Energy Efficiency Improvements in Air Traffic: the Case of Airbus A320

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ABSTRACT:

Structural improvements in aircraft design, aimed at achieving improved energy efficiency, can significantly reduce emissions of greenhouse gases (GHG) through reduced fuel consumption. This work investigates consistent improvements regarding the introduction of the structural component called "winglet," positioned at the top of the aircraft wing, and the increased sales of Airbus Group A320. Data used are taken from air traffic in Spain for the 2010-2014 period, with projections being made for 2020. The results show that the winglet element reduces CO_2 equivalent emissions associated with Spain’s air transport for the 2015-2020 period of between 62.88 and 56.59 Gg. depending on the scenario considered in 2020.

KEYWORDS:

CO2 emissions, A320, Ceo, air traffic, Spain, energy efficiency.

1. INTRODUCTION

By signing the 1997 Kyoto Protocol, European Union (EU) Member States and the member countries of the European Environmental Agency (EEA) are committed to reducing Greenhouse Gas (GHG) emissions for 2050 to 80-95% of 1990 levels (EEA, 2014). Final agreement reached by United Nations Climate Change Conference in Paris (see text of agreement at UN, 2015) has reinforce the role of mitigation policies. As one of the European Union (EU) Members States, Spain's authorities have to face staunch commitments derived from what is known as the H2020 strategy, which is the more ambitious EU package to fight against global warning. Within the framework of Horizon 2020, Spain is obliged to improve its energy efficiency by 20%. This implies an accumulated reduction in final energy consumption of 15,979 Ktoe for the 2014-2020 period (European Union, 2013; Eurostat, 2014; MINETUR, 2014; MAGRAMA, 2014 a).

In Spain, air traffic is considered a key-GHG emission sector , and responsible for a total emissions volume of 3,149.23 Gg of CO_2 equivalent (CO_2e) for 2012. This number represented 3.95% of total transport emissions (MAGRAMA, 2014 b).

The benefits of a higher level of energy efficiency are commonly acknowledged and include the mitigation of GHG emissions. Energy efficiency in air transport has shown a sustained improvement during the 2005-2012 period, equivalent to a reduction of 18.71% (Table 1).

Table 1. Evolution of the key indicators for air traffic in Spain 1990-2012 (Gg.)

	1990	1995	2000	2005	2008	2009	2010	2011	2012
CO_2e (Gg,)	2,000	2,311	3,716	4,449	4,500	3,936	3,854	3,662	3,149
Energy Units (TJ)	27,536	31,806	51,155	61,239	61,937	54,185	53,054	50,413	43,349
Operations	-	-	-	2,210,449	2,420,072	2,168,580	2,119,665	2,140,308	1,924,866
Passengers	-	-	-	179,643,919	202,698,848	186,764,003	192,046,395	203,627,283	193,449,137
Energy efficiency (TJ /Operation)	-	-	-	0.027	0.025	0.024	0.025	0.023	0.022

Source: Own production from MAGRAMA (2014a).

The Geneva Convention on Long-range Transboundary Air Pollution (1982) laid the foundations for the development of an international environmental legal framework. Its objectives included reducing the damage to human health and the environment caused by transnational air pollution. Deriving from this Convention, the Gothenburg Protocol, signed in 1999 by all the Members States of the European Union, sought to abating acidification, eutrophication and ground-level ozone, by establishing limits to the main causative polluting agents (SO_2, NO_2, VOCs and NH_3). This Protocol was revised in 2012, to establish new emission ceilings for these polluting agents to be achieved by 2020, and transferred it to the European and national legislation on air quality.

Among the measures adopted in Spain to achieve the national emissions ceiling were those for transportaiton, including action on air fleets. If all of the gas emissions associated with air transport are taken into consideration, the reduction of NO_X emissions is especially important and for several reasons. Firstly isits impact as an ozone precursor and the commitments assumed by Spain to mitigate ozone precursors. Specifically, experts from the Intergovernmental Panel on Climate Change (IPCC) indicate that aircrafts emit gases and particles directly into the upper Troposphere and the lower Stratosphere--altitudes between 9 and 13 km--thus affecting their composition. These emissions alter the concentration of the gases making up those layers of the atmosphere, and trigger the formation of condensation trails and the possibility of increasing the quantity of cirrus clouds (IPPC, 1999). Particularly important are the emissions of nitric oxide (NO_x - NO) and nitrogen dioxide (NO_2), which, in conjunction with the Non-Methane Volatile Organic Compounds (NMVOCs) act as ozone precursors, at both the tropospheric level to favour global warming and at ground level. Their reaction with sunlight is harmful for human beings (Table 2) (MAGRAMA, 2015). Ozone is the main contributing agent to photochemical smog, which is related to respiratory health problems such as Chronic Obstructive Pulmonary Disease (COPD) (Berend, 2015), among other effects.

Table 2. Breakdown of polluting gas emissions from air traffic.
Series 2009-2012 (Gg.)

	CO_2	CH_4	N_2O	NO_X	CO	NMVOCs	SO_2
2009	3,936.39	0.02	0.12	19.69	3.47	0.59	1.25
2010	3,854.23	0.02	0.12	19.53	3.38	0.54	1.22
2011	3,662.38	0.02	0.12	18.52	3.22	0.52	1.16
2012	3,149.23	0.02	0.10	15.93	2.78	0.45	1.00

Source: Own production from UNFCCC, 2014.

From the 1960s, the aviation industry has drastically reduced its emissions by 70%, in terms of Revenue Passenger Kilometres (RPKs). Aircrafts are now 75% quieter whilecarbon monoxide levels have been reduced by 50% and unconsumed hydrocarbons by 90% (IATA, 2015).

In line with this trend, the objectives marked by the industry are to: a) improve global fleet fuel efficiency by an annual average of 1.5% until 2020, b) stabilise net aviation CO_2 emissions as of 2020, and, c) reduce net CO_2 emissions by 50% for 2050 in relation to 2005 (ATAG, 2015). These objectives will be ratified in the 39th Assembly of the International Civil Aviation Organisation (ICAO) to be held in Paris this year.

The afore-mentioned objective obliges aeronautical manufacturers to develop technologies that allow the reduction of environmentally polluting emissions through R&D projects (ATAG, 2015). The aeronautical research programme, Clean Sky Joint Undertaking (CSJU, 2008), launched in 2008, must be specifically mentioned. It has the co-participation of industry sector companies including the Airbus Group, Safran, Thales, Rolls Royce.

The CSJU is composed of six R&D projects. These are called Integrated Technology Demonstrators (ITDs), oriented towards environmental improvement in engines, aerodynamics and design. For this paper, it is the ITD known as SMART Fixed Wing Aircraft (SFWA) which is of special interest. Its objective is the development of new products related to aircraft wings to achieve improved aerodynamics, thus contributing to reaching the general objectives of the CSJU programme.

