EUROPEAN
COMMISSION

Brussels, 10.9.2013
SWD(2013) 324 final

NAIADES II

COMMISSION STAFF WORKING DOCUMENT

Greening the fleet: reducing pollutant emissions in inland waterway transport

Accompanying the document

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions

Towards quality inland waterway transport

{COM(2013) 623 final}

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1. INTRODUCTION

The Commission's Communication on NAIADES II sets out the ambition of making inland waterway transport a quality mode of transport in all its dimensions. This accompanying staff working document compares the performance of inland waterway transport (IWT) in terms of emissions with that of the other land-based modes of transport, provides a comprehensive analysis of options and identifies further steps for reducing emissions of air pollutants from the IWT fleet.

The 2011 Commission White Paper on transport, *Roadmap to a Single European Transport Area — Towards a competitive and resource-efficient transport system*, promotes a modal shift of freight transport towards rail and IWT, which have fewer societal impacts than road transport. Indeed, IWT produces fewer accidents, less congestion and less noise than road transport. However, the opposite is true as regards air-pollutant emissions.

The sector-wide analysis of IWT emissions presented in this staff working document examines a coherent set of actions needed to improve the performance of IWT with respect to air emissions. These actions are part of a broader approach for which the framework is presented here, but which needs to be integrated into various separate initiatives. These include initiatives currently under development in other policy areas, such as the review of EU air quality policy and the ongoing review of the Non-Road Mobile Machinery Directive, and new actions to be undertaken specifically for the greening of IWT. Further fine-tuning and technical validation of these policy measures will be carried out, and final decisions taken, in the course of the relevant procedures, taking into account the contribution of this document.

2. METHODOLOGY

The findings of the staff working document are based on two studies: a report prepared as part of the PLATINA project[1] which identified and screened possible measures for greening the fleet, and a study[2] commissioned by DG MOVE to assess in detail the most effective measures identified. Unless otherwise stated, all figures and tables providing detailed calculations are based on these studies.

The analysis broadly follows the Commission's impact assessment methodology: identify problems and corresponding drivers and, from these, derive objectives and policy options to be assessed and compared in quantitative and qualitative terms against a business-as-usual (BAU) scenario.

A broad range of possible measures, identified from reviewing the literature and consulting experts, is divided into four categories: infrastructure measures, ship-related technical measures, ship-operational measures and organisational measures. These are subsequently screened, on the basis of expert judgment, for effectiveness and technical and regulatory feasibility. Both regulatory and voluntary actions are considered. From this analysis, it is concluded that reducing emission limits through regulatory measures, triggering 'ship-related technical measures', would be by far the most effective approach. In a further step, a broad-brush assessment is conducted for five scenarios, involving the introduction of emission standards with two possible levels of stringency and two possible implementation deadlines.

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1 *Technical support for an impact assessment on greening the inland fleet*, PLATINA final report, April 2013.

2 *Contribution to impact assessment of measures for reducing emissions of inland navigation*, PANTEIA, April 2013 (http://ec.europa.eu/transport/modes/inland/index_en.htm).

From the assessment, it appears that setting emission levels for existing and new IWT engines in the medium term (2020) that are equivalent to those applying to road transport would stretch the limits of technological feasibility.

It has therefore been decided to include an intermediary step consisting of a detailed analysis of the technological maturity, emission reduction potential, side-effects and costs of various existing and new emission reduction technologies, with a view to identifying the best intermediate options. In this way, it is possible to identify the most mature and effective technologies, which are subsequently used to calibrate the policy options. This produces two 'intermediate' policy options with two levels of stringency. In addition, for the options with the most stringent emission limits, three variants are identified and assessed. A number of sensitivity tests were run to investigate how the results of the calculations vary according to changes in important assumptions with respect to:

- fuel prices and differences between liquefied natural gas (LNG) and diesel prices;
- alternative fuels (methanol instead of LNG);
- external cost unit prices for CO_2 emissions;
- research and development (R&D) costs for developing new low-emission engines.

In view of the longevity of IWT vessels and engines, 2050 is used as the assessment horizon. Projections of the costs of developing and deploying the technologies required to implement the policy options take account of substantial economies of scale with implementation in other sectors, e.g. for after-treatment technologies and the use of alternative fuels. The economic, social and environmental impacts are analysed from the point of view of vessel owners, technology providers, public administrations, the sector and the public at large. For the vessel owners, both the investment and total operational costs have been considered.

The emissions and related external costs generated by the IWT sector depend on various parameters. For example: the type and volume of goods carried, the transport distance, the vessel type and loading capacity, loading factor, loaded kilometre factor, transportation speed, the specific energy consumption and emission profile of the engine used and the region in which the vessel is operating.

Since precise and comprehensive data on the engine composition of the fleet are not registered at European level, a dedicated fleet/engine renewal and emission model was developed to estimate IWT vessel and engine numbers, their lifetime and emission profiles between 2011 and 2050. A model was built using the available data sets[3], which were improved by cross-reference and quality checking with vessel owners. Weighted average values were calculated for the EU-27, differentiating between 10 typical vessel types. As legislation is based primarily on the net power of the propulsion engines, engine power is mapped to vessel types, taking account of the practice of using multiple engines for the propulsion of larger vessels and push boats. The model relies on a number of specific assumptions regarding the lifetime of the engines and their emission profiles which differentiate according to vessel size and age. It uses an emission profile for the main pollutants, NOx and particulate mass (PM), depending on the year of construction of the engine (older engines are considered to emit more pollutants than more recent engines). More information is provided in Section 3 of the Annex.

It should be noted that the analysis is limited to propulsion engines and therefore excludes stationary engines, for which there is a lack of data. As a consequence, the impacts of

[3] Notably the IVR database 2012 – http://www.ivr.nl.

emissions from auxiliary engines and the cost of their possible inclusion in emission limit legislation is not included in the analysis of policy options.

The analysis is limited to IWT vessels carrying freight. The number of passenger vessels is significant (25 %) but, as they operate seasonally, they have fewer hours of operation than freight vessels and are assumed to have a share of 8-9 % of total IWT fuel consumption between 2012 and 2050. The average age of passenger vessels tends to be higher than for cargo vessels. The average engine power is roughly the same.

The environmental impacts of IWT concern primarily the emission of CO_2 and air pollutants – nitrogen oxides (NOx), particulates, sulphur dioxide (SO_2) and non-methane volatile organic compounds (NMVOC) – which can be measured in grams per tonne kilometre (tkm). However, each substance has a different impact on human health and the ecosystem and has to be evaluated differently. The externalities are quantified and expressed in terms of a common monetary unit, so that results can be compared and used for the design and assessment of policy measures.

The starting point for the calculations of the external costs for road transport and IWT are the Marco Polo freight transport external cost coefficients, as reflected in the calculations provided by the Commission's Joint Research Centre (JRC)[4]. The Marco Polo approach is currently the only methodology available which allows emissions of the various transport modes to be compared consistently on a European scale. The approach follows the methodology presented in the IMPACT handbook on estimating external costs in the transport sector[5]. The general approach of the handbook consists of calculating emission factors and multiplying them by the unit costs per externality. The JRC emissions data are based on the cost of tank-to-wheel emissions.

3. CONSULTATION

In mid-2012, the Commission set up a dedicated Common Expert Group on reducing emissions from the IWT fleet, which it would chair. The purpose of the group is to advise the Commission in preparing the ground for legislative initiatives to reduce emissions of air pollutants from IWT, to reflect on possible flanking measures and to exchange experience and information in this field.

The expert group involved Member State authorities, river commissions and key stakeholders[6], including engine and ship manufacturers, the engine retrofitting industry, independent experts and representatives of the IWT sector and ports. Various Commission services are also represented: DG Environment, DG Climate, DG Enterprise, the JRC's Institute for Energy and Transport and the Trans-European Transport Network Executive Agency.

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[4] *External cost calculator for Marco Polo freight transport project proposals (call 2013)*, JRC Martijn Brons, Panayotis Christidis, Report EUR 25929 EN, April 2013: http://ftp.jrc.es/EURdoc/JRC81002.pdf.

[5] *Handbook on estimation of external costs in the transport sector. Internalisation Measures and Policies for All external Cost of Transport (IMPACT),* Version 1.1. Delft, CE, 2008.

[6] European Shippers Council (ESC), European Barge Union (EBU), European Skippers' Organisation (ESO-OEB), Inland Navigation Europe (INE), *Promotie Binnenvaart Vlaanderen* (PBV), European Association of Internal Combustion Engine Manufacturers (Euromot), Association for Emissions Control by Catalyst (AECC), Community of European Shipyards Associations (CESA), European Federation for Inland Ports (EFIP), European Sea Ports Organisation (ESPO), European Marine Equipment Council (EMEC), etc.

The Group held its first meeting on 18 September 2012, followed by meetings on 23 October, 22 November and 17 December 2012 and 12 March 2013. There has been a high level of participation and involvement on the part of the stakeholders.

The Commission also held a stakeholder consultation, between 15 January and 8 April 2013[7], on the revision of Directive 97/68/EC on non-road mobile machinery (the NRMM Directive).

In meetings of the Expert Group, the participants consistently expressed the view that effort was needed on pollutant reduction to secure and maintain IWT's good environmental image. Pointing to the current economic situation, IWT operators have asked for financial help to implement pollution reduction measures. The engine manufacturers consider that R&D for new engine designs is profitable only if the market is big enough. As the IWT sector is relatively small with a low engine renewal rate, the most economical approach would be to align emission limits with international standards[8]. Some Member States expressed concerns regarding the sector's low earning capacity as compared with the high investment costs and its difficulties in accessing finance. Some stakeholders asked that intermediate stages be skipped in favour of stable long-term standards ensuring a stable long-term investment climate.

4. PROBLEM DEFINITION

4.1. Description of the problem

IWT has for decades been one of the most environmentally friendly modes of transport. It still has clear advantages as regards energy efficiency, low congestion and low noise and accident levels.

Although IWT emits much less CO_2 than road transport, the external costs[9] of its emissions to air (air pollutants and CO_2) are roughly equal to those of road transport. This is due to the higher cost of IWT air-pollutant emissions.

Table 1: Weighted average external costs (in euro$_{2011}$/1 000 tkm) for EU-27

2011	Climate change costs	Air pollution costs	Total external costs
Road	€ 6.95	€ 7.00	€ 13.95
IWT	€ 3.06	€ 10.47	€ 13.53

Air pollutants present serious risks to health. Even relatively low concentrations of air pollutants have been related to a range of adverse health effects.

Monetised total external costs of air pollution from IWT in the EU-27 for 2012-50 are estimated at € 51.5 billion. However, not all vessel categories contribute to the same extent: roughly 80 % of the external costs come from vessels of over 110 m and push boats, which represent only 20 % of the fleet in terms of numbers. The smaller vessels, which are used less

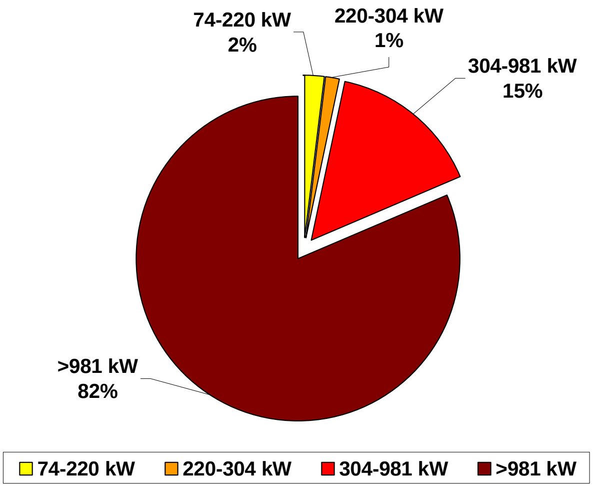
[7] http://ec.europa.eu/enterprise/sectors/automotive/documents/consultations/2012-emissions-nrmm/index_en.htm.

[8] In particular the US EPA tier 4 standards.

[9] Source: *Technical support for an impact assessment on greening the inland fleet*, PLATINA final report, April 2013.

intensively, represent 80% of the fleet, but account for only 20% of the external costs generated by IWT.

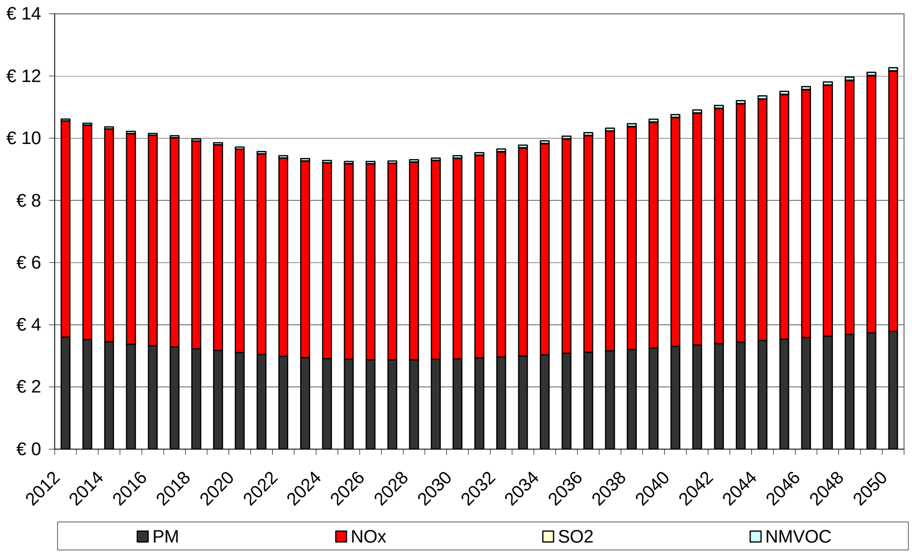
Figure 1: Discounted external costs of pollutants from IWT in 2011-50, by type of vessel (BAU scenario)



Like vessel categories, not all pollutants contribute in the same way to the overall impact of air-pollutant emissions. Figure 2 shows that PM and NOx emissions account for most of the impact.

Figure 2 also demonstrates the low contribution of SOx emissions to the overall impact of air pollutants from IWT. New legislation in force since January 2011 sets the same sulphur content limits for IWT fuel as for road transport fuel. As a result, as shown in the BAU analysis of this report, the problem of SO_2 emissions is largely solved for IWT transport, unlike that of PM and NOx emissions.

