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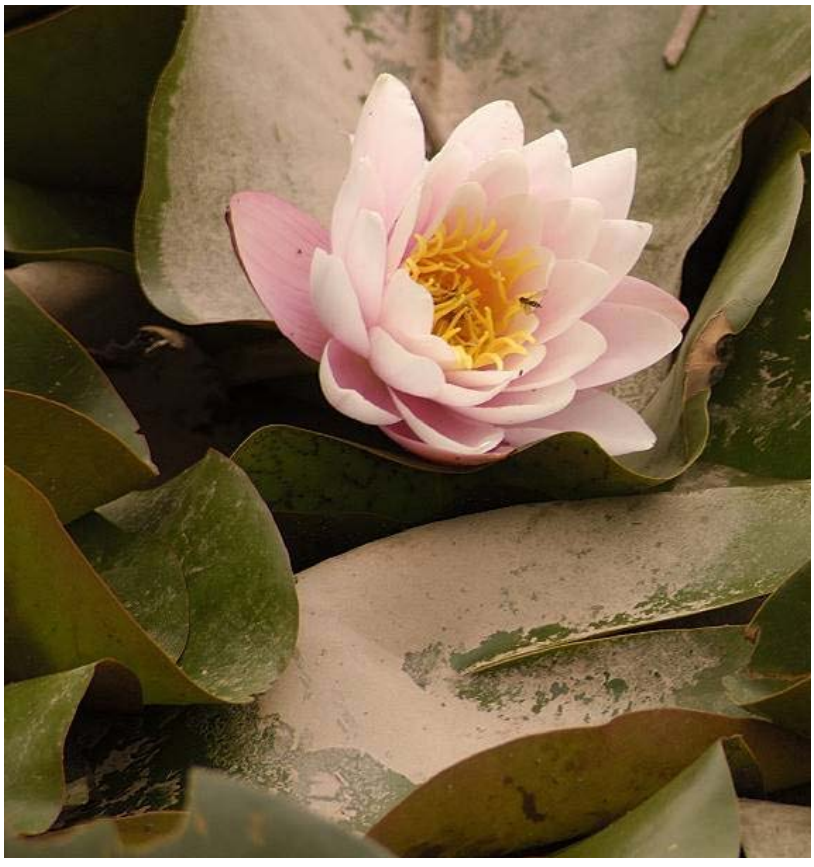
Study of the impacts on possible inclusion of the flexibility scheme for sectors currently not covered by Directive 97/68/EC (railcars, locomotives and inland waterway vessels)

European Commission, DG ENTR

Project number – 11/005092 | Version A | 31-05-2009



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PROJECTDESCRIPTION
Study of the impacts on possible inclusion of the flexibility scheme for sectors currently not covered by Directive 97/68/EC (railcars, locomotives and inland waterway vessels)

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ABBREVIATIONS AND GLOSSARY

ABT	Average trading and banking system used in the US
CCNR	Central Commission for Navigation on the Rhine
CI engine	compression ignited engine or diesel engine
DPF	diesel particulate filter; it is a device removing diesel particulate matter or soot from the exhaust gas of a diesel engine
EGR	Exhaust gas recirculation (EGR) is a nitrogen oxide (NOx) emissions reduction technique used in most gasoline and diesel engines. EGR works by recirculating a portion of an engine's exhaust gas back to the engine cylinders.
Externality	An externality occurs when an economic activity causes external costs or external benefits to third party stakeholders who did not directly affect the economic transaction.
GDP	Gross domestic product
HC	A hydrocarbon is an organic compound consisting entirely of hydrogen and carbon. Hydrocarbons contribute to the formation of ozone and the resulting smog problem. Hydro carbons come from the incomplete burning of any organic matter such as oil and the evaporation from petroleum fuels, solvents, dry cleaning solutions, and paint.
IMO	International maritime organization
IWT	Inland waterway transport
IWW	Inland waterways
Modal share	Modal share, describes the percentage of transport users using a particular type of transportation. For example, if 85% of all transport users use cars (passenger) or heavy duty vehicles (goods) to get from A to B, while 15% use the train. Then the railway c transport modal share is 15% while the motor vehicle modal share is 85%.
NO_x	Nitrogen oxide referring to any binary compound of oxygen and nitrogen, or to a mixture of such compound. NO_x react with volatile organic compounds in the presence of heat and sunlight to form Ozone. Ozone can cause adverse effects such as damage to lung tissue and reduction in lung function mostly in susceptible populations (children, elderly, asthmatics). Ozone can be transported by wind currents and cause health impacts far from the original sources.
NPV	Net present value; the net present value at time 0 of a stream of costs or benefits B0, $B_1 \ldots B_N$, is given by $NPV = B_0 + \frac{B_1}{1+r} + \ldots + \frac{B_N}{(1+r)^N}$ where r is the relevant discount rate
PM	Particulate matter (PM) or fine particles, are tiny particles of solid or liquid suspended in a gas. Human activities, such as the burning of fossil fuels in vehicles, power plants and various industrial processes generate significant amounts of particles. Increased levels of fine particles in the air are linked to health hazards such as heart disease, altered lung function and lung cancer.

Railcar	A railcar (not to be confused with a railway car) is a self-propelled railway vehicle designed to transport passengers.
SCR	Selective catalytic reduction (SCR) is a nitrogen oxide (NOx) reduction technique. It converts NOx with the aid of a catalyst into diatomic nitrogen, N2, and water, H2O. A gaseous reductant, typically urea, is added to a stream of flue or exhaust gas and is absorbed onto a catalyst. Carbon dioxide, CO2 is a reaction product when urea is used as the reductant.
Secondary engine	Secondary engines are defined in Directive 2002/88/EC as engines installed in or on a motor vehicle, but not providing motive power to the vehicle.
Shunter	A shunter or switcher is a small railroad locomotive intended not for moving trains over long distances but rather for assembling trains ready for a road locomotive to take over, disassembling a train that has been brought in.
SME	Small or medium enterprise
Sunk cost	Costs that cannot be recovered once they have been incurred.
TREMOVE	TREMOVE is a policy assessment model used by the EC to study the effects of different transport and environment policies on the transport sector. It covers all European countries and is developed by the Catholic University of Leuven and Transport & Mobility Leuven.
Ultra low sulphur diesel	standard for defining diesel fuel with substantially lowered sulphur contents

1 Introduction

1.1 Background

Directive 97/68/EC (hereafter 'NRMM Directive') recognizes as a fundamental principle - in relation to the environment and sustainable development - that all persons should be effectively protected against recognized health risks from air pollution and that this necessitates in particular the control of emissions of NO_2, particulates (PT) – black smoke and other pollutants (CO, NO_X, HC, e.a.). It also aims at establishing the internal market by harmonizing the laws between Member States, with the protection of environment and health as main objective.

The initial NRMM Directive adopted in 1997 covered only compression ignition (CI) engines for land based applications only, and introduced emission limit STAGES I & II for such engines.

The first amendment, Directive 2002/88/EC, enlarged the scope of application to spark ignition (SI) gasoline-fuelled engines up to 18 kW, as they are commonly used in lawn and garden machines (hedge trimmers, brush cutters, lawnmowers, garden tractors, snow blowers, etc.), in light-duty industrial machines (generator sets, welders, pressure washers, etc.) and in light logging machines (chainsaws, log splitters, shredders, etc.), and introduced emission limit stages I & II for these engines.

With a second amendment, Directive 2004/26/EC, engines for Inland Waterway Vessels (IWWV) and for railcars and locomotives were added to the scope of the Directive. That amendment also introduced more stringent emission limit values of exhaust emissions through new emission limit stages for engines already covered by the Directive, which depending on the type of machinery are entering into force following different timetables, the latest by the year 2014. These new emission limit stages are referred to as IIIA, IIIB and IV.

For every type of the engine and machinery covered by the Directive and its amendments, measurement procedures, operating and testing conditions are described in the Directive as well.

The flexibility scheme was introduced in the amendment of 2004/26/EC, to facilitate the transposition from stage II to stage IIIA, at a time when the scope of the Directive was broadened and adaptation provisions were considered indispensable.

The flexibility scheme is a procedure provided for in the NRMM Directive which allows an original equipment manufacturer to place on the market, during the period between two successive stages of limit values, a limited number of non-road mobile machinery which is fitted with engines that still comply with the previous stage of emission limit values.

The flexibility scheme can be used to place on the market compression ignition (diesel) engines used in construction and forestry machinery but not for propulsion of locomotives, railcars or inland waterway vessels (Article 4, § 6).

The current stage of emission limits applicable for type approval of the majority of diesel engines is referred to as Stage IIIA, but will be replaced by the more stringent Stage IIIB entering into force as of 1st January 2010.

According to the existing provisions, a manufacturer can choose between two alternative options for his decision to use the flexibility scheme:

Option 1 (percentage of annual sales)

The number of engines placed on the market under a flexibility scheme shall, in each engine (power) category, not exceed 20% of the manufacturer's annual sales of equipment with engines in that engine (power) category (calculated as the average of the latest 5 years sales on the EU).

Option 2 (fixed quantity)

As an optional alternative, the equipment manufacturer may seek permission for his engine suppliers to place on the market a fixed number of engines under the flexibility scheme. The fixed numbers of engines in each engine category that may be placed on the market under this option are limited to maximum values which are specified in the Directive. This table was included to accommodate small enterprises producing lower volumes of engines compared to big industries and that the included numbers of engines were the result of a discussion between Commission and industry.

The following table depicts the number of engines that would be allowed to be placed on the market in stage IIIB (for an equivalent 20% of annual sales):

ENGINE CATEGORY (kW)	Number of engines under **flexibility** scheme of **20%**
37-56	80
56-75	70
75-130	100
130-560	50

1.2 Objectives

The aim of this study is to assess the impacts, in case of inclusion to the flexibility scheme, of the propulsion engines presently excluded from the use of this measure, being installed in railcars, locomotives and inland waterway vessel, either by the use of the percentage or by the use of the fixed quantity from the OEM.

The study has been conducted for two different scenarios for the classification of engines according to power categories of stage IIIb:

Scenario No 1

Study of impacts of the implementation of the current flexibility scheme to the excluded sectors

Fixed numbers of engines (for increased flexibility of 20%)

ENGINE CATEGORY (kW)	Number of engines under

	flexibility scheme of **20%**
37-56	80
56-75	70
75-130	100
130-560	50

and

Scenario No 2

Study of impacts of the implementation to the excluded sectors, of an increased flexibility scheme to a percentage of 50% and a maximum quantity of fixed engine numbers as presented in the following table:

Fixed numbers of engines (for increased flexibility of 50%)

ENGINE CATEGORY (kW)	Number of engines under **flexibility** scheme of **50%**
37-56	200
56-75	175
75-130	250
130-560	125

As the "fixed quantity" option does not cover engines above 560 kW, it has not been explored further in this report.

1.3 General approach and common assumptions

All the scenarios analysed in this study share a series of common assumptions.

First, for the unit values of external costs, we use the average value for the EU provided in the European Handbook on external costs (CE Delft, 2008) – this is consistent with the approach used in the IA Study.

Table 1-1: Average external costs (EUR/ton)

5155	NO_x
30625	PM
1171	HC

Second, all costs and benefits are discounted to 2007, at a discount rate of 4%.

Third, we evaluate three possible assumptions with respect to the time frame within which the IIIA engines allowed under the flexibility mechanism are allowed on the market:

- All engines covered by the flexibility mechanism are put on the market in the first year of stage IIIB (“one year flexibility”)
- All engines covered by the flexibility mechanism are put on the market in the first two years of stage IIIB, spread evenly over this period (“two year flexibility”).
- All engines covered by the flexibility mechanism are put on the market in the first three years of stage IIIB, spread evenly over this period (“three year flexibility”).

2 Railcars and locomotives

In the IA study, the following options have been considered:

- Option 0: no action or leaving the stage IIIB limit introduction in 2012 for both railcars and locomotives
- Option 1: set the stage IIIb limit for all rail vehicles in 2016
- Option 2: set the stage IIIb limit for big railcars and locomotives (> 560 kW) in 2016; keep the stage IIIb limit for small railcars and locomotives (<560 kW) in 2012

In what follows, we systematically undertake the following steps for all engines:

- We calculate the difference in annual NOx and PM emission between an average IIIA and an average IIIB engine for each power class, using the technical assumptions used in the IA study; these technical assumptions may depend on the option under analysis.
- We combine these data with the unit external costs to obtain the annual difference in external costs between an average IIIA and an average IIIB engine for each power class.
- We combine the assumed engine lifetime expressed in hours with the average hours of use per year, to obtain the expected engine lifetime in years.
- We estimate the average number of engines put yearly on the market in the 5 years preceding the beginning of stage IIIB (which may vary, depending on the engine application and on the option under analysis)
- We combine this estimate with the allowed flexibility to obtain the number of IIIA engines that can be put on the market in the first three years of stage IIIB; we consider three possible scenarios for the distribution over time of the placing on the market of these engines (see above).
- Compliance costs are calculated as the additional cost of a IIIB engine compared to a IIIIA engine. Investment expenses are only incurred in the year the engine is put on the market, while maintenance and user costs are incurred until the engine is taken out of operation (this, until the end of the calculated lifetime). Saved expenses are thus mainly concentrated at the beginning of IIIB.
- For all applications, more than one technical solution is possible to comply with stage IIIB. We shall assume that the manufacturer will always choose the solution with the lowest net present value of compliance costs. As the assumed solution does not depend on the power of the engine, but only on the application, the same solution will be chosen for each application, independently of the option and the flexibility scheme under consideration.
- Additional external costs are directly proportional to the number of IIIA engines that are in operation. They thus first increase until all IIIA engines allowed under flexibility have been put on the market, and remain constant until the first batch of IIIA engines are reaching the end of their economic life; total additional external costs then decline.
- Finally, we calculate the net present value (NPV) of additional costs and benefits, using the same discount rate as in the IA study.

In what follows, we shall first present the used projection of new diesel engines for railway applications until 2020. Next, we shall successively analyse the changes in

compliance costs and external costs for each railway application (railcars, shunters and mainline locomotives). For each application, we calculate how each possible variant of the flexibility scheme leads to changes compared to the options analyse in the IA study. Section 2.5 summarizes.

2.1 Projections of post 2004 engines

As in the IA study, we use the Rail Diesel Study for our projections of the **cumulative** total number of post-2004 diesel rail engines (see Table 2-1). These projections are differentiated according to the application (railcar, shunters and mainline locomotives), but not according to power class. As some options under analysis depend on the power of the engine, assumption will be made on the distribution of these engines according to their power class.

Table 2-1: Projected estimates for the **cumulative** total number of post-2004 diesel rail engines according to the rail diesel study[1]

Year	Diesel railcar engines	Mainline loco engines	Shunting loco engines
2005	775	635	419
2006	1549	1272	839
2007	2325	1911	1261
2008	3100	2553	1684
2009	3877	3197	2109
2010	4653	4020	2652
2011	5430	4846	3197
2012	6207	5674	3743
2013	6985	6504	4291
2014	7796	7336	4840
2015	8203	7364	4859
2016	8644	7395	4879
2017	9086	7427	4900
2018	9527	7462	4923
2019	9969	7498	4947
2020	11292	7464	4925

2.2 Railcars

For railcars, we maintain the assumptions used in the IA study with respect to emission factors and average power, load factors and operating hours per year. We assume a load factor fraction of 0.3 and 3500 hours of use per year. All railcars have an engine power above 130 kW.

