THE INCLUSION OF INTERNATIONAL AVIATION IN THE EUROPEAN UNION EMISSIONS TRADING SYSTEM

Bachelor's Degree in Aeronautical Management
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Títol del Treball Fi de Grau: The inclusion of International Aviation in the European Union Emissions Trading System	
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Paraules clau

- **Català:** EU ETS, Cap-and-Trade System, Aviació Internacional, preu òptim.
- **Castellà**: EU ETS, Cap-and-Trade System, Aviación Internacional, precio óptimo.
- **Anglès:** EU ETS, Cap-and-Trade System, International Aviation, optimum price.

Resum del Treball Fi de Grau

- **Català:** El treball establert proposa entendre quins són els efectes de la inclusió de l'aviació internacional dins el sistema europeu ETS. Concretament, es pretén analitzar com podria repercutir en termes econòmics el fet de tractar les emissions de CO_2 procedents de l'aviació com a drets d'emissió subjectes al sistema Cap-and-Trade.

- **Castellà:** El trabajo establecido propone entender los efectos de la inclusión de la aviación internacional dentro del sistema europeo ETS. Concretamente, se pretende analizar cómo podría repercutir en términos económicos el hecho de tratar las emisiones de CO_2 procedentes de la aviación como derechos de emisión sujetos al sistema Cap-and-Trade.

- **Anglès:** The aim of this project is to recognize which economic consequences could have for the European airline operators being subject under the Cap-and-Trade System where CO_2 emissions are traded as allowances.

Contents

1. INTRODUCTION

1.1 Context

1.1.1 The European Union Emissions Trading System

The European Union Emissions Trading System (EU ETS) is the first European cap-and-trade system of allowances. The aim of the EU ETS is to reach a reduction from a certain level of emissions in a cost-effective way. This European system is currently the world's largest emission trading scheme and represents the cornerstone of the European Climate Change Programme.

1.1.2 International Aviation

Carbon emissions generated from international aviation showed an 85% rising [1] from 1990 to 2004 with a 4.4% traffic increasing [2] average from 1990 to 2008, which is expected to augment during the coming years. In 2008, to control CO_2 emissions from the aviation sector, the European Commission, the European Parliament and the European Council agreed on **including the international aviation sector** in the EU ETS, which as far as then was limited to fixed installations

[3]. However, it was not until the 1 January **2012** when emissions from international aviation flights were regulated under the EU ETS.

1.1.3 The Cap-and-Trade System

To reduce annual greenhouse gas emissions, the EU ETS is ruled under a Cap-and-Trade system split between international aviation sector and fixed installations sector. The cap is the total amount of emission allowances allocated during a concrete period of time where **an allowance right equals to one tonne of CO_2[1].**

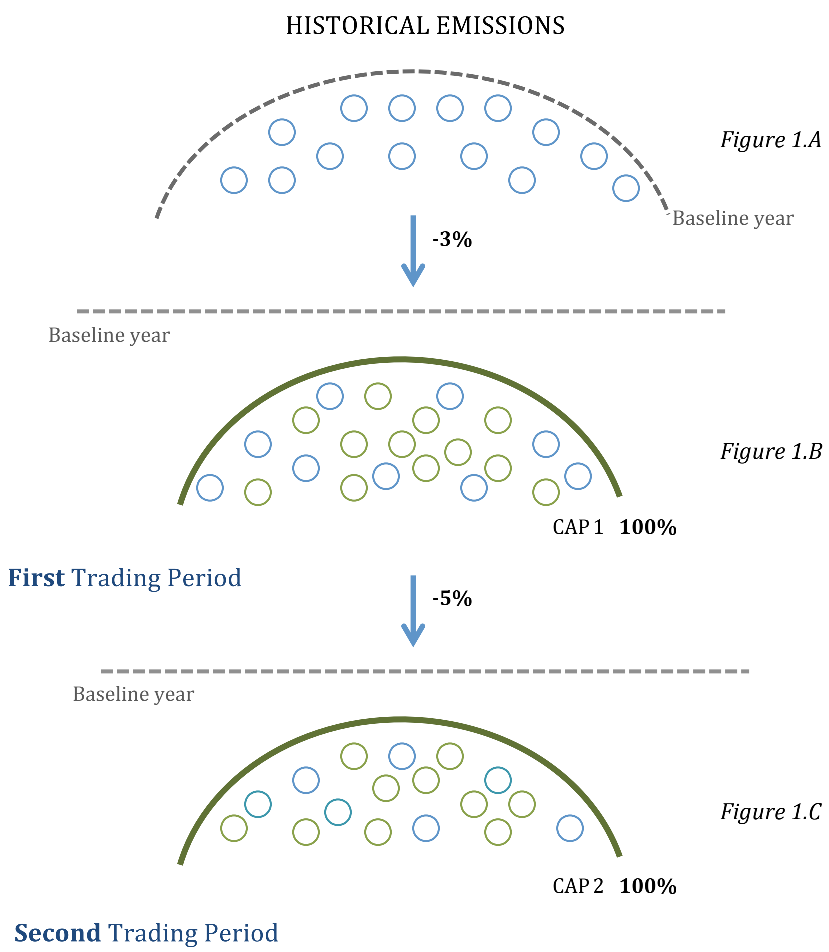


Figure 1: Representation of the Cap-and-Trade system

[1] Or other greenhouse gas emissions with the same equivalence to one tonne of CO_2.

To establish the cap for the international aviation sector, the Commission taking the role as the Regulator, obtains a certain amount of **historical emissions** from the average of greenhouse gas emissions generated under the EU ETS scope between the years 2004, 2005, and 2006. The quantity of historical emissions estimated [4], is used **as a base line reference to calculate the posterior caps' level** for each trading period (Fig. 1.A).

The initial cap established for the first trading period (2012), was set at a **3% level below the amount of historical emissions certified**, i.e. 97% of historic aviation emissions (Fig. 1.B). Therefore, the Regulator distributed the allowances that conformed the cap between the operators; 85% free of allocation and 15% under auctioning.

In the second trading period (2013-2020), the cap is set a **5% below the baseline year**. In the second period and for each year; 3% of the allowances are distributed to new entrants, free allocation is decreased to 82% and auctioning is maintained in 15% (Fig. 1.C).

1.2 Motivation of the research

Apparently, the caps set by the Regulator remain fixed but with an option for the airline operator to **exceed** it when the number of rights obtained does not cover the total amount of emissions generated by the airline operator. As a consequence of surpassing the cap with extra-emissions, the operators receive a **fine** (currently of 100€ per tonne emitted [5]).

That fact presents the motivation to answer the question whether the price per extra-emission emitted should be interpreted as a real fine (i.e. disincentive) or it should be understood as an emission tax/price that is paid for the additional emissions beyond the initial endowment of allowances?

Moreover, which effect will have on the airline operators establishing a fixed emission price/fine with no adjustment regarding if is affordable or not for the operators?

Therefore, a growing demand from aviation transport is expected for the coming years, fact that sets another doubt; **will the cap remain fixed or it will be adjusted to the air traffic growth requests?** If the cap remains fixed, it could severely penalize the traffic demand, with the consequent macroeconomic costs, unless a big technological change in aircraft engines and energetic technologies is expected to occur in the coming years.

1.3 Objectives

The aim of this project is to **recognize which possible economic consequences could have for the European airline operators being subject under the Cap-and-Trade System where emissions are traded as allowances**. **Consequently understand and analyse which possible effect could have on the operators paying a static tax for the extra emissions generated that cannot be covered with tradable rights.**

Therefore, to accomplish the main objective, a serial of sub-objectives are proposed:

1. Understand what the EU ETS for international aviation is and which is the overarching objective of the system.

2. Identify and understand how the key elements that conform the system functions, and the reason to create an own ETS market apart from the fixed installations market.

3. Understand how the cap-and-trade system functions. How are the caps established, what is an allowance and how allowances are distributed over the airline operators.

