Instruments to reduce pollutant emissions of the existing inland vessel fleet

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1 Introduction

Inland waterway transport (IWT) has a key performance on the GHG emissions per tonne kilometre shipped. Due to its potential to limit climate change, the recent EU Transport White Paper has set high goals for the non-road modes.

The Ports of Rotterdam, Antwerp and others strive to increase the use of IWT in their hinterland transport. The Port of Rotterdam authority has imposed a modal split on the newly built container terminals, thus increasing the use of rail and IWT. The growth is estimated to result in a quadrupling of inland barge container traffic on the Rhine corridor in the timeframe 2010-2035.

Local air quality is another environmental issue, however, that plays a key role. Due to reasons of long ship engine lifetimes and progress made in road transport emissions, IWT needs to improve its air pollution profile. To turn the potential of IWT into real growth, it is important to:

- improve the air pollutant profile of inland shipping;
- take responsibility to maintain the air quality levels along inland waterway corridors over Europe, especially in urban areas where road transport, industry and IWT contribute to levels that will need to be in accordance with the EU air quality directive 2008/51.

A new set of standards for new engines will shortly be proposed by the European Commission to be introduced in 2016. However, these will probably not be as tight as the Euro-VI standards for road transport. In addition, the long lifetime of inland barge engines (30,000 to over 200,000 hours, depending on the engine type) will result in a slow uptake of the phase-IV engines in the fleet.

The German and Dutch authorities have the opinion that not only the air pollutant emissions of new engines need to be curbed, but deliberate over the development of instruments that will reduce the pollutant emissions of the existing fleet ('legacy fleet'), in addition to the limitedly effective subsidy schemes applied in recent years.

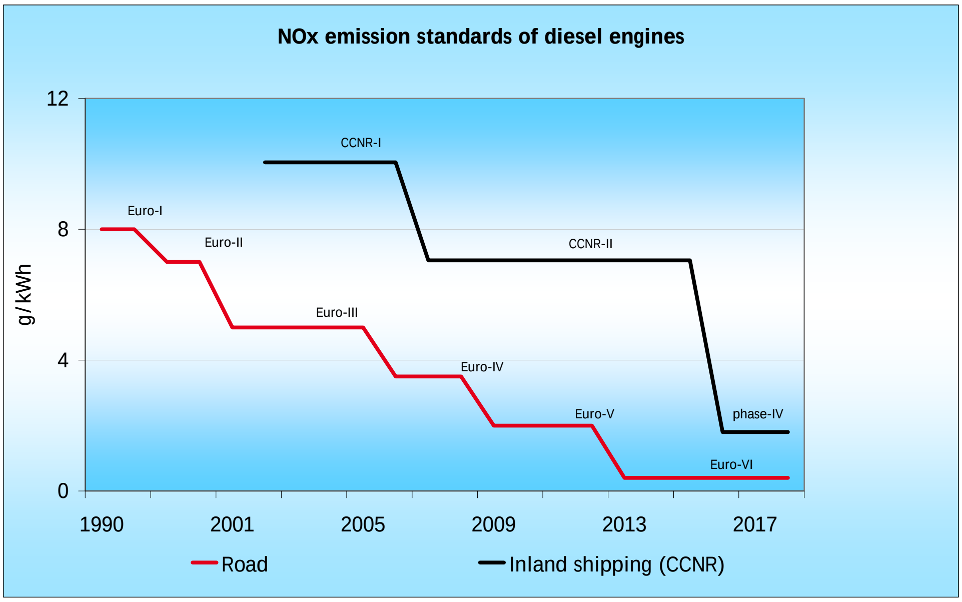
This paper demonstrates the need for measures that improve the environmental performance of inland navigation and provides an overview of suitable policy instruments to improve the environmental performance of inland shipping.

