2015 – 2019 with RP3 running from 2020 – 2024. Environment is one of the Key Performance Areas (KPAs) with a Key Performance Indicator (KPI) set against en-route horizontal flight efficiency.

The IAA's actual performance for this KPI was well below the target in each of the first four years of RP2 largely due to free route airspace and the IAA is confident that the target for 2019 will also be achieved.

Table 20 Horizontal En-route Flight Efficiency Ireland 2015-2019

Horizontal En-route Flight Efficiency - Ireland 2015-2019					
	2015	**2016**	**2017**	**2018**	**2019**
Target	2.6%	2.6%	2.6%	2.6%	2.6%
Actual	1.30%	1.40%	1.35%	1.26%-	-

Airport Carbon Accreditation

Dublin and Cork airports are part of the Airport Council International's Airport Carbon Accreditation (ACA) scheme, which airports use to keep track of the impact of greenhouse gas emissions from airport controlled activities. Dublin and Cork airports are certified at Level 2 (Reduction) of the scheme.

Dublin Airport's footprint decreased from a baseline of 36,917 tonnes CO_2 to 29,720 tonnes CO_2, a decrease of 19% from 2011-2018. Cork Airport's footprint decreased from a baseline of 5,231 tonnes CO_2 to 4,609 tonnes CO_2, a decrease of 12% from 2011-2018.

Dublin Airport intends to become carbon neutral under the Airport Carbon Accreditation Scheme by 2020 through the implementation of numerous energy saving construction and equipment replacement projects. Such initiatives align with EU energy efficiency and renewable energy regulatory requirements.

Cork Airport holds monthly meetings between the Asset Care Manager and Senior Management to report on energy efficiency improvement opportunities, action plans, consumption levels and patterns and monitored usage relative to targets and objectives. In order to achieve its goal of becoming carbon neutral by 2020, green electricity will be used and the remainder will be generated using on-site sources. daa has installed a pilot solar array at Dublin Airport, and intends to install further solar PV grounds from 2020. Further energy efficiency projects are proposed to upgrade existing equipment and buildings in the next Capital Investment Plan period. Aer Lingus reported in 2018 that 53% of its electricity use as being from renewable energy.

Airport Energy Efficiency

Dublin Airport has maintained staff engagement in energy efficiency with initiatives such as "Take the Stairs Week" and "Water Week". Dublin Airport's Fuel Hydrant System will be extended on a phased basis to additional piers. In August 2018 Dublin Airport began the installation of FEGP facilities on Piers 1 and 3, with an expected completion at the end of the first quarter of 2019. A recent report from Zurich Airport entitled: Aircraft Ground Energy Systems at Zurich Airport indicates reductions in carbon emissions from 19.1 kg CO_2/hour for Diesel GPU to 0.7 kg CO_2/hour for FEGP for Short haul Aircraft and from 38.2 kg CO_2/hour for Diesel GPU to 1.2 CO_2/hour for FEGP for long haul aircraft.

A priority for Shannon Airport is achieving the Government 2020 energy saving target of 33%; this will also contribute to the reduction of their aviation related emissions. It has committed to improving its energy consumption by having ESB International review and provide guidance on how it can be more energy efficient in Q3 2018. In Q3 2017 all associated runway lighting was replaced by LED lighting. The vehicle replacement programme will continue to utilise electrical vehicles where possible. Airport management continues to participate in workshops associated with energy efficiencies and reducing our carbon footprint. A number of minor energy efficiency projects were funded under our capital expenditure programme during 2018. The airport continues to actively monitor its energy consumption in order to reduce OPEX and in addition a reduction in emissions.

Sustainable Alternative Fuels

Ireland will support and promote the production, storage and distribution of sustainably produced biofuels for use in aviation. Ireland can contribute to this objective of alternative fuel use in Aviation through research and development projects in collaboration with relevant public bodies. For example, Ireland has a relatively high level of students participating in science and engineering courses. There is therefore, an opportunity for Ireland to channel science research into the development of sustainable alternative fuels.

Relative to fossil fuels, sustainably produced biofuels result in a reduction in CO_2 emissions across their life cycle. Carbon dioxide absorbed by plants during the growth of the biomass is roughly equivalent to the amount of carbon dioxide produced when the fuel is burned in a combustion engine – which is simply returned to the atmosphere. This would allow the biofuel to be approximately carbon neutral over its life cycle. However, there are emissions produced during the production of biofuels, from the equipment needed to grow the crop, transport the raw goods, refine the fuel and so on. When these elements are accounted for, many biofuels are still expected to provide an anticipated reduction in overall CO_2 lifecycle emissions of up to 80% compared to fossil fuels.