4. Analyse the cap-and-trade system, which are the principal variables involved in the system and how they behave under two different cases.

5. Establish some basic guidelines about how to determine the ideal tax to pay for the extra emissions generated.

1.4 Document structure

The document is organized in three main sections in order to achieve the partial objectives proposed:

Section 2 presents the **Literature Review**. It is initiated with an exposition of the three stages that conform the EU ETS, how are developed, why there is a separate emissions market for international aviation and how the cap for fixed installations functions. It continues with a comparison of the main differences between the two sectors. Which finally concludes with the development of the key design parameters that conform the EU ETS in international aviation (relevant information to properly understand the following section).

Section 3 is divided in two parts, the first part where the cap and trade system **structure** for international aviation is presented and all the components that conform the system are detailed. The purpose is to transmit to the reader the knowledge (through the use of figures) required to understand the following **analysis** of the Cap-and-Trade system.
In the second part some considerations about how to possible determine an optimum price are developed. The purpose of this section is not to find which will be the exact price-quantity but to argue the main **guidelines** on how to possible establish the rate to pay for the operators who exceeded the frontier.

Finally, in **Section 4** are presented the final **conclusion** that collects the most remarkable arguments developed during the project.

2. LITERATURE REVIEW

The Emission Trading System for fixed installations is implemented in three stages [7,8]:

- **Phase I (2005-2007)**:

Initial three-year pilot phase focused on emissions from power generators and energy-intensive industrial sectors. It was a 'learning by doing' stage where it was possible to develop a strong basis to **set the caps on national allocations plans** for allowances. Almost all allowances were shared out to companies free of charge with a forty-euro penalty per tonne due to non-emission compliance.

The phase ended with a success in establishing a price reference for carbon and for developing the necessary infrastructure tools to control and verify emissions from fixed installations.

- **Phase II (2008-2012):**

Experienced acquired on the previous step was crucial to detect new demands subsequently implemented. **Allowances given away for free decreased** in a ninety per cent while **penalty per tonne rose to one hundred euro**. The EU Commission reduced the total volume of emission allowances by 6.5% reported from 2005 reference year.

However companies were allowed to buy extra allowances from Kyoto Protocol's Clean Development Mechanism and Joint Implementation. That fact let the EU ETS to become the most important international carbon market [3].

- **Phase III (2013-2020):**

Current development phase planned to run five more years. This stage includes several design adjustments starting with the **inclusion of a single EU-wide cap** with an annual decrease of 1.74% which leaves behind the national cap system and its national allocation plans. This harmonization will assure a significant decrease on greenhouse gas emissions by 2020. Auctioning is the default method where more than of 40% allowances will be allocated. This percentage will be increased each year. More over implementation of a full auctioning for the power sector will conclude at the end of the phase with a 30% free allocation decrease.

The Kyoto Protocol did not established any regulation to mitigate international aviation's emissions, as a result, **the Commission decided to regulate emissions from international aviation separately from fixed installations**, which are considered under the Kyoto Protocol targets [3,6].

However the unilateral decision taken by the Commission on including international aviation in the EU ETS created big controversy. Many non-European countries in disagreement, appealed the decision was not taken by the International Civil Aviation Organization (ICAO), causing an infringement of the Chicago Convention[2] and many other international conventions.

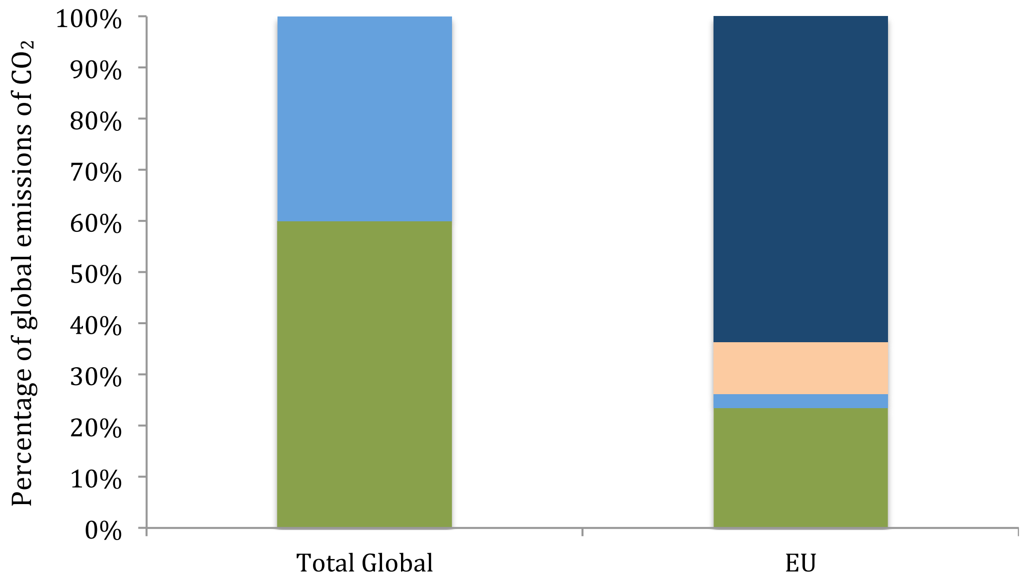
[2] Convention on international civil aviation held on December 7, 1994.

The EU ETS for international aviation runs through **two trading periods**, 2012 and 2013-2020. In each period emissions are limited under a concrete level, i.e. the **cap**. Allowances are created corresponding to the cap which is established in accordance to a benchmark year [7, 8].

Every airline operator receives a certain amount of free allowances to cover its emissions. Airline operators who need extra permits are allowed to buy them from EU auctions, carriers or other international emissions trading mechanism (Table 1).

Therefore, the EU ETS operates through a **cap-and-trade** mechanism based on the principal of **creating tradable rights to emit that are distributed free of charge or through auctioning.** Permits under the name **EUA** (European Union Allowance) are allocated for fixed installations while **EUAA** (European Union Aviation Allowance) are for airline operators [8].

Table 1: Representation of a comparison between CO_2 emissions generated in 2006 from international aviation, domestic aviation, intra-EU flights departing from EU and emissions from flights over the rest of the world [8].



Rest of world		384.590
Intra-EU		51.100
Domestic	226.477	16.466
International	360.502	134.823

2.1 The cap for Fixed Installations

For the first two phases of the EU ETS for fixed installations (2005-2007 and 2008-2012) the cap was set under national levels through **National Allocation Plans** (NAPs). Accordingly, before the initiation of the first and second phase, each Member State had to decide the number of allowances to allocate through the presentation of its NAPs to the Commission [9].

Due to **lack of reliable emissions data** and experience, for the initial trading period the amount of allowances established was set through estimation, which caused a surplus on the quantity of permits, i.e. allowances exceeded demand. Most of allowances were freely distributed. Phase one was a **pilot** stage to obtain reliable emission data also to consolidate NAPs for the posterior phase.

In phase two (2008-2012), through knowledge acquired and verified emission reported in phase one, the Commission diminished the emissions allowance reducing the cap in a 6.5% comparing to 2005 levels. However in 2008, the economic **crisis** decreased in Europe the production from thousands of enterprises. Consequently demand for allowances diminished. Installations produced less, leading to a great reduction from emissions generated causing a surplus in the number of allowances.

In the actual period (phase three; 2013-2020) an important reform has been implemented. NAPs are left behind leading the inclusion of a **single cap** for all the Member States. The most important feature is the 1.74% reduction for each year of the average emissions issued by the Member States in the period 2008-2012 (the number of allowances will be reduced annually by 37.435.387). More than half of permits are distributed under auctioning. In order to achieve a 40% reduction by 2030 compared to 1990 greenhouse gas emissions levels, the cap will be lowered by 2.2% each year from 2021.

The cap for international aviation will be reviewed on section 3.

2.2 EU ETS Scheme Comparison

To properly understand the overall function of the EU ETS is essential to present the differences between the two systems through the key design elements that conform both schemes.