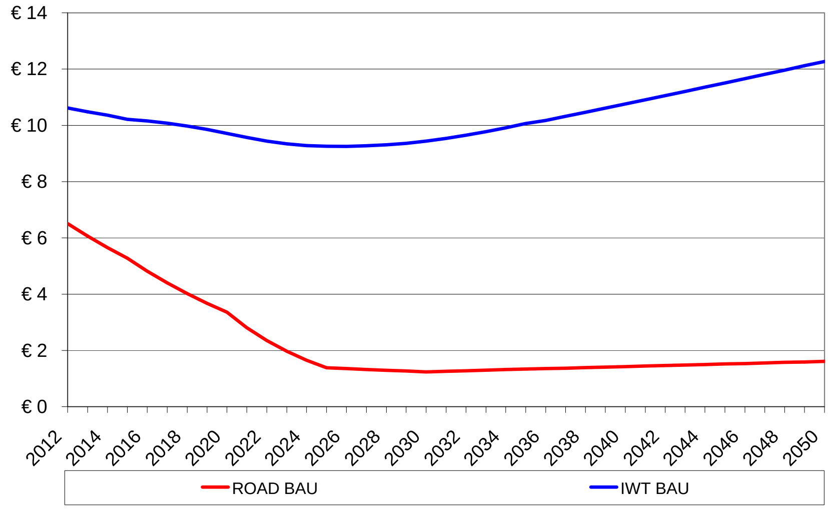
Figure 2: Business-as-usual in IWT — breakdown of air-pollutant emissions; EU-27 average (€/1 000 tkm)



NOx and PM emissions from IWT have been subject to EU standards since the early 2000s. They are currently governed by the Stage IIIA standards under the NRMM Directive[10] and the CCNR 2 standards under the CCNR[11] Regulations. It should be noted that emissions of some pollutants, such as ultra-fine particulates, are currently not regulated. IWT standards are generally less stringent than the EURO V standards that currently apply to heavy-duty road vehicles. As from 31 December 2013, emission limits for these vehicles will become even stricter, but there are no plans to reduce the limits for IWT. Also, IWT engines have a long lifetime and therefore only a few of them are currently subject to emission standards.

With the progress made with electrification in rail transport, the higher economies of scale in short sea-shipping and the significant reduction in road transport emissions over the past 15 years, IWT is now the transport mode with the highest air pollution impact per tonne/km transported[12]. In view of the White Paper target of shifting 30% and 50% of freight transport to rail and IWT by 2030 and 2050 respectively, the impact of IWT on air pollution is likely to increase if nothing is done to counteract it.

Figure 3: Air pollution costs in €/1 000 tkm: BAU scenario



Source: 2013 PANTEIA NEA

Given persistent non-compliance with EU air quality standards and the emerging evidence from the World Health Organisation as to the harmful effects of pollution from diesel combustion, the IWT sector will need to make additional efforts if it is to contribute — on a par with other transport modes — to reducing emissions to air. IWT needs to catch up with road and rail in order to maintain a level playing-field as regards air pollutant emissions.

4.2. Underlying causes of the problem

The main causes of the problem of the relatively high air-pollutant emissions from IWT are the regulatory framework, the long lifetime of inland vessels and engines, the lack of non-regulatory incentives for skippers to reduce emissions and the lack of alternative fuels. These factors are exacerbated by the small size of the market for inland vessels and their engines.

[10] For further details, see Section 2 in Annex.

[11] The Central Commission for the Navigation of the Rhine is an international organisation with five Member States: Belgium, France, Germany, the Netherlands and Switzerland.

[12] Scientific note on the Marco Polo calculator 2013 — ftp://ftp.jrc.es/pub/EURdoc/JRC81002.pdf.

4.2.1. Regulatory framework not conducive to the green propulsion of vessels

The EU regulatory framework setting emission limits for IWT started to enter into force later and is less stringent than arrangements for other modes, in particular road transport. IWT emission standards are applicable only to new engines entering the market, as is the case in other sectors, but for IWT this limitation has a much larger impact due to the longevity of the engines (see below). It is possible that rules applying only to new engines entering the market may have led vessel owners to renew existing engines rather than buying new engines that comply with emission limits.

As things stand, EU regulations do not authorise cleaner LNG-fuelled engines; vessels can navigate using LNG only as an exception granted case-by-case and for a limited period.

4.2.2. Long serviceable lifetime of IWT engines as compared with road transport engines

The long lifetime of inland barge engines (30 000 to over 200 000 hours, depending on the engine type) results in a slow uptake of the new engines in the ageing fleet. According to the IVR[13] database, because of the longevity of vessels and engines, only 17 % of the active motorised cargo fleet is equipped with engines that comply with the current or previous IWT emission standards. In contrast to road transport, where vehicle turnover is five to seven years, IWT vessels have an average age of 20 to 50 years, depending on the vessel category. Innovations are introduced at a very slow pace.

4.2.3. Lack of incentives for vessel operators/owners to limit air-pollutant emissions

CO_2 reduction strategies usually generate co-benefits for the IWT operators due to the lower fuel consumption they entail. Operators have little or no economic incentive to invest in after-treatment or end-of-pipe devices to reduce NOx or PM emissions, on the other hand. On the contrary, in fact: the use of these technologies is usually associated with higher operational and investment costs. Also, the shippers, as the IWT operators' clients, provide little or no incentive, financial or otherwise, to operate more environmentally-friendly vessels.

4.2.4. Small market for inland vessels

The relatively small and specialised market for inland vessels limits the scope for sector-specific R&D. With about 11 500 vessels operating in the EU-27, engine suppliers are limited to existing technology rather than relying on innovation.

4.2.5. Absence of alternative fuels in the sector

Deployment of LNG-operated vessels is also hampered by a shortage of bunkering facilities along the waterways. For the time being, the limited number of LNG vessels means that there is not a strong business case for investing in LNG bunkering, but the high bunkering costs (due to the lack of facilities) discourage construction of LNG vessels. The Commission's Clean Power for Transport initiative[14], which requires LNG bunkering along the inland waterways of the core TEN-T network by 2025, seeks to break this vicious circle.

4.3. Existing legal framework for addressing emissions

Until the adoption of Directive 2004/26/EC, which amended the NRMM Directive and set emission limits for IWT from January 2007 onwards, there were no EU-wide compulsory emission limits for inland waterway vessel engines. The Directive sets limits for exhaust

[13] International Association for the representation of the mutual interests of the inland shipping and the insurance and for keeping the register of inland vessels in Europe.

[14] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2013:0017:FIN:EN:PDF.

emissions for the following pollutants: carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx) and particulate mass (PM).

As regards the IWT sector, the Directive:

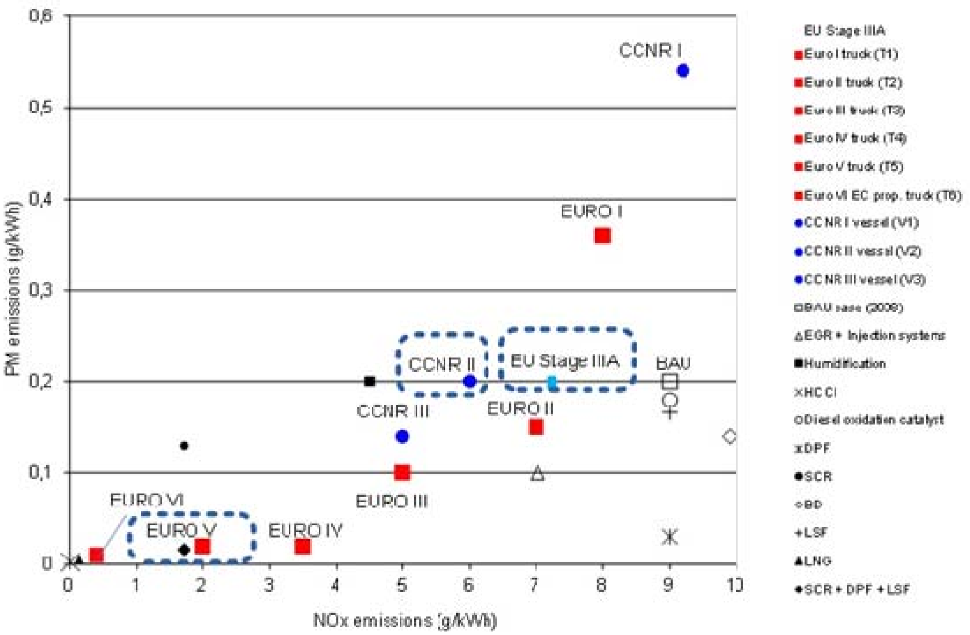
- establishes differentiated emission limits for new IWT propulsion engines coming onto the market, to be validated in a specific test cycle and subject to type approval;
- sets emission limit standards for existing engines in IWT vessels navigating with a Community certificate; and
- subjects auxiliary engines of over 560 kW to the same requirements as propulsion engines, while less powerful auxiliary engines have to comply with the general standards applying to spark ignition or compressed ignition engines.

The current Stage IIIA emission standards entered into force on 1 January 2007, 1 January 2009 or 1 January 2012, depending on the engine category. Only new engines installed on vessels since 2007 have to apply these standards.

Directive 2006/87/EC laying down technical requirements for inland waterway vessels requires engines on board vessels to comply with the standards in the NRMM Directive and allows a number of exemptions and transitional periods for existing and replacement engines.

Specific rules apply depending on the date a vessel entered into service and the power range of the engine. Engines over 19 kW installed before 2003 are not subject to any emission standards. Engines installed between 2003 and 2007 on vessels operating on the Rhine have to comply with CCNR 1 standards, whereas those installed since 2007 are covered by the CCNR 2 standards, in accordance with the relevant CCNR Regulations. The CCNR 2 standards differ slightly from the Stage IIIA NRMM standards.

Figure 4: Current emission standards for road transport and IWT: NOx/PM



The emission of SOx from IWT is regulated by a different legal framework, Directive 2009/30/EC governing the quality of gasoil used in inland navigation, which limits the sulphur content of fuel used in IWT to 10 mg sulphur per kg fuel as of January 2011, the same value as for road haulage, resulting in a substantial reduction of SO_2 emissions from IWT.

With respect to emissions of CO_2 and other greenhouse gases, there are no specific regulations for the inland shipping sector, but IWT has a clear advantage over road haulage, as demonstrated in Section 3 of the Annex.

4.4. How would the situation change all things being equal?

4.4.1. Developments in IWT under the business-as-usual (BAU) scenario

The business-as-usual reference scenario presented below describes changes to emissions if no further targeted policy measures were to be taken. In this scenario, it is assumed that voluntary measures will be implemented at their current level to promote fuel efficiency and emission reduction. Emission limits for IWT do not change, but a number of other factors do:

- IWT flows will increase according to the medium baseline scenario in the 2011 study *Medium- and long-term perspective of IWT in the European Union*[15];
- the access arrangements announced by the port of Rotterdam[16] will enter into force in 2025, allowing only vessels with engines complying with Stage IIIA standards;
- all single-hull tankers will be scrapped between 2012 and 2019 as a result of the Regulation on the European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN);
- under its Green Deal Initiative[17], the Netherlands will deploy 50 LNG vessels in the largest vessel classes (110/135 m motor vessels and push barges) by 2015;
- engine renewal rates will be low in the short term as a result of investments for new engines and new vessels being postponed to 2018. Further detailed information on renewal assumptions is provided in Section 3 of the Annex;
- it is estimated that the total number of vessels, especially the smallest, will decrease over time, with only the 110 m category expected to continue to grow;
- the great majority of engines will be replaced by conventional diesel engines that comply with the CCNR 2 standard.

In this scenario, it is expected that 6 600 engines on existing vessels will need to be replaced in 2018-50, and 2 400 new vessels will come into operation, on the basis of a total fleet in 2012 of 11 500 vessels with 12 500 propulsion engines.

4.4.2. Calculation of emission trends, 2012-50

Emissions calculations concentrate on the most critical emissions for IWT: NOx and PM. NOx and PM emission trends are projected on the basis of current and assumed future fleet/engine populations and engines' key emission characteristics. Figure 5 and 6 show the projections for NOx and PM emissions respectively, broken down by vessel category. It is clear that emissions from smaller vessels are expected to decrease later than those for larger vessels. NOx and PM values are both expected to stabilise in the long run at the legal level currently applying under emission standards for new engines, which corresponds to the IIIA

[15] http://www.ce.nl/publicatie/medium_and_long_term_perspectives_of_inland_waterway_transport_in_the_european_union/1213.

[16] http://www.portofrotterdam.com/en/Port/port-in-general/port-vision-2030/Documents/Port-vision-2030/index.html.

[17] http://www.government.nl/issues/energy/green-deal.

standard. The IIIA emission limits for IWT are about ten times higher than the EURO VI emission limits for road transport.

Figure 5: NOx emission trends in BAU scenario by vessel type

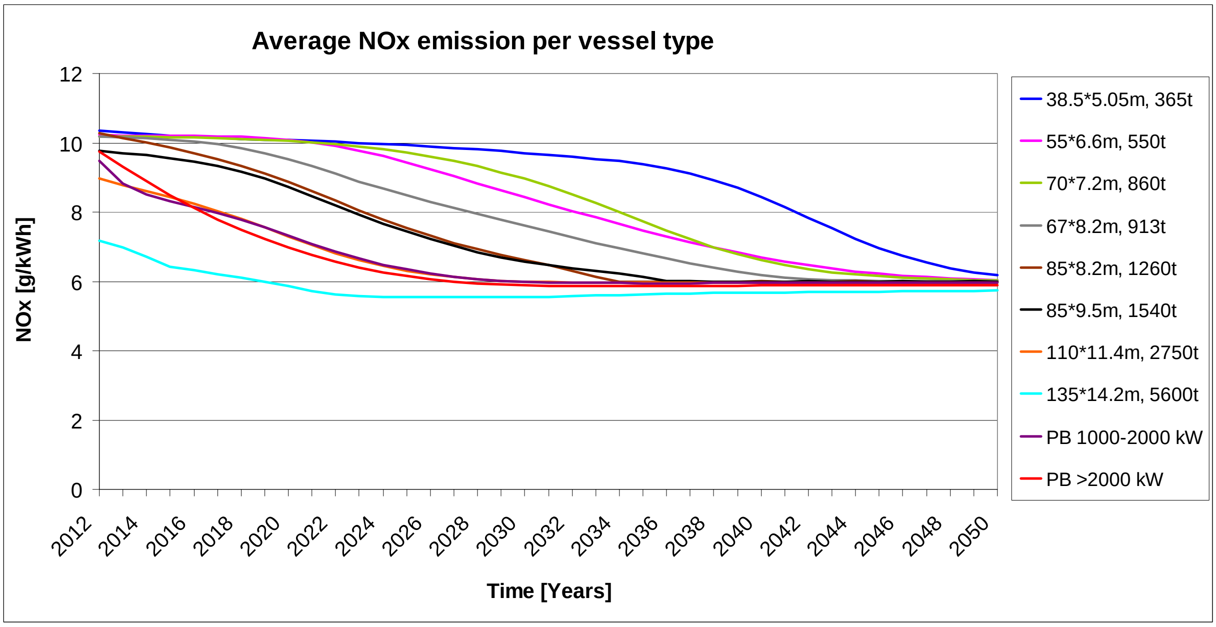
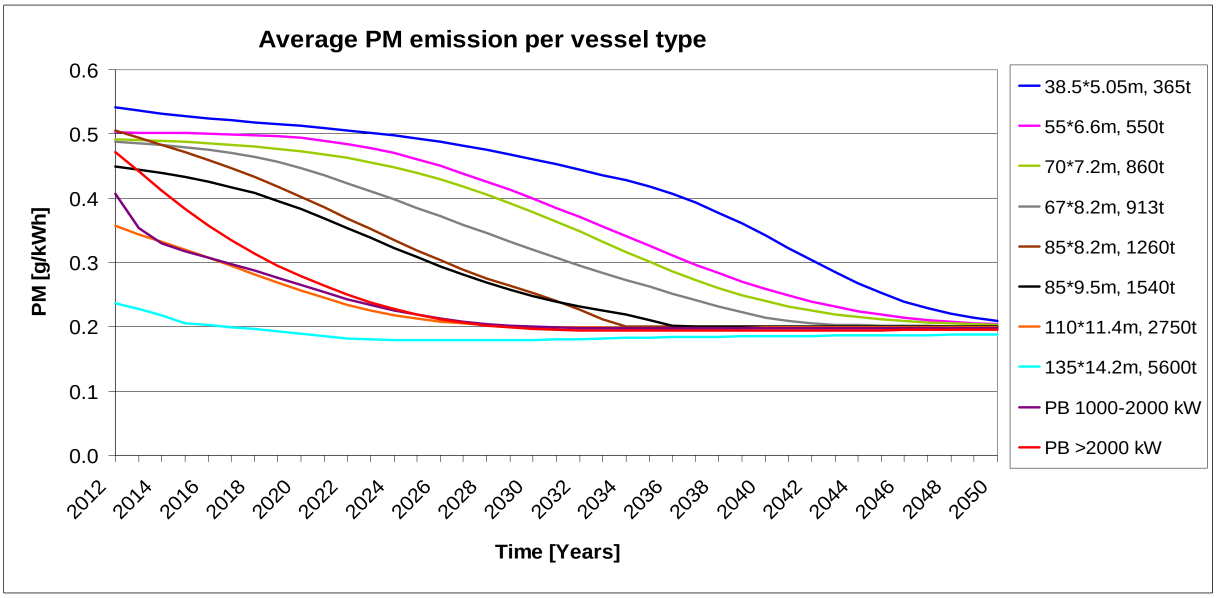