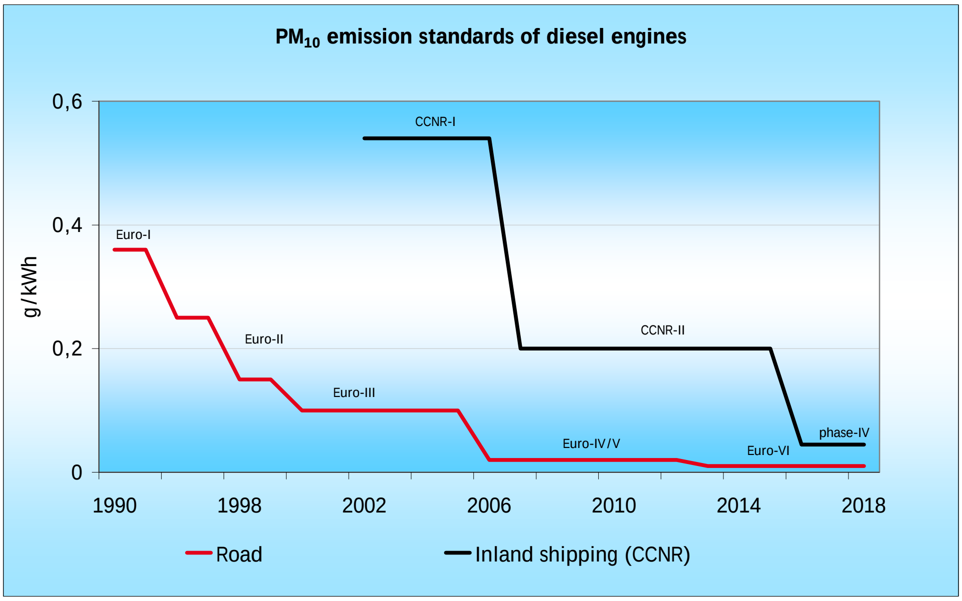
2 The need for action

Emission legislation for new engines

During the beginning of the nineties, inland shipping was the sustainable transport mode. However, since then the Euro standards for road transport were introduced. Since 1992, the Euro standards were tightened several times, leading to significant lower emissions per unit of output for truck engines, see Figure 1.

Figure 1 NO$_x$ and PM emission standards of inland barge and road transport





Note: Data refer to new type approvals and are rounded of to year. Values from EU Directive 2004/26 are not included, since the CCNR standards are more stringent and the market follows these standards. Emissions standard is based on 1,800 rpm engines.

The barge fleet is characterised by its high average age. For example, the IVR data base shows that the *average* year of build for inland barge engines is 1978 for dry cargo vessels and 1983 for liquid cargo vessels. This picture is confirmed by Germanische Lloyd (2001).

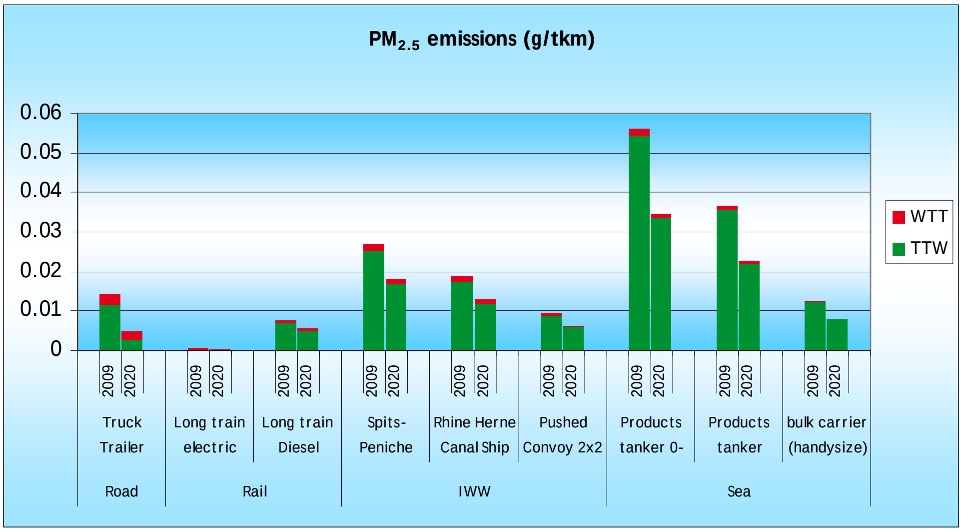
Reports (TNO, 2009 and VITO, 2004) indicate *median* lifetimes of main engines of between 9 and 13 years old.

