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STUDY OF THE ENVIRONMENTAL EFFECTIVENESS OF RESTRICTIVE MEASURES ON DOMESTIC FLIGHTS IN SPAIN

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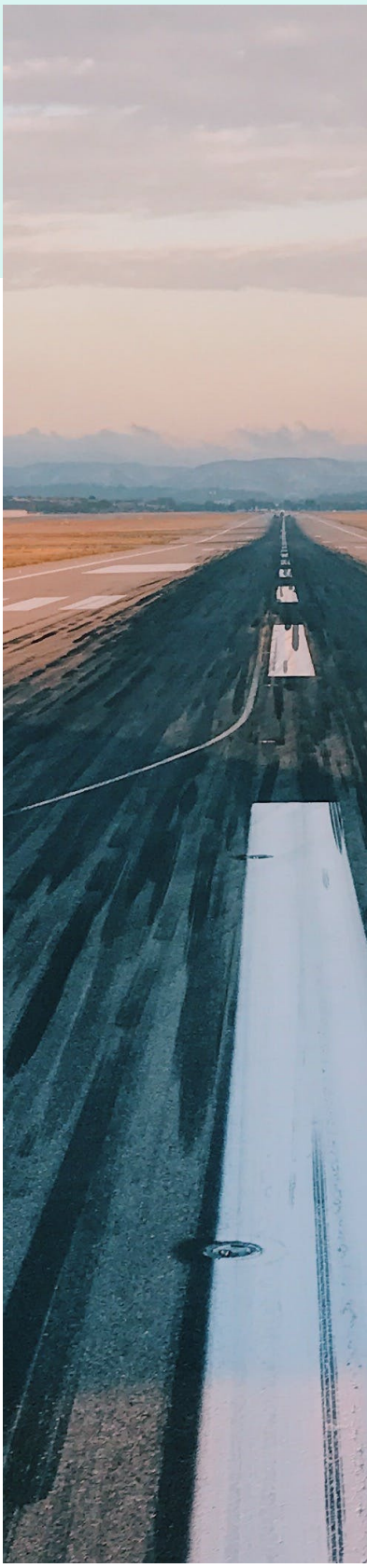
1 EXECUTIVE SUMMARY



- The objective of this report is to analyze the environmental efficiency of the possible restrictive measures on domestic flights in favor of high-speed rail transport in Spain.

- Air routes with a rail alternative of less than 3 hours will be studied, and in more detail the case of the Madrid-Barcelona air bridge. At these last two airports, the volume of operations potentially affected by a measure of this type would account for less than 5% of the total.

- In the arena of intra-European aviation, flights of less than 500 km of range account for only 3.8% of CO2 emissions. In Spain, domestic aviation is responsible for 1.2% of the country's total emissions.

- The CO2 emissions associated with the construction of high-speed rail tracks are a fundamental factor when evaluating the environmental efficiency of the railway. With current traffic, it has been estimated that the Madrid-Barcelona line will need 40 years to amortize these emissions, and this without taking into account other negative effects such as, for example, the environmental impact on the territory.

- The volume of CO2 corresponding to the emissions of all air connections likely to be replaced by high-speed trains in less than 3 hours represents 0.1% of the total CO2 emissions in Spain in 2019, the same percentage as the emissions from railways with diesel locomotives still in existence on the national rail network.

- The potential for reducing CO2 emissions if the Madrid-Barcelona air bridge were replaced by a railway connection could reach 136.7 ktCO2. This would mean approximately 0.68% of the total emissions of Spanish aviation in 2019. The calculation did not take into account the CO2 emissions during the construction of the railway.

- The long construction time of high-speed rail lines (from 18 to 26 years on average), plus the necessary subsequent environmental amortization period, means that by the time the possible new lines would make a net contribution to the reduction of emissions, the aviation could already be sustainable.

- There is a clear potential for reducing emissions in the efficient interconnection of commercial aviation and rail transport. This would go through measures such as enabling more train-airport links or implementing single intermodal tickets.

- Aviation has really useful tools at its disposal for the significant reduction of its emissions, such as sustainable aviation fuels (SAF), electric propulsion, with batteries or hydrogen cells, the emissions trading system (EU ETS), as well as efficiency measures in operations and air management. The European Commission has just launched its legislative proposal "Fit for 55" promoting all these ways.