Figure 6: PM emission trends in BAU scenario by vessel type



5. OBJECTIVE

The objective is to set a policy and regulatory framework whereby state-of-the-art emission reduction technologies will be adopted, thus enabling IWT to catch up with other land transport modes as regards the emission of pollutants.

6. POLICY OPTIONS

6.1. Which options have been considered?

We identify and analyse a large number of measures that could reduce emissions. A detailed list of measures is provided in Section 11 of the Annex. In total, 37 technical measures are examined in the following four categories:

- infrastructure measures (waterway upgrading, ports and mooring places, waterway information);
- ship-related technical measures (change in fleet structure, fuels, propulsion systems, hydrodynamics measures, after-treatment systems and auxiliary systems);
- ship-operational measures (sailing behaviour, e.g. smart and eco-efficient steaming, maintenance); and
- organisational measures (transport management, e.g. fewer empty trips, increased load factor).

The majority of the measures were found not to be effective (often less than 5% emission reduction) and have been discarded. Certain measures shown to have substantial emission reduction potential, e.g. fewer empty trips, larger vessels or improved propeller systems, can be influenced only by the market operators themselves. As such measures would produce significant co-benefits for the operators, it is assumed that their implementation is prevented by other market barriers, such as unbalanced trade, saturation of fleet capacity, etc. These measures are therefore discarded. Voluntary measures were also analysed and discussed by the Common Expert Group. From the discussion, it appeared that it may not be easy to replicate the impact of regional voluntary measures at EU level and that such measures would not bring down emissions from IWT significantly. These measures are therefore included in the business-as-usual scenario.

The conclusion from the preliminary screening is that stricter emission standards are the only effective way to achieve significant reductions in emissions from IWT. The next step consists of determining the level of ambition for such standards. For this purpose, a preliminary investigation considered five options, involving standards with two possible levels of stringency[18] and two possible implementation deadlines[19], looking mainly at technical feasibility, impact on emissions and cost of implementation. In view of the expected technical difficulties in applying to all IWT vessels, by 2020, emission limits equivalent to those applying to road transport, the preliminary investigation concludes that a more differentiated approach is needed to identify policy options.

6.2. Which options have been assessed in detail?

Following a detailed examination of the feasibility of various technologies (see Section 2 on methodology), two policy options for compulsory emission standards were assessed in detail.

6.2.1. Description of the policy options

The two policy options considered are the ‘Conservative Option’, with higher, more lenient emission limits, and the ‘Innovation Option’, with lower, more stringent limits. The characteristics of the two options are described in the table below:

[18] 1) standards aligned with existing international standards and 2) standards equivalent to those of road transport.
[19] 2020 and 2035.

Table 2: General description of the policy options

	Description of the policy option
Conservative Option **C**	This option takes the emission limits one level higher, from Stage IIIA to Stage IIIB, . which is still well below the limits for road. It applies to new engines only. The Stage IIIB emission limits are aligned with international standards. Hence, R&D for these engines have already been done. Unlike the current Stage IIIA engines, Stage IIIB engines cannot be retrofitted with state-of-the-art Selective Catalyst Reduction (SCR) technology to further reduce NO_X emissions.
Innovation Option **I**	This option, which has been assessed with three variants, involves stricter emission limits for the whole fleet (existing and new engines). The limits for new engines differ according to power range and policy variant (Stage IIIB, IVB or V); for existing engines, a single limit is set (Stage IVA) — or none, depending on the variant and engine category. Stages IVB and V set emission limits for ultrafine particles (PN), methane and ammonia (see paragraph 6.2.3), as well as for CO, HC, NOx and PM. The three variants have the same overall impact in terms of total emissions by 2030, but vary in terms of scope and the date of entry into force of the emission limits. This option subjects a limited number of IWT engines to a Stage V emission limit similar to the EURO VI limit for heavy-duty road vehicles.

The limit values considered for NOx and PM, the most important pollutants, are presented in the table below for the various emission stages considered, along with the Stage IIIA values currently in force. Comprehensive tables of emission limits per pollutant for all stages are presented in Sections 2 and 6 of the Annex.

Table 3: Summary of the NOx and PM emission limits of the different standards

Standards	NOx g/kWh	PM
Stage IIIA	(NOx + CO) 7.5 - 11	0.2 - 0.50
Stage IIIB	1.8 - 2.1	0.045 - 0.14
Stage IVA	1.8 - 2.1	0.03
Stage IVB	1.2	0.02
Stage V	0.4	0.01

The Conservative Option takes the same approach to introducing new compulsory emission limits as that adopted for previous updates of the NRMM limits: a restricted reduction of limits entering into force within a relatively short timeframe. As the option covers new engines only, engines with a broad range of emission profiles will continue to operate on the EU's inland waterways: a large number of old engines that do not comply with any emission limits, and more recent engines complying with CCNR 1, CCNR 2, Stage IIIA or, for newly installed engines, Stage IIIB. The Stage IIIB standard is aligned to the US EPA tier 4 standard (to be implemented from the beginning of 2014 in the US) and the IMO tier 3 standard (see

Section **8** of the Annex).

The Innovation Option sets emission limits that reflect the state of the art in emission reduction technology, which is becoming increasingly mature in power categories where due to the introduction of stringent emission standards for heavy-duty road engines were introduced. This option covers both new and existing engines and so prevents regulatory distortion in decisions as to whether to recondition an existing engine or replace it with a new one. (In principle, existing engines can be reconditioned *ad infinitum*). The Innovation Option has differentiated emission limits depending on the power of an engine and whether or not it is new. The dates of entry into force of the emission limits also vary.

For existing engines, a single set of emission limits (Stage IVA) is considered, that can in principle be achieved by all existing engines equipped with retrofitting devices.

For new engines, two emission standards are considered: for smaller engines, a basic Stage IVB, which is less ambitious than the limits for road transport, and a Stage V limit, equivalent to road transport, for larger engines. In view of the R&D needed for Stage V, this standard would not enter into force before 2020, or 2022 for one of the variants.

At this point, it must be noted that Stage V limit values as suggested for the purpose of this study were deliberately chosen to be identical with those of Euro VI of heavy duty road vehicles. Given a number of structural differences between engines and their use in the road and shipping sectors, respectively, this assumption will however require further technical validation in order to confirm whether limit values can be simply transposed by direct analogy, as suggested, or whether certain adaptations will be needed. Also, it is worthwhile mentioning that underlying test cycles for NRMM and road vehicles are different so that the direct reference to road standards must be seen and assessed in the right perspective.

Given the limited impact of emissions from smaller vessels, some variants of the Innovation Option propose more lenient emission limits than Stage IVA or IVB in order to reduce overall compliance costs.

Three variants have been assessed for the Innovation Option. For the sake of comparability, they have been designed in such a way as to achieve the same external costs of air pollutant emissions by 2030:

- **Option I-L** 'Innovation Option — Level playing-field': This variant sets the most stringent emission levels of all policy options and variants; it covers all existing and new propulsion engines of the IWT fleet. It does not differentiate between small and large engines, except for the highest category of new engines, which have to apply Stage V limits. It favours a level playing-field between the different vessel categories and between existing and new vessels. It allows more time (until 2022) for large vessels to adapt to Stage V.
- **Option I-E** 'Innovation Option — Efficiency': This variant requires more effort from vessels with the biggest engines, which generate most of the air pollution. It sets less stringent standards for smaller new engines and no emission limits for existing engines normally used on vessels of less than 55 m. The more lenient requirements for smaller vessels are compensated by an earlier introduction of Stage V for larger vessels (by 2020). This variant is the most effective in terms of emission reduction per euro invested, by avoiding high investment costs where emission reduction potential is lower.
- **Option I-M** 'Innovation Option — Mix': This variant is a mix of the first two variants. For engines normally used on vessels of less than 38 m, the requirements are the same as for variant I-E. For engines normally used on vessels of between 38 m and 55 m, they are the same as for variant I-L. Stage V requirements also apply to larger vessels from 2020.

The tables below provide an overview of the emission limits for the policy options and the variants.

Table 4: Emission limits for new engines (coming onto the market and to be installed on board vessels):

New engines		Option I-L	Option I-E	Option I-M	Option C
75 ≤ P ≤ 220	L ≤ 38	IVB by 2017	IIIB by 2017	IIIB by 2017	IIIB by 2017
220 < P ≤ 304	38 < L ≤ 55	IVB by 2017	IIIB by 2017	IVB by 2017	IIIB by 2017
304 < P < 600	55 < L ≤ 85 (85X8.2 m)	IVB by 2017	IVB by 2017	IVB by 2017	IIIB by 2017
600 ≤ P <981	85 ≤ L <110 (85X9.5 m)	IVB by 2017	IVB by 2017	IVB by 2017	IIIB by 2017
P ≥ 981	L ≥ 110	IVB by 2017 V by 2022	IVB by 2017 V by 2020	IVB by 2017 V by 2020	IIIB by 2017

(P = installed net propulsion power of the vessel in kW; L = length of the vessel that is most representative for the installed power)

Table 5: Emission limits for existing engines:

Existing engines		Option I-L	Option I-E	Option I-M	Option C
75 ≤ P ≤ 220	L ≤ 38	IVA between 2017 and 2027	-	-	-
220 < P ≤ 304	38 < L ≤ 55	IVA between 2017 and 2027	-	IVA between 2017 and 2027	-
304 < P < 600	55 < L ≤ 85 (85X8.2 m)	IVA between 2017 and 2027	IVA between 2017 and 2027	IVA between 2017 and 2027	-
600 ≤ P <981	85 ≤ L <110 (85X9.5 m)	IVA between 2017 and 2027	IVA between 2017 and 2027	IVA between 2017 and 2027	-
P ≥ 981	L ≥ 110	IVA between 2017 and 2027	IVA between 2017 and 2027	IVA between 2017 and 2027	-

(P = installed net propulsion power of the vessel in kW; L = length of the vessel that is most representative for the installed power)

6.2.2. Available technologies for achieving standards

Implementation of new standards depends on the necessary technological advances and a sufficiently large market to attract suppliers. IWT engines represent a small market, but the technologies to achieve the emission limits have been developed for, and are already applied in, other markets. This section sets out which of the various technologies available can be used to achieve the individual emission standards. It would, of course, be for the market to decide which technology to adopt, as the limits are strictly technology-neutral. Also, it should be noted that further technological advances may render compliance with these standards technically easier or less expensive in the future.

Stage IIIB

The emission levels for this standard can be achieved by adding Selective Catalyst Reduction (SCR) equipment to a Stage IIIA or CCNR 2 engine. The standard can also be achieved for new engines — with no additional R&D — without adding retrofitting equipment. As such Stage IIIB engines already have low-performance SCR, no additional SCR equipment can be retrofitted to further improve on NOx emissions.

Stage IVA

This standard addresses only existing engines. Its emission levels can be achieved by retrofitting engines with state-of-the-art SCR and Diesel Particulate Filter (DPF) equipment. This assessment assumes the presence of closed-wall flow filters, which are highly effective and reliable. This solution would not work for a limited number of the most polluting engines and these would need to be replaced by a new engine.

Stage IVB

The emission levels for this standard can be achieved by retrofitting Stage IIIA or CCNR 2 engines with state-of-the-art equipment. LNG-propelled vessels can also achieve Stage IVB through the addition of SCR and DPF for dual-fuel LNG or possibly SCR only for mono-fuel LNG. This standard also sets limits for particulate numbers (PN) to limit the emission of fine methane (CH_4) and ammonia (NH_3) particulates.

Stage V

The proposed Stage V emission levels can as of today only be achieved by vessels with LNG engines, which have lower NOx and PM pollutant emissions than diesel engines. LNG engines achieve further reductions when equipped with SCR and/or DPF filters, bringing emission levels down to values similar to those applied in EURO VI heavy-duty road standards. Further R&D is required to achieve Stage V for IWT diesel engines.