Table 2-2: Emission factors and average power for railcars

Engine emission level class	Emission factor NOx g/kWh	Emission factor PM g/kWh	avg power kW
1980-1989	13.7	0.53	350
1990-2004	7	0.14	350
2004-Stage IIIA	6	0.1	400

[1] Table 3.1 and 3.2 in Rail Diesel Study WP4 (page 13)

Stage IIIA	3.6	0.1	400
Stage IIIB	2	0.025	400

Combining the emission factors and average power of Table 2-2 with the assumed load factors and yearly operating hours, we obtain the difference in annual NOx and PM emissions between a typical IIIA and a typical IIIB railcar. When we combine this further with the unit external costs of Table 1-1, we obtain the average difference in external costs per year – see Table 2-3.

Table 2-3: Difference between stage IIIA and stage IIIB railcar

NOx emissions per year (tonnes)	0.672
PM emissions per year (tonnes)	0.0315
external costs per year (EUR)	4429

As in the IA study, we assume an engine lifetime of 25 000 hours.

Combined with the average hours of use per year, this yields an expected engine lifetime of (approximately) 7 years.

We envisage two possible technical solutions, with respective compliance costs:

Table 2-4: Compliance costs for railcars

	DPF +EGR	SCR
Investment cost	15000	15000
Operating cost	4000	5000
NPV (EUR)	38,431.30	50,000.00

Thus, we shall assume from now on that the manufacturers will choose a combination of DPF and EGR to obtain compliance for railcars. Annual compliance costs with SCR will be represented for informational purposes only.

We now analyse the changes in compliance and environmental costs for option 0 and 1 respectively. For railcars, option 2 is the same as option 0. Therefore we do not report seperately on option 2.

2.2.1 Option 0

Under option 0, the stage IIIb emission limits for railcars become applicable in 2012.

In the 5 years preceding 2012, the expected average annual sales of equipment with engines in that engine (power) category are 776.2 units (see Table 2-1).

Table 2-5 gives the number of engines that are allowed annually on the market, depending on how many years of flexibility are allowed. The table assumes 7 years of lifetime.

Table 2-5: Railcar flexibility under option 0

Years of flexibility	Years for placing on the market	Annual # engines under 20% flexibility	Annual # engines under 35% flexibility	Annual # engines under 50% flexibility	Year of withdrawal from the market
1 year flexibility	2012	155	272	388	2018
2 year flexibility	2012-2013	78	136	194	2018-2019
3 year flexibility	2012-2014	52	91	129	2018-2020

We now consider the three possible scenarios for the timing of the flexibility mechanism.

For the sake of illustration, we give the detailed distribution over time of the changes in compliance costs (for both technical solutions) and of the changes in external costs in:

- Table A-1 for one year flexibility
- Table A-2 for two year flexibility
- Table A-3 for three year flexibility

And this for the 20% flexibility scheme – the detailed results for 35% and 50% flexibility are available on request.

Table 2-6 gives the NPV of benefits and costs for each variant under option 0 Despite the fact that the annual increase in environmental costs is larger than the annual savings in operating costs (with DPF and EGR), the NPV of saved compliance costs is larger than the NPV of increased environmental costs – this uniquely due to the initial investment costs.

The longer the flexibility period, the lower both the savings in compliance costs and the increases in environmental costs. This is uniquely due to the fact that part of these costs and benefits now accrue with a one year lag. Due to discounting, they weigh less heavily in the calculation of the NPV.

Table 2-6: NPV of net benefits of flexibility for railcars under option 0

	20% flexibility	35% flexibility	50% flexibility
One year flexibility			
NPV saved compliance costs with DPF+EGR	5,099,825	8,924,694	12,749,563
NPV additional environmental costs	3,527,451	6,173,039	8,818,627
NPV net benefits with DPF +EGR	1,572,375	2,751,656	3,930,937

Two year flexibility			
NPV saved compliance costs with DPF+EGR	5,001,752	8,753,066	12,504,379
NPV additional environmental costs	3,459,615	6,054,326	8,649,038
NPV net benefits with DPF +EGR	1,542,137	2,698,739	3,855,342
Three year flexibility			
NPV saved compliance costs with DPF+EGR	4,906,193	8,585,838	12,265,482
NPV additional environmental costs	3,393,519	5,938,658	8,483,797
NPV net benefits with DPF +EGR	1,512,674	2,647,180	3,781,685

2.2.2 Option 1

Under option 1, the stage IIIb emission limits for railcars become applicable in 2016. [2]

The reader has to keep in mind that the baseline for this calculation is option 1 without flexibility, **not** option 0.

In the 5 years preceding 2016, the expected average annual sales of equipment with engines in that engine (power) category are 710 units (see Table 2-1).

Table 2-7 gives the number of engines that are allowed annually on the market, depending on how many years of flexibility are allowed. The table assumes 7 years of lifetime.

Table 2-7: Railcar flexibility under option 1

	Years for placing on the market	Annual # engines under 20% flexibility	Annual # engines under 35% flexibility	Annual # engines under 50% flexibility	Year of withdrawal from the market
1 year flexibility	2016	142	249	355	2022
2 year flexibility	2016-2017	71	124	178	2022-2023
3 year flexibility	2016-2018	47	83	118	2022-2024

[2] At least if one assumes, as was done in the IA study, that all railcar engines have a power below 560 kW.

The distribution over time of the changes in compliance costs (for both technical solutions) and of the changes in external costs are given in:

- Table A-4 for one year flexibility
- Table A-5 for two year flexibility
- Table A-6 for three year flexibility

And this for the 35% flexibility scheme – the detailed results for 20% and 50% flexibility are available on request.

Table 2-8 gives the NPV of benefits and costs.

We observe that the costs and the benefits of flexibility are smaller when option 1 is chosen than when option 0 is chosen. This is due to the fact that, compared to option 0, 2 things have changed:

- Both costs and benefits are now in a more distant future, and are thus discounted more heavily.
- The number of engines that are expected to be put on the market in the 5 years preceding stage IIIB is lower; this also implies that, for any flexibility variant, the engines that are allowed under the flexibility scheme are also lower than under option 0.

Table 2-8: NPV of net benefits of flexibility for railcars under option 1

	20% flexibility	35% flexibility	50% flexibility
One year flexibility			
NPV saved compliance costs with DPF+EGR	3,987,555	6,978,221	9,968,887
NPV additional environmental costs	2,758,115	4,826,701	6,895,286
NPV net benefits with DPF +EGR	1,229,440	2,151,520	3,073,600
Two year flexibility			
NPV saved compliance costs with DPF+EGR	3,910,871	6,844,024	9,777,177
NPV additional environmental costs	2,705,074	4,733,879	6,762,685
NPV net benefits with DPF +EGR	1,205,797	2,110,145	3,014,493
Three year flexibility			
NPV saved compliance costs with DPF+EGR	3,836,153	6,713,269	9,590,384
NPV additional environmental costs	2,653,393	4,643,438	6,633,483
NPV net benefits with DPF +EGR	1,182,760	2,069,830	2,956,901

2.3 Shunters

We maintain the assumptions used in the IA study with respect to emission factors and average power, load factors and operating hours per year. We assume a load factor fraction of 0.15 and 2000 hours of use per year.

Table 2-9: Emission factors and average power for shunters

Engine size class	Engine emission level class	Emission factor NOx g/kWh	Emission factor PM g/kWh	avg power kW
130-560 kW	Stage IIIA	3.6	0.1	540
130-560 kW	Stage IIIB	3.6	0.025	540
561-2000 kW	Stage IIIA	6	0.1	1250
561-2000 kW	Stage IIIB	3.6	0.025	1250

Combining the emission factors and average power of Table 2-9 with the assumed load factors and yearly operating hours, we obtain the difference in annual NOx and PM emissions between a typical IIIA and a typical IIIB shunter. When we combine this further with the unit external costs of Table 1-1, we obtain the average difference in external costs per year – see Table 2-10.

Table 2-10: Difference between stage IIIA and stage IIIB shunter

	130-560 kW	561-2000 kW
NOx emissions per year (tonnes)	0	0.9
PM emissions per year (tonnes)	0.01215	0.028125
external costs per year (EUR)	372.09375	5500.828125

As in the IA study, we assume an engine lifetime of 25 000 hours.

Combined with the average hours of use per year, this yields an expected engine lifetime of (approximately) 12.5 years – for the ease of calculations, we will assume 13 years.

We envisage two possible technical solutions, with respective compliance costs:

Table 2-11: Compliance costs for shunters

	DPF +EGR	SCR
Investment cost	30000	30000
Operating cost	5000	4000
NPV	75,771.52	66,386.45

Thus, we shall assume from now on that the manufacturers will choose for SCR to obtain compliance for shunters. Annual compliance costs with DPF+EGR will be represented for informational purposes only.

As the projections of the rail diesel study do not differentiate according to power class, but the options analysed in the IA do, we assume that 70% of the shunters are in the power category 130-560 kW, and 30% are in the power category 560-2000 kW. This is consistent with the assumptions used in the IA study.

2.3.1 Option 0

Under option 0, the stage IIIb emission limits for railcars become applicable in 2012.

In the 5 years preceding 2012, the expected average annual sales of engines for shunters are 471.6 units (see Table 2-1). Note that we need to differentiate between power classes because the emission factors depend on the power class (see Table 2-9).

Table 2-12 gives the number of engines that are allowed annually on the market, depending on how many years of flexibility are allowed. This table assumes a lifetime of 13 years.

Table 2-12: Shunter flexibility under option 0

Years of flexibility	Power range	Years for placing on the market	Annual # engines under 20% flexibility	Annual # engines under 35% flexibility	Annual # engines under 50% flexibility	Year of withdrawal from the market
One year flexibility	130-560 kW	2012	66	116	165	2024
	560-2000 kW		28	50	71	
Two year flexibility	130-560 kW	2012-2013	33	58	83	2024-2025
	560-2000 kW		14	25	35	
Three year flexibility	130-560 kW	2012-2014	22	39	55	2024-2026
	560-2000 kW		9	17	24	

The distribution over time of the changes in compliance costs (for both technical solutions) and of the changes in external costs are given by:

- Table A-9 for one year flexibility
- Table A-10 for two year flexibility
- Table A-11 for three year flexibility

And this for the 20% flexibility scheme – the detailed results for 35% and 50% flexibility are available on request.

Table 2-13 gives the NPV of benefits and costs. In the case of shunters, the annual operating costs due to compliance are higher than the annual environmental costs. Table

2-13 shows that there is a much more pronounced gap between compliance costs and environmental costs than in the case of railcars.

As in the case with railcars, we see that if the same number of IIIA engines is allowed on the market over a longer period, the NPV of both saved compliance costs and increased environmental costs is lower. The NPV of total benefits is also lower, which is due to the high value of the investment costs.

Table 2-13: NPV of net benefits of flexibility for shunters under option 0

	20% flexibility	35% flexibility	50% flexibility
One year flexibility			
NPV saved compliance costs with SCR	5,546,102	9,705,678	13,865,254
NPV additional environmental costs	1,538,305	2,692,033	3,845,762
NPV net benefits with SCR	4,007,797	7,013,645	10,019,492
Two year flexibility			
NPV saved compliance costs with SCR	5,439,446	9,519,030	13,598,615
NPV additional environmental costs	1,508,722	2,640,263	3,771,805
NPV net benefits with SCR	3,930,724	6,878,767	9,826,810
Three year flexibility			
NPV saved compliance costs with SCR	5,335,525	9,337,168	13,338,812
NPV additional environmental costs	1,479,898	2,589,821	3,699,744
NPV net benefits with SCR	3,855,627	6,747,347	9,639,068

2.3.2 Option 1

Under Option1, Stage IIIb limits are postponed to 2016 for all shunters.

In the 5 years preceding 2016, the expected average annual sales of engines for shunters are 441 units (see Table 2-1). Note that we need to differentiate between power classes because the emission factors depend on the power class (see Table 2-9).

Compared to option 0, 2 things have changed:

- Both costs and benefits are now in a more distant future, and are thus discounted more heavily.
- The number of engines that are expected to be put on the market in the 5 years preceding stage IIIB is lower; this also implies that, for any flexibility variant, the

engines that are allowed under the flexibility scheme are also lower than under option 0.

Table 2-14 gives the number of engines that are allowed annually on the market, depending on how many years of flexibility are allowed.

Table 2-14: Shunter flexibility under option 1

Years of flexibility	Power range	Years for placing on the market	Annual # engines under 20% flexibility	Annual # engines under 35% flexibility	Annual # engines under 50% flexibility	Year of withdrawal from the market
One year flexibility	130-560 kW	2016	62	108	154	2028
	560-2000 kW		26	46	66	
Two year flexibility	130-560 kW	2016-2017	31	54	77	2028-2029
	560-2000 kW		13	23	33	
Three year flexibility	130-560 kW	2016-2018	21	36	51	2028-2090
	560-2000 kW		9	15	22	

The distribution over time of the changes in compliance costs (for both technical solutions) and of the changes in external costs are given by:

- Table A-12 for one year flexibility
- Table A-13 for two year flexibility
- Table A-14 for three year flexibility

And this for the 35% flexibility scheme – the detailed results for 20% and 50% flexibility are available on request.

Table A-7 gives the NPV of benefits and costs – the interpretation of the differences compared to option 0 is similar to the interpretation in the case of railcars.

2.3.3 Option 2

In the case of option 2, Stage IIIB is postponed until 2016 for shunters with a power above 560 kW.

This implies that we now need to differentiate between power classes, not only because the emission factors depend on the power class (see Table 2-9), but also because the timing of the flexibility scheme depends on the power class.

In the 5 years preceding 2012, the annual sales of shunters engines with power < 560 kW is expected to be 330 units; in the 5 years preceding 2016, the annual sales of shunter engines with power > 560 kW was 132.42 units (see Table 2-1).

Table 2-15 gives the number of engines that are allowed annually on the market, depending on how many years of flexibility are allowed.

Table 2-15: Shunter flexibility under option 2

Years of flexibility	Power range	Years for placing on the market	Annual # engines under 20% flexibility	Annual # engines under 35% flexibility	Annual # engines under 50% flexibility	Year of withdrawal from the market
One year flexibility	130-560 kW	2012	66	116	165	2024
	560-2000 kW	2016	26	46	66	2028
Two year flexibility	130-560 kW	2012-2013	33	58	83	2024-2025
	560-2000 kW	2016-2017	13	23	33	2028-2029
Three year flexibility	130-560 kW	2012-2013	22	39	55	2024-2026
	560-2000 kW	2016-2017	9	15	22	2028-2030

The distribution over time of the changes in compliance costs (for both technical solutions) and of the changes in external costs are given by:

- Table A-15for one year flexibility
- Table A-16 for two year flexibility
- Table A-17 for three year flexibility

And this for the 50% flexibility scheme – the detailed results for 20% and 35 % flexibility are available on request.

Table A-8 gives the NPV of benefits and costs – the interpretation of the differences compared to option 0 is similar to the interpretation in the case of railcars.

2.4 Mainline locomotives

The technical assumptions are again taken from the IA study.

We assume a load factor of 0.25 and 2000 hours of usage per year for all engine size classes.

Table 2-16: Emission factors and average power for mainline locomotives

engine size class	engine emission level class	NOX g/kWh	PM g/kWh	avg powr kW
561-2000 kW	1980-1989	15.4	0.34	1700
561-2000 kW	1990-2004	10.7	0.16	1700
561-2000 kW	2004-stage IIIA	9.9	0.1	1900
561-2000 kW	Stage IIIA	6	0.1	1900
561-2000 kW	Stage IIIB	3.6	0.025	1900
> 2000 kW	1980-1989	15.4	0.34	2000
> 2000 kW	1990-2004	10.7	0.16	2000
> 2000 kW	2004-stage IIIA	9.9	0.1	2200
> 2000 kW	Stage IIIA	7.4	0.1	2200
> 2000 kW	Stage IIIB	3.6	0.025	2200

Combining the emission factors and average power of Table 2-16 with the assumed load factors and yearly operating hours, we obtain the difference in annual NOx and PM emissions between a typical IIIA and a typical IIIB mainline locomotive. When we combine this further with the unit external costs of Table 1-1, we obtain the average difference in external costs per year – see Table 2-17.