- Rail transport must play a fundamental role in the sustainable transport of the future, although not necessarily through high speed.

2 INTRODUCTION AND CONTEXT

The challenge of the environmental sustainability of aviation has managed to attract the attention of public opinion in recent years. The urgency of the serious climate crisis we are facing means that quick solutions must be sought, sometimes without all the in-depth analysis that would be recommended, to a problem that encompasses all sectors of the economy.

In the area of transportation, this quest inevitably leads to confronting the environmental credentials of the different available modes of mobility, primarily using greenhouse gas emissions as their measure. To centre the debate, Figure 1 shows the contribution of the different modes of transport at a European level. It should be noted that these estimates do not include emissions associated with the construction of infrastructures, the relevance of which we will discuss later.

In this context, leaving aside road and maritime transport, different political initiatives in Europe have raised the possibility of a ban on commercial flights on short routes, provided that they have a viable rail alternative. As an example, in June 2020 Austria conditioned its aid package to its flag carrier with the elimination of flights that could be made by train in less than 3 hours. This measure mainly affected the Vienna-Salzburg route, which began to be operated by a reinforced train service from the Viennese airport itself [5].

However, it has been a French legislative initiative, currently pending, that has caused the greatest impact by prohibiting flights with an alternative rail of less than two and a half hours [13]. As part of the Climate Resilience Law, with measures initially proposed from a citizen convention, the debate generated has centered around the efficiency of the said measure when it comes to reducing polluting emissions.

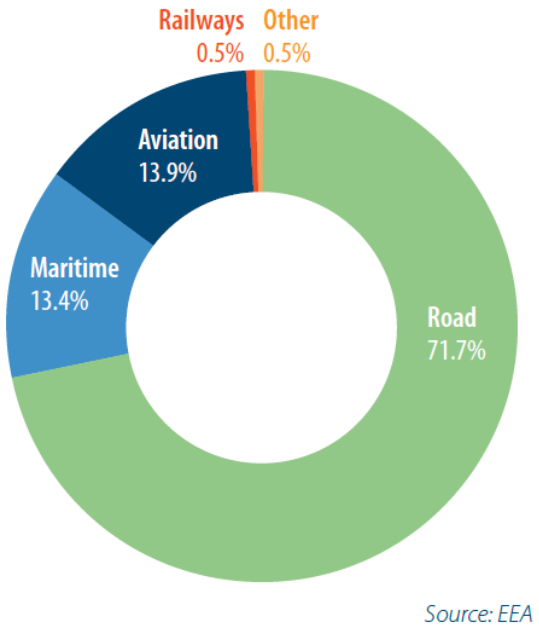


FIGURE 1. DISTRIBUTION OF TRANSPORT GREENHOUSE GAS (GHG) EMISSIONS IN EUROPE IN 2018 [3].

"The urgency of the serious climate crisis we are facing means that quick solutions must be sought, sometimes without all the in-depth analysis that would be recommended".

Not counting the exception provided for connecting flights, an analysis by the independent environmental organization Transport & Environment placed the maximum achievable at a 0.8% reduction in CO2 emissions attributable to French aviation. A figure that is undoubtedly irrelevant and that, in their opinion, seeks more to satisfy the environmental concern of public opinion, although it does not imply any real change [16].

In Spain, the debate has focused, for some time now, on the case of the Madrid-Barcelona route, where environmental organizations and some political entities have proposed similar measures. In fact, in the long-term document Spain 2050, published by the government in 2021, the French proposal is directly copied, although without any details.

The objective of this report is to analyze, by means of estimates, the possible environmental efficiency of a measure of these characteristics in Spain, in which certain domestic flights were prohibited in favor of transport by train. The calculations will focus on CO2 emissions, a long-lived greenhouse gas with well-identified dynamics, without considering other impacts of aviation currently being studied, such as NOx or condensation trails. In this regard, it is important to bear in mind that the proposed law in France specifically exempts decarbonized flights from the ban, a category that has yet to be specified but that, in any case, will allow the continuation of research and the application of sustainable technologies that eliminate these negative impacts. This is the case of electric aviation, either with batteries or with hydrogen cells, which is precisely on short-range routes where it is expected that it will first enter service.

