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CO_2 EMISSIONS SAVINGS PRODUCED BY THE CONSTRUCTION OF AN UPGRADED FREIGHT RAIL CORRIDOR. APPLICATION TO EXTREMADURA

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Summary:

Human activity since the industrial revolution through the use of fossil fuels is changing the natural composition of the atmosphere increasing the so called Greenhouse Gases (GHG). Extremadura's government decided to react actively towards the predicted climatic variations, and for that the "Strategy for Climatic Change for Extremadura" (2009-2012) was approved, which marked the strategies to follow regarding the mitigation and adaptation to climate change. Among the strategies some concrete measures are included like developing annual inventories of GHG emissions and contributing to the development and demonstration of innovative approaches, technology methods and instruments.

With this objective in mind, we develop this investigation where data and conclusions dealing with the savings of CO_2 emissions are given through a comparison of the actual freight transport in the area of influence of the line Badajoz-Puertollano with various scenarios of exploitation for the new planned infrastructures. The savings of the emissions will be caused by:

- *The lowering of the emission factors (kg CO_2/t·km) in the upgraded railway line in respect to the actual one.*
- *The commissioning of the upgraded line will reduce the number of lorries circulating on roads, whose emission factors in unitary terms are far more superior to those ones which will be produced by the use of the new railways.*

The research concludes that the commissioning of the corridor will delete 863,000 transport operations on lorries for a five-year period, reducing the CO_2 emissions in relation with the road: a 59% if the traction is diesel and an 82% if it is electric.

Key Words: *Railway, freight transport, CO_2 emissions.*

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Introduction and objectives

The Trans-European Transport Network (TEN-T) is formed by a compound of priority lines of transport which make the communication of people and freight easier throughout Europe. The 16th axis was a high capacity railway freight corridor with high performance which was included in this net since 2003. It came from the ports of Sines and Algeciras, it went through the Iberian Peninsula and crossed the centre of the Pyrenee through a low elevation tunnel to get to Paris. In December 2013 the European Parliament (EU, 2013) establishes a radical change in the priority core ideas of the TEN-T reducing the 30 initial main axis to 9 in the 2014-2020 period. A part of the 16th axis, more specifically the Manchegan-Extremaduran freight railway corridor (Cofemanex), disappears as main idea of the Core Network, to become part of the Comprehensive Network, whose construction is not expected until 2050. Cofemanex is part of the Madrid-Ciudad Real-Badajoz railway line, it has 304 km of length and runs in a cross-wise way (from east to west) by the communities of Castilla La Mancha (91 Km) and Extremadura (213Km). Cofemanex starts in Puertollano (Castilla La Mancha) and finishes in Badajoz (Extremadura) at the Portuguese border (Figure 1).

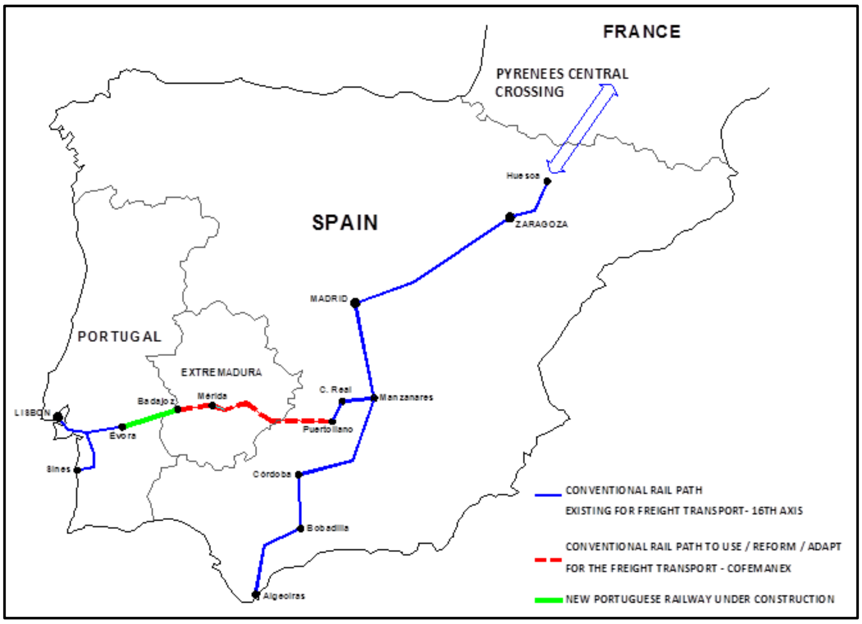

Fig. 1. Geographical zone of the Manchegan-Extrememaduran Railway Freight Corridor (Cofemanex)

The close inauguration of the extension works of the Panama Canal is going to increase predictably the traffic of huge merchant ships coming from the main Asian harbours, so the ports of Sines and Algeciras which serve as an entrance and an exit to the Iberian Peninsula, will gain lots of freight. In order to guarantee the correct transport of the products which leave the port of Sines to Europe, it will be necessary that Extremadura has a railway freight infrastructure that allows the traffic of upgraded railways.