Table 2-17: Difference between stage IIIA and stage IIIB mainline locomotive

	561-2000 kW	> 2000 kW
NOx emissions per year (tonnes)	3.42	6.27
PM emissions per year (tonnes)	0.106875	0.12375
external costs per year (EUR)	17630.1	32321.85

As in the IA study, we assume an engine lifetime of 30 000 hours.

Combined with the average hours of use per year, this yields an expected engine lifetime of (approximately) 10 years.

We envisage two possible technical solutions, with respective compliance costs:

Table 2-18: Compliance costs for mainline locomotives

	EGR	SCR
Investment cost	80000	85000
Operating cost	30000	15000

NPV	320,250	203,394

Despite the lower investment costs of EGR, with an expected lifetime of 10 years, the lower operating costs linked to SCR lead to a clear cost advantage. Thus, we shall assume from now on that the manufacturers will choose SCR to obtain compliance for mainline locomotives.

We assume that 85% of the mainline locomotives are in the power category 560-2000 kW, and 15% are in the power category above 2000 kW. This is consistent with the assumptions used in the IA study.

For mainline locomotives, option 2 is the same as option 1, and will therefore not be discussed separately.

2.4.1 Option 0

In the 5 years preceding 2012, the expected average annual sales of engines for mainline locomotives are 714.8 units (see Table 2-1). We need to differentiate according to power class because the emission factors depend on the power class.

Table 2-19 gives the number of engines that are allowed annually on the market, depending on how many years of flexibility are allowed.

Table 2-19: Loco flexibility under option 0

Years of flexibility	Power range	Years for placing on the market	Annual # engines under 20% flexibility	Annual # engines under 35% flexibility	Annual # engines under 50% flexibility	Year of withdrawal from the market
One year flexibility	560-2000 kW	2012	122	213	304	2021
	> 2000 kW		21	38	54	
Two year flexibility	560-2000 kW	2012-2013	61	106	152	2021-2022
	> 2000 kW		11	19	27	
Three year flexibility	560-2000 kW	2012-2014	41	71	101	2021-2023
	> 2000 kW		7	13	18	

Table A-18 gives the NPV of benefits and costs.

2.4.2 Option 0b

During the IA study, the railway industry had raised the specific concern that no IIIB locomotives might be available at all before 2016. In this case, sticking to option 0 would actually lead to negative environmental impacts, because very old engines would be kept

in operation, rather than being replaced by IIIA engines. We will therefore explore this possibility, which we will call “Option 0b”. Due to limitations in data availability, our approach here will differ slightly from the approach used in the IA study.

With an engine lifetime of ten years, we assume that the old engines that will remain in operation under option 0b would have been placed on the market in the period 1990-2004. Combining the emission factors and average power of Table 2-16 with the assumed load factors and yearly operating hours, we obtain the difference in annual NOx and PM emissions between a typical locomotive put on the market in 1990-2004 and a typical IIIA mainline locomotive. When we combine this further with the unit external costs of Table 1-1, we obtain the average difference in external costs per year – see Table 2-20.

Table 2-20 Difference between 1990-2004 and IIIA mainline locomotive

	560-2000 kW	> 2000 kW
NOx emissions per year (tonnes)	5.0925	3.84
PM emissions per year	0.0615	0.075
external costs per year (EUR)	26252	19795

In order to estimate the number of “old” mainline locomotives that would be kept on the market under option 0b, we use the average of the projection of new engines put on the market in the period 2012-2015 (Table 2-1) – using average numbers rather the year per year estimate allows to smooth out outliers. We assume that the “old” mainline locomotives are subsequently taken out of operation pro rata the number of stage IIIB complaint engines that are put on the market. As it can be expected that, after 2016, railway operators will want to catch up with the delayed replacement of old vehicles, we shall assume that the annual replacement rate will again be equal to the average of the projection of new engines put on the market in the period 2012-2015.

Table 2-21: Cumulated number of old loco engines kept on the market under option 0 if no IIIB engines available

	2012	2013	2014	2015	2016	2017	2018
560-2000 kW	535.075	1070.15	1605.225	2140.3	1605.225	1070.15	535.075
> 2000 kW	94.425	188.85	283.275	377.7	283.275	188.85	94.425
Sum	629.5	1259	1888.5	2518	1888.5	1259	629.5

In this case, option 0 would lead to an additional environmental cost, which is represented in Table 2-22.

Table 2-22: Increased environmental cost under option 0 if no IIIB engines available

	2012	2013	2014	2015	2016	2017	2018
560-2000 kW	14,046,702	28,093,404	42,140,106	56,186,808	42,140,106	28,093,404	14,046,702
> 2000 kW	1,869,162	3,738,324	5,607,485	7,476,647	5,607,485	3,738,324	1,869,162
Sum	15,915,864	31,831,727	47,747,591	63,663,455	47,747,591	31,831,727	15,915,864

The NPV of this increase is 218,098,023 EUR.

Under a flexibility scheme, part of these old engines would still be replaced by IIIA engines. In this case, flexibility would thus allow a *decrease* in environmental costs.

Table A-20 to Table A-28 give the number of "old" engines kept on the market for the different flexibility schemes. This allows then to calculate the NPV of the environmental gains (Table 2-23).

Table 2-23: Option 0b NPV of environmental gains compared to "no flex"

	20%	35%	50%
1 year	53,342,966	65,411,322	77,479,677
2 year	51,605,222	62,370,270	73,135,319
3 year	49,912,036	59,407,195	68,902,354

These savings in environmental costs are an underestimation of the benefits of flexibility under option0b. Indeed, under option 0b, maintenance costs and fuel consumption for railway operators will increase as they keep older engines in operations. These opportunity costs cannot be adequately captured with the data that are available.

2.4.3 Option 1

Under option 1, stage IIIB is postponed until 2016 for all mainline locomotives.

In the 5 years preceding 2016, the expected average annual sales of engines for mainline locomotives are 669 units (see Table 2-1). Table 2-24 gives then the number of engines that are allowed annually on the market, depending on how many years of flexibility are allowed.

Table 2-24: Locos flexibility under option 1

Years of flexibility	Power range	Years for placing on the market	Annual # engines under 20% flexibility	Annual # engines under 35% flexibility	Annual # engines under 50% flexibility	Year of withdrawal from the market
One year flexibility	560-2000 kW	2016	114	199	284	2027
	> 2000 kW		20	35	50	
Two year flexibility	560-2000 kW	2016-2017	57	99	142	2027-2028
	> 2000 kW		10	18	25	
Three year flexibility	560-2000 kW	2016-2018	38	66	95	2027-2029
	> 2000 kW		7	12	17	

2.5 Summary for railcars and locomotives

Table 2-27 to Table 2-29 give an overview of:

- Saved compliance costs
- Additional external costs
- Net benefits

For each option that has been taken into consideration in the IA study, and for each possible version of the flexibility scheme.

In the interpretation of these gains and losses, it is important to keep in mind that they are calculated relative to the option as analysed in the IA study, and not relative to option 0.

A few points are immediately obvious:

- The net benefits of increased flexibility are always positive. This is not surprising, as the IA study had already indicated that option 1 would lead to net benefits for society, at least for the compliance costs reported on pp 180-182 of the IA study.
- For each option, the highest benefits are always obtained for 1 year flexibility and 50% flexibility.

Therefore, it is enlightening to calculate the relative benefits and costs of each variant of the flexibility scheme compared to the (1 year, 50% combination). This is summarized in Table 2-30. This summary table shows clearly that the benefits and costs of spreading the flexibility scheme over a longer period of time are very small compared to the benefits and costs of changes in the flexibility percentage.

This does not however necessarily imply that the flexibility, *if applied to railway applications*, should entirely be concentrated in the first year. Indeed, flexibility does not only allow to decrease compliance costs by postponing compliance for part of the product range. Flexibility also allows manufacturers to cope with capacity constraints, to realise economies of scale for individual product series and to smooth out peaks in demand. For this purpose, it might be better to spread flexibility over a longer period of time. These benefits cannot be captured adequately with the data we have at hand, but could very well be the most important benefits of flexibility.

Another point to keep in mind is that most of the analysis above was conducted under the assumptions that meeting stage IIIB would actually be technically feasible. When we compare the estimates of Table 2-27 to Table 2-29 with the results of Table 2-23, we see that the saved compliance costs are slightly smaller the environmental *benefits* of flexibility under option 0 in case no stage IIIB locomotives would be available before 2016. Thus, if it would be decided to stock to option 0, the most important benefit of flexibility may well lie in smaller environmental costs rather than in smaller compliance costs (at least, if it is not possible for the railway industry to comply with stage IIIB for locomotives before 2016).

It is also enlightening to compare these results with those obtained in the IA study.

Table 2-25: Benefits of option 1 and option 2 compared to option 0 according to the IA study

	Option 1	Option 2
Decrease in compliance cost (million EUR)	1034	802

Increase in environmental costs (million EUR)	671	549
Net benefit (million EUR)	363	253

This shows that the **NPV of increased flexibility is more than an order of magnitude smaller than the NPV of moving to option 1 or option 2**. This is true, both for the (negative) environmental impacts as for the (positive) impacts on compliance costs.

We should also remind the reader that the IA study has concluded that a lot of uncertainty surrounds actual compliance costs. The IA study has proposed an alternative estimate of compliance costs that led to the conclusion that option 1 and 2 would actually lead to **net losses** for society compared to option 0.

Therefore:

- With environmental costs and compliance costs that are roughly of the same order of magnitude
- With significant uncertainty surrounding compliance costs

the most important benefit of flexibility is probably that it allows coping with the possibility that complying with stage IIIB would be technically infeasible for mainline locomotives in 2012. If this is indeed the case, then flexibility brings clear net benefits to society.

Table 2-26 gives an overview of the most important effects of increased flexibility.

Table 2-26: Overview of the possible impacts of flexibility (railway applications)

Category	Discussion
Functioning of the internal market	Increased flexibility would attenuate some of the issues that had been identified in the IA study in case option 0 would be maintained: • Possible temporary monopoly position of the first manufacturer to develop IIIb compliant engines • Withdrawal of some railcars from the UK market due to size restrictions • Decrease of competition in locomotive market if manufacturers are not ready in time to comply with stage IIIB • Negative impact on competition between rail operators (incumbents can use their existing rolling stock, new entrants will have to buy compliant material) • Cross-border transport will be reduced as maintenance and refuelling facilities will not be installed across the EU unless specified in TSI's Even in the absence of flexibility, option 1 would solve most problems related to the functioning of the internal market. The impact of increased flexibility on the functioning of the internal market would thus be very small if option 1 would be chosen. Even in the absence of flexibility, option 2 would solve most problems related to the functioning of the internal market for the engines categories > 560 kW. The impact of increased flexibility on the functioning of the internal market would thus be very small *for this engine category* if option 1 would be chosen. For engines < 560 kW, increased flexibility would attenuate some of the issues that had been identified in the IA study.

Competitiveness, trade and investment flows	Actual compliance costs saved under flexibility are very small compared to the savings that are possible under option 1 and 2. Therefore, the effects of flexibility on competitiveness, trade and investment flows are also likely to be very small compared to the effects of choosing option 1 or 2.
Operating costs and costs of business	Actual compliance costs saved under flexibility are very small compared to the savings that are possible under option 1 and 2.
Administrative burden to companies/SME's	No SMEs are involved in the production of railway engines or locomotives. Some rail freight operators are SMEs. For those operators who plan to renew their fleet in 2012-2016, increased flexibility could bring benefits (as they are likely to buy small numbers of locomotives anyway). However, due to the small number of engines allowed under the flexibility scheme, they are unlikely to affect the market price in a significant way.
Property rights	The project team has investigated this point, but has not identified any information that indicates that this could be an issue.
Innovation and technological development	Increased flexibility would allow for a longer development period for some engine series. However, this effect is very small compared to the effect of postponing IIIB until 2016.
Consumer and households	Actual compliance costs saved under flexibility are very small compared to the savings that are possible under option 1 and 2. Therefore, the impacts on consumer and households are likely to be negligible compared to the impacts of adoption option 1 or 2
Specific regions, sectors or workers	The impact of increased flexibility on specific regions, sectors or workers are likely to be negligible compared to the impacts of adoption option 1 or 2.
Third countries and international relations	Flexibility would not really change anything.
Impact on public authorities, including administrative costs	Actual compliance costs saved under flexibility are very small compared to the savings that are possible under option 1 and 2. Therefore, the impacts on financial transfers from public authorities to railway operators are likely to be negligible compared to the impacts of adoption option 1 or 2
Impact on macroeconomic environment	Actual compliance costs saved under flexibility are very small compared to the savings that are possible under option 1 and 2 (which had already been evaluated as being negligible from a macroeconomic point of view).
Employment and labour markets	Increased flexibility would somewhat attenuate the labour market impacts amongst locomotive manufacturers in case option 0 would be maintained, but less so than under option 1 or 2.
Standards and rights related to job quality	The project team has investigated this point, but has not identified any information that indicates that this could be an issue.
Social inclusion and protection of particular groups	The impact of increased flexibility on social inclusion and the protection of particular groups are likely to be negligible compared to the impacts of option 1 or 2.

Public health and safety	The impact of increased flexibility on the environment is likely to be negligible compared to the impacts of option 1 or 2.