The principal differences are summarized on Table 2:

Table 2: EU ETS markets comparison

	FIXED INSTALLATIONS	INTERNATIONAL AVIATION
Actual phase	Phase III	Phase III
Sectors covered	Energy and industrial installations, power and heat generators, domestic aviation	International Aviation from member states and third countries
Cap decreasing	Annual decreasing	Trading period decreasing
Type of emissions covered	CO_2, N_2O, PFCs[3]	CO_2
Geographical scope	28 EU countries and the three EEA-EFTA[4] states	All flights into, out of and between the EEA[5]
Trading Entity	European Commission	European Commission through Member States
Allocation rules	Allowances defined at a EU level with a uniform allocation approach	Allowances set at a Member State level
Interplay with the Kyoto Protocol	Regulated under the Kyoto Protocol	Not subject under the Kyoto Protocol
Allowance distributing mechanism	Auctioning	Free allocation and auctioning
Monitoring method	Monitoring and reporting annual emissions by fixed installation	Reporting annual emissions through estimated or actual fuel consumption by aircraft operator

[3] Carbon dioxide (CO_2) from
- Power and heat generation
- Energy-intensive industry sectors including oil refineries, steel works and production of iron, aluminium, metals, cement, lime, glass, ceramics, pulp, paper, cardboard, acids and bulk organic chemicals
- Commercial aviation

Nitrous oxide (N_2O) from production of nitric, adipic, glyoxal and glyoxlic acids
Perfluorocarbons (PFCs) from aluminium production
[4] Iceland, Liechtenstein and Norway
[5] The twenty-eight EU Member States, plus Iceland, Liechtenstein and Norway are included in the EU ETS. Very light aircraft will not be covered. Military, police, customs and rescue flights, flights on state and government business, and training or testing flights will also be exempted

2.3 EU ETS Framework

The aim of this chapter is to review each of the five ETS design parameters efficiently articulated to reduce the emissions level (geographical scope, trading entity, allocation rules, interplay with the Kyoto Protocol, allowance mechanism, monitoring method) commented on the previous figure. The detection of the principal elements has been made through the literature review from the document *Giving wings to emissions trading, (2005).*

It is important to keep in mind that the system nowadays is developing under phase three and some elements from the EU ETS established in the initial phase have experimented modifications and adjustments in relation to the current stage [10].

2.3.1 Geographical Scope

As to date, three types of flights are included under the EU ETS [11]:

1- **Flights between aerodromes in the EEA but not in outermost regions[6].**

   With the exclusion of those flights with activity between aerodromes in an outermost region an aerodrome outside from the region.

2- **Flights between aerodromes in the same outermost region.**

   With origin and destination in the nine outermost countries that belong to Portugal, Spain and France.

3- **Flights between aerodromes in Croatia and aerodromes in the EEA. Outermost regions are not included[7].**

[6] The outermost regions are Canary Islands, French Guiana, Guadeloupe, Martinique, Mayotte, Réunion, Saint Martin, Azores, and Madeira. The territories Gibraltar, Aland Islands, Jan Mayen, Ceuta and Melilla are considered member states of the EEA.
[7] Since 1 January 2014 Croatia is fully integrated into the aviation part of EU ETS. Operators of flights within Croatia and between Croatia and non-EEA countries need to surrender emission allowances only for flights carried out from 1 January 2014 onwards.

> Flights between aerodromes in Croatia and aerodromes located elsewhere in the EEA omitting those in outermost regions are fully covered under the EU ETS.

There is still a lot of controversy in how **intercontinental emissions** from flights departing from third countries outside the EU must be regulated. Nowadays the Commission [12] concludes that from 2014 to 2020, flights to and from countries outside the EEA **only the emissions from the proportion of the flight that takes place within the EEA airspace would be covered**. Emissions taking place outside the EEA airspace will be exempted. Also, flights between the EEA to or from developing countries, which emit less than 1% of global aviation emissions, are fully exempted.

2.3.2 Trading Entity and the carbon markets

The European Commission is in charge to assign a concrete quantity of allowances to each Member State. Therefore there are no national allocation plans as in the past was established for fixed installations. Member States will be only responsible for surrendering the amount of rights planned by the Commission [13].

The trading entity is the airline operator who needs to surrender allowances in relation to the emissions generated. An airline operator is referred as the *natural or legal person that **operates** an aircraft at the time it performs an activity specified in Annex I to the EU ETS Directive* [12].
Airline operators with low levels of GHG, once they have covered its emissions are allowed to trade with their extra permits, selling to other airline operators or saving them for future consumption.

The carbon markets are economic systems where enterprises, governments, individuals or other institutions trade with allowances from greenhouse gas

emissions. Nowadays exist two types of carbon markets, the **regulatory compliance** market and the **voluntary** market.
The regulatory market is set up for companies due to governmental restrictions must report its greenhouse gas emissions. On the voluntary market, transactions between carbon emissions are set on a volunteer basis and function apart from the regulatory market.

Clean Development Mechanism (CDM), Joint Implementation (JI) and Emissions Trading (ET) are the three flexible mechanisms (Fig. 2) created to meet with the Kyoto Protocol targets [11].

Clean Development Mechanism

The CDM lets Annex I countries from the United Nations Framework Convention on Climate Change (UNFCCC) to complete with its Kyoto Protocol's objectives by funding greenhouse gas emission reduction projects from developing countries. CDM projects generate tradable emissions credits named Certified Emission Reduction[8] (**CERs**).

Joint Implementation

JI functions in a very similar way to CDM. The main difference is that JI countries can only finance emission reduction projects from non-development countries included in the Annex I from the UNFCCC. JI tradable emission credits are the Emission Reduction Unit[9] (**ERUs**).

Emissions Trading

Emissions Trading include countries from the Kyoto Protocol Annex I. The tradable credits are Assigned Amount Unit (**AAUs**).

The three mechanisms belong to the regulatory market including also the EU ETS. Installations under the EU ETS who need extra permits to cover its emissions are allowed to buy a certain amount of allowances from CDM and JI programs. Therefore fixed installations can only buy additional permits from markets under the Kyoto

[8] One CER equals to one metric tonne of CO_2
[9] One EUR equals to one metric tonne of CO_2

Protocol scope, fact that does not include the EU ETS market for international aviation.

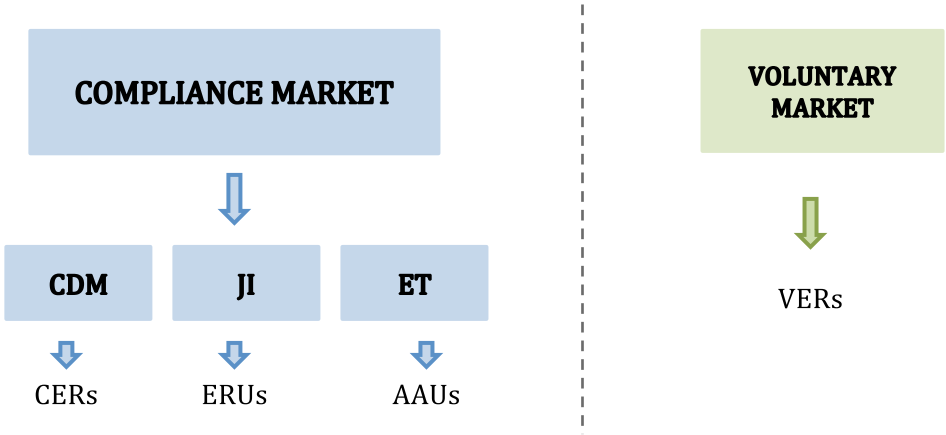


Figure 2: Carbon markets representation

A comparative tool between the two markets is demand. Whereas demand in the regulatory market is created through a regulatory instrument, in the voluntary market, trading emission permits are much modest because only voluntary buyers generate demand.