Figure 7: Schematic representation of technologies allowing new engines to reach Stage IIIB, Stage IVB and Stage V standards

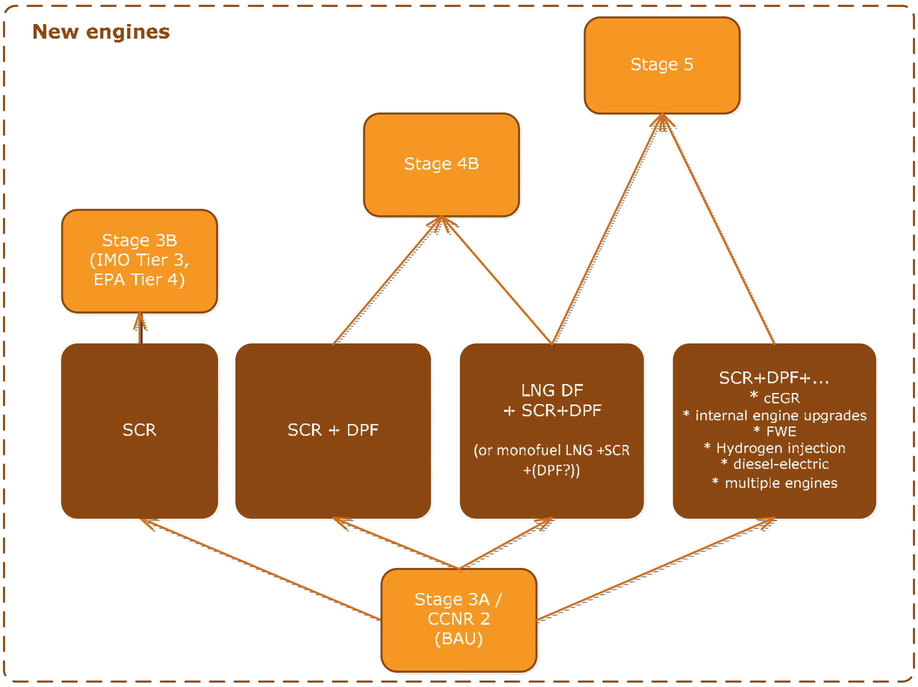
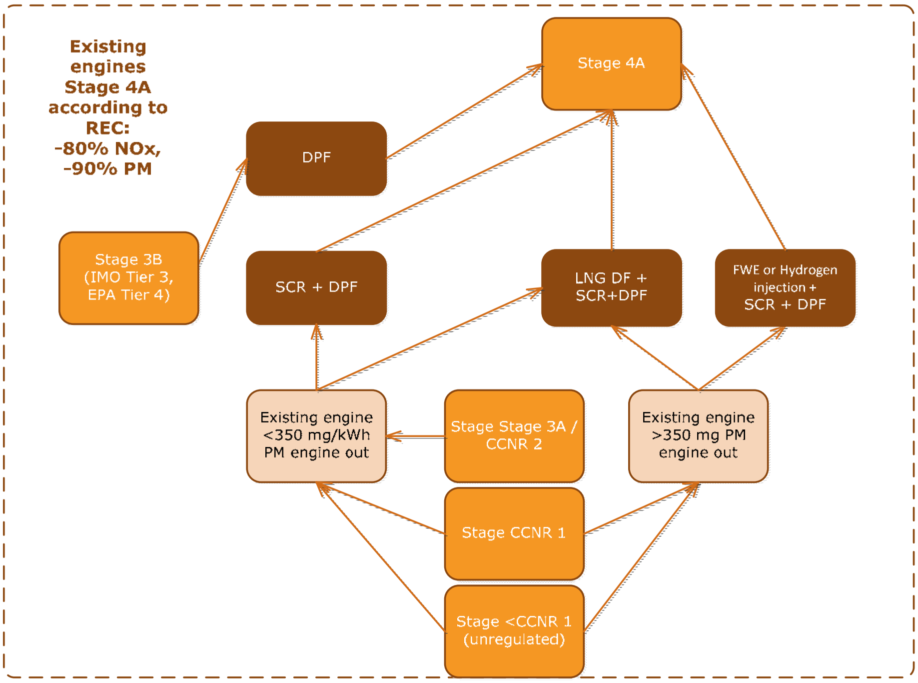


Figure 8: Schematic representation of technologies allowing existing engines to reach Stage IVA standards



6.2.3. Pollutants addressed by the proposed standards

The current standards cover up to four pollutants: carbon monoxide (CO), hydrocarbons (HC), nitrogen oxide (NOx) and particulates (see Section 6 of the Annex for further details).

However, in order to ensure that these are not replaced by harmful new pollutants, other substances are also taken into account. Depending on the policy option, additional limit values are included for:

- NH_3, which can result from the NOx reduction process;
- CH_4, a greenhouse gas that can result from using LNG;
- Particulate number (PN), with a limit for fine particles chosen to be identical with the one of EURO VI standard for heavy-duty vehicles.

6.2.4. Entry into force of standards

For both the Innovation Option and the Conservative Option, the standards could for instance be applied from 2017 onwards for new engines, except for Stage V, which would be introduced at a later stage, for instance in 2020 or 2022.

For existing engines, standards could be introduced gradually from 2017 as and when vessel certificates are renewed. In view of certificates' period of validity, the standards for existing engines would be implemented by 2027[20]. This would prevent additional inspections of the vessels and give a transition period for operators in order to allow sufficient time for retrofitting their engines.

These timings may be further refined in view of the outlook for the sector with respect to the current economic crisis.

[20] The certificates are valid for up to 10 years, in accordance with Article 2.06 of Annex II to Directive 2006/87/EC.

7. IMPACTS OF THE POLICY OPTIONS

This section describes in quantitative and qualitative terms the health and environmental, economic and social impacts of the policy options. The qualitative impacts are scored using '+++' for very positive, '++' for positive, '+' for rather positive, '0' for neutral, '-' for rather negative, '--' for negative and '---' for very negative scores.

7.1. Health and environmental impacts

The most significant transport-related air pollutants are particulates (PM), nitrogen oxide (NOx), sulphur dioxide (SO_2) and volatile organic compounds (VOC), and ozone (O_3) as an indirect pollutant. Their known impacts include, but are not limited to, health effects, building and material damages, crop losses and impacts on ecosystems and biodiversity.

The effects of PM on health occur at levels of exposure currently being experienced by most urban and rural populations. Chronic exposure to particulates contributes to the risk of developing cardiovascular and respiratory diseases and of lung cancer. In the EU, average life expectancy is 8.6 months lower due to exposure to the PM2.5 produced by human activity.

Excessive ground-level ozone, a by-product of NOx and VOCs, can have a marked effect on human health. It can give rise to breathing problems, trigger asthma, reduce lung function and cause lung disease. In Europe, it is currently one of the air pollutants of highest concern. Several European studies have reported that daily mortality rises by 0.3 % and the rate of heart disease by 0.4 % per 10 $\mu g/m^3$ increase in ozone exposure[21].

Epidemiological studies have shown that symptoms of bronchitis in asthmatic children increase in association with long-term exposure to NO_2. An increased incidence of reduced lung function is also linked to NO_2 at concentrations currently measured (or observed) in European cities.

The breakdown of air-pollutant emissions in the IWT sector shows that NOx and PM account for more than 95 % of the impacts of all pollutants emitted, so these emissions have been analysed in detail. Tables and graphs on how they have changed over time are presented in Section 9 of the Annex.

By 2030, the Innovation Option reduces NOx emissions by 72 000 tonnes and PM by 3 700 tonnes as compared with the BAU scenario, whereas the Conservative Option reduces NOx by 39 000 tonnes and PM by 2 400 tonnes.

The Innovation Option would provide a significant stimulus to the switch to LNG engines. Consequently, as compared with the Conservative Option, it would involve lower emissions of CO_2 and PM, both pollutants that contribute to climate change. The increased use of LNG may also result in higher methane emissions, which also contribute to climate change, but their impact would be mitigated by the use of methane catalysts.

Given the fact that it makes the most use of SCR/DPF technology, the Innovation Option scores highest for PN/HC/CO reduction. Variant I-E scores lower than I-L, as there are no emission limits for the smallest category of vessels. Option C shows no reduction for these pollutants.

Overall, the emission reductions would lead to external cost savings, as compared with the BAU scenario, of € 23 billion with the Innovation Option and € 14 billion with the Conservative Option. As shown in Figure 9, the Innovation Option is expected to result in lower external costs for air pollutants per tonne/km than for heavy-duty road vehicles by

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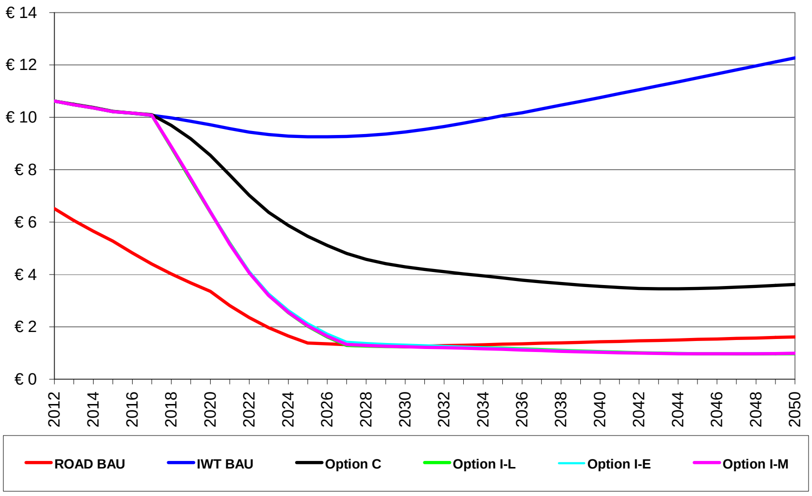
[21] Source: World Health Organisation.

2030. Option C, whilst decreasing air pollutants from IWT, will not compete with road freight transport as regards external air pollution costs, even in the very long term. The Innovation Option would reduce external costs by approximately 45 % by 2030. Option C would achieve a 28 % reduction of external costs in that time.

Figure 9: External costs of air pollutants for BAU IWT and road haulage and policy options I-L, I-E, I-M and C (€/1 000 tkm)



Please note that in the graph above, I-L and I-E curbs are hidden by the I-M curb.

Table 6 : Score of the options

The scores of the options are set out in the table below:

	Option I-L	*Option I-E*	*Option I-M*	*Option C*
NOx reduction in 2030	86 %	85 %	85 %	54 %
as compared with BAU	+++	+++	+++	+
PM reduction in 2030	92 %	90 %	91 %	58 %
as compared with BAU	+++	+++	+++	+
CO_2 reduction in 2030	11 %	11 %	11 %	0 %
as compared with BAU	+	+	+	0
PN/HC/CO reduction	+++	+	++	0/+
CH_4 reduction	0	0/-	0/-	0
Reduction of external costs in 2030 as compared with BAU (€)	€ 23 369 m	€ 23 233 m	€ 23 382 m	€ 14 479 m
Reduction of external costs in 2030 as compared with BAU (%)	45 %	45 %	45 %	28 %

7.2. Economic impact

7.2.1. Economic costs of the policy options

For the Conservative Option, the total marginal costs for the new standards, including the cost of ownership, amount to € 400 million. For the Innovation Option, the total marginal costs are of the same order of magnitude, ranging between € 500 and 670 million depending on the policy variant.

The Innovation Option requires significantly more investment than the Conservative Option, however, with total marginal investments at net present value estimated at € 1.9 billion. The

Conservative Option would require an initial marginal investment of only € 210 million. These figures have to be compared with the € 1.2 billion investment which would be required in the BAU scenario.

The difference between total costs of ownership and total investment are due to the large differences between the two options in terms of operational costs/savings. The costs of the Innovation Option are significantly reduced by savings attributable to lower fuel (LNG) prices, whereas the costs for the Conservative Option, which are the lowest, increase due to additional maintenance, fuel and urea consumption.

In order to valuate future costs and benefits, a discount rate of 4% has been used. LNG is assumed to be 20% cheaper than diesel at the point of delivery[22].

Table 7: Costs for the IWT sector by policy option

	Economic Costs			
	Option I-L	*Option I-E*	*Option I-M*	*Option C*
total cost IWT[23]	€ 670 m	€ 492 m	€ 545 m	€ 403 m
investments by IWT[24]	€ 1 886 m	€ 1 935 m	€ 1 972 m	€ 210 m

7.2.2. Financing the implementation of the measures

The marginal investment for a single engine complying with the new emission standards ranges between € 17 000 for a Stage IIIB engine on a small vessel and € 1 412 000 for a powerful LNG engine on a push boat. The number of vessels that would need to be fitted with new engines over the entire period covered by the assessment[25] is estimated at € 9 000.

The marginal investment to upgrade an existing engine to Stage IVA standard for a small vessel is expected to range between € 44 000 for a small engine and € 200 000 for a large diesel engine. Requirements for retrofitting existing engines, when spread over a period of 10 years[26], would affect roughly 5 000 engines.

Further detail on financing requirements for various categories of engine and various emission standards is provided in Section 10 of the Annex.

Owners of smaller vessels often have a more limited financing capacity, as the value of the vessels, which serves as collateral for loans, is also lower.. Moreover, loans are granted on the basis of the level of indebtness of the owner and of the return on investment. Considering that the societal benefit of clean air is not a financial return on investment, the financing aspect especially in light of the table 8 on the financial feasibility, is a key issue. However, it is clear that ship-owners are required to continue to invest in safe and sustainable navigation, which is also the case for operators in other modes of transport.

Financing decisions need to take account of the total costs of ownership, not only investment costs. As explained in the previous section, total ownership costs differ significantly from investment costs. Cumulative discounted cash flows for a 110 m vessel can vary significantly depending on the emission standards and technologies adopted (see Figure 10 providing an example comparing the cumulative cash flow between diesel engines and LNG engines for a

[22] This assumption is based on desk research and expert judgement.
[23] Marginal investment costs + operational costs for the IWT sector over 20 years.
[24] Marginal investment costs for the IWT sector.
[25] From 2018, a possible date of entry into force of the new standards, to 2050.
[26] e.g. 2017-26 —certificates are valid for up to 10 years, in accordance with Article 2.06 of Annex II to Directive 2006/87/EC.

110m vessel). As regards investment in LNG, the recurrent savings from adopting LNG-based solutions may also serve as collateral for owners requesting finance.

Figure 10: Cumulative discounted cash flows for a 110 m vessel by emission standard/technology

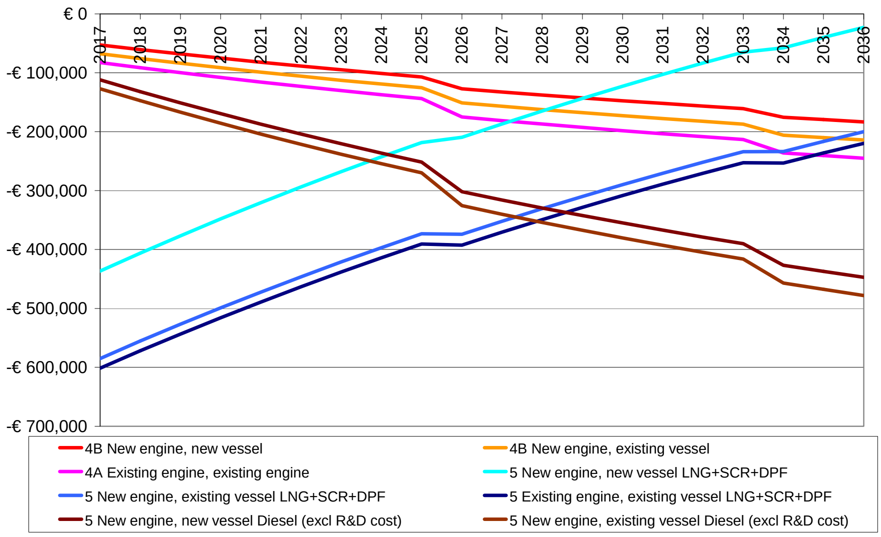


Table 8: Score of the options

The scores of the options are as follows:

	Option I-L	*Option I-E*	*Option I-M*	*Option C*
Financing feasibility	---	-	--	-

7.3. Social impacts

Option I-L would boost employment because of the need to retrofit engines and the consequent increased demand for products and services from engine manufacturers, equipment suppliers and wharves. By exempting existing engines in smaller vessels, Option I-E would have less of an impact in terms of employment. With its off-the-shelf solutions, Option C would generate the least employment in the sector of sustainable ship technologies.

