BRAINTRAINS

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BELGIAN RESEARCH ACTION THROUGH INTERDISCIPLINARY NETWORKS

Deliverable D 4.2

Scenario 1: Best-case

15/02/2017

BRAIN-TRAINS

Transversal assessment of new intermodal strategies

WP 4: Sustainability impact

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CONTENTS

1. INTRODUCTION

Within the framework of the BRAIN-TRAINS project, a SWOT analysis was performed to identify the current state of the intermodal rail freight transport in Belgium. A final selection of 17 SWOT elements according to the impact and likelihood of happening in the future has been achieved (Vanelslander et al., 2015). Furthermore, three divergent Belgian scenarios with a time frame set in the year 2030 have been built for further analysis. These scenarios are directly linked to the third strategic goal of the European Commission's White Paper on transport (2011), which aims to shift the 30% of road freight over 300 km to other modes such as rail transport by 2030. As a result, a best, worst and medium case scenarios have been developed, depending on whether the 30% shift will have been successfully accomplished, the status quo will have been maintained or the goal will not have been completely reached by 2030, respectively (Troch et al., 2015).

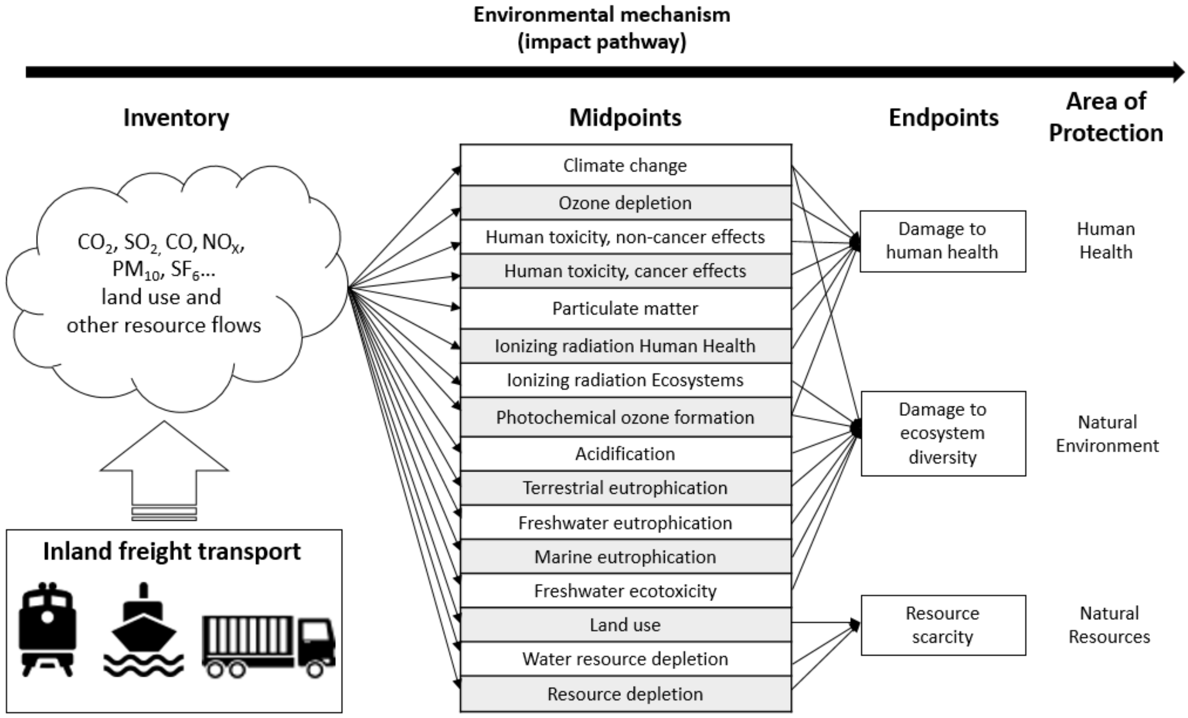
The 17 SWOT elements have been translated into clear and measurable parameters for the scenario development, defining for every parameter an input value to quantify the scenarios. Moreover, all processes are analysed in the same unit of measurement, chosen as "tonne-kilometre (tkm)", which represents the transport of one tonne of goods over a distance of one kilometre. One of the selected elements from the SWOT analysis is the "strength of rail transport to reduce costs and externalities". This element contains five measurable parameters, four being related to the environmental aspect of the rail freight transport: transport emissions (CO_2 emissions and other emissions), energy consumption and noise exposure (Vanelslander et al., 2015).

The Life Cycle Assessment (LCA) methodology has been chosen to analyse the environmental impact of rail freight transport. Moreover, a comparison between the environmental impacts related to rail freight transport, inland waterways transport and road transport has been performed.

The LCA methodology allows studying complex systems like intermodal transport, providing a system perspective analysis that allows assessing environmental impacts through all the stages of the intermodal freight transport system (transport operation, vehicle and infrastructure), from raw material extraction, through materials use, and finally disposal.

Furthermore, the LCA methodology allows modelling in a quantitative and multi-criteria way the environmental impacts of all relevant pollutant emissions and energy and material consumptions in numerous midpoint environmental impact categories, such as climate change, resource depletion, acidification, human toxicity or ecotoxicity for example. Then, as can be seen in figure 1, the influence of these midpoint categories to endpoint categories such as damage to human health, damage to ecosystem diversity and resource scarcity can be evaluated. These endpoint categories are related to the areas of protection of human health, natural environment and natural resources, respectively (European Commission, 2010).

FIGURE 1. DIAGRAM OF THE LIFE CYCLE IMPACT ASSESSMENT METHODOLOGY APPLIED ON RAIL TRANSPORT

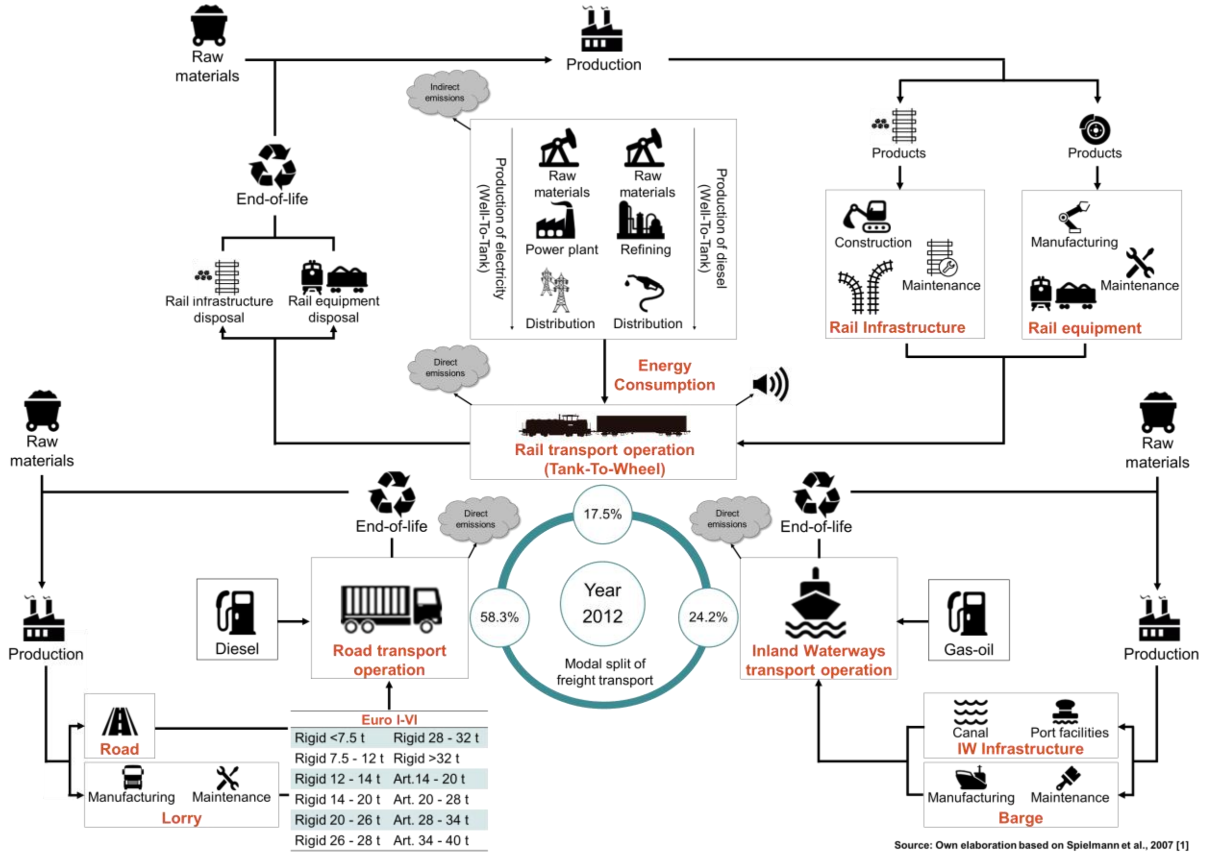


SOURCES: EUROPEAN COMMISSION, 2010 AND SALA ET AL., 2012

Figure 2 presents the stages considered in our study for the rail freight transport, inland waterways transport and road freight transport. In Belgium, road transport was responsible for 58.3% of the total inland freight expressed in tonne-kilometres in 2012, representing the dominant mode of the three major inland transport modes. Inland waterways accounts for 24.3% and rail transport for 17.5% (Eurostat, 2015).

A detailed study of the rail freight transport has been conducted, collecting data directly from Infrabel (the Belgian railway infrastructure manager) and B-Logistics, which is the main rail freight operator in Belgium. The rail freight system is divided in three sub-systems: rail transport operation, rail infrastructure and rail equipment (locomotives and wagons). The specific energy consumption of electric and diesel trains has been determined separately. Upstream emissions related to the production and distribution of the energy to the traction unit and the direct emissions during the rail transport activity (exhaust emissions to air related to the diesel combustion in locomotives, emissions to soil from abrasion of brake linings, wheels, rails and overhead contact lines and the sulphur hexafluoride (SF_6) emitted during conversion at traction substations related to electricity consumption) have been determined. In order to adjust as closely as possible the environmental impact related to the yearly electricity consumption, and since the electricity supply mix varies widely over the years, our LCA study uses the electricity supply mix in Belgium corresponding to the appropriate year. The life cycle phases of construction, maintenance and disposal of rail infrastructure and manufacturing, maintenance and disposal of rail equipment are analysed.

FIGURE 2. INLAND FREIGHT TRANSPORT SYSTEM BOUNDARIES



SOURCE: OWN ELABORATION BASED ON SPIELMANN ET AL., 2007

In the case of both inland waterways transport and road transport in Belgium, the Ecoinvent v3 database has been used as a model (Weidema et al., 2013). Information relative to the total annual freight moved by inland waterways transport in Belgium by barge type, fuel consumption in the vessel transport operation and waterways infrastructure characteristics for several years have been collected. Similarly, information relative to the total annual freight moved by road transport in Belgium by weight classification and heavy duty vehicle technology type, fuel consumption in the road transport operation and road infrastructure characteristics for several years have been collected.

The purpose of this deliverable is to discuss the first results obtained from the study of the environmental impacts of inland freight transport using the LCA methodology.

2. ENERGY CONSUMPTION

This section deals with the final energy consumption during the transport operation for rail freight transport, inland waterways transport and road freight transport. In the deliverable D.1.3 of the BRAIN-TRAINS project (Troch et al., 2015) the values extracted from EcoTransIT (2008) had been fixed as reference values for the energy consumption parameter, which represents the European average energy consumptions for cargo transport within Europe.

Moreover, the values of energy consumption from EcoTransIT comprise both the final energy consumption during transport operation and the energy consumption of the generation of fuels and electricity (EcoTransIT, 2008).

As shown in table 1, the values from EcoTransIT (2008) are 456 kJ/tkm for rail traffic performed by electric traction, 530 kJ/tkm for rail traffic performed by diesel locomotives, and 1082 kJ for lorry transport performed by an articulated lorry of 34-40 t with a Euro 3 engine technology. Subsequently, it has been considered interesting to include in the project the study of inland waterways transport as well. In order to be coherent with the rest of reference values, the European averages of EcoTransIT (2008) have been used. Thus, an energy consumption of 438 kJ/tkm for inland waterways transport downstream and 727 kJ/tkm for inland waterways transport upstream have been chosen.

Besides the values extracted from EcoTransIT, the Ecoinvent v3 database has been used as source of reference values as well. The model used in our study is mainly based on the methodology used in the Ecoinvent v3 database, thus in order to compare our results, the choice of the Ecoinvent v3 database seems to be coherent. Moreover, the values of energy consumption extracted from the Ecoinvent v3 database represent the final energy consumption during transport operation, which is consistent with the values of energy consumption obtained in the BRAIN-TRAINS project.

Thereby, from Ecoinvent v3 database has been extracted as reference value an energy consumption of 417 kJ/tkm for rail freight transport using the Belgian traction mix (unspecified in the database). It comprises 260 kJ/tkm of electricity consumption and 157 kJ/tkm of diesel consumption for the year 2014. The energy consumption for inland waterways transport is 402 kJ/tkm, representing a European average. For road transport has been chosen the energy consumption of 739 kJ/tkm, which represents a European average of freight transport in a lorry of the size class >32 t gross vehicle weight and Euro 3 emissions technology.

TABLE 1. REFERENCE VALUES USED TO COMPARE THE RESULTS ON ENERGY CONSUMPTION OF OUR STUDY

	EcoTransIT (2008)	Ecoinvent v3
Year represented	2005	2014
Electricity consumption (Belgian traction mix)[1]	-	260 kJ/tkm
Diesel consumption (Belgian traction mix)[1]	-	157 kJ/tkm
Rail transport (Belgian traction mix)[1]	-	417 kJ/tkm
Electric trains	456 kJ/tkm	-
Diesel trains	530 kJ/tkm	-
Inland waterways transport[2]	-	402 kJ/tkm
Inland waterways transport downstream	438 kJ/tkm	-
Inland waterways transport upstream	727 kJ/tkm	-
Road transport lorry >32t[3]	-	739 kJ/tkm
Road transport 34 - 40 t	1082 kJ/tkm	-

SOURCES: ECOTRANSIT (2008) AND ECOINVENT V3 DATABASE (WEIDEMA ET AL., 2013). THE VALUES FROM ECOINVENT V3 HAVE BEEN TAKEN FROM THE PROCESSES: [1]"TRANSPORT, FREIGHT TRAIN {BE}| PROCESSING | ALLOC REC, U"; [2]"TRANSPORT, FREIGHT, INLAND WATERWAYS, BARGE {RER}| PROCESSING | ALLOC REC, U"; [3]"TRANSPORT, FREIGHT, LORRY >32 METRIC TON, EURO3 {RER}| ALLOC REC, U".

