Estimation of the Greenhouse effect caused by the Spanish fleet of tugboats

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Abstract:

In October 2008, the Marine Environment Protection Committee (MEPC) adopted the Annex VI of the revised regulation MARPOL which entered into force in July 2010. Several revisions were made, inter alia, to the rules on Ozone-depleting substances, which is expected to produce a significant benefit for the environment and human health, especially for people living in port cities and coastal communities. At present, the sensitivity of the citizens regarding the emissions originated in the port areas are increasing, perhaps because the most important commercial ports are placed within densely populated cities.

In this context, it is presented the objective to determine how much is the effect of the greenhouse gases emissions caused by the Spanish tugboat fleet in the carbon footprint of the Spanish maritime transport. For this purpose, the structure of the tugboats fleet is formalized and the emissions amount of CO_2 equivalent originated by the fleet as well as its distribution between ports and regions are estimated and analysed according to the existing methodology used by the International Maritime Organization (IMO) for merchant ships. Then in this work, it is estimated the atmospheric emissions from both the main and auxiliary engines of all the tugs that constitute the analysed fleet. Finally, the profile of the Spanish tugboat that is the most polluting is formalized, according to location, age, deadweight, length and power installed.

Keywords: Greenhouse effect, fleet emissions, CO_2 emissions, tugboats,

NOMENCLATURE

GHG: Greenhouse Gases
CO_2: Carbon Dioxide
CH_4: Methane
N_2O: Nitrous Oxide
CO_2 E: Emissions of CO_2 equivalent
DWT: Deadweight
Tons: Metric tonnes
ECA: Emission Controlled Areas
IMO: International Maritime Organization
DO: Distilled fuel Oil
MDO: Marine Diesel Oil
MCR: Maximum Continuous Rating
kW: Kilowatts
NV: Number of tugboats
PI: Power installed in kW

1. INTRODUCTION

Nowadays, the air pollution from ships is an issue of general concern and is generating numerous legal regulations at European and worldwide level. In the same way, it is being originated new environmental concepts for the evaluation of the air pollution, accepted and used internationally, such as the carbon footprint.

There is a legal framework that regulates air emissions from the maritime transport which we will refer to. This is the MARPOL (Marine Pollution) 73/78, its Annex VI sets limits for certain air pollutants such as sulphur and nitrogen oxides. These limits must be strictly complied by all ships built from 2005. In addition to these defined limits, the MARPOL Convention defines several areas around the world where the limits for air emissions are even stricter, these areas are known as emission controlled areas (ECAs).

This Annex VI is focused in the air pollution and ship efficiency. This Annex entered into force 19/05/2005. In this context, the IMO force to use fuels with determinate qualities (looking at the sulphur contents) and propulsion systems with design which increase their efficiency (reducing the nitrous oxides emissions) in compliance with the limits established in MARPOL, Annex VI.

The usage of fuels with low sulphur contents is a key point, especially for maritime operations at port levels, because reducing the sulphur contents consequently, the air emissions of poisoning substances for the citizens leaving nearby the ports locations will decrease.

Other maritime regulations are focusing on the control and reporting of the CO2 emissions from shipping such as the "Regulation (EU) 2015/757 of the European Parliament" (known as MRV, Monitoring, Reporting and Verification of CO2 emissions from the maritime transport), and the implementation of the IMO Data Collection system for reporting of fuel consumption and CO2 emission from the shipping around the world. Both regulations are for ships above 5000 GT and with doing less than 300 voyages per year.

The atmospheric emissions from the ships are caused by the fuel combustions on board. This combustion emits exhaust gases to the atmosphere producing the pollution.

This pollution has local and globally consequences, therefore its reporting in the most transparent way will help to get a better control and understanding of their origin and consequences, being this of general interest.

The pollutants may be classified in two types. Ones, known as GHG, are the cause of global warming, which main component is the CO_2. The environmental effects of the GHG can be measured by the *Carbon Footprint* of the activity under analysis.