Given that the developmental cost for new aircraft to fulfil those new requirements would be extremely high (between 5,000 and 10,000 million Euros, with the return on the investment being at least 10 years), industry leaders--Boeing Co. and Airbus Group--decided to modify their most successful models, B737 and A320, respectively. These modifications focus on technological innovations applied to the power units, aero-structural improvement, and others, in accordance with the master lines of projects such as the CSJU. The B737 model evolved into the Max version, while the A320 into the NEO version. The development of these new models has been accelerated by the design of the Chinese prototype, COMAC; it is foreseen to enter into service between 2019 and 2020. Nevertheless, this model does not have features similar to the models mentioned above (El Mundo, 2015).

The development of structural elements such as the winglet--an angular prolongation at the tip of the wing--has been of particular interest. In the case of Airbus Group, this improvement is installed on the new units of the current versions of the A320, designated as 'Current Engine Option' (Ceo). It is also included in retrofitted versions, including the designation 'New Engine Option' (Neo), at the end of the commercial name of each aircraft. The A320 Neo, A330 Neo and A380 Neo models are in the process of industrialisation. The new development, the A350XWB, is already in service thanks to the delivery of its first unit in January 2015 (Airbus Group, 2015a).

Based on the above, the objective of this work is to consider the impact on the reduction of fuel consumption and polluting gas emissions, associated with the introduction of the improved model for a reference aircraft in the air fleet operating in Spain. In others words, the question posed by this paper is: “To what extent could this improved model to reduce fuel consumption and polluting gas emissions in air transport in Spain”. The question is relevant considering the Spanish contribution in the global fight against Climate Change. Also, the time is right to consider Spanish commitments for the 2020 horizon.

For this purpose, a bottom-up analysis has been performed with the reference scenario corresponding to 2014. Together with this scenario, three end scenarios, with projection to 2020, have been considered, and named a) Central Scenario, b) Pessimistic Scenario and, c) Optimistic Scenario. Each scenario incorporates various penettation levels for the new reference aircraft model, as well as the renovation and maintenance of the previous models. For the best of our knowledge this is the first paper that conducts this type of analysis and therefore, paper contributes to this growing body of knowledge around the impacts on energy efficiency in aircrafts on CO_2 emissions.

The results allow optimism with respect to being able to reach the objectives fixed by Air Transport Action Group (ATAG) for 2020, in terms of reduction of polluting emissions (ATAG, 2015). The reference aircraft considered in this paper is the A320 and its improved model is the Ceo that incorporates winglets.

The work is structured as follows; After the introduction, Section 2 describes the technical improvement oriented towards energy consumption efficiency. Section 3 describes the methodology and data used. The main results are provided and discussed in Section 4. The most important conclusions and recommendations are summarised in Section 5.

2. TECHNICAL IMPROVEMENT

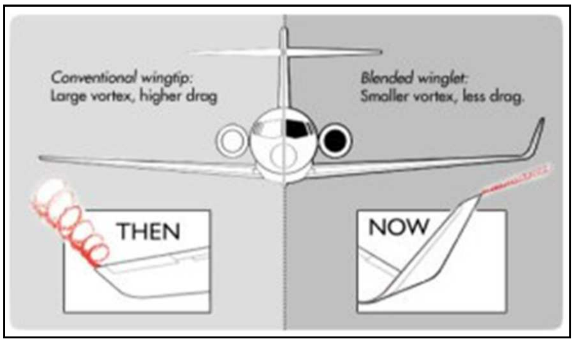
2.1 Origin and technical functionality of the Winglet as a structural element

Traditionally, the aeronautic industry has continually sought to reduce induced drag.

With the oil crises of the 1970s and the upsurge of fuel prices, aircraft manufacturing companies were forced to analyse how to reduce consumption and improve efficiency. It was at that time when engineer Richard T. Whitcomb of the

National Aeronautics and Space Administration (NASA) involved in its Aircraft Energy Efficiency Program (ACEE), developed the winglet concept (NASA, 2007) based on the flight characteristics of gliding birds. Whitcomb's study showed that tairflow around the wing tip is characterised by a flow over the wing and inwards, and by another flow, below the wing tip flowing outwards. Whitcomb proved that it was possible to reduce induced drag through an angled, curved vertical surface, above or below the tip (Guerrero *et al.*, 2011; Whitcomb, 1976). Figure 1 shows how the air flow acts with and without a winglet.

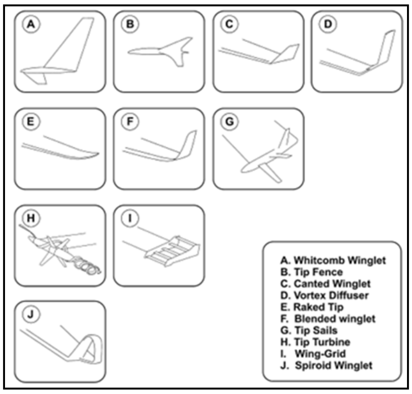
Fig 1. Difference in the vortices with, and without, a winglet.



Source: The Flight Engineer (2015).

This is a major field of research for aircraft manufacturers, with the objective being to improve efficiency and reducing environmental impact. To this end, numerous devices on the wing tip have been developedto attain improved efficiency. Figure 2 shows some of the devices that have been developed over the past decades (Guerrero *et al.*, 2011).

Fig 2. Various winglet solutions.



Source: Guerrero et al. (2011).

2.2 Introduction of winglets on the Airbus A320 model

In 2014, the sales of the Airbus Group consortium A320 family of aircrafts (A319/A320/A321) amounted to 490 units, which signified 56% of the single-aisle market segment[1] they belong to (Airbus Group, 2015b). The number of orders, in September 2015, reached 3,621 units (Airbus Group, 2015c). In relation to the new A320 version--the Neo--its most important change consisted in the use of engines with greater power and efficiency; this translated into the following advantages over the old version of the A320 (Airbus Group, 2012a):

- 15% fuel consumption reduction.
- 50% reduction of NO emissions.
- 8% reduction in operating costs.

[1] Also called "Narrow-body aircraft," of regional range, with a 3-4 m diameter fuselage, 6 seats abreast and up to 180 seats with a single-aisle configuration.

- Smaller acoustic impact (up to 15dB below that termed Stage IV by the European Directive 2010/26/EU for technical aspects on tests and approvals of non-road engines).

Also, the retrofitted model includes winglets that Airbus Group renamed with the term “sharklets” (Airbus Group, 2012b). The first A320 Neo fligh took place in 2014 (Airbus Group, 2014) and the first unit entered into service in December 2015 (Airbus Group, 2015c). Table 3 shows the most important differences between the Airbus A320 Ceo and Airbus A320 Neo (Airbus Group, 2015c).