2.1. Rail freight transport

The specific energy consumption during the rail transport activity of electric and diesel trains has been determined separately on the basis of the total annual energy consumption of electricity and diesel and the total annual rail freight moved by each energy traction from the period 2006 to 2012, using the data in table 2. The data from SNCB include the energy consumed by trains, such as the empty returns, shunting activity, maintenance of trains, as well as electrical losses in catenary (SNCB, 2009; SNCB, 2013 and SNCB, 2015). The Belgian high voltage network has distribution losses of 5% and the railway network has transmission losses of 7% (Infrabel, 2014). Spielmann et al. (2007) estimate a diesel consumption of the shunting activity of 0.68 g/tkm. As the diesel net calories are 42.8 MJ/kg, the shunting activity results in 29.104 kJ/tkm.

TABLE 2. RAIL FREIGHT TRANSPORT PERFORMANCE AND ENERGY CONSUMPTION IN BELGIUM

Year	2006	2007	2008	2009	2010	2011	2012
Rail freight (millions tkm)	8442	8148	7882	5439	5729	5913	5220
Electric traction consumption (TJ)	3489	3261	3382	2472	2092	2248	1922
Diesel traction consumption (TJ)	1449	1339	1282	739	721	582	465
Total consumption (TJ)	4939	4600	4664	3211	2813	2830	2387
Energy consumption (kJ/tkm)	585	565	592	590	491	479	457

SOURCES: SNCB, 2009; SNCB, 2013 and SNCB, 2015

The energy consumption for the Belgian rail freight transport has been calculated as 457 kJ/tkm in 2012. However, no differentiation can be made between electric and diesel traction. The rail freight traction share in table 3 has been used to calculate the rail freight moved by electric and diesel traction, enabling to determine the specific energy consumption of electric and diesel trains separately. It should be noted that the use of diesel traction is decreasing in Belgium, which means that only a small part of the rail freight produces exhaust emissions.

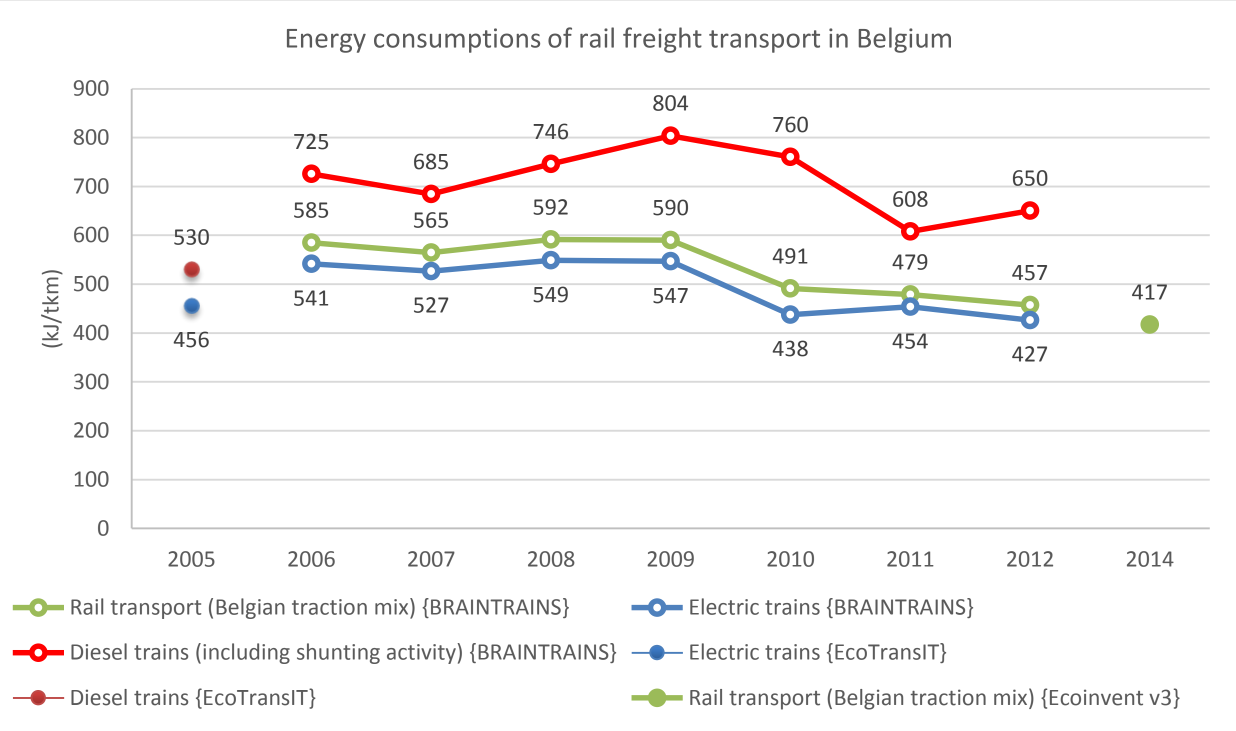
TABLE 3. ELECTRIC AND DIESEL RAIL FREIGHT TRACTION SHARE IN FLANDERS

Year	1990	2000	2004	2007	2008	2009	2011	2012	2013
Electric traction	61%	61.2%	77%	76%	78.2%	83.1%	83.8%	86.3%	85.2%
Diesel traction	39%	28.8%	23%	24%	21.8%	16.9%	16.2%	13.7%	14.8%

SOURCES: FLEMISH ENVIRONMENT AGENCY (VMM, 2005, 2006, 2007, 2008, 2009, 2010, 2012, 2013 AND 2014)

Figure 3 shows the values of energy consumption of electric and diesel trains calculated in our study from the period 2006 to 2012. If we take year 2012 as an example, 86.3% of the 5,220 million tkm of rail freight in Belgium were moved with electric traction, resulting in 4,505 million tkm. The total electricity consumed in 2012 was 1922 TJ, therefore the specific energy consumption of electric trains was 427 kJ/tkm. Similarly, 13.7% of the 5,220 million tkm of rail freight in Belgium were moved with diesel traction, resulting in 715 million tkm. The total diesel consumed in 2012 was 465 TJ, including the diesel consumption of the shunting activity, therefore the specific energy consumption of electric trains was 650 kJ/tkm.

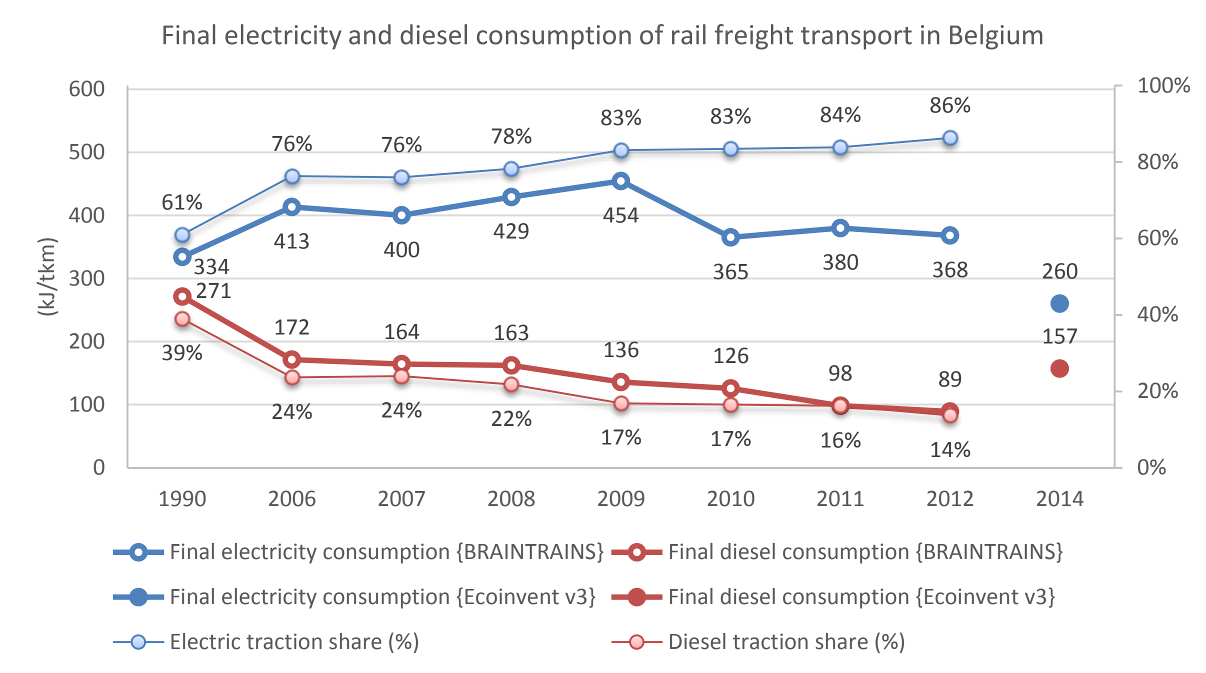
FIGURE 3. ENERGY CONSUMPTIONS OF RAIL FREIGHT TRANSPORT IN BELGIUM OBTAINED IN OUR STUDY AND THE VALUES OF ECOTRANSIT (2008) AND ECOINVENT V3



By comparing the reference values used in EcoTransIT (2008) of 456 kJ/tkm for electric traction and 530 kJ/tkm for diesel traction with the energy consumptions obtained in our study, for the year 2006 (which is the year with available data closest to EcoTransIT study) our results for Belgium show higher energy consumptions with 541 kJ/tkm and 725 kJ/tkm of electricity and diesel (including shunting activity) consumed, respectively.

The final electricity and diesel consumed for goods transport in figure 4 is calculated using the specific energy consumption of electric and diesel trains (see figure 3) and the electric and diesel traction share (see table 3). The results of our study show that, in 2012, 368 kJ of electricity and 89 kJ of diesel (included 29 kJ of shunting activity) were needed to move 1 tkm in Belgium. According to Ecoinvent v3 data in 2014, a consumption of 260 kJ of electricity and 157 kJ of diesel were required to move 1 tkm of rail freight in Belgium. The results of final electricity consumption from our study are always higher than the value used by Ecoinvent v3. However, since the year 2009, the final diesel consumption from our study shows values lower than the value from Ecoinvent v3. The discrepancies between the values of our study and those of Ecoinvent v3 should be highlighted, since they point out a need for updating the Ecoinvent v3 database.

FIGURE 4. FINAL ELECTRICITY AND DIESEL CONSUMPTION OF RAIL FREIGHT TRANSPORT IN BELGIUM



2.2. Inland waterways transport

The average energy consumption during the inland waterways transport activity by barge has been determined using the class specific fuel consumption of barges in Wallonia (Service Public Wallonie, 2014). It has been aggregated using the total carrying capacity of each vessel class by year (ITB - *Instituut voor het Transport langs de Binnenwateren / Institut pour le Transport par Batellerie*) from the period 2006 to 2012 (showed in table 4) as allocation factor.

TABLE 4. TONNAGE (TONNE/YEAR) OF DRY BULK BARGES IN BELGIUM BY VESSEL CLASS

Vessel class	2006	2007	2008	2009	2010	2011	2012
< 250 t	2 448	3 947	4 176	3 323	2 871	3 446	3 595
251 t – 450 t	115 068	103 812	96 513	91 662	87 596	78 726	72 071
451 t – 650 t	85 909	80 693	72 066	72 836	68 222	63 551	63 193
651 t – 850 t	77 600	71 358	64 625	61 135	58 988	54 852	50 646
851 t – 1000 t	72 450	65 900	65 486	58 151	55 850	48 416	41 895
1001 t – 1500 t	320 440	325 035	317 936	296 911	280 938	268 805	263 778
1501 t- 2000 t	132 898	138 658	131 161	129 578	134 418	118 650	110 414
2001 t – 2500 t	160 131	144527	141 009	138 400	136 363	128 367	137 369
2501 t – 3000 t	278 908	260 489	224 229	227 298	229 233	228 739	222 872
> 3000 t	265 451	321 592	393 622	445 115	498 284	510 206	511 032
TOTAL	1 511 303	1 516 011	1 510 823	1 524 409	1 552 763	1 503 758	1 476 865

SOURCES: ITB, NEWSLETTERS

Table 5 shows the methodology used to calculate the average fuel consumption of inland waterways transport by weighted arithmetic mean each year taking as an example the year 2012. The average fuel consumption of 2012 for dry bulk cargo was 6.73 g/tkm.

TABLE 5. AVERAGE FUEL CONSUMPTION OF DRY BULK BARGES IN BELGIUM IN 2012

Vessel class	Tonnage (t)[1]	Share	Class specific fuel consumption(g/tkm)[2]	Contribution to average fuel consumption (g/tkm)
< 250 t	3 595	0.24%	10.248	0.02
251 t – 450 t	72 071	5%	10.248	0.50
451 t – 650 t	63 193	4%	9.492	0.41
651 t – 850 t	50 646	3%	8.736	0.30
851 t – 1000 t	41 895	3%	8.736	0.25
1001 t – 1500 t	263 778	18%	8.064	1.44
1501 t- 2000 t	110 414	7%	7.392	0.55
2001 t – 2500 t	137 369	9%	7.392	0.69
2501t – 3000 t	222 872	15%	7.392	1.12
> 3000 t	511 032	35%	4.200	1.45
TOTAL	1 476 865	100%	-	**6.73**

SOURCES: [1]ITB, NEWSLETTERS AND [2]SERVICE PUBLIQUE WALLONIE, 2014

Table 6 shows the average fuel consumption of inland waterways transport calculated from the period 2006 to 2012. If we compare the energy consumptions for inland waterways transport obtained in our study with the reference values extracted from EcoTransIT (2008) and Ecoinvent v3 database, our results show lower energy consumptions. Thereby, the values used in EcoTransIT (2008) for the year 2005 are 438 kJ/tkm and 727 kJ/tkm for inland waterways transport downstream and upstream, respectively. In the case of Ecoinvent v3 database, the energy consumption for inland waterways transport for the year 2014 is 402 kJ/tkm. It should be noted that the reference values represent European averages, whereas our results represent a Belgian average.

TABLE 6. AVERAGE FUEL CONSUMPTION OF INLAND WATERWAYS TRANSPORT OF DRY BULK IN BELGIUM

Year	2006	2007	2008	2009	2010	2011	2012
Average fuel consumption (g/tkm)	7.45	7.30	7.11	6.97	6.85	6.77	6.73
Average energy consumption (kJ/tkm)[1]	319	312	304	299	293	290	288

[1]CONSIDERING THAT DIESEL NET CALORIES ARE 42.8 MJ/KG

2.3. Road transport

The average fuel consumption during the road freight transport activity has been determined using the average diesel consumption in Belgium from the TRACCS database (Papadimitriou et al., 2013) showed in table 7 and the actual payload of each lorry class calculated from the period 2005 to 2010 (see table 8). The data from the TRACCS project have been converted from g/km to g/tkm dividing by the actual payload of each lorry gross vehicle weight (GVW) class.