The main aim of this investigation is to determine the savings of CO_2 emissions produced by the adaptation and commissioning of the upgraded railway freight line (Cofemanex) through a comparison of the current transport conditions in freight transport in the area of influence of the Badajoz-Puertollano railway line with the different predicted scenarios of exploitation in the new infrastructure. We understand "area of influence", when speaking about the calculus of the CO_2 emissions, the geographical zones of origin and destination to which the use of a railway line between Badajoz and Puertollano means distance savings. The range of the assessment in the difference of the emissions is done only for those movements directly attributable to the railway line or with equivalence in the road transport inside the autonomous community of Extremadura.

The emission savings will be due to two causes:

– The lowering of the emission factors (kg CO_2/t·km) of the upgraded railway line regarding the current one.
– The commissioning of the upgraded line will reduce the number of lorries circulating on roads, whose emission factors in unitary terms are far more superior to those ones which will be produced by the use of the new railways.

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1. Methodology

In Figure 2, a descriptive diagram of the process of quantifying (t) and valuation (€) of the CO_2 emissions savings is shown.

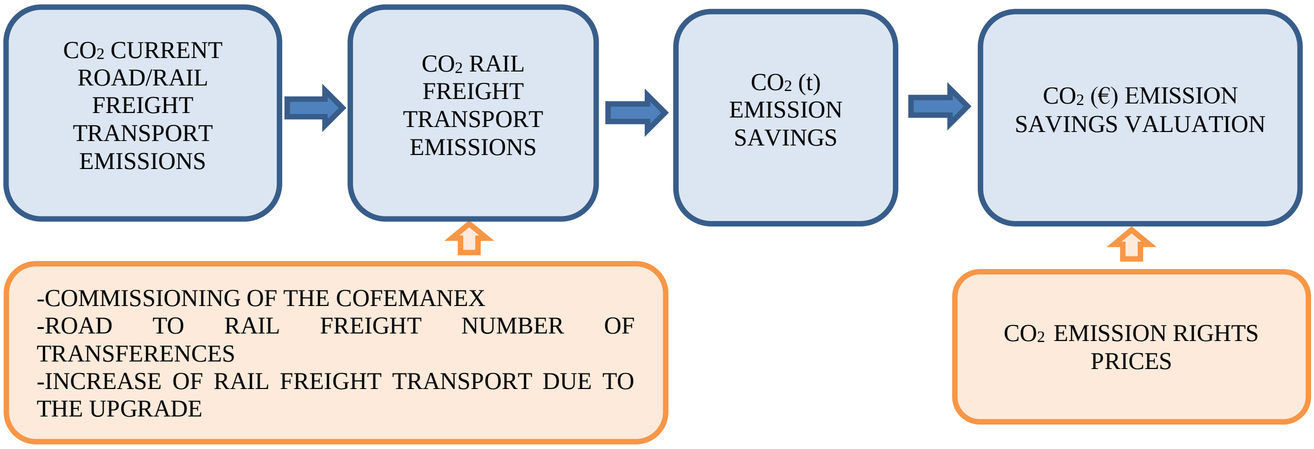

Fig. 2 Quantifying and valuation process of the CO_2 emissions savings

2. Freight transport current situation in the area of influence

2.1. Road freight

The transport of freight by road with Extremadura as the origin or the destination (M.Fomento 2013) is enclosed in Table 1. The table also includes the average of the medium loads estimated from this values.

Table 1. Road Freight Transport. Estimation of the net medium load

Operations with freight loads by road:				
Intra-municipal	2,850,086	operations		
Interregional	1,168,288	operations		
International	84,324	operations		
Total	4,102,698	operations		
Operations with empty running by road:				
Intra-municipal	1,446,167	operations		
Interregional	395,507	operations		
International	29,815	operations		
Total	1,871,489	operations		
Total of transport operations by road:			% empty	% load
Intra-municipal	4,296,253	operations	33.66%	66.34%
Interregional	1,563,795	operations	25.29%	74.71%
International	114,139	operations	26.12%	73.88%
Total	5,974,187	operations	31.33%	68.67%
Freight quantity transported by road:				
Intra-municipal	17,031,000	tonnes		
Interregional	11,937,000	tonnes		
International	961,000	tonnes		
Total	29,929,000	tonnes		
Average load per operation:				
Intra-municipal	3.96	tonnes		
Interregional	7.63	tonnes		
International	8.42	tonnes		
Total	5.01	tonnes		

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In Table 1 we can see that only 3.21% of the freight transport by Extremaduran roads have an international origin or destination, being the 39.88% national and the remaining 56.91% regional.

From the calculus of the emission factor on freight transport by road, we take as load the average of those obtained in the long haul and very long haul freight transport (national and international) for a security coefficient of 1.25 to consider an improvement in the management of transport. Under this premises the net average load considered is 10.03 t. This value includes the repercussion of the empty running trips.

2.2. Rail freight

The freight movement by rail with Extremadura as origin or destination is enclosed in Table 2.