As a background to this scenario, it is worth remembering the commitments assumed by the European aeronautical industry as a whole for the total decarbonisation of the sector in 2050, including intermediate objectives. This ambition, aligned with the community strategy of the European Green Deal and with the legislative proposal "Fit for 55" of the European Commission [9], is reinforced in Spain with the commitment to achieve net zero emissions in the main airports by 2040[1].

It also seems appropriate to point out that, in the Commission's own proposal, it is estimated that the aviation industry employs around 400,000 workers directly in the European Union, contributing 2.1% of GDP. The aeronautical sector is identified as a key element for social and regional cohesion, promoting tourism, economic activity and connecting people [10].

Finally, it should be noted that all traffic and emissions data correspond to the situation prior to the COVID19 pandemic. In addition to an unbearable cost in human lives, this terrible scourge radically changed transport habits, and air traffic in particular.

1 *https://portal.aena.es/es/corporativa/aena-invertira-alrededor-550-millones-euros-en-plan-accion-climatica-en-periodo-2021-2030.html?p=1237548067436*

3 IMPLEMENTATION SCENARIOS

This study will focus on the evaluation of CO2 emissions associated with domestic air routes likely to be replaced by viable rail alternatives of less than 3 hours of travel time, expanding the original French proposal to better adapt it to the high-speed routes available in Spain. In addition, a more detailed analysis of the Madrid-Barcelona air bridge will be carried out, the main route within this category, with 2.5 million passengers in 2019 (AENA data).

On the other hand, the emissions of the train alternative will be estimated, both during its use and in the construction of the necessary infrastructures. This will allow us to calculate the potential for reducing CO2 emissions with a restrictive measure for aviation, make comparisons and place it against the set of emissions in Spain.

Before entering the field of emissions, the volume of operations that could be affected by these restrictive measures in three of the main airports in Spain, and which have a greater potential for application, will also be analysed:

- Madrid-Barajas.
- Barcelona-El Prat.
- Málaga-Costa del Sol.

In defense of the restrictive measures for domestic flights, it is common to add the argument that this would promote the decongestion of the airports involved, eliminating the need for expansion, or reducing other local environmental impacts such as noise. To evaluate this hypothetical benefit, the operations of the three airports in 2019 have been reviewed. In the first two, the total number of operations that would be reduced with the suppression of the air bridge compared to the annual total has been extracted. In the third, the same exercise has been repeated with the connections to Madrid and Barcelona, two of its main routes, and which in the latter case would require high-speed routes of at least 5 hours. Figure 2 shows the reduced importance of the operations analyzed compared to the total volume at the airports, so this additional benefit can be considered practically marginal.