While a range of biofuels exist, they are principally available in three forms - (1) biodiesel made from pure plant oil, recovered vegetable oil or tallow and typically blended with diesel in a 5%

mix, (2) bioethanol made from sugar beet, wheat, whey or other crops and blended with petrol in a 5% mix or in an 85% mix for use in flexible fuel vehicles, and (3) pure plant oil, which is not blended and requires modification of most vehicle engines before use.

Since the first biofuel flight in a commercial aircraft took place in 2008, there has been a huge amount of work by the aviation industry globally. Airlines and partners around the world are starting to use sustainable alternative fuels in commercial flights. Soon, this will be a routine part of airline energy planning, but for the moment, these flights are special - they demonstrate the willingness of the industry to kick-start the field of renewable energy in aviation.

Biofuels offer a tangible and practical means to effect immediate and quantifiable emissions reductions in the transport sector, which is currently trailing behind industry, energy and agriculture in achieving the targeted emissions reductions established in the National Climate Change Strategy.

The development of sustainable alternative aviation fuels could provide a very large part of the industry's emissions-reduction strategy. Research has shown that, on a full carbon lifecycle basis, using the equivalent quantity of some alternative fuels could reduce CO_2 emissions by around 80% compared to the jet fuel they replace.

Research into Sustainable Alternative Fuels

Ireland will continue to encourage and facilitate research and development in the areas of sustainable and renewable fuels in the aviation sector. In doing so, Ireland will work with Enterprise Ireland and the relevant public bodies in establishing collaborative programmes for academic research through existing or new university, research institution or industrial research projects. This research could focus on the development of aviation specific sustainable alternative fuels.

Climate change research is funded in Ireland by the Government primarily through the EPA. The EPA supports a national climate change research programme to address key challenges for Ireland, develop essential research infrastructures both in the context of EU and international research activities, and investment, and observation and assessment, programmes. The EPA has a statutory role in coordinating environmental research in Ireland and is also responsible for promoting access to Horizon 2020 funding under the climate action, environment, resource efficiency and raw materials pillar, and for the EU's Joint Programming Initiatives which aim to enhance collaboration between national research programmes in Europe to address key societal challenges in a more efficient and effective manner. In addition a number of other agencies, such as the SEAI, Teagasc, Department of Agriculture, Food and the Marine, Met Éireann and the Irish Research Council also fund research which helps to inform climate change policy in Ireland. The EPA currently coordinates with these Agencies in planning its research.

Shannon Group is collaborating with the University of Limerick (Prof Luuk van der Wielen in the Bernal Institute and his colleagues) to identify potential joint R&D projects, and to identify

Shannon Group property which could be an appropriate location for UL research infrastructure. This collaboration is at an early stage and is not yet delivering emissions reductions. Some of the research which has been analysed as part of this collaboration concerns the production and future of biofuels.

Economic/Market-Based Measures

EU Emissions Trading Scheme (ETS)

A European Union Emissions Trading Scheme (EU-ETS) was established in 2003 for a variety of industrial sectors and is one of the key environmental policies introduced by the EU to reduce emissions of carbon dioxide and other greenhouse gases. In 2009 the scheme was extended to include aviation. The Environmental Protection Agency (EPA) is the competent authority responsible for implementing this scheme in Ireland. To reduce administrative costs, each aircraft operator is administered by a single country.

Aircraft operators are required to record and report carbon dioxide emissions (calculated on the basis of measuring fuel consumed) and to surrender European Union Aviation Allowances (EUAAs) equal to these emissions. The number of free allowances each operator receives is capped, requiring operators to either reduce their emissions or purchase EUAAs on the market.

Ireland administers a significant portion of the total verified emissions from aviation in the European Economic Area (EEA). For example, in 2016 verified greenhouse gas emissions from the aviation sector in the EEA was 61.4 million tonnes and aircraft operators administered by Ireland reported 10.5 million tonnes CO_2 or 17% of the total. The sector includes commercial and non-commercial operators, with the commercial operators accounting for 99.9% of the total emissions from aviation.

Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)

When introduced 2009, the EU-ETS applied to all flights landing at or departing from an EU/EEA airport. Since 2014, EU flights to and from destinations outside the EU/EEA were exempted from the EU-ETS. This temporary measure (now extended to 2023) is to allow for the implementation of a global market based measure (GMBM) for international aviation. This GMBM was developed by ICAO and is known as the Carbon Offsetting and Reduction Scheme for International Aviation or CORSIA. This GMBM is one of several measures introduced by ICAO to achieve the goal of carbon neutral growth for aviation from 2020. In the CORSIA, Operators will be required to offset carbon emissions above the 2020 baseline by purchasing emission units, therefore incentivising emissions reduction.