Table 2-27: Summary table for 1 year flexibility (railcars and locomotives)

Flexibility percentage	0.2			0.35			0.5		
	Option 0	Option 1	Option 2	Option 0	Option 1	Option 2	Option 0	Option 1	Option 2
Saved compliance costs	35,501,270	28,303,960	30,192,433	62,127,222	49,531,930	52,836,758	88,753,175	70,759,900	75,481,082
Increase in external costs	24,724,569	19,711,867	20,523,130	43,267,996	34,495,768	35,915,477	61,811,422	49,279,668	51,307,824
Net benefits	10,776,701	8,592,093	9,669,303	18,859,227	15,036,162	16,921,281	26,941,753	21,480,232	24,173,259

Table 2-28: Summary table for 2 year flexibility (railcars and locomotives)

Flexibility percentage	0.2			0.35			0.5		
	Option 0	Option 1	Option 2	Option 0	Option 1	Option 2	Option 0	Option 1	Option 2
Saved compliance costs	34,818,553	27,759,653	29,611,809	60,932,468	48,579,393	51,820,666	87,046,383	69,399,132	74,029,523
Increase in external costs	24,249,096	19,332,793	20,128,454	42,435,919	33,832,387	35,224,794	60,622,741	48,331,982	50,321,135
Net benefits	10,569,457	8,426,860	9,483,355	18,496,549	14,747,005	16,595,872	26,423,642	21,067,150	23,708,388

Table 2-29: Summary table for 3 year flexibility (railcars and locomotives)

Flexibility percentage	0.2			0.35			0.5		
	Option 0	Option 1	Option 2	Option 0	Option 1	Option 2	Option 0	Option 1	Option 2
Saved compliance costs	34,153,342	27,229,303	29,046,073	59,768,348	47,651,279	50,830,628	85,383,355	68,073,256	72,615,183
Increase in external costs	23,785,816	18,963,438	19,743,898	41,625,177	33,186,017	34,551,822	59,464,539	47,408,596	49,359,746
Net benefits	10,367,526	8,265,864	9,302,175	18,143,171	14,465,262	16,278,806	25,918,816	20,664,661	23,255,438

Table 2-30: percentage change in costs and benefits compared to 1 year, 50% flex

1 year flexibility									
Flexibility percentage	0.2			0.35			0.5		
	Option 0	Option 1	Option 2	Option 0	Option 1	Option 2	Option 0	Option 1	Option 2
Saved compliance costs	-60%	-60%	-60%	-30%	-30%	-30%	0%	0%	0%
Increase in external costs	-60%	-60%	-60%	-30%	-30%	-30%	0%	0%	0%
Net benefits	-60%	-60%	-60%	-30%	-30%	-30%	0%	0%	0%
2 year flexibility									
Flexibility percentage	0.2			0.35			0.5		
	Option 0	Option 1	Option 2	Option 0	Option 1	Option 2	Option 0	Option 1	Option 2
Saved compliance costs	-61%	-61%	-61%	-31%	-31%	-31%	-2%	-2%	-2%
Increase in external costs	-61%	-61%	-61%	-31%	-31%	-31%	-2%	-2%	-2%
Net benefits	-61%	-61%	-61%	-31%	-31%	-31%	-2%	-2%	-2%
3 year flexibility									
Flexibility percentage	0.2			0.35			0.5		
	Option 0	Option 1	Option 2	Option 0	Option 1	Option 2	Option 0	Option 1	Option 2
Saved compliance costs	-62%	-62%	-62%	-33%	-33%	-33%	-4%	-4%	-4%
Increase in external costs	-62%	-62%	-62%	-33%	-33%	-33%	-4%	-4%	-4%
Net benefits	-62%	-62%	-62%	-33%	-33%	-33%	-4%	-4%	-4%

3 Inland waterways

3.1 Generalities

The following options have been studied in the IA study:

- Option 0: no action or no introduction of new emission limits stage IIIB/IV
- Option 1: continue with the CCNR stage IIIB and stage IV proposal to strengthen emission limits
- Option 2: continue with the Euromot stage IIIB and stage IV proposal to strengthen emission limits

The approach we have used for inland waterways differs on some points to the approach used for the railway applications.

The most important difference is that in the IA study, very little attention has been paid to stage IIIB, as the bulk of increased compliance costs lies in the proposals for stage IV. Therefore, for the purposes of this study, we had to introduce several assumptions with respect to stage IIIB that have not been used in the IA study, and the comparability with the results of the IA study is thus limited.

Before we proceed with the detailed calculations per option, we summarize the most important common assumptions.

Emission limits for inland waterway vessels are differentiated according to swept volume (expressed as L/Cyl), but are expressed as g/kWh. In order to obtain an estimate of polluting emissions per new engine (expressed as tonnes per year), it is thus essential to have an estimate of the kWh of work performed per year per engine.

In order to do so, we have used the following correspondence table between swept volume and average maximum power[3]:

Table 3-1: Correspondence table between swept volume and average maximum power

Displacement L/cyl	Average maximum power
< 0.9	70
0.9-1.2	150
1.2 - 2.5	250
2.5 - 3.5	1000
3.5 - 7.0	1300
7.0 -15	1300
15.0 - 20	1300

In what follows, it is important to keep in mind that the table above is at best a very rough approximation. For instance, it is possible to have a 1200 kW high speed engine that runs at 1800 rpm and is 3 L/cyl or one that runs at 700 rpm and is 15 L/cyl.

For all engine types, we have assumed an annual usage of 3000 hours and a load factor of 0.55 – this is consistent with the assumptions used in the IA study.

We calculate the difference in annual NOx and PM emission between an average IIIA and an average IIIB engine for each power class, using the emission limits corresponding to the Euromot and the CCNR proposal respectively. The CCNR emission limits differentiate between NOx and HC, while the stage IIIA and the Euromot limits have been

[3] Obtained from industry.

expressed as the sum of both pollutants. For every engine class, we assume that the proportion NOx/HC in the IIIA and Euromot emission limits follows the CCNR proposal.

Table 3-2: difference between stage IIIA, Euromot and CCNR emission limits

Displacement L/cyl	Pollutant	CCNR emission limits (g/kWh)	Euromot emission limits (g/kWh)	stage IIIA emission limits (g/kWh)	IIIA - CCNR emission limits (g/kWh)	IIIA – Euromot emission limits ((g/kWh)	IIIA-CCNR (tonnes per engine per year)	IIIA-EUROMOT (tonnes per engine per year)
< 0.9	PM	0.14	0.14	0.40	0.26	0.26	0.03	0.03
	NOx	4.00	4.32	6.00	2.00	1.68	0.23	0.19
	HC	1.00						
0.9-1.2	PM	0.12	0.12	0.30	0.18	0.18	0.04	0.04
	NOx	4.00	4.32	5.76	1.76	1.44	0.44	0.36
	HC	1.00						
1.2 - 2.5	PM	0.11	0.11	0.20	0.09	0.09	0.04	0.04
	NOx	4.20	4.70	6.05	1.85	1.34	0.76	0.55
	HC	0.80						
2.5 - 3.5	PM	0.11	0.11	0.20	0.09	0.09	0.15	0.15
	NOx	4.80	4.80	6.17	1.37	1.37	2.26	2.26
	HC	0.80						
3.5 - 7.0	PM	0.14	0.11	0.20	0.06	0.09	0.13	0.19
	NOx	4.80	4.97	6.17	1.37	1.20	2.94	2.57
	HC	0.80						
7.0 -15	PM	0.14	0.14	0.27	0.13	0.13	0.28	0.28
	NOx	5.00	5.34	6.72	1.72	1.38	3.70	2.96
	HC	0.80						
15.0 - 20	PM	0.20	0.34	0.50	0.30	0.16	0.64	0.34
	NOx	5.20	6.07	7.54	2.34	1.47	5.02	3.16
	HC	0.8						

We combine these data with the unit external costs used in the IA study (see Table 1-1) to obtain the annual difference in external costs between an average IIIA engines on the one hand and an average IIIB engine for each option on the other hand. This calculation is undertaken per engine class.

Table 3-3: annual difference in external costs between an average IIIA and an average IIIB engine

Displacement L/cyl		IIIA-CCNR (EUR per ship per year)	IIIA-Euromot (EUR per ship per year)
< 0.9	PM	920	920
	Nox	1,191	1,000
	Total	2,110	1,920
0.9-1.2	PM	1,364	1,364
	Nox	2,246	1,837
	Total	3,610	3,202
1.2 - 2.5	PM	1,137	1,137
	NOx	3,930	2,858

	Total	5,067	3,995
2.5 - 3.5	PM	4,548	4,548
	Nox	11,665	11,665
	Total	16,213	16,213
3.5 - 7.0	PM	3,941	5,912
	Nox	15,165	13,269
	Total	19,106	19,181
7.0 -15	PM	8,540	8,540
	Nox	19,065	15,252
	Total	27,604	23,791
15.0 - 20	PM	19,707	10,511
	Nox	25,874	16,291
	Total	45,582	26,802

As in the IA study, we assume that an engine has a lifetime of 35 000 hours. Combining the assumed engine lifetime expressed in hours with the average hours of use per year, yields an expected engine lifetime in years of approximately 12 years.

As in the IA study, we assume that 270 new engines are put on the market annually in the 5 years preceding the beginning of stage IIIB; for the distribution over engine classes, we assume that they are distributed proportionally to the quantities contained in Table 6.7 of the JRC report. Table 3-4 represents both the assumed future engine sales and engines allowed on the market under the flexibility scheme according to engine class and the percentage applied.

Table 3-4: Assumed future engine sales and engines allowed on the market under the flex scheme according to engine class

Displacement L/cyl	Sales according to JRC report	Assumed future sales	20 %	35%	50%
< 0.9	4	8	2	3	4
0.9-1.2	1	2	0	1	1
1.2 - 2.5	19	39	8	14	20
2.5 - 3.5	9	19	4	7	9
3.5 - 7.0	81	168	34	59	84
7.0 -15	4	8	2	3	4
15.0 - 20	12	25	5	9	12
Total	130	270	55	96.35	134.5

As the assumed future sales in the IA report are much higher than observed sales in the recent past, the figures above are probably an overestimation. We have to keep this in mind when interpreting the results.

We combine this estimate with the allowed flexibility to obtain the number of IIIA engines that can be put on the market in the first three years of stage IIIB; we consider three possible scenarios for the distribution over time of the placing on the market of these engines:

- All engines covered by the flexibility mechanism are put on the market in the first year of stage IIIB (“one year flexibility”)

- All engines covered by the flexibility mechanism are put on the market in the first two years of stage IIIB, spread evenly over this period (“two year flexibility”).
- All engines covered by the flexibility mechanism are put on the market in the first three years of stage IIIB, spread evenly over this period (“three year flexibility”).

Compliance costs are calculated as the additional cost of a IIIB engine compared to a IIIIA engine. Investment expenses are only incurred in the year the engine is put on the market, while maintenance and user costs are incurred until the engine is taken out of operation (this, until the end of the calculated lifetime). Saved expenses are thus mainly concentrated at the beginning of IIIB. We assume that saved fixed costs are proportional to the number of engines put on the market under the flexibility scheme. This is probably overestimates actual savings, as part of these fixed costs are development costs that are common to all engine classes.

Additional external costs are directly proportional to the number of IIIA engines that are in operation. They thus first increase until all IIIA engines allowed under flexibility have been put on the market, and remain constant until the first batch of IIIA engines are reaching the end of their economic life; total additional external costs then decline.

Finally, we calculate the net present value (NPV) of additional costs and benefits, using the same discount rate as in the IA study.

In what follows, we first successively analyse the changes in compliance costs for both options (CCNR and Euromot proposal). Subsequently, we calculate how each possible variant of the flexibility scheme leads to changes compared to the options analyse in the IA study. Section 3.7 summarizes.

3.2 Option 1: CCNR proposal

Compliance costs for the stage IIIB CCNR proposal depend on whether or not SCR is needed for compliance. In case no SCR is needed, variable compliance costs increase by at most a few percentages compared to stage IIIA (which is more than an order of magnitude lower than the percentage changes for the stage IV CCNR proposal – see the IA study). In case SCR would be needed, the increase in variable costs compared to stage IIIA would be comparable to the increase in variable costs corresponding to the Stage IV Euromot proposal - however, this is a worst-case scenario.

After some discussion with the industry, it was decided to assume the following annual user and maintenance costs for CCNR stage IIIB:

- 2000-3000 EUR if no SCR is installed
- 7000-8000 EUR if SCR is installed; this figure includes urea consumption of 5000 EUR per year. With the low level of reduction required in stage IIIB, the engine could be retuned to recover this cost in improved fuel economy. However, that would involve the manufacturer carrying out the required test program for a re-calibration which industry claims would not be justified by the sales volumes. If an aftermarket SCR would be fitted by the dealer, the potential fuel saving would not be realised.

On top of these increased operational costs, 7 million EUR development costs would be incurred if all manufacturers were to run a development program to meet the CCNR stage IIIB. Our contacts in industry reckon that many manufacturers would not do this but that their dealers would apply an aftermarket SCR system and certify in their own name to maintain their business. The total development cost would thus be less if some manufacturers would decide to exit.

A lot of uncertainty thus surrounds the estimates of compliance costs.

We will consider here three possible scenarios:

- CCNR1: No SCR needed: 2 500 EUR extra annual user and maintenance costs for all engines, no extra development costs
- CCNR2: SCR needed, all engines retuned by the manufacturers: 2 500 extra annual user and maintenance costs for all engines (this sum is net of fuel savings due to the retuning), fixed development cost of 7 million EUR spread over the period during which IIIA engines can be put on the market under the flexibility scheme
- CCNR3: SCR needed, SCR installed by the dealers, no engines retuned: 7 500 EUR extra annual user and maintenance costs for all engines, no extra development costs

Using these 3 scenarios will allow us to verify whether our results are robust.

Under the CCNR proposal, the year where the stage IIIB emission limits become applicable depends on the engine class.

Table 3-5: timing of stage IIIB in the CCNR proposal

Displacement L/cyl	Year
< 0.9	2012
0.9-1.2	2013
1.2 - 2.5	2013
2.5 - 3.5	2012
3.5 - 7.0	2012
7.0 -15	2012
15.0 - 20	2013

3.3 Option 2: the Euromot proposal

. For option 2, extra annual user and maintenance costs would lie between 1500 and 2000 EUR. We shall calculate saved compliance costs for 1500, 1750 and 2000 EUR per year (the lower bound, the central value and the higher bound to this interval).

On top of this, certification costs of 20 000 EUR per engine family would be incurred, with 10 propulsion engine families and 15 auxiliary engine families on the European market. We assume that these certification costs are spread evenly over the period during which IIIA engines can be put on the market under the flexibility scheme.

Under the Euromot proposal, the year where the stage IIIB emission limits become applicable depends on the engine class.

Table 3-6: timing of stage IIIB in the Euromot proposal

Displacement L/cyl	Year
< 0.9	2012
0.9-1.2	2013
1.2 - 2.5	2014
2.5 - 3.5	2013
3.5 - 7.0	2012
7.0 -15	2013
15.0 - 20	2014

3.4 One year flexibility

In this section, we limit our discussion to 20% flexibility. The calculation for 35% and 50% flexibility are straightforward extensions that are discussed in detail in Section B.1.1 and B.1.2.

For the IIIA engines falling under the flexibility scheme with one year flexibility, Table 3-7 gives the timing for their placing on the market on the one hand and their withdrawal on the other hand (assuming a lifetime of 12 years).

Table 3-7: IWW, timing under one year flexibility

	CCNR proposal		Euromot proposal	
Displacement L/cyl	Years of placing on the market	Years of withdrawing from the market	Years of placing on the market	Years of withdrawing from the market
< 0.9	2012	2024	2012	2024
0.9-1.2	2013	2025	2013	2025
1.2 - 2.5	2013	2025	2014	2026
2.5 - 3.5	2012	2024	2013	2025
3.5 - 7.0	2012	2024	2012	2024
7.0 -15	2012	2024	2013	2025
15.0 - 20	2013	2025	2014	2026

The environmental costs of 20% flexibility can be summarized in Table 3-8 and Table 3-9, where we give, for both the CCNR and the Euromot proposal:

- The annual increase in environmental costs for all engine categories
- The NPV of these increased environmental costs
- The relative importance of each engine category in the total increase in the NPV of environmental costs

Table 3-8: IWW, one year 20% flexibility, environmental cost under CCNR proposal

Displacement L/cyl	2012	2013 to 2024	2025	NPV	% of total NPV
< 0.9	3,507	3,507	0	29,932	0.35%
0.9-1.2	0	1,499	1,499	12,307	0.14%
1.2 - 2.5	0	39,987	39,987	328,194	3.80%
2.5 - 3.5	60,611	60,611	0	517,362	5.99%
3.5 - 7.0	642,843	642,843	0	5,487,159	63.57%
7.0 -15	45,866	45,866	0	391,500	4.54%
15.0 – 20	0	227,207	227,207	1,864,797	21.61%
Total	752,826	1,021,520	268,694	8,631,251	100.00%

Table 3-9: IWW, one year 20% flexibility, environmental cost under Euromot proposal

Displacement L/cyl	2012	2013	2014 to 2024	2025	2026	NPV	% of total NPV
< 0.9	3,190	3,190	3,190	0	0	27,230	0.35%
0.9-1.2	0	1,330	1,330	1,330	0	10,915	0.14%
1.2 - 2.5	0	0	31,529	31,529	31,529	248,820	3.24%
2.5 - 3.5	0	60,611	60,611	60,611	0	497,464	6.48%
3.5 - 7.0	645,371	645,371	645,371	0	0	5,508,742	71.80%
7.0 -15	0	39,530	39,530	39,530	0	324,445	4.23%
15.0 - 20	0	0	133,597	133,597	133,597	1,054,320	13.74%
Total	648,561	750,033	915,158	266,597	165,126	7,671,935	100.00%

We can make the following observations:

- The NPV of increased environmental costs is higher if flexibility is applied to the CCNR proposal (8,631,251 EUR) than when it is applied to the Euromot proposal (7,671,935 EUR). This is what we should have expected, as the emission limits of the CCNR proposal are more stringent than for the Euromot proposal. Moreover, the emission limits of the CCNR proposal come into force earlier than the emission limits of the Euromot proposal.
- For both proposals, more than 80% of increased environmental costs are due to the engines in the categories (3.5-7 Displacement L/cyl) and (15- 20 Displacement L/cyl). This is not surprising, as these are the categories with the highest market shares.
- The increases in environmental costs are extremely small compared to the benefits of both options compared to option 0, as calculated in the IA study: 2 804 million EUR for the CCNR proposal, 1 979 million EUR for the Euromot proposal. Of course, these results are not perfectly comparable, as the IA study has not explicitly covered the environmental benefits of stage IIIB. However, the order of magnitude gives an indication of how much is as stake.