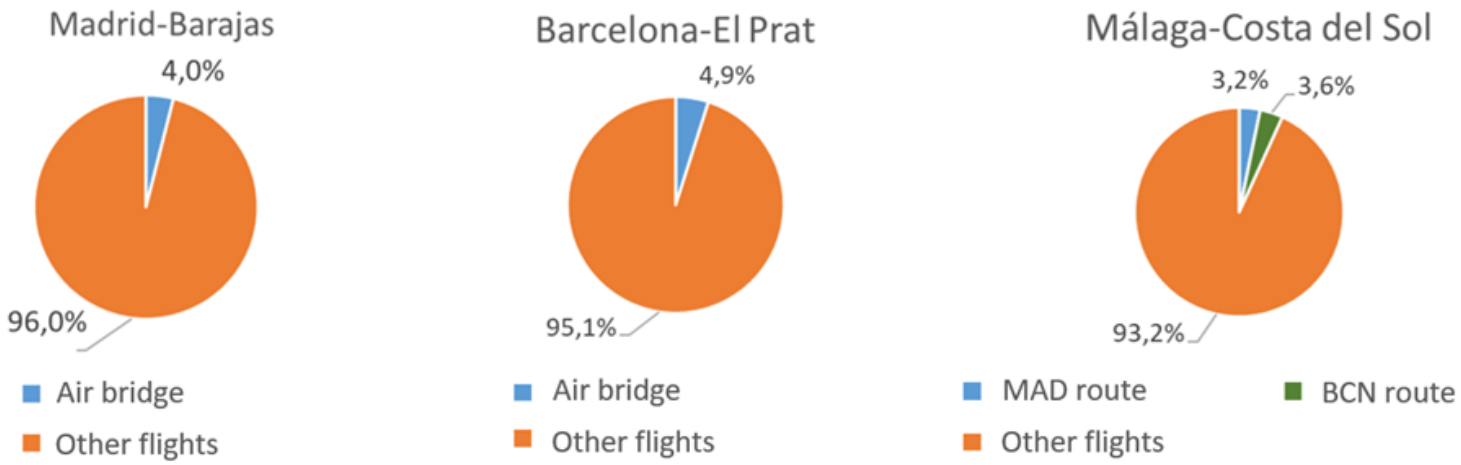


FIGURE 2 RELATIVE VOLUME OF MAD-BCN AIRLIFT OPERATIONS AND MALAGA AIRPORT CONNECTIONS.

4 EMISIONS STUDY

Within Europe, flights of less than 500 km account for a significant 24.1% of all air passengers, although they only contribute 3.8% of CO2 emissions [3]. If the range were extended to 1,000 km, and connections not subject to rail replacement were discounted (for example, flights to islands), the maximum potential for reducing emissions would rise to 6-11% of the total. However, it is necessary to place this potential range in the context of the total emissions of European aviation, where it would represent only 2-4% of the total (Figure 3, [17]).

When carrying out this type of hypothetical study, in which the potential for reducing emissions by eliminating short-haul aviation is analyzed, the environmental cost of implementing the alternative is usually not taken into account. This is particularly misleading as it does not consider the emissions associated with the construction of high-speed rail lines, the volume of which may even lead to their being discouraged based on the CO2 emissions of their complete life cycle.

We are going to briefly study the case of the Madrid-Barcelona high-speed rail line to better understand how this initial impact on emissions is amortized. We will use data collected in reference [6], endorsed by the European Environment Agency [1], although always with the prudence of knowing they are estimates.

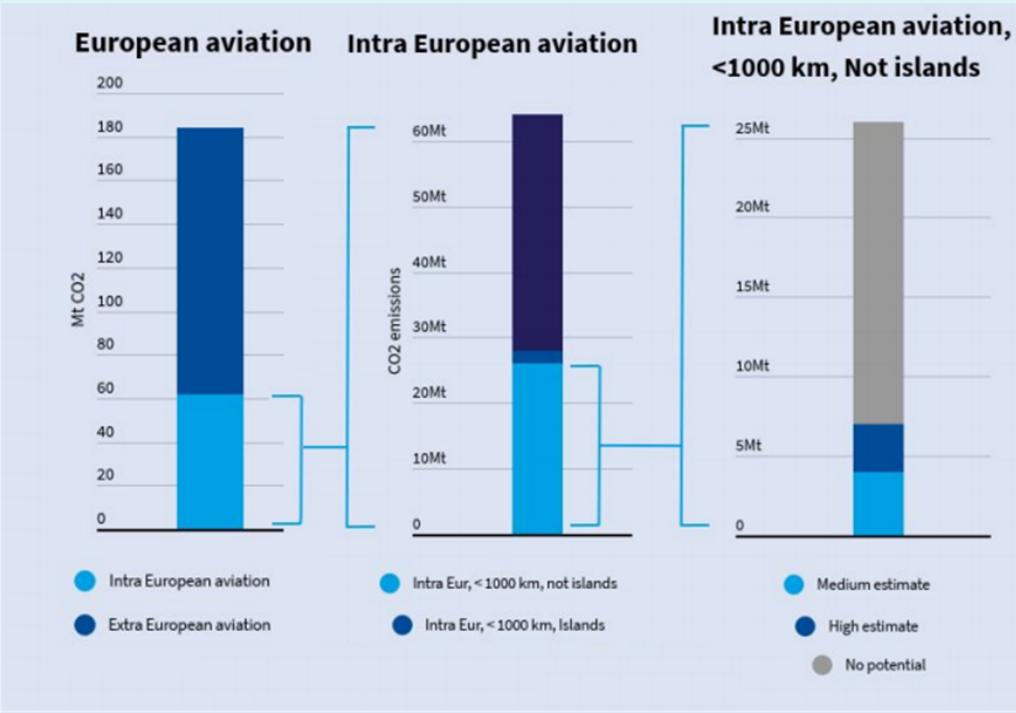


FIGURE 3 MAXIMUM AVIATION EMISSION POTENTIAL REDUCTION FROM SWITCHING TO RAIL IN EUROPE [17].