The CORSIA began on 01 January 2019 with the recording and collection of baseline fuel emissions date for 2019 and 2020. There will be 3 Phases of implementation of the CORSIA: Pilot 2021-2023 (voluntary), First Phase 2024-2026 (voluntary) and Second Phase 2027-2030. Ireland in common with other EU member states has volunteered to participate in the Pilot and First Phases.

Table 21 Progress on Action Plan Measures

Action Plan 2015-2019	Action Measure 2019-2023
Aircraft Related Technology	
• Investment by Irish airline operators in next generation aircraft and engine technologies • Implementation of operational decisions to minimise environmental impact of airline operations • Irish registered operator Ryanair is Europe's largest airline and current industry leader in terms of global environmental efficiency • Aer Lingus started using the Honeywell GoDirect Fuel Efficiency software in 2012, to support reductions in fuel use and carbon emissions • In September 2014 Ryanair committed to purchasing 100 Boeing 737 MAX 200 aircraft; this model provides up to 20% better fuel efficiency per seat than the current most efficient single-aisle airplanes. The first deliveries will be in 2019	• daa aims to develop measures which will promote the use of the most modern and fuel-efficient aircraft by airlines • daa aims to promote the reduction of carbon and noise emissions and improve air quality by encouraging the use of low emission vehicles airside and landside • Aer Lingus is committed to having a modern fleet, as newer aircraft (for example A321NEOLR) provide a new generation engine type and sharklets which will reduce fuel consumption by 15% and CO_2 emissions when compared with existing generation aircraft (A320CEO family). The A321NEOLR will have lightweight seats installed in economy class • Separately, all of Aer Lingus short haul aircraft (A320/A321CEO) have lightweight seat covers and carpets installed resulting in a weight reduction and consequent fuel efficiency improvement • Aer Lingus has ordered eight A321NEO long range aircraft with delivery from 2019 • By 2018 Aer Lingus fitted 31 of their 37 A320/21 aircraft with airflow deflectors which help prevent the generation of a whistling sound during a phase of descent. In addition, all IAG Airlines monitor operational noise performance to ensure flights are operated sensitively and to identify improvements where possible • In addition, IAG (parent of Aer Lingus) is committed to Carbon neutral growth from 2020 and a net reduction of 50% CO2 emissions by 2050 versus 2005 • Aer Lingus actively works with Air Traffic Flow Management Stake-holders across Europe to amend flown patterns to ensure the flights flown are the most optimised profiles available (removal of

	altitude cap on Standard Instrument Departures (SIDs) through liaison with Portuguese and UK CAA, Route Straightening, Missed Approach Procedure Amendment at Dublin) • Aer Lingus engages with Aircraft OEMs & OALs to influence best practice flying techniques in terms of fuel efficiency (Single Engine Taxi Out, Land Light Extension, Vortex Generators A320 A/C) and technology (Boeing Winds on A330 A/C) • Ryanair continuously invests in fuel-efficient new aircraft and improved engine technology; it delivers a CO_2 per passenger km value which is 25% lower than the average of the four other big European airlines and 39% lower than the average of 21 airlines tracked globally by MSCI (2016) • New Boeing 737-MAX-200 to arrive in spring 2019 to Ryanair will reduce fuel consumption by up to 16% per seat, reducing CO_2 and NOx emissions • Winglets reduce fuel burn and CO_2 emissions by 4%, and light-weight seats reduce fuel burn by an additional 1% per aircraft
Operational Improvements	
Aireon System	
• First Aireon satellites successfully launched in January 2017 (Iridium NEXT Satellites, equipped with Aireon Space-Based ADS-B receivers) • All 66 satellites are now in position and transmitting live data • Space-based ADS-B data for aircraft surveillance and management will improve air traffic management services, especially in oceanic and remote areas where radar coverage is not practical or non-existent • The trial implementation of Advanced Surveillance-Enhanced Procedural Separation (ASEPS) on the North Atlantic using ADS-B is planned for the 28th of March or soon thereafter • Use of this technology will allow ANSPs to provide for more efficient separation between flights in many areas, and also enhance safety. It will offer airlines substantial fuel savings and efficiencies on the North Atlantic alone	• IAA working with other Aireon investors to obtain regulatory approval from EASA for the operational use of satellite-based ADS-B data • Aircraft Locating and Emergency Response Tracking (ALERT) will be operational from the 30th of April 2019 • The footprint of terrestrial surveillance sources could also be reduced through this technology
Point Merge	