If, faced with the need to make new investments, some ship-owners may decide to leave the profession. It is expected that the freight would then be carried by other vessels, by truck or by rail. This may therefore affect structure of IWT sector but no overall effect on employment. Further analysis may provide more insight in this matter.

Table 9: Score of the options

The scores of the options are as follows:

	Option I-L	*Option I-E*	*Option I-M*	*Option C*
Labour market effects	+++	++	++	+

7.4. Administrative burden

Administrative burden may increase with the variety of technologies used for ship propulsion. In particular, technologies that may give rise to safety considerations (e.g. LNG) may entail separate certification and information requirements, resulting in additional administrative costs. Developing general standards could prevent these costs from becoming too high. Additional administrative burden could also be substantially reduced if the entry into force of new emission limits were to coincide with the renewal of certificates, when vessels have to be inspected in any case. Technology-neutral standards may also contribute significantly to keeping administrative burden within reasonable proportions.

Administrative burden would be reduced where certain vessel categories are exempted from applying standards, such as in variant I-E, Option C and, to a lesser extent, variant I-M. With variant I-L, all vessels would be subject to emission standards, so this variant would entail the greatest administrative burden.

Table 10: Score of the options

The scores of the options are as follows:

	Option I-L	*Option I-E*	*Option I-M*	*Option C*
Reduction of administrative burden	--	0/-	-	0

7.5. Who is affected and how?

In general, the EU population will benefit from reduced emissions of substances that are harmful to human health, in particular NOx and PM. There may be marginal environmental effects, both positive (reduced CO_2 and PM emissions) and negative (increased methane emissions).

For the inland shipping companies and owner-operators, the most important issues are financial. Increased expenditure for vessel engines and associated equipment, and increased running costs, may raise the cost base for IWT to a certain extent, but it is considered that the modal shift effect would be negligible and earning capacity will not necessarily be negatively affected, provided that a level playing-field is maintained so that operators can pass on the costs to their customers. For the largest vessels, operating costs may actually fall due to fuel cost savings if LNG is adopted. Furthermore, the increased use of LNG may also present new market opportunities for IWT.

The retrofitting of vessels will also involve a financial cost due to the (limited) time for which they are out of service. This has been taken into account in the cost/benefit analysis.

Crew members operating LNG engines will require training for safety reasons. Crew members are expected to benefit in terms of health from cleaner engines.

Engine manufacturers, equipment suppliers and ship wharves may face increased demand. If this demand is sufficiently spread over time, the sector should be able to prevent capacity bottlenecks. If a Stage V diesel engine is developed, upfront R&D would be necessary for engine manufacturers and equipment suppliers. If higher emission standards are adopted in other parts of the world, manufacturers may have a 'first mover' advantage and decrease production costs.

The fuel production industry will be positively affected in the event of increased demand for LNG.

Ports will benefit from cleaner air and will have to ensure that LNG bunkering facilities are provided for the inland waterways network.

8. COMPARING THE OPTIONS

8.1. Cost/benefit analysis

The benefits for society are substantial with all the policy options, but about 50% greater with the Innovation Option than with the Conservative Option. As total marginal costs are roughly equal for all the options, this results in substantially better cost/benefit ratios for the Innovation Option.

As regards the variants of the Innovation Option, variant I-E (optimised for efficiency) has the best cost/benefit ratio, as requirements for vessel categories with higher-cost/lower-benefit ratios are excluded. Variant I-L, which covers all vessels, has the lowest cost/benefit ratio of the three variants, with Option I-M in the middle.

Due to its low investment costs for the operators, the Conservative Option has the best benefit/investment ratio.

Table 11: Cost/benefit analysis result by policy option

	Cost/benefit analysis results			
	Option I-L	*Option I-E*	*Option I-M*	*Option C*
total cost IWT[27]	€670 m	€492 m	€545 m	€403 m
investments by IWT[28]	€1 886 m	€1 935 m	€1 972 m	€210 m
Net impact for society[29]	€22 698 m	€22 740 m	€22 706 m	€14 076 m
Benefit/cost ratio[30]	33.9	46.2	41.6	34.9
Benefit/investment[31] ratio	12.4	12	11.9	68.6

Further analysis (see Section 5 of the Annex) shows that the category of large vessels/large engines (>981 kW) has a major influence on the results. This class has a very high benefit/cost ratio (113 to 129) and also significantly lower external costs (reduced by 50% as compared with the business-as-usual scenario). Moreover, in this vessel class, all new LNG-propelled vessels added to the fleet reduce both the operational costs for the ship-owner/operator and the external costs for society as compared with BAU. Setting Stage V emission limits for this class of vessel — as envisaged under the Innovation Option — will promote conversion to LNG and trigger significant societal and economic benefits.

8.2. Technical feasibility

Engine manufacturers are currently developing Stage IIIB technology in order to comply with US standards for marine engines. This will be in the near future "off the shelf" technology. As no Stage IVA, IVB or V level requirements exist yet, existing engines would need to be retrofitted to comply with these more stringent standards. If engine manufacturers do not consider the IWT engine market large enough to justify R&D investments to develop engines that comply with the emission standards, it is expected that integrators will adapt existing engines by adding SCR and/or DPF equipment where necessary.

As of today Stage V emission standards could already be met with LNG dual-fuel combined with SCR and DPF or, probably, with LNG mono-fuel combined with SCR. A Stage V diesel engine needs to be developed for the large existing vessels unable to convert to LNG. Option I-L allows more time for developing the Stage V technologies, resulting in a higher score for technical feasibility than for Options I-E and I-M, where less time is available.

[27] Marginal investment costs + operational costs for the IWT sector over 20 years.
[28] Marginal investment costs for the sector.
[29] Reduction of external costs as compared with BAU — total costs for IWT.
[30] Reduction of external costs/total costs IWT.
[31] Reduction of external costs/investment costs IWT.

Certain smaller vessels may lack space in the engine room for the retrofitting equipment (filter, SCR, urea tank). This problem is only relevant for Option I-L, as in Option I-E existing small vessels are exempt. Option I-M takes an intermediate approach in this respect.

With R&D already done or planned and no need for retrofitting, Option C scores well for technical feasibility.

Table 12: Score of the options

The scores of the options are as follows:

	Option I-L	*Option I-E*	*Option I-M*	*Option C*
New engines	-	-	-	+++
Retrofit existing engines	---	0/-	-	+++

8.3. Summary

This section provides a brief overall comparison of the two options. Table 6 at the end of the section summarises the findings in a multi-criteria scoring table.

The Innovation Option would reduce pollution from IWT by 50 % in 2030 as compared with business-as-usual, the Conservative Option by 28 %. The Innovation Option closes the gap between IWT and road transport, in terms of external costs of air-pollutant emissions per tonne/km, by 2030. This would help to level the playing-field by ensuring convergence of the emission limits applying to road transport and IWT. In contrast, with the Conservative Option pollutants emitted by IWT per tkm remain higher than for road transport, even in 2050. The impact of this option may be further reduced if operators put off reconditioning their existing engines to avoid the surplus costs of cleaner new engines. For the Innovation Option, where existing engines are also covered, operators may on the contrary opt for engine renewal as an alternative to investing substantial sums in their existing engines, further bolstering the positive effect of this option.

The Conservative Option is based on an existing international standard that does not require additional R&D from the engine manufacturers. The Innovation Option deviates from international standards for a small product market; however, the broader market for the relevant technologies is large and is expected to grow significantly in the future. An important drawback of the Conservative Option is that NOx emissions cannot be reduced further due to the integration of SCR equipment into the engine. On the financing side, this Option is more affordable but does not exploit the potential of today's state of the art technology and would require further revisions which is not conductive for establishing a stable investment outlook.

The Innovation Option requires significantly greater investment than the Conservative Option, but would stimulate innovation leading to long-term cost improvements taking also into account these would be stable standards for the longer term. The Conservative Option requires rather limited upfront investment (only 9 % of those for the Innovation Option), but the operational costs are higher, so total ownership costs are comparable. The Conservative Option would also entail less administrative burden.

Of the variants of the Innovation Option, variant I-L ensures a better level playing-field between the small and larger vessel operators, as they all have to reduce engine emissions. However, this detracts from the cost effectiveness of the option and the overall investment needs. Nevertheless, the broad scope of variant I-L means that the entry into force of the Stage V emission standards that represent the biggest challenge from a technological point of view can be delayed, without negatively affecting the overall societal benefits. Variant I-E achieves the best benefit/investment ratio, by exempting those categories where the cost/benefit ratio is rather low, i.e. existing engines for the smaller vessels. Consequently, the overall investment requirements for this variant are significantly lower. Furthermore, potential technical difficulties in this category of smaller vessels, e.g. lack of space on the smaller vessel and old engines difficult to retrofit, can be avoided. Option I-M is a mix between the two previous options and may represent a compromise solution.

Table 13: Multi-criteria scores for the options

	Option I-L	*Option I-E*	*Option I-M*	*Option C*
NOx reduction (2030)	+++ (86%)	+++ (85%)	+++ (85%)	+ (54%)
PM reduction (2030)	+++ (92%)	+++ (90%)	+++ (91%)	+ (58%)
CO_2 reduction (2030)	+ (11%)	+ (11%)	+ (11%)	0 (0%)
PN/HC/CO reduction	+++	+	++	0/+
CH_4 reduction	0	0/-	0/-	0
Technical feasibility	--	-	-	+++
Financing feasibility	---	-	--	-
Labour market effects	+++	++	++	+
Level playing-field with road emissions	yes	yes	yes	no
Reduction of administrative burden	--	0/-	-	0
Benefit/cost ratio (efficiency)	33.9	46.2	41.6	34.9
Benefit/investment ratio	12.4	12	11.9	68.6

8.4. Marginal impact of standards for existing engines

As the Conservative Option covers only new engines, it is useful to consider separately the extent to which the inclusion of existing engines contributes to the overall impact of the Innovation Option.

Setting Stage IVA standards for existing engines means that they either have to be retrofitted with DPF and SCR equipment or replaced. As can be expected, measures for existing engines are less effective than for new engines. The compliance costs for existing engines represent about 50% of the overall compliance costs for the Innovation Option. The contribution to the overall external cost reduction, however, is only about 20%. Nevertheless, the benefit/cost multiplier for existing engines is still a respectable 10 to 18, depending on the variant.

Because of the lower cost/benefit ratio for existing engines, the ratio for new engines under the Innovation Option is higher than for the option as a whole. With a benefit/cost multiplier of 60 to 70, measures for new engines under the Innovation Option score very high.

Table 14: Share of new engines in the cost/benefit analysis

	Share of new engines in the cost/benefit analysis			
	Option I-L	Option I-E	Option I-M	Option C
Reduction of external costs	€ 18 943 m	€ 19 239 m	€ 19 239 m	€ 14 479 m
Share of total external cost	81 %	83 %	82 %	100 %
Costs IWT industry	€ 293 m	€ 278 m	€ 294 m	€ 403 m
Share of total cost IWT	44 %	57 %	54 %	100 %
Share societal benefit	€ 18 649 m	€ 18 960 m	€ 18 814 m	€ 14 076 m
Benefit/cost ratio	63.5	68.1	63.8	34.9

Table 15: Share of existing engines in the cost/benefit analysis

	Share of existing engines in the cost/benefit analysis		
	Option I-L	Option I-E	Option I-M
Reduction of external costs	€4425 m	€3994 m	€4143 m
Share on total external cost	19%	17%	18%
Costs IWT industry for retrofitting (net present value)	€376 m	€214 m	€250 m
Share of total cost IWT	56%	43%	46%
Share societal benefit	€4048 m	€3779 m	€3892 m
Benefit/cost ratio	10.7	17.7	15.5

9. IMPLEMENTATION ASPECTS

9.1. Monitoring and compliance checking

The compliance of engines with emission standards is currently verified through the system of type-approval certificates, which state that a certain engine (configuration) complies with the given emission standards. The type-approval certificate is issued for all the engine families of a certain power category as a condition of being placed on the market. It should be noted that type approval exists only for traditional diesel-fuelled engines in the range of 19-560 kW and for petrol-fuelled engines up to 19 kW. For other ranges and/or technologies, certification might be required for individual engine configurations on the basis of specific Member State legislation. Vessels are inspected periodically by competent authorities in the Member States in order to verify their compliance with the technical requirements of Directive 2006/87/EC. Currently, these inspections do not cover engine emissions beyond verifying the existence of a certificate. The competent authorities deliver Community or Rhine certificates allowing the vessels to (continue to) sail.

For new engines, the current type-approval system may need to be extended to engines operating with alternative fuels, with a view to reducing administrative burden and barriers to innovation. For existing engines, compliance with the new standards could be verified when the vessel is next inspected, which would coincide with their entry into force.

Furthermore, verification of real-world compliance may be considered under forthcoming new legislation, depending on technological progress and the availability of verification equipment.

It may also be useful to include in the vessel certificate information about the engine and the retrofitted equipment installed on board, if any. This would require amendments to Annexes IV (Model Community Inland Navigation Certificate) and V (Model Register of Community Inland Navigation Certificates) to Directive 2006/87/EC. Also, the European Hull Database, which contains information on IWT vessel certificates, could be expanded to include information on vessel engines.

9.2. Regulatory issues

The ongoing revision of the NRMM Directive also covers the revision of standards for new engines in vessels. The options for emission limits for new engines, as set out in the present staff working document, are being fed into the revision process.

Directive 2006/87/EC lays down the technical requirements with which vessels must comply to obtain a Community certificate and be authorised to navigate. It provides a possible framework for regulating the emissions of existing engines. The Directive already requires that IWT propulsion engines comply with the standards referred to in the NRMM Directive and allows for standards to be set for monitoring the emission limits.

If Stage V standards are adopted, it is expected that LNG-fuelled vessel propulsion will develop strongly, requiring the establishment of a streamlined framework of technical requirements for LNG-fuelled vessels. This requires further work on standards which can be adopted within the framework of the Directive 2006/87/EC.