The emissions corresponding to the train are calculated based on the CO2 emissions associated with electricity generation (288 gCO2/kWh) in Spain, 6 times higher than the French electricity system [7]. In case of arguing a renewable certification in the railway electricity supply, it could be understood that a case of carbon leakage would simply occur, since this would not change the Spanish energy mix and its total emissions. Furthermore, an increase in total electricity demand could force more fossil fuel-powered power plants to come online.

Since its entry into service in 2008, this railway service has achieved a share of 62% (2018) in passenger transport between the two cities [11], which we can put at about 4 million passengers per year, most of whom changed the plane by the train even in spite of its high prices. Table 1 shows an approximate calculation of the amortization of the 6.9 Mt of CO2 emitted during the construction of the high-speed line [6], which takes us to a period of 40 years until, finally, the change of such a volume of passengers becomes environmentally profitable. The latter without taking into account the pernicious effect accumulated during that amortization period due to CO2 emissions, a long-term greenhouse gas. In other cases of high-speed roads such as the Basque Y, the object of a detailed study, not even with terms of 100 years, the emissions of its construction are amortized [6].

Other effects, such as the environmental impact on the territory and the barrier effect, are not usually considered either due to the difficulty of their evaluation, although they are undoubtedly very relevant. Based on data from the European Environment Agency, it is estimated that in our environment this damage to the territory is around 10 times greater in the high-speed rail network than in airports [3].

On the other hand, the emissions associated with the construction of airports cannot be neglected at all, although their relevance is less due to their dimensions compared to long-distance railway lines, in addition to serving multiple routes.

From a more global perspective, and to place transport emissions in context, the 2019 National Greenhouse Gas Inventory estimated the contribution of domestic aviation in Spain at 1.2% of total CO2 emissions, compared to 1. 3% of maritime transport or 33.3% of road transport [15]. Using these total emissions values and the detailed statistics of passengers on domestic flights in Spain in 2019,[2] the CO2 emissions associated with air connections on routes with rail alternatives of less than 3 hours have been estimated, also separating those corresponding to the airlift Madrid-Barcelona (Figure 4). To carry out the calculation, the direct average of emissions per national flight has been considered, which is probably considered conservative since the numerous flights to the Canary Islands contribute in a greater proportion.

In-house made from referenced data	Transferred Passengers from planes to trains (Mpax)	Distance (km)	Carbon intensity (gCO2/pax·km)	CO2 annual emissions (ktCO2/año)	AVE line construction CO2 emissions (MtCO2)	CO2 annual emissions savings (ktCO2/año)	Needed years for line emissions amortization
High-speed train	4	621	32	79,49	6,9	-174,51	39,5
Air bridge	-4	500	127	-254,00			

TABLE 1. ESTIMATED AMORTIZATION OF CO2 EMISSIONS IN THE CONSTRUCTION OF THE MADRID-BARCELONA HIGH-SPEED LINE.

2 *Data: AENA (https://portal.aena.es/es/corporativa/estadisticas-trafico-aereo.html).*

In order to contextualize the figures obtained, two emissions values associated with the railway have been included in the graph:

- CO2 emissions corresponding to the construction of the Madrid-Barcelona high-speed line annualized for a useful life of 60 years.
- The volume of CO2 corresponding to emissions from railways with diesel locomotives still existing in Spain [15].

As can be seen, this last concept contributes to emissions at the same level as all air connections that can be replaced by high-speed trains in less than 3 hours. Both stand at 0.1% of total CO2 emissions in Spain in 2019.