• Point Merge has almost eradicated need to put aircraft into traditional, circular holding patterns at Dublin Airport • Greatly reduces aircraft fuel burn and CO_2 emissions • CDA's allow aircraft to reduce their fuel burn by up to 250kg of fuel and 750kg of CO_2 per arrival • Airlines landing at Dublin Airport using Point Merge in 2013 saved an average 127kg of fuel and reduced their fuel requirement by 19.1% per flight. Flight length was also reduced by an average 11.3 miles, a 17% reduction [39]	• Implementation of Point Merge at the two main runways at Dublin Airport means 96% of the total air traffic are engaging with this practice • This has led to reduced fuel burn by up to 250kg per flight, depending on aircraft size and associated environmental benefits, notably a reduction of CO_2 emissions • Point Merge will be an integral part of parallel runway airspace organisation in coming years
RDI and HIRO	
• Reduced departure operational trials were successfully completed at the end of 2014 and the procedures for RDI are now fully operational • There has been a reduction in the departure interval of up to 15 seconds • Average separation achieved is 4.1NM (minimum 3.5NM) • Work is ongoing to increase the departure capacity from 33 to 35 aircraft movements per hour. Together with HIRO, this will improve the efficiency of the main runway at Dublin Airport even further • The introduction of RDIs and HIROs at Dublin Airport has created more efficiency for arrivals and departures and helped to maximise the capacity of the existing runways, by increasing slot capacity and reducing average taxi times. Further work will continue with airlines and daa to ensure the proactive promotion of HIROs	• As part of its ongoing initiative to enhance the efficiency of single runway operations on the two main runways at Dublin Airport, the IAA reduced the interval between successive departing aircraft of the same category to 1NM • The next stage is to commence an Operational Trial to support a robust justification of reducing the distance from the departure end of the runway; this will be known as Refined Reduced Departure Intervals (RRDI) • The potential environmental benefits will be primarily fuel burn and ground noise reduction
UK/Ireland FAB	
• In 2013, the UK/Ireland FAB helped airlines make savings of 29,000 tonnes of jet fuel and 90,000 tonnes of CO_2 • From 2008-2013 estimated savings amounted to more than 100,000 tonnes of jet fuel and over 310,000 tonnes of CO_2 • A Cost-Benefit Analysis completed in 2011 has shown the significant added value the FAB delivers to customers. The quantitative savings outlined show	• Apart from further jet fuel and CO_2 emissions savings, several new initiatives have been completed under the FAB, such as Dynamic Sectorisation of Airspace Trials (DSOT), Cross Border Arrivals Management (XMAN), and the Single European Sky Performance Scheme

[39] Aer Lingus Continuous Descent Approaches were measured at 86.6% for 2018 for UK NATS Airports

that total cumulative enabled savings from 2008-2020 are estimated at 332,000 tonnes of fuel and 1.06m tonnes of CO_2 emissions	
Airport Carbon Accreditation	
• Dublin, Cork, and Shannon Airports are accredited at Level 2: "Reduction" status, meaning they have successfully reduced their overall emissions and carbon footprint year after year	• Dublin Airport intends to become carbon neutral under the scheme by 2020 through the implementation of numerous energy saving construction and equipment replacement projects • Cork Airport also intends to become carbon neutral by 2020, through initiatives such as the use and generation of green electricity and various other renewable energy projects
Airport Energy Efficiency	
• In 2012 daa signed a Public Sector Partnership agreement with the SEAI which committed daa to an overall target of 33% improvement in energy efficiency by 2020 • daa purchased 9 electric vehicles for use in Dublin and Cork Airports as part of its drive to lower its carbon footprint. This will result in more than 200,000kg of CO_2 savings over the lifetime of the vehicles. It also makes daa one of the largest electric fleet operators in Ireland • In 2018, Aer Lingus purchased 61 electric baggage tractors, belt loaders, passenger stairs and pushback tugs. Electric vehicles currently comprise 38% of Aer Lingus Ground Service Equipment fleet • Dublin Airport reduced its energy usage by 44.3% from its 2006-2008 baseline, earning it second place in the SEAI Annual Public Energy Efficiency report in the category of Public Sector bodies in Ireland • The SEAI Energy Awards reward public sector organisations which excel in terms of organisational energy goals by delivering new or improved technology deployments, management solutions or staff engagement. Dublin Airport was shortlisted for the third year in a row in 2017 • Dublin Airport received the ISO 50001 Energy Management Certification in August 2016 • Dublin Airport has received grant based incentives in the Better Energy in	• Dublin Airport: Fixed Electrical Ground Power (FEGP) was introduced to aircraft stands on Pier 4; it reduces energy usage by aircraft during turnaround, reduces carbon emissions from this activity, and the actual energy usage has less impact on air quality and noise, by reducing the amount of airside traffic and using fixed electrical units instead of the traditional diesel Auxiliary Power Units • A new €40 million aviation fuel farm has been opened at Dublin Airport. It has six times the capacity of the previous fuel farm, and is connected to a fuel hydrant system which will service aircraft parked on Pier 4. This hydrant system will facilitate aircraft refuelling which takes less than half the time the previous system took. The number of fuel vehicles on the apron area was also halved • Dublin Airport initiatives such as "Take the Stairs Week" and "Water Week" have maintained staff engagement on a continuing basis • Dublin Airport is developing numerous energy related projects such as additional solar PV for the roof of Terminal 1, and converting terminal campus building lighting to LED. Conversion of the remainder of the light fleet to EVs and ways to expand EV infrastructure are also being investigated • Shannon Airport has committed to improving its energy consumption by having ESB International review and