Emission performance of the different modes and projected developments for the next ten years

The modes should not only be compared on the basis of the performance of the engine, but also from a transport performance perspective. In the recently published CE Delft STREAM study (CE, 2011), a comparison of the air pollutant emission performance between modes is made. The study concludes that on average, pollutant emissions of inland barges are not lower than those of road transport, if average logistical characteristics (ship type, load factor, loaded trips and end haulage) and average emissions technology is taken into account.

Between 2009 and 2020 the well-to-wheel $PM_{2.5}$ and NO_x emission factors will decrease most for trucks (50-65%), compared to 30% for inland waterway and rail diesel. This trend is the result of the effective European emission standards that apply to truck engines. For the other modes the reduction is smaller because of a slower fleet renewal and in the case of inland barge engines also because of less stringent emission standards (CE, 2011). Figure 2 and Figure 3 show the expected development for the different modes.

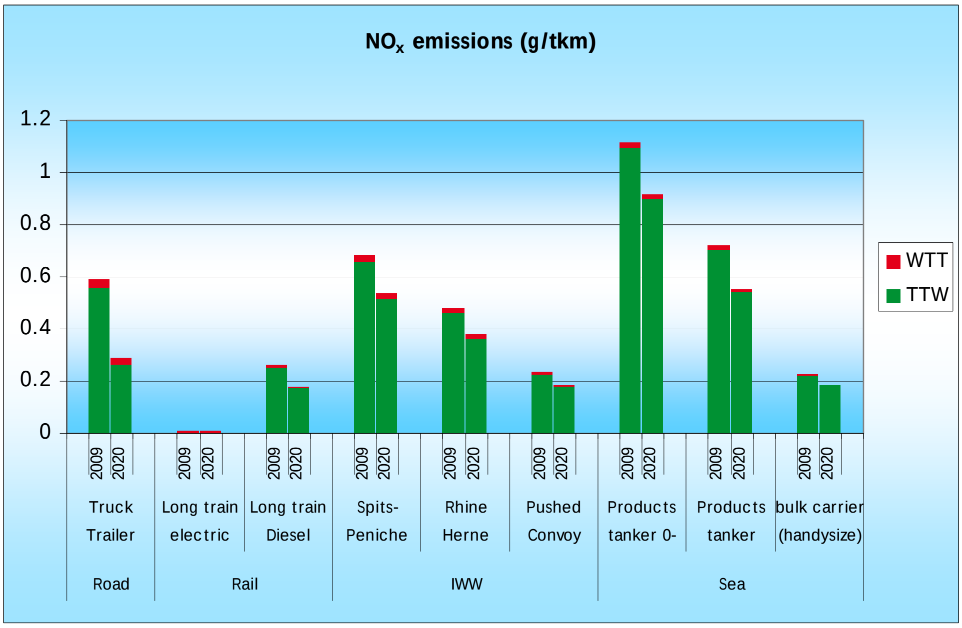
Figure 2 Comparison of $PM_{2.5}$ emissions 2009 and 2020 for selected vehicle types



Note: WTW refers to well-to-wheel, TTW refers to tank-to-wheel, WTT refers to well-to-tank. Detouring not included.

Source: CE, 2011.

Figure 3 **Comparison of NO_x emissions 2009 and 2020 for selected vehicle types**



Note: WTW refers to well-to-wheel, TTW refers to tank-to-wheel, WTT refers to well-to-tank. Detouring not included.

Source: CE, 2011.