The use of alternative fuels also means that standards need to be developed for fuel storage, transport bunkering and safe handling. The Commission's Clean Power for Transport Strategy will provide the framework for the adoption of these standards.

Changes to CCNR standards should be synchronised with EU developments in order to avoid multiple legislative requirements on European waterways.

Furthermore, the United Nations Economic Commission for Europe (UNECE) would need to amend the ADN rules to allow the transportation of LNG as cargo.

9.3. Research and development needs in support of greening the IWT fleet

Emission reductions in IWT depend on further R&D, in particular to adapt existing technologies to the specific context and to lower the cost of deployment. The following non-exclusive list of topics has been identified as requiring further R&D efforts:

- Clean technology needs to be developed for using LNG as mono-fuel as well as dual-fuel in the IWT context, and/or in gas-electric applications, in order to further reduce fuel costs and to reduce the engine-out performance as regards NOx and PM.
- Stage V diesel engines need to be developed, possibly using a combination of techniques that have been developed for smaller engines but are currently still considered experimental for large engines.
- Further research on the combination of LNG with SCR/DPF: in particular, measurements of emissions in real-life situations from various types of dual-fuel and mono-fuel LNG engines could shed light on whether SCR and DPF are actually necessary to achieve the required standards. Compliance costs could be reduced if the engine-out emission levels are lower than currently assumed.
- Research on technical solutions to prevent or reduce methane emissions, for instance by using high pressure LNG technologies or methane slip catalysts.
- Standardisation of SCR and DPF modules adapted to common power ranges and types of engine and flexible enough to be installed in various circumstances on board vessels, with a view to reducing the compliance cost and administrative burden of enforcing new emission standards.
- Capacity building of system integrators that provide Stage IV and V engines by integrating components from various suppliers.
- Technologies and procedures for monitoring compliance with emission standards.

9.4. Financing support

Reducing emissions from IWT engines has high societal benefits, but also significant costs for IWT operators. In view of the benefits, it may be justified for European and national authorities to provide financial incentives for the early adoption of standards.

The Commission services will explore the possibilities of activating the forthcoming Horizon 2020 and Connecting Europe Facility instruments to support investments in emission reduction technologies and help overcome the problem of access to finance. To support the access to finance, the possibility will be explored of creating a sub-window for IWT under the

Horizon 2020 risk-sharing instruments. Also, support will be provided to help the sector with R&D activities in relation to emission reduction and monitoring technologies.

The IWT sector's Reserve Fund may also be activated to support the greening of the fleet, subject to a revision of the Funds Regulation planned under NAIADES II.

10. NEXT STEPS

The Commission will further pursue the preparatory work to establish the framework for the greening of the fleet in the framework of NAIADES II, which identifies a coherent set of required measures and actions.

The assessment in this staff working document of the options for reducing the emissions from IWT will be further refined in the framework of the preparatory work for the adoption of future regulations. For instance, the impact of emission standards for the IWT passenger transport sector needs to be further analysed and integrated into the overall assessment of the policy options. The impact of, and options for, the inclusion of auxiliary engines — also excluded from the overall assessment — will also require further attention. The impact on labour taking into account the SME policies could be further refined.

Further sensitivity analyses will be carried out, for instance to analyse variations for the timing of the entry into force of the new emission standards and of certain assumptions made to assess the impacts and distortive effect of leaving certain existing engines unregulated. Further reflection is also needed on procedures and technologies for verifying compliance with emission standards.

The regulatory work, in combination with standardisation, R&D and financing support, will lay the basis for a new framework within which the IWT sector can regain its lead position also as regards air pollutant emissions.

11. CONCLUSION

Inland waterway transport is an important pillar of a sustainable EU transport system, as its overall external costs are lower than those of road transport, justifying a targeted EU policy in favour of developing IWT further.

There is, however, a gap to be closed between IWT and road transport in the field of air pollution, where road scores better than IWT. The analysis done so far indicates that one of the most effective approach may be to strengthen the legislation on emission limits whilst, however helping the sector to overcome obstacles to innovation, including access to finance, an issue which needs to be closely monitored in conjunction with development of the economic outlook for the sector.

The impact of more stringent emission standards can be mitigated by differentiating standards according to vessel/engine categories and staggering the entry into force of the standards.

The Commission services will refine the analysis of options for greening IWT vessels, as presented in this staff working document, and feed this work into the various legal initiatives already under preparation or to be launched, in particular the revision of the NRMM Directive, the update of the technical requirements for existing inland waterway vessel engines under Directive 2006/87/EC and the preparation of new standards for LNG-fuelled vessel propulsion in the framework of the ADN Directive and Directive 2006/87/EC.

ANNEX

Section 1: Changes in EU emission standards for road heavy-duty diesel engines

Between 1992 and 2013, steady progress was made with the reduction of air-pollutant emissions through the exhaust gases from heavy-duty road vehicles. EURO VI standards have introduced, for the first time, a PN emission limit to reduce emissions of the ultrafine particles that are most harmful to human health.

Stage	Date	Test	CO	HC	NOx	PM	PN	Smoke
			g/kWh				1/kWh	1/m
Euro I	1992, ≤ 85 kW	ECE R-49	4.5	1.1	8	0.612		
	1992, > 85 kW		4.5	1.1	8	0.36		
Euro II	1996.1		4	1.1	7	0.25		
	1998.1		4	1.1	7	0.15		
Euro III	1999.10 EEV only	ESC & ELR	1.5	0.25	2	0.02		0.15
	2000.1		2.1	0.66	5	0.10[a]		0.8
Euro IV	2005.1		1.5	0.46	3.5	0.02		0.5
Euro V	2008.1		1.5	0.46	2	0.02		0.5
Euro VI	2013.01	WHSC	1.5	0.13	0.4	0.01	8.0×10^{11}	
a: PM = 0.13 g/kWh for engines < 0.75 dm^3 swept volume per cylinder and a rated power speed > 3 000 min-1								

Steady-state testing

Source: www.dieselnet.com

Section 2: Stage IIIA standard of the NRMM Directive for Inland Waterway Vessels

Stage IIIA is the standard currently applicable to IWT engines placed on the market and new engines installed on board vessels for navigation. The values and dates of entry into force of the emission limits depend on the type of pollutant and the engine category.

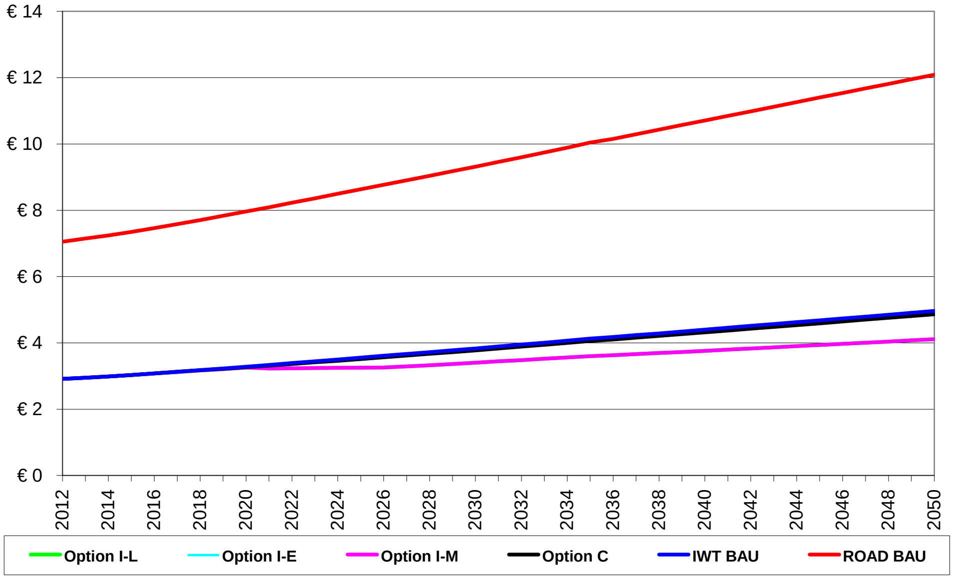
Category	Displacement (dm^3 per cylinder)	Date	CO	NOx + HC	PM
			(g/kWh)		
V1:1	D ≤ 0.9, P > 37 kW	2007.01	5	7.5	0.4
V1:2	0.9 < D ≤ 1.2		5	7.2	0.3
V1:3	1.2 < D ≤ 2.5		5	7.2	0.2
V1:4	2.5 < D ≤ 5	2009.01	5	7.2	0.2
V2:1	5 < D ≤ 15		5	7.8	0.27
V2:2	15 < D ≤ 20, P ≤ 3 300 kW		5	8.7	0.5
V2:3	15 < D ≤ 20, P > 3 300 kW		5	9.8	0.5
V2:4	20 < D ≤ 25		5	9.8	0.5
V2:5	25 < D ≤ 30		5	11	0.5

Source: www.dieselnet.com

Section 3: CO_2 cost comparison between road and IWT – 2012-50

The graph below shows changes in CO_2 emissions from IWT in comparison with those from road transport. In order to determine the external costs, one tonne of CO_2 is costed at € 86.60 (2011 level). The use of LNG in the Innovation Option reduces CO_2 emissions by about 20 %.

Climate change costs (CO_2) in euro per 1 000 tkm

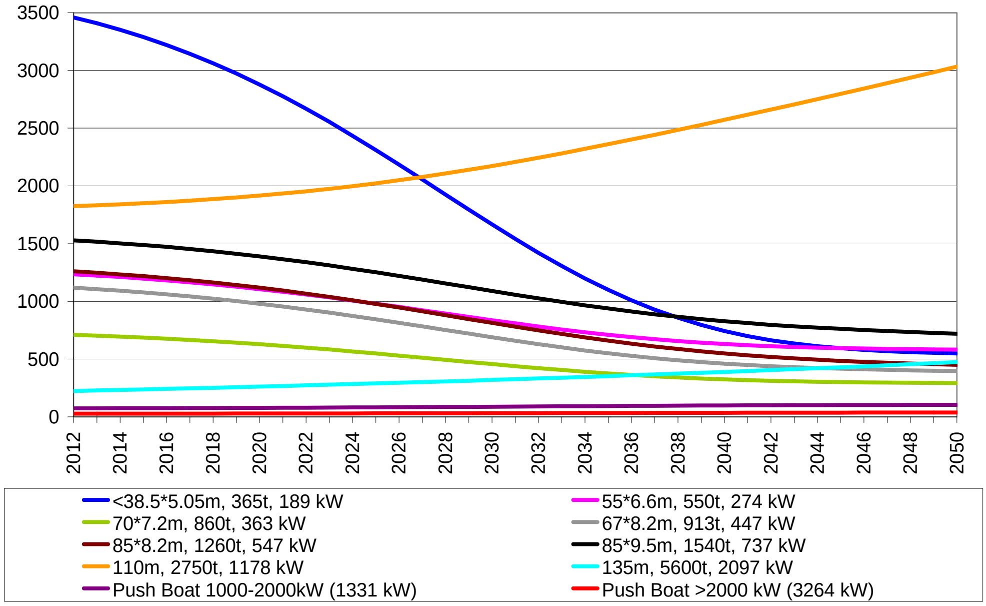


Section 4: Assumptions regarding changes in the IWT fleet up to 2050

4.1 Expected changes in the size of the IWT fleet

The current trend in the number of IWT vessels in Europe is extrapolated into the future. This involves smaller vessels continuing to be replaced by larger (mostly 110 m) vessels.

Changes in the inland motorised fleet for freight transport:

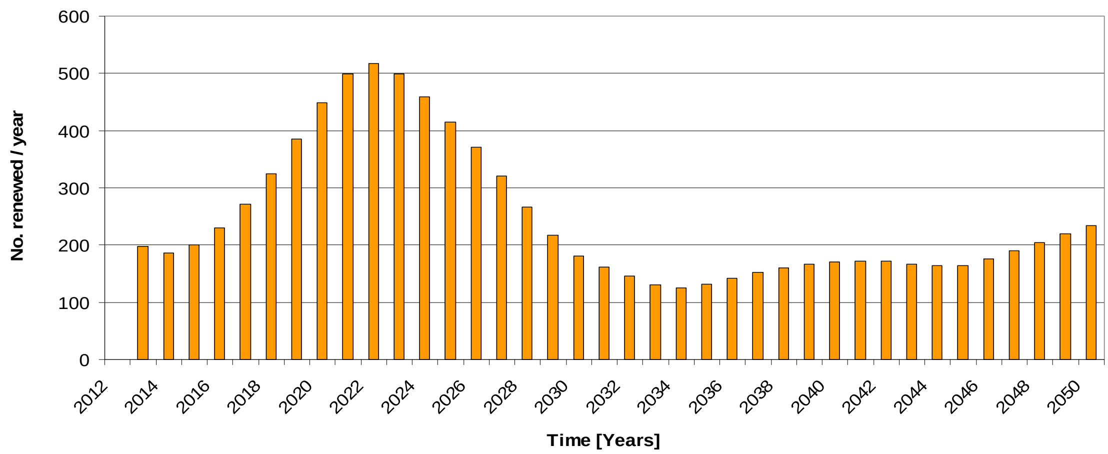


Size of the inland vessel fleet for freight transport by vessel class — 2012, 2030 and 2050

CEMT[32]	I	II	III	III	III	IV	V	VI	V	VI	TOTAL
Length (m) or power (kW)	≤38.5	55	70	67	85	85	110	135	Push boat 1 000-2 000 kW	Push boat ≥2 000 kW	
Power (kW)	189	274	363	447	547	737	1 178	2 097	1 331	3 264	
Length (m)	≤38.5	55	70	67	85	85	110	135			
Beam (m)	5.05	6.6	7.2	8.2	8.2	9.5					
Tonnage (t)	365	550	860	913	1 260	1 540	2 750	5 600			
2012	3 461	1 235	711	1 118	1 260	1 528	1 824	223	73	27	11 645
2030	1 666	836	456	689	814	1 090	2 173	319	88	31	8 162
2050	548	581	292	397	450	719	3 033	474	104	38	

4.2 Renewal of IWT engines — estimated totals per year

The graph below shows estimated numbers of IWT engines that will have to be renewed in the coming years. The first peak in the graph reflects the aftermath of the economic crisis (postponed investments) and the need for the engines of some vessels to be renewed so that they can continue to enter the port of Rotterdam from 2025.