Table 2. Current load for Extremadura as the origin/destiny in the Cofemanex

Sort of traffic	Weekly travel	Days of use	Tonnes per year
Coal traffic	**10**	**520**	**189,280**
Ammonia traffic	**3**	**156**	**75,816**
Coke traffic	**2**	**104**	**40,560**
Cereal traffic	**1**	**52**	**26,000**
Scrap metal traffic	**1**	**52**	**29,120**
TOTAL			**360,776**

Source: Coloma,JF (2015a)

The international traffic with Badajoz as the origin or the destination in 2014 consisted of 6 trains (3 going away and 3 coming back) from Merida to Lisbon. We are talking about 400 metre long trains, composed by 30 containers. In one year this means a load of 187,200 t/year of inter-modal international transport. Therefore, the sum of the load (origin/destiny and transit) which currently has the Cofemanex Corridor is 547,976 t/year.

3. Situation of freight transport in the area of influence with the commissioning of the Cofemanex

In the calculus of the CO_2 emissions, under this situation, several additional scenarios have been considered:

- We have taken into account a growth rate of rail freight movements with Extremadura as the interior origin or destination and also the increase of the transport operations due to improvements in other infrastructures (Panama Canal, Port of Sines, etc).
- We have considered a freight movement transfer rate from road freight to rail freight due to the upgrade in the analysed infrastructure.
- We can see a reduction of the emission factors in planned railway compositions in the adapted line, in respect to the compositions of the line in its current state.
- We have dismissed the impact of passengers because the Cofemanex inversion will be used mainly to adapt the current railway line as an upgraded highly-functioning corridor. Furthermore, the highly-functioning mixed train (passengers/freight) is currently being built, which will link from north to south all the main settlements of Extremadura with Madrid, therefore the circulation of passengers in the Cofemanex is expected to be symbolic.

In Table 3 we enclose the potential demand predicted for railway transport under the following premises:

- Badajoz-Puertollano railway stretch devoted to freight transport.
- The port of Sines fulfils its traffic of 1,7 millions of containers by the year 2016.
- The improvement of the Portuguese railway network in the Sines-Badajoz stretch, expected for 2019.

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Table 3 - Freight potential demand of Cofemanex. Period 2017-2021

Tonnes Transported	2017	2018	2019	2020	2021
Extremaduran origin/destination	1,163,940	1,190,711	1,220,478	1,263,195	1,326,355
Transit	1,225,588	1,253,776	1,931,745	1,999,356	2,099,324
Total	**2,389,528**	**2,444,487**	**3,152,223**	**3,262,551**	**3,425,679**

Source: Coloma,JF (2015a)

In Table 4 we enclose the modal predicted distribution.

Table 4. Modal distribution of the Prognosis of the Demand. Year 2019

	METHODS	%
Extremaduran origin/destination	Railway	32
	Road	68
Transit	Railway	10
	Road	53
	Port of Sines	37
Total	Railway	19
	Road	59
	Port of Sines	22

Source: Coloma,JF (2015a)

4. Methodology for the calculus of CO_2 emissions savings

The analysis has been focused in the emissions directly imputable from the commissioning of the Badajoz-Puertollano railway line as a highly-functioning corridor for freight transport in the area of the Autonomous Community of Extremadura.

The area of influence has already been defined, regarding the effects of the calculus of the emissions of CO_2, in the geographical zones of origin and destination to which the use of a railway line between Badajoz and Puertollano means distance savings.

The calculated distance for the calculus in rail freight are those of the railway line. In the case of road transport we have taken into account the length of the Extremaduran route of the main tracks which link the different opposites of freight attraction and creation.

The difference in the CO_2 emissions between the current situation and the future (upgraded line) will be the result of:

- The difference in values between the emission factors applicable to current rail freight and the new possible railway compositions to the adapted line.
- The difference in the emission factors in road freight and the new railway possible compositions in the adapted line, applied to the freight previously transferred from road to rail transport.

In unitary terms evident savings are produced about the CO_2 emissions (kg of CO_2 per each net tonne and kilometre). Nevertheless, globally speaking, the emissions of the line will suffer an increase due to the larger number of freight transported in the period taken into account.

4.1. Emission factors in road freight

The Catalan Office for Climate Change (OCCC, 2011) provides values to road freight emission factors that vary mainly with the typology of the vehicle, fuel and area used. In this research we have considered the use of the European

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Monitoring and Evaluation Programme (EMEP, 2013) for being a more precise method in which the emission factor depends on:

- Technologies of the vehicle. There are in circulation different technologies from EURO I to EURO V which provide very different consumption and emission factors. We take EURO V diesel technology as the main type for being the most spread in the spatial and temporal scope of the investigation.
- Medium load. According to the shown statistics in the characterisation of the current situation (without upgrading the railway line).
- Type of vehicle. The most efficient vehicle, according to the EMEP classification, is a lorry between 26 and 28 tonnes of maximum gross weight.
- Type of track and speed. It is considered, because of caution in the assessment, that the lorries carry out their entire duty on dual carriageway. In relation to speed, we consider that the speed suits the maximum admitted by the EMEP (86 km/h). The urban movements, due to their low representation in the total journey, are not taken into account.
- Topography. Being this an extensive study about comparative studies (railway / railway and road / road) we assume the approximation derived from not considering the localised effect of the gradients.

Table 5 encloses the emission factor per road freight from the equations gathered in the EMEP study.