Community and EXCEED energy efficiency design sectors through project work in 2016 and 2017 which included Surface Car Park, Apron lighting, internal lighting and heating system upgrades • The refurbishment of the old Aer Lingus Head Office Building was completed to LEED Platinum standard in 2017, and the first ESBI tenants moved in. It also has a BER rating of A3. It was awarded a Chambers Ireland CSR Award in the Environment Category in the same year • A Solar PV installation was installed in Dublin Airport in 2017, in collaboration with ESB. It comprises 650m2 solar PV array within the drinking water reservoir complex that will power 60% of the annual pumping needs for the reservoir • Dublin Airport was awarded the IAA Aviation Sustainability and Environment Award in 2016 • The Dublin Airport Energy team promoted leading suppliers of renewable energy and energy efficient products through the Annual Smart Energy Exhibition • Dublin is the first airport to be certified ISO 55001, which is a framework for an asset management system that helps a business to pro-actively manage the lifecycle of its assets, from acquisition to decommission • Cork Airport reached a reduction of 44% from the 2006-2008 average energy usage • In 2016, Cork Airport was rated fourth out of Public Sector bodies in the SEAI Annual Public Sector Energy Efficiency report, 37% reduction in CO_2 emissions, and annual savings of €875,000 • Other successful energy reduction projects at Cork Airport include the installation of energy efficiency lighting and wind-speed and wind direction vain to control heating • Shannon Airport: In Q3 2017 all associated runway lighting was replaced by LED lighting • Also at Shannon Airport a number of minor energy efficiency projects were funded under the capital expenditure	provide guidance on how it can be more energy efficient in Q3 2018 and beyond • At Shannon Airport the vehicle replacement programme continues to utilise electrical vehicles where possible

programme during 2018	
Sustainable Alternative Fuels	
• Ireland will support and promote the production, storage, and distribution of sustainably produced biofuels for use in aviation • Ireland will continue to encourage and facilitate research and development in the areas of sustainable and renewable fuels in the aviation sector • It will work with Enterprise Ireland and relevant public bodies in establishing collaborative programmes, through the Horizon 2020 research and innovation programme, for academic research through existing or new university, research institution or industrial research projects	• Shannon Group is collaborating with the University of Limerick to identify potential joint research and development projects, and to identify Shannon Group property which could be an appropriate location for UL research infrastructure • Through this collaboration, access was given to a recent PhD thesis on production costs, climate impact, and future supply of renewable jet fuels, which highlights the importance of jet fuels and their long-term potential for more environmentally friendly aviation
Economic/Market-Based Measures	
• Ireland is a member of the EU ETS for aviation • Ireland is working with EU partners to develop the necessary mechanisms at EU level to achieve the implementation of CORSIA • Ireland is actively engaging with its airline operators on practical measures in relation to compliance with CORSIA requirements	• CORSIA will begin on 01 January 2019 with the recording and collection of baseline fuel emissions date for 2019 and 2020. There will be 3 Phases of implementation of the CORSIA: Pilot 2021-2023 (voluntary), First Phase 2024-2026 (voluntary) and Second Phase 2027-2030. Ireland in common with other EU Member States has volunteered to participate in the Pilot and First Phases

New Measures

Shannon Low Level Route Structure Removal

Following a review of the lower air traffic service (ATS) route structure in Shannon en-route and another review of flight planning data submitted by aircraft operators in the lower airspace, it was established that in excess of 50% of aircraft were not using the lower ATS route structure for flight planning.

As the lower ATS route structure in the Shannon en-route controlled portion of the Shannon Flight Information Region (FIR) is neither used for channelling the flow of traffic or the provision of ATS, the IAA decided to put in place a project to remove this route structure.