TABLE 7. FUEL CONSUMPTION (G/KM) OF ROAD FREIGHT TRANSPORT IN BELGIUM

Heavy Duty Lorry	Fuel Consumption[1] (g/km)						Fuel Consumption (g/tkm)					
	2005	2006	2007	2008	2009	2010	2005	2006	2007	2008	2009	2010
Rigid <7.5 t	109	109	109	109	109	109	231	241	252	288	293	312
Rigid 7.5 - 12 t	146	146	145	146	146	146	124	129	135	155	157	167
Rigid 12 - 14 t	153	154	154	154	154	154	94	98	102	117	118	126
Rigid 14 - 20 t	179	179	178	178	178	178	79	82	86	98	99	106
Rigid 20 - 26 t	215	214	213	213	213	213	67	70	73	83	84	89
Rigid 26 - 28 t	226	226	226	225	225	225	59	62	65	73	74	79
Rigid 28 - 32 t	260	260	260	260	260	260	61	63	66	75	77	81
Rigid >32 t	255	254	253	253	253	253	55	58	60	69	69	74
Art. 14 - 20 t	172	171	170	170	170	170	58	60	63	72	73	77
Art. 20 - 28 t	215	213	212	212	212	212	54	56	58	66	67	72
Art. 28 - 34 t	225	223	222	222	222	222	45	46	48	55	56	59
Art. 34 - 40 t	254	253	252	252	252	251	43	45	47	53	54	57

SOURCE: [1]TRACCS PROJECT (PAPADIMITRIOU ET AL., 2013)

Table 8 presents the methodology used to calculate the actual payload of each lorry GVW class using the maximum payload and the load factor for each year. It should be noted that in the same year, on the one hand, the fuel consumption in g/km increases with the size of the lorry (from 109 g/km to 254 g/km in 2005), but on the other hand, the fuel consumption in g/tkm decreases with the size of the lorry (from 231 g/tkm to 43 g/tkm in 2005). This is due to increased payload (see table 8) with the GVW category. Furthermore, in the same GVW category, the fuel consumption (in g/tkm) increases over the years as a result of a decrease in the load factor (from 23.3% in 2005 to 17.4% in 2010), which entails a decrease in the actual payload.

TABLE 8. ACTUAL PAYLOAD CALCULATED AFTER MAXIMUM PAYLOAD AND LOAD FACTOR

Heavy Duty Lorry	Maximum Payload (t/vehicle) [1]	Load Factor (%) [1]						Actual Payload (t/vehicle)					
		2005	2006	2007	2008	2009	2010	2005	2006	2007	2008	2009	2010
Rigid <7.5 t	2	23.3%	22.4%	21.4%	18.7%	18.5%	17.4%	0.47	0.45	0.43	0.38	0.37	0.35
Rigid 7.5 - 12 t	5							1.17	1.12	1.07	0.94	0.93	0.87
Rigid 12 - 14 t	7							1.64	1.57	1.50	1.32	1.30	1.22
Rigid 14 - 20 t	9.7							2.26	2.17	2.07	1.82	1.79	1.68
Rigid 20 - 26 t	13.7							3.20	3.07	2.93	2.57	2.53	2.38
Rigid 26 - 28 t	16.4							3.82	3.67	3.50	3.07	3.03	2.84
Rigid 28 - 32 t	18.4							4.29	4.11	3.93	3.44	3.40	3.19
Rigid >32 t	19.7							4.60	4.41	4.21	3.69	3.64	3.42
Art. 14 - 20 t	12.6							2.95	2.83	2.70	2.37	2.34	2.19
Art. 20 - 28 t	17.1							3.99	3.82	3.65	3.20	3.16	2.96
Art. 28 - 34 t	21.5							5.02	4.82	4.60	4.03	3.98	3.74
Art. 34 - 40 t	25.3							5.91	5.67	5.41	4.75	4.68	4.40

SOURCE: [1]TRACCS PROJECT (PAPADIMITRIOU ET AL., 2013)

In order to do an average energy consumption for every year, the tonne-kilometers moved by each lorry GVW category have been used to calculate a weighted arithmetic mean. Table 9 shows the methodology used to calculate the average fuel consumption of road freight transport each year taking as an example the year 2010. The average fuel consumption of 2010 for road freight transport in Belgium was 66.47 g/tkm.

TABLE 9. AVERAGE FUEL CONSUMPTION OF ROAD FREIGHT TRANSPORT IN BELGIUM IN 2010

Heavy Duty Lorry	Freight transport performance (million tkm)						Share of tkm	Contribution to average fuel consumption (g/tkm)
	2005	2006	2007	2008	2009	2010	2010	2010
Rigid <7.5 t	259	240	224	240	229	212	0.65%	2.01
Rigid 7.5 - 12 t	774	736	702	654	639	599	1.83%	3.05
Rigid 12 - 14 t	142	125	110	97	87	77	0.23%	0.30
Rigid 14 - 20 t	1435	1347	1268	1172	1129	1048	3.20%	3.38
Rigid 20 - 26 t	1963	1888	1820	1727	1716	1628	4.97%	4.44
Rigid 26 - 28 t	15	47	75	9	7	8	0.03%	0.02
Rigid 28 - 32 t	460	458	456	423	434	421	1.28%	1.05
Rigid >32 t	4796	4484	4204	4256	4042	3762	11.48%	8.49
Art. 14 - 20 t	128	111	96	97	90	82	0.25%	0.19
Art. 20 - 28 t	98	83	69	76	68	61	0.19%	0.13
Art. 28 - 34 t	117	98	81	92	82	148	0.45%	0.27
Art. 34 - 40 t	30511	29042	27769	28056	26455	24737	75.45%	43.13
TOTAL	40700	38660	36873	36898	34979	32784	100%	66.47

Table 10 shows the average fuel consumption of road freight transport calculated from the period 2005 to 2010 in Belgium. It should be noted that the lorry GVW category “articulated 34-40 t” represents approximately 75% of the road freight transport performance every year in Belgium. Therefore, this lorry GVW category will be used to compare the different inland freight transport modes because it is representative.

TABLE 10. AVERAGE FUEL CONSUMPTION OF ROAD FREIGHT TRANSPORT OF DRY BULK IN BELGIUM

	2005	2006	2007	2008	2009	2010
Average fuel consumption (g/tkm)	50.05	52.00	54.27	61.54	62.50	66.47
Average energy consumption (kJ/tkm)[1]	2142	2225	2323	2634	2675	2845
Road transport Art. 34 - 40 t (kJ/tkm)	1837	1910	1996	2273	2301	2447

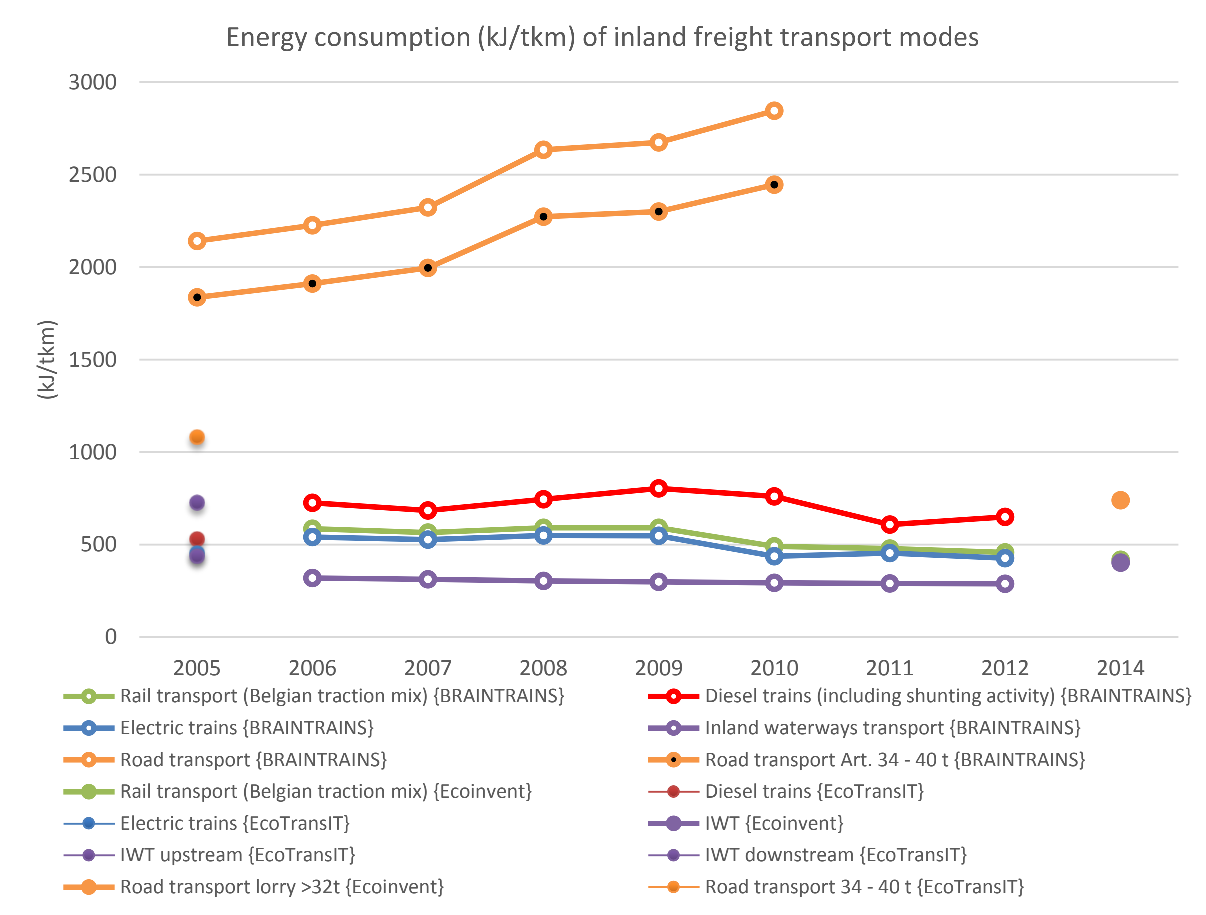
[1]CONSIDERING THAT DIESEL NET CALORIES ARE 42.8 MJ/KG

The values of energy consumption in road transport of our study are much higher than the values of EcoTransIT (2008) and Ecoinvent v3 database. This is the result of the lowest load factor considered in our study. Thereby, the value used in EcoTransIT (2008) for an articulated lorry of 34–40 t for the year 2005 is 1082 kJ/tkm. In the case of Ecoinvent v3 database the energy consumption for a lorry of >32t for the year 2014 is 739 kJ/tkm. It should be noted that the reference values represent European averages, whereas our results represent a Belgian average.

2.4. Comparison of energy consumption of inland freight transport modes in Belgium

Figure 5 shows a comparison of the energy consumptions obtained in the BRAIN-TRAINS project and the reference values from EcoTransIT (2008) and Ecoinvent v3 (years 2005 and 2014 respectively).

FIGURE 5. ENERGY CONSUMPTIONS (KJ/TKM) OF INLAND FREIGHT TRANSPORT MODES IN BELGIUM



In view of figure 5, we can make the following observations:

- Inland waterways transport is the most energy-efficient mode of inland freight transport. It represents the least energy consuming mode of transport in our study, but also in both the EcoTransIT (2008) and Ecoinvent databases.
- Within rail freight transport, electric traction has the lowest energy consumption, while diesel traction has the highest. The Belgian traction mix, which includes a combination of electric and diesel traction, achieves an intermediate consumption, but closer at the energy consumption of the electric traction due to its highest share of the Belgian traction mix.
- As mentioned above, the values of energy consumption in road transport of our study are much higher than the reference values, because the load factors considered in our study are lower. In order to improve the results of our study, we will proceed to collect data from road freight operators involved in intermodal transport and use sensitivity analysis.

3. TRANSPORT EMISSIONS

A division of the transport emissions produced during the processes related to the energy consumption has been made:

- Well-To-Tank (WTT) emissions are the indirect emissions produced at the upstream energy processes, which start with the raw materials extraction, continue with the diesel refining or electricity production and end with the energy distribution to the vehicle, such as locomotive, barge or lorry for example.
- Tank-to-Wheel (TTW) emissions are the exhaust emissions produced during the diesel combustion in the vehicle during the transport activity.
- Well-To-Wheel (WTW) emissions are the sum of the indirect emissions related to the production and distribution of the energy to the vehicle and the exhaust emissions during the transport activity.

Emissions from transport are produced at different stages depending on the type of energy used. For rail transport with diesel traction, inland waterways transport and road transport, main emissions are produced as exhaust emissions during the vehicle operation activity in the TTW stage, when the combustion of the fuel in the engine is produced. It should be noted that during oil extraction and refining, emissions are also produced. For rail transport with electric traction, main emissions are produced during the electricity production at power plan in the WTT stage.

In our study, the LCA approach has been used, taking into consideration the overall life cycle of the energy carrier which means that, in addition to the emissions of the combustion (TTW stage for fuel and WTT stage for electricity), the emissions of the supply chain are added. They include emissions from extraction of raw materials, refining and distribution of fuel and production and distribution of electricity. Furthermore, the application of LCA methodology on transport allows analysing not only the transport emissions related to the energy consumption during the transport operation, but also the emissions related to the construction of rail infrastructure, inland waterways infrastructure and road infrastructure and the manufacturing of vehicles, such as locomotives, wagons, barges or lorries for example. Moreover, the maintenance and disposal of both infrastructure and vehicles is also considered (Spielmann et al., 2007).

3.1. Direct emissions (Tank-to-Wheel emissions)

This section deals with the direct emissions or TTW emissions during the transport operation for rail freight transport, inland waterways transport and road freight transport.

3.1.1. Rail freight transport

Three types of direct emissions produced during the TTW stage of rail freight transport can be distinguished: the exhaust emissions to air related to the diesel combustion in locomotives, the direct emissions to soil from abrasion of brake linings, wheels and rails and the sulphur hexafluoride (SF_6) emissions to air during conversion of electricity at traction substations. The exhaust emissions are calculated using the emission factors of Spielmann et al. (2007) and the previously calculated diesel consumption. To determine particle emissions, it is necessary to add the particles produced by the abrasion of wheels and rails to those produced by the combustion of diesel.