The other pollutants are known as "air pollutants", they cause an impact localized in the area where they are emitted. These pollutants are Sulphur Oxides, Nitrogen Oxides, Particulate Matter, among others.

The evaluation of the effect of the GHG emissions caused by the Spanish tugboat fleet in the carbon footprint of the Spanish maritime transport is important due to the tugboats are part of the maritime transport cycle, therefore, the carbon footprint added by the tugs will have effects on the total carbon footprint of the maritime transport of the country. In this paper, we focus on the analysis of the effect caused by the emissions of the GHG from the tug boats fleet operating within Spanish ports.

Moreover, currently there is a special sensitivity about the emissions at ports, perhaps because the most important commercial ports are set deep into cities where there is a big population density, so that is needed to know the impact of the ports activity on the health and its global effect, being this at the same time, one of the major concerns of the citizens.

In this context, it is made this study whose establishes the objective of determination of the GHG of tugboats fleet in Spain, and its contribution on the carbon footprint of the Spanish maritime transport.

It is analysed and compared two years, taking one of the years when happened the economic crisis in Spain (2007) and the other year is the most recent data for the fleet, January 2017. Therefore, it is analysed the fleet for the years 2007 and until January 2017. This is allowing us to check the evolution of the tugboats fleet and its impact on the Carbon footprint of Spanish maritime transport.

For such purpose, it is formalized the fleet structure and it is estimated and analysed the CO_2 concentration originated by the tugboats fleet. Likewise, it is analysed the distribution of the CO_2 by regions. All these analyses are done following the IMO methodology used in its 3rd IMO GHG Study, 2014 for the estimation of ship emissions and, it is applied the GINI indexes for analysis of the inequality of the CO_2 equivalent. Finally, it is formalized the profile of the tug boat that is the most polluting in function of its location, age, deadweight, length and power installed

In the following epigraphs, it is presented the methodology and the data used, the results obtained and the general conclusions of the research done.

2. METHODOLOGY AND DATA USED

For estimating the GHG, also the carbon footprint, and the CO_2 concentration it is employed two methodologies. They are explained in this section.

2.1. METHODOLOGY FOR ESTIMATION OF GHG EMISSIONS FROM THE SPANISH TUG FLEET

The estimation of the GHG caused by the tugs fleet is done from the fuel consumption for each individual tug by applying the bottom-up methodology (Buhaug, Corbett et al., 2009).

In this paper, for the estimation of the fuel consumption is considered the data of the main engines and auxiliary engines, it will give the base for the estimation of the GHG emissions.

The amount of pollution gases produced by the ships mainly depends of the following factors:

- Quantity and fuel type in use
- Propulsion type and design
- Operational mode and running hours

The marine engines installed on the Spanish tugboats fleet analysed are medium speed diesel engines. The technical data for the main engines and auxiliary engines installed on each tugboat has been obtained from the Fairplay database.

The tugboats fleet treated on this study is the one that is operating in the ports within Spanish coast. The Spanish ports have environmental restrictions regarding the fuel quality used by the ships within port waters. Therefore, all the ships sailing in Spanish waters must use fuels with low sulphur contents. At this regard, the fuel employed in this work is *Distilled Oil*, with a sulphur content of 0.1%.

For this study, we have considered the load factor for the main engine and the auxiliary engines defined in the final report "Chevron Richmond Long Wharf Shipping Emissions Model" (ICF, 2014), considering that the Main Engines run at 31% MCR and the auxiliary engines are operating at 43% MCR, for all the operational modes.

The determination of the running hours of each tugboat per year has been done by analysing the maritime traffic for each Spanish port. It has been estimated that each merchant ship operating within Spanish ports need the assistance of the tug boats for one hour. The maritime traffic in Spanish ports it has been obtained from the annual reports published by the National Statistics Institute (*INE*) for the years 2007 and 2016.

