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IMPLICATIONS OF POTENTIAL NEW REGULATORY MEASURES TO ADDRESS AVIATION EMISSIONS

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Abstract

This work is an analysis of the implications of the potential new regulatory policies being recently proposed in the European Union, in particular the mandatory blending of SAF (on top of the already existing CORSIA or ETS), to address aviation emissions from a technical, operational and economic perspective. As a continuation of previous work from the Department of Aerospace Systems, Air Transport and Airports from the ETSIAE (Universidad Politécnica de Madrid), the air traffic structure of the European Union in 2019 has been analysed based on publicly available data from EUROCONTROL and EUROSTAT. The output has been used as the reference scenario for the implementation of the mandatory blending of SAF, expected to take over at the beginning of 2025, since it is expected that by then, air traffic will reach the pre-COVID levels. The results show that all the policy options considered so far have uneven impact among the different stakeholders and that before deciding going forward with any of the presented options, extra work needs to be done to overcome the different challenges that would potentially arise.

Keywords: Regulation, SAF, emissions, European Union, blending

1. Introduction

The rebound of air traffic after the economic crisis of 2008 and the development of emerging countries had, as a consequence, an increase of the CO_2 emissions that became a source of concern for customers, operators and legislators. While the COVID-19 pandemic has slowed down the increase in emissions, it is expected that the situation of 2019, in terms of traffic and passengers, is reached again by 2025 and this would suppose that in a few years at the same rhythm, without any further measure taken more than the fleet renovation, aviation would become one of the key pollutant sectors by 2045 [1, 2].

Different entities and organizations have proposed a variety of plans and measures with the purpose of reducing emissions and incentivize the development of new technologies that could help mitigate the impact of air transport. One of those initiatives is CORSIA, the Carbon Offsetting and Reduction Scheme for International Aviation [3]. The objective of CORSIA is to set a threshold based on the emissions of 2019 (2020 was excluded due to the alteration of flights caused by COVID) and neutralize all the emissions that surpass that threshold by forcing the affected operators in carbon reduction projects [3-6].

The European Union, years before the implementation of CORSIA, established the Directive 2008/101/EC [7], which later included aviation emissions in the Emission Trading System (ETS) and hence, forced the airlines to start accounting for their emissions and to comply with the limits accordingly. Otherwise, they must economically compensate for the excesses. The impact of this directive is proposed to be modified in the Proposal for a Regulation of the European Parliament and of the Council [8], commonly known as the “Fit for 55” package, that was released on the 14th of July

2021. In line with the Green Deal [9], the package includes a set of proposals to modify the current EU legislation in order to achieve the goal of reducing the greenhouse gas emissions by at least a 55% by year 2030 [10]. The key changes for aviation that this package includes are the phase-out of the free allowances assigned to airlines in ETS, eliminating them by 2027, the revision of the Energy Taxation Directive, that introduces a fuel tax, and the ReFuelEU Aviation proposal, which will accelerate the introduction and usage of sustainable aviation fuels (SAF) [11]. This latest proposal comes as the more innovative of the three, since, while there is a general consensus about the relevance that SAFs will have in the reduction of emissions, with some authors making them responsible for the 64% of savings by 2050 [12], the limited feedstock and infrastructure currently available reflect in the cost of these products and are the main reasons why the market penetration is currently minimal. To increase it, the ReFuelEU establishes a SAF obligation with three possible approaches: on the supply side, by imposing fuel suppliers to include a percentage of SAF in all the jet fuel distributed in the EU airports; on the demand side, by forcing airlines to use a share of SAF in all the flights from EU airports and the third approach, which combines the previous ones by obligating the distributors to provide jet fuel with a mix of SAF but with some flexibility and the airlines to uptake fuel before departing from the EU airports.

ALTERNATE (Assessment of alternative aviation fuels development) is a H2020 funded project that aims at developing a framework to increase the possibilities of using SAFs in commercial air transport and, consequently, reduce its impact on climate change. This Chinese and European cooperation project is investigating means to stimulate a wider SAF utilization, considering both technical and economic areas, including the possible use of more feedstocks and sustainable production pathways than the existing ones. New fuel candidates are being evaluated according to improved modelling methods, considering LCA and economic modelling to examine climate change effects and technical, economic and environmental consequences of their use. Key objectives of ALTERNATE are evaluating the different options available for the introduction of SAFs in the normal operation of the airlines and proposing and evaluating mitigation strategies based on the use of alternative jet fuel pathways.