Table 5. Emission factors of the lorry type (CO_2 g/km)

Hypothesis		Emission factor
Fuel	Diesel	612.74
Technology	EURO V	
Typology	RT >26-28t Euro-V	
Type of track	Dual Carriageway	
Medium speed	86 km/h	
Topography	Without effect in gradient	

Source: EMEP (2013)

Having justified in the second section a net average transport of 10.03 t per lorry (including empty running), the emission factor by road turns out to be 0.061 CO_2kg/t•km. Unlike what happens in rail freight, the road transport emissions don't depend in such an accented way on the type of vehicle, because the vehicles used on a large scale present the already mentioned characteristics and are not affected by the net transported load in appreciable quantities.

4.2 Emission factors of rail freight

The value of the emissions of rail freight transport depends on the following variables:

- The type of traction. We appreciate notable differences between diesel and electric traction.
- Total net transported load. It is the variable with the largest impact in the emissions in unitary terms, CO_2 g per each net tonne (t) and kilometre. The net load transported depends on the type of freight transported because this determines the railway composition.

We can differentiate four types of basic freight: cars, bulk, iron and steel and petrochemical products. Each one of this freight requires the use of a type of carriage, which presents different capacities or relationships between the transported net tonne (t) and tare (empty carriage weight). These differences are only perceptible among the designs of car transport and the rest mainly due to the volume of the cars, so we can state that if the rest of variables are preserved, the consumption between trains with carriages to transport bulk, iron and steel and petrochemical products are equivalent.

The size of the train has also a decisive effect in the reduction of the emissions in unitary terms. Being the locomotive the most heavy piece of the train, so it is convenient to lengthen the trains so the necessary energy to move the machine is diluted when the net total load is increased.

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- Measure of empty running operations. Each loaded transport operation requires a certain number of empty running operations. The emissions of the empty running operations must be charged to the net tonnes (t) of the loaded operations.
- The characteristics of the line. The lines present characteristics that directly affect the emissions of the transport operations, but also present other characteristics that repress the free election of the previous variables. The lines can be electrified or not, have a route with different gradient typologies, sidings that limit the maximum lengths of the trains and routes with different speed limits. Cofemanex presents soft gradients because its route occupies mainly the Guadiana's meadows and Serena's peneplain.

In Table 6 and Table 7 we enclose the emission factors for the different types of traction and transported load adopting a empty coefficient with a value of 0,80 for the transport of cars and 1,00 for the rest (which means that one empty carriage circulates per each loaded carriage).

Table 6. Emission factors (CO_2kg/t·km) for diesel 333 trains and soft gradient

Net Load (t)	Cars	Bulk	Iron and Steel	Petrochemicals
15	0.387	0.284	0.284	0.288
105	0.133	0.058	0.052	0.053
210	0.111	0.041	0.035	0.036
300	0.101	0.035	0.028	0.029
420	0.100	0.031	0.025	0.026
510	0.098	0.029	0.024	0.024
600	0.960	0.028	0.022	0.023
705	0.096	0.027	0.022	0.022
765	0.095	0.026	0.021	0.022

Source: González,I y García, A (2010)

Table 7. Emission factors (CO_2kg/t·km) for electric trains 250 and soft gradient

Net Load (t)	Cars	Bulk	Iron and Steel	Petrochemicals
15	0.173	0.149	0.149	0.151
105	0.054	0.028	0.026	0.026
210	0.045	0.019	0.017	0.017
300	0.043	0.016	0.013	0.014
420	0.041	0.014	0.011	0.012
510	0.040	0.013	0.011	0.011
600	0.040	0.012	0.010	0.010
705	0.040	0.012	0.010	0.010
765	0.039	0.011	0.009	0.009

Source: González,I y García, A (2010)

The values of the previous table have included the emission factors related to the necessary electric "mix" for the creation and transport of the electric power.

Coloma (2015b) incorporates in his research a calculus of emissions in the Cofemanex from the Ecological Transport Information Tool, developed by the Institut für Energie und Umweltforschung Heidelberg. This study produces slightly superior values to those of González and García (2010). Although, the "Railroad observatory" (M.Fomento, 2011), provides slightly inferior emission values for soft gradients. In this investigation we use the values of González and García (2010) because they adapt better to the local conditions of load, profile and typology of the existent load in the Cofemanex.

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4.3 Emission factor per electric power consumption in Extremadura

The emission factor per electric power depends on the mix or sources of creation used in the national system. The Extremaduran power generating facilities carry out an extremely important role in the national electric mix. Extremadura produces a total of 21,342 GWh of which 5,485 GWh come from renewable energies, needing 4,477 GWh for its internal consumption. The rest of the electric energy that is produced is taking to other Spanish regions. This means that Extremadura supplies electric energy to itself from its own renewable sources and produces 4.7 times more electric energy that it needs for its internal consumption (AEE, 2011).

The Directive (2009) for the use of energy coming from renewable sources, establishes as a general aim that in Spain renewable sources represent at least 20% of the final energy by 2020. In Extremadura this indicator since 2011 exceeds 30% so this required value is thoroughly achieved. This implies in a way, that the CO_2 emission factor for the electric power consumed in the railway line would be fewer than the one from the national electric mix, in which no renewable energy sources have a strong presence. Nevertheless, in the estimation of CO_2 emission savings we have operated with factors linked with the national electric mix considering the regulatory frame in force which defines the electric national system.