The atmospheric emissions caused by the exhaust gases from the ships are compound by several pollutants which are originating the greenhouse effect (with a global effect), and by other pollutants known as air pollutants with a localized effect in the area where they are emitted.

This study analyses the following GHG:

- CO_2
- CH_4
- N_2O

The emissions are estimated applying the equation 1:

$$E_i = C_{T,j} \times EF_i \qquad \text{[Tons]} \qquad [1]$$

Where:
E: Emissions quantity, tons
C_T: Total fuel consumption, tons
EF: Emission factor
i: Pollutant, Ton pollutant / Ton fuel
j: Fuel type, (MDO)

2.1.1. CARBON FOOTPRINT

The carbon footprint is defined as "the totality of all GHG emitted by direct or indirect effect of one individual, organization, event or product. The carbon footprint is measured in mass of CO_2 equivalent". Hence, for the estimation of the carbon footprint for the analysed fleet, it is considered the emissions of CO_2, N_2O and CH_4, expressing all of them in CO_2 equivalent as it is shown in the equation 2.

$$CF = \sum CO_{2eq} \qquad \text{[Tons]} \qquad [2]$$

Where:
CF: Total Sum of the GHG analysed expressed as CO_2 E, Tons
CO_{2eq}: GHG emissions as CO_2 equivalent, Tons

2.2. METHODOLOGY FOR CALCULATING CONCENTRATION INDEXES OF THE GHG EMISSIONS FROM THE TUGBOAT FLEET

The concentration indexes try to highlight the greater or less degree of proximity in the total distribution of the values of a variable within a population. Therefore, these concentration indexes are indicators of the degree of distribution or concentration for the variable under analysis.

There are numerous studies on methodological aspects to measure these inequalities or concentrations, most of the studying on these indexes are on health inequalities. Among the best known classical studies are those that analyse and examine the different health inequality indexes and those that propose a classification of the indexes according to their level of complexity, possible uses and suitability of the different measures for the study of inequalities (Wagstaff et al., 1991, Pamuk et al., 1993, Kunst &

Mackenbach, 1994; Brown, 1994). In more recent works, new indexes have been incorporated to measure health inequalities based on the entropy notion (Bacallao et al., 2002).

In addition, in line with the spatial scope of the analysis that is intended to be developed in the present study, differences in health conditions between different geographic areas of the same country have been described (Kirchgässler, 1990; Lahelma & Valkonen, 1990; Csaszi, 1990; Cook, 1990).

Among all the measures of inequality used in health, in the present work we focus on the GINI coefficient. This is a first approach for application of this tool onto the analysis of the GHG emissions of the fleet of tugboats.

In this sense, a series of concentration indexes for certain variables of the sector of Spanish tugboats is formalized. It is a question of knowing in each period if the emission variable of GHG analysed tends to a more homogeneous distribution, or on the contrary, the concentration increases.

These indexes, which synthesize the global concentration in a population, provide very useful information, when quantifying the level of concentration of the variable that is examined in each case.

The GINI coefficient is based on the Lorenz curve, which is a cumulative frequency function that compares the empirical distribution of a variable with the uniform (equality) distribution. This uniform distribution is represented by the diagonal y = x. The greater the distance, or more properly, the area between the Lorenz curve and this diagonal, the greater the inequality

In its application on GHG emissions analysis from the tugboats fleet, the "X" axis represents the accumulated of the population variable under analysis (in our analysis: number of tugs, dead weight and power installed) and the axis "Y", the cumulative variable GHG emissions (in Tonnes of CO_2 equivalent).