Next, we need to consider compliance costs.

For the Euromot proposal, the saved annual user and maintenance costs (and their NPV in 2007) are given by Table 3-10.

Table 3-10: IWW, one year 20% flexibility, saved annual user and maintenance cost under Euromot proposal

	2012	2013	2014 to 2024	2025	2026	NPV
Low	61,062	61,685	81,000	19,938	19,315	678,755
Average	71,238	71,965	94,500	23,262	22,535	791,880
High	81,415	82,246	108,000	26,585	25,754	905,006

With 1 year and 20% flexibility, 100 000 EUR certification costs are saved in 2012 – the NPV of this sum is 82 193 EUR.

Even with the highest estimates, we see that the estimated value of saved compliance costs is much lower than the increase in environmental costs.

For the CCNR proposal, the saved annual user and maintenance costs (and their NPV in 2007) are given by Table 3-11.

Table 3-11: IWW, one year 20% flexibility, saved annual user and maintenance cost under CNR proposal

	2012	2013 to 2024	2025	NPV in 2007
CCNR1&2	101,769	135,000	33,231	1,141,420
CCNR3	305,308	405,000	99,692	3,424,259

Under CCNR2, we should also add the saved development costs of 1,400,000 EUR in 2012, which has a NPV of 1,150,698 EUR.

In any case, we see that the saved compliance costs never exceed the 3.5 million EUR, which is again significantly below the increased environmental costs. However, if compliance with the CCNR stage IIIB is possible without use of SCR, the compliance costs are quite close to the compliance costs linked to the Euromot proposal.

The gains in compliance costs are extremely small compared to the costs of both options compared to option 0, as calculated in the IA study: 2 138 million EUR for the CCNR proposal, 1 145 million EUR for the Euromot proposal. Of course, these results are not perfectly comparable, as the IA study has not explicitly covered the compliance costs of stage IIIB. However, the order of magnitude gives an indication of how much is as stake.

3.5 Two year flexibility

In this section, we limit our discussion to 20% flexibility. The calculation for 35% and 50% flexibility are straightforward extensions that are discussed in detail in Section B.2.

For the IIIA engines falling under the flexibility scheme with two year flexibility, Table 3-12 gives the timing for their placing on the market on the one hand and their withdrawal on the other hand (assuming a lifetime of 12 years).

Table 3-12: IWW, timing under two year flexibility

	CCNR proposal		Euromot proposal	
Displacement L/cyl	Years of placing on the market	Years of withdrawing from the market	Years of placing on the market	Years of withdrawing from the market
< 0.9	2012-2013	2024-2025	2012-2013	2024-2025
0.9-1.2	2013-2014	2025-2026	2013-2014	2025-2026
1.2 - 2.5	2013-2014	2025-2026	2014-2015	2026-2027
2.5 - 3.5	2012-2013	2024-2025	2013-2014	2025-2026
3.5 - 7.0	2012-2013	2024-2005	2012-2013	2024-2025
7.0 -15	2012-2013	2024-2025	2013-2014	2025-2026
15.0 - 20	2013-2014	2025-2026	2014-2015	2026-2027

The environmental costs of 20% flexibility can be summarized in Table 3-13 and Table 3-14, where we give, for both the CCNR and the Euromot proposal:

- The annual increase in environmental costs for all engine categories
- The NPV of these increased environmental costs

Table 3-13: IWW, two year 20% flexibility, environmental cost under CCNR proposal

	2012	2013	2014-2024	2025	2026	NPV
< 0.9	1,753	3,507	3,507	1,753	0	29,356
0.9-1.2	0	750	1,499	1,499	750	12,070
1.2 - 2.5	0	19,994	39,987	39,987	19,994	321,883
2.5 - 3.5	30,306	60,611	60,611	30,306	0	507,413
3.5 - 7.0	321,421	642,843	642,843	321,421	0	5,381,636
7.0 -15	22,933	45,866	45,866	22,933	0	383,971
15.0 - 20	0	113,604	227,207	227,207	113,604	1,828,935
Total	376,413	887,173	1,021,520	645,107	134,347	8,465,265

Table 3-14: IWW, two year 20% flexibility, environmental cost under Euromot proposal

	2012	2013	2014	2015-2024	2025	2026	2027	NPV
< 0.9	1,595	3,190	3,190	3,190	1,595	0	0	26,706
0.9-1.2	0	665	1,330	1,330	1,330	665	0	10,705
1.2 - 2.5	0	0	15,764	31,529	31,529	31,529	15,764	244,035
2.5 - 3.5	0	30,306	60,611	60,611	60,611	30,306	0	487,897
3.5 - 7.0	322,686	645,371	645,371	645,371	322,686	0	0	5,402,804
7.0 -15	0	19,765	39,530	39,530	39,530	19,765	0	318,206
15.0 - 20	0	0	66,798	133,597	133,597	133,597	66,798	1,034,045
Total	324,281	699,297	832,595	915,158	590,878	215,861	82,563	7,524,398

We can make the following observations:

- As in the case of “one year flexibility” the NPV of increased environmental costs is higher if flexibility is applied to the CCNR proposal (8,465,265 EUR) than when it is applied to the Euromot proposal (7,524,398 EUR).
- With 2 year flexibility, part of the environmental costs of flexibility is postponed compared to one year flexibility. Due to discounting, the total cost is thus lower.

Next, we need to consider compliance costs.

For the Euromot proposal, the saved annual user and maintenance costs (and their NPV in 2007) are given by Table 3-15.

Table 3-15: IWW, two year 20% flexibility, saved annual user and maintenance cost under Euromot proposal

	2012	2013	2014	2015-2024	2025	2026	2027	NPV
Low	30,531	61,373	71,342	81,000	50,469	19,627	9,658	665,702
Average	35,619	71,602	83,233	94,500	58,881	22,898	11,267	776,652
High	40,708	81,831	95,123	108,000	67,292	26,169	12,877	887,602

With two year and 20% flexibility, 50 000 EUR certification costs are saved in 2012 and 2013 – the NPV of this sum is 80,612 EUR.

For the CCNR proposal, the saved annual user and maintenance costs (and their NPV in 2007) are given by Table 3-16.

Table 3-16: IWW, two year 20% flexibility, saved annual user and maintenance cost under CNR proposal

	2012	2013	2014-2024	2025	2026	NPV
CCNR1&2	50,885	118,385	135,000	84,115	16,615	1,119,469
CCNR3	152,654	355,154	405,000	252,346	49,846	3,358,408

Under CCNR2, we should also add the annual saved development costs of 700,000 EUR in 2012 and 2013, which has a NPV of 1,128,569 EUR.

In any case, we see that the saved compliance costs never exceed the 3.5 million EUR.

Due to discounting, saved compliance costs are thus lower than under one year flexibility.

As the 35% and the 50% flexibility schemes are a straightforward extension of all the cases that have been discussed above, we will from now on limit ourselves to an enumeration of the results.

3.6 Three year flexibility

For the IIIA engines falling under the flexibility scheme with three year flexibility, Table 3-17 gives the timing for their placing on the market on the one hand and their withdrawal on the other hand (assuming a lifetime of 12 years).

Table 3-17: IWW, timing under three year flexibility

	CCNR proposal		Euromot proposal	
Displacement L/cyl	Years of placing on the market	Years of withdrawing from the market	Years of placing on the market	Years of withdrawing from the market
< 0.9	2012-2014	2024-2026	2012-2014	2024-2026
0.9-1.2	2013-2015	2025-2027	2013-2015	2025-2027
1.2 - 2.5	2013-2015	2025-2027	2014-2016	2026-2028
2.5 - 3.5	2012-2014	2024-2026	2013-2015	2025-2027
3.5 - 7.0	2012-2014	2024-2006	2012-2014	2024-2026
7.0 -15	2012-2014	2024-2026	2013-2015	2025-2027
15.0 - 20	2013-2015	2025-2027	2014-2016	2026-2028

As the calculations are a straightforward extension of the approach used in the previous sections, we refer to Section B.3 for the detailed results.

3.7 Summary for inland waterways

Table 3-20 to Table 3-22 give an overview of:

- Saved compliance costs
- Additional external costs
- Net costs,

for each option that has been undertaken in the IA study, and for each possible version of the flexibility scheme. We only represent the upper and the lower bounds of the range of compliance costs that we have considered.

In the interpretation of these results, it is important to keep in mind that:

- They are calculated relative to the option as analysed in the IA study, and not relative to option 0.
- Contrary to what we have found with the railways, increased flexibility always entails **net costs** to society: the increased environmental costs always outweigh the saved compliance costs by a significant margin.

For both options, the lowest increase in net costs is obtained for 20% and 3 year flexibility.

Therefore, we also calculate the relative benefits and costs of each variant of the flexibility scheme compared to the (3 year, 20%) combination. This is summarized in Table 3-23. The summary table shows clearly that the benefits and costs of spreading the flexibility over a longer period of time are very small compared to the benefits and costs of changes in the flexibility percentage.

We also see that the compliance costs for stage IIIB are small compared to the compliance costs for stage IV, certainly in the case of the Euromot proposal. This is mainly due to the fact that the development costs linked to Euromot stage IIIB are sunk, because they are required for the US market anyway. It is still unclear whether compliance with the CCNR stage IIIB limits would require SCR, but if it does not, then the compliance costs for the CCNR proposal are quite close to the estimates for the Euromot proposal (at least for stage IIIb).

It also noteworthy that, under the Euromot proposal, the compliance costs are more sensitive to changes in the number of years of flexibility than the environmental costs. This is due to the fact that the compliance costs include the certification costs, which are concentrated at the beginning of stage IIIB. Due to discounting, a longer or shorter flexibility period has a disproportionally large effect on the net present value of these certification costs. In the case of the CCNR proposal, fixed costs are only incurred in the case of the CCNR2 variant, but the NPV of this variant always lies between the NPV of the CCNR1 and the CCNR3 variant.

The total costs and benefits of each option, as calculated in the IA study, are summarized in Table 3-18. In the interpretation of this table, one has to keep in mind that the IA study has not considered the compliance costs for stage IIIB, because they were thought to be very small compared to the compliance costs for stage IV.

Table 3-18: costs and benefits for IWW according to the IA study

	CCNR proposal	Euromot proposal
Environmental benefits	2 804 million EUR	1 979 million EUR

Compliance costs (high estimate)	2 138 million EUR	1 145 million EUR
Compliance costs (low estimate)	1 774 million EUR	780 million EUR
Net benefits (high compliance costs)	666 million EUR	834 million EUR
Net benefits (low compliance costs)	1 030 million EUR	1 199 million EUR

Even under a (1 year, 50%) flexibility scheme, we see that extended flexibility has a very small effect on environmental costs, compliance costs and net costs, when compared to the total costs and benefits of each policy option.

Table 3-19: Overview of the possible impacts of flexibility (IWW applications)

Category	Discussion
Functioning of the internal market	The application of the CCNR proposal could lead some engine manufactures to exit from the European market. Flexibility will not change the fundamental issues (high fixed compliance costs for a small market in stage IV)
Competitiveness, trade and investment flows	Based upon the information gathered, no changes are expected compared to the current situation.
Operating costs and costs of business	The savings in compliance costs linked to flexibility in stage IIIB are very small compared to compliance costs in stage IV.
Administrative burden to companies/SME's	Most IWT companies are SMEs. For those enterprises that plan to renew their fleet in 2012-2016, increased flexibility could bring benefits. The global effects are very small however compared to the effects of stage IV. Moreover, due to the small number of engines allowed under the flexibility scheme, they are unlikely to affect the market price in a significant way.
Property rights	No specific effects are expected
Innovation and technological development	Increased flexibility would allow for a longer development period for some engine series.
Consumer and households	Taking into account the small modal share of IWT, the high level of competition in that market, and the small costs savings implied by flexibility, any cost pass through to the final customer can be expected to very small.
Specific regions, sectors or workers	The environmental costs of flexibility in stage IIIB are very small compared to the environmental benefits of stage IV
Third countries and international relations	No specific effects are expected

Impact on public authorities, including administrative costs	Some public authorities can be expected to increase their financial support for IWW in order to compensate for the financial costs. However, the savings in compliance costs linked to flexibility in stage IIIB are very small compared to compliance costs in stage IV.
Impact on macroeconomic environment	With EU27 GDP estimated at 12,870,560 million EUR (EUROSTAT), estimated compliance costs do not have a significant macroeconomic impact.
Employment and labour markets	Increased costs for IWT could lead to some job losses, but could be compensated by public support. However, the savings in compliance costs linked to flexibility in stage IIIB are very small compared to compliance costs in stage IV.
Standards and rights related to job quality	The project team has investigated this point, but has not identified any information that indicates that this could be an issue.
Social inclusion and protection of particular groups	The project team has investigated this point, but has not identified any information that indicates that this could be an issue.
Public health and safety	The impact of increased flexibility on the environment is negligible compared to the impacts of stage IV.