Tradable credits from the voluntary market are called Voluntary Emissions Reduction (**VERs**) and cannot be used in the compliance market (Fig. 2).

2.3.3 Interplay with the Kyoto Protocol

The Kyoto Protocol does not regulate greenhouse gas emissions from fuel consumption caused by international aviation's activity. Furthermore in this field is not included domestic aviation[10], which its emissions are fully covered under the Kyoto Protocol [2].

The difference between domestic an international is that domestic flights take off and land in the same country making possible to assign the emissions generated to a certain state. On the contrary the main problem for international aviation is the difficulty to attribute CO_2 emissions given that **a single flight operates along more than one country.**

In the pre-Kyoto Protocol negotiations, there was a lack of consensus over who should take responsibility for the emissions caused from international aviation. The way to tackle international aviation emissions was different from fixed installations since it was difficult to allocate them to a single state given the fact that airline operators conduct an activity that involve different countries.
Originally the parties negotiating the Kyoto Protocol agreed to include an explicit compromise specific for the developed countries to limit its emissions from international aviation through the International Civil Aviation Organization. However, there was no final consensus even though the member countries of ICAO recognised the emission trading system as a cost-effective mechanism [2].

As a solution to the poor international cooperation and the difficulties to adopt measures, the European Commission decided to take a leading ship position including the international aviation on the emission trading market [4].

10 Domestic aviation is the term related to flights that take place between to airports in the same country independently of the carrier's nationality or the following destination of the aircraft.

2.3.4 Allowance Distributing Mechanism

The total amount of allowances that will be distributed (i.e. the Cap established in an absolute level) (Table 3) is calculated according to the arithmetic average of the historical emissions between years 2004-2006 from aircraft performing an aviation activity included on the EU ETS [14]. The reason for it is that the baseline period for aviation allocation under the EU ETS is different from the baseline for the EU's overall reduction commitment for fixed installations as it takes into account the significant growth in aviation over the last fifteen years. For further information read section 2.1.2.

Table 3: CO_2 Emission allowances for international aviation in the EU ETS [14].

Trading Period	Annual Area-Wide Cap	Free Distribution	Benchmark (per 1000 TKM)	Auctioning	Special Reserve (total over 8 years)
2012	212.892.052	182.561.019	0.6797	32.216.651	0
Each year (2013-2020)	208.502.525	172.486.396	0.6422	31.552.390	50.483.824

The total distribution of allowances corresponding to each Member State is complemented by the individualized allocation of those permits to airline operators. The procedure used to distribute allowances over airline operators will be explained in section 2.3.5.

The Commission establishes three mechanism of allowances distribution [7, 14]:

- **Free Allocation**

Free of charge allocation is the general method used through a benchmarking period to allocate allowances without any financial burden and to guarantee an equal and harmonized system across all the Member States (Table 3). The amount of allowances distributed to each airline operator is determined through the implementation of a ratio:

$$\text{EU wide cap} \times \frac{\text{TKM flown by the aircraft in the benchmark period}}{\text{TKM flown by all the aircraft in the benchmark period}}$$

Where:

EU wide cap**:** the average of emissions from aviation from 2004-2006

Benchmark period**:** referred to 2010 calendar year

Example:

Table 4: EU ETS free allocation example [14]

Total EU wide cap	100
Total TKM per aircraft operator	600
Total TKM per the total of aircraft operators	10.000
Number of allowances allocated for aircraft operator	$\mathbf{100 \times \frac{600}{10000} = 6}$

The ratio represents two critical problems that can rely on a disadvantage between airline operators. Airline operators have an important incentive to increase their market share and tonne-kilometres during the benchmark period to obtain a higher amount of allowances. Also, non-energy efficient operators might be in a favoured position. This mechanism of distribution should be revised in order to favour energy efficient operators (Table 4).

- **Auctioning**

Auctioning is the method that the Member States distribute allowances to airline operators with a financial cost. This means that operators have to buy an increasing proportion of allowances through auctions.

Revenues generated from the auctioning of allowances, should be used to reduce greenhouse gas emissions and to deal with the effects of climate change in the EU and third countries. Those revenues should also be used as financial supply for research and development projects. Auction revenues must be used to fund measures to avoid deforestation and facilitate adaptation in developing countries.

- **New Entrants**

Special allowance is the reserve implemented in the second phase of the emissions trading scheme for aviation. The particular reserve is intended to airline operators such as new entrants. Also for airline operators that recently started their activity or those already in the system whose activity has increased significantly[11]. The remaining quantity in the special reserve will be used for auctioning.

EUAAs are the carbon allowances that aircraft operators use as certificates to cover its greenhouse gas emissions. EU ETS in aviation works as an open cape-and-trade scheme, which means that operators can buy extra EUAAs on the carbon market from other operators. As agreed under the European Commission [4] it is also accepted to buy extra allowances as ERUs and CERs from the Clean Development Mechanism and the Joint Implementation of the Kyoto Protocol[12] commented on the section 2.3.2. Airlines are permitted to use ERUs or CERs with a restricted use of 1.5% to the subsequent period.

On the other side and to ensure the correct function of the Kyoto Protocol, airline operators are **not** allowed to sell EUAs to other sectors. This measure is imposed due international aviation is not included in the Kyoto Protocol targets [2,4].

At the end of a trading period airline operators are obliged to compute an equal number of EUAs to their CO_2 emissions from the years proceeded. In the case that the quantity of EUAs acquired do not cover the emissions a penalty at a rate of one hundred euros per exceeding tonne of CO_2 is charged. During the consecutive year, the airline will be obligated to compensate the shortfall by reducing its emissions properly.

[11] Aircraft operators whose full-scope TKM data increase by an average of more than 18% annually between the monitoring year for which TKM data was summited and the second calendar year of that period can apply for allocation from the special reserve.
[12] One CER represents the reduction of one metric ton of CO_2 (carbon dioxide or its equivalent in other greenhouse gases). These credits are generated under the Clean Development mechanism of the UNFCCC's Kyoto Protocol
One ERU is a tradable certificate that represents one tonne of CO_2. These credits are generated under the Joint Implementation mechanism of the UNFCCC's Kyoto Protocol.

2.3.5 Monitoring and Reporting Methods

Rules for monitoring and reporting CO_2 emissions from airline operators have been settled under the M&R EU Regulation [15,16] directly applicable in all Member States and from the emissions of the second trading period starting in 2013[13].

At the beginning of every year, the European Commission publishes a list of each airline operator identified by Eurocontrol is assigned to a Member State whose flights will take place under the geographical framework of the EU ETS. Each airline operator for administrative simplicity reasons will be assigned to one administering participating country that will take charge of the airline operator.

Firstly airline operators will have to submit to the Competent Authority (CA) of its Member State responsible the templates containing the monitoring plans for annual emissions and tonne-kilometre. Those templates explain how they will report the fuel consumption (Monitoring Plan report) and the tonne-kilometre data (TKM report).

Once the CA has approved the templates, the airline operator is allowed to start reporting its TKM from the benchmark year [4].

- **TONNE-KILOMETRE REPORT**

Airline operators must submit a tonne-kilometre report **when apply for free allocation of allowances**, i.e. TKM report is the document required to apply for allowances without financial burden. On the contrary, if an operator does not present the subject information will not take part on the free allowance process.

The application must be made subject to the TKM transported by the airline from the flights **of the monitoring year established** (benchmark year 2010 for the first two trading periods).

To distribute free allowances the European Commission establishes a ratio that divides the total allowances to be allocated free of charge between the total tonne-kilometres transported in 2010 from all operators who submitted the application.

[13] Emissions before 2013 where regulated under the MRG Guidance, (2007).

Each operator will receive a number of allowances equal to the TKM transported from 2010 (benchmark year) and multiplied by the ratio. For that reason TKM report is the most important document for an airline [16].