As an application of the GINI coefficient to the present analysis we start from equation (3):

$$GII = \left(\sum_{i=1}^{k-1} (p_i - q_i) \right) \Big/ \left(\sum_{i=1}^{k-1} p_i \right) \qquad [3]$$

Where:

GII: GINI coefficient of inequality of CO_2 E

p_i: accumulated percentage for the population variable analysed (X) which has k individuals, and is determined by equation (4)

$$p_i = \sum_{i=1}^{i} \left(X_i \Big/ \sum_{i=1}^{k} X_i \right) = \sum_{i=1}^{i} X_i \Big/ \sum_{i=1}^{k} X_i \qquad [4]$$

q_i is the cumulative percentage of the variable CO_2 equivalent emission (GX) of the analysed population (X) that has *k* individuals, which is determined by equation (5)

$$q_i = \sum_{i=1}^{i} \left(GX_i \Big/ \sum_{i=1}^{k} GX_i \right) = \sum_{i=1}^{i} GX_i \Big/ \sum_{i=1}^{k} GX_i \qquad [5]$$

Substituting in (3), we obtain the general equation (6) then it can determine the inequalities in the concentration of CO2 equivalent of the fleet.

$$GII / X(t) = \left(\sum_{i=1}^{k-1} \left[\left(\sum_{i=1}^{i} X_i \Big/ \sum_{i=1}^{k} X_i \right) - \left(\sum_{i=1}^{i} GX_i \Big/ \sum_{i=1}^{k} GX_i \right) \right] \right) \Big/ \left(\sum_{i=1}^{k-1} \left(\sum_{i=1}^{i} X_i \Big/ \sum_{i=1}^{k} X_i \right) \right) \qquad (6)$$

The variables used in building the concentration indexes are indicated in the table 1.

Table 1: The variables used in building the concentration indexes

G^{a}	$X(t)^{b}$			$GX(t)^{c}$
	$NV(t)$	$DWT(t)$	$KW(t)$	$CO_2E(t)$
1	$NV_1(t)$	$DWT_1(t)$	$KW_1(t)$	$CO_2E_1(t)$
...	...	...	...	...
i	$NV_i(t)$	$DWT_i(t)$	$KW_i(t)$	$CO_2E_i(t)$
...	...	...	...	...
k	$NV_k(t)$	$DWT_k(t)$	$KW_k(t)$	$CO_2E_k(t)$
Total	$\sum_{i=1}^{k} NV_i(t)$	$\sum_{i=1}^{k} DWT_i(t)$	$\sum_{i=1}^{k} KW_i(t)$	$\sum_{i=1}^{k} CO_2E_i(t)$

Source: Authors

Where:
a = Groups of variables. In this study, the groups are made by regions, deadweight and power installed.
b = Population variable analysed for the fleet *i* in the period *t* (NV, DWT, KW)
c = variable for GHG emissions (CO_2 E)

2.2.1. RATES OF CO_2 EQUIVALENT FOR THE TUGBOATS FLEET

Since the GINI indexes only explain the inequality in the general context in an aggregate way, as a complement to a more disaggregated analysis, the rates of CO_2 equivalent are formalized -by regions- for the same variables.

The expression determining the average rate of CO_2 equivalent of a population variable X of the fleet *i* of group G in a period *t* is given by the following relation:

$$AR / X_i(t) = \left[GX_i(t)/X_i(t)\right] \quad (7)$$

Where:

AR /X^{i} (t) = rate of CO_2 equivalent of a population variable X of the fleet *i* of group G in a period *t* given as a fraction of unity

The values of the variables AX and X are those established in Table 1. In this sense, the rates determined with the totals correspond to the average CO_2 equivalent emission rates of the analysed variable.

Equation (7) measures CO_2 equivalent of the variable static in a given period; however, it is interesting to see its evolution in different periods.

2.3. DATA

In Spain, the fleet of port tugboats is distributed on base-ports throughout 9 coastal Autonomous Communities (Basque Country, Cantabria, Asturias, Galicia, Andalusia, Community of Murcia, Valencia, Catalonia, Balearic Islands, Canary Islands) and two Autonomous cities (Ceuta and Melilla), as indicated in Fig.1.