It is generally accepted that some type of incentive mechanism needs to be implemented to make sustainable fuel attractive for the airlines in addition to the CORSIA and European Emissions Trading System (ETS) provisions. In the context of the project, the evolution of the air traffic in the period 2003-2019 has been analysed, allowing to get an understanding of the trends that were developed during that time and that are expected to continue once the impact of the COVID-19 is mitigated. Since the data for 2020 and 2021 was affected on a great extent by the flight restrictions imposed by governments, the data of 2019 has been taken as a reference to explore the effects of the three possible approaches of the ReFuelEU Aviation proposal in the EU countries and analyse the advantages and disadvantages of each option.

Preliminary results show important differences among countries since some of the EU members have a very centralized airport network due to the country configuration (eg. The Netherlands) while others have a more disperse one (eg. Spain). This means that in some cases, forcing providers to make SAF available in all the airports would suppose a great logistic challenge that would not provide a big difference from making it available in the main airport while in others, it might be necessary in order to reach the percentages of SAF established by ReFuelEU Aviation. However, there seems to be a remarkable difference between the airlines that have a very strong hub-and-spoke strategy vs. those that operate a point-to-point model, since the latter need the product available in a higher number of airports.

2. Methodology

The results presented in this paper were obtained by applying the model developed in the Department of Aerospace Systems, Air Transport and Airports from the ETSIAE, part of the Technical University of Madrid [13-15]. It is based on the analysis of the information stored in the databases of the European Organization for the Safety of Air Navigation (EUROCONTROL) and the European Commission's Eurostat Air Transport Statistics (Eurostat). The combination of both sources has provided a very clear picture of the air traffic in the European Union during 2019. As mentioned before, the data for 2020 and 2021 has been dismissed due to the unusual circumstances encountered due to the COVID-19 pandemic.

2.1 Assumptions

The assumptions that have been considered throughout the study are:

- The number of flights analyzed each year has been limited as per the standard practices of the industry [16]: the only week taken into consideration has been the central week of June since it is consider that it represents the average traffic of the year.
- All the non-civil and not scheduled flights have been removed.
- The passenger-version of the aircrafts has been used over the cargo due to the usual mix of load transported. The number of seats corresponds to a dual-class configuration for the legacy airlines and a single-class for low-cost carriers.
- The distance between the airports has been assumed as the orthodromic distance and calculated with the great-circle formula:

$$\Delta\sigma = \arccos\left(sin\varphi_1 sin\varphi_2 + cos\varphi_1 cos\varphi_2 \cos(\Delta\lambda)\right) \tag{1}$$

$$d = r\Delta\sigma \tag{2}$$

  φ and λ are the geographical latitude and longitude in radians of the two airports, Δφ and $\Delta\lambda$ are their absolute differences, $\Delta\sigma$ is the central angle between the airports and r is the Earth's radius (6 371 km).

- The fuel consumption per flight has been calculated with the EMEP/Corinair database [17] without considering the take-off weight, the speed nor the altitude.
- The CO_2 emissions have been estimated following the value used in the EU ETS directive [7], this is, multiplying the fuel consumption in kg by 3.15.
- The production unit used is the revenue passenger-kilometer (RPK).

3. Results

3.1 Energy Demand and CO_2 Emissions per Country in 2019

Table 1 shows the distribution of the fuel uptake per country after analyzing, using the described methodology, the data related to 2019. For this analysis, only the departure flights have been considered. The country where most of the fuel was lifted in the EU was Germany (DE) with 10.06 million tonnes, which are equivalent to 31.70 million tonnes of CO_2, more than 20% of the total. The three countries with the higher uptake values (Germany, Spain and France) add up to a 50.5% of the total fuel, almost the same as the other 24 countries together. This is a reflection of the high concentration of air traffic in the EU and gives an indication on where to focus the initiatives to reduce its impact.