5. CO_2 emissions savings

In Table 8 we enclose the current CO_2 emissions produced in the Badajoz-Puertollano line (Cofemanex).

Table 8. Current CO_2 emissions in the Badajoz-Puertollano line

Type of freight	Net Load (t/train)	Net Load (t/year) y (%)		Length (km)	Emission Factor (CO_2 km /t·km)	Emissions (CO_2 t)
Coal Trains	364.0	189,280	34.54%	21.70	0.033	135.54
Ammonia Trains	486.0	75,816	13.84%	206.37	0.025	391.15
Coke Trains	390.0	40,560	7.40%	142.35	0.032	184.76
Cereal Trains	500.0	26,000	4.74%	112.15	0.030	87.48
Scrap Metal Trains	560.0	29,120	5.31%	142.35	0.024	99.49
Containers Trains	600.0	187,200	34.16%	62.00	0.030	348.19
	Total	547,976	100.00%		Total	1,246.61

In Table 9 we have calculated the weighted average movement of the transported freight currently by road and that will be transferred to Cofemanex once it is functioning. In this table "ADT" is the vehicles average daily traffic, the "%H" is the percentage of heavy ones and "ADTH" is the daily average intensity of heavy ones (M.Fomento, 2014). From this values "Weight 1" is obtained as the % of ADTH from each route over the total; and "Weight 2" as the % of the ADTH obtained from eliminating the routes that link areas situated outside the area of influence of the railway line. This last consideration is carried out through the coefficient "Use" in Table 9.

Table 9. Average weighted movement (km) of transported freight currently by road which would be later transfered to the Badajoz – Puertollano railway line

Route	Measuring Point	ADT	%H	ADTH	Weight 1	Use	Weight 2	Length (km)
A-5	North of Miajadas	8,967	16.52	1,481	15.90%	1,0	24,12%	169
A-5	West of Badajoz	8,332	21.76	1,813	19.46%	1,0	29,53%	75
A-66 north oriented	North of Mérida	10,443	16.00	1,671	17.93%	0,5	13,61%	195
A-66 south oriented	South of Almendralejo	14,657	19.00	2,785	29.89%	0,2	9,07%	115
N-430	Exit to Ciudad Real	1,807	48.92	884	9.49%	1,0	14,40%	144
N-432	South of La Albuera	4,389	10.37	455	4.88%	1,0	7,41%	141
N-435	South of La Albuera	2,739	8.36	229	2.46%	0,5	1,86%	114
Totals				9.318	100,00%		100,00%	
Length weighted average								111

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The weighted average distance is used in lorries and is measured inside the Extremaduran territory, travelling between Merida and the Origin/Destination main points in the area of influence of the Cofemanex. This allows us to obtain an weighted average length for heavy vehicle trips which travel on the routes which communicate Merida with the Origin/Destination main points placed inside de area of influence of the railway line.

In Table 10 we enclose the emission factors for the planned upgraded railway compositions of 750 t with the commissioning of the Cofemanex.

Table 10. Emission factor for the planned upgraded railway compositions

Emission factors (CO_2kg/t·km)			
Type of freight	**Weight**	**Diesel**	**Electric**
Coal Trains	34.54%	0.026	0.011
Ammonia Trains	13.84%	0.022	0.010
Coke Trains	7.40%	0.026	0.011
Cereal Trains	4.74%	0.026	0.011
Scrap Metal Trains	5.31%	0.021	0.010
Containers Trains	34.16%	0.026	0.011
	100.00%	0.025	0.011

We show below the emissions savings based on the emission factors and previously justified lengths. We use the following values:

– Emission factors. The emission factor in road freight is 0.061 CO_2 kg/t•km (section 4.1). The current emission factor in diesel rail freight is 0.030 CO_2 kg/t•km according to the average weighted emissions in Table 8. The emission factor in diesel railway in the upgraded line is 0.025 CO_2 kg/t•km reducing to 0.011 CO_2 kg/t•km in electric traction according to the weighted average emissions in Table 10.
– Movement lengths by lorry. We have obtained 111km of weighted average movement for lorries with an origin/destination outside Extremadura according to Table 9 and 112.15 km of weighted average movement for lorries with intraregional origin/destination. To the extraction of this data we have considered the connection between Badajoz and Don Benito, equivalent to the current intraregional freight movements by road.
– Movement lengths by railway. It shows 112.15 km of intraregional movement and 213.34 km of transit movement which is equivalent to the approximate length of Extremaduran route.

