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Charges for barges?

Preliminary study of economic incentives to reduce engine emissions from inland shipping in Europe

Final report

Delft, December 2004

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Publication Data

Bibliographical data:
H.P. (Huib) van Essen, J. (Jasper) Faber, R.C.N. (Ron) Wit
Charges for barges? Preliminary study of economic incentives to reduce engine emissions from inland shipping in Europe
Delft, CE, 2004

Inland shipping / Emissions / Economy / Costs / Policy / Policy Instruments / Standards / EC /
VT: Charges

Publication number: 04.4916.36

CE-publications are available from www.ce.nl

Commissioned by: Ministry of Housing, Spatial Planning and the Environment

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Summary

Background: emission standards and persistent problems with air quality
Emissions from traffic and transport are a significant cause of negative environmental and health effects at the regional and global level. In order to reduce these negative impacts, transport policy has typically aimed at bringing down specific emissions by means of regulation. Examples are obligatory emission standards for various types of road transport and, recently, for rail transport and inland shipping.

However, forecasts show that these policies will not solve some very persistent problems associated with traffic. Especially emissions of carbon dioxide (CO_2), oxides of nitrogen (NO_x) and small particles (PM_{10}) remain a problem.

Added value of economic incentives
In recent years, European transport policy has moved towards an internalisation of all external costs, including pollution. It aims at providing a basis for a sustainable and economically efficient transport system. A number of countries have introduced differentiated, use-dependent charges for several transport modes, particularly road and rail. For historical and legal reasons, until now charges have not been imposed on inland shipping.

This report studies the potential pricing policies to reduce emissions in inland shipping. It focuses on incentives to reduce NO_x emissions.
Economic incentives for inland shipping may reveal some of the most cost-effective measures to ameliorate air quality and have three clear advantages over emission standards:
- They encourage reduction of emissions even below current or future standards.
- They apply to both existing and new vessels.
- They allow the shipper to choose between new engine types and end-of-pipe solutions.

Compared with regulation, economic incentives for inland shipping have the disadvantage of the higher cost of compliance (e.g. higher administrative burden) and legal barriers that need to be overcome before some economic incentives can be introduced.

Pricing potentially effective for emission reduction inland shipping
This study shows conclusively that it is indeed possible to design economic incentives that will induce the owners of inland vessels to invest in emission reducing technology. The potential for emission reduction is considerable. Measures to reduce emissions in inland shipping are as cost effective as options in other modes of transport.

Three type of incentives
Three types of economic incentives have been studied for this report: a differentiated fuel charge, a differentiated waterway charge and differentiated harbour dues. All incentives act by charging vessels with low emissions less than vessels with high emissions.

A detailed calculation shows that an incentive level of € 2.5 per kg of NO_x emitted constitutes an adequate incentive that will induce vessels responsible for the majority of emissions to invest in emission reducing technology. This level is less than the environmental and health impact of a kilogramme of NO_x, estimated at € 8 per kg. At level of € 2.5 per kg, many of the larger vessels will be able to earn back their investment in emission reducing technology within three years.

The incentives studied differ in their effectiveness, their feasibility and in their possibilities to guarantee compliance.

Differentiated fuel charge: potentially effective - legally and practically difficult
A differentiated fuel charge can be a very effective incentive from an environmental point of view. It has the advantage that it not only induces a reduction of the emissions of NO_x (and the correlated emissions of PM_{10}), but also the emissions of SO_2 and CO_2.
However, the introduction of a fuel charge is not possible under current international law. The main obstacle is a prohibition on fuel charges in the Mannheim Convention. Provided the political will in all the parties to the Mannheim Convention, it may be possible to circumvent this problem by signing a new treaty as has been with Convention on Waste. The establishment of the Convention on Waste independent from the Mannheim Convention shows that adaptation to the Mannheim Convention and the interpretation of it, depend to a large extent on political will in the Member States.

Another disadvantage of a differentiated fuel charge is the potential for non-compliance. Vessels may bunker fuel in other countries, or take in fuel from other vessels that have lower emission factors and that have therefore paid smaller charges.

Differentiated waterway charge: effective option with mainly legal constraints
A differentiated waterway charge or a kilometre charge could establish a well targeted incentive to reduce emissions. Waterway charges are technically feasible, as is proven by the introduction of road charges for HGVs in various Member States. The additional investments may be modest as more and more vessels are introducing electronic river information systems and other devices to communicate with the waterway authorities. However, the legal feasibility of differentiated waterway charges remain unclear. A simultaneous introduction of charges in other modes of transport, or, alternatively, an amendment of the Mannheim Convention, may be needed to make differentiated waterway charges legally possible.