In 2017 the residual route structures from Shannon Low Level airspace were removed facilitating full Free Route in the Shannon en-route controlled portion of the Shannon FIR and building on the success of Free Route Airspace (FRA), which has been operational since 2009 in the Shannon Upper Information Region (UIR), Shannon Oceanic Transition Area (SOTA) and Northern Oceanic Transition Area (NOTA).

IAA ANSP has now extended FRA into the lower airspace below flight level 245 except for high density Dublin TMA (Terminal Manoeuvring Area). Ireland now has the lowest (and most efficient) Free Route structure in Europe. It is hoped that this expansion of FRA will allow customers operating in the lower airspace to file the most optimum trajectory available with a view to realising savings in the areas of fuel burn and CO_2. This brings the airspace in line with upper airspace operations but also allows for more accurate and flexible flight plan filing by airspace users thus ensuring maximum flight efficiency.

This expansion of free route forms part of the Borealis Alliance FRA Project with the project forming one of the seven steps of the Borealis FRA Programme, enabling airline and business aviation customers to plan and take the most cost effective, fuel efficient and timely routes across the entire airspace managed by the nine Borealis Alliance members.

Borealis Free Route Airspace

Borealis Alliance is an alliance of nine air navigation service providers, including the Irish Aviation Authority and manages 38% of total European air traffic annually. The Borealis Alliance actively facilitates cooperation between its members that will make a contribution to the operational and financial performance of air traffic services for the benefits of airline customers.

In 2015, the Borealis Alliance announced the launch of a programme to deliver seamless and integrated Free Route Airspace (FRA) across the whole of Northern Europe by 2021. This will see FRA available to more than a third of Europe's air traffic in line with the 2021 deadline set in the EC Pilot Common Project (PCP). In doing so, the programme will make a major contribution to the Single European Sky for which it was recognised in the 2016 European Commission's SES awards.

The strategic project of Free Route Airspace is building on the successful implementation of Free Route Airspace in Shannon Upper Airspace in 2009 and work initiated through the three existing FABs – the Danish-Swedish, UK-Ireland and North European FABs – and the North European Free Route Airspace programme, but is voluntarily being expanded by the ANSPs to maximise the benefits for customers.

Benefits of Borealis: Free Route Airspace allows airlines to plan their preferred route, allowing for optimal efficiency and significant fuel and CO_2 savings, to the benefit of airlines and passengers. As a result of the completion of the Borealis FRA Programme in 2022, the Alliance forecasts the following annual benefits:

Figure 11 Estimated enabled benefits from Borealis FRA in 2022 per annum

Estimated enabled benefits from Borealis FRA in 2022[1] per annum ([1]Borealis FRA SAAM modelling results for the seven implementation steps)

RNAV-1

RNAV-1 offers the ability to use Area Navigation (RNAV) functionality in all phases of flight except final approach and missed approach. It is used to define routes in terminal airspace which meet the needs of the aircraft operators and the air navigation services provider. This often means shorter, more direct routes with simple connections to the en-route structure. With environmental issues now playing a major role, routes can be designed to make best advantage of the airspace available and, where possible, by-pass densely populated areas, thus reducing noise pollution and CO_2 emissions.

RNAV-1 allows Dublin Terminal Airspace RNAV operations that are consistent in the various ECAC States, based on a common set of design and operation principles, ensuring consistent levels of flight safety. This is in contrast to the historic situation, where the variations in RNAV approval requirements, the variations and procedure design and procedure publication/charting, and the variations in navigation data integrity, were recognised to be not without safety implications.

RNAV-1 defines European RNAV operations which satisfy a required track-keeping accuracy of ±1 NM for at least 95% of the flight time. This level of navigation accuracy can be achieved using DME[40]/DME, GNSS (inc. GPS) or VOR[41]/DME and the Dublin area is suitably equipped to deliver this service.

40 DME = Distance Measuring Equipment
41 VOR = VHF (Very High Frequency) Omnidirectional Radio Range

Required Navigation Performance (RNP) Approaches

In line with the developments detailed in the previous paragraphs, the IAA ANSP is applying where possible, the latest Performance Based Navigation (PBN) criteria, in the design and development of flight procedures. The main focus of this activity is for Dublin Airport where the greatest traffic volumes are seen. Along with existing developments in Dublin airspace, the IAA ANSP is developing flight procedures for RNP equipped aircraft. Currently, approx. 60-70% of the fleet at Dublin Airport are RNP capable, and it is expected that this figure will increase.