The modal distribution expected in Table 4 shows that the potential expected demand predicted for the years 2017-2021 corresponds to a 41% of the rail freight movement and a 59% of the freight gathering by road. Including everything that has been exposed we obtain the CO_2 emissions savings which are enclosed in Table 11 for diesel traction and Table 12 for electric traction

Table 11. Emission savings in Cofemanex with diesel traction

Freight transport in Rail transport	**Current**	**2017**	**2018**	**2019**	**2020**	**2021**
Intraregional origin/destination (t)	360,776	1,163,940	1,190,711	1,220,478	1,263,195	1,326,355
Extra-regional freight transit transport (t)	187,200	1,225,588	1,253,776	1,931,745	1,999,356	2,099,324
Total (t)	547,976	2,389,528	2,444,487	3,152,223	3,262,551	3,425,679

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Freight transport in Rail transport	Current	2017	2018	2019	2020	2021	
Growth of the rail freight (t) (41%)		**755,036.32**	**22,533.19**	**290,171.76**	**45,234.48**	**66,882.48**	
Intraregional origin/destination (t)		367,778.48	10,975.93	112,348.73	17,513.89	25,895.57	
Extra-regional origin/destination (t)		387,257.84	11,557.26	177,823.03	27,720.59	40,986.91	
Growth through the gathering of road freight (t) (59%)		**1,086,515.68**	**32,425.81**	**417,564.24**	**65,093.52**	**96,245.52**	
Intraregional origin/destination (t)		529,242.20	15,794.63	161,672.56	25,202.92	37,264.36	
Extra-regional origin/destination (t)		557,273.48	16,631.18	255,891.68	39,890.60	58,981.16	**Totals**
Emission savings due to upgrades (CO_2 t)		**618.43**	**18.46**	**252.32**	**39.33**	**58.16**	**986.69**
Intraregional origin/destination (CO_2 t)		205.93	6.15	62.91	9.81	14.50	299.30
Extra-regional origin/destination (CO_2 t)		412.49	12.31	189.41	29.53	43.66	687.40
Emission savings due to gathering from road freight (CO_2 t)		**4,342.50**	**129.60**	**1,667.23**	**259.90**	**384.28**	**6,783.51**
Intraregional origin/destination (CO_2 t)		2,126.03	63.45	649.46	101.24	149.70	3,089.87
Extra-regional origin/destination (CO_2 t)		2,216.47	66.15	1,017.77	158.66	234.59	3,693.64
Total emission saving (CO_2 t)		**4,960.92**	**148.05**	**1,919.55**	**299.24**	**442.44**	**7,770.20**

Table 12. Emission savings in Cofemanex with electric traction

Freight transport in Rail transport	Current	2017	2018	2019	2020	2021	
Intraregional origin/destination (t)	360,776	1,163,940	1,190,711	1,220,478	1,263,195	1,326,355	
Extra-regional freight transit transport (t)	187,200	1,225,588	1,253,776	1,931,745	1,999,356	2,099,324	
Total (t)	547,976	2,389,528	2,444,487	3,152,223	3,262,551	3,425,679	
Growth of the rail freight (t) (41%)		**755,036.32**	**22,533.19**	**290,171.76**	**45,234.48**	**66,882.48**	
Intraregional origin/destination (t)		367,778.48	10,975.93	112,348.73	17,513.89	25,895.57	
Extra-regional origin/destination (t)		387,257.84	11,557.26	177,823.03	27,720.59	40,986.91	
Growth through the gathering of road freight (t) (59%)		**1,086,515.68**	**32,425.81**	**417,564.24**	**65,093.52**	**96,245.52**	
Intraregional origin/destination (t)		529,242.20	15,794.63	161,672.56	25,202.92	37,264.36	
Extra-regional origin/destination (t)		557,273.48	16,631.18	255,891.68	39,890.60	58,981.16	**Totales**
Emission savings due to upgrades (CO_2 t)		**2,398.64**	**71.58**	**978.65**	**152.56**	**225.57**	**3,827.01**
Intraregional origin/destination (CO_2 t)		798.74	23.84	244.00	38.04	56.24	1,160.86
Extra-regional origin/destination (CO_2 t)		1,599.90	47.75	734.65	114.52	169.33	2,666.16
Emission savings due to gathering from road freight (CO_2 t)		**6,084.92**	**181.60**	**2,336.20**	**364.19**	**538.48**	**9,505.38**
Intraregional origin/destination (CO_2 t)		2,979.09	88.91	910.05	141.87	209.76	4,329.68
Extra-regional origin/destination (CO_2 t)		3,105.83	92.69	1,426.15	222.32	328.72	5,175.70
Total emission saving (CO_2 t)		**8,483.56**	**253.18**	**3,314.85**	**516.75**	**764.05**	**13,332.39**

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6. Economic estimation of the CO_2 emissions savings

The European System of Commerce Rights for Greenhouse Gases Emission (GHG) (Directive, 2003) was created to achieve the objectives of the European union regarding climate change, inside the first European Programme about Climate Change (COM, 2000). Assuming the agreement of transforming Europe in a high energetic efficient economy and lowering the carbon emissions, during the first months of 2007 the European Commission presented an integrated package of proposals about energy and climate which included concrete actions for the achievement of three ambitious objectives with the time horizon of 2020:

- Reducing the total GHG emissions by 20% in respect to the levels of 1990.
- Reach the objective of 20% of renewable energy consumption.
- Improve the energetic efficiency by 20%.

This directives were previous to the Spanish set of laws which controls the commerce set of rules of the Greenhouse gases emission's rights (Ley, 2005) and which modifies this to perfect and expand the general set of gases emission commerce laws and include aviation in it (Ley, 2010). The National Plans of Assignment of Greenhouse Gases Emission's rights stablish the distribution of the emission's rights among the industrial installations affected by previous laws.