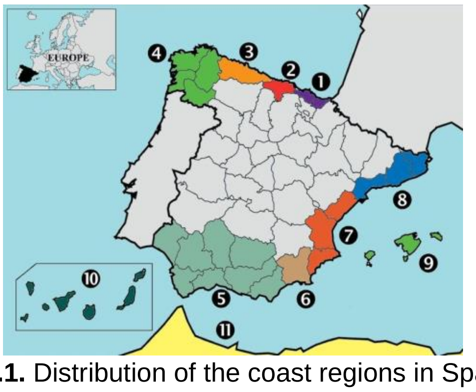

Fig.1. Distribution of the coast regions in Spain

The structure of the tugboat fleet has been made using the *Fairplay* database. From this database, it has been extracted the values of the installed power, technical data of main and auxiliary engines, structural data (length, breadth, draft, deadweight). The available data are structured by regions, deadweight and installed power.

Regarding the operational time of the tugboats, the data available in the annual report of the *National Institute of Statistics (INE)* of the Government of Spain are taken as reference. This is reporting the number of merchant ships operating in each Spanish port. For each merchant ship is considered that one tugboat will assist her for one hour.

Therefore, any indicator of emission of GHG of the Spanish tugboat sector is elaborated from these sources.

The application on the tugboats fleet in Spain of the tools formalized in the methodology has allowed us to obtain results for the inequality in the concentration of CO_2 equivalent by regions, the associated *Lorenz curves* and the rates of CO_2 equivalent.

Table 2: Evolution of the tugboats fleet structure

	No. Tugs		**DWT (tons)**		**GT (Tons)**		**Power (KW)**		**CO2 Eq (tons/year)**	
Region	**2007**	**2017**	**2007**	**2017**	**2007**	**2017**	**2007**	**2017**	**2007**	**2017**
BASQUE COUNTRY	15	19	1819	5169	2863	8134	24689	56641	1853	2365
CANTABRIA	4	7	649	1828	1623	2925	17740	31178	767	1289
ASTURIAS	14	14	3076	3161	4805	4889	33838	35966	1123	1119
GALICIA	27	32	7866	9707	10223	13685	69602	94469	3102	2737
ANDALUSÍA	47	47	5952	7409	10670	14066	90962	112784	11197	12919
MURCIA COM	7	7	4054	4054	5378	5378	33943	33943	1590	1967
VALENCIA	29	32	4173	6182	7855	9910	74190	91831	5821	6061
CATALONIA	12	17	1747	3016	3542	6140	35932	60849	8184	8194
BALEARIC ISLANDS	4	5	651	1201	924	1831	7966	11710	1234	5063
CANARY ISLANDS	26	24	4429	4231	7361	6747	60412	62606	14451	13590
CEUTA & MELILLA	5	5	950	950	1065	1065	7673	7673	1767	1453

Source: Authors

3. RESULTS

By applying the methodology of the section 2, it is obtained the results shown in the following epigraphs within this section.

3.1. CONCENTRATION INDEXES AND LORENZ CURVES

The concentration indexes for the GHG emissions from the tugboats fleet operating in Spanish ports for the years 2007 and up to 2017 are shown in Table 3. They are structured by regions, for the variables analysed: number of tugs, deadweight and installed power.

Table 3: Concentration Indexes of GHG (GII) for the tugboats fleet, by regions

Year	$GII_{NV}{}^{a}$	$GII_{DWT}{}^{b}$	$GII_{KW}{}^{c}$
2007	0.377	0.555	0.366
2017	0.423	0.626	0.437

Source: Authors

Where:

a = Concentration indexes of GHG of the tugboat fleet in Spain by NV.
b= GHG levels (CO_2 E) of the Spanish tugboat fleet by DWT
c = GHG levels (CO_2 E) of the Spanish tugboat fleet by PI

The CO_2 equivalent emitted by the Spanish tugboat fleet by regions, in 2017, according to the number of tugboats, deadweight and installed power, has increased its concentration as it is indicated by the GINI indexes (see Table 3). It is indicating that the CO_2 equivalent emissions in the Spanish ports in the years analysed (2007 and 2017), has increased their inequality.