Table 3-20: summary table for 1 year flexibility (IWW)

Flexibility percentage	0.20%		0.35%		0.50%	
	CCNR	Euromot	CCNR	Euromot	CCNR	Euromot
Lower limit saved compliance costs	1,141,420	760,948	1,997,485	1,331,657	2,853,550	1,902,368
Upper limit saved compliance costs	3,424,259	987,199	5,992,454	1,727,598	8,560,649	2,467,997
Increase in external costs	8,631,251	7,671,935	15,104,689	13,425,887	21,578,127	19,179,839
Lower limit net costs	5,206,992	6,684,736	9,112,235	11,698,289	13,017,478	16,711,842
Upper limit net costs	7,489,831	6,910,987	13,107,204	12,094,230	18,724,577	17,277,471

Table 3-21: summary table for 2 year flexibility (IWW)

Flexibility percentage	0.20%		0.35%		0.50%	
	CCNR	Euromot	CCNR	Euromot	CCNR	Euromot
Lower limit saved compliance costs	1,119,469	746,314	1,959,072	1306049	2,798,674	1,865,784
Upper limit saved compliance costs	3,358,408	968,214	5,877,215	1,694,375	8,396,021	2,420,535
Increase in external costs	8,465,265	7,524,398	14,814,214	13,167,697	21,163,163	18,810,996
Lower limit net costs	5,106,857	6,556,184	8,936,999	11,473,322	12,767,142	16,390,461
Upper limit net costs	7,345,796	6,778,084	12,855,142	11,861,648	18,364,489	16,945,212

Table 3-22: summary table for 3 year flexibility (IWW)

Flexibility percentage	0.20%		0.35%		0.50%	
	CCNR	Euromot	CCNR	Euromot	CCNR	Euromot
Lower limit saved compliance costs	1,098,082	737,287	1,921,643	1,290,252	2,745,205	1,843,217
Upper limit saved compliance costs	3,294,246	956,692	5,764,930	1,674,211	8,235,614	2,391,730
Increase in external costs	8,303,536	7,484,606	14,531,187	13,098,061	20,758,839	18,711,515
Lower limit net costs	5,009,290	6,527,914	8,766,257	11,423,850	12,523,225	16,319,785
Upper limit net costs	7,205,454	6,747,319	12,609,544	11,807,809	18,013,634	16,868,298

Table 3-23: percentage change in costs and benefits compared to 3 year, 20% flex (IWW)

1 year flexibility (IWW)						
Flexibility percentage	0.20%		0.35%		0.50%	
	CCNR	Euromot	CCNR	Euromot	CCNR	Euromot
Lower limit saved compliance costs	3.95%	3.21%	81.91%	80.62%	159.87%	158.02%

Upper limit saved compliance costs	3.95%	3.19%	81.91%	80.58%	159.87%	157.97%
Increase in external costs	3.95%	2.50%	81.91%	79.38%	159.87%	156.26%
Lower limit net costs	3.95%	2.40%	81.91%	79.20%	159.87%	156.01%
Upper limit net costs	3.95%	2.43%	81.91%	79.24%	159.87%	156.06%
2 year flexibility (IWW)						
Flexibility percentage	0.20%		0.35%		0.50%	
	CCNR	Euromot	CCNR	Euromot	CCNR	Euromot
Lower limit saved compliance costs	1.95%	1.22%	78.41%	77.14%	154.87%	153.06%
Upper limit saved compliance costs	1.95%	1.20%	78.41%	77.11%	154.87%	153.01%
Increase in external costs	1.95%	0.53%	78.41%	75.93%	154.87%	151.33%
Lower limit net costs	1.95%	0.43%	78.41%	75.76%	154.87%	151.08%
Upper limit net costs	1.95%	0.46%	78.41%	75.80%	154.87%	151.14%
3 year flexibility (IWW)						
Flexibility percentage	0.20%		0.35%		0.50%	
	CCNR	Euromot	CCNR	Euromot	CCNR	Euromot
Lower limit saved compliance costs	0.00%	0.00%	75.00%	75.00%	150.00%	150.00%
Upper limit saved compliance costs	0.00%	0.00%	75.00%	75.00%	150.00%	150.00%
Increase in external costs	0.00%	0.00%	75.00%	75.00%	150.00%	150.00%
Lower limit net costs	0.00%	0.00%	75.00%	75.00%	150.00%	150.00%
Upper limit net costs	0.00%	0.00%	75.00%	75.00%	150.00%	150.00%

A Detailed results for railcars and locomotives

A.1 Railcars

Table A-1: Railcars: option 0, 20% and 1 year flexibility

	Annual cost	2013 to 2018
Change in compliance costs (EUR) (DPF+EGR)	-2,949,560	-620,960
Change in compliance costs (EUR) (SCR)	-3,104,800	-776,200
Change in external costs (EUR)	687,534	687,534

Table A-2: Railcars: option 0, 20% and 2 year flexibility

	2012	2013	2014 to 2018	2019
Change in compliance costs (EUR) (DPF+EFR)	-1,474,780	-1,785,260	-620,960	-310,480
Change in compliance costs (EUR) (SCR)	-1,552,400	-1,940,500	-776,200	-388,100
Change in external costs (EUR)	343,767	687,534	687,534	343,767

Table A-3: Railcars: option 0, 20% and 3 year flexibility

	2012	2013	2014	2015 to 2018	2019	2020
Change in compliance costs (EUR) (DPF+EFR)	-983,187	-1,190,173	-1,397,160	-620,960	-413,973	-206,987
Change in compliance costs (EUR) (SCR)	-1,034,933	-1,293,667	-1,552,400	-776,200	-517,467	-258,733
Change in external costs (EUR)	229,178	458,356	687,534	687,534	458,356	229,178

Table A-4: Railcars: option 1, 35% and 1 year flexibility

	2016	2017 to 2022
Change in compliance costs (EUR) (DPF+EGR)	-4,721,500	-994,000
Change in compliance costs (EUR) (SCR)	-4,970,000	-1,242,500
Change in external costs (EUR)	1,100,569	1,100,569

Table A-5: Railcars: option 1, 35% and 2 year flexibility

	2016	2017	2018 to 2022	2023
Change in compliance costs (EUR) (DPF+EGR)	-2,360,750	-2,857,750	-994,000	-497,000
Change in compliance costs (EUR) (SCR)	-2,485,000	-3,106,250	-1,242,500	-621,250

Change in external costs (EUR)	550,284	1,100,569	1,100,569	550,284

Table A-6: Railcars: option 1, 35% and 3 year flexibility

	2016	2017	2018	2019 to 2022	2023	2024
Change in compliance costs (EUR) (DPF+EGR)	-1,573,833	-1,905,167	-2,236,500	-994,000	-662,667	-331,333
Change in compliance costs (EUR) (SCR)	-1,656,667	-2,070,833	-2,485,000	-1,242,500	-828,333	-414,167
Change in external costs (EUR)	366,856	733,712	1,100,569	1,100,569	733,712	366,856

A.2 Shunters

Table A-7: NPV of net benefits of flexibility for shunters under option 1

	20% flexibility	35% flexibility	50% flexibility
One year flexibility			
NPV saved compliance costs with SCR	4,437,241	7,765,171	11,093,102
NPV additional environmental costs	1,230,744	2,153,801	3,076,859
NPV net benefits with SCR	3,206,497	5,611,370	8,016,243
Two year flexibility			
NPV saved compliance costs with SCR	4,351,909	7,615,841	10,879,773
NPV additional environmental costs	1,207,075	2,112,382	3,017,688
NPV net benefits with SCR	3,144,834	5,503,459	7,862,085
Three year flexibility			
NPV saved compliance costs with SCR	4,268,766	7,470,340	10,671,914
NPV additional environmental costs	1,184,014	2,072,025	2,960,035
NPV net benefits with SCR	3,084,752	5,398,315	7,711,879

Table A-8: NPV of net benefits of flexibility for shunters under option 2

	20% flexibility	35% flexibility	50% flexibility
One year flexibility			
NPV saved compliance costs with SCR	5,213,443	9,123,526	13,033,608
NPV additional environmental costs	1,272,670	2,227,172	3,181,674
NPV net benefits with SCR	3,940,774	6,896,354	9,851,934

Two year flexibility			
NPV saved compliance costs with SCR	5,113,185	8,948,073	12,782,962
NPV additional environmental costs	1,248,195	2,184,342	3,120,488
NPV net benefits with SCR	3,864,989	6,763,732	9,662,474
Three year flexibility			
NPV saved compliance costs with SCR	5,015,497	8,777,120	12,538,743
NPV additional environmental costs	1,224,349	2,142,610	3,060,871
NPV net benefits with SCR	3,791,149	6,634,510	9,477,871

Table A-9: Shunters: option 0, 20% and one year flexibility

	2012	2013 to 2024
Change in compliance costs (EUR) (130-560 kW) (DPF+EGR)	-2,310,840	-330,120
Change in compliance costs (EUR) (> 560 kW) (DPF+EGR)	-990,360	-141,480
Total change in compliance costs (EUR) (DPF+EGR)	-3,301,200	-471,600
Change in compliance costs (EUR) (130-560 kW) (SCR)	-2,244,816	-264,096
Change in compliance costs (EUR) (> 560 kW) (SCR)	-962,064	-113,184
Total change in compliance costs (EUR) (SCR)	-3,206,880	-377,280
Change in external costs (EUR) (130-560 kW)	24,567	24,567
Change in external cost (EUR) (>560 kW)	155,651	155,651
Total change in external costs (EUR)	180,219	180,219

Table A-10: Shunters: option 0, 20% and two year flexibility

	2012	2013	2014 to 2024	2025
Change in compliance costs (EUR) (130-560 kW) (DPF+EGR)	-1,155,420	-1,320,480	-330,120	-165,060
Change in compliance costs (EUR) (> 560 kW) (DPF+EGR)	-495,180	-565,920	-141,480	-70,740
Total change in compliance costs (EUR) (DPF+EGR)	-1,650,600	-1,886,400	-471,600	-235,800

Change in compliance costs (EUR) (130-560 kW) (SCR)	-1,122,408	-1,254,456	-264,096	-132,048
Change in compliance costs (EUR) (> 560 kW) (SCR)	-481,032	-537,624	-113,184	-56,592
Total change in compliance costs (EUR) (SCR)	-1,603,440	-1,792,080	-377,280	-188,640
Change in external costs (EUR) (130-560 kW)	12,284	24,567	24,567	12,284
Change in external cost (EUR) (>560 kW)	77,826	155,651	155,651	77,826
Total change in external costs (EUR)	90,109	180,219	180,219	90,109

Table A-11: Shunters: option 0, 20% and three year flexibility

	2012	2013	2014	2015 to 2024	2025	2026
Change in compliance costs (EUR) (130-560 kW) (DPF+EGR)	-770,280	-880,320	-990,360	-330,120	-220,080	-110,040
Change in compliance costs (EUR) (> 560 kW) (DPF+EGR)	-330,120	-377,280	-424,440	-141,480	-94,320	-47,160
Total change in compliance costs (EUR) (DPF+EGR)	-1,100,400	-1,257,600	-1,414,800	-471,600	-314,400	-157,200
Change in compliance costs (EUR) (130-560 kW) (SCR)	-748,272	-836,304	-924,336	-264,096	-176,064	-88,032
Change in compliance costs (EUR) (> 560 kW) (SCR)	-320,688	-358,416	-396,144	-113,184	-75,456	-37,728
Total change in compliance costs (EUR) (SCR)	-1,068,960	-1,194,720	-1,320,480	-377,280	-251,520	-125,760
Change in external costs (EUR) (130-560 kW)	8,189	16,378	24,567	24,567	16,378	8,189
Change in external cost (EUR) (>560 kW)	51,884	103,768	155,651	155,651	103,768	51,884
Total change in external costs (EUR)	60,073	120,146	180,219	180,219	120,146	60,073

Table A-12: Shunters: option 1, 35 % and 1 year flexibility

	2016	2017 to 2028
Change in compliance costs (EUR) (130-560 kW) (DPF+EGR)	-3,785,005	-540,715
Change in compliance costs (EUR) (> 560 kW) (DPF+EGR)	-1,622,145	-231,735
Total change in compliance costs (EUR) (DPF+EGR)	-5,407,150	-772,450
Change in compliance costs (EUR) (130-560 kW) (SCR)	-3,676,862	-432,572
Change in compliance costs (EUR) (> 560 kW) (SCR)	-1,575,798	-185,388
Total change in compliance costs (EUR) (SCR)	-5,252,660	-617,960
Change in external costs (EUR) (130-560 kW)	40,239	40,239
Change in external cost (EUR) (>560 kW)	254,947	254,947
Total change in external costs (EUR)	295,186	295,186

Table A-13: Shunters: option 1, 35 % and 2 year flexibility

	2016	2017	2018 to 2028	2029
Change in compliance costs (EUR) (130-560 kW) (DPF+EGR)	-1,892,503	-2,162,860	-540,715	-270,358
Change in compliance costs (EUR) (> 560 kW) (DPF+EGR)	-811,073	-926,940	-231,735	-115,868
Total change in compliance costs (EUR) (DPF+EGR)	-2,703,575	-3,089,800	-772,450	-386,225

Change in compliance costs (EUR) (130-560 kW) (SCR)	-1,838,431	-2,054,717	-432,572	-216,286
Change in compliance costs (EUR) (> 560 kW) (SCR)	-787,899	-880,593	-185,388	-92,694
Total change in compliance costs (EUR) (SCR)	-2,626,330	-2,935,310	-617,960	-308,980
Change in external costs (EUR) (130-560 kW)	20,120	40,239	40,239	20,120
Change in external cost (EUR) (>560 kW)	127,473	254,947	254,947	127,473
Total change in external costs (EUR)	147,593	295,186	295,186	147,593

Table A-14: Shunters: option 1, 35 % and 3 year flexibility

	2016	2017	2018	2019 to 2028	2029	2030
Change in compliance costs (EUR) (130-560 kW) (DPF+EGR)	-1,261,668	-1,441,907	-1,622,145	-540,715	-360,477	-180,238
Change in compliance costs (EUR) (> 560 kW) (DPF+EGR)	-540,715	-617,960	-695,205	-231,735	-154,490	-77,245
Total change in compliance costs (EUR) (DPF+EGR)	-1,802,383	-2,059,867	-2,317,350	-772,450	-514,967	-257,483
Change in compliance costs (EUR) (130-560 kW) (SCR)	-1,225,621	-1,369,811	-1,514,002	-432,572	-288,381	-144,191
Change in compliance costs (EUR) (> 560 kW) (SCR)	-525,266	-587,062	-648,858	-185,388	-123,592	-61,796
Total change in compliance costs (EUR) (SCR)	-1,750,887	-1,956,873	-2,162,860	-617,960	-411,973	-205,987
Change in external costs (EUR) (130-560 kW)	13,413	26,826	40,239	40,239	26,826	13,413
Change in external cost (EUR) (>560 kW)	84,982	169,965	254,947	254,947	169,965	84,982
Total change in external costs (EUR)	98,395	196,791	295,186	295,186	196,791	98,395

Table A-15: Shunters: option 2, 50% and 1 year flexibility

	2012	2013	2014	2015	2016	2017 to 2024	2025	2026	2027	2028
Change in compliance costs (EUR) (130-560 kW) (DPF+EGR)	-5,777,100	-825,300	-825,300	-825,300	-825,300	-825,300	0	0	0	0
Change in compliance costs (EUR) (> 560 kW) (DPF+EGR)					-2,317,350	-331,050	-331,050	-331,050	-331,050	-331,050
Total change in compliance costs (EUR) (DPF+EGR)	-5,777,100	-825,300	-825,300	-825,300	-3,142,650	-1,156,350	-331,050	-331,050	-331,050	-331,050
Change in compliance costs (EUR) (130-560 kW) (SCR)	-5,612,040	-660,240	-660,240	-660,240	-660,240	-660,240	0	0	0	0
Change in compliance costs (EUR) (> 560 kW) (SCR)					-2,251,140	-264,840	-264,840	-264,840	-264,840	-264,840
Total change in compliance costs (EUR) (SCR)	-5,612,040	-660,240	-660,240	-660,240	-2,911,380	-925,080	-264,840	-264,840	-264,840	-264,840
Change in external costs (EUR) (130-560 kW)	61,418	61,418	61,418	61,418	61,418	61,418	0	0	0	0
Change in external cost (EUR) (>560 kW)	0	0	0	0	364,210	364,210	364,210	364,210	364,210	364,210
Total change in external costs (EUR)	61,418	61,418	61,418	61,418	425,628	425,628	364,210	364,210	364209.8	364209.8