The methodologies used for quantification and report of the emission rights are the following:

- Greenhouse Gases Protocol (GHG, 2016). International tool mostly used by governments and companies to comprehend, quantify and handle GHG emissions.
- GHG Inventory. It is based in the GHG Protocol and establishes the specifications for the quantification and the report of GHG emissions, its validation and verification (Aenor, 2012).
- Carbon footprint in organizations (Aenor, 2015).

The road and rail freight transport are out of the European Union Emissions Trading System, and there isn't a specific and suitable classification system about the measurement and control of the rights of emissions reports.

In this investigation we consider the transport as an activity inside the constructive process of an organization so we can estimate economically the savings considering the historic average contributions of emission rights. By means of the creation of a market with CO_2 emissions right we will be able to internalise in the company's accounts the environmental cost of this emissions.

The European Union emission rights are the European Union Allowance (EUA). Figure 3 illustrates the recent evolution of the emission rights. As it shows, we can state that it is a high-volatility market, which depends on numerous uncertainties such as:

- Efficiency and speed in the implementation of measures promoted by different countries to reduce the greenhouse gas emissions effect included in recent international agreements.
- Technological change in energy sources used in transport.
- Technological development in the transmitters.
- The complexity derived from a free market with emission rights and therefore subject to speculative processes, accented by the weakening of fossil fuels.

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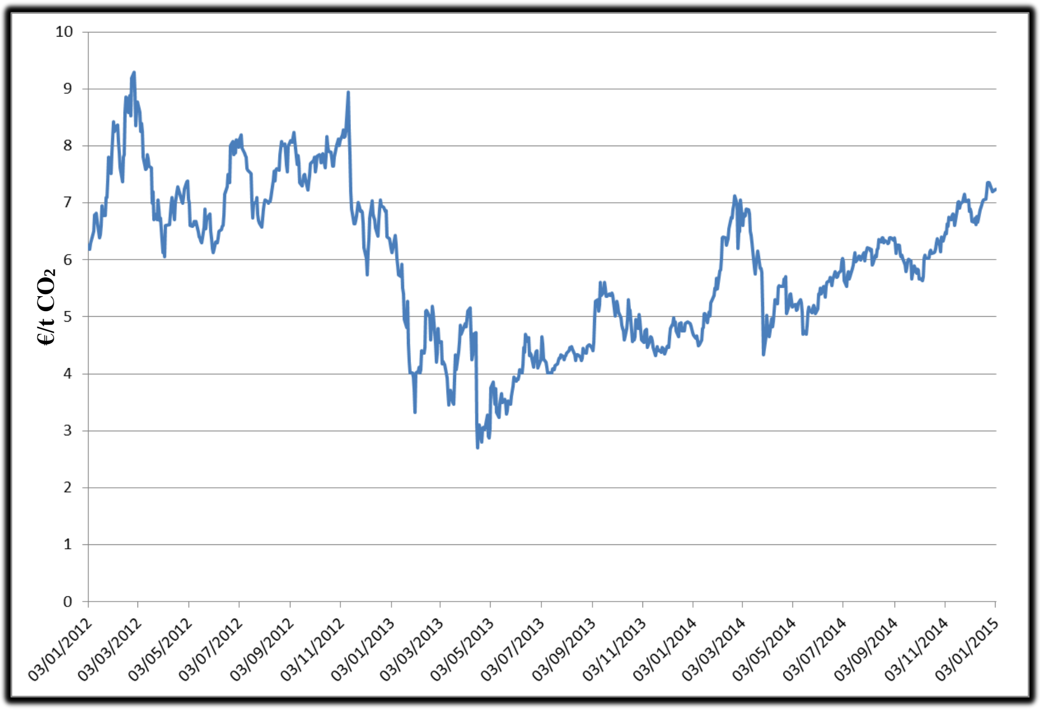

Fig. 3 Recent evolution of the emission rights price (€/CO_2t). SendeCO₂ (2015)

Due to all of this, there exists a big uncertainty about future evolution in contributions about emission rights. Synapse Energy Economics has gathered more than 75 different price scenarios. These scenarios include those realised by energy departments and environment in USA, in Massachusetts Institute of Technology and the University of Duke. On top of the base of this data gathering we have considered three possible evolutions in the CO_2 price of the emission rights, which are shown in Figure 4:

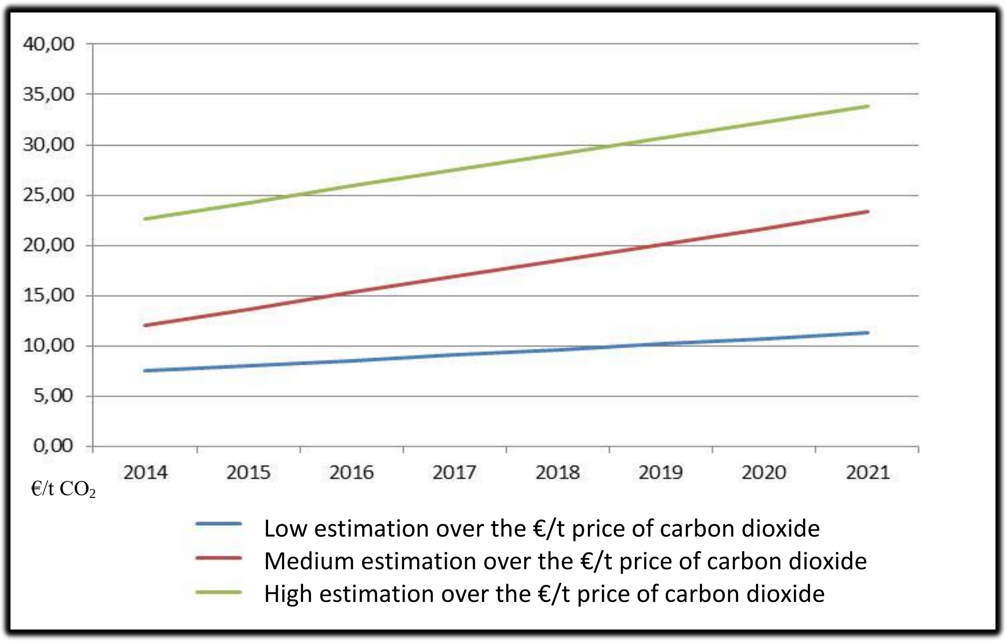

Fig. 4 Predicted evolution of emission rights (€/ CO_2 t). Synapse (2014).

In Table 13 (diesel traction) and Table 14 (electric traction) we show the final estimated savings in emission rights using the results of Tables 11 and Table 12 and the predictions of Synapse Energy Economics.

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Table 13. Evaluation of CO_2 emissions savings with diesel traction.

Emission rights predicted prices (€/CO_2t)	2017	2018	2019	2020	2021
Low Estimation	9.13	9.68	10.22	10.77	11.31
Medium Estimation	16.90	18.50	20.11	21.71	23.32
High Estimation	27.48	29.07	30.67	32.27	33.87

Valuation of the CO_2 emissions savings (€)	2017	2018	2019	2020	2021	Totals
Low Estimation	45,299.08	1,432.63	19,621.16	3,221.89	5,005.06	**74,579.81**
Medium Estimation	83,833.79	2,739.50	38,598.70	6,497.28	10,316.70	**141,985.97**
High Estimation	136,302.86	4,304.51	58,878.15	9,656.86	14,985.76	**224,128.14**

Table 14. Valuations of CO_2 emissions savings with electric traction

Emission rights predicted prices (€/CO_2t)	2017	2018	2019	2020	2021
Low Estimation	9.13	9.68	10.22	10.77	11.31
Medium Estimation	16.90	18.50	20.11	21.71	23.32
High Estimation	27.48	29.07	30.67	32.27	33.87

Valuation of the CO_2 emissions savings (€)	2017	2018	2019	2020	2021	Totals
Low Estimation	77,464.91	2,449.91	33,883.63	5,563.85	8,643.19	**128,005.49**
Medium Estimation	143,362.23	4,684.76	66,655.80	11,220.11	17,815.82	**243,738.73**
High Estimation	233,088.38	7,361.05	101,676.22	16,676.36	25,878.79	**384,680.80**

7. Conclusions

Human activity since the industrial revolution through the use of fossil fuels is changing the natural composition of the atmosphere increasing the so called Greenhouse Gases (GHG). Extremadura's government decided to react actively towards the predicted climatic variations, and for that the "Strategy for Climatic Change for Extremadura" (J.Extremadura, 2009) was approved, which marked the strategies to follow regarding the mitigation and adaptation to climate change. Among the strategies some concrete measures are included like developing annual inventories of GHG emissions and contributing to the development and demonstration of innovative approaches, technologies methods and instruments.

With this objective in mind, we develop this investigation where data and conclusions dealing with the savings of CO_2 emissions are given through a comparison of the actual freight transport in the area of influence of the line Badajoz-Puertollano with various scenarios of exploitation for the new planned infrastructures. The savings of the emissions will be caused by:

- The lowering of the emission factors (kg CO_2/t·km) in the upgraded railway line in respect to the actual one.
- The commissioning of the upgraded line will reduce the number of lorries circulating on roads, whose emission factors in unitary terms are far more superior to those ones which will be produced by the use of the new railways.

By the period 2017 to 2021 the corridor would have extracted from roads 863,204 transport operations by lorry. For the data obtaining, we take as a starting point the potential demand described in section 3 and the percentage of rail/road estimated bypass in 2019, which is the 59%. It is necessary to have in mind that per each net tonne transported in the corridor a 59% less of CO_2 would be emitted than if it were transported by road with diesel rail traction, and an 82% less if the rail traction would be electric.

As a reference point, we can state that CO_2 emissions of industrial processes in the region, were 441,900 t in the year 2011. This means a total savings accumulated in the period from 2017 to 2021 in the CO_2 emissions around 1.76% and

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3.02% for railway compositions with diesel traction and electric respectively, about the emissions of the current industrial processes in the region.

Operating under the hypothesis of being able to apply the predicted evolution of the CO_2 emission rights price in the world market to the transport sector (a sector which is currently out of the European Union Emissions Trading System) we would obtain all the savings gathered by the period 2017 to 2021 which vary between 74,580 € and 224,128 € for railway compositions with diesel traction and between 128,005 € and 384,681 € for electric traction.

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