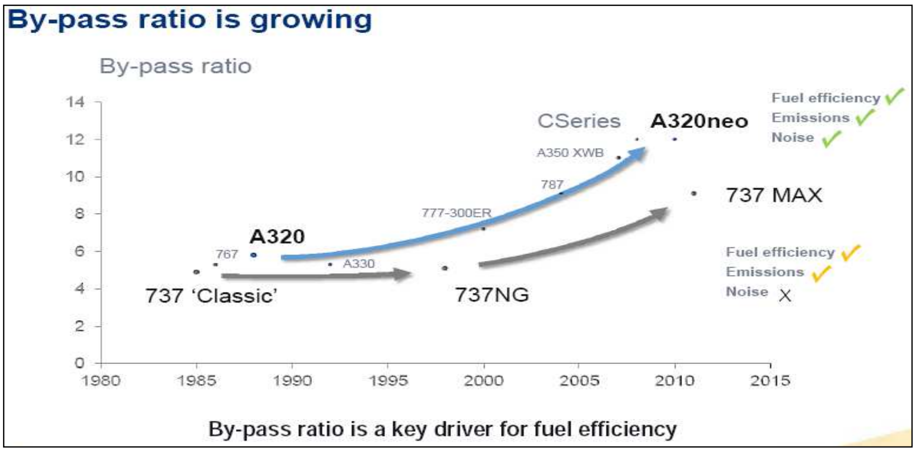
Table 3. Comparison of specifications A320 Ceo versus A320 Neo

CHARACTERISTICS	A320 Trad. and Ceo	A320 Neo
Standard Seats	150	150
Range (Nm.)	3,300	3,700
Range (km)	6,100	6,850
MTOW Basic Tons	73.5	73.5
MTOW Max. Option Tons	78.0	79.0
Thrust LB SLST	27,000	27,000

Source: Airbus Group, 2015c.

In December 2012, Airbus Group delivered the first production unit of its A320 Ceo model as an intermediate step between its traditional model and the A320 Neo. The main innovation was the inclusion of sharklets (Airbus Group, 2012b). Sharklets on the Ceo and Neo models measure 2.4 metres in height and have a weight of 200 kg (Kingsley-Jones, 2009); these allow saving a maximum of 3.5% of fuel per flight and the associated emissions based on a variety of variables, including flight distance. This capacity, together with the other innovative characteristic of the A320 Neo provide increased market competitiveness, as is shown in Figure 3 (Airbus Group, 2012a).

Fig 3 Evolution of the versions of the models A320 and Boeing 737.



Source: Airbus Group, 2012a.

3. METHODOLOGY AND DATA

3.1 Methodology

When calculating fuel consumption savings and GHG emissions associated with the introduction of the improved Airbus A320 model into the Spanish fleet, a bottom-up analysis has been made for the 2015-2020 period. To calculate savings, the historical data corresponding to the 2010-2012 and 2013-2014 periods are analysed. Data from 2014 defines the baseline scenario.

To incorporate a sensitivity analysis, three final scenarios have been considered. These are: a) Central Scenario (Annexe 2), b) Pessimistic Scenario (Annexe 3), and, c) Optimistic Scenario (Annexe 4).

The final scenarios are derived from the application of the sharklet reduction factor, which is defined as the percentage of consumption and emissions savings with the integration of the element into the aircraft structure. Together with the reduction factor, the final scenarios are deduced from the evolution factors. These factors provide information about the introduction of new aircrafts and their fleet replacement and maintenance. Both the sharklet reduction factor (at 1.5% - a conservative criterion) and the evolution factors (Airbus Group, 2015e) were applied on the 2014 Instrument Flight Rules (IFR) for the A320 Traditional and A320 Ceo (sharklets) models for each year of the 2015-2020 period (Airbus Group, 2015d). The evolution factors considered were:

- Growth (3%) on additional units (A320 Ceo and A320 Neo).
- Replacement (18%) on replacement of the Traditional A320 units without sharklets
- Maintenance (79%) applied on the A320 Traditional without sharklets.

For the incorporation of the sensitivity analysis, a variation of ±5% was allowed in the growth, replacement and maintenance rates. Table 4 describes the evolution factors applied to each of the three final scenarios. The air activities of all other aircraft operation models are understood to grow by 3% per annum for the period under analysis, according to Airbus Group. (Airbus Group, 2015e).market studies.

Table 4. Scenarios projected for the period 2015-2020

SCENARIO	GROWTH (%)	REPLACEMENT (%)	MAINTENANCE (%)
Central scenario	3	18	79
Pessimistic scenario (- 5%)	1	15	84
Optimistic scenario (+5%)	5	21	74

Source: Airbus Group, 2015e.

3.2 Data

Air Traffic Data

Air traffic statistics were constructed from the IFR traffic defined as "operated flights which satisfy specific rules on instrumental equipment and conform to the definition of the ICAO, Point 3.6 of , Annex 2, of the Convention on International Civil Aviation when in controlled Airspace" (Eurocontrol, 2005).

The number of operations (take-offs and landings) per model and for all types of traffic (commercial, passenger and cargo) distributed between the Traditional A320 and the A320 Ceo (equipped with sharklets) models comes from Spain's Airports and Air Navigation Agency (AENA, 2015) and expressed as percentages. These percentages were applied on IFR traffic values from Eurocontrol (Eurocontrol, 2015) so that they could later be compared with the series, projected in Europe until 2020 by this European air navigation safety organisation. This has allowed the GHG emissions to be calculated for the 2013-2014 period and to complete the data set that was necessary to provide the projection to 2020, taking 2014 as reference.

By applying the evolution factors for years 2015-2020, as indicated in the previous section, the specific number of Traditional model units in service throughout the series was obtained. However, the number of units corresponding to the new A320 Neo version could not be segraged from those of A320 Ceo, in each case of entry for a new unit into service; these originated by applying the growth and replacement evolution factors. Nevertheless, this fact lacks relevance, as this study is limited to the innovative use of sharklets, which are fitted in both models and associated with the aforementioned 1.5% savings factor.

The economic growth estimates were taken from the International Monetary Fund (IMF, 2015) and from Eurocontrol (Eurocontrol, 2015). For the calculation of the economic value of fuel savings, the average price of kerosene published by Indexmundi (2015) was used. The calorific value per litre was taken from Berkeley (2015).

Emissions data

CO_2e emissions data related to air transport operations in Spain came from the Spain's National Institute of Statistics (INE, 2015). The measurement units are expressed in tons of CO_2e and are consistent with the data offered by the European Environment Information and Observation Network (EIONET, 2015). The most recent year for which data is currently available for this research is 2012. For later years, the value of the emissions and the associated energy units were calculated from the annual IFR traffic, with values of 2.02 Mg. CO_2 and 0.03 TJ, respectively, which were maintained as constant until 2020.