Table A-16: Shunters: option 2, 50% and 2 year flexibility

	2012	2013	2014	2015	2016	2017	2018 to 2025	2025	2026 to 2028	2029
Change in compliance costs (EUR) (130-560 kW) (DPF+EGR)	-2,888,550	-3,301,200	-825,300	-825,300	-825,300	-825,300	-825,300	-412,650	0	0
Change in compliance costs (EUR) (> 560 kW) (DPF+EGR)	0	0	0	0	-1,158,675	-1,324,200	-331,050	-331,050	-331,050	-165,525

Total change in compliance costs (EUR) (DPF+EGR)	-2,888,550	-3,301,200	-825,300	-825,300	-1,983,975	-2,149,500	-1,156,350	-743,700	-331,050	-165,525
Change in compliance costs (EUR) (130-560 kW) (SCR)	-2,806,020	-3,136,140	-660,240	-660,240	-660,240	-660,240	-660,240	-330,120	0	0
Change in compliance costs (EUR) (> 560 kW) (SCR)	0	0	0	0	-1,125,570	-1,257,990	-264,840	-264,840	-264,840	-132,420
Total change in compliance costs (EUR) (SCR)	-2,806,020	-3,136,140	-660,240	-660,240	-1,785,810	-1,918,230	-925,080	-594,960	-264,840	-132,420
Change in external costs (EUR) (130-560 kW)	30,709	61,418	61,418	61,418	61,418	61,418	61,418	30,709	0	0
Change in external cost (EUR) (>560 kW)	0	0	0	0	182,105	364,210	364,210	364,210	364,210	182,105
Total change in external costs (EUR)	30,709	61,418	61,418	61,418	243,523	425,628	425,628	394,919	364,210	182104.9

Table A-17: Shunters: option 2, 50% and 3 year flexibility

	2012	2013	2014	2015	2016	2017	2018	2019	2025	2026	2027-2028	2029	2030
Change in compliance costs (EUR) (130-560 kW) (DPF+EGR)	-1,925,700	-2,200,800	-2,475,900	-825,300	-825,300	-825,300	-825,300	-825,300	-550,200	-275,100	0	0	0
Change in compliance costs (EUR) (> 560 kW) (DPF+EGR)	0	0	0	0	-772,450	-882,800	-993,150	-331,050	-331,050	-331,050	-331,050	-220,700	-110,350
Total change in compliance costs (EUR) (DPF+EGR)	-1,925,700	-2,200,800	-2,475,900	-825,300	-1,597,750	-1,708,100	-1,818,450	-1,156,350	-881,250	-606,150	-331,050	-220,700	-110,350
Change in compliance costs (EUR) (130-560 kW) (SCR)	-1,870,680	-2,090,760	-2,310,840	-660,240	-660,240	-660,240	-660,240	-660,240	-440,160	-220,080	0	0	0
Change in compliance	0	0	0	0	-750,380	-838,660	-926,940	-264,840	-264,840	-264,840	-264,840	-176,560	-88,280

costs (EUR) (> 560 kW) (SCR)													
Total change in compliance costs (EUR) (SCR)	-1,870,680	-2,090,760	-2,310,840	-660,240	-1,410,620	-1,498,900	-1,587,180	-925,080	-705,000	-484,920	-264,840	-176,560	-88,280
Change in external costs (EUR) (130-560 kW)	20,473	40,945	61,418	61,418	61,418	61,418	61,418	61,418	40,945	20,473	0	0	0
Change in external cost (EUR) (>560 kW)	0	0	0	0	121,403	242,807	364,210	364,210	364,210	364,210	364,210	242,807	121,403
Total change in external costs (EUR)	20,473	40,945	61,418	61,418	182,821	304,224	425,628	425,628	405,155	384,682	364209.8	242806.6	121403.3

A.3 Mainline locomotives

Table A-18: NPV of net benefits of flexibility for locos under option 0

	20% flexibility	35% flexibility	50% flexibility
One year flexibility			
NPV saved compliance costs	24,855,343	43,496,850	62,138,357
NPV additional environmental costs	19,658,813	34,402,924	49,147,034
NPV net benefits with SCR	5,196,529	9,093,927	12,991,324
Two year flexibility			
NPV saved compliance costs	24,377,356	42,660,372	60,943,389
NPV additional environmental costs	19,280,759	33,741,329	48,201,898
NPV net benefits with SCR	5,096,596	8,919,043	12,741,491
Three year flexibility			
NPV saved compliance costs	23,911,624	41,845,342	59,779,061
NPV additional environmental costs	18,912,399	33,096,698	47,280,997
NPV net benefits with SCR	4,999,225	8,748,644	12,498,063

Table A-19: NPV of net benefits of flexibility for locos under option 1

	20% flexibility	35% flexibility	50% flexibility
One year flexibility			
NPV saved compliance costs	19,879,164	34,788,537	49,697,911
NPV additional environmental costs	15,723,009	27,515,266	39,307,523
NPV net benefits with SCR	4,156,155	7,273,272	10,390,388

Two year flexibility			
NPV saved compliance costs	19,496,873	34,119,527	48,742,182
NPV additional environmental costs	15,420,644	26,986,126	38,551,609
NPV net benefits with SCR	4,076,229	7,133,401	10,190,573
Three year flexibility			
NPV saved compliance costs	19,124,383	33,467,671	47,810,958
NPV additional environmental costs	15,126,031	26,470,554	37,815,077
NPV net benefits with SCR	3,998,352	6,997,117	9,995,881

Table A-20: Option 0b: “old” mainline engines on the market with 1 year and 20% flexibility

	2012	2013	2014	2015	2016	2017	2018
Old 560-2000 kW engines kept on the market	414	949	1484	2019	1484	949	414
Old > 2000 kW engines kept on the market	73	167	262	356	262	167	73

Table A-21: Option 0b: “old” mainline engines on the market with 1 year and 35% flexibility

	2012	2013	2014	2015	2016	2017	2018
Old 560-2000 kW engines kept on the market	322	857	1393	1928	1393	857	322
Old > 2000 kW engines kept on the market	57	151	246	340	246	151	57

Table A-22: Option 0b: “old” mainline engines on the market with 1 year and 50% flexibility

	2012	2013	2014	2015	2016	2017	2018
Old 560-2000 kW engines kept on the market	231	766	1301	1837	1301	766	231
Old > 2000 kW engines kept on the market	41	135	230	324	230	135	41

Table A-23: Option 0b: “old” mainline engines on the market with 2 year and 20% flexibility

	2012	2013	2014	2015	2016	2017	2018
Old 560-2000 kW engines kept on the market	474	949	1484	2019	1484	949	414
Old > 2000 kW engines kept on the market	84	167	262	356	262	167	73

Table A-24: Option 0b: “old” mainline engines on the market with 2 year and 35% flexibility

	2012	2013	2014	2015	2016	2017	2018
Old 560-2000 kW engines kept on the market	429	857	1393	1928	1393	857	322

Old > 2000 kW engines kept on the market	76	151	246	340	246	151	57

Table A-25: Option 0b: “old” mainline engines on the market with 2 year and 50% flexibility

	2012	2013	2014	2015	2016	2017	2018
Old 560-2000 kW engines kept on the market	383	766	1301	1837	1301	766	231
Old > 2000 kW engines kept on the market	68	135	230	324	230	135	41

Table A-26: Option 0b: “old” engines on the market with 3 year and 20% flexibility

	2012	2013	2014	2015	2016	2017	2018
Old 560-2000 kW engines kept on the market	495	989	1484	2019	1484	949	414
Old > 2000 kW engines kept on the market	87	175	262	356	262	167	73

Table A-27: Option 0b: “old” engines on the market with 3 year and 35% flexibility

	2012	2013	2014	2015	2016	2017	2018
Old 560-2000 kW engines kept on the market	464	928	1393	1928	1393	857	322
Old > 2000 kW engines kept on the market	82	164	246	340	246	151	57

Table A-28: Option 0b: “old” engines on the market with 3 year and 50% flexibility

	2012	2013	2014	2015	2016	2017	2018
Old 560-2000 kW engines kept on the market	434	868	1301	1837	1301	766	231
Old > 2000 kW engines kept on the market	77	153	230	324	230	135	41

B Detailed results for IWW

B.1 One year flexibility

B.1.1 35 % flexibility

The environmental costs of 35% flexibility are summarized in Table B-1 and Table B-2 where we give, for both the CCNR and the Euromot proposal:

- The annual increase in environmental costs for all engine categories
- The NPV of these increased environmental costs (we have omitted the relative shares, which are the same as under 20 % flexibility)

Table B-1: IWW, one year 35% flexibility, environmental cost under CCNR proposal

	2012	2013 to 2024	2025	NPV
< 0.9	6,137	6,137	0	52,381
0.9-1.2	0	2,624	2,624	21,537
1.2 - 2.5	0	69,978	69,978	574,340
2.5 - 3.5	106,069	106,069	0	905,384
3.5 - 7.0	1,124,974	1,124,974	0	9,602,528
7.0 -15	80,265	80,265	0	685,125
15.0 - 20	0	397,612	397,612	3,263,394
Total	1,317,446	1,787,660	470,214	15,104,689

Table B-2: IWW, one year 35% flexibility, environmental cost under Euromot proposal

	2012	2013	2014 to 2024	2025	2026	NPV
< 0.9	5,583	5,583	5,583	0	0	47,652
0.9-1.2	0	2,327	2,327	2,327	0	19,101
1.2 - 2.5	0	0	55,176	55,176	55,176	435,434
2.5 - 3.5	0	106,069	106,069	106,069	0	870,562
3.5 - 7.0	1,129,399	1,129,399	1,129,399	0	0	9,640,298
7.0 -15	0	69,178	69,178	69,178	0	567,779
15.0 - 20	0	0	233,795	233,795	233,795	1,845,061
Total	1,134,982	1,312,557	1,601,527	466,545	288,970	13,425,887

Increased flexibility does not change the relative costs of the CCNR and the Euromot proposal. However, the environmental costs of flexibility remain very small compared to the total environmental benefits of both proposals (2 804 million EUR for the CCNR proposal, 1 979 million EUR for the Euromot proposal).

For the Euromot proposal, the saved annual user and maintenance costs (and their NPV) are given by Table 3-10.

Table B-3: IWW, one year 35% flexibility, saved annual user and maintenance cost under Euromot proposal

	2012	2013	2014-2024	2025	2026	NPV
Low	106,858	107,948	141,750	34,892	33,802	1,187,820
Average	124,667	125,939	165,375	40,708	39,436	1,385,791
High	142,477	143,931	189,000	46,523	45,069	1,583,761

With 1 year and 35% flexibility, 175,000 EUR certification costs are saved in 2012 – the NPV of this sum is 143,837 EUR.

Even with the highest estimates, we see that the estimated value of saved compliance costs is much lower than the increase in environmental costs.

For the CCNR proposal, the saved annual user and maintenance costs (and their NPV) are given by Table 3-11.

Table B-4: IWW, one year 35% flexibility, saved annual user and maintenance cost under CNR proposal

	2012	2013	2025	NPV
CCNR1&2	178,096	236,250	58,154	1,997,485
CCNR3	534,288	708,750	174,462	5,992,454

Under CCNR2, we should also add the saved development costs of 2 450 000 EUR in 2012, which has a NPV of 2 013 721 EUR.

In any case, we see that the saved compliance costs never exceed the 6 million EUR, which is again significantly below the increased environmental costs. However, if compliance with the CCNR stage IIIB is possible without use of SCR, the compliance costs are quite close to the compliance costs linked to the Euromot proposal.

The gains in compliance costs are again extremely small compared to the costs of both options compared to option 0, as calculated in the IA study: 2 138 million EUR for the CCNR proposal, 1 145 million EUR for the Euromot proposal.

B.1.2 50 % flexibility

The environmental costs of 50% flexibility can be summarized in Table B-5 and Table B-6 where we give, for both the CCNR and the Euromot proposal:

- The annual increase in environmental costs for all engine categories
- The NPV of these increased environmental costs (we have omitted the relative shares, which are the same as under 20 % flexibility)

Table B-5: IWW, one year 50% flexibility, environmental cost under CCNR proposal

	2012	2013-2024	2025	NPV
< 0.9	8,767	8,767	0	74,830
0.9-1.2	0	3,749	3,749	30,767
1.2 - 2.5	0	99,968	99,968	820,486
2.5 - 3.5	151,528	151,528	0	1,293,406
3.5 - 7.0	1,607,106	1,607,106	0	13,717,896
7.0 -15	114,664	114,664	0	978,749
15.0 - 20	0	568,018	568,018	4,661,992
Total	1,882,065	2,553,800	671,735	21,578,127

Table B-6: IWW, one year 50% flexibility, environmental cost under Euromot proposal

	2012	2013	2014-2024	2025	2026	NPV
< 0.9	7,975	7,975	7,975	0	0	68,074
0.9-1.2	0	3,325	3,325	3,325	0	27,288
1.2 - 2.5	0	0	78,822	78,822	78,822	622,049
2.5 - 3.5	0	151,528	151,528	151,528	0	1,243,660
3.5 - 7.0	1,613,428	1,613,428	1,613,428	0	0	13,771,855
7.0 -15	0	98,826	98,826	98,826	0	811,113
15.0 - 20	0	0	333,992	333,992	333,992	2,635,801
Total	1,621,403	1,875,082	2,287,896	666,493	412,814	19,179,839

Increased flexibility does not change the relative costs of the CCNR and the Euromot proposal. However, the environmental costs of flexibility remain very small compared to the total environmental benefits of both proposals (2 804 million EUR for the CCNR proposal, 1 979 million EUR for the Euromot proposal).

For the Euromot proposal, the saved annual user and maintenance costs (and their NPV) are given by Table B-7.

Table B-7: IWW, one year 50% flexibility, saved annual user and maintenance cost under Euromot proposal

	2012	2013	2014-2024	2025	2026	NPV
Low	152,654	154,212	202,500	49,846	48,288	1,696,886
Average	178,096	179,913	236,250	58,154	56,337	1,979,701
High	203,538	205,615	270,000	66,462	64,385	2,262,515

With 1 year and 50% flexibility, 250 000 EUR certification costs are saved in 2012 – the NPV of this sum is 205 482 EUR.

Even with the highest estimates, we see that the estimated value of saved compliance costs is much lower than the increase in environmental costs.

For the CCNR proposal, the saved annual user and maintenance costs (and their NPV) are given by Table B-8

Table B-8: IWW, one year 50% flexibility, saved annual user and maintenance cost under CNR proposal

	2012	2013-2024	2025	NPV
CCNR1&2	254,423	337,500	83,077	2,853,550
CCNR3	763,269	1,012,500	249,231	8,560,649

Under CCNR2, we should also add the saved development costs of 3 500 000 EUR in 2012, which has a NPV of 2,876,745 EUR.

In any case, we see that the saved compliance costs never exceed the 9 million EUR, which is again significantly below the increased environmental costs. However, if compliance with the CCNR stage IIIB is possible without use of SCR, the compliance costs are quite close to the compliance costs linked to the Euromot proposal.

The gains in compliance costs are again extremely small compared to the costs of both options compared to option 0, as calculated in the IA study : 2 138 million EUR for the CCNR proposal, 1 145 million EUR for the Euromot proposal.