The report must content detailed information specified above through the following calculations:

Total tonne–kilometres = distance [km] x total mass of freight [t]

Where:

Distance *= great circle distance [km] + 95 [km]*

Distance equals to the great circle distance[14] between the origin and the destination adding and additional fixed factor.

Total mass of freight *= mass of freight [t] +mass of mail [t]+ mass of passengers and checked baggage [t]*

Total mass of freight is the weight of the cargo, mail and passengers carried.

The mass of passengers and checked baggage can be calculated throw two methods:

- Default value of 100 kg for each passenger and his checked baggage.
- Concrete value with the actual or standard passenger and baggage weight reflected in the mass and balance documentation.

It also must be reported:

- Changes and deviations from the approved monitoring plan.
- Registration of airline and types of airline used by the operator subject to the system.
- Chosen for calculating the weight of passengers and checked baggage method as well as for cargo and mail.

[14] GCD equals to the shortest distance between two spots located on the surface of a sphere.

- Total passenger-km and tonne-kilometres for all flights subject to the scheme, carried out during the year.
- For each aerodrome pair:
  - The ICAO designator for two airports
  - Distance (GCD + 95 fixed factor)
  - Total number of flights
  - Total weight of passengers and checked baggage
  - Total number of passengers
  - Total number of passenger-km
  - Total weight of freight and mail
  - Total number of tonne-km

The CA is in charge to verify every report prior to referral to the competent authority.

- **MONITORING PLAN REPORT**

The Monitoring Plan specifies how tonne-kilometre emissions from airline operators generated during one year will be reported [16]. Monitoring plans are presented in paper and digital format with the inclusion of additional documentation requested. TKM monitoring plans should be introduced at least four months before the beginning of a trading period. In each case the competent authority must approve the plan. The monitoring plan must include:

- A completed list of the airline's fleet, the number of airline per type and the fuel consumption method of calculation for each airline.
- An indicative list of the types and number of airline that are expected to join the fleet.
- A description of procedures, systems and responsibilities used to update the list during the monitoring year.
- A description of the procedures used to control the list of operated flights as well as procedures to ensure which flights are included and which are exempt.

- A description of the activities and management of data acquisition and control activities and quality assurance, including maintenance and calibration of measuring equipment.
- A description of the methods used for monitoring (and transmission, storage and retrieval) of fuel consumption data, including:
    - The methodology chosen to calculate the fuel consumption.
    - The procedures for measuring the fuel supply and fuel tanks.
    - The procedure to ensure that the total uncertainty of fuel measurements meet the requirements for monitoring and reporting.
    - The procedure for measuring the density of the fuel and emission factors used for each type of fuel used.

- **MONITORING PLAN THROUGHOUT THE YEAR**

Once the calendar year has started each airline operator must pay for the emissions generated over the previous year through the delivery of a certain number the allowances [16].
To be able to determine how many allowances must be delivered, airline operators need to monitor the CO_2 emissions per flight generated in the geographical scope that covers the EU ETS.
The quantity of emissions determined in the monitoring plan will be the official amount to measure if the airline has exceeded the permissible capacity.

For each flight emissions are calculated through the following method:

$$Em = AD \times EF$$

Where:

_Em_: total amount of CO_2 [t]

_AD_: amount of fuel consumed [t]

_EF_: emission factor [t CO_2/t fuel]

<u>Annual fuel consumption</u>

The annual fuel consumption is calculated based on the quantity and type of fuel including the fuel consumed by the Auxiliary Power Unit[15] (APU).

The M&R Regulation allows are two different methods (Method A and Method B) for determining the annual fuel consumption of a flight which is covered under the EU ETS. The airline operator can only choose one of the two approaches.

METHOD A[16]

$$F_{Y,A} = T_Y - T_{Y+1} + U_{Y+1}$$

Where:

$F_{Y,A}$: Total fuel consumed for the flight Y under consideration using method A [t]

T_Y: Quantity of fuel contained in aircraft tanks once fuel uplift for the flight Y under consideration is complete [t]

T_{Y+1}: Amount of fuel contained in aircraft tanks once fuel uplift for the subsequent flight Y+1 is complete [t]

U_{Y+1}: Fuel uplift for the subsequent flight Y+1 [t]

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[15] Airplane device used primarily during aircraft ground operation that provides electric power. An APU can also provide backup electric power during in-flight operations.

[16] Section 1 of Annex III of the M&R Regulation: *"Actual fuel consumption for each flight [t] = Amount of fuel contained in aircraft tanks once fuel uplift for the flight is complete [t] – Amount of fuel contained in aircraft tanks once fuel uplift for subsequent flight is complete [t] + Fuel uplift for that subsequent flight [t]" [6].*

Particular situations to be contemplated:

1) If at any case there is no fuel uplift for the flight or subsequent flight scheduled, the fuel resting in the tanks will be the corresponded when the flight Y and Y+1 takes off.

2) Due to technical maintenance reasons where the fuel tanks must be emptied and in exceptional cases where the variable T_{N+1} cannot be specified, fuel concerning the following flight Y+1 will correspond to the fuel tanks of the following aircraft activity.

METHOD B[17]

$$F_{Y,B} = R_{Y-1} - R_Y + U_Y$$

Where:

$F_{Y,B}$: Total fuel consumed for the flight Y under consideration using method B [t]

R_{Y-1}: Quantity of fuel remaining in the aircraft tanks at the end of the previous flight Y-1 [t]

R_Y: Quantity of fuel remaining in the aircraft tanks at the end of the flight Y under consideration [t]

U_Y: Fuel uplift for the flight Y under consideration [t]

[17] Section 1 of Annex III of the M&R Regulation: "*Actual fuel consumption for each flight [t] = Amount of fuel remaining in aircraft tanks at block-on at the end of the previous flight [t] + Fuel uplift for the flight [t] - Amount of fuel contained in tanks at block-on at the end of the flight [t]*" [6].

Particular situations to be contemplated:

In the event that that an aircraft does not perform a flight previous to the flight under consideration, the variable R_{Y-1} will be substitute with the amount of fuel remaining in aircraft tanks at the end of the previous activity of the aircraft.

DENSITY

To correctly count emissions using Method A or B, the amount of fuel uplift or remaining in the tanks must be determined under the same units of volume[18]. As for that reason mass values must be converted to actual density values using the following formula [16]. In addition in the case that fuel is determined in units of volume (litres or m^3), the operator must convert it to weight (kg) using actual density values. The following formula determines:

$$M = V \cdot \rho \cdot f$$

Where:

M: Mass of fuel [t]

V: Volume of fuel [L]

ρ: Actual fuel density determined for the applicable temperature [kg/L]

f: Correction factor for making units consistent. When ρ is expressed as kg/L then f adopts a value of 1t/1000kg.

Only in the case where there is no density data ρ available a standard density factor of 0.8kg/L will be applied (with the prior approval of the CA).