To complete this simplified study, we are going to subtract from the reported air emissions the CO2 that would be emitted by its high-speed rail alternative. Thus, we would obtain that the suspension of the Madrid-Barcelona air bridge could achieve a reduction of 136.7 ktCO2, without taking into account the significant volume of CO2 emitted during the construction of the railway. This would mean approximately 0.68% of the total emissions of Spanish aviation in 2019 [14]. If the measure were extended to all air routes with a rail alternative of less than 3 hours, this figure would be around 0.9%. This estimated environmental benefit, clearly residual, fits perfectly with the estimate already outlined by T&E for the French case.

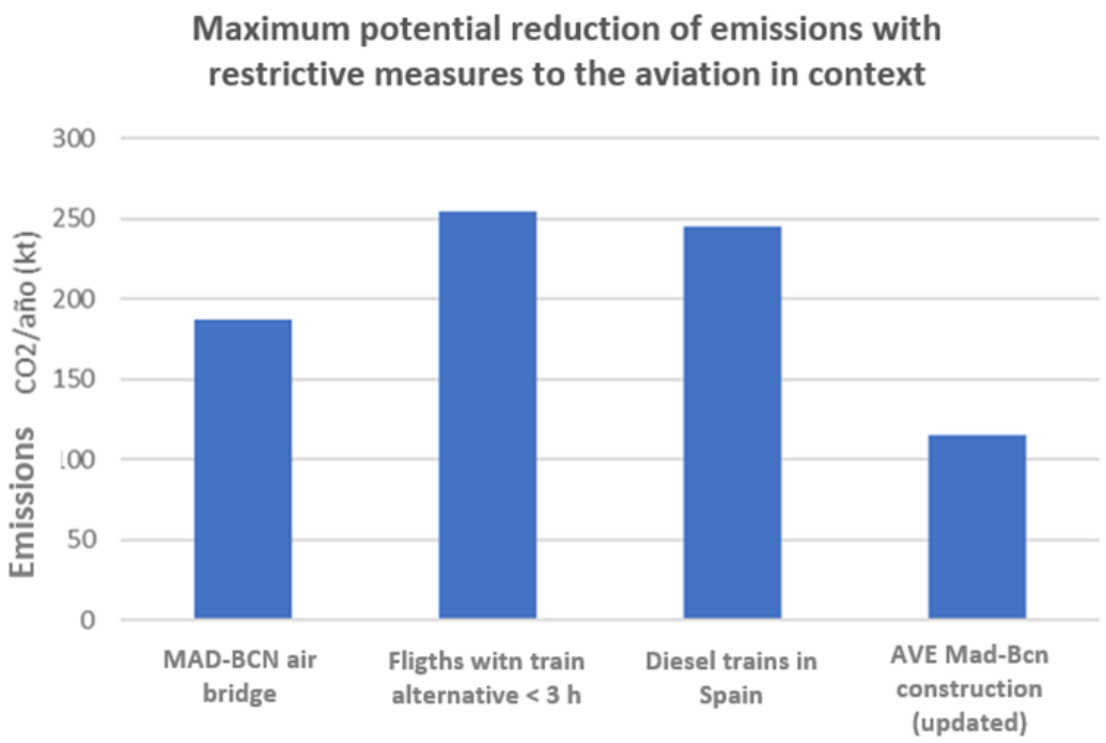


FIGURE 4 CO2 EMISSIONS FROM DOMESTIC FLIGHTS IN SPAIN WITH A RAIL ALTERNATIVE OF < 3 H IN CONTEXT. OWN ELABORATION FROM REFERENCED DATA (2019).