Since the emission factors of Spielmann et al. (2007) are used by the Ecoinvent v3 database as well, we have used the direct emissions of the process from Ecoinvent v3 “Transport, freight train {BE}| processing | Alloc Rec, U” as reference values. Table 11 presents the direct emissions of rail freight transport in Belgium using the Belgian traction mix of diesel and electric traction in table 3 and in figure 4. Moreover, the reference process of Ecoinvent v3 database is used to compare the direct emissions.

TABLE 11. DIRECT EMISSIONS (G/TKM) OF RAIL FREIGHT TRANSPORT (BELGIAN TRACTION MIX OF DIESEL AND ELECTRIC TRACTION) IN BELIGIUM

Rail transport (Belgian traction mix) (g/tkm)	2006	2007	2008	2009	2010	2011	2012	Ecoinvent v3 2014
CO_2	12.62	12.08	11.95	9.99	9.25	7.23	6.55	11.55
SO_2	1.93E-04	6.91E-05	6.08E-05	5.08E-05	4.70E-05	3.68E-05	3.33E-05	2.20E-03
Cd	4.01E-08	3.84E-08	3.80E-08	3.17E-08	2.94E-08	2.30E-08	2.08E-08	3.67E-08
Cu	6.82E-06	6.53E-06	6.46E-06	5.40E-06	5.00E-06	3.91E-06	3.54E-06	6.24E-06
Cr	2.01E-07	1.92E-07	1.90E-07	1.59E-07	1.47E-07	1.15E-07	1.04E-07	1.84E-07
Ni	2.81E-07	2.69E-07	2.66E-07	2.22E-07	2.06E-07	1.61E-07	1.46E-07	2.57E-07
Se	4.01E-08	3.84E-08	3.80E-08	3.17E-08	2.94E-08	2.30E-08	2.08E-08	3.67E-08
Zn	4.01E-06	3.84E-06	3.80E-06	3.17E-06	2.94E-06	2.30E-06	2.08E-06	3.67E-06
Pb	4.41E-10	4.22E-10	4.18E-10	3.49E-10	3.23E-10	2.53E-10	2.29E-10	4.04E-10
Hg	8.02E-11	7.68E-11	7.60E-11	6.35E-11	5.88E-11	4.60E-11	4.16E-11	7.32E-11
CO	6.34E-02	6.07E-02	6.00E-02	5.02E-02	4.65E-02	3.63E-02	3.29E-02	5.80E-02
NO_x	2.21E-01	2.11E-01	2.09E-01	1.75E-01	1.62E-01	1.26E-01	1.14E-01	2.02E-01
$PM_{2.5}$	5.14E-03	4.92E-03	4.86E-03	4.06E-03	3.76E-03	2.94E-03	2.66E-03	4.71E-03
PM_{10}	1.57E-02	1.57E-02	1.57E-02	1.57E-02	1.57E-02	1.57E-02	1.56E-02	1.60E-02
PM_{10} > PM > $PM_{2.5}$	7.10E-03	7.08E-03	7.08E-03	7.01E-03	6.99E-03	6.92E-03	6.90E-03	7.07E-03
Methane	5.22E-04	4.99E-04	4.94E-04	4.13E-04	3.82E-04	2.99E-04	2.71E-04	4.77E-04
Toluene	1.60E-04	1.54E-04	1.52E-04	1.27E-04	1.18E-04	9.20E-05	8.33E-05	1.47E-04
Benzene	4.01E-04	3.84E-04	3.80E-04	3.17E-04	2.94E-04	2.30E-04	2.08E-04	3.67E-04
Xylene	1.60E-04	1.54E-04	1.52E-04	1.27E-04	1.18E-04	9.20E-05	8.33E-05	1.47E-04
NMVOC	2.03E-02	1.95E-02	1.93E-02	1.61E-02	1.49E-02	1.17E-02	1.06E-02	1.86E-02
Ammonia	8.02E-05	7.68E-05	7.60E-05	6.35E-05	5.88E-05	4.60E-05	4.16E-05	7.32E-05
N_2O	4.01E-04	3.84E-04	3.80E-04	3.17E-04	2.94E-04	2.30E-04	2.08E-04	3.67E-04
SF_6 from electricity	5.05E-06	4.89E-06	5.24E-06	5.55E-06	4.46E-06	4.65E-06	4.50E-06	3.18E-06
Emissions to soil of Fe	1.78E-02	1.78E-02	1.78E-02	1.78E-02	1.78E-02	1.78E-02	1.78E-02	1.78E-02

The emissions of SO_2 are dependent on the sulphur concentration in the diesel. They have been estimated by assuming that all sulphur in the fuel is transformed completely into SO_2 (Ntziachristos and Samaras, 2000). Conventional road-transport diesel is regulated by Directive 2003/17/EC, establishing a low sulphur content with a maximum limit of 10 ppm sulphur by mass from 2009. However, the European Union Fuel Quality Monitoring report shows that diesel in Belgium has an average sulphur content of 8 ppm since 2008 (Twisse and Scott, 2012).

TABLE 12. CONCENTRATION OF SULPHUR IN DIESEL IN PPM

Year	1990	1991/95	1996	1997	1998	1999	2000	2001	2002	2003/04	2005	2006	2007	2008/12
Diesel Sulphur content (ppm)	1700	1300	600	480	440	406	294	269	47	40	31	24	9	8

SOURCES: VANHERLE ET AL., 2007 AND TWISE AND SCOTT, 2012

Table 13 shows the direct emissions of diesel trains including shunting activity in Belgium using the diesel consumption from figure 2.

TABLE 13. DIRECT EMISSIONS (G/TKM) OF DIESEL TRAINS (INCLUDING SHUNTING ACTIVITY) IN BELGIUM

Diesel trains (including shunting activity) (g/tkm)	2006	2007	2008	2009	2010	2011	2012
CO_2	53.33	50.34	54.82	59.10	55.90	44.66	47.79
SO_2	8.14E-04	2.88E-04	2.79E-04	3.01E-04	2.84E-04	2.27E-04	2.43E-04
Cd	1.70E-07	1.60E-07	1.74E-07	1.88E-07	1.78E-07	1.42E-07	1.52E-07
Cu	2.88E-05	2.72E-05	2.96E-05	3.19E-05	3.02E-05	2.41E-05	2.58E-05
Cr	8.48E-07	8.00E-07	8.71E-07	9.39E-07	8.88E-07	7.10E-07	7.60E-07
Ni	1.19E-06	1.12E-06	1.22E-06	1.31E-06	1.24E-06	9.94E-07	1.06E-06
Se	1.70E-07	1.60E-07	1.74E-07	1.88E-07	1.78E-07	1.42E-07	1.52E-07
Zn	1.70E-05	1.60E-05	1.74E-05	1.88E-05	1.78E-05	1.42E-05	1.52E-05
Pb	1.86E-09	1.76E-09	1.92E-09	2.07E-09	1.95E-09	1.56E-09	1.67E-09
Hg	3.39E-10	3.20E-10	3.49E-10	3.76E-10	3.55E-10	2.84E-10	3.04E-10
CO	2.68E-01	2.53E-01	2.75E-01	2.97E-01	2.81E-01	2.24E-01	2.40E-01
NO_X	9.32E-01	8.80E-01	9.58E-01	1.03E+00	9.77E-01	7.81E-01	8.36E-01
$PM_{2.5}$	2.17E-02	2.05E-02	2.23E-02	2.40E-02	2.27E-02	1.82E-02	1.94E-02
PM_{10}	1.65E-02	1.64E-02	1.65E-02	1.66E-02	1.65E-02	1.63E-02	1.64E-02
PM_{10} > PM >$PM_{2.5}$	8.49E-03	8.38E-03	8.54E-03	8.68E-03	8.57E-03	8.19E-03	8.30E-03
Methane	2.20E-03	2.08E-03	2.27E-03	2.44E-03	2.31E-03	1.85E-03	1.97E-03
Toluene	6.78E-04	6.40E-04	6.97E-04	7.51E-04	7.11E-04	5.68E-04	6.08E-04
Benzene	1.70E-03	1.60E-03	1.74E-03	1.88E-03	1.78E-03	1.42E-03	1.52E-03
Xylene	6.78E-04	6.40E-04	6.97E-04	7.51E-04	7.11E-04	5.68E-04	6.08E-04
NMVOC	8.59E-02	8.11E-02	8.84E-02	9.52E-02	9.01E-02	7.20E-02	7.70E-02
Ammonia	3.39E-04	3.20E-04	3.49E-04	3.76E-04	3.55E-04	2.84E-04	3.04E-04
N_2O	1.70E-03	1.60E-03	1.74E-03	1.88E-03	1.78E-03	1.42E-03	1.52E-03
Emissions to soil of Fe	1.78E-02	1.78E-02	1.78E-02	1.78E-02	1.78E-02	1.78E-02	1.78E-02

Table 14 shows the direct emissions of electric trains in Belgium using the electricity consumption showed in figure 2. The only direct emissions produced by electric locomotives are the direct emissions from abrasion of brake linings, wheels and rails and the SF_6 emissions to air during conversion of electricity at traction substations.

TABLE 14. DIRECT EMISSIONS (G/TKM) OF ELECTRIC TRAINS IN BELGIUM

Electric trains (g/tkm)	2006	2007	2008	2009	2010	2011	2012
PM_{10}	1.55E-05	1.55E-05	1.55E-05	1.55E-05	1.55E-05	1.553E-05	1.55E-05
SF_6	6.62E-09	6.44E-09	6.71E-09	6.68E-09	5.35E-09	5.545E-09	5.21E-09
PM_{10} > PM >$PM_{2.5}$	6.67E-06	6.67E-06	6.67E-06	6.67E-06	6.67E-06	6.673E-06	6.67E-06
Emissions to soil of Fe	1.78E-05	1.78E-05	1.78E-05	1.78E-05	1.78E-05	1.779E-05	1.78E-05

3.1.2. Inland waterways transport

Table 15 shows the exhaust emissions produced during the TTW stage of inland waterways transport. They have been calculated using the emission factors of Spielmann et al. (2007) and the previously calculated diesel consumption (see table 6). As mentioned above, the emission factors of Spielmann et al. (2007) are used by the Ecoinvent v3 database as well, thus we have used the direct emissions of the process from Ecoinvent v3 "Transport, freight, inland waterways, barge {RER}| processing | Alloc Rec, U" as reference values.

TABLE 15. DIRECT EMISSIONS (G/TKM) OF INLAND WATERWAYS TRANSPORT IN BELGIUM

Inland waterways transport (g/tkm)	2006	2007	2008	2009	2010	2011	2012	Ecoinvent v3 2014
CO_2	23.63	23.14	22.55	22.12	21.72	21.46	21.34	29.60
SO_2	2.98E-02	2.92E-02	1.42E-02	1.39E-02	1.37E-02	1.35E-04	1.35E-04	5.64E-03
Cd	7.45E-08	7.30E-08	7.11E-08	6.97E-08	6.85E-08	6.77E-08	6.73E-08	9.39E-08
Cu	1.27E-05	1.24E-05	1.21E-05	1.19E-05	1.16E-05	1.15E-05	1.14E-05	1.60E-05
Cr	3.72E-07	3.65E-07	3.55E-07	3.49E-07	3.42E-07	3.38E-07	3.36E-07	4.70E-07
Ni	5.21E-07	5.11E-07	4.98E-07	4.88E-07	4.79E-07	4.74E-07	4.71E-07	6.58E-07
Se	7.45E-08	7.30E-08	7.11E-08	6.97E-08	6.85E-08	6.77E-08	6.73E-08	9.39E-08
Zn	7.45E-06	7.30E-06	7.11E-06	6.97E-06	6.85E-06	6.77E-06	6.73E-06	9.39E-06
Pb	8.19E-10	8.02E-10	7.82E-10	7.67E-10	7.53E-10	7.44E-10	7.40E-10	1.88E-07
Hg	1.49E-10	1.46E-10	1.42E-10	1.39E-10	1.37E-10	1.35E-10	1.35E-10	6.58E-10
CO	2.01E-02	1.97E-02	1.92E-02	1.88E-02	1.85E-02	1.83E-02	1.82E-02	2.54E-02
NO_X	3.72E-01	3.65E-01	3.55E-01	3.49E-01	3.42E-01	3.38E-01	3.36E-01	4.70E-01
$PM_{2.5}$	6.88E-03	6.73E-03	6.56E-03	6.44E-03	6.32E-03	6.25E-03	6.21E-03	8.67E-03
PM_{10}	2.90E-04	2.85E-04	2.77E-04	2.72E-04	2.67E-04	2.64E-04	2.62E-04	3.71E-04
PM_{10} > PM > $PM_{2.5}$	5.74E-04	5.62E-04	5.47E-04	5.37E-04	5.27E-04	5.21E-04	5.18E-04	7.23E-04
Methane	1.79E-04	1.75E-04	1.71E-04	1.67E-04	1.64E-04	1.62E-04	1.61E-04	2.25E-04
Toluene	5.96E-05	5.84E-05	5.69E-05	5.58E-05	5.48E-05	5.41E-05	5.38E-05	7.52E-05
Benzene	1.42E-04	1.39E-04	1.35E-04	1.33E-04	1.30E-04	1.29E-04	1.28E-04	1.78E-04
Xylene	5.96E-05	5.84E-05	5.69E-05	5.58E-05	5.48E-05	5.41E-05	5.38E-05	7.52E-05
NMVOC	7.45E-03	7.30E-03	7.11E-03	6.97E-03	6.85E-03	6.77E-03	6.73E-03	9.39E-03
Ammonia	3.86E-04	3.78E-04	3.69E-04	3.62E-04	3.55E-04	3.51E-04	3.49E-04	4.87E-04
N_2O	5.96E-04	5.84E-04	5.69E-04	5.58E-04	5.48E-04	5.41E-04	5.38E-04	3.11E-03
Benzo(a)pyrene	5.74E-08	5.62E-08	5.47E-08	5.37E-08	5.27E-08	5.21E-08	5.18E-08	7.24E-11
HCl	7.90E-06	7.73E-06	7.53E-06	7.39E-06	7.26E-06	7.17E-06	7.13E-06	9.95E-06

As mentioned above, the emissions of SO_2 are dependent on the sulphur concentration in the diesel. The gas-oil used in barges has been regulated by several European Directives, such as the Directive 93/12/EC, establishing a sulphur content of gas-oil used in inland waterways transport of 2000 ppm from 1994; Directive 1999/32/EC establishing a sulphur content of gas-oil of 1000 ppm from 2008; and Directive 2009/30/EC establishing a sulphur content of gas-oil of 10 ppm from 2011 (see table 16).