[18] Litres, US gallons or m^3

3. CAP-AND-TRADE SYSTEM

3.1 Background: EU ETS Structure

Current operating mechanism developed in two trading periods:

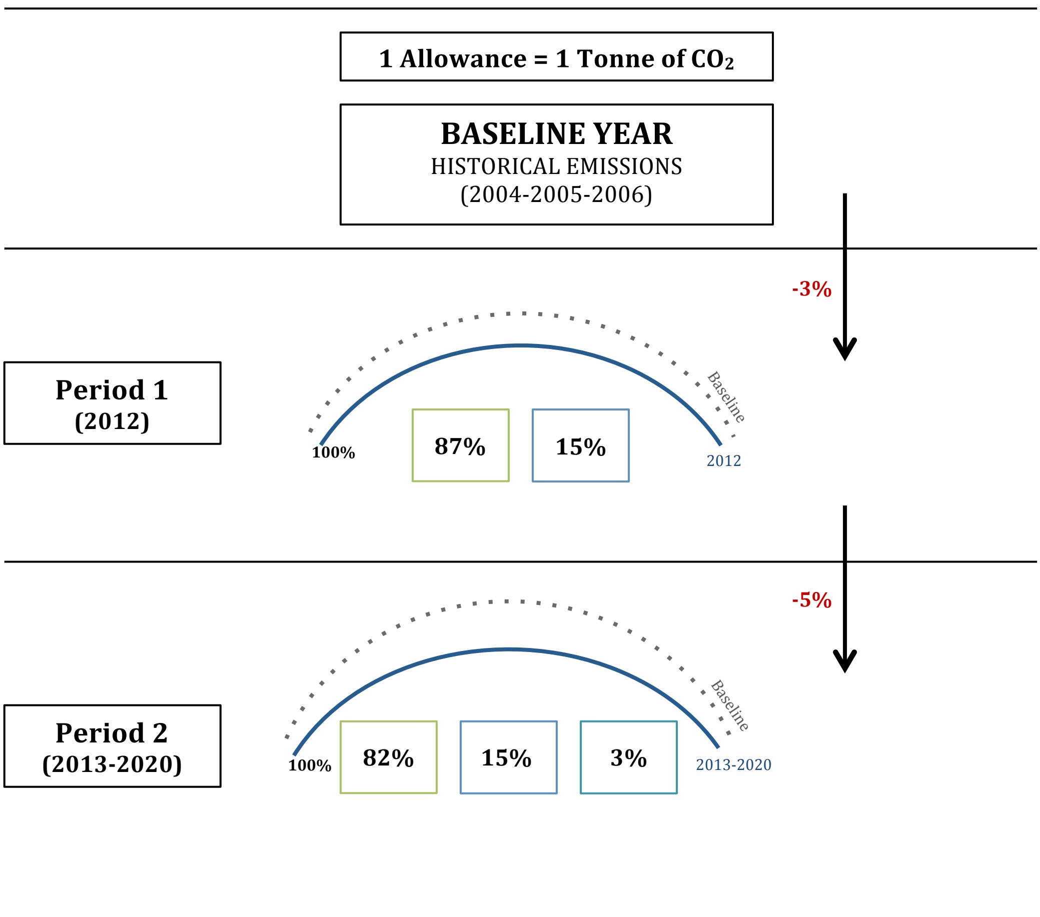

Figure 3: EU ETS Cap-and-Trade System

The EU ETS currently caps the number of emissions from international aviation through a cap-and-trade system for the **first** (2012) and **second** trading period (2013-2020).

The system is organized under two caps related to the corresponding trading period (Fig. 3). The caps are set under a **reference baseline year**, which is calculated through the average of greenhouse gas emissions generated by international aviation between the years 2004, 2005 and 2006 [6].

For the first trading period the baseline year quantity has been reduced a 3% compared to the baseline period. Meaning that the cap will be equal to 97% of the historical emissions (baseline period). The amount of allowances is distributed between the airline operators for free (87%) and under auctioning (15%)

The same procedure is followed for the second trading period. The cap is targeted to be reduced a 5% from the baseline year, which means the total amount of allowances is diminished. The quantity of allowances allocated under the cap is assigned for free (82%), under auctioning (15%) and to new entrants (3%).

3.2 Analysis of the EU ETS

Before 2012, airline operators were allowed to emit as much as they needed with a zero price penalty and under no regulation. Once the EU ETS started to operate (2012), the Commission, taking the role as a Regulator, established a **frontier** (i.e. the cap) with the aim of limiting the number of emissions. Despite that fact, airline operators were still allowed to emit under the same levels from before 2012. But on the contrast when an airline operator exceeds its corresponding share of the frontier (i.e. its number of allowances does not cover the total amount of emissions generated) an economic **penalty** is imposed.

Therefore, as far as it can be understood from the European Commission documentation, it seems that the EU Commission wants to fix the limits of the current cap-and-trade system (Fig. 3), which means the system will not be adapted to meet with the exponential aviation **demand** increase, expected over the future years. Thus, airline operators shall be allowed to emit “for free” under the same levels than the past years (receiving a great amount of allowances free of charge) but the frontier established will not be augmented to meet with the increasing demand.

As a result, when an airline operator may generate extra emissions that cannot be covered with allowances (emissions outside the frontier) must pay a penalty to **internalise** the environmental externality caused [7]. **What is important to notice is the fact that the penalty imposed to emit outside the cap is equivalent to put a price to the emissions, thus implicitly allowing the operators to emit beyond the fixed cap. This means that such price/tax for extra emissions and its impact on the entire system must be careful analysed**. What is more remarkable is the probably fact, that if the penalty is low enough in comparison with the benefits obtained by the airline operators to emit (i.e. operating more), those airline operators will be willing to pay the fine. Therefore, due to for the coming years is expected a high increase of the aviation transport it can be predicted that the real cap, will be bigger than the one established by the Regulator which corresponds to the demand from the baseline year.

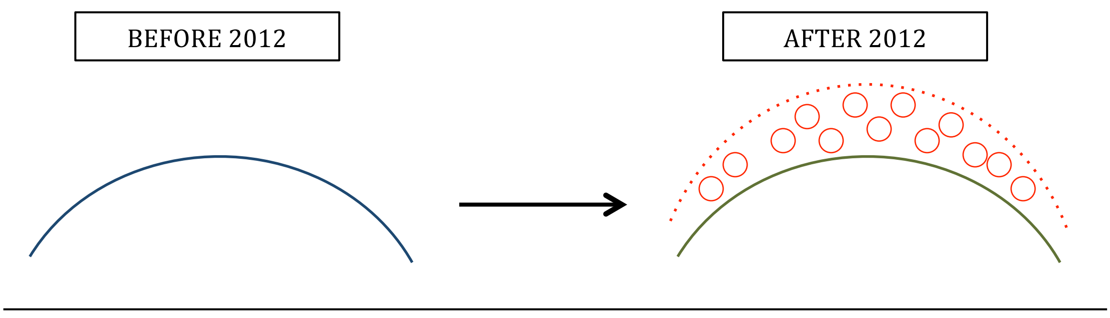

Figure 4: The Cap before and after the EU ETS

As it is possible to see in Fig. 4, before 2012, airline operators were not subject to any restriction and could freely emit to responding the demand. After 2012, once EU ETS came into function, a cap was set over the emissions generated in 2004-2006, so the same level of emissions was kept. Also, airline operators received a great amount of allowances for free (probably due to grandfathering/retrospective arguments). However, when an operator cannot cover its emissions it can pay a fine to emit outside the cap. As a consequence, the amount of extra allowances can generate a new cap, higher than the one fixed by the EU ETS Regulator, which probably would meet the airline operator demand.

3.3 EU ETS Emission Pricing: what is the optimum price?

As understood in the previous analysis, the penalties to extra tonne emission out of the free-allocated endowment **can be indeed interpreted as a price**, such as a *pigouvian* tax. It is understood by our side that there must be an **optimal price** for the extra emissions generated, **since there is a trade-off between being too restrictive**, i.e. fixing a price so high that the cap will be close to the one fixed by ETS, which may cause that the future air traffic demand could not be attended (with the huge economic costs for the European macroeconomy and competitiveness), and **being too lax**, i.e. emissions for free, which may lead to a non-sustainable air transportation system.

To illustrate the concept, let state three hypothetical assumptions for a 2030 scenario:

1) Demand from international aviation highly increases in comparison to 2012.
2) Emissions are regulated under a fixed cap subject to no demand adjustment.
3) The penalty for exceeding the frontier is subject to a fixed price.

Under these assumptions, it is possible to observe two potential scenarios:

Case 1- If the fine charged for each extra tonne of CO_2 generated is 100€ and in operational terms it means a **low** rate, airline operators will be able to afford the fine therefore to emit outside the cap established.

Airline operators will be able to emit as much as they require due to 100€ fine is an affordable cost to internalize. Therefore the 100€ rate will indirectly establish a new frontier due to the Regulator is putting a price on the carbon emission.