Flight procedure development includes the provision of three lines of RNP approach (altitude) minima, LNAV: Lateral Navigation, LNAV - (Baro) VNAV: Lateral Navigation with barometric vertical guidance & LPV (200): Localiser Performance with Vertical guidance. The addition of these RNP procedures aligns with CDA, RNAV-1 and Free Route developments by the IAA ANSP by ensuring the most efficient use of airspace, taking environmental considerations into account at all phases of flight.

Airport Collaborative Decision Making (A-CDM)

This is a European wide initiative to improve Air Traffic Flow and Capacity Management at airports through optimising resources, reducing delays, and improving the predictability of events during the progress of a flight. It integrates airports and ATM systems and covers the arrival, turnaround and departure processes to maximise the pre-departure sequence of an aircraft. This increases the efficiency for the turnaround process and thus will increase the capacity of European airspace.

Dublin A-CDM is a joint initiative between Dublin Airport and the IAA. Under EU regulation 716/2014, Dublin Airport has been selected as one of the Pilot Common Project (PCP) airports, to support the implementation of the European Air Traffic Management Master Plan. Dublin Airport has been identified as one of the major European airports to implement Pre-Departure Sequencing (PDS) by 1st January 2021. The programme is aimed at improving airside efficiency, allowing collaboration between all the main airport partners - daa, IAA, Aircraft Operators, Ground Handlers, EUROCONTROL & Met Éireann - to share operational data to enhance decision making and reduce overall delays in the operations.

Dublin Airport commenced live operational trials on the 18th April 2018 with all airlines and ground handlers and moved A-CDM to 24*7 operations on the 15th January 2019. A six month verification exercise commenced with EUROCONTROL in January 2019 to verify the data accuracy, after which Dublin Airport becomes a fully approved/compliant A-CDM airport, subject to the approval of the Network Manager.

Further investigation is required to establish the actual environmental benefits this project can deliver. Saying this, with this rich supply of data and additional timestamp outside the scope of the A-CDM project, the iAOP should be able to drive additional environmental benefits for Dublin

Airport and its Airlines. This could deliver a reduction in overall delays for arriving and departing traffic, which could further result in less aircraft fuel burn.

EUROCONTROL data collected from 17 A-CDM airports in April 2016 from 2.2 million annual departures showed that A-CDM led to a 7.7% reduction in fuel burn. Carbon dioxide emissions were reduced by 102,700 tonnes and sulphur dioxide by 28,700 kg.

Potential environmental benefits from ACDM are applicable primarily to aircraft operators, who will benefit from reduced fuel burn and CO_2 emissions, reduced taxiing times & reduced queuing at runway holding points. The A-CDM will increase punctuality of departures and arrivals with better airport slot adherence and more efficient use of the existing infrastructure and resources. Airport noise will also be reduced as a result of reduced apron and taxiway congestion. Furthermore, as the European take-up of A-CDM increases, the EUROCONTROL Network Management Operations Centre (NMOC) will benefit from enhanced predictability and better network management, thereby enabling user-preferred trajectories which give benefits in terms of fuel burn and CO_2 emissions.

Initial Airport Operations Plan (iAOP)

This project will provide a holistic view of the airport operations and will aim to achieve maximum efficiency based on data collection, information sharing and co-ordination, leading to more stream-lined decision making for all Dublin iAOP partners (Airlines, ground handlers, Air Traffic Control, etc.). It will use IAA flight trajectory data, local weather data, and A-CDM data to share runway capacity and stand data with iAOP partners.

Conclusion

This action plan provides an overview of the actions undertaken by Ireland and Irish stakeholders, either alone or in collaboration with others such as the European Union, in order to mitigate the effects of climate change. Section II of this action plan was finalised on 11 April 2019, and shall be considered as subject to update after that date.

Ireland must continue to be vigilant in order to reduce the level of CO_2 emissions. Ireland will aim to meet its international commitments and ensure that emissions continue to be rigorously controlled, making use of clean technologies at every possible opportunity.

Ireland's strategic location on the periphery of Europe and the nature of the operational improvements in the provision of air navigation services means that the positive effects of the projects will be felt not just in Ireland but further afield with airlines from many countries benefitting from the efficiency improvements being implemented by Ireland over the coming years. The initiatives being implemented by Ireland and Irish companies, such as the Aireon Project, the Borealis Alliance, and A-CDM will undoubtedly lead to CO_2 emissions reductions, the benefits of which will be felt on a global scale.

Ireland will also benefit from actions at the supranational level, particularly when those projects expected to bring the most benefits to Member States will be deployed by the European Commission through legally binding instruments called Common Projects.