Due to the difficulty in estimating their impact, the following variables within IFR operations have not been considered:

- Flight speed.
- Flight altitude.
- Flight route.
- Operational load.
- Piloting style.
- Age and maintenance of the engines (Loss of efficiency with age).
- Maintenance of the aero-structure (Dirtiness, condensed water, etc.).

4. RESULTS AND DISCUSSION

4.1 Emissions and air traffic in Spain (2010-2014)

In recent years, Spain'sair traffic has experienced a progressive decline in the number of operations and volume of emissions (Annex 1). Both variables reached their minimum level in 2013, with a number of 1,528,000 IFR flights and 3,089.89 tons of CO_2e, respectively. In 2014, the number reached 1,587,000 IFR flights. Passenger numbers have adjusted to these trends amounting to 195,226,852 in 2014 (AENA, 2015).

Annex 1 offers CO_2 emissions data for the2010-2014 period, the energy units corresponding to the fuel consumption, the evolution of the national GDP, AENA operations and the complete IFR traffic values from Eurocontrol. Annex 1 also shows the information broken down by aircraft model, its unitary value in CO_2 and energy units. It can be seen that until 2009, the CO_2 emissions and fuel consumption almost duplicated 1990 stastics (the reference year for the fulfilment of the Kyoto Protocol agreements), arriving at a value of 3,936.00 Gg. (UNFCCC, 2014). Later, this number descended to a value of 3,208.18 Gg. in 2014, which represents an increase of 157.45% with respect to 1990. During the initial stage of the crisis, which began in 2007 and until 2012, a negative impact is confirmed for national and international numbers, to later recover growth abroad. This recovery was not as clear for Spain's economy, which showed a timid recovery in 2014.

At the end of 2012 and with the entry into operation of the A320 family (A318/A319/A320/A321) aircrafts equipped with sharklets, growth began with national operations of 1% and 3% for 2013 and 2014 for this model respectively. Assuming a direct relationship between emissions and fuel consumption per conducted operation, two scenarios were compared to obtain the results. The first incorporated a quota for aircrafts equipped with sharklets, and the second one without them. The CO_2 data and total energy units for national air traffic and those corresponding to A320 units operating in 2013-2014, were taken from the operations data provided by AENA. The considered percentages were: 31.98% (2013) and 30.97% (2014) for the traditional version, and 0.99% (2013) and 3.11% (2014) for the Ceo model. Those percentages were applied to all IFR flights (Eurocontrol, 2015). Finally, it was understood that the emissions and energy units per capita would remain constant for the period. The data considered were 2.02 Mg CO_2 and 0.03 TJ, respectively, per IFR flight. In order to obtain the global results, this data were multiplied by the respective number of IFR flights (Annexe 2). Table 5 shows the main results.

Table 5. Comparison between emissions and energy units in scenarios with sharklets and without sharklets for the period 2013-2014

YEAR	**2013**			**2014**		
MODEL	**Scenario with sharklets**	**Scenario without sharklets**	**Dif.**	**Scenario with sharklets**	**Scenario without sharklets**	**Dif.**
A320 total (IFR)	503,743	503,743	-	540,743	540,743	-
A320 Trad. (IFR)	488,655	488,655	-	491,425	491,425	-
CO_2 (Gg)	988.29	988.29	-	993.90	993.90	-
Energy Units (TJ)	13,604.82	13,604.82	-	13,681.94	13,681.94	-
A320 Ceo (IFR)	15,088	15,088	-	49,318	49,318	-
CO_2 (Gg)	30.06	30.51	-0.46	98.25	99.74	-1.49
Energy Units (TJ)	413.76	420.06	-6.30	1,352.48	1,373.08	-20.59

Source: AENA, 2015.

4.2 Projection for the2015-2020 period

When calculating the impact of the new aircraft on fuel consumption and volume of GHG emissions in the 2015-2020 period, it was accepted that Spain would maintain an average interannual growth level of 2.26%, until 2020 (IMF, 2015). Also, the Eurozone and other advanced economies will maintain an average growth of 1.6% for the first, and 3.72% for the second, which is why these economies will provide a favourable context for the growth of air traffic. Along this same line, the European perspective offered by Eurostat and Airbus Group, agree in that air traffic will have an interannual growth of approximately 3.24% (Airbus Group, 2015e) (Eurocontrol, 2015).

Apart from the aforementioned growth rates, the percentage distribution of IFR flights per aircraft was obtained, according to growth, replacement and maintenance rates (Airbus Gorup, 2015b) and the contribution by model within the A320 family. Finally, obtaining the annual savings with respect to the reference year of 2014, the CO_2 emissions avoided and energy units segregated by year, by model and as a whole were calculated. The following results are given for each of the three scenarios considered.

Central scenario

Table 6 shows how the total IFR traffic forecast, considered by Eurocontrol for the scenario, are greater than the projection made for the central scenario, according to evolution, growth, replacement and maintenance factors. In particular, for 2020 they are 4.59% higher. On the other hand, the quota for traditional A320 plummets, that is, the new models incorporating sharklets, play an important role in IFR traffic by the A320 family for 2020.

Table 6. Distribution of IFR traffic. Central scenario. 2015 versus 2020

YEAR	2015			2020		
CRITERION	NUMBER	TOTAL & % of QUOTA	QUOTA A320 (%)	NUMBER	TOTAL & % of QUOTA	QUOTA A320 (%)
IFR EUROCONTROL	**1,652,000**			**1,921,000**		
PROJECTED IFR	**1,619,867**			**1,836,545**		
Subtotal A320 IFR	**542,222.58**	**33,47%**	**100%**	**587,259.48**	**31.98%**	**100%**
A320 Trad.	388,225.78	23,97%	71.60%	119,459.26	6.50%	20.34%
A320 Ceo	153,996.81	9.51%	28.40%	467,800.22	25.47%	79.66%
OTHER MODELS	1,077,645	66.53%	-	1,249,286.60	68.02%	-

Source: Own production

Since 2014, the CO_2 emissions and energy consumption increase by 15.33%, when calculating IFR flights, thus reaching a global amount of 3,700.18 Gg. of CO_2 and 50,937 TJ in 2020, as shown in Figure 4.

Fig 4 Evolution of CO_2 emissions, energy units and their saving for the period 2015-2020. Central scenario.

Source: Own production

The percentage contribution of the Traditional A320 and the Ceo model in 2020 was 20.34%, as opposed to 79.66% in relative terms. If those values are compared with 2014 data (90.88% for the first model, and 9.12% for the second), one can appreciate the respective contribution of each as significantly reversed. The evolution of that contribution has given rise to an estimated savings on emissions and energy units for the entire 2015-2020 series of 59.73 Gg. CO_2 and 822.31 TJ respectively, that is, 0.28% for the total of 20,846.04 Gg. of CO_2 and 287,028.90 energy units (TJ).