Differentiated harbour dues: legally possible – require much higher levels

Differentiated harbour dues may constitute an effective incentive to reduce emissions of NO_x and PM_{10}. They have two main advantages. There are no legal obstacles to differentiated harbour dues and there is only a small risk of non-compliance.

To induce a reduction of emissions, differentiated harbour dues need to be considerably higher than current harbour dues. The current harbour dues amount to approximately one tenth of the differentiated dues that would be necessary.

Another problem might be that an introduction of differentiated harbour dues in all Dutch harbours would require concerted action by a large number of local authorities. As their interests diverge, this would probably not be feasible. An introduction of differentiated fees in the CCR region or the EU Member States would be even harder to achieve. However, a concerted action of the two largest ports in the Netherlands may be feasible, and this report shows that this may also be a powerful incentive to reduce NO_x emissions.

Impact of economic incentive on the total tax burden of inland shipping

Economic incentives affect the transport system by changing the playing field. Due to the virtual absence of taxes on inland shipping, effective economic incentives cannot be based on a mere differentiation of existing tariffs. All economic incentives will result in a higher tax burden or higher operational costs for inland vessels.

The extra costs of the economic incentives for an average ship will be about 8% of the total operating costs. If such a ship is equipped with an SCR, the extra costs are about 2% of the total operating costs.

Impact on competitive position of inland shipping

Inland shipping will lose its tax and duty free status and will have to compete with other modes of transport without this benefit. This might depress demand and cause a modal shift away from inland shipping.

However this needs to be valued behind the background of the developments in pricing of other modes, e.g. the introduction of road pricing systems and rail infrastructure charges, in an increasing number of European countries.

Economic incentives for inland shipping will also level the playing field on which the different modes of transport operates: currently, road and rail transport are taxed heavier than inland shipping.

The increase in the tax burden and its effects might be diminished when at least part of the revenue would be ploughed back into the sector, for example by subsidising investments in emission reducing technologies.

1 Introduction

1.1 Background

Emissions from traffic and transport are a significant cause of negative environmental and health impacts at the regional level, particularly emissions of acidifying substances (NO_x and SO_2), particulates (PM_{10}) and volatile organic compounds (VOCs). Furthermore, at the global level, CO_2 emissions from transport contribute to global warming.

Several studies have shown that the transport sector is unsustainable due to these emissions[1]. In spite of improvement in European air quality over the past decade, nearly 90% of the residents of urban areas are exposed to excessive levels of particulates, NO_x, benzene and ozone in the outside air. Standards are currently being exceeded in many parts of the Netherlands as well.

Due in part to this situation, the European Transport Council (4 April 2000) concluded that further action is necessary in order to achieve sustainable mobility. Initiatives have since been taken by establishing short-term commitments under the UN/ECE Gothenburg Protocol and the EU National Emission Ceiling (NEC) Directive with emission ceilings for NO_x, SO_2, VOCs and NH_3 for 2010. Also, emission standards have been introduced for internal combustion engines of various types of road transport and, recently, of rail transport and inland shipping[2]. Accordingly, the forecast is that by 2010 the standards for several substances will no longer be exceeded. The exceptions are, however, NO_x and particulates[3].

Inland shipping

Without policy intervention, the share of emissions from inland shipping will rise considerably. Especially the share in emissions of NO_x and particulates will rise. In the Netherlands, inland shipping is expected to contribute 21% of the transport sector NO_x emissions and 30% of particulate emissions in 2010[4]. The rising share of emissions from inland shipping has two causes: rising absolute emissions from inland shipping and successful reduction of emissions from other sources of transport, especially road transport.

In regions with a large share of inland shipping in total transport, like the Rhine and Po estuaries, the problem is urgent. Coincidentally or not, these same regions have severe problems with NO_x concentrations in the outside air.

1 OECD, Environmentally Sustainable Transport (EST, 2000), WHO/ECE.21/2001/1 and EUR/00/ 502609094/1.

2 EU Directive 2004/26/EC.

3 Beck, J.P., R.J.M. Folkert, and W.L.M. Smeets (eds), 2004: 'Beoordeling van de Uitvoeringsnotitie Emissieplafonds verzuring en grootschalige luchtverontreiniging 2003', *RIVM rapport* 500037003/2004, Bilthoven.

4 Annema, J.A. and R. van der Brink (2002), internal memo RIVM 'Referentieraming emissies transport sector'.

Why this preliminary study?
The rising share of emissions from inland shipping has led to policy initiatives at several levels. The Central Commission on Navigation on the Rhine (CCR), for example, has introduced emission standards for new engines, effective from 2002. Directive 2004/26/EC has put a limit to the emissions from internal combustion engines in non-road mobile machinery. Unlike its precursors, this directive also applies to engines in vessels on inland waterways.