Case 2- On the other hand, if the 100€ rate represents an **unaffordable** rate for airline operators (i.e. the Regulator is establishing a highly negative incentive to the airline operator), thus will oblige operators to not emit over the frontier. That fact will generate dissatisfaction and less welfare for the customers and for the entire European macroeconomy. Airline operators will not be able to cover all the demand. If so, it could be penalizing a lot to the traffic demand, with the consequent macroeconomic costs, unless that a big change in aircraft engines and energetic technologies is expected to happen over the next future years, where operators will have to adapt and incorporate this new technology in order to survive in the market.

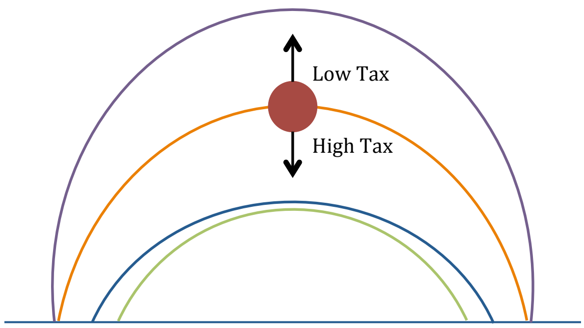

Figure 5: EU ETS and an optimum price

As we can see in Fig. 5, the green curve represents the fixed cap established by the Regulator where airline operators receive allowances for free. The blue curve represents the baseline year. If the economic cost to move from the green frontier to the orange is 100€ and it represents an unaffordable price for the operator, it will generate less welfare and discomfort for the economy.

On the other hand, if 100€ fine is very affordable for the companies; it will be possible to emit more, fact that will cause more damage to the environment (purple frontier).

Hence, we assume there is an optimum price (red spot) between the damage caused to emit and generating less welfare.

4. PRICING GUIDELINE

4.1 Considerations on how to determine an optimum price

Clean air is a scarce resource and that is why EU-ETS aims at regulating the level of emissions. It is understood in this work that there must be a certain level of pollution that is not affordable for permitting the live with acceptable comfort. Therefore, we refer to the existence of such real limit as the **hard-constraint cap**, a cap limit that cannot be exceeded with emissions from airline operators (nor anyone else), because the health of live beings could be seriously injured. Surpass that limit would generate devastating effects for the environment and consequently will not be accepted for the society.

In addition, and without loss of generality, we assume that no important technological changes will happen on the following years or decades that could substantially contribute to reduce the levels of emissions per flight, i.e., same airplane models and flight efficiency will remain in the same order of nowadays (the expected emission reductions pointed in the future Air Traffic Management (ATM) are considered, but not affecting the discussion). Given the case where a revolutionary technological change happens, the following discussion should be reconsidered and even could become useless (e.g., if a new type of clean engines is invented and aircraft do not pollute anymore, the model discussed will only remain interesting at theoretical level).

The main argument proposed in this work is that **there is a trade-off between the benefits of having clean air and the benefit of flying to transport people and loads.** However as soon as the level of emissions (E) approaches to the hard-constraint cap (Fig. 6), **the price to pay for the emissions generated outside the EU ETS cap (free emission rights) should increase**, since the emissions are reaching a critical and dangerous level. Moreover the price to pay for exceeding the hard-constraint cap would have to be boundless (i.e., infinite). Thus, since the level of emissions depends on the level of traffic (under the consideration of same technological frame) **the emission price must be variable (dynamic) and not static**, and relative to the proximity to the hard-constraint cap level (which should be quantitatively accounted).

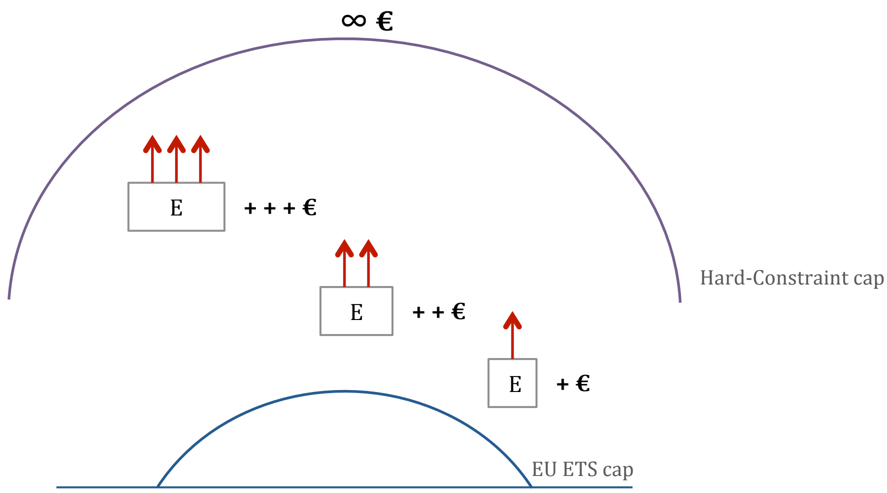

Figure 6: Hard-Constraint cap

But as close as the emissions from an airline operator get to the limit, the variable price should increase to generate **higher incentives** for the airline operators to reduce its level of emissions. The fact of paying a higher amount means that operators

are emitting too much, evidence that affects negatively on the benefit of flying (i.e. demand reduction).
Thus, through a price setting, the Regulator can force the operators to become **more efficient** in their operations. Then, only airline operators that can adapt and become more efficient will remain (risk that the Regulator will have to accept).

The optimum price regarding a social cost point of view; when the price to pay for the emissions generated increases, fewer emissions will be generated. So, the social welfare will augment (i.e. higher clean air levels) but the social cost will increase due to the traffic air transportation will decrease (i.e. less supply). Contrary, when the price decreases, the number of emissions will augment, fact that equals to a fewer social welfare (i.e. lower clean air level), so the social cost will increase (i.e. due to the pollution augment).

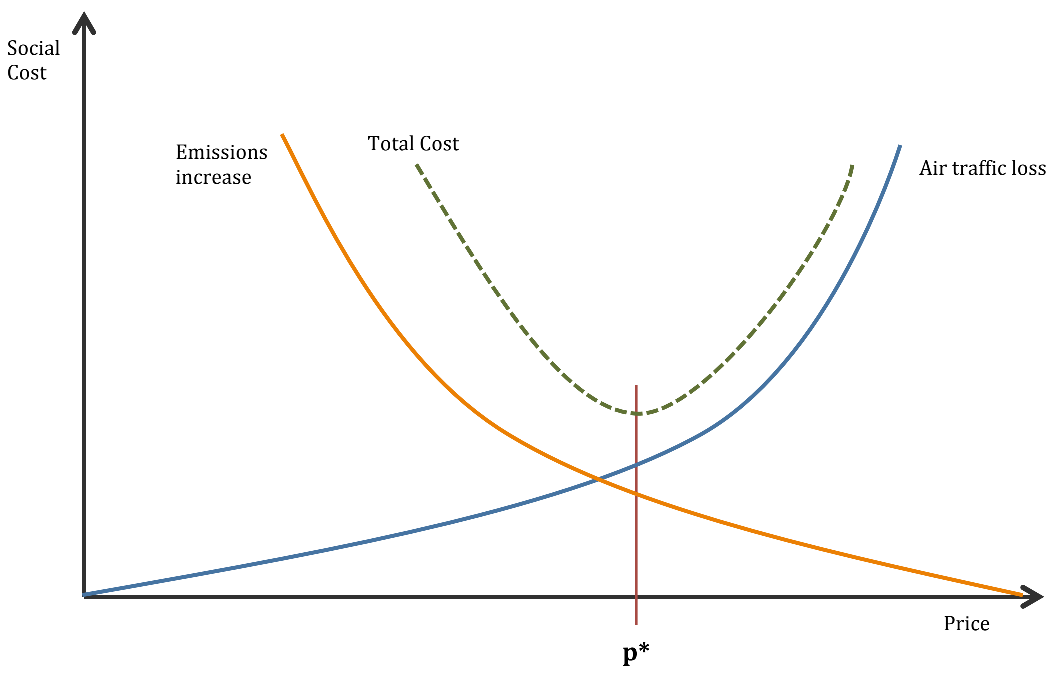

Figure 7: Optimum price (p) representation*

Where would be the optimum price? The **optimum price** (**p*** in Fig. 7) would be the point where the total cost endured by the society is minimum. See the dashed green line in Fig. 7, which is obtained from adding the social cost coming from having fewer flights together with the social cost generated by the total pollution emitted by those flights. Thus, in the long-term, when the operators will have internalized those social costs in its own production structures, the engines and the operations are expected to become much more efficient (EU ETS's ultimate objective) up to the point that a natural equilibrium of total emissions will be reached considering the actual trade-off between the socials benefits of flying and the social costs of having air polluted. Regulator must also be careful with fairness issues at the moment of setting pricing policies, thus reminding not to put too much relative pressure on weakest operators.