These initiatives will require joined-up action between Government departments, national agencies and local authorities. These bodies must make air quality an integral part of their planning processes. The shift from solid fuel to cleaner alternatives must also be encouraged and incentivised.

The links between health and air quality must be better communicated by all public bodies involved in air quality assessment and management in order to raise awareness of the critical issues with policy and decision makers as well as with the general public.

Ireland and its stakeholders are fully committed to addressing the climate change impacts of commercial aviation and achieving the required level of GHG emissions reductions through an integrated strategy of technological and operational improvements as well as the implementation of a comprehensive and robust policy framework.

Aviation emissions need to be curbed and then to decline, in line with the 1.5^{o}C warming limit and the need to minimise the risk of dangerous climate impacts. The measures detailed in this report can help to do this and also contribute to a more efficient and effective transport system for Europe. However they require all Member States to act together and with a sense of urgency. Further delay will only result in greater dependence on imported energy and will make the 1.5^{o}C objective harder to achieve.

Appendix A – Detailed Results for ECAC Scenarios From Section A

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[42] RPK (billion)	All-Cargo Traffic (IFR movements) (million)	Freight Tonne Kilometres transported[43] FTKT (billion)	Total Revenue Tonne Kilometres[42, 44] 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.					

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

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

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

2. Implemented Measures Scenario

2A) 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.					

2B) 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.					

2C) 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.					

List of Abbreviations

ACARE – Advisory Council for Research and Innovation in Europe

ACARS – Aircraft Communications Addressing and Reporting System

ACA – Airport Carbon Accreditation

ACC – Area Control Centres

ACCAPEG – Aviation and Climate Change Action Plan Expert Group

A-CDM – Airport Collaborative Decision Making

ACI – Airports Council International

ADS-B– Automatic Dependent Surveillance Broadcast

AEM – Advanced Emission Model

AFTF – Alternative Fuels Task Force (of ICAO CAEP)

AIRE – The Atlantic Interoperability Initiative to Reduce Emissions

ALERT – Aircraft Locating and Emergency Response

ANS – Air Navigation Service

AOC– Air Operator Certificates

APER TG - Action Plans for Emissions Reduction Task Group of the ECAC/EU Aviation and Environment Working Group (EAEG)

ATC – Air Traffic Control

ATM – Air Traffic Management

BAU – Business as Usual

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

daa – Dublin Airport Authority

DSOT – Dynamic Sectorisation of Airspace Trials

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

EPA – Environmental Protection Agency

EU – European Union

EUAA – European Union Aviation Allowance

EU ETS – the EU Emissions Trading System

F1AB – Functional Airspace Block

FANS – Future Air Navigation System

FEGP – Fixed Electrical Ground Power

FIR – Flight Information Region

FP7 - 7th Framework Programme

FRA – Free Route Airspace

GHG – Greenhouse Gas

GMBM – Global Market-based Measure

Green STAR – Standard Arrival

Green IA – Initial Approach

HF – High Frequency

HIRO – High Intensity Runway Operations

HVO – Hydro-treated Vegetable Oil

IAA – Irish Aviation Authority

iAOP – Initial Airport Operations Plan

ICAO – International Civil Aviation Organisation

IFR – Instrumental Flight Rules

IPCC – Intergovernmental Panel on Climate Change

IPR – Intellectual Property Right

JTI – Joint Technology Initiative

KPA – Key Performance Area

KPI – Key Performance Indicator

LTO cycle – Landing/Take-off Cycle

MBM – Market-based Measure

MT – Million tonnes

OFA - Operational Focus Area

PCP – Pilot Common Project

PDS – Pre-Departure Sequencing

RDI – Reduced Departure Intervals

RED – Renewable Energy Directive

RNAV – Area Navigation

RNP AR – Required Navigation Performance Authorization Required

RNP STAR – Required Navigation Performance Standard Arrival

RPAS – Remotely Piloted Aircraft

RPK – Revenue Passenger Kilometre

RRDI – Refined Reduced Departure Interval

RTK – Revenue Tonne Kilometre

RTD – Research and Innovation

SES – Single European Sky

SESAR – Single European Sky ATM Research

SESAR JU – Single European Sky ATM Research Joint Undertaking

SESAR R&D – SESAR Research and Development

SWAFEA – Sustainable Ways for Alternative Fuels and Energy for Aviation

SWIM – System Wide Information Management

TMA - Terminal Manoeuvring Area

ToD – Top of Descent

UNEP – United Nations Environmental Programme

XMAN – Cross Border Arrivals Management

An Roinn Iompair,
Turasóireachta agus Spóirt
Department of Transport,
Tourism and Sport