In the last year under analysis, around 50% of the tugboat fleet emitted almost 77% of the CO_2 equivalent, distributed in five regions: Balearic Islands, Canary Islands, Catalonia, Ceuta & Melilla and Murcia (see Fig. 2).

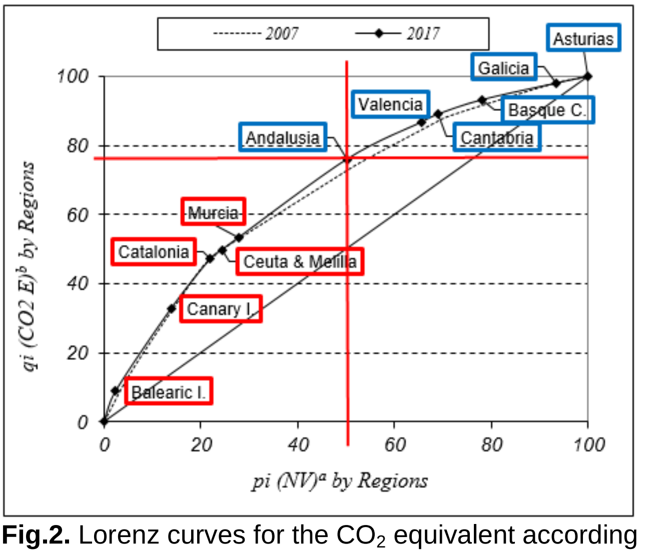

Fig.2. Lorenz curves for the CO_2 equivalent according to the number of tugboats of the Spanish fleet, by regions

a= cumulative percentage by NV
b= cumulative percentage of CO_2 E

Also, looking at the deadweight of the tugboat fleet, 50% of the total deadweight tons of the fleet is emitting 83% of the CO_2 equivalent, distributed in six regions: Balearic Islands, Canary Islands, Catalonia, Ceuta & Melilla, Andalusia and Valencia (see Fig. 3).

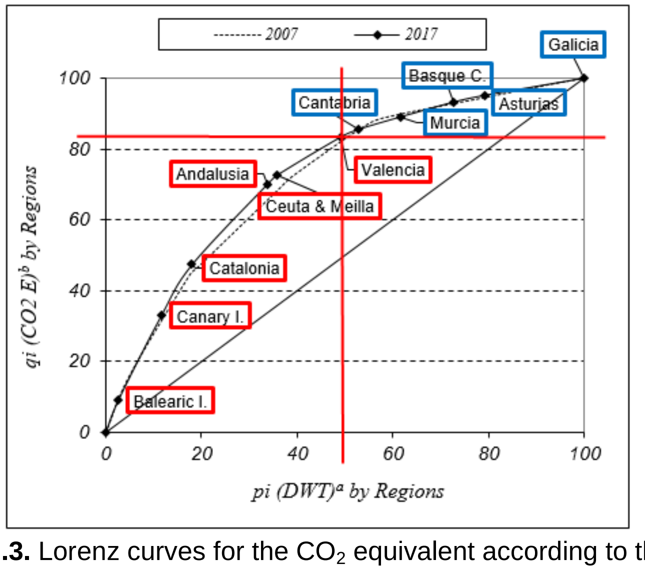

Fig.3. Lorenz curves for the CO_2 equivalent according to the

deadweight of the tugboats fleet, by regions

a= cumulative percentage by DWT
b= cumulative percentage of CO_2 E

For the last variable analysed, 50% of the power installed concentrates almost 80% of the equivalent CO_2 emissions. The regions that are emitting these percentages are Balearic Islands, Canary Islands, Ceuta & Melilla, Catalonia and Andalusia, (see Fig.4).