Table 1. Fuel uptake and CO_2 emissions of departures in each EU member state during 2019

Country ISO Code	Fuel uptake (million tonnes)	CO_2 (million tonnes)	Percentage	CO_2 (kg)/RPK
AT	1.01	3.18	2.1%	0.138
BE	1.49	4.69	3.1%	0.110
BG	0.36	1.13	0.7%	0.096
CY	0.43	1.35	0.9%	0.095
CZ	0.56	1.76	1.2%	0.100
DE	10.06	31.69	20.7%	0.122
DK	1.06	3.34	2.2%	0.111
EE	0.07	0.22	0.1%	0.095
ES	7.32	23.06	15.0%	0.098
FI	0.79	2.49	1.6%	0.096
FR	7.23	22.77	14.8%	0.146
GR	2.12	6.68	4.4%	0.106
HR	0.33	1.04	0.7%	0.102
HU	0.37	1.17	0.8%	0.092
IE	1.17	3.69	2.4%	0.094
IT	5.19	16.35	10.7%	0.130
LT	0.12	0.38	0.3%	0.090
LU	0.53	1.67	1.1%	0.098
LV	0.15	0.47	0.3%	0.064
MT	0.18	0.57	0.4%	0.097
NL	3.48	10.96	7.1%	0.107
PL	1.12	3.53	2.3%	0.083
PT	1.79	5.64	3.7%	0.105
RO	0.50	1.58	1.0%	0.092
SE	1.14	3.59	2.3%	0.119
SI	0.04	0.13	0.1%	0.111
SK	0.08	0.25	0.2%	0.129
Total	**48.70**	**153.41**	**100%**	**0.114**

In terms of efficiency the best results are obtained by Latvia (LV), with values of 0.064 kilograms of CO_2(kg) per revenue passenger-kilometer due to the majority of its operations being carried-out by WIZZ Air which has an exceptional efficiency performance (case discussed in Section 3.2) and Baltic Airlines, which has a specialized fleet for the type lower distance-ranges that predominate in the region [18]. On the other side of the spectrum was France, with 0.146 CO_2(kg) per RPK, due in part to the high number of long-haul flights that service its overseas territories.

3.2 Energy Demand and CO_2 Emissions per Airline in 2019

Table 2 includes the breakdown of the fuel lifted by the ten airlines with higher values. Highlighted in italics are the airlines considered as low-cost: Ryanair, EasyJet Europe, Eurowings, Wizz Air and Vueling. The airline with the highest fuel consumption, Ryanair, used 3.47 million tonnes of fuel, the equivalent of all the fuel provided by the Netherlands during the same year. Following closely was Lufthansa, an iconic legacy airline, with 3.07 million tonnes of fuel. It is interesting to notice that, while the amount of fuel for departures from the EU might be similar, Ryanair focus its business on this same region, while Lufthansa has a more international network that includes long-distance routes. This means that while the total fuel consumption of Ryanair is closely aligned with the results from Table 2, the actual values for Lufthansa could have been noticeable higher. The same applies to the other legacy airlines included in the scope of Table 2.

Table 2. Fuel uptake and CO_2 emissions of departures of the ten leading airlines during 2019

Airline	Fuel uptake (million tonnes)	CO_2 (million tonnes)		CO_2 (kg)/RPK
Ryanair	*3.47*	*0.66*	*7.1%*	*0.096*
Lufthansa	3.07	0.59	7.0%	0.101
Air France	2.51	0.48	5.8%	0.101
KLM	1.81	0.34	4.1%	0.108
Iberia	1.08	0.21	2.5%	0.096
Alitalia	0.99	019	2.3%	0.095
EasyJet Europe	*0.99*	*0.19*	*2.3%*	*0.096*
Eurowings	*0.92*	*0.18*	*2.1%*	*0.101*
WIZZ Air	*0.83*	*0.16*	*1.9%*	*0.076*
Vueling	*0.83*	*0.16*	*1.9%*	*0.097*

In terms of fuel efficiency, the airline with the best results is WIZZ Air, with 0.076 CO_2 kilograms per revenue passenger kilometer. This is due in part by its fleet, which is mainly composed by the newer versions of the Airbus A320 and A321, that have an average age of 5 years [19] and by the type of routes that they operate, mostly intra-EU and with an average distance range of 1,400km. Alitalia, EasyJet Europe, Ryanair, Iberia and Vueling manage to maintain their efficiency below the 0.100 CO_2/RPK, but Eurowings, Lufthansa, Air France and KLM surpass that value, which in the case of the legacy airlines is mainly due to the relevance that the long-haul flights have in their schedule.

4. Analysis

4.1 ReFuelEU for Aviation

The European Union considers that until newer propulsion technologies are fully developed, SAF will have in the decarbonization of the air transport section. However, there are facing several obstacles that limit their entrance in the market, mainly the lack of raw materials and the limited number of facilities available for its production. That is why it is agreed that policy actions are needed to reverse this situation. One of its most recent initiatives is the ReFuelEU, which aims to increment the production of SAF in the EU by introducing regulations to make its use compulsory [8].