3 Available technical measures

The measures to reduce the emissions of existing barges are currently limited to after treatment systems. Over the last years, Selective Catalytic Reduction (SCR) and more limitedly Diesel Particulate Filter (DPF) have been applied under available subsidy regimes. More recently, LNG has been identified as a potential fuel to reduce emissions. The first ship 'Argonon' will be put into service early next year.

In Annex A, we provide an overview, including cost figures from literature and estimates from industry consultation.

The engine producers have not shown interest in developing technologies for improving the environmental performance of IWT engines. There are three reasons for this:
- no legislation;
- limited interest shown from ship-owners;
- IWT has a relatively limited market size compared to other markets.

It is therefore well possible that the technical potential is not fully utilised (e.g. internal engine measures to reach CCNR-2) and that the costs can be reduced.

The following technologies could be applied to existing engines and have shown to be best, according to Germanische Lloyd (2001):
- Selective Catalytic Reduction (SCR);
- Diesel Particulate Filter (DPF);
- Emulsified Fuels;

In case of new ships technologies like LNG, Diesel-electric traction, exhaust gas recirculation (EGR) can also be applied.

Research by Arcadis (2011) has shown that from a society point of view the benefits of application of SCR and DPF technology on existing vessels outweigh the costs.

In Annex A, these technologies are shortly elaborated.

4 Different types of instruments possible

Basically three instruments can be used to reduce emissions:
1. Regulation.
2. Economic instruments.
3. Voluntary initiatives and agreements.

1. Regulation

Obligatory emission standards exist for new engines, but tighter emission standards for engines already installed have never been applied in EU transport policy. However, in 2008 the IMO agreed upon an upgrade for certain existing engines[1]. Other examples of setting standards for existing installations can be found in the IPPC Directive (1996/61/EC). Existing coal fired power generation plants and waste incineration installations have been adapted since the early nineties. Also within the CCNR, new legislation is applied to existing ships using a system of transition periods.

The measure can be implemented most successfully at EU level, with the least affection of the internal market.

From the beginning of 2012, re-engining a ship with an existing revised engine is forbidden. Engines can only be replaced by new ones. Potentially, re-engining could also be accelerated by limiting the number of times a major overhaul may be executed. However, this might be difficult to define and control. In addition, coordinated installation of Euro-V truck engines in small ships could bring environmental benefits.

Environmental zoning is an alternative to the application of mandatory emission standards for all existing ships. Several EU countries have implemented low emission zones for cars and trucks[2]. The first example in IWT is the designation of the Port of Rotterdam area as an environmental zone. Inland barge engines will have to meet CCNR-2 regulation from 2025 onwards. The decision was made in the context of the expansion of the Maasvlakte area. The measure was needed to ensure that Air Quality Directive 2008/51 will be met in the distant future.

Potentially, environmental zoning can be as effective as standardisation since ships need to load and unload goods. The environmental criteria set in Rotterdam will be limitedly effective in the period until 2020.

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1 Marine diesel engines with a power output that exceeds 5,000 kW and a per cylinder displacement at or above 90 litres constructed between 1 January 1990 and 1 January 2000 are upgraded to Tier I. NO_x reducing kits need to be installed during the first renewal survey and only applies to main engines due to the criteria set.

2 http://www.lowemissionzones.eu/ .

The introduction of an environmental zone may on the one hand reduce the attractiveness for industry to settle and hence reduce the number of port calls. On the other hand, the environmental performance of inland ports will become increasingly important as a license to operate, especially in a scenario of growth.

As a result of the limitation of barriers to trade, environmental zones can only be applied if such a scheme is needed in the context of difficulties with meeting Air Quality Directive 2008/51. This is another complicating factor.

2. Economic incentives

Economic incentives for inland shipping may reveal some of the most cost effective measures to ameliorate air quality. They have three clear advantages over emission standards:

- They apply to both existing and new vessels.
- They allow the shipper to choose between new engine types, end-of-pipe solutions or do nothing.
- They encourage reduction of emissions even below current or future standards.