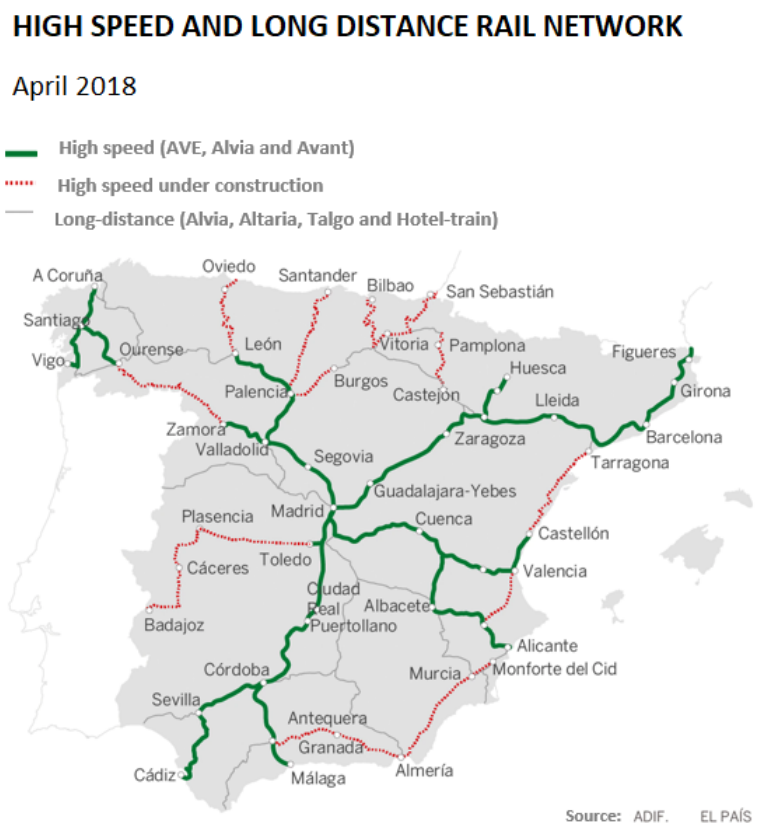


FIGURE 5. HIGH-SPEED AND LONG-DISTANCE RAIL NETWORK IN SPAIN (APRIL 2018).

Finally, it should be noted that the emissions associated with both the generation of electricity that powers high-speed rail and intra-European aviation are covered by the EU ETS, the European emissions trading system, which has certified significant reductions in the impact of aviation since its implementation,[3] and that the European Commission proposes to expand and strengthen [9].

[3] *193 Mt CO2 (2013-2020) EEA / EASA / Eurocontrol: European Aviation Environmental Report 2019.*

5 ALTERNATIVES

In the context of the climatic urgency that threatens us, understanding the agents and mechanisms that contribute most significantly to global warming must be a priority for everyone. This is the only way to implement effective measures to reduce emissions that mitigate the current situation. Air transport, as a whole and to the extent that it is concerned, must also assume its responsibility and work on far-reaching solutions to achieve the goal of decarbonisation by 2050.

The dilemma between the plane and the train could be, to a large extent, a false dilemma. Although the emissions of the railway, once built, are clearly lower per kilometer and passenger, the fields of application of both means of transport, and therefore the opportunities to reduce emissions by replacement, overlap less than it is usually thought as presented previously. In addition, the long construction time of the tracks (from 18 to 26 years on average [3]), plus the necessary subsequent environmental amortization period, means that by the time the possible new lines would make a net contribution to the reduction of emissions, aviation could already be environmentally sustainable.

However, as stated in the European Union roadmap for sustainable mobility [11], rather than opposing them, there is clear potential in the efficient interconnection of both means of transport. With a limited construction effort, enabling these train-airport links could contribute to the reduction of emissions and other problems associated with road traffic, while making some clearly inefficient air connections superfluous. To make it a reality, it would also be necessary to implement single intermodal tickets, which would extend the current rights of air passengers to the train.

The same roadmap also points out the great tools that the aviation industry is working on today to reduce its emissions: sustainable aviation fuels (SAF) and alternative electric or hydrogen propulsion. All the research, economic and legislative effort invested in these areas will have repercussions on environmental benefits not only for domestic flights, but also for medium and long-distance flights, the greatest challenge in terms of emissions facing aviation [8]. It is worth highlighting the mandates already in place in countries such as Norway on the use of SAF, or the one recently proposed by the European Commission [10], as well as other types of specific regulations that encourage innovation and the application of these technologies.

Other mechanisms already in place to get the goal of the decarbonization of aviation are emissions offsets and market measures, in their various variants (EU ETS, CORSIA, voluntary) [8]. The French environmental legislative proposal itself, already mentioned, includes a section that will require the compensation of emissions from all domestic flights by 2024 with certified national projects.