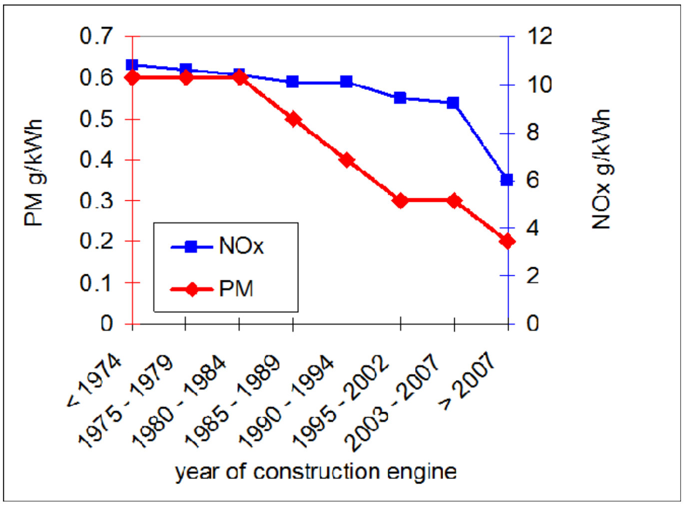
4.3 Assumptions regarding engine emission profiles

Engine emission profiles vary according to the year of construction. Therefore, based on the number of engines in a certain class of year of construction, weighted averages were taken to determine the profile of NOx and PM emissions, which are the most relevant for the external

[32] CEMT = Conférence Européenne des Ministres des Transports / European Conference of Transport Ministers

costs. The emission profiles[33] applied in the model for the various engine base years are presented below.

Year of construction of main engine	NOx [g/kWh]	PM[g /kWh]
<1974	10.8	0.6
1975-1979	10.6	0.6
1980-1984	10.4	0.6
1985-1989	10.1	0.5
1990-1994	10.1	0.4
1995-2002	9.4	0.3
2003-2007*	9.2	0.3
>2007*	6	0.2



Section 5: Benefit/cost ratio by vessel class

The table below presents the benefit/cost ratio of each policy option by vessel category. This is calculated by dividing the net present value (NPV) of the total societal benefits by the NPV of the total costs of ownership.

	OPTION I-L	OPTION I-E	OPTION I-M	OPTION C
<38.5*5.05 m, 365 t, 189 kW	1.7	1.5	1.5	1.5
55*6.6 m, 550 t, 274 kW	2.2	3.7	2.2	3.7
70*7.2 m, 860 t, 363 kW	3.2	3.2	3.2	5.4
67*8.2 m, 913 t, 447 kW	4.8	4.8	4.8	11.2
85*8.2 m, 1 260 t, 547 kW	7.4	7.4	7.4	19.1
85*9.5 m, 1 540 t, 737 kW	7.6	7.6	7.6	21.1
110 m, 2 750 t, 1 178 kW	33.8	37.5	37.5	34.5
135 m, 5 600 t, 2 097 kW	-39.1 (win-win)	-39.9 (win-win)	-39.9 (win-win)	47.6
Push boat 1 000-2 000 kW (1 331 kW)	11.6	10.2	10.2	36.0
Push boat >2 000 kW (3 264 kW)	-69.8 (win-win)	-70.7 (win-win)	-70.7 (win-win)	56.4
TOTAL	33.9	46.2	41.9	34.9

The compliance costs for the industry are quite low compared with the benefits of the measures for society at large. The negative ratios shown in the table for 135 m motor vessels and push boats > 2 000 kW indicate a 'win-win' situation. For these types of vessel, which are assumed to operate 24/7, the compliance costs are negative, i.e. there are 'compliance benefits'.

[33] Emission profiles for engines <1974-2003 were based on figures from report TNO 2010 Denier van der Gon, H., Hulskotte, J. *Methodologies for estimating shipping emissions in the Netherlands. A documentation of currently used emission factors and related activity data*. BOP Report, 2010.

Section 6: List of pollutants taken into consideration for the policy options

This table provides a short description of the pollutants that have been taken into account for analysing the new emission limits.

Pollutants	Description	Already in Stage IIIA?
CO (carbon monoxide):	Colourless, odourless and poisonous gas produced by the incomplete burning of carbon fuels. CO reduces the flow of oxygen in the bloodstream and is particularly dangerous to persons with heart disease.	Yes
HC (hydrocarbons):	HC are produced by incomplete combustion of hydrocarbon fuels (e.g. gasoline and diesel). HC include many toxic compounds that can cause cancer and other adverse health effects. HC also react with NOx in the lower atmosphere to form ground-level ozone, a major component of smog. The application of a diesel oxidation catalyst will reduce the HC emission.	Yes
NOx (nitrogen oxide):	NOx is a generic term for mono-nitrogen oxides NO and NO_2 (nitric oxide and nitrogen dioxide). These are produced from the reaction of nitrogen and oxygen gases in the air during combustion, especially at high temperatures. NOx reacts to form smog and acid rain. It affects human health (cardiovascular and respiratory diseases).	Yes
NH_3 (ammonia):	Unreacted ammonia, referred to as ammonia slip, can be a by-product of certain NOx reduction processes. An ASC (Ammonium Slip Catalyst) can be applied to prevent ammonium slip in the exhaust and this is assumed to be in place to reach standards IVA, IVB and V. The limit value of 10 ppm was taken from the Euro VI value for heavy-duty vehicles.	No
CH_4 (methane):	The main component of natural gas. This greenhouse gas emitted, for example, by engines running on LNG, could have an impact on global warming. A methane slip catalyst is assumed to be in place to make sure that emissions remain below the limit values. The limit value of 0.5 gram per kWh CH_4 was taken from the Euro VI standard for gas engines in heavy-duty vehicles.	No
PM (particulate matter):	PM are tiny pieces of solid or liquid matter associated with the Earth's atmosphere. Sources can be man-made or natural. PM can adversely affect human health (lung cancer in particular) and also have impacts on the climate and precipitation. Subtypes of atmospheric PM include suspended particulate matter (SPM), respirable suspended particle (RSP; particles of 10 micrometres or less in diameter), fine particles and soot.	Yes
PN (particle number):	A limit on the number of particles is introduced to avoid the emission of small particles which can diffuse deeply in the lungs and be absorbed into the bloodstream, with severe negative health impacts. The PN limit is a further development of regulations on PM emissions and is additional to the gram per kWh limit for PM (mass). The PN limit is introduced for heavy-duty road vehicles at the Euro VI standard based on the steady-state test cycle.	No

Section 7: Pollutant emission values for Stages IIIB, IVA, IVB and V

The table below sets out the emission limits for the standards analysed. Some standards apply to both new and existing engines, while others apply to one group only.

	CO	HC	NOx	PM	PN	CH_4	NH_3
Existing and new engines Stage IIIB	g/kWh	g/kWh	g/kWh	g/kWh	1/kWh	g/kWh	ppm
75 ≤ P(*) < 130	5	5.4 (NOx + HC)		0.14	-	-	-
130 ≤ P ≤ 220	3.5	1	2.1	0.11	-	-	-
220 < P ≤ 304	3.5	1	2.1	0.11	-	-	-
304 < P < 600	3.5	1.0	2.1	0.11	-	-	-
P ≥ 600	3.5	0.19	1.8	0.045	-	-	-
Existing engines Stage IVA	g/kWh	g/kWh	g/kWh	g/kWh	1/kWh	g/kWh	ppm
75 ≤ P < 130	5	5.4 (NOx + HC)		0.03	-	0.5	10
130 ≤ P ≤ 220	3.5	1.0	2.1	0.03	-	0.5	10
220 < P ≤ 304	3.5	1.0	2.1	0.03	-	0.5	10
304 < P < 600	3.5	1.0	2.1	0.03	-	0.5	10
600 ≤ P < 981	3.5	0.19	1.8	0.03	-	0.5	10
P ≥ 981	3.5	0.19	1.8	0.03	-	0.5	10
New engines Stage IVB	g/kWh	g/kWh	g/kWh	g/kWh	1/kWh	g/kWh	ppm
75 ≤ P ≤ 220	3.5	0.19	1.2	0.02	8.0X10^{11}	0.5	10
220 < P ≤ 304	3.5	0.19	1.2	0.02	8.0X10^{11}	0.5	10
304 < P < 600	3.5	0.19	1.2	0.02	8.0X10^{11}	0.5	10
600 ≤ P < 981	3.5	0.19	1.2	0.02	8.0X10^{11}	0.5	10
P ≥ 981	3.5	0.19	1.2	0.02	8.0X10^{11}	0.5	10
New engines Stage V	g/kWh	g/kWh	g/kWh	g/kWh	1/kWh	g/kWh	ppm
P ≥ 981	3.5	0.19	0.4	0.01	8.0X10^{11}	0.5	10

(*) P = installed net propulsion power of the vessel in kW

Section 8: American Tier 4 — future standard for marine engines

The table below shows the emission limits for US Tier 4 standards applicable to IWT and maritime engines from 2014.

Tier 4 Standards for Category 2 and Commercial Category 1 engines of over 600 kW

Maximum engine power	Displacement (L/cyl)	Model year	PM (g/kW-hr)	NO_X (g/kW-hr)	HC (g/kW-hr)
600 ≤ kW < 1 400	all	2017+	0.04	1.8	0.19
1 400 ≤ kW < 2 000	all	2016+	0.04	1.8	0.19
2 000 ≤ kW < 3 700[a]	all	2014+	0.04	1.8	0.19
kW ≥ 3 700	disp. <15.0	2014 –2015	0.12	1.8	0.19
	15.0 ≤ disp.<30.0	2014 –2015	0.25	1.8	0.19
	all	2016+	0.06	1.8	0.19

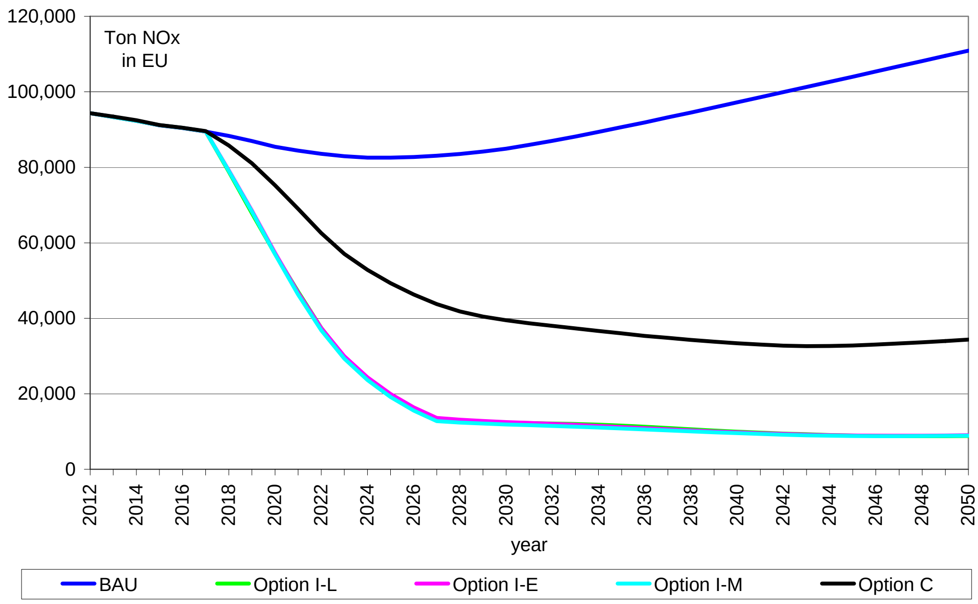
Section 9: Impacts of the policy measures on NOx and PM emissions

The table below shows expected changes in the absolute quantity (in tonnes) of NOx and PM produced by IWT up to 2050 under the two policy options and the BAU scenario.

Changes in quantity of NOx produced by IWT up to 2050 by policy option

Absolute level of NOx production by IWT in Europe in tonnes per year:					
Year	**Business-as-usual (BAU)**	**Option I-L**	**Option I-E**	**Option I-M**	**Option C**
2012	94 350	94 350	94 350	94 350	94 350
2020	85 422	57 033	57 323	56 955	75 246
2030	84 965	12 318	12 524	11 875	39 480
2040	97 201	9 959	9 774	9 565	33 382
2050	110 910	8 853	9 034	8 943	34 354

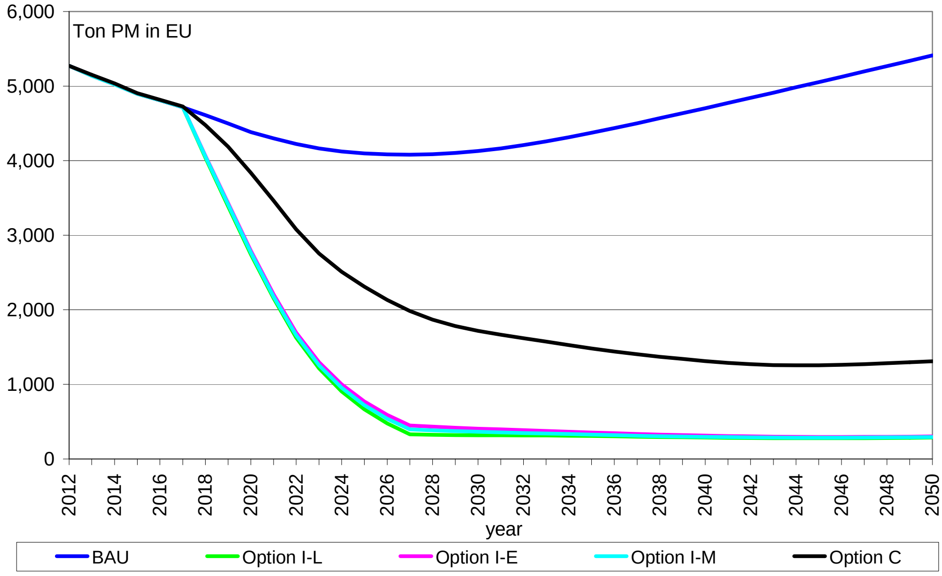
Reduction of NOx production by IWT in Europe per year as compared with BAU in absolute number of tonnes and percentage as compared with BAU:				
Year	**Option I-L**	**Option I-E**	**Option I-M**	**Option C**
2020	28 389	28 099	28 468	10 177
2030	72 647	72 441	73 090	45 484
2040	87 242	87 428	87 636	63 819
2050	102 057	101 876	101 967	76 556
2020	33 %	33 %	33 %	12 %
2030	86 %	85 %	86 %	54 %
2040	90 %	90 %	90 %	66 %
2050	92 %	92 %	92 %	69 %



Changes in quantity of PM produced by IWT up to 2050 by policy option

Absolute level of PM production by IWT in Europe in tonnes per year:					
Year	**Business-as-usual (BAU)**	**Option I-L**	**Option I-E**	**Option I-M**	**Option C**
2012	5 271	5 271	5 271	5 271	5 271
2020	4 383	2 744	2 792	2 771	3 838
2030	4 129	318	407	363	1 718
2040	4 704	286	313	296	1 313
2050	5 411	286	302	293	1 310

Reduction of PM production by IWT in Europe per year as compared with BAU in absolute number of tonnes and percentage as compared with BAU:				
Year	**Option I-L**	**Option I-E**	**Option I-M**	**Option C**
2020	1 639	1 590	1 612	544
2030	3 811	3 722	3 766	2 411
2040	4 418	4 391	4 408	3 391
2050	5 125	5 109	5 118	4 101
2020	37 %	36 %	37 %	12 %
2030	92 %	90 %	91 %	58 %
2040	94 %	93 %	94 %	72 %
2050	95 %	94 %	95 %	76 %



Section 10: Marginal initial investment cost of complying with the standards

This section provides us with the costs to the IWT industry of compliance with the standards. The costs are given for a single vessel, whether it has one or several engines on board, and for various situations: new engines on new vessels, new engines on existing vessels and engines on existing vessels that need to be retrofitted.