TABLE 16. CONCENTRATION OF SULPHUR IN GAS-OIL USED IN INLAND WATERWAYS TRANSPORT IN PPM

Year	2006	2007	2008	2009	2010	2011/12
Gas-oil Sulphur content (ppm)	2000	2000	1000	1000	1000	10

3.1.3. Road transport

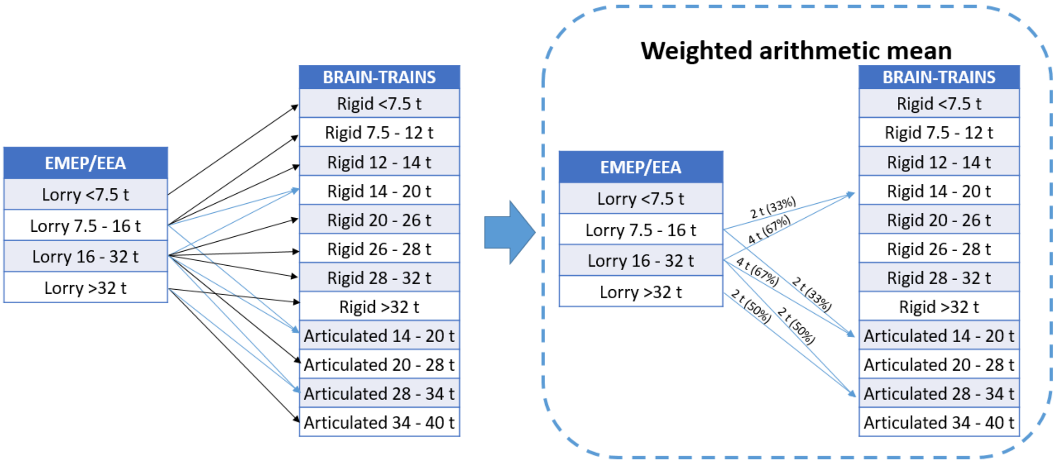
Table 17 shows the exhaust emissions produced during the TTW stage of road freight transport. They have been determined using the previously calculated diesel consumption (see table 10) and the emissions factors from two sources. For fuel dependent emissions such as CO_2 and heavy metals, the emission factors of Spielmann et al. (2007) have been used. For other pollutant emissions dependent on the engine emission technology have been used the tier 2 emission factors from EMEP/EEA air pollutant emission inventory guidebook 2013 (Ntziachristos et al., 2014). As mentioned above, the emission factors of Spielmann et al. (2007) are used by the Ecoinvent v3 database as well, thus we have used the direct emissions of the process from Ecoinvent v3 “Transport, freight, lorry >32 metric ton, Euro 3 {RER}| Alloc Rec, U” as reference values.

TABLE 17. DIRECT EMISSIONS OF AVERAGE ROAD TRANSPORT AND ROAD TRANSPORT BY A LORRY ARTICULATED 34-40 T

	Average road transport (g/tkm)						Lorry articulated 34 – 40 t (g/tkm)						Ecoinvent v3
	2005	2006	2007	2008	2009	2010	2005	2006	2007	2008	2009	2010	2014
CO_2	158.74	164.93	172.16	195.19	198.25	210.85	136.12	141.58	147.94	168.43	170.51	181.33	55.09
SO_2	3.10E-03	2.50E-03	9.77E-04	9.85E-04	1.00E-03	1.06E-03	2.66E-03	2.14E-03	8.39E-04	8.50E-04	8.60E-04	9.15E-04	2.82E-04
Cd	5.00E-07	5.20E-07	5.43E-07	6.15E-07	6.25E-07	6.65E-07	4.29E-07	4.46E-07	4.66E-07	5.31E-07	5.38E-07	5.72E-07	1.50E-07
Cu	8.51E-05	8.84E-05	9.23E-05	1.05E-04	1.06E-04	1.13E-04	7.30E-05	7.59E-05	7.93E-05	9.03E-05	9.14E-05	9.72E-05	3.66E-07
Cr	2.50E-06	2.60E-06	2.71E-06	3.08E-06	3.13E-06	3.32E-06	2.15E-06	2.23E-06	2.33E-06	2.65E-06	2.69E-06	2.86E-06	5.18E-07
Ni	3.50E-06	3.64E-06	3.80E-06	4.31E-06	4.38E-06	4.65E-06	3.00E-06	3.12E-06	3.26E-06	3.72E-06	3.76E-06	4.00E-06	1.52E-07
Se	5.00E-07	5.20E-07	5.43E-07	6.15E-07	6.25E-07	6.65E-07	4.29E-07	4.46E-07	4.66E-07	5.31E-07	5.38E-07	5.72E-07	1.73E-09
Zn	5.00E-05	5.20E-05	5.43E-05	6.15E-05	6.25E-05	6.65E-05	4.29E-05	4.46E-05	4.66E-05	5.31E-05	5.38E-05	5.72E-05	3.00E-05
Pb	5.51E-09	5.72E-09	5.97E-09	6.77E-09	6.88E-09	7.31E-09	4.72E-09	4.91E-09	5.13E-09	5.84E-09	5.91E-09	6.29E-09	9.00E-07
Hg	1.00E-09	1.04E-09	1.09E-09	1.23E-09	1.25E-09	1.33E-09	8.58E-10	8.93E-10	9.33E-10	1.06E-09	1.08E-09	1.14E-09	9.15E-08
Cr(IV)	5.00E-09	5.20E-09	5.43E-09	6.15E-09	6.25E-09	6.65E-09	4.29E-09	4.46E-09	4.66E-09	5.31E-09	5.38E-09	5.72E-09	1.04E-09
As	5.00E-09	5.20E-09	5.43E-09	6.15E-09	6.25E-09	6.65E-09	4.29E-09	4.46E-09	4.66E-09	5.31E-09	5.38E-09	5.72E-09	1.73E-09
CO	3.69E-01	3.50E-01	3.28E-01	3.34E-01	3.12E-01	3.06E-01	3.19E-01	3.04E-01	2.87E-01	2.94E-01	2.76E-01	2.68E-01	8.24E-02
NMVOC	7.97E-02	7.46E-02	6.90E-02	6.93E-02	6.39E-02	6.18E-02	6.59E-02	6.26E-02	5.87E-02	5.99E-02	5.58E-02	5.39E-02	1.26E-02
NO_x	1.83E+00	1.81E+00	1.79E+00	1.92E+00	1.84E+00	1.84E+00	1.59E+00	1.58E+00	1.57E+00	1.70E+00	1.62E+00	1.62E+00	4.46E-01
N_2O	2.73E-03	2.84E-03	2.99E-03	3.44E-03	4.17E-03	5.11E-03	2.40E-03	2.56E-03	2.74E-03	3.18E-03	3.85E-03	4.81E-03	3.71E-04
NH_3	6.38E-04	6.64E-04	6.94E-04	7.85E-04	9.74E-04	1.20E-03	4.90E-04	5.12E-04	5.36E-04	6.11E-04	7.58E-04	9.62E-04	1.56E-04
$PM_{2.5}$	5.11E-02	4.81E-02	4.48E-02	4.54E-02	4.21E-02	4.09E-02	4.52E-02	4.32E-02	4.07E-02	4.19E-02	3.92E-02	3.81E-02	8.96E-03
indeno(1,2,3-cd)pyrene	3.08E-07	3.20E-07	3.35E-07	3.79E-07	3.86E-07	4.11E-07	2.37E-07	2.47E-07	2.59E-07	2.95E-07	2.99E-07	3.18E-07	-
benzo(k)fluoranthene	1.34E-06	1.39E-06	1.46E-06	1.65E-06	1.68E-06	1.79E-06	1.03E-06	1.07E-06	1.13E-06	1.28E-06	1.30E-06	1.39E-06	-
benzo(b)fluoranthene	1.20E-06	1.25E-06	1.30E-06	1.48E-06	1.50E-06	1.60E-06	9.22E-07	9.61E-07	1.01E-06	1.15E-06	1.16E-06	1.24E-06	-
benzo(a)pyrene	1.98E-07	2.06E-07	2.15E-07	2.44E-07	2.48E-07	2.64E-07	1.52E-07	1.59E-07	1.66E-07	1.90E-07	1.92E-07	2.05E-07	-

The emission factors from EMEP/EEA have been converted from g/km to g/tkm dividing by the actual payload (table 8) of each lorry gross vehicle weight (GVW) category. As shown in figure 6, the emissions factor from EMEP/EEA are classified in four GVW categories. In order to be coherent with the energy consumption, it has been decided to translate the emission factor of EMEP/EEA from 4 lorry GVW categories to 12 lorry GVW categories.

FIGURE 6. GROSS VEHICLE WEIGHT CLASSIFICATION OF LORRRIES USED BY EMEP/EEA AND THE TRANSLATION TO THE CLASSIFICATION USED IN THE BRAIN-TRAIN PROJEC



The road transport emissions dependent on the engine are delimited by the "Euro" emission standards, which are regulated by several European policies, such as the Directive 91/542/EEC (Euro I and Euro II), the Directive 1999/96/EC (Euro III, Euro IV and Euro V) and the EC Regulation 595/2009 (Euro VI). The emission engine technologies presents in our study are the following: Conventional, Euro I, Euro II, Euro III, Euro IV and Euro V. The emission engine technology Euro IV appears in the year 2006 in the Belgian heavy duty vehicle market, and the Euro V in the year 2009. The emission engine technology Euro VI appears in the year 2014, thus it is not included in our study.

Since the emissions related to the engine technology are dependent on the lorry GVW category as well, 48 different types of lorries have been considered in the year 2005 (12 lorry GVW categories split in 4 emission engine technologies), 60 different types of lorries have been taken into account in the years from 2006 to 2008 and 72 different types of lorries have been included in the years 2009 and 2010.

In order to determine an average emission for every year, the tonne-kilometers moved by each lorry GVW category and emission engine technology have been used to calculate a weighted arithmetic mean. The methodology is the same as the one used in the energy consumption (see table 9).

3.1.4. Comparison of direct emissions of inland freight transport modes in Belgium

This section compares some selected pollutants emitted as exhaust emissions obtained in the BRAIN-TRAINS project and the reference values from the Ecoinvent v3 database. These pollutants as direct emissions do not yet represent environmental impact categories such as climate change or acidification. These direct emissions during transport operation are part of the inventory analysis and this, together with the energy consumption during transport operation and the emissions, energy and material consumptions from the vehicle and infrastructure stages, constitute the required elements to model the freight transport system. It is necessary to consider all the elements from the inventory analysis to evaluate the contribution of the freight transport to environmental impact categories. Therefore, this section compares pollutant emissions as substances produced during the transport activity and not as environmental impacts.

Figure 7 shows a comparison of the carbon dioxide (CO_2) exhaust emissions obtained in the BRAIN-TRAINS project and the reference values from Ecoinvent v3. Since the CO_2 emissions are dependent on the fuel consumption, the modes of transport with higher fuel consumption emit higher levels of CO_2. Rail freight transport in Belgium includes a part of diesel traction, but the fuel consumption is lower than the other transport modes, being the main energy source of rail transport the electricity.

FIGURE 7. CO_2 EXHAUST EMISSIONS (G/TKM) OF INLAND FREIGHT TRANSPORT MODES IN BELGIUM

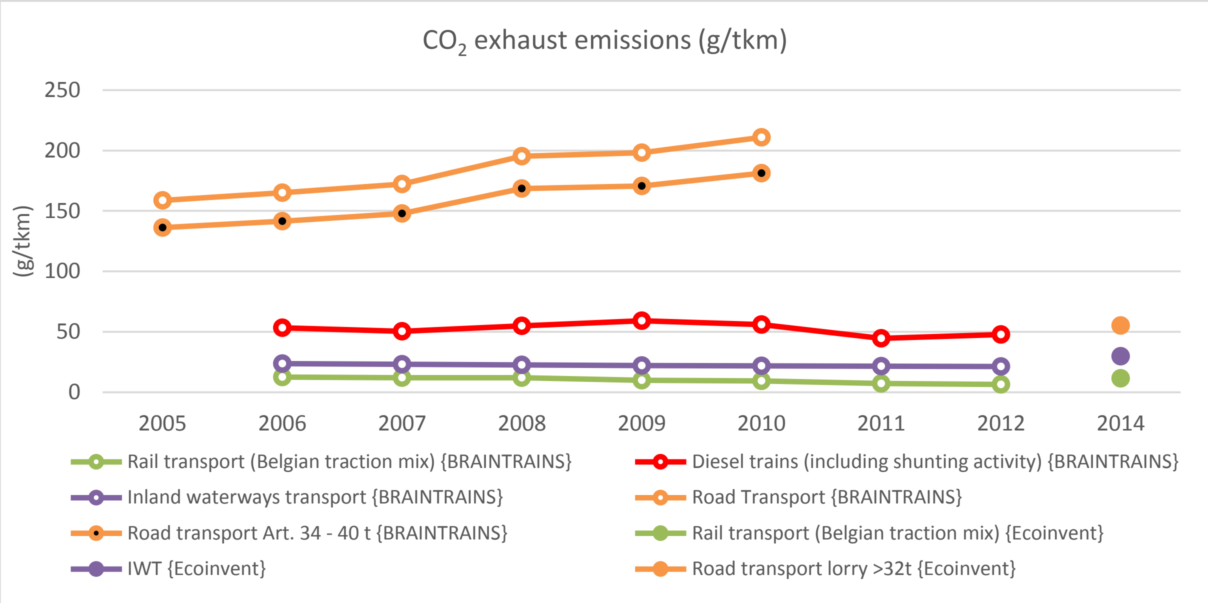


Figure 8 compares the sulphur dioxide (SO_2) exhaust emissions obtained in the BRAIN-TRAINS project and the reference values from Ecoinvent v3. Since the SO_2 emissions of inland waterways transport range from 29.8 mg/tkm in 2006 to 13.7 mg/tkm in 2010, they are not included in the graph to allow a better understanding. These high SO_2 emissions of inland waterways transport are due to the elevated sulphur content of gas-oil used in the years 2006 and 2007 with a sulphur content of 2000 ppm, and the years from 2008 to 2010 with 1000 ppm of sulphur concentration in diesel. After 2011 the sulphur content of Gas-oil has been limited to 10 ppm and this, together with lower fuel consumption than lorries and diesel trains, has caused barges emit lower levels of SO_2 than lorries and diesel trains. Since the main energy source of rail freight transport is electricity, the SO_2 exhaust emissions from diesel locomotives are the lowest.