B.2 Two year flexibility

B.2.1 35 % flexibility

Table B-9: IWW, two year 35% flexibility, environmental cost under CCNR proposal

	2012	2013	2014	2025	2026	NPV
< 0.9	3,068	6,137	6,137	3,068	0	51,373
0.9-1.2	0	1,312	2,624	2,624	1,312	21,123
1.2 - 2.5	0	34,989	69,978	69,978	34,989	563,295
2.5 - 3.5	53,035	106,069	106,069	53,035	0	887,973
3.5 - 7.0	562,487	1,124,974	1,124,974	562,487	0	9,417,864
7.0 -15	40,133	80,265	80,265	40,133	0	671,949
15.0 - 20	0	198,806	397,612	397,612	198,806	3,200,637
Total	658,723	1,552,553	1,787,660	1,128,937	235,107	14,814,214

Table B-10: IWW, two year 35% flexibility, environmental cost under Euromot proposal

	2012	2013	2014	2015	2025	2026	2027	NPV
< 0.9	2,791	5,583	5,583	5,583	2,791	0	0	46,736
0.9-1.2	0	1,164	2,327	2,327	2,327	1,164	0	18,734
1.2 - 2.5	0	0	27,588	55,176	55,176	55,176	27,588	427,060
2.5 - 3.5	0	53,035	106,069	106,069	106,069	53,035	0	853,820
3.5 - 7.0	564,700	1,129,399	1,129,399	1,129,399	564,700	0	0	9,454,908
7.0 -15	0	34,589	69,178	69,178	69,178	34,589	0	556,860
15.0 - 20	0	0	116,897	233,795	233,795	233,795	116,897	1,809,579

Total	567,491	1,223,770	1,457,042	1,601,527	1,034,036	377,758	144,485	13,167,697

For the Euromot proposal, the saved annual user and maintenance costs (and their NPV) are given by Table B-11.

Table B-11: IWW, two year 35% flexibility, saved annual user and maintenance cost under Euromot proposal

	2012	2013	2014-2024	2025	2026	2027	NPV
Low	53,429	107,403	124,849	88,321	34,347	16,901	1,164,978
Average	62,334	125,303	145,657	103,041	40,072	19,718	1,359,141
High	71,238	143,204	166,465	117,762	45,796	22,535	1,553,304

With two year and 35% flexibility, 87,500 EUR certification costs are saved in 2012 and 2013 – the NPV of this sum is 141,071 EUR.

For the CCNR proposal, the saved annual user and maintenance costs (and their NPV) are given by Table B-12.

Table B-12: IWW, two year 35% flexibility, saved annual user and maintenance cost under CNR proposal

	2012	2013	2014	2025	2026	NPV
CCNR1&2	89,048	207,173	236,250	147,202	29,077	1,959,072
CCNR3	267,144	621,519	708,750	441,606	87,231	5,877,215

Under CCNR2, we should also add the annual saved development costs of 1 225 000 EUR in 2012 and 2013, which has a NPV of 1,974,996 EUR.

B.2.2 50 % flexibility

Table B-13: IWW, two year 50% flexibility, environmental cost under CCNR proposal

	2012	2013	2014	2025	2026	NPV
< 0.9	4,383	8,767	8,767	4,383	0	73,391
0.9-1.2	0	1,874	3,749	3,749	1,874	30,176
1.2 - 2.5	0	49,984	99,968	99,968	49,984	804,707
2.5 - 3.5	75,764	151,528	151,528	75,764	0	1,268,533
3.5 - 7.0	803,553	1,607,106	1,607,106	803,553	0	13,454,091
7.0 -15	57,332	114,664	114,664	57,332	0	959,927
15.0 - 20	0	284,009	568,018	568,018	284,009	4,572,338
Total	941,033	2,217,932	2,553,800	1,612,767	335,867	21,163,163

Table B-14: IWW, two year 50% flexibility, environmental cost under Euromot proposal

	2012	2013	2014	2015	2025	2026	2027	NPV
< 0.9	3,988	7,975	7,975	7,975	3,988	0	0	66,765
0.9-1.2	0	1,662	3,325	3,325	3,325	1,662	0	26,763
1.2 - 2.5	0	0	39,411	78,822	78,822	78,822	39,411	610,086
2.5 - 3.5	0	75,764	151,528	151,528	151,528	75,764	0	1,219,743
3.5 - 7.0	806,714	1,613,428	1,613,428	1,613,428	806,714	0	0	13,507,011
7.0 -15	0	49,413	98,826	98,826	98,826	49,413	0	795,514
15.0 - 20	0	0	166,996	333,992	333,992	333,992	166,996	2,585,112
Total	810,701	1,748,242	2,081,489	2,287,896	1,477,194	539,654	206,407	18,810,996

Table B-15: IWW, two year 50% flexibility, saved annual user and maintenance cost under Euromot proposal

	2012	2013	2014	2015	2025	2026	2027	NPV
Low	76,327	153,433	178,356	202,500	126,173	49,067	24,144	1,664,254
Average	89,048	179,005	208,082	236,250	147,202	57,245	28,168	1,941,630
High	101,769	204,577	237,808	270,000	168,231	65,423	32,192	2,219,005

With two year and 50% flexibility, 125 000 EUR certification costs are saved in 2012 and 2013 – the NPV of this sum is 201,530 EUR.

Table B-16: IWW, two year 50% flexibility, saved annual user and maintenance cost under CNR proposal

	2012	2013	2014-2024	2025	2026	NPV
CCNR1&2	127,212	295,962	337,500	210,288	41,538	2,798,674
CCNR3	381,635	887,885	1,012,500	630,865	124,615	8,396,021

Under CCNR2, we should also add the saved annual development costs of 1 750 000 EUR in 2012-2013, which has a NPV of 2,821,423 EUR.

B.3 Three year flexibility

B.3.1 20 % flexibility

Table B-17: IWW, three year 20% flexibility, environmental cost under CCNR proposal

	2012	2013	2014	2015-2014	2025	2026	2027	NPV	% of total NPV
< 0.9	1,169	2,338	3,507	3,507	2,338	1,169	0	28,795	0.35%
0.9-1.2	0	500	1,000	1,499	1,499	1,000	500	11,840	0.14%
1.2 - 2.5	0	13,329	26,658	39,987	39,987	26,658	13,329	315,733	3.80%
2.5 - 3.5	20,204	40,407	60,611	60,611	40,407	20,204	0	497,719	5.99%
3.5 - 7.0	214,281	428,562	642,843	642,843	428,562	214,281	0	5,278,820	63.57%

7.0 -15	15,289	30,577	45,866	45,866	30,577	15,289	0	376,635	4.54%
15.0 - 20	0	75,736	151,471	227,207	227,207	151,471	75,736	1,793,993	21.61%
Total	250,942	591,449	931,955	1,021,520	770,578	430,071	89,565	8,303,536	100.00%

Table B-18: IWW, three year 20% flexibility, environmental cost under Euromot proposal

	2012	2013	2014	2015	2016-2024	2025	2026	2027	2028	NPV	% of total NPV
< 0.9	1,063	2,127	3,190	3,190	3,190	2,127	1,063	0	0	26,196	0.35%
0.9-1.2	0	443	887	1,330	1,330	1,330	887	443	0	10,501	0.14%
1.2 - 2.5	0	0	10,510	21,019	31,529	31,529	31,529	21,019	10509.62	239,372	3.20%
2.5 - 3.5	0	20,204	40,407	60,611	60,611	60,611	40,407	20,204	0	478,576	6.39%
3.5 - 7.0	215,124	430,247	645,371	645,371	645,371	430,247	215,124	215,124	0	5,397,763	72.12%
7.0 -15	0	13,177	26,354	39,530	39,530	39,530	26,354	13,177	13176.81	317,909	4.25%
15.0 - 20	0	0	44,532	89,065	133,597	133,597	133,597	89,065	44532.3	1,014,289	13.55%
Total	216,187	466,198	771,251	860,116	915,158	698,971	448,960	359,031	68,219	7,484,606	100.00%

Due to the changes in timing, the relative shares of the engine classes have changed compared to the 1 year flexibility scheme, but these changes are very small. In the case of the CCNR, they are not even noticeable at the 2-digit level.

Next, we need to consider compliance costs.

For the Euromot proposal, the saved annual user and maintenance costs (and their NPV in 2007) are given by Table 3-15.

Table B-19: IWW, three year 20% flexibility, saved annual user and maintenance cost under Euromot proposal

	2012	2013	2014	2015	2016-2024	2025	2026	2027	NPV
Low	20,354	40,915	67,915	74,562	81,000	60,646	40,085	30,738	658,215
Average	23,746	47,735	79,235	86,988	94,500	70,754	46,765	35,862	767,917
High	27,138	54,554	90,554	99,415	108,000	80,862	53,446	40,985	877,620

With three year and 20% flexibility, 33 333 EUR certification costs are saved in 2012 and 2013 – the NPV of this sum is 79,072 EUR.

For the CCNR proposal, the saved annual user and maintenance costs (and their NPV in 2007) are given by Table 3-16.

Table B-20: IWW, three year 20% flexibility, saved annual user and maintenance cost under CNR proposal

	2012	2013	2014	2015	2025	2026	2027	NPV
CCNR1&2	33,923	78,923	123,923	135,000	101,077	56,077	11,077	1,098,082
CCNR3	101,769	236,769	371,769	405,000	303,231	168,231	33,231	3,294,246

Under CCNR2, we should also add the saved annual development costs of 466,667 EUR in 2012-2014, which has a NPV of 1,107,008 EUR.

B.3.2 35 % flexibility

Table B-21: IWW, three year 35% flexibility, environmental cost under CCNR proposal

	2012	2013	2014	2015-2024	2025	2026	2027	NPV
< 0.9	2,046	4,091	6,137	6,137	4,091	2,046	0	50,392
0.9-1.2	0	875	1,749	2,624	2,624	1,749	875	20,719
1.2 - 2.5	0	23,326	46,652	69,978	69,978	46,652	23,326	552,533
2.5 - 3.5	35,356	70,713	106,069	106,069	70,713	35,356	0	871,008
3.5 - 7.0	374,991	749,983	1,124,974	1,124,974	749,983	374,991	0	9,237,935
7.0 -15	26,755	53,510	80,265	80,265	53,510	26,755	0	659,111
15.0 - 20	0	132,537	265,075	397,612	397,612	265,075	132,537	3,139,488
Total	439,149	1,035,035	1,630,922	1,787,660	1,348,511	752,625	156,738	14,531,187

Table B-22: IWW, three year 35% flexibility, environmental cost under Euromot proposal

	2012	2013	2014	2015	2016-2024	2025	2026	2027	2028	NPV
< 0.9	1,861	3,722	5,583	5,583	5,583	3,722	1,861	0	0	45,843
0.9-1.2	0	776	1,552	2,327	2,327	2,327	1,552	776	0	18,376
1.2 - 2.5	0	0	18,392	36,784	55,176	55,176	55,176	36,784	18391.84	418,901
2.5 - 3.5	0	35,356	70,713	106,069	106,069	106,069	70,713	35,356	0	837,508
3.5 - 7.0	376,466	752,933	1,129,399	1,129,399	1,129,399	752,933	376,466	376,466	0	9,446,085
7.0 -15	0	23,059	46,119	69,178	69,178	69,178	46,119	23,059	23059.43	556,341
15.0 - 20	0	0	77,932	155,863	233,795	233,795	233,795	155,863	77931.52	1,775,006
Total	378,327	815,846	1,349,689	1,505,204	1,601,527	1,223,200	785,681	628,305	119,383	13,098,061

For the Euromot proposal, the saved annual user and maintenance costs (and their NPV) are given by Table B-11.

Table B-23: IWW, three year 35% flexibility, saved annual user and maintenance cost under Euromot proposal

	2012	2013	2014	2015	2016-2024	2025	2026	2027	NPV
Low	35,619	71,602	118,852	130,483	141,750	106,131	70,148	53,792	1,151,876
Average	41,556	83,536	138,661	152,230	165,375	123,819	81,839	62,758	1,343,855
High	47,492	95,469	158,469	173,977	189,000	141,508	93,531	71,723	1,535,835

With three year and 35% flexibility, 58,333 certification costs are saved annually in 2012-2014 – the NPV of this sum is 138,376 EUR.

For the CCNR proposal, the saved annual user and maintenance costs (and their NPV) are given by Table B-12.

Table B-24: IWW, three year 35% flexibility, saved annual user and maintenance cost under CNR proposal

	2012	2013	2014	2015-2024	2025	2026	2027	NPV

CCNR1&2	59,365	138,115	216,865	236,250	176,885	98,135	19,385	1,921,643
CCNR3	178,096	414,346	650,596	708,750	530,654	294,404	58,154	5,764,930

Under CCNR2, we should also add the saved annual development costs of 816,667 EUR in 2012 and 2013, which has a NPV of 1,937,264 EUR.

B.3.3 50 % flexibility

Table B-25: IWW, three year 50% flexibility, environmental cost under CCNR proposal

	2012	2013	2014	2015-2024	2025	2026	2027	NPV
< 0.9	2,922	5,844	8,767	8,767	5,844	2,922	0	71,988
0.9-1.2	0	1,250	2,499	3,749	3,749	2,499	1,250	29,599
1.2 - 2.5	0	33,323	66,645	99,968	99,968	66,645	33,323	789,333
2.5 - 3.5	50,509	101,018	151,528	151,528	101,018	50,509	0	1,244,298
3.5 - 7.0	535,702	1,071,404	1,607,106	1,607,106	1,071,404	535,702	0	13,197,049
7.0 -15	38,221	76,443	114,664	114,664	76,443	38,221	0	941,588
15.0 - 20	0	189,339	378,679	568,018	568,018	378,679	189,339	4,484,983
Total	627,355	1,478,622	2,329,888	2,553,800	1,926,445	1,075,178	223,912	20,758,839

Table B-26: IWW, three year 50% flexibility, environmental cost under Euromot proposal

	2012	2013	2014	2015	2016-2024	2025	2026	2027	2028	NPV
< 0.9	2,658	5,317	7,975	7,975	7,975	5,317	2,658	0	0	65,489
0.9-1.2	0	1,108	2,216	3,325	3,325	3,325	2,216	1,108	0	26,252
1.2 - 2.5	0	0	26,274	52,548	78,822	78,822	78,822	52,548	26274.05	598,431
2.5 - 3.5	0	50,509	101,018	151,528	151,528	151,528	101,018	50,509	0	1,196,440
3.5 - 7.0	537,809	1,075,619	1,613,428	1,613,428	1,613,428	1,075,619	537,809	537,809	0	13,494,408
7.0 -15	0	32,942	65,884	98,826	98,826	98,826	65,884	32,942	32942.04	794,772
15.0 - 20	0	0	111,331	222,661	333,992	333,992	333,992	222,661	111330.7	2,535,724
Total	540,468	1,165,495	1,928,127	2,150,291	2,287,896	1,747,428	1,122,401	897,578	170,547	18,711,515

Table B-27: IWW, three year 50% flexibility, saved annual user and maintenance cost under Euromot proposal

	2012	2013	2014	2015	2016-2024	2025	2026	2027	NPV
Low	50,885	102,288	169,788	186,404	202,500	151,615	100,212	76,846	1,645,537
Average	59,365	119,337	198,087	217,471	236,250	176,885	116,913	89,654	1,919,793
High	67,846	136,385	226,385	248,538	270,000	202,154	133,615	102,462	2,194,050

With three year and 50% flexibility, 83,333 EUR certification costs are saved annually in 2012- 2014 – the NPV of this sum is 197,680 EUR.

Table B-28: IWW, three year 50% flexibility, saved annual user and maintenance cost under CNR proposal

	2012	2013	2014	2015-2024	2025	2026	2027	NPV
CCNR1&2	84,808	197,308	309,808	337,500	252,692	140,192	27,692	2,745,205

CCNR3	254,423	591,923	929,423	1,012,500	758,077	420,577	83,077	8,235,614

Under CCNR2, we should also add the saved annual development costs of 1,166,667 EUR in 2012-2014, which has a NPV of 2,767,519 EUR.

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