Economic incentives have already been applied in road transport. In Norway, a **NO_x tax** applies to all economic activities. And from 2012, the **port dues** for inland barges in Rotterdam not meeting the CCNR-2 standard will be increased by 10%.

Emission taxation/fund

From a theoretical perspective, an emission tax is an effective and efficient measure to reduce pollutant emissions, since the incentive base is directly linked to the emission that needs to be reduced. However, to be effective the tax burden on ship-owners could result in financial problems, like e.g. ability to finance abatement technologies.

In Norway, a NO_x tax was introduced 1st of January 2007 of € 1.9 (NOK 15) per kg NO_x. Propulsion engines exceeding 750 kW - aimed at marine engines - are subject to taxation. Emissions from sources that are subject to the so-called Norwegian Environmental Agreement are exempted from the NO_x tax. Affiliated enterprises pay € 0.5 per kg NO_x to the NO_x Fund, instead of paying the government tax. Undertakings that join the Environmental Agreement are obliged to apply for support for measures to reduce NO_x emissions in situations with a return-on-investment time shorter than three years, taking the fiscal NO_x tax and the support from the fund into account. Support will be granted for investment costs (up to 80%) as well as operating costs. Between 2011 and 2016, the NO_x Fund is committed to reduce emissions by 16 kton. The NO_x Fund has granted significant parts of the overall granted budget for LNG and SCR investment projects, mainly for seagoing ships. The NO_x Fund is set up by 15 co-operating business organisations.

Emissions are reported on the basis of engine certificates and bunker delivery notes.

As an example, CE (2004) estimated that an average incentive level for investment in SCR, the most cost effective measure, should be around € 2.5 per kg NO_x. The Norwegian NO_x tax is close to this incentive level. State aid is not applicable in case of a business fund, and therefore grants could be higher than 50-70% of the investment costs. This increases the attractiveness of investments under a NO_x Fund for industry.

The Mannheim convention does not seem to explicitly forbid a levy on pollutant emissions. Pollutant emissions are not directly related to inland shipping, since in principle the emissions can be reduced to zero by technical means, although such a reduction would be costly. However, whether or not such a levy will hold, remains subject of discussion (CE, 2004).

In the EU, the Norwegian approach could be used to reduce emissions. To do so, an internationally coordinated emissions (NO_x and PM) tax for inland shipping could be introduced and a business fund should be set up. An advantage of the Norwegian approach is that the total needed funds for a limited number of adapted ships (e.g. biggest 10%) can be produced by the entire sector. Disadvantage of this approach is a significant administrative burden.

National governments are the most obvious regulative bodies to introduce an emission tax. The industry is free to set up such an emission fund.

Differentiated port dues can be used to provide incentives for clean shipping. However, harbour dues are not directly related to emissions. Therefore, this instrument does not provide an incentive to reduce the emissions of inland navigation by improving transport efficiency (e.g. increased load factors).

From the perspective of installation of SCR catalysts on ships, CE (2004) has investigated this approach and concluded that harbour dues are too low to be used as a single incentive. However, harbour dues could be effective as part of a package of measures. Based on differentiation in both the origin and destination port, the needed financial incentive for an SCR catalyst is roughly four to five times higher than the current port dues.

In case of an environmental mark-up on the port dues for existing ships with the amount of twice the current port dues, the incentive needed is roughly two times higher than the mark-up.
This would lead to a situation where ships with the current average environmental performance pay three times the current port dues and ships equipped with SCR the current port dues.

Table 1 Overview of port dues and needed incentives (€) for SCR investment

	Average incentive needed for SCR investment on one return trip	2011 port dues return trip	Mark-up of port with twice the current port dues
1,000-1,500 tonne	760	225	450
1,500-3,000 tonne	1,386	405	810
>3,000 tonne	2,097	630	1,260

Note: The port dues are based on data for the Port of Rotterdam. The average incentive needed is based on 50 €/kW investment costs, 3 €/Mwh operational costs and a depreciation period of 3 years and 8% interest.

Source: Adapted from CE (2004); Port of Rotterdam.