The sulphur content of diesel used by road transport and diesel trains in Belgium has decreased from 31 ppm in 2005 and 24 ppm in 2006 to stabilise in 9-8 ppm after 2007. This has led to a decrease in the SO_2 emissions of road transport despite the increase of fuel consumption by tonne-kilometre over the years due to lower load factors.

Ecoinvent v3 database estimates a sulphur content of 300 ppm in the diesel used by diesel locomotives and barges in the year 2014, which points out a need for updating the Ecoinvent v3 database. For road transport, Ecoinvent v3 database considers properly a diesel sulphur content of 10 ppm.

FIGURE 8. SO_2 EXHAUST EMISSIONS (MG/TKM) OF INLAND FREIGHT TRANSPORT MODES IN BELGIUM

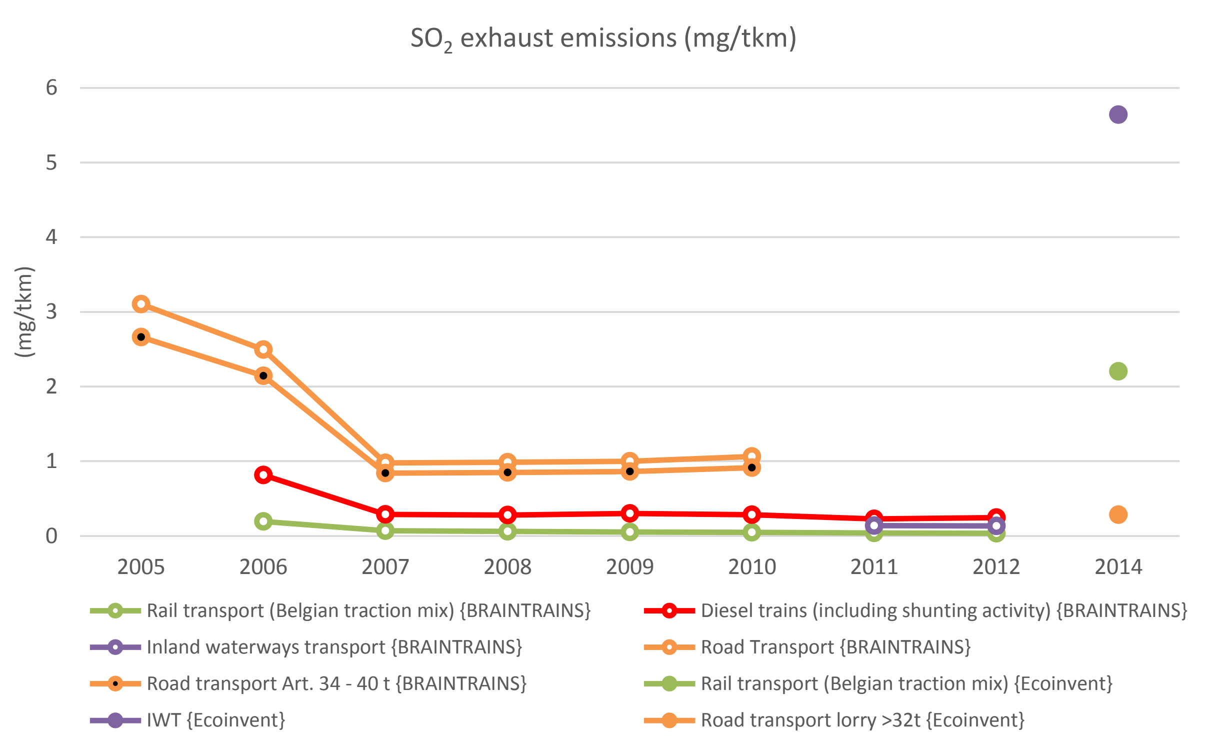


Figure 9 presents a comparison of heavy metals (Cadmium, Copper, Chromium, Nickel, Selenium, Zinc, Lead and Mercury) from exhaust emissions obtained in the BRAIN-TRAINS project and the reference values from Ecoinvent v3. Heavy metals emissions are associated with the metal content of the fuel, thereby the modes of transport with higher fuel consumption emit higher levels of heavy metals. The two main heavy metals emitted as exhaust emissions are the Copper and the Zinc.

FIGURE 9. HEAVY METALS FROM EXHAUST EMISSIONS (µG/TKM) OF INLAND FREIGHT TRANSPORT MODES IN BELGIUM

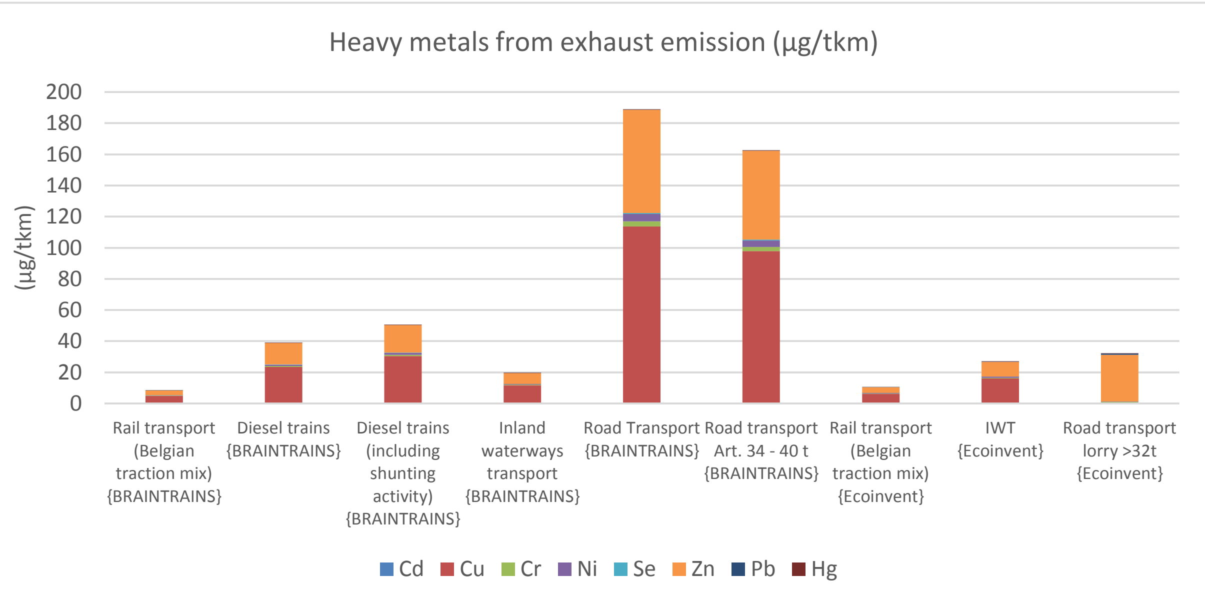


Figure 10 compares the carbon monoxide (CO) exhaust emissions obtained in the BRAIN-TRAINS project and the reference values from Ecoinvent v3. The emissions of CO are a product of incomplete combustion, which causes the partial oxidation of the carbon in the fuel and forming CO instead of CO_2. For road transport, the Euro emission standards have reduced the limit of CO emissions over the years. Therefore, despite the increased fuel consumption, the CO emissions have decreased.

FIGURE 10. CO EXHAUST EMISSIONS (MG/TKM) OF INLAND FREIGHT TRANSPORT MODES IN BELGIUM

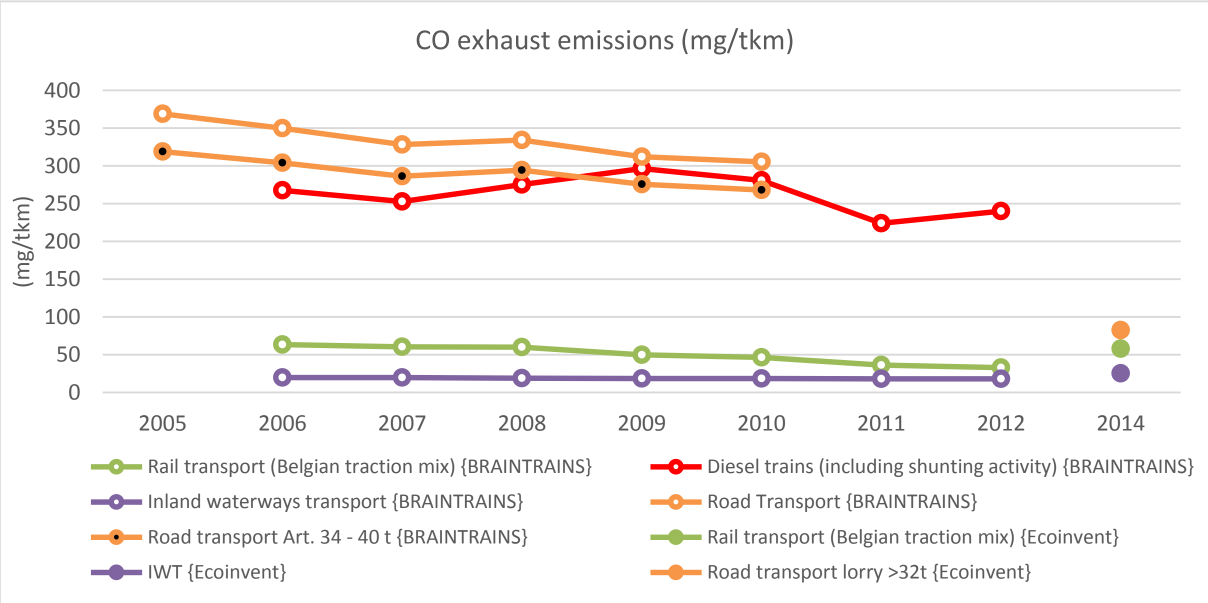


Figure 11 shows a comparison of the nitrogen oxides (NO_x) exhaust emissions obtained in the BRAIN-TRAINS project and the reference values from Ecoinvent v3. The emissions of NO_x are a product of the combustion of fuel in the engine in the presence of air. It comprises a mixture of nitric oxide (NO) and nitrogen dioxide (NO_2). For road transport, the Euro emission standards have reduced the limit of NO_x emissions over the years. Therefore, despite the increased fuel consumption, the NO_x emissions remain almost stable.

FIGURE 11. NO_x EXHAUST EMISSIONS (MG/TKM) OF INLAND FREIGHT TRANSPORT MODES IN BELGIUM

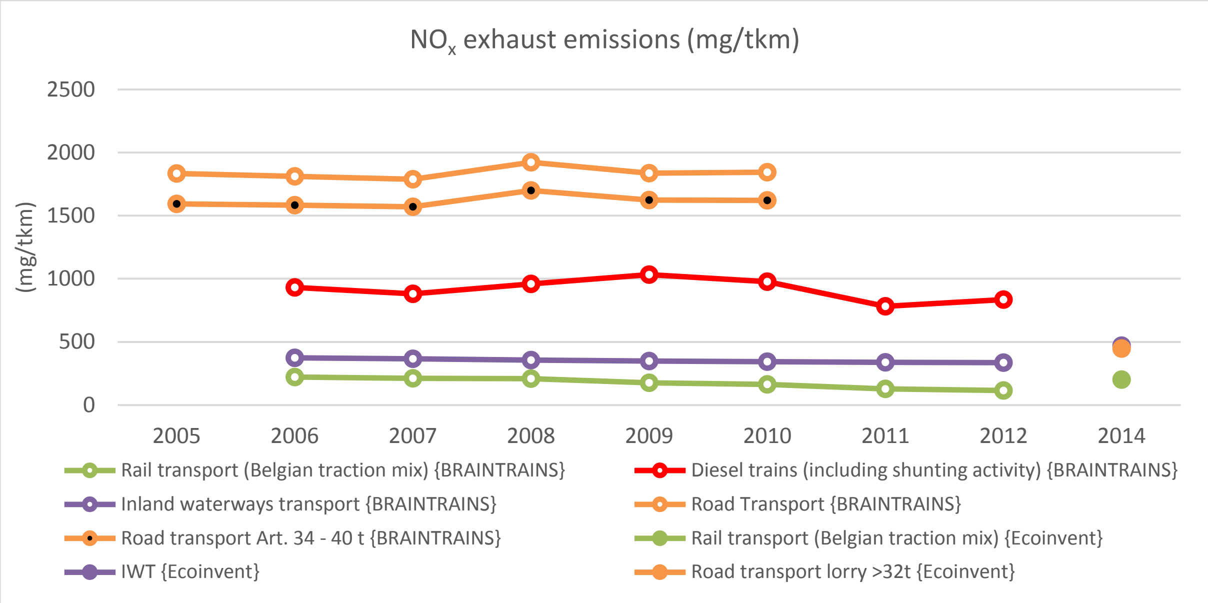
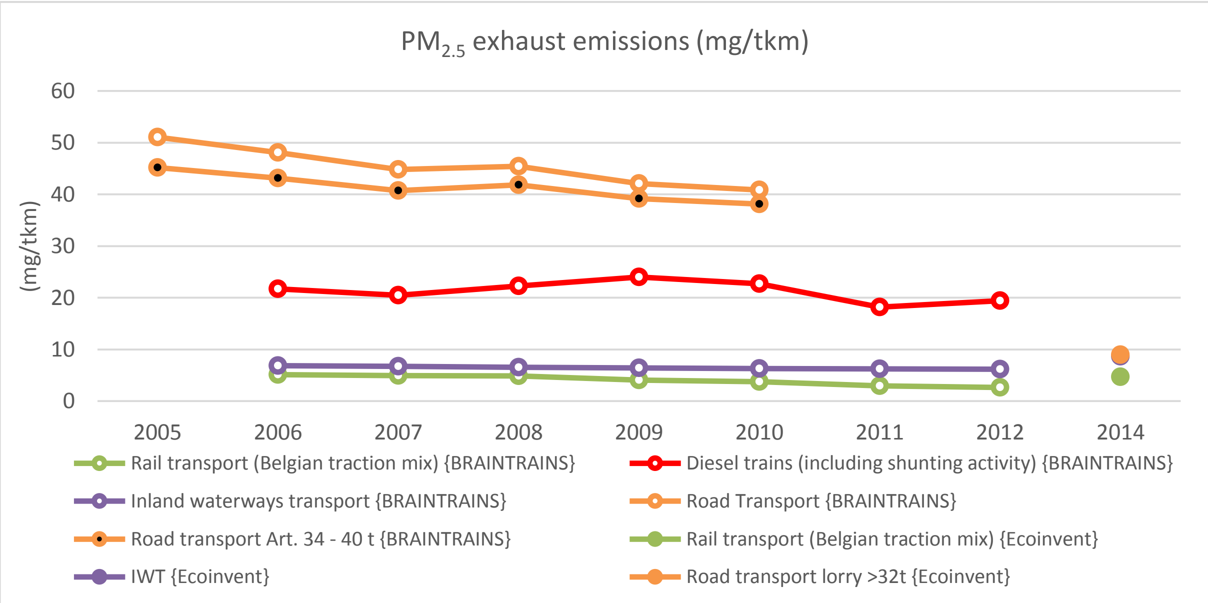


Figure 12 compares the particulate matter ($PM_{2.5}$) exhaust emissions obtained in the BRAIN-TRAINS project and the reference values from Ecoinvent v3. Particulate matter emissions are produced as a result of an incomplete combustion. For road transport, the Euro emission standards have reduced the limit of $PM_{2.5}$ emissions over the years. Therefore, despite the increased fuel consumption, the $PM_{2.5}$ emissions remains have decreased.