Marginal initial investment cost of hardware and installation for new vessels with new engines:

NEW ENGINES, NEW VESSELS					
Emission standards >	**Stage IIIB Diesel**	**Stage IVB Diesel**	**Stage IVB/V LNG SCR DPF**	**Stage V Diesel Incl R&D**	**Stage V Diesel Excl R&D**
≤38.5*5.05 m, 365 t, 189 kW	€ 17 758	€ 25 969			
55*6.6 m, 550 t, 274 kW	€ 20 213	€ 30 412			
70*7.2 m, 860 t, 363 kW	€ 21 714	€ 33 491			
67*8.2 m, 913 t, 447 kW	€ 21 979	€ 33 614			
85*8.2 m, 1 260 t, 547 kW	€ 22 728	€ 34 908			
85*9.5 m, 1 540 t, 737 kW	€ 25 835	€ 41 502			
110 m, 2 750 t, 1 178 kW	€ 35 001	€ 55 530	€ 591 148		€ 122 834
135 m, 5 600 t, 2 097 kW	€ 60 418	€ 96 494	€ 961 237		€ 216 325
Push boat 1 000-2 000 kW (1 331 kW)	€ 45 366	€ 70 015	€ 947 515	€ 790 414	€ 146 061
Push boat > 2 000 kW (3 264 kW)	€ 92 284	€ 147 991	€ 1 412 126		€ 334 484

Initial investment cost of hardware installation for existing vessels with engine replacement (new engine):

NEW ENGINES, EXISTING VESSELS					
	Stage IIIB Diesel SCR	**Stage IVB Diesel SCR DPF**	**Stage V LNG SCR DPF**	**Stage V Diesel including R&D cost**	**Stage V Diesel excluding R&D cost**
<38.5*5.05 m, 365 t, 189 kW	€ 22 866	€ 34 908			
55*6.6 m, 550 t, 274 kW	€ 25 516	€ 39 693			
70*7.2 m, 860 t, 363 kW	€ 27 130	€ 42 969			
67*8.2 m, 913 t, 447 kW	€ 27 387	€ 43 078			
85*8.2 m, 1 260 t, 547 kW	€ 27 935	€ 44 021			
85*9.5 m, 1 540 t, 737 kW	€ 31 386	€ 51 216			
110 m, 2 750 t, 1 178 kW	€ 40 724	€ 65 544	€ 724 537		€ 132 849
135 m, 5 600 t, 2 097 kW	€ 69 657	€ 112 661	€ 1 176 592		€ 232 493
Push boat 1 000-2 000 kW (1 331 kW)	€ 54 741	€ 86 422	€ 2 446 947	€ 806 820	€ 162 467
Push boat > 2 000 kW (3 264 kW)	€ 105 790	€ 171 626	€ 4 230 662		€ 358 119

Existing vessels with existing engine adapted to meet emission limit (retrofit):

EXISTING ENGINES, EXISTING VESSELS		
	Stage IVA Diesel SCR DPF	**Stage V LNG SCR DPF**
<38.5*5.05 m, 365 t, 189 kW	€ 43 847	
55*6.6 m, 550 t, 274 kW	€ 48 975	
70*7.2 m, 860 t, 363 kW	€ 52 446	
67*8.2 m, 913 t, 447 kW	€ 52 542	
85*8.2 m, 1 260 t, 547 kW	€ 53 134	
85*9.5 m, 1 540 t, 737 kW	€ 60 931	
110 m, 2 750 t, 1 178 kW	€ 75 558	€ 739 359
135 m, 5 600 t, 2 097 kW	€ 128 829	€ 1 200 520
Push boat 1 000-2 000 kW (1 331 kW)	€ 102 828	€ 2 613 550
Push boat > 2 000 kW (3 264 kW)	€ 195 261	€ 4 543 833

Section 11 : Long list of actions that can reduce emissions from IWT

11.1 Infrastructure measures

Area	Measures	Contribution to fuel reduction / emissions to air	Reduction potential fuel (%)	Reduct. pot CO2 (%)	Reduct. pot SO2 (%)	Reduct. pot. PM2.5 (%)	Reduct. pot. NOx (%)	Source
Waterway upgrading	Reduce waterway bottlenecks (e.g. one-way traffic)	Less need for slowing down cruising speed; less manoeuvres; less fuel consumption per tkm	Depending on local conditions; rough estimation: Less than -5%	Less than -5%				DST, 2012
	Improve fairway conditions (draught characteristics)	(1) More water depth/draughts allow for larger ships (lower emissions per tkm); (2) More water depth reduces low water resistance of vessels (less fuel consumption/ emissions under same conditions)	Depending on specific circumstances Up to -68% (depending on specific circumstances)	Up to -68% (depending on specific circumstances)				DST, 2012
Ports and mooring places	Shore side power (walstroom)	Turning off head or auxiliary engine during mooring using less polluting sources of electrical energy; potential savings low since vessels generally have very short mooring times	Less than -5%	Less than -5%				CCNR, 2012
			--	--	--	Locally -95%	Locally -99%	TNO, 2008
	Optimization of locking procedure and traffic management	Creating green waves, preventing waiting times and efficient slot management; optimisation of cruising and approaching speeds	Less than -5%	Less than -5%				DST, 2012
Waterway information	Better prediction of available water depth	Providing topical information on available water depths; optimisation of load factor; less emissions per tkm	Rhine: appr. -5% Danube: up to -20 -30%	Rhine: appr. -5% Danube: up to -20 -30%				DST, 2012
	Electronic ECDIS charts with relevant depth information	Providing topical information on available water depths; optimisation of load factor; less emissions per tkm	Depending on various frame conditions; rough estimation: Less than -5%	Less than -5%				DST, 2012

11.2. Ship-related technical measures

Area	Measures	Contribution to fuel reduction / emissions to air	Reduction potential fuel (%) not cumulative	Reduct. pot CO_2 (%)	Reduct. pot SO_2 (%)	Reduct. pot. PM2.5 (%)	Reduct. pot. NOx (%)	Source
Change fleet structure	Use larger vessel units	Higher carrying capacity resulting in lower emissions per tkm through economies of scale (also depending on infrastructure conditions)	Up to -75% depending on difference in scale	Up to -75% depending on difference in scale				CCNR, 2012
	Use more coupled convoys instead of single propelled vessels	Higher carrying capacity resulting in lower emissions per tkm	Up to -20% depending on vessel types	Up to -20% depending on vessel types				DST, 2012
	Optimise hull dimension and form	Less hydrodynamic resistance; less fuel consumption per tkm (mainly addressed to container and passenger vessels)	-5% to -15%	-5% to -15%				DST, 2012
	Reduce vessel weight	Utilization of high-strength steel or lightweight construction material; applicability limited; improving ratio between payload and deadweight; less fuel consumption per tkm	Less than -5%	Less than -5%				DST, 2012
Fuels	Use LNG (Liquefied Natural Gas)	Substitute for diesel oil, other engine technology and additional measures needed	No reduction as such (except for cheaper fuel type)	-20%	--	-95%	-50%	PLATINA wiki, Binnenschif f-fahrt 11/2011
				-15% to -25%	--	More than -30%	More than -30%	IDVV, 2012
	Apply dual fuel (LNG-diesel)	Partly substitute diesel oil by LNG	-20%	-20%	--	-95%	-50%	IDVV, 2012
	Use hydrogen / fuel cells	Other engine technology and additional measures; long term development	No reduction	-100%	-100%	-100%	-100%	CREATING 2006
Propulsion system	Exchange of main diesel engine	Change of conventional main diesel engine with improved fuel consumption characteristics	-15% to -20%	-15% to -20%				CCNR, 2012 DST, 2012
	Overhaul of existing engines	Intensive revision of existing main engine	-7% to -10%	-7% to -10%				DST, 2012
	Apply diesel-electric propulsion	Direct reduction of fuel consumption	-10% to -20%	-10% to -20%		More than -20%	More than -20%	CCNR, 2012
			-10 to -15%	-10 to -15%				DST, 2012
	Apply hybrid propulsion	Buffering of propulsion energy as electrical energy; promising for ships that manoeuvre often	-10%	-10%				CCNR, 2012, DST, 2012
	Improved propeller systems	For instance counter-rotating or skew propellers; more efficient propulsion; less fuel consumption with same propulsion power	-20% to -30%	-20% to -30%				CCNR, 2012
			-5% to -20%	-5% to -20%				DST, 2012
			-10% to -20%	-10% to -20%	--	-10% to -20%	-10% to -20%	IDVV, 2012

Area	Measures	Contribution to fuel reduction / emissions to air	Reduction potential fuel (%) not cumulative	Reduct. pot CO2 (%)	Reduct. pot SO2 (%)	Reduct. pot. PM2.5 (%)	Reduct. pot. NOx (%)	Source
Hydrodynamic measures	Air lubrication	Air supply to lubrication device; questionable if successful. Potentially reduce space in cargo hold	-10%	-10%				CCNR, 2012
			Less than -5%	Less than -5%				DST, 2012
			-10% to -20%	-10% to -20%	--	-10% to -20%	-10% to -20%	IDVV, 2012
	Wake field separation plate	Plate/device mounted to the aft part	Up to -15 % (large 2 propeller vessel) up to -25% (large 3 propeller vessel)	Up to -15 % (large 2 propeller vessel) up to -25% (large 3 propeller vessel)				DST, 2012
	Adjustable tunnel apron	Device mounted to the aft part	Less than -10%	Less than -10%				CCNR, 2012 DST, 2012
	Coupling point optimisation	Improving hydrodynamics between motorised unit and dumb barge; Modification of coupling point and fore part of coupled convoys; common for coupled convoys that are permanently coupled.	-15%	-15%				CCNR, 2012
			-20%	-20%				DST, 2012
	Multiple propeller propulsion	Reduction of draught with smaller propellers	-5% to -10%	-5% to -10%				DST, 2012
Auxiliary systems	Waste heat energy recovery	Improve heating system; intensified utilization of engine waste heat	Less than -5%	Less than -5%				CCNR, 2012 DST, 2012
After treatment systems	SCR-Technology (selective catalytic reduction)	Technology where a reducing agent is injected in order to remove NOx and PM emissions	--	--	--	-35%	-81%	Pauli and Schweig-hofer, 2008
			--	--	--	--	-85% to -95%	NEA et al, 2011
	Emulsified fuels	Introducing water into the combustion process to reduce the nitrogen oxides and particulate contained in the exhaust of diesel engines by lowering the peak temperatures in the combustion process	Negative impact on fuel consumption; Assumption less than +5%	--	--	-80% or higher	-20% to -30% or higher	Germani-cher Lloyd, 2001
	Diesel Particulate Filter	Particulate filters (DPFs), or particulate traps, are used to 'catch' the particulate matter from the exhaust gas in a filter	+2% to +3%	+2% to +3%	+2% to +3%	-96%	+2% to +3%	www. Cleanest ship.eu
	SCR + DPF	Combination of both after treatment technologies	+2% to +3%	+2% to +3%	+2% to +3%	-96%	-81%	DST, 2012

11.3 Ship operational measures

Area	Measures	Contribution to fuel reduction / emissions to air	Reduction potential fuel (%) not cumulative	Reduct. pot CO2 (%)	Reduct. pot SO2 (%)	Reduct. pot. PM2.5 (%)	Reduct. pot. NOx (%)	Source
Sailing behaviour	Smart and eco-efficient steaming	Computer-assisted speed management; General speed reduction and adaptation of speed to varying navigation channel dimensions; Utilization of appropriate control devices and econometers (tempomaat)	-5% to -10% (or more)	-5% to -10% (or more)				CCNR, 2012
			-6,7%	-6,7%				Ecorys, 2012
	Optimise trim and heel	Utilization of appropriate control devices; consideration of load distribution during loading	-5%	-5%				DST, 2012
	Optimise track choice	Selection of most favourable track (rather deep than low water depth); less fuel consumption per tkm	Up to -5%	Up to -5%				DST, 2012
Maintenance	Clean underwater bodies/hull plating, clean ballast tanks and bilges	Reduce underwater friction and resistance; less fuel consumption and emissions per tkm	Less than -5%	Less than -5%				CCNR, 2012 DST, 2012
	Clean and undamaged propellers	More propulsion power with same fuel consumption levels	Less than -5%	Less than -5%				CCNR, 2012
			less than -10%	less than -10%				DST, 2012

11.4 Organisational measures

Area	Measures	Contribution to fuel reduction / emissions to air	Reduction potential fuel (%) not cumulative	Reduct. pot CO2 (%)	Reduct. pot SO2 (%)	Reduct. pot. PM2.5 (%)	Reduct. pot. NOx (%)	Source
Transport management	Reduce empty trips	Improve voyage planning by better use of information systems; reduction of empty returns; reducing emissions per tkm	Potentially up to -40%	Potentially up to -40%				DST, 2012
	Increase load factor for loaded trips	Intensified utilization of information systems; better use of carrying capacity; reducing emissions per tkm	-5 to -10%	-5 to -10%				DST, 2012
	Organise downstream navigation in formations	Intensified cooperation between operators; lower fuel consumption; reducing emissions per tkm	Less than -10%	Less than -10%				DST, 2012

11.5 Result of screening of measures

Type of measure	Area	Technical measure	Criterion 1: Significant emission reduction potential (max. %)	Criterion 2: Technical feasibility: Applicability on large proportion of fleet	Criterion 3: Temporal feasibility: Significant results by 2020
Ship-related technical	Fleet structure	Use larger vessel units	75%	1	1
	Fuels	Use LNG (Liquefied Natural Gas) (PM reduction)	95%	1	1
		Apply dual fuel (LNG and diesel) (PM reduction)	95%	1	1
	Propulsion system	Exchange of main diesel engine	20%	1	1
		Overhaul of existing engines	10%	1	1
		Apply diesel-electric propulsion	20%	1	1
	After-treatment system	Apply SCR (selective catalytic reduction) (NOx reduction)	95%	1	1
		Apply diesel particulate filter (DPF) (PM reduction)	96%	1	1
		Combine SCR and DPF (PM reduction)	96%	1	1
Ship-operational measures	Sailing behaviour	Apply smart and eco-efficient steaming	10%	1	1
Organisational measures	Transport management	Reduce empty trips	40%	1	1
		Increase load factor for loaded trips	10%	1	1