It is therefore a significant reduction of CO_2 and TJ in quantitative terms. It corresponds to 25.47% of the fleet for 2020, given the potential of introducing the element in the rest of the fleet where it has not yet been implemented, the Traditional A320 as well as the other models represent 6.50% and 68.02%, respectively (74.53%).

Pessimistic scenario

Table 7 shows how the total IFR traffic forecast, considered by Eurocontrol for the scenario, are higher in comparison with the projection made for the pessimistic scenario, according to evolution, growth, replacement and maintenance factors. Specifically, they are 4.81% greater for 2020. Again, the quota is for the Traditional A320 plummets, whereas the new models with integrated sharklets play an important role in IFR traffic made by the A320 family for 2020.

Table 7. Distribution of IFR traffic. Pessimistic scenario. 2015 versus 2020

YEAR	2015			2020		
CRITERION	NUMBER	TOTAL & % of QUOTA	QUOTA A320 (%)	NUMBER	TOTAL & % of QUOTA	QUOTA A320 (%)
IFR EUROCONTROL	**1,652,000**			**1,921,000**		
PROJECTED IFR	**1,618,880.89**			**1,832,786.03**		
Subtotal A320 IFR	**541,236.22**	**33.43%**	**100%**	**583,500.51**	**31.84%**	**100%**
A320 Trad.	412,797	25.50%	76.27%	127,020	6.93%	21.77%
A320 Ceo	128,439	7.93%	23.73%	456,481	24.91%	78.33%
OTHER MODELS	1,077,645	66.57%	-	1,249,286	68.16%	-

Source: Own production

Since 2014, CO_2 emissions and energy consumption logically increase by a value of 15.10%, when making IFR flights. The global amount reaches 3,692.92 Gg. of CO_2 and 50,836.62 TJ in 2020, respectively, as shown in Figure 5.

Fig 5 Evolution of CO_2 emissions, energy units and their saving for the period 2015-2020. Pessimistic scenario.

Source: Own production

The percentage contribution of the Traditional A320 and the Ceo model in 2020 was 21.77%, as opposed to 78.23% in relative terms. If those values are compared with the 2014 data (90.88% for the first model, and 9.12% for the second), once again, it is seen that the respective contribution of each has been greatly reversed. This variation in the evolution has given rise to an expected reduction of emissions and energy units for the entire 2015-2020 series, with 56.59 Gg. CO_2 and 778.98 TJ, respectively. That is a value of 0.28% on the total of 20,823.08 Gg. of CO_2 and 286,649.68 TJ.

There is therefore a significant reduction of CO_2 and TJ in quantitative terms that corresponds to 24.91% of the fleet for 2020, given the potential of introducing the element in the rest of the fleet where it has not yet been implemented, Traditional A320 as well as the other models that represent 6.93% and 68.16% respectively (75.09%).

Optimistic scenario

Finally, Table 8 shows how the total IFR traffic forecast, considered by Eurocontrol for the scenario, are higher in comparison with the projection made for the optimistic scenario. Also, for this scenario, the quota for the Traditional A320 plummets, whereas the new models with integrated sharklets play an important role in IFR flights made by the A320 family for 2020.

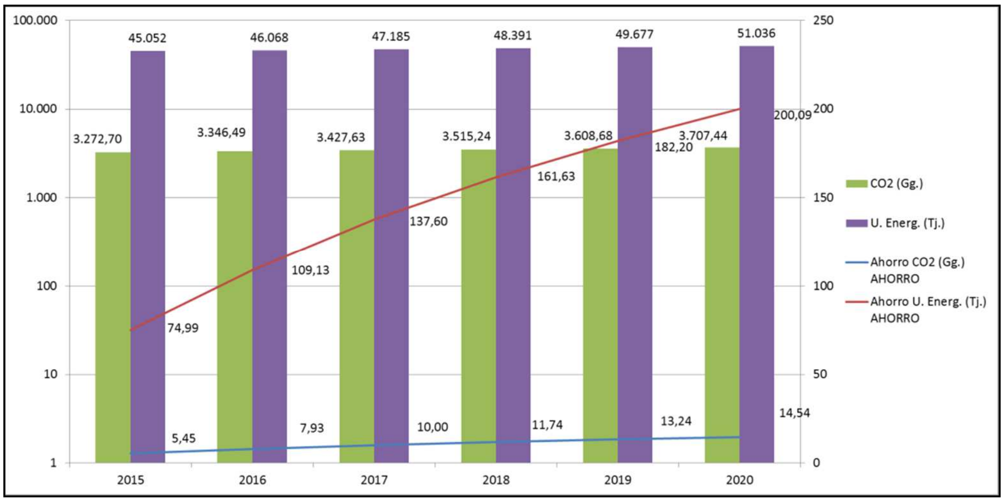
Table 8. Distribution of IFR traffic. Optimistic scenario. 2015 versus 2020

YEAR	2015			2020		
CRITERION	NUMBER	TOTAL & % of QUOTA	QUOTA A320 (%)	NUMBER	TOTAL & % of QUOTA	QUOTA A320 (%)
IFR EUROCONTROL	1,652,000			1,921,000		
PROJECTED IFR	1,620,853.61			1,840,303.98		
Subtotal A320 IFR	543,208.94	33.51%	100%	591,018.46	32.12%	100%
A320 Trad.	363,655	22.44%	66.95%	111,899	6.08%	18.93%
A320 Ceo	179,554	11.08%	33.05%	479,120	26.03%	81.07%
OTHER MODELS	1,077,645	6.49%	-	1,249,286	67.88%	-

Source: Own elaboration

As expected, since 2014, the CO_2 emissions and energy consumption increase with a value of 15.56%, when making IFR flights, reaching a global amount of 3,707.44 Gg. of CO_2 and 51,036.48 TJ, respectively, in 2020, as shown in Figure 6.

Fig 6 Evolution of CO_2 emissions, energy units
and their saving for the period 2015-2020. Optimistic scenario.



Source: Own production

The percentage contribution of the Traditional A320 and the Ceo model in 2020 was 18.93%, as opposed to 81.07% in relative terms. If those values are compared with 2014 data (90.88% for the first model, and 9.12% for the second), once again, it can be seen that the respective contribution of each has been significantly reversed. This variation gives rise to an expected reduction of emissions and energy units for the entire 2015-2020 series is 62.88 Gg. CO_2 and 865.63 TJ, respectively. That is a value of 0.28% on the total of 20,878.18 Gg. of CO_2 and 287,408.12 TJ.

It is therefore an important reduction of CO_2 and TJ in quantitative terms, corresponding to 26.03% for 2020 fleet, given the potential of the element introduced in the rest of the fleet where it has not yet been implemented, Traditional A320 and the other models, which represent 6.08% and 67.88%, respectively (73.97%).