FIGURE 12. $PM_{2.5}$ EXHAUST EMISSIONS (MG/TKM) OF INLAND FREIGHT TRANSPORT MODES IN BELGIUM



3.2. LCA emissions

A LCA study comprises four stages. First, the goal and scope definition, which in this deliverable is to compare the environmental impacts of the different inland freight transport modes in Belgium (see figure 2). The functional unit chosen is "one tonne-kilometre of freight transported".

The second stage of a LCA is the inventory analysis, collecting data directly from Infrabel and B-Logistics in the case of rail freight transport and complementing the information using the Ecoinvent V3.1 database. The model used in Ecoinvent V3.1 has been adapted to the Belgian situation in the case of both inland waterways transport and road transport (using the calculated transport parameters of tonne-kilometres, load factor, payload, number of vehicles, and characteristics of infrastructures for example). **The information collected from Infrabel and B-Logistics has not been fully modelled, therefore the results on LCA presented in this deliverable are subject to a degree of uncertainty. Moreover, these results may slightly differ from the final results that will be presented in the upcoming deliverables. Therefore, a more detailed study of impact assessment will be carry out in the next deliverable.**

The third stage is the impact assessment. All calculations were made with the SimaPro 8.0.5 software using the Life Cycle Impact Assessment (LCIA) method "ILCD 2011 Midpoint+" (version V1.06 / EU27 2010), which is the method recommended by the European Commission (European Commission, 2010). "ILCD 2011 Midpoint+" is a midpoint method including 16 environmental impact indicators.

The fourth stage is the assessment of the results obtained in the previous stage.

3.2.1. Rail freight transport

As mentioned above, for the LCA of the Belgian rail freight transport, all life cycle phases of rail freight transport operation, rail infrastructure (construction, maintenance and disposal), and rail equipment (manufacturing, maintenance and disposal) are taken into account

Rail transport operation stage includes the processes that are directly connected with the train activity, such as the direct emissions explained above and the indirect emissions from the electricity production. As shown in table 18, in order to adjust as closely as possible the environmental impact related to the yearly electricity consumption, and since the electricity supply mix is different every year, our LCA study uses the electricity supply mix in Belgium corresponding to the appropriate year (from 2006 to 2012) according to Eurostat data. The electricity imports from France, the Netherlands and Luxembourg have been modelled considering the supply mix of the exporting countries. The production of solar energy by Infrabel in the years 2011 and 2012 has been included as well.

TABLE 18. SUPPLY ELECTRICITY MIX IN BELGIUM

Energy source	2006	2007	2008	2009	2010	2011	2012
Nuclear	43.08%	44.83%	43.93%	46.71%	44.78%	47.51%	41.88%
Natural gas	23.26%	24.12%	23.34%	26.31%	25.88%	22.19%	22.18%
Hard coal	5.24%	5.43%	5.25%	5.92%	5.82%	4.99%	4.99%
Oil	0.38%	0.40%	0.38%	0.43%	0.43%	0.37%	0.37%
Treatment blast furnace gas	1.53%	1.58%	1.53%	1.72%	1.70%	1.45%	1.45%
Treatment of coal gas	0.07%	0.07%	0.07%	0.08%	0.08%	0.06%	0.06%
Hydro, pumped storage	1.23%	1.26%	1.36%	1.48%	1.32%	1.26%	1.41%
Hydro, run-of-river	1.57%	1.63%	1.77%	1.81%	1.61%	1.46%	1.79%
Wind, <1MW turbine	0.01%	0.01%	0.02%	0.03%	0.04%	0.07%	0.09%
Wind, >3MW turbine	0.03%	0.05%	0.06%	0.10%	0.12%	0.23%	0.29%
Wind, 1-3MW turbine	0.29%	0.40%	0.53%	0.85%	1.05%	1.98%	2.47%
Wind, 1-3MW turbine, offshore	0.01%	0.01%	0.02%	0.03%	0.04%	0.07%	0.09%
Co-generation, biogas	0.45%	0.46%	0.45%	0.50%	0.50%	0.43%	0.43%
Co-generation, wood chips	2.35%	2.43%	2.35%	2.65%	2.61%	2.24%	2.24%
Imports from FR	11.72%	9.27%	8.18%	2.19%	3.58%	8.50%	8.96%
Imports from LU	2.70%	2.28%	1.80%	2.24%	2.09%	1.82%	1.67%
Imports from NL	6.10%	5.76%	8.96%	6.93%	8.36%	5.37%	9.63%
Infrabel (solar energy)	0	0	0	0	0	0.003%	0.004%

SOURCES: EUROSTAT AND WEIDEMA ET AL. (2013)

Table 19 presents the results obtained in the Life Cycle Impact Assessment (LCIA) of one tonne-kilometre of freight transported by rail in Belgium using the Belgian traction mix of diesel and electric traction and the reference values from Ecoinvent v3 database. The results of LCIA from our study are always higher than the reference values of the process from Ecoinvent v3 “Transport, freight train {BE}| processing | Alloc Rec, U”.

The year 2009 presents the maximum impact in 12 indicators including the highest positive impact in the indicator water resource depletion. The negative score in the indicator water resource depletion indicates that water has been emitted or returned to the environment, becoming a positive impact. The emission of water to the environment is produced in the electricity generation at the natural gas power plant. However, this results should be interpreted with caution due to the uncertainty of the methodology. The year 2006 presents the maximum impact as result of the higher exhaust emissions produced in the diesel locomotives in the following indicators: photochemical ozone formation, terrestrial and marine eutrophication.

TABLE 19. LIFE CYCLE IMPACT ASSESSMENT OF RAIL FREIGHT TRANSPORT (BELGIAN TRACTION MIX OF DIESEL AND ELECTRIC TRACTION) IN BELIGIUM

Impact category	Unit	2006	2007	2008	2009	2010	2011	2012	Ecoinvent v3
Climate change	kg CO_2 eq	7.64E-02	7.47E-02	7.83E-02	8.63E-02	7.44E-02	6.71E-02	7.05E-02	5.37E-02
Ozone depletion	kg CFC-11 eq	1.33E-08	1.28E-08	1.32E-08	1.35E-08	1.13E-08	1.16E-08	1.10E-08	9.01E-09
Human toxicity, non-cancer effects	CTUh	1.62E-08	1.59E-08	1.63E-08	1.97E-08	1.74E-08	1.72E-08	1.86E-08	1.16E-08
Human toxicity, cancer effects	CTUh	6.59E-09	6.51E-09	6.53E-09	8.54E-09	7.70E-09	7.52E-09	8.27E-09	5.21E-09
Particulate matter	kg $PM_{2.5}$ eq	3.91E-05	3.84E-05	3.88E-05	4.44E-05	3.94E-05	3.72E-05	4.08E-05	2.86E-05
Ionizing radiation HH	kBq U235 eq	7.00E-02	6.73E-02	6.99E-02	7.15E-02	5.69E-02	6.59E-02	5.90E-02	4.35E-02
Ionizing radiation E (interim)	CTUe	1.18E-07	1.15E-07	1.19E-07	1.24E-07	9.93E-08	1.11E-07	9.99E-08	7.56E-08
Photochemical ozone formation	kg NMVOC eq	4.16E-04	4.04E-04	4.06E-04	3.97E-04	3.56E-04	3.08E-04	3.15E-04	3.34E-04
Acidification	molc H+ eq	4.59E-04	4.48E-04	4.53E-04	4.78E-04	4.25E-04	3.84E-04	3.97E-04	3.51E-04
Terrestrial eutrophication	molc N eq	1.53E-03	1.48E-03	1.49E-03	1.44E-03	1.29E-03	1.11E-03	1.10E-03	1.23E-03
Freshwater eutrophication	kg P eq	1.53E-05	1.46E-05	1.54E-05	1.77E-05	1.56E-05	1.49E-05	1.82E-05	9.99E-06
Marine eutrophication	kg N eq	1.41E-04	1.36E-04	1.37E-04	1.33E-04	1.19E-04	1.03E-04	1.02E-04	1.13E-04
Freshwater ecotoxicity	CTUe	3.98E-01	3.91E-01	4.02E-01	4.96E-01	4.41E-01	4.40E-01	4.87E-01	2.86E-01
Land use	kg C deficit	1.78E-01	1.76E-01	1.79E-01	1.97E-01	1.74E-01	1.64E-01	1.69E-01	1.10E-01
Water resource depletion	m^3 water eq	-7.84E-05	-7.89E-05	-7.87E-05	-1.05E-04	-8.91E-05	-7.71E-05	-8.13E-05	-5.29E-05
Mineral, fossil & ren. resource depletion	kg Sb eq	1.97E-06	1.95E-06	1.99E-06	2.35E-06	2.06E-06	2.08E-06	2.15E-06	1.24E-06

Tables 20 and 21 shows the results obtained in the Life Cycle Impact Assessment of one tonne-kilometre of freight transported by diesel trains and electric trains in Belgium, respectively. The year 2009 presents the maximum impact in 13 indicators for diesel and electric trains, including the highest positive impact in the indicator water resource depletion for electric trains.

TABLE 20. LIFE CYCLE IMPACT ASSESSMENT OF DIESEL TRAINS (INCLUDING SHUNTING ACTIVITY) IN BELGIUM

Impact category	Unit	2006	2007	2008	2009	2010	2011	2012
Climate change	kg CO_2 eq	9.05E-02	8.69E-02	9.25E-02	1.05E-01	9.74E-02	8.34E-02	8.95E-02
Ozone depletion	kg CFC-11 eq	1.38E-08	1.31E-08	1.42E-08	1.56E-08	1.46E-08	1.21E-08	1.29E-08
Human toxicity, non-cancer effects	CTUh	1.37E-08	1.36E-08	1.40E-08	1.91E-08	1.75E-08	1.69E-08	1.92E-08
Human toxicity, cancer effects	CTUh	6.24E-09	6.21E-09	6.20E-09	8.47E-09	7.74E-09	7.51E-09	8.26E-09
Particulate matter	kg $PM_{2.5}$ eq	6.18E-05	5.96E-05	6.30E-05	7.34E-05	6.80E-05	5.95E-05	6.42E-05
Ionizing radiation HH	kBq U235 eq	7.74E-03	7.47E-03	7.91E-03	8.99E-03	8.29E-03	7.27E-03	7.77E-03
Ionizing radiation E (interim)	CTUe	3.84E-08	3.68E-08	3.94E-08	4.38E-08	4.07E-08	3.44E-08	3.68E-08
Photochemical ozone formation	kg NMVOC eq	1.19E-03	1.13E-03	1.23E-03	1.34E-03	1.26E-03	1.03E-03	1.10E-03
Acidification	molc H+ eq	9.96E-04	9.49E-04	1.02E-03	1.14E-03	1.07E-03	8.92E-04	9.58E-04
Terrestrial eutrophication	molc N eq	4.49E-03	4.26E-03	4.61E-03	5.03E-03	4.73E-03	3.86E-03	4.13E-03
Freshwater eutrophication	kg P eq	1.18E-05	1.18E-05	1.20E-05	1.58E-05	1.44E-05	1.39E-05	1.54E-05
Marine eutrophication	kg N eq	4.11E-04	3.90E-04	4.22E-04	4.60E-04	4.33E-04	3.53E-04	3.78E-04
Freshwater ecotoxicity	CTUe	3.62E-01	3.60E-01	3.68E-01	4.99E-01	4.58E-01	4.43E-01	5.00E-01
Land use	kg C deficit	2.72E-01	2.63E-01	2.79E-01	3.12E-01	2.86E-01	2.52E-01	2.67E-01
Water resource depletion	m^3 water eq	-3.30E-05	-3.34E-05	-3.27E-05	-4.62E-05	-4.14E-05	-4.24E-05	-4.67E-05
Mineral, fossil & ren. resource depletion	kg Sb eq	1.79E-06	1.77E-06	1.82E-06	2.33E-06	2.11E-06	2.05E-06	2.26E-06