The analysis shows that port dues would need to be increased significantly for ships to make investing in SCR catalysts profitable. In case of the combination of DPF and SCR, the needed incentive is even bigger.

Data from the TREMOVE and TRANSTOOLS models show transport costs are between 0.015 and 0.07 €/tkm. Taking these figures into account for a 1,500-3,000 tonne ship and a single trip distance of 500 km, an environmental mark-up on the port dues with a height of twice the current port dues would lead to an increase of overall costs with 1-2%.

The port of Rotterdam will increase port dues for ships that do not meet the CCNR-2 standard with 10% as of 2012. The profits will be used for air pollutant innovation projects. Port dues are determined by the local governments or private port authorities. The proposed increase is, however, not high enough to achieve significant effects. Inland port authorities will not be keen to increase the port dues as significantly as needed, because of economic reasons. Further exploration should be done in the context of coordinated introduction, like environmental zoning.

Subsidy programmes to accelerate the introduction of CCNR-2 engines, DPF's and SCR catalysts existed in the Netherlands, Germany and Belgium in the period 2007-2010, and some programmes still run.

In Germany, the subsidy scheme was limitedly effective, since no more than 40% of the allocated funds were used. Mainly re-engining with CCNR-2 engines has happened, including the application of DPF's in a number of cases. No SCR catalysts have been subsidised until mid-2010.

In the Netherlands, the programme has been evaluated and was deemed to be ineffective (SenterNovem, 2009). Uncertainty with respect to costs and functioning of the system were mentioned as main reasons. The main issue is that the subsidy does not cover the full investment (and operational) costs and there are no additional financial incentives (e.g. environmental taxes) to make investments in these technologies economically profitable. The evaluation ends with the recommendation that to increase the sense of urgency within the sector, additional flanking policies are needed.

The Netherlands stopped subsidising CCNR-2 engines after the introduction of CCNR-2 as the standard in 2007. The request in Germany is CCNR stage 2 plus 30% more reduction of PM, at the moment. There is a lack of limit values for stage 3 or 4 for effective subsidy criteria, at the moment.

Scrapping schemes could be evaluated as an alternative to the schemes run over the last years. However, they basically have the same problem as the subsidy schemes described: the financial incentive provided is not sufficient for ship-owners to replace their ships by new ones.

Subsidies can be applied within the limits of EU state aid rules.

3. Voluntary agreements and initiatives

Better market organisation could also contribute to improved environmental behaviour, if shippers are interested in better environmental performance. Several shippers like Akzo and Bayer[3] have concluded long term contracts with a Dutch ship-owners co-operative. The ships in service are equipped with an SCR catalyst.

The examples show that long term contracts provide a solid basis for investment in new technologies for ship-owners. However, half of the

3 http://www.inlandnavigation.eu/Content2.aspx?id=61&type=2

contracts are negotiated on the spot market. This implies that for ship-owners some kind of guaranteed shipper's interest needs to be made clear, as a basis for an investment decision.

To this end, a voluntary standardisation scheme has been developed by the Green Award Foundation, that already operates a global safety and environment certification scheme for seagoing ships. The scheme has been set up on request of the inland shipping sector. The requested certification scheme has been developed to:
- lead to recognition of and motivation for clean ships;
- serve as a tool for charterers to choose clean ships.

The Green Award scheme's requirements[4] include amongst other compliance with CCNR-2 as a minimum. Additional points can be obtained for SCR, DPF, LNG, diesel-electric drive, fuel consumption monitoring and cruise controlling. As a result of financial support, the certification costs amount to € 400 for three years.

It is expected that 50 ships will enter the program during 2011, and the goal is to have 550-600 ships certified in 2015. Certified ships are listed on the website of Green Award (www.greenaward.org). In the first years, the Green Award scheme for inland barges will be partly financed by subsidies. During this period, the system needs to reach maturity. This means that for a significant increase of the number of clean engines, ports and shippers will need to provide incentives (discounts or operational benefits, better market position) for certified ships. At the moment, the number of incentive providers (charterers and inland ports) is limited (only Port of Rotterdam), but discussions with the main sea ports are underway.