Finally, Table 9 shows the comparison of the results obtained in terms of savings in CO_2 (Gg.) and Energy Units (TJ) in the three scenarios:

Table 9. Savings of emissions and energy units 2015-2020 for the different scenarios

YEAR	**2015-2020**	
SCENARIO/SAVING	**CO_2 (Gg.)**	Energy Units (TJ)
Central scenario	59.73	822.31
Pessimistic scenario (- 5%)	56.59	778.98
Optimistic scenario (+5%)	62.88	865.63

Source: Own production

5. CONCLUSIONS AND POLICY IMPLICATIONS

This paper calculates the savings in fuel consumption and GHG emissions in air transport in Spain as a result of the entry into operation of a more efficient aircraft model. Specifically, improvements were considered in the A320 family of aircrafts, which represents one of the two most used models for civil air traffic worldwide. For this purpose, a bottom-up analysis was developed with a reference scenario being 2014. The results were calculated for the 2015-2020 period and incorporated a sensitivity analysis that considered three final scenarios.

The main results obtained indicate that the savings is significant in the three scenarios for both fuel consumption and GHG emissions.

Starting with this statement and in agreement with the ATAG objective for the airlines to reach a value of 3,390.79 Gg. of CO_2 emissions for 2020 (an annual reduction of 1.5%), we can conclude that this objective is attainable in the optimistic scenario for which 3,707.44 Gg. of emissions have been estimated. This represents a difference of only 316.65 Gg. Given that this is an optimistic scenario, we recommend focusing efforts on approximately 68% of the IFR flight quota, operated with models other than the A320, to assure this target.

Being conservative in the central scenario, the reduction in fuel consumption (822.31 TJ) would be equivalent to 10,960,000 Euros. This considers an average price of 0.49 €/litre for aviation kerosene, an exchange rate of 0.943 Euros per US Dollar (01/12/2015) and a calorific value of 36.8 MJ per litre.

Therefore, it is essential that aviation itself and the national government develop programmes, both operational and technological to improve energy efficiency per litre of fuel used, with the corresponding reduction of emissions in each of the air operations in Spain, as this is beneficial for both the environment and human health. Likewise, among the legislative measures for the fulfilment of the emissions reduction targets that may be put forward, there could be those that favour air traffic when aircrafts with winglets are seen at airports in Spain. This could either be through promotion, or by establishing some type of control that would allow the number of aircraft that do not use winglets to be restricted in Spain's air traffic. Other measures, such as eco-labelling, aimed at changing consumer patterns, educational programmes and green taxes might remain in force.

This paper helps reduce uncertainty about the expected impact of the issues identified for the necessary investments to operate aircfrats considered. These results could be useful for a broad range of stakeholders including policymaker, companys and consumers.

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ANNEXES

ANNEXE 1: Global table of the 2010-2014 series

		2010		2011		2012		2013			2014		
TOTAL CO2 EMISSIONS (Gg.)	TOTAL	**3,854.00**		**3,662.00**		**3,149.00**		**3,089.89**			**3,208.18**		
	Variation BASE/1990	192.70%		183.10%		157.45%		154.49%			160.41%		
	Variation BASE/2010	100.00%		95.02%		81.71%		80.17%			83.24%		
ENERGY UNITS (TJ)	TOTAL	**53,054**		**50,413**		**43,349**		**42,535**			**44,164**		
	Variation BASE/1990	192.67%		183.08%		157.43%		154.47%			160.39%		
	Variation BASE/2010	100.00%		95.02%		81.71%		80.17%			83.24%		
GDP		**0.01%**		**-1.00%**		**-2.60%**		**-1.23%**			**1.39%**		
OPERATIONS	TOTAL	**2,119,665**	**100%**	**2,140,308**	**100%**	**1,924,866**	**100%**	**1,790,948**	**100%**		**1,832,911**	**100%**	
	A320 Trad.	694,037	32.74%	686,458	32.07%	622,545	32.34%	572,746	31.98%		567,573	30.97%	
	A320 Ceo							17,684	0.99%		56,960	3.11%	
	A320 Neo							0	0.00%		0	0.00%	
	OTHER MODELS	1,425,628	67.26%	1,453,850	67.93%	1,302,321	67.66%	1,200,518	67.03%		1,208,378	65.93%	
IFR FLIGHTS	TOTAL IFR FLIGHTS EUROCONTROL	**1,608,000**	**100%**	**1,665,000**	**100%**	**1,557,000**	**100%**	**1,528,000**	**100%**		**1,587,000**	**100%**	
	Variation on PREVIOUS YEAR	1.71%		3.54%		-6.49%		-1.86%			3.86%		
	TOTAL PROJECTED IFR												
	Variation on PREVIOUS YEAR												
	DIF, IFR EUROC, Vs PROJECTED												
A320 IFR, CO2 (Gg.) & ENERGY UNITS (TJ)	Subtotal IFR A320	694,037	32.74%	534,013	32.07%	503,569	32.34%	503,743	32.97%	**100.00%**	540,743	34.07%	**100.00%**
	Subtotal A320 CO2 (Gg.)	1,663.44		1,174.51		1,018.46		1,018.35			1,092.15		
	Subtotal A320 Energy Units (TJ)	22,898.90		16,168.89		14,020.04		14,018.58			15,034.43		
	A320 Trad.	**694,037**	**32.74%**	**534,013**	**32.07%**	**503,569**	**32.34%**	**488,655**	**31.98%**	**97.00%**	**491,425**	**30.97%**	**90.88%**
	CO2 (Gg.)	1,663.44		1,174.51		1,018.46		988.29			993.90		
	TJ	22,898.90		16,168.89		14,020.04		13,604.82			13,681.94		
	A320 Ceo y Neo							**15,088**	**0.99%**	**3.00%**	**49,318**	**3.11%**	**9.12%**
	CO2 (Gg.)							30.06			98.25		
	TJ							413.76			1,352.48		
	A320 Neo												
	CO2 (Gg.)												
	TJ												
	OTHER MODELS	913,963	43.12%	1,130,987	52.84%	1,053,431	54.73%	1,024,257	67.03%		1,046,257	65.93%	
	CO2 (Gg.)	2,190.56		2,487.49		2,130.54		2,071.54			2,116.03		
	TJ	30,155.10		34,244.11		29,328.96		28,516.72			29,129.22		
CO2 units per IFR (Mg.)		2.40		2.20		2.02		2.02			2.02		
Energy Units (TJ) per IFR		0.03		0.03		0.03		0.03			0.03		
TOTAL CO2 SAVING (Gg.)								0.46			1.50		
TOTAL Energy Unit SAVING (TJ)								6.30			20.60		

ANNEXE 2: Table of Projection 2015-2020. Central scenario.