The area of ground operations and air traffic management also offers great opportunities to reduce emissions in aviation, without the need to achieve major technological advances first. If the Single European Sky is finally implemented, weighed down by political rather than technical problems, between 8.6% and 11.2% of emissions could be saved on all intra-European flights.

"If the Single European Sky is finally implemented, weighed down by political rather than technical problems, between 8.6% and 11.2% of emissions could be saved on all intra-European flights".

Other measures such as the suppression of the practice of tankering (loading fuel where it is cheapest, with the associated excess weight) would mean a saving in CO2 emissions from European aviation of 0.54%. This could probably be achieved with a simple harmonization of the cost of refueling [2], an initiative also included in the European Commission proposal [10]. It should not be forgotten that, although it may seem modest, this latest reduction in emissions is of the order of magnitude of those analyzed in this report, although probably not as striking.

The environmental usefulness of taxes on aviation, through direct taxes or on conventional fuel, also generates a great debate. Although its effectiveness has been questioned, a possible positive role is suggested by connecting its collection with investment in decarbonization measures [4]. On the other hand, it seems clear that it can be a useful tool in favoring the change towards sustainable fuels. In fact, the European Commission also includes a measure in this sense in its "Fit for 55" package of measures, both for fuels for aviation and maritime use [9].

With regard to the railway, it is worth noting the great opportunity to reduce emissions associated with the many lines served by diesel locomotives still in use in Spain, as previously mentioned. This reduction would not necessarily have to come through massive electrification, perhaps not efficient for reduced traffic, but through the introduction of biodiesel in conventional machines or, as a European project led by the Spanish CAF seeks to implement, through locomotives powered by hydrogen [4].

Short-range cross-border rail connections, clearly improvable at present, could also contribute to eliminating air and road traffic where they are not efficient.

Finally, in long-range rail connections, it could also be of interest to evaluate the alternative of conventional lines, with a lower construction impact, compared to high-speed lines.

In addition to facilitating a transition of both passenger and freight traffic to rail, and the consequent savings in emissions, it could also better serve other purposes such as greater structuring of the territory. In this regard, the proposal of environmental organizations for the implementation of a railway system with integrated cadenced schedules (HCI) [5] is very interesting. In any case, these long rail routes should offer affordable prices, thus avoiding the risk of once again restricting travel in favor of passengers with a privileged economic capacity.

4 *https://www.caf.net/es/sala-prensa/nota-prensa-detalle.php?e=316*

5 *https://es.greenpeace.org/es/noticias/propuesta-mejorar-tren/*

6 CONCLUSIONS

- The debate on the prohibition of air routes for their substitution by rail connections focuses on the range of up to 500 km. In longer distances, or in short journeys but with a complex orography, the European Environmental Agency itself does not dare to rule on whether said change of mode of transport would be beneficial in terms of the impact on our environment [1]. In any case, if it is still decided to assess any restrictive measure on domestic aviation, it will be essential to protect the innovation and implementation of decarbonized propulsion technologies, as stated in the aforementioned French bill.

- In our opinion, this dilemma between train and plane when making a trip, for the reasons already stated, does not seem to be the really important issue when facing the environmental challenge of global warming. Perhaps it could be reformulated towards how to take advantage, jointly and efficiently, of both forms of transport to really reduce polluting emissions. Of course, this can only be addressed in the context of other means of mobility, if it is really intended to achieve significant benefits.

- A complex problem, such as GHG emissions in aviation, is not usually solved with simple recipes. The range of measures “Fit for 55”, recently proposed by the European Commission, is a good example of this [9]. Cosmetic or advertising measures can even become counterproductive, by creating the impression that it is acting decisively, when it is not. As argued by T&E, the leading European organization working towards sustainable transport, "what we need is less symbolic environmentalism and more real change" [16].

- To achieve this significant change in commercial aviation, reducing emissions first, and eliminating them by 2050, it will be necessary to advance with all available tools and strategies (efficient traffic management, SAF, gradual improvements and alternative propulsion, compensation and measures economic), applied to all air traffic segments. The effort of the industry, but also the support and involvement of the public authorities and the travelers themselves, will be key to achieving it.

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