For a significant effect on the environmental performance of inland barges, attention needs to be paid to:
- exploration of the willingness of shippers for providing incentives to ship-owners with Green Award certificates;
- international extension of the scheme.

For an effective Green Award scheme, it needs to be very clear to what extent ship-owners can count on additional rates on the spot market depending on the environmental performance of the ship. It needs to be investigated how this can be organised and if and how this can be done in a transparent way, within the legal boundary conditions (e.g. forbidden price agreements). Ports can relatively easily provide reductions on their published tariffs, but with flexible cargo rates, this is more difficult.

Voluntary environmental initiatives can be mainly found in business-to-consumer markets. Inland waterway transport is, however, mainly a business-to-business market (coal, sand, gravel, animal fodder, chemicals). This may make it more difficult to introduce voluntary environmental initiatives.

4 Detailed information can de be found here: http://www.greenaward.org/greenaward/file.php?id=214&hash=0b56d501187be02986eac46d230b1f6f .

5 Discussion of (policy) options

Effectiveness, cost, cost effectiveness and legal constraints are the four main criteria to assess government policies. Below, we shortly elaborate the criteria for all basic policy options. The four criteria are discussed from a socio-economic point of view, regardless the cost distribution.

The cost distribution strongly depends on the type of instrument chosen. Clearly, in case of a subsidy the costs will mainly be born by the government, and in case of an economic incentives and standards, the sector will need to invest in technologies. Furthermore, economic incentives and standards need to be discussed in an EU and CCNR framework.

In Table 2, the main options are discussed on the basis of the criteria mentioned.

Table 2 Analysis of different instruments

	Regulation		Economic Instruments			
	Standard	**Environmental zoning**	**Subsidy**	**Emission fund**	**Green Award**	**Differentiated port dues**
Effectiveness	The effectiveness of a standard would be highest. If paying a levy or applying measures is the cheapest	If enough ports will be involved, as effective as a standard	Ship owners can voluntarily decide to apply clean techniques. Proven to be ineffective	Effectiveness will depend on incentive level, and the company (e.g. ship size, overall fuel consumption, depreciation policy) characteristics	Not possible to predict, depending on incentives from market	Strongly dependent on height of mark-ups and number of ports involved. High effectiveness needs very ambitious policy
Cost effectiveness	Compared to an economic incentive, a standard also applies to ships that are small or used relatively limited. Application only to certain market segments can result in unfair competition	Cost effectiveness same as standard.	Depending on the boundary conditions for subsidy application.	The cost effectiveness of an economic incentive is high, since the instrument guarantees that measures will be taken that provide the most value for money.		
Who carries the costs initially?	IWT sector	IWT sector	Government/IWT sector	IWT sector, but NO_x fund could be partly funded by government	IWT sector, but with guaranteed support from shippers	IWT sector (but higher transport fares)
Legal constraints	No precedent in EU transport law. IMO and IPPC show precedents. CCNR uses transition periods for introducing regulations for existing ships	Only possible within context of EU air quality Directive, unless voluntarily agreed	The application of subsidies is without legal constraints, as far as the EU state aid rules are respected	A business fund can be set up free. However, a government tax may not be in line with the Mannheim convention	System needs to meet the legal boundary conditions of the internal competition	Low (within the legal boundary conditions of internal competition)

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Annex A Description of technical measures

A Selective Catalytic Reduction (SCR)

Concept
Selective Catalytic Reduction (SCR) is a technology where a reducing agent is injected in order to remove NO_x emissions. The technology has been installed for several years already on Euro-IV and -V trucks An SCR system can be retrofitted and can be applied to main engines as well as to auxiliary engines. In most cases ammonia is used as agent to reduce NO_x into nitrogen and water.