		2015			2016			2017			2018			2019			2020		
TOTAL CO2 EMISSIONS (Gg.)	TOTAL	**3,271.48**			**3,343.59**			**3,423.34**			**3,509.79**			**3,597.67**			**3,700.18**		
	Variation BASE/1990	163.57%			167.18%			171.17%			175.49%			179.88%			185.01%		
	Variation BASE/2010	84.89%			86.76%			88.83%			91.07%			93.35%			96.01%		
ENERGY UNITS (TJ)	TOTAL	**45,035.00**			**46,027.74**			**47,125.51**			**48,315.65**			**49,588.46**			**50,936.55**		
	Variation BASE/1990	163.55%			167.15%			171.14%			175.46%			180.09%			184.98%		
	Variation BASE/2010	84.89%			86.76%			88.83%			91.07%			93.47%			96.01%		
GDP		3.07%			2.54%			2.23%			2.01%			1.90%			1.78%		
OPERATIONS	TOTAL																		
	A320 Trad.																		
	A320 Ceo																		
	A320 Neo																		
	OTHER MODELS																		
IFR FLIGHTS	TOTAL IFR FLIGHTS EUROCONTROL	**1,652,000.00**			**1,710,000.00**			**1,760,000.00**			**1,813,000.00**			**1,865,000.00**			**1,921,000.00**		
	Variation on PREVIOUS YEAR	4.10%			3.51%			2.92%			3.01%			2.87%			3.00%		
	TOTAL PROJECTED IFR	**1,619,867.25**			**1,656,816.49**			**1,697,320.04**			**1,740,970.89**			**1,787,457.70**			**1,836,545.00**		
	Variation on PREVIOUS YEAR	102.07%			102.28%			102.44%			102.57%			102.67%			102.75%		
	DIF, IFR EUROC, Vs PROJECTED	101.98%			103.21%			103.69%			104.14%			104.34%			104.60%		
A320 IFR, CO2 (Gg.) & ENERGY UNITS (TJ)	Subtotal IFR A320	542,222.58			546,842.49			554,046.81			563,399.46			574,559.13			587,259.48		
	Subtotal A320 CO2 (Gg.)	1,091.96	**33.47%**		1,098.69	**33.01%**		1,111.09	**32.64%**		1,128.18	**32.36%**		1,144.60	**32.14%**		1,173.53	**31.98%**	
	Subtotal A320 Energy Units (TJ)	15,031.90			15,124.55			15,295.22			15,530.46			15,819.71			16,154.74		
	A320 Trad.	**388,226**			**306,698**			**242,292**			**191,410**			**151,214**			**119,459**		
	CO2 (Gg.)	785.18	**23.97%**	**71.60%**	620.29	**18.51%**	**56.09%**	490.03	**14.27%**	**43.73%**	387.12	**10.99%**	**33.97%**	301.24	**8.46%**	**26.32%**	241.60	**6.50%**	**20.34%**
	TJ	10,808.73			8,538.90			6,745.73			5,329.13			4,210.01			3,325.91		
	A320 Ceo y Neo	**153,997**			**240,144**			**311,755**			**371,989**			**423,345**			**467,800**		
	CO2 (Gg.)	306.78	**9.51%**	**28.40%**	478.40	**14.49%**	**43.91%**	621.06	**18.37%**	**56.27%**	741.05	**21.37%**	**66.03%**	843.36	**23.68%**	**73.68%**	931.92	**25.47%**	**79.66%**
	TJ	4,223.17			6,585.65			8,549.49			10,201.33			11,609.70			12,828.83		
	A320 Neo																		
	CO2 (Gg.)																		
	TJ																		
	OTHER MODELS	1,077,645			1,109,974			1,143,273			1,177,571			1,212,899			1,249,286		
	CO2 (Gg.)	2,179.51	**66.53%**		2,244.90	**66.99%**		2,312.25	**67.36%**		2,381.61	**67.64%**		2,453.06	**67.86%**		2,526.65	**68.02%**	
	TJ	30,003.09			30,903.19			31,830.28			32,785.19			33,768.75			34,781.81		
CO2 units per IFR (Mg.)		2.02			2.02			2.02			2.02			2.02			2.02		
Energy Units (TJ) per IFR		0.03			0.03			0.03			0.03			0.03			0.03		
TOTAL CO2 SAVING (Gg.)		4.67			7.29			9.46			11.29			12.84			14.19		
TOTAL Energy Unit SAVING (TJ)		64.31			100.29			130.20			155.35			176.80			195.36		

ANNEXE 3: Table of Projection 2015-2020. Pessimistic scenario.

		2015			2016			2017			2018			2019			2020		
TOTAL CO2 EMISSIONS (Gg.)	TOTAL	**3,270.26**			**3,340.69**			**3,419.04**			**3,504.34**			**3,595.83**			**3,692.92**		
	Variation BASE/1990	163.51%			167.03%			170.95%			175.22%			179.79%			184.65%		
	Variation BASE/2010	84.85%			86.68%			88.71%			90.93%			93.30%			95.82%		
ENERGY UNITS (TJ)	TOTAL	**45,018.21**			**45,987.77**			**47,066.42**			**48,240.64**			**49,500.02**			**50,836.62**		
	Variation BASE/1990	163.49%			167.01%			170.93%			175.19%			179.76%			184.62%		
	Variation BASE/2010	84.85%			86.68%			88.71%			90.93%			93.30%			95.82%		
GDP		3.07%			2.54%			2.23%			2.01%			1.90%			1.78%		
OPERATIONS	TOTAL																		
	A320 Trad.																		
	A320 Ceo																		
	A320 Neo																		
	OTHER MODELS																		
IFR FLIGHTS	TOTAL IFR FLIGHTS EUROCONTROL	**1,652,000.00**			**1,710,000.00**			**1,760,000.00**			**1,813,000.00**			**1,865,000.00**			**1,921,000.00**		
	Variation on PREVIOUS YEAR	4.10%			3.51%			2.92%			3.01%			2.87%			3.00%		
	TOTAL PROJECTED IFR	**1,618,880.89**			**1,655,063.40**			**1,694,932.02**			**1,738,051.18**			**1,784,086.96**			**1,832,786.03**		
	Variation on PREVIOUS YEAR	102.01%			102.24%			102.41%			102.54%			102.65%			102.73%		
	DIF, IFR EUROC, Vs PROJECTED	102.05%			103.32%			103.84%			104.31%			104.54%			104.81%		
A320 IFR, CO2 (Gg.) & ENERGY UNITS (TJ)	Subtotal IFR A320	541,236.22			545,089.40			551,658.79			560,479.76			571,188.40			583,500.51		
	Subtotal A320 CO2 (Gg.)	1,090.74	**33.43%**		1,095.79	**32.93%**		1,106.80	**32.55%**		1,122.73	**32.25%**		1,142.77	**32.02%**		1,166.27	**31.84%**	
	Subtotal A320 Energy Units (TJ)	15,015.11			15,084.58			15,236.14			15,455.45			15,731.27			16,054.81		
	A320 Trad.	**412,797**			**326,110**			**257,627**			**203,525**			**160,785**			**127,020**		
	CO2 (Gg.)	834.87	**25.50%**	**76.27%**	659.55	**19.70%**	**59.83%**	521.04	**15.20%**	**46.70%**	411.63	**11.71%**	**36.31%**	325.18	**9.01%**	**28.15%**	256.90	**6.93%**	**21.77%**
	TJ	11,492.83			9,079.34			7,172.68			5,666.41			4,476.47			3,536.41		
	A320 Ceo y Neo	**128,439**			**218,980**			**294,032**			**356,955**			**410,404**			**456,481**		
	CO2 (Gg.)	255.87	**7.93%**	**23.73%**	436.24	**13.23%**	**40.17%**	585.75	**17.35%**	**53.30%**	711.10	**20.54%**	**63.69%**	817.58	**23.00%**	**71.85%**	909.37	**24.91%**	**78.23%**
	TJ	3,522.28			6,005.24			8,063.46			9,789.03			11,254.80			12,518.40		
	A320 Neo																		
	CO2 (Gg.)																		
	TJ																		
	OTHER MODELS	1,077,645			1,109,974			1,143,273			1,177,571			1,212,899			1,249,286		
	CO2 (Gg.)	2,179.51	**66.57%**		2,244.90	**67.07%**		2,312.25	**67.45%**		2,381.61	**67.75%**		2,453.06	**67.98%**		2,526.65	**68.16%**	
	TJ	30,003.09			30,903.19			31,830.28			32,785.19			33,768.75			34,781.81		
CO2 units per IFR (Mg.)		2.02			2.02			2.02			2.02			2.02			2.02		
Energy Units (TJ) per IFR		0.03			0.03			0.03			0.03			0.03			0.03		
TOTAL CO2 SAVING (Gg.)		3.90			6.64			8.92			10.83			12.45			13.85		
TOTAL Energy Unit SAVING (TJ)		53.64			91.45			122.79			149.07			171.39			190.64		