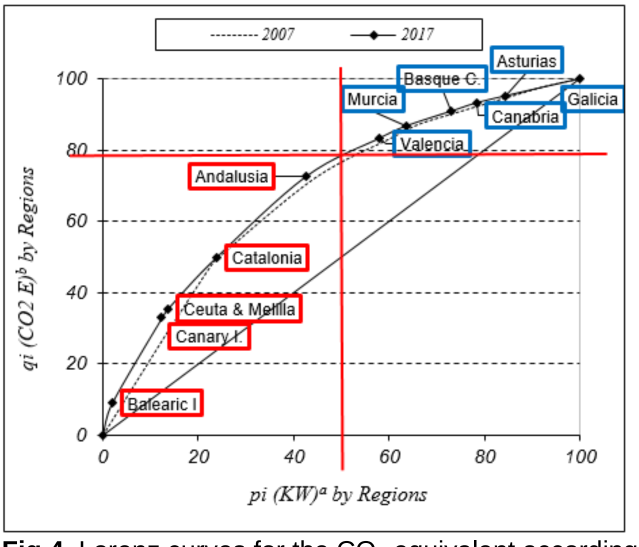

Fig.4. Lorenz curves for the CO_2 equivalent according to the power installed on the tugboats, by regions

a= cumulative percentage by total PI, kW
b= cumulative percentage of CO_2 E

3.2. RATES OF THE CO_2 EQUIVALENT

The rates of the CO_2 equivalent by regions for each year analysed, is shown in the table 4.

Table 4: **Rates of CO_2 equivalent of the tugboats fleet and the variations, by regions**

Coastal Spanish Regions	TCO_2 E / *NV*[a]			TCO2 E / DWT[b]			TCO_2 E / *kW*[c]		
	2007	2017	Var	2007	2017	Var	2007	2017	Var
Basque Country	124	124	0.77	1.0	0.5	-55.08	0.075	0.042	-44.37
Cantabria	192	184	-4.01	1.2	0.7	-40.36	0.043	0.041	-4.42
Asturias	80	80	-0.35	0.4	0.4	-3.03	0.033	0.031	-6.25
Galicia	115	86	-25.56	0.4	0.3	-28.51	0.045	0.029	-35.00
Andalusía	238	275	15.38	1.9	1.7	-7.31	0.123	0.115	-6.94
Murcia	227	281	23.72	0.4	0.5	23.72	0.047	0.058	23.72
Valencia	201	189	-5.64	1.4	1.0	-29.72	0.078	0.066	-15.88
Catalonia	682	482	-29.33	4.7	2.7	-42.01	0.228	0.135	-40.88
Balearic I	308	1.013	228.29	1.9	4.2	122.44	0.155	0.432	179.16
Canary I	556	566	1.88	3.3	3.2	-1.56	0.239	0.217	-9.25
Ceuta & Melilla	353	291	-17.79	1.0	0.5	-55.08	0.075	0.042	-44.37

Source: Authors
a= The rate of the CO_2 equivalent per NV
b= The rate of the CO_2 equivalent per DWT
c= The rate of the CO_2 equivalent per PI

In addition to the rates estimated by regions, it has been obtained the results for the rates of the CO_2 equivalent emitted by the tugboats fleet until 2017 by age, deadweight and lengths. The purpose of this is to determinate the profile of the most polluting tugboat that is operating in Spain for that specific year. These results, which are not shown in this paper due to size limitations, are formalized in conclusion 4.