Emission reduction
Up to 90% of NO_x emissions can be reduced when using urea as agent. According to measurements on a SCR system on an inland shipping vessel 85% of NO_x emissions can be reduced for all loads. Urea consumption is approximately 5% of fuel consumption.

Costs
The costs for retrofitting an SCR-installation on a vessel range between € 20 and 65/kW, exclusive of engineering and installation costs. A rough estimate for installation costs is € 50,000. However, the costs of installation strongly depend on ship dependent factors. In case of a new-build system, installation costs are significantly lower. Prices for the 40% urea solution needed are between € 300 and 400 per metric ton. The costs for urea range between € 4-5/MWh.

Pilot projects
SCR technology has been applied in several ships, mainly in after treatment systems, since engine manufacturers do not apply integrated systems yet. With the introduction of phase-IV in 2016, engine manufacturers will probably need to install the SCR technology. For the new-build market, the costs for SCR catalysts may reduce due to size of scale advantages. However, the size of the market is limited.

Market consultation has shown that the costs of after treatment installations will probably not drop in case of significant market expansion, since retrofit installations need to be specifically designed per ship.

Implementation of SCR catalysts on the entire EU fleet will roughly cost € 650 million, excluding costs for urea and maintenance. These costs can be equally divided into engineering and installation cost and capital investments. Operational costs represent 14% of total costs in case of a three year depreciation period.

B Diesel Particulate Filters

Concept
Diesel particulate filters (DPF's), or particulate traps, are used to 'catch' the particulate matter from the exhaust gas in a filter. DPF's are already widely used in road transport for several years. DPF's can be applied on main engines as well as on auxiliary engines.

With wall-flow filters most (95%) of the particulate matter is removed, because the exhaust gas is forced to pass the filter material. In case of partial flow filters, as the name already suggests, only a part (40-50%) of the flow is filtered. Due to their higher reduction potential, wall-flow filters are state-of-the-art.

In order to deal with the increased backpressure as a result of particulate capturing, the DPF needs to be regenerated periodically. Particulate matter will be combusted at a temperature between 550°C and 600°C, a temperature which normally will not be reached, since the average engine load is limited. Therefore active or passive regeneration is needed to remove the particulate matter. In case of active regeneration the pressure in the DPF is monitored continuously.

Application, advantages and disadvantages
Compared to the application of DPF's in trucks, the allowable backpressure of inland shipping engines is lower. This results in the need for larger filters and associated higher costs. The size of DPF systems can be a problem for especially smaller vessels. In general it can be said the space required by a DPF is two to three times the engine volume.

Costs
The investment costs for inland vessels are between € 40-50 and € 70-110/kW, plus costs for the installation of the filter. However, if the DPF is installed together with the SCR, additional installation costs are insignificant.

The overall investments costs for DPF installation on the entire EU fleet amount to € 550 million, not taking into account installation costs, since these can be covered by the installation cost of the SCR catalyst.

C Emulsified fuels

General
Emulsion fuels are a mixture of hydrocarbons, water and additives. The main interest of introducing water into the combustion process is reducing the nitrogen oxides contained in the exhaust of diesel engines by lowering the peak temperatures in the combustion process, in particular in the upper load and speed range. To avoid separation of the components, so-called emulsifiers must be added in the production process. The water content is 30 per cent by volume.

NO_x and PM reduction
Studies have shown that, in modern engines, a NO_x reduction of about 20 to 30% can be achieved by using emulsion fuels. Particulate emissions, too, can be reduced by about 80% (Germanische Lloyd, 2001).

In addition to the reduction of NO_x and particulates, the use of emulsified fuels has some negative or unknown effects.
- a reduction in performance. Maximum performance of the engine decreases roughly at the same rate as the increase in water content in per cent.
- increase in consumption. Up to 20 per cent of added water content is fuel consumption-neutral. In case of modern engines with fuel injection systems, the use of emulsions has a negative impact on fuel consumption.
- Increase of uncombusted hydrocarbons (HC) and carbon mono-oxides (CO).
- The influence on the wear at the injection system is not sufficiently known.