The proposal considers different options to make the use of SAF mandatory, combining different criteria for the responsibility of fulfilling the margins established and how the amount of SAF needed is measured. Table 3 summarizes the main characteristics of the six policy options currently considered.

Table 3. Summary of the policy options of ReFuelEU [8]

Policy Option	Obligation		Measure	
	Supplier	Airline	% Volume	CO2 intensity
A1	✓		✓	
A2	✓			✓
B1		✓	✓	
B2		✓	✓	
C1	✓	✓	✓	
C2	✓	✓		✓

The obligation to the suppliers entails that the percentage of fuel blend required by the policy is responsibility of the supplier, who must ensure that all airports in the EU contain the blend. The obligation for the airlines means that they need to ensure that across all their flights with origin in the EU, they need to load an amount of SAF equivalent to the percentage required by the policy. Policy option B2 however, presents a reduced scope, since only the intra-EU flights are considered and hence, the reduction in CO_2 emissions is less relevant in comparison with the other five options. Regarding the measure of the SAF blending, there are two approaches: the first one considers a volume-based approach and the second a CO_2 intensity reduction, which depends on the characteristics of the SAF loaded. Table 4 and Table 5 summarize the ramp-up requirements established by ReFuelEU.

Table 4. Volume based approach to the introduction of SAF for policy options A1, B1, B2 and C1 [8]

	2025	2030	2035	2040	2045	2050
SAF (%)	2	5	20	32	38	63
Of which RFNBOs	-	0,7	5	8	11	28

Table 5. CO_2 intensity approach for policy options A2 and C2 [8]

	2030	2040	2050
CO2 intensity reduction from the use of SAF	- 5%	- 29%	- 59%

At the moment, the considered as preferred policy options are the C1 and C2 ones, which divide the responsibility among airlines, since they are obliged to refuel before every flight that departures from the EU, and suppliers, who need to provide blended fuel to all airports of the EU although they would be exempted during the first few years of the implementation.

Due to the high decarbonization potential of renewable fuels of non-biological origins (RFNBOs), which can save over an 85% of emissions in comparison with conventional fuel, all the policy options include incentives to encourage the production of RFNBOs. Policy options A1, B1, B2 and C1 contemplate a gradual increase in the percentage of blended RFNBOs (as already broken-down in Table 4) and policies A2 and C2 a multiplier to be used in the accounting whose value evolves progressively to compensate the price difference with other fuels.

4.2 Implications

The decision taken by the European Commission on how to apply the ReFuelEU Aviation program will have a big impact among the different stakeholders of the air traffic industry. Although the initiative it is committed to *ensure a level playing field in the air transport market* [8], until the production and distribution of SAF becomes more mature, the cost of the final product is going to be noticeably higher than the price of conventional fuel.

4.2.1 Policy Options A1 and A2

As explained previously, these policy options set the responsibility on providing the requested amount of SAF in the providers, who are obliged to start providing blended fuel to all the airports in the EU starting from 2025.

The main advantage of these options is that the *level playing field* for aviation will be easily maintained, since by providing blended fuel to all airports, the price of blended fuel becomes the actual price of fuel, and all airlines are affected equally, including the foreign ones. On the other hand, the main inconvenience is that the production of fuel is currently limited to a few factories through the EU, mainly in the Netherlands, Finland, Spain and France [20]. The logistic cost to transport SAF from these factories to all the airports in the EU will not only have an economic impact in the price of the fuel itself, therefore increasing the burden in the operational costs of the airlines, it would also reduce the CO_2 savings achieved by the usage of SAF.

If analyzed at country level, there are mainly two groups of countries: one with a very centralized network of airports in which the main one supplies most fuel (Netherlands, Luxembourg, Malta…) and others in which the network is more decentralized (Spain, Greece, Croatia…). For these countries the distribution of SAF is even more complicated, which will again affect the cost on the fuel and would become an incentive for airlines to load more fuel than necessary in airports where fuel is cheaper (a practice commonly known as ‘tankering’). This practice, which is already a source of concern for the EU due to the extra CO_2 emissions that entails, would reduce even more the gains expected by the usage of SAF.