Setting an optimum price for the emissions should lead to a social commitment scenario in which it could be possible to operate flights to cover social demand at the maximum extent, whereas the operations will be the most efficient for polluting the minimum (i.e. generating the lowest number of emissions). Only then the society could benefit from the air transport but without resigning to clean air welfare.

Therefore the optimum price will be reached by the existence of a social **Marginal Rate of Substitution**, where the society will renounce a certain amount of the aggregated welfare (or aggregated utility) obtained by flying (thus polluting the air) to obtain a certain amount of welfare that brings having clean air.

The implementation of the proper formula (out of the scope of this project) will be the key tool to determine the **price** (i.e. incentive) that will exercise a **natural pressure** on the airline operators to make them become more efficient (in this scenario we assume all the airline operators pays the same price per tonne of emission). The pressure will augment as soon as the emissions from an airline operator gets closer to the limit, and will be reduced as soon as the society considers that the levels of air cleanliness are enough compared to the benefits of polluting for flying.

But what is efficiency for an airline operator? Accepting the case when demand greatly increases and assuming equal efficiency levels (i.e. an operator produces 100 units then emits 1 tonne. If the production rises to 200 units then will emit 2 tonnes), the level of pollution highly increases. Therefore, if the airline operator greatly **increments its efficiency**, if before 100 units emitted 1 tonne of emissions, now being twice as efficient, 100 units will emit half tonne (and 200 units, 1 tonne).

Thus, **efficiency is the relation between what an airline operator produces and what the airline operator emits**.

Table 5: Efficiency increment example

NO EFFICIENCY INCREMENT

UNITS PRODUCED		PRICE per tonne (€)		EMISSION (t)
100 u.		5 €		1 tonne

Scenario 1

EFFICIENCY INCREMENT

UNITS PRODUCED		PRICE per tonne (€)		EMISSION (t)
100 u.		2.5 €		0,5 tonne

UNITS PRODUCED		PRICE per tonne (€)		EMISSION (t)
200 u.		5 €		1 tonne

Scenario 2

If demand greatly increases and the same levels of efficiency are maintained as in scenario 1 from, the price per tonne of emission will exponentially increase (i.e. less distance with the hard-constraint cap due to operators emit more) (Table 5).

However in scenario 2 where there is an efficiency increment by the airline operator, is possible to observe that the operator paying the same price per tonne of emission will emit less and produce more regarding the levels of production (i.e. operating) (Table 5). Consequently, only adjusting the operator's efficiency, these will gain more economic welfare due to a production increment under the same price.

It is important to take into account when the Regulator fixes the price to pay for the emissions generated, it has repercussions to the air transport client (the one who finally internalizes the cost of flying). Therefore, what the Regulator is causing through the price increment is that some flights will lose its clients due to flying will not be affordable for them (i.e. not possible to internalize the cost). Thus, the flight will not be performed, fact that will generate a decrease in the number of emissions. But, there will be some flights that will merely lose half of demand, so, the activity will still be performed and emissions will only be less reduced.

On the other hand, and changing the model perspective, what will happen if there is an economic **crisis** in the European market? The first direct consequence of a crisis situation will be the loss of demand, i.e., demand falls, airline operators emit and pollute less, fact that would generate a **price decreasing** due to emissions are far from the hard-constraint cap. Thus, allows the Regulator to relax the pressure to be efficient on the airline operators. So probably, the airline operators would become less efficient, (due to the price to pay is much lower). That fact would not be a matter because it would let operators to adapt to the crisis situation.

Therefore, the variable price to pay for the emissions generated would have to properly respond to the traffic demand fluctuations.

5. CONCLUSION

Before the EU ETS came into function airline operators produced/flown over any environmental restriction. Therefore, the EU ETS taking the role as a Regulator apparently established the price as an incentive so that airline operators could produce the same level of welfare, generating fewer costs in order to let the airline operator be aware (i.e. internalizing the cost) about the negative externalities of the pollution generated by their flights, since clean air is a limited benefit resource and it is very valued (even necessary) for the social welfare.

After the analysis of the main EU-ETS aspects, as well as after the light shed over the underlying emission market dynamics, it can be concluded that the **price to pay for the extra emissions generated outside the EU ETS cap must be dynamic, not static as it is now**. In addition, price should be growing proportionally to the proximity to the hard-constraint cap, a theoretical limit used in the analysis. However, the hard-constraint cap must be real limit that should be calculated and which should not be exceeded due to the potential harmful effects to the society (emissions price should converge to infinite at the hard-constraint cap border).

Therefore, under a scenario of prosper and growing economy in which air transport shall be more demanded, airline operators must be gradually penalized with a higher emission price because a higher air traffic demand entails a increase in the level of emissions (except if new technological or procedural changes allows a reduction of emission per flight in the same proportion than the traffic increase). By dynamically increasing the price, the Regulator can generate a scenario for the operators in that they are forced to become **more efficient in their operations.** Of course, a higher price means a higher risk of losing the least efficient operators, thus reducing the EU-wide traffic demand and losing the respective social utility related to such demand.

However, if the emission price is set taking into consideration the market dynamics observed in this document, the level of demand utility finally lost should naturally be balanced with the level of utility obtained for a less polluted air. On the other hand, under a scenario of economic crisis (with important air traffic demand reductions), the Regulator could **diminish the pressure over the airline operators** with the application of a lower the price that shall permit to relax the needs of being emission-efficient for being competitive in the market of air transport, thus **favouring the survival of those companies that might be already punished by the crisis and in turn favouring the recovery of the macro-economy**. Again, a dynamic price correctly set should lead to a equilibrium in which the benefits of flying for the society are naturally balanced with the benefits of having a cleaner air (equilibrium determined according to the aggregated/social marginal rate of substitution for those two goods).

In other words; **the variable emission price (or penalty) should be established by the Regulator at any moment so that the marginal social benefit obtained by the emissions reduction and the marginal social cost caused by less air traffic are equal (optimal price).**

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List of Figures and Tables

Nomenclature

AAU	Assigned Amount Unit
ATM	Air Traffic Management
APU	Auxiliary Power Unit
CA	Competent Authority
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CO_2	Carbon Dioxide
EC	European Commission
EEA	European Economic Area
EEA-EFTA	European Economic Area-European Free Trade Association
ELFAA	European Low Fares Airline Association
ERU	Emission Reduction Unit
ET	Emission Trading
EU	European Union
EU ETS	European Union Emissions Trading System
GCD	Great Circle Distance
GHG	Greenhouse Gas
ICAO	International Civil Aviation Organization

JI	Joint Implementation
KP	Kyoto Protocol
MRR	Monitoring and Reporting Regulation
N_2O	Nitrous Oxide
NAP	National Allocation Plan
PFCs	Perfluorocarbons
T	Tonne
TKM	Tonne-Kilometre
UNFCCC	United Nations Framework Convention on Climate Change
VER	Voluntary Emission Reduction