3.3. CARBON FOOTPRINT FOR THE ANALYSED FLEET

The carbon footprint of the studied fleet is made by converting all the GHG emissions of the tugboats fleet into CO_2 equivalent, applying the methodology specified in section 2 in this paper. The results of the tugboats fleet are detailed by regions in Table 5 (for 2007 and up to 2017)

Table 5: Total GHG and CO2 equivalent (tons) of the tugboat Fleet, by regions on 2007 and up to 2017

	2007				*2017*			
Coastal Spanish Regions	*CO_2*	*CH_4*	*N_2O*	*CO_2 E*	*CO_2*	*CH_4*	*N_2O*	*CO_2 E*
Basque Contry	1.827	0.034	0,085	1853	2332	0.044	0.109	2365
Cantabria	756	0.014	0.035	767	1271	0.024	0.059	1289
Asturias	1107	0.021	0.052	1123	1104	0.021	0.052	1119
Galicia	3058	0.057	0.143	3102	2698	0.050	0.126	2737
Andalusía	11038	0.207	0.516	11197	12736	0.238	0.596	12919
Murcia	1567	0.029	0.073	1590	1939	0.036	0.091	1967
Valencia	5739	0.107	0.268	5821	5975	0.112	0.280	6061
Catalonia	8068	0.151	0.377	8184	8077	0.151	0.378	8194
Balearic I.	1216	0.023	0.057	1234	4991	0.093	0.234	5063
Canary I.	14245	0.267	0.667	14451	13397	0.251	0.627	13590
Ceuta & Melilla	1742	0.033	0.082	1767	1432	0.027	0.067	1453
Total tugs Spain	**50366**	**0.943**	**2.356**	**51091**	**55952**	**1.047**	**2.618**	**56758**

Source: Author

3.3.1. SPANISH CARBON FOOTPRINT

The last national carbon footprint results published by the Ministry of the Environment of Spain dates from 2014, therefore, being the last official data, they are used as reference for this study.

The carbon footprint of Spain in 2014 was 328.9 million tonnes of CO_2 equivalent.

For the same period, the Spanish Ministry of the Environment considered that 25% of the country's carbon footprint is caused by diffuse emissions sectors. This means the activities that are not subject to the emissions trading. Hence, they represent those sectors less intensive in the use of the energy. This category includes the following sectors:

- Residential, commercial and institutional
- Transport
- Agricultural and livestock
- Waste Management
- Fluorinated gases
- Industry not subject to emissions trading

In 2014, the emissions originated by the whole transport sector (road, air and sea) were 77.2 million tons of CO_2 equivalent. The road transport is estimated to be the source of 95% of the carbon footprint of the total transport sector in Spain. Therefore, the amount of emissions produced by air and sea transport are approximately 3.86 million tons of CO_2 equivalent. This amount of emissions is estimated to be distributed to 50% between air and sea transport as an estimation in the absence of specific data.

Table 6: Carbon footprint of the maritime transport in Spain for 2014. Carbon footprint originated by the tugboats fleet in 2017, and percentage of the total carbon footprint caused by the tugboat fleet.

Country	**Carbon footprint of maritime transport (kTon CO_2 E / year)**	**Carbon footprint of tugboats fleet (kTon CO_2 E / year)**	**Percentage caused by the tugboats fleet**

Spain	1930	56.758	2.94 %

Source: Author

4. CONCLUSIONS

1. The methodology used for determination of the GINI indexes is shown as an efficient tool to determine the concentration and inequality of the GHG emissions by regions for the tugboats fleet in Spain. This methodology may be applied in other population groups.
2. The concentration of GHG originated by the tugboats fleet shows an increase of 12.2% in the period under review (2007-2017). The tugboats that concentrate most of the GHG emissions are in the regions of Balearic Islands, Canary Islands, Catalonia, Andalusia and Ceuta & Melilla.
3. At the beginning of 2017, the Spanish tugboat fleet produced the 2.94% of the carbon footprint originated by the maritime transport sector of the country.
4. The profile of the most polluting tugboat of the Spanish fleet at the beginning of 2017 is identified as a tugboat operating on the Mediterranean coast, with an age between 10 and 15 years, over 30 meters in length, with a deadweight between 100 and 300 tons and with more of 4,000 kW of power installed.

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