4.2.2 Policy Options B1 and B2

In the case of policy options B1 and B2, where the responsibility of achieving a certain level of SAF usage/reduction of CO_2 intensity is shifted to the airlines, the disadvantage related to the transportation of SAF to all the different airports disappears, as airlines can decide where to refuel, as long as the objectives are met. This is especially positive for airlines that base their business model in a hub-and-spoke approach, because focusing the use of blended fuel only in their hub will in most cases cover the requirements. However, airlines that have a point-to-point business model will be more affected since they would need to ensure that the supply of SAF reaches a higher number of airports, which as a consequence will increase their costs. As an example, if the two leader airlines of the market (Lufthansa and Ryanair) are compared, there are big differences in the implications of policies B1 and B2. Lufthansa, which is considered as a legacy airline and hence, bases its business in a hub-and-spoke model, loaded 57.06% of the total fuel it used for their departures from the EU in Frankfurt airport. In comparison, Ryanair, an airline specialized in point-to-point routes, needs to add up the load in 30 airports to reach the 57% of its fuel consumption.

Another potential drawback of these policies is related to the scarcity of SAF. The need of airlines to fulfill the requirements of the EU in order not to get fined, can open the door to a speculative SAF market in which either bigger airlines, which are supposed to have more financial resources at their disposal, can monopolize the production of fuel or suppliers can artificially raise the prices knowing that some airlines would be willing to pay more and leaving outside airlines with lower purchasing power. This could be aggravated by the possible intervention of foreign airlines, with their own motivation for the use of SAF, that could diminish the amount of SAF available for local ones. These situations, and any others in this line, will unbalance the *playing field* of aviation.

4.2.3 Policy Options C1 and C2

Policy options C1 and C2 leaves the responsibility of fulfilling the SAF blending mandates to suppliers, having to provide blended fuel to all airports as in options A1 and A2. The difference is that, during the first years of the implementation, they are allowed certain degree of flexibility, so the distribution can be done only in certain airports, as long as the ramp-up levels are achieved, to limit the logistic costs. Also, and in order to safeguard the *level playing field,* all airlines departing from the EU must uplift fuel before their departure. The amount of fuel loaded would need to be reported on a yearly basis to the European organization in charge, and it needs to be at least 90% of the cumulative fuel needed for all the flights that depart from the EU.

One of the suggestions that the document presents is that to facilitate the distribution of SAF, the first airports that could receive SAF are those supplied by the Central Europe Pipeline System (CEPS) [21]: Brussels (EBBR), Frankfurt am Main (EDDF), Luxembourg (ELLX) and Amsterdam Schiphol (EHAM). While this option presents the minimal logistics cost and might be the most convenient for fuel suppliers, it will have an uneven impact among airlines, and specially the EU ones. Airlines with hubs in those airports (namely Brussels Airlines, Lufthansa, Luxair and KLM), will face the impact of higher fuel costs in comparison with airlines with hubs elsewhere since it is supposed that at this time the production of SAF will not be fully developed still and will still be scarce. Another effective distribution strategy for suppliers could be to provide blended fuel to the main airport of each member state, in order to distribute the burden among all of them. But in this case, it would cause a gap between legacy and low-cost airlines, which use secondary airports as a way to reduce their operational costs.

5. Conclusions

This paper has reviewed the fuel uplift structure in the EU and the CO_2 emissions generated during 2019 at a country and airline levels using the tool developed by the Department of Aerospace Systems, Air Transport and Airports from the ETSIAE, which has proven again to be an efficient and accurate method relying only in publicly available data. Then, the latest proposal by the EU to tackle the increase of emissions expected after the sector recovers from the COVID-19 crisis has been discussed and the implications of the different policy options have been reviewed, which have been summarized in Table 6:

Table 6. Summary of the implications of the different policy options for ReFuelEU.

Policy Option	Advantages	Disadvantages
A1 -A2	- Maintenance of the level playing field for aviation - Blended fuel price becomes fuel price	- Blended fuel price affected by high logistic costs. - Transportation of fuel reduces CO_2 savings
B1 – B2	- Reduced logistic costs - High CO_2 savings due to limited logistics	- Affects the level playing field: ○ More beneficial for hub-and-spoke airlines than for point-to-point ones. ○ Airlines with high purchasing power might monopolize the SAF market
C1 – C2	- Limited logistic implications during the first years	- Affects the level playing field during the first years: ○ Airlines with hubs in the airports supplied by pipeline will face higher fuel costs if only blended fuel is distributed there. ○ Airlines without a base in those airports might struggle to reach the required percentage of mandatory bending. ○ Airlines that use secondary airports will have difficulties to get blended fuel.

Since all of them present disadvantages that could affect unequally the parties involved, the EU needs to revise the approaches followed and try to build a final proposal that overcomes the challenges assessed.

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8. Copyright Statement

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