TABLE 21. LIFE CYCLE IMPACT ASSESSMENT OF ELECTRIC TRAINS IN BELGIUM

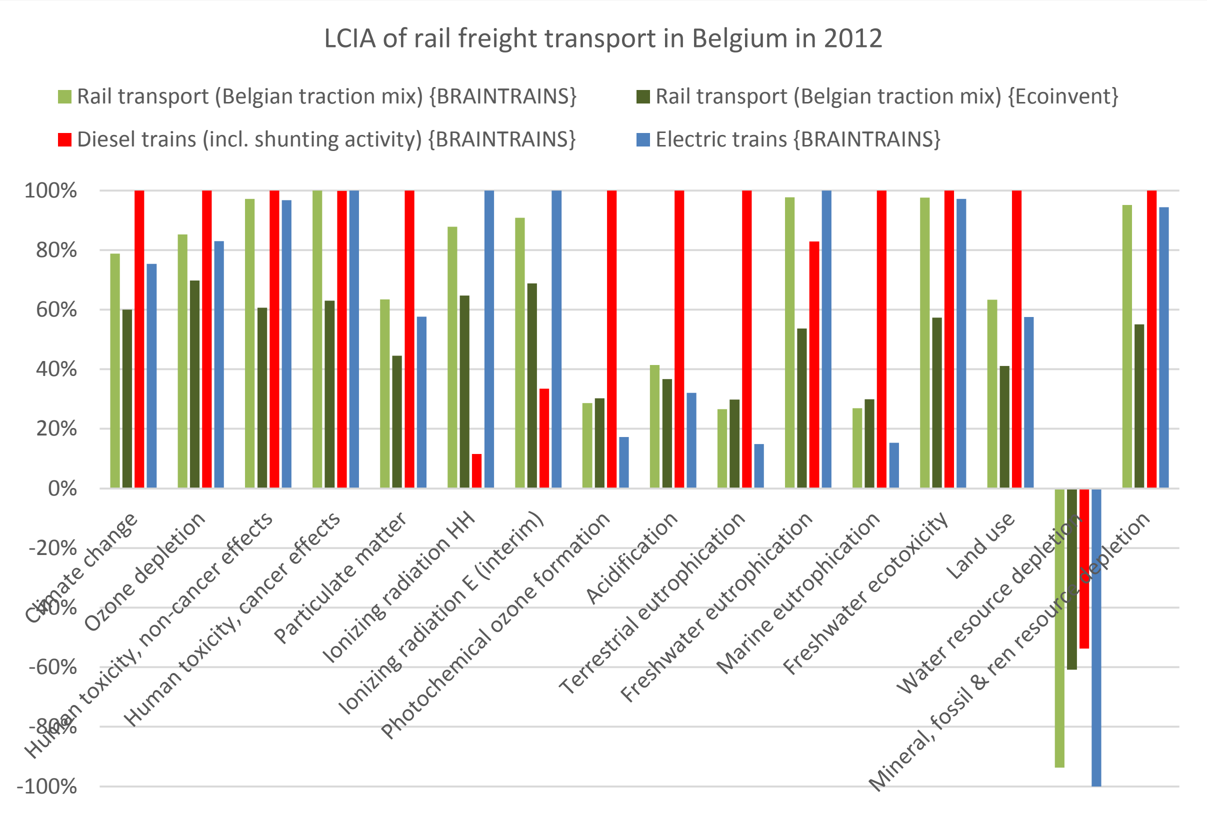
Impact category	Unit	2006	2007	2008	2009	2010	2011	2012
Climate change	kg CO_2 eq	7.21E-02	7.09E-02	7.44E-02	8.26E-02	6.98E-02	6.39E-02	6.75E-02
Ozone depletion	kg CFC-11 eq	1.31E-08	1.27E-08	1.30E-08	1.31E-08	1.06E-08	1.15E-08	1.07E-08
Human toxicity, non-cancer effects	CTUh	1.70E-08	1.66E-08	1.69E-08	1.99E-08	1.74E-08	1.73E-08	1.85E-08
Human toxicity, cancer effects	CTUh	6.70E-09	6.61E-09	6.62E-09	8.56E-09	7.69E-09	7.52E-09	8.27E-09
Particulate matter	kg $PM_{2.5}$ eq	3.20E-05	3.17E-05	3.20E-05	3.85E-05	3.37E-05	3.29E-05	3.71E-05
Ionizing radiation HH	kBq U235 eq	8.93E-02	8.61E-02	8.71E-02	8.42E-02	6.66E-02	7.73E-02	6.72E-02
Ionizing radiation E (interim)	CTUe	1.43E-07	1.39E-07	1.41E-07	1.40E-07	1.11E-07	1.26E-07	1.10E-07
Photochemical ozone formation	kg NMVOC eq	1.75E-04	1.73E-04	1.78E-04	2.05E-04	1.77E-04	1.69E-04	1.90E-04
Acidification	molc H+ eq	2.93E-04	2.90E-04	2.95E-04	3.44E-04	2.98E-04	2.86E-04	3.08E-04
Terrestrial eutrophication	molc N eq	6.07E-04	6.00E-04	6.18E-04	7.07E-04	6.08E-04	5.79E-04	6.14E-04
Freshwater eutrophication	kg P eq	1.63E-05	1.55E-05	1.63E-05	1.81E-05	1.58E-05	1.51E-05	1.86E-05
Marine eutrophication	kg N eq	5.69E-05	5.61E-05	5.78E-05	6.60E-05	5.68E-05	5.41E-05	5.79E-05
Freshwater ecotoxicity	CTUe	4.09E-01	4.02E-01	4.12E-01	4.95E-01	4.38E-01	4.39E-01	4.85E-01
Land use	kg C deficit	1.49E-01	1.48E-01	1.52E-01	1.74E-01	1.51E-01	1.46E-01	1.54E-01
Water resource depletion	m^3 water eq	-9.25E-05	-9.33E-05	-9.15E-05	-1.17E-04	-9.85E-05	-8.38E-05	-8.68E-05
Mineral, fossil & ren. resource depletion	kg Sb eq	2.03E-06	2.01E-06	2.04E-06	2.36E-06	2.05E-06	2.08E-06	2.13E-06

Figure 13 compares the results on LCIA of different modes of rail freight transport in Belgium (year 2012) and the reference values from Ecoinvent v3 (year 2014). Diesel trains (including shunting activity) present the maximum impact in 11 indicators. It should be noted the high difference in comparison with the other rail freight transport modes due to the exhaust emissions produced in the diesel locomotives in the following indicators: photochemical ozone formation, acidification and terrestrial and marine eutrophication.

For the indicator climate change, diesel trains present the maximum impact due to the exhaust emissions during the transport activity. Even if the electric traction emits SF_6 during electricity conversion at traction substations, the main greenhouse gas emissions are produced in the electricity generation, especially in the natural gas power plants.

Electric trains present the maximum impact in the indicators related with the radiation due to the use of nuclear power in the electricity production in Belgium. The indicator "Human toxicity, cancer effects" shows similar values in the three rail freight transport modes studied due to the similar steel demand in the railway construction.

FIGURE 13. LCIA OF RAIL FREIGHT TRANSPORT IN BELGIUM



3.2.2. Comparison of the LCA emissions of inland freight transport modes in Belgium

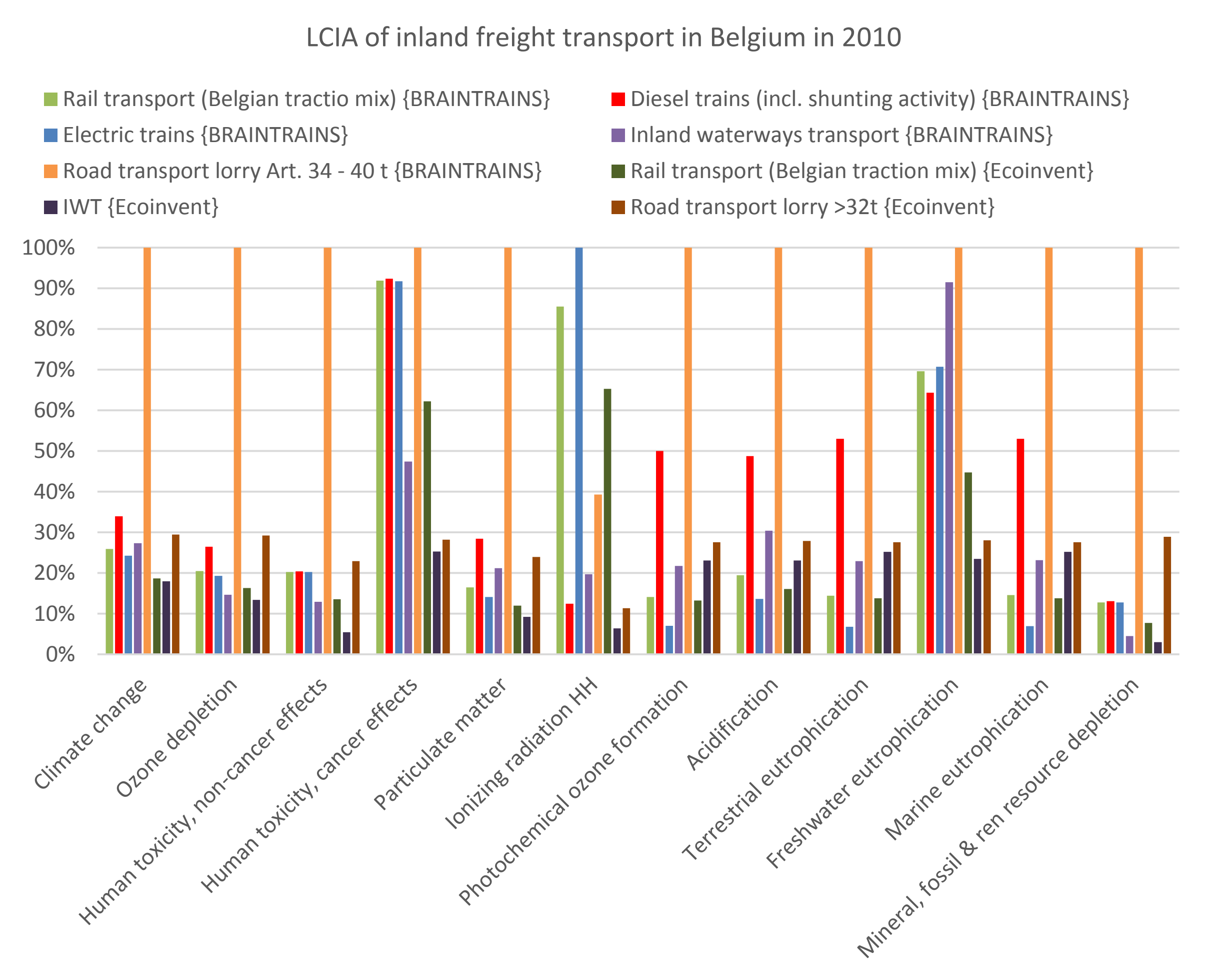
Figure 14 shows a comparison of the results on LCIA of different modes of inland freight transport in Belgium (year 2010) and the reference values from Ecoinvent v3 (year 2014). Road transport presents the maximum impact in all the indicators except the indicator ionizing radiation. The electric trains present the maximum impact in this indicator due to the use of nuclear power in the electricity generation in Belgium.

The exhaust emissions calculated during the road transport activity have caused the high difference in comparison with the other transport modes in the following indicators: climate change, photochemical ozone formation, acidification and terrestrial and marine eutrophication. Road transport presents an elevated fuel consumption and this, together the low load factor, has caused the high exhaust emissions of road freight transport.

For the indicator particulate matter, the direct emissions in the road transport activity of tire wear, break wear and road wear have a strong influence in the result of the indicator.

Focusing on the inland waterways transport, it presents a high impact in the indicators human toxicity, cancer effects and freshwater eutrophication. This is the result of the infrastructure demand of canals and port facilities.

FIGURE 14. LCIA OF INLAND FREIGHT TRANSPORT IN BELGIUM



4. CONCLUSION AND PERSPECTIVES

The energy efficiency in the railway sector will improve in the future. Some points to improve the efficiency of the rail freight transport will be the weight reduction through new materials of locomotives and wagons. This would allow the saving of the energy consumed during transport activity, but also energy consumed in the manufacture and disposal of rail vehicles. Moreover, the development of new engines, the energy recovery systems from braking and improved aerodynamics in rolling stock, will lead to a reduction in the energy consumption.

Furthermore, the use of cleaner energy such as electricity from renewable sources or replacing diesel by other sources of cleaner energy as biodiesel in diesel locomotives, will lead to the reduction of environmental impacts. It should be noted that the use of biodiesel produces advantages in terms of CO_2 emissions, but analysing the life cycle of the biodiesel the pollution could be transferred from air when combustion to soil and water during crop production. Therefore, the environmental advantages of the use of biodiesel depend on the specific type and source of the biodiesel.

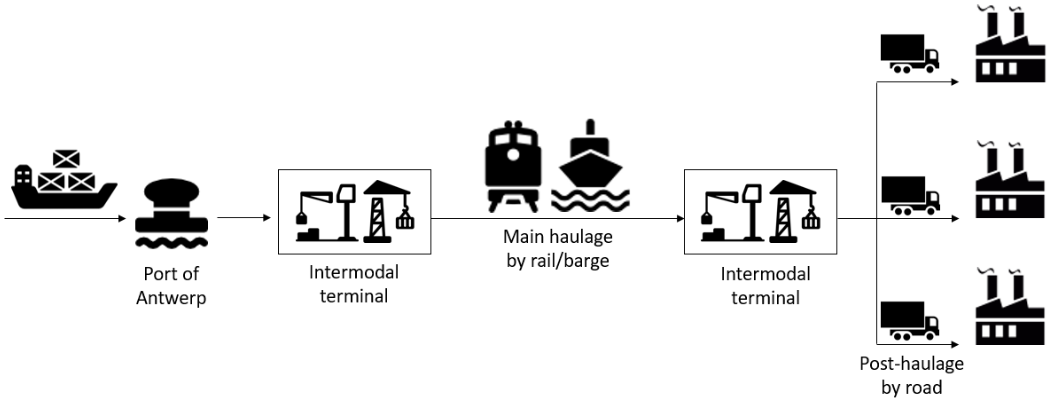
The environmental impacts related to the parameter energy consumption depend on the proportion of use of electric and diesel traction. A decrease in diesel traction of the rail freight transport in Belgium will lead to a reduction of exhaust emissions. However, the complete replacement of diesel traction by electric traction is difficult, because Belgium is mainly an exporter and importer of goods rather than a transit country. This activity causes a large shunting activity performed by diesel locomotives. Furthermore, the environmental impact related to electricity consumption depends on the electricity supply mix of Belgium. Therefore, in order to develop the scenarios it is necessary to know the proportion of use of electric traction and the electricity supply mix in Belgium with a time horizon in 2030.

In the framework of the BRAIN-TRAINs project, in a first stage we have analysed the environmental impacts of rail freight transport, inland waterways transport and road freight transport independently. The first results on energy consumption, direct emissions and impact assessment have been explained in the present deliverable. In the upcoming deliverables we will analyse how the possible increase of rail freight transport in the modal split affects the environmental impact of inland freight transport in Belgium. More precisely, the increase of rail demand to be analysed has been estimated in the deliverable D.1.3 of the BRAIN-TRAINS project as 133%, 64% or 10% for a best best-case scenario, medium-case scenario and worst-case scenario, respectively (Troch et al., 2015).

Since the BRAIN-TRAINS project deals with the possible development of intermodal freight transport in Belgium, in a second stage we will carry out a study of the environmental impacts related to intermodal freight transport. For this, we will proceed to collect data from intermodal freight operators to study existing intermodal routes. In collaboration with B-Logistics, some consolidated intermodal routes have been identified from the Port of Antwerp to the Port of Zeebrugge or the Terminal Container Athus. Moreover, the major international intermodal route from the Port of Antwerp to Ludwigshafen (Germany) could be analysed. Additionally, the environmental impact related to the handling of containers in the intermodal terminals could be analysed as well.

As shown in Figure 15, in the intermodal routes starting from the Port of Antwerp mentioned above, the main haulage (that is, the largest part of the journey) is made by rail (alternatively, inland waterways transport could be used). The post-haulage (that is, the final stage of the transport chain) is made by road. This last road transport stage should be as short as possible. At the intermodal terminal, the containers are transferred between modes of transport. Therefore, the intermodal terminal works like a point of collection, sorting, transhipment and distribution of goods.

FIGURE 15. INTERMODAL FREIGHT TRANSPORT WITH MAIN HAULAGE BY RAIL OR INLAND WATERWAYS TRANSPORT



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