ANNEXE 4: Table of Projection 2015-2020. Optimistic scenario.

		2015			2016			2017			2018			2019			2020		
TOTAL CO2 EMISSIONS (Gg.)	TOTAL	**3,272.70**			**3,346.49**			**3,427.63**			**3,515.24**			**3,608.68**			**3,707.44**		
	Variation BASE/1990	163.63%			167.32%			171.38%			175.76%			180.43%			185.37%		
	Variation BASE/2010	84.92%			86.83%			88.94%			91.21%			93.63%			96.20%		
ENERGY UNITS (TJ)	TOTAL	**45,051.79**			**46,067.71**			**47,184.59**			**48,390.66**			**49,676.90**			**51,036.48**		
	Variation BASE/1990	163.61%			167.30%			171.36%			175.74%			180.41%			185.34%		
	Variation BASE/2010	84.92%			86.83%			88.94%			91.21%			93.63%			96.20%		
GDP		3.07%			2.54%			2.23%			2.01%			1.90%			1.78%		
OPERATIONS	TOTAL																		
	A320 Trad.																		
	A320 Ceo																		
	A320 Neo																		
	OTHER MODELS																		
IFR FLIGHTS	TOTAL IFR FLIGHTS EUROCONTROL	**1,652,000.00**			**1,710,000.00**			**1,760,000.00**			**1,813,000.00**			**1,865,000.00**			**1,921,000.00**		
	Variation on PREVIOUS YEAR	4.10%			3.51%			2.92%			3.01%			2.87%			3.00%		
	TOTAL PROJECTED IFR	**1,620,853.61**			**1,658,569.58**			**1,699,708.06**			**1,743,890.59**			**1,790,828.44**			**1,840,303.98**		
	Variation on PREVIOUS YEAR	102.13%			102.33%			102.48%			102.60%			102.69%			102.76%		
	DIF, IFR EUROC, Vs PROJECTED	101.92%			103.10%			103.55%			103.96%			104.14%			104.38%		
A320 IFR, CO2 (Gg.) & ENERGY UNITS (TJ)	Subtotal IFR A320	543,208.94			548,595.58			556,434.83			566,319.17			577,929.87			591,018.46		
	Subtotal A320 CO2 (Gg.)	1,093.18	**33.51%**		1,101.60	**33.08%**		1,115.38	**32.74%**		1,133.63	**32.47%**		1,155.62	**32.27%**		1,180.79	**32.12%**	
	Subtotal A320 Energy Units (TJ)	15,048.69			15,164.52			15,354.31			15,605.47			15,908.15			16,254.67		
	A320 Trad.	**363,655**			**287,287**			**226,957**			**179,296**			**141,644**			**111,899**		
	CO2 (Gg.)	735.48	**22.44%**	**66.95%**	581.03	**17.32%**	**52.37%**	459.02	**13.35%**	**40.79%**	362.62	**10.28%**	**31.66%**	286.47	**7.91%**	**24.51%**	226.31	**6.08%**	**18.93%**
	TJ	10,124.64			7,998.46			6,318.79			4,991.84			3,943.55			3,115.41		
	A320 Ceo y Neo	**179,554**			**261,309**			**329,478**			**387,023**			**436,286**			**479,120**		
	CO2 (Gg.)	357.70	**11.08%**	**33.05%**	520.56	**15.76%**	**47.63%**	656.37	**19.38%**	**59.21%**	771.01	**22.19%**	**68.34%**	869.14	**24.36%**	**75.49%**	954.47	**26.03%**	**81.07%**
	TJ	4,924.05			7,166.06			9,035.52			10,613.63			11,964.60			13,139.26		
	A320 Neo																		
	CO2 (Gg.)																		
	TJ																		
	OTHER MODELS	1,077,645			1,109,974			1,143,273			1,177,571			1,212,899			1,249,286		
	CO2 (Gg.)	2,179.51	**66.49%**		2,244.90	**66.92%**		2,312.25	**67.26%**		2,381.61	**67.53%**		2,453.06	**67.73%**		2,526.65	**67.88%**	
	TJ	30,003.09			30,903.19			31,830.28			32,785.19			33,768.75			34,781.81		
CO2 units per IFR (Mg.)		2.02			2.02			2.02			2.02			2.02			2.02		
Energy Units (TJ) per IFR		0.03			0.03			0.03			0.03			0.03			0.03		
TOTAL CO2 SAVING (Gg.)		5.45			7.93			10.00			11.74			13.24			14.54		
TOTAL Energy Unit SAVING (TJ)		74.99			109.13			137.60			161.63			182.20			200.09		

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