However, the following arguments could be brought forward for investigating *additional* policies, like economic instruments, in order to strengthen current policies and to reverse the projected trend of an increasing share of NO_x of inland shipping:
- Both the CCR and the EU standards only apply to **new** engines. Given the rather long lifetime of engines (up to several decades), it will take a long time before these standards translate into a significant reduction of emissions.
- Neither the EU nor the CCR standards are ambitious from an environmental point of view. Even with the existing technology, emissions can be reduced much more.
- Compliance with agreed National Emission Ceilings (NECs), might become more difficult without additional policies.
- Several studies show that costs of reducing NO_x in inland shipping are low compared to other sectors[5]. From a macro-economic point of view, it is therefore economically efficient to allocate a substantial part of the NO_x emission reductions that are needed for meeting the NECs in European Member States to the inland shipping sector.

1.2 Objective of the study

The objective of this study can be formulated as follows:

To identify and analyse the possibilities of economic incentives to reduce engine emissions of transport by inland navigation operating in European waters.

1.3 Scope of this study

The subject of this study is the appropriateness of financial-economic incentives to reach environmental goals. It is, in other words, a combination of pricing policy and environmental policy. In order to demarcate this specific combination of instrument and goal from other issues in both areas of policy, we will briefly discuss both policy areas in this section.

Pricing policy within the framework of transport policy
Infrastructure use is often supplied at no cost to the user. Sometimes, the user is charged, but at a flat fee, so that heavy users pay the same amount as incidental

[5] Brink, R.M.M. van den, A. Hoen, B. Kampman, R. Kortmann and B.H. Boon, 2004: 'Optiedocument Verkeersemissies: effecten van maatregelen op verzuring en klimaatverandering', *RIVM Rapport* 773002026.

users. Pricing policy changes this situation. It charges the user of infrastructure according to his use. Heavy users pay more. On top of making prices user dependent, pricing policy can also account for the differences in environmental burden and, consequently, lead to prices that better reflect the differences in social costs that are caused.

Pricing policy can have different aims:

- To finance infrastructure expenditure.
- To reach environmental or societal objectives.
- To increase economic efficiency.

An example of the first type of pricing are toll-highways. An example of the second type are congestion charges. The third type might be the internalisation of external costs in a kilometre charge.

Infrastructure and environment are scarce goods. They have to be used efficiently. Charging the user with scarcity and possible damages (the societal costs) will result in an efficient use of these scarce goods. The costs of scarce goods that currently have no price, like the environment, may be passed on to the consumer in several ways. Examples are taxes, levies, and auctioned emission trading.

When the costs of scarcity and damages are passed on to the user of infrastructure, a transport company or shipper can make an informed choice between different modes of transport. This leads to fair competition within and between modes of transport and to a more efficient use of infrastructure and the environment.

In comparison with other instruments, based on command and control, cost-charging has the advantage that it maintains or enhances freedom of choice. Therefore, optimisation, innovation and diffusion are encouraged, without passing on the external costs to the rest of the society.

Market mechanisms in environmental policy

Environmental policy goals can be reached by several types of instruments. The most prominent are regulation and market based instruments. Examples of regulations are obligatory use of catalytic converters or the ban of leaded gasoline. Examples of market based instruments are emission trading, subsidies, and taxes.

The environmental goals that are most relevant for this study are emissions of carbon dioxide (CO_2), sulphur oxide (SO_2), particles (PM_{10}) and oxides of nitrogen (NO_x). These emissions harm the environment in different ways. CO_2 contributes to the anthropogenic greenhouse effect. This is a global phenomenon, so the effects of CO_2 emissions are global. PM_{10} causes health effects on a regional scale and therefore is not a global phenomenon. Neither are SO_2 and NO_x that contribute to acidification. Most of the acidification in the

Netherlands, for example, has a domestic origin, although over a third comes from abroad[6].

In drawing up environmental policy for the inland shipping sector, economic incentives such as levies and emission trading form an attractive option because they give the sector, according to economic theory, the flexibility to take steps to achieve a pre-defined emission target at least cost.

1.4 Criteria for selecting policy instruments

When designing policy instruments, policy makers have to assess possible options on three aspects:
- Will the instrument work?
- Can it be implemented?
- How much will it cost?

The first question relates to the effectiveness of the instrument, the second to the feasibility, and the third to the cost-effectiveness.
Particularly in for the EC also the criteria of subsidiarity plays a role.

All these criteria are briefly discussed below.

It is evident that some of the criteria conflict with one another and do not always point in the same direction with regard to the choice of policy instruments. Choices must be made and trade-offs assessed.

Effectiveness
It is clear that any policy instrument should achieve its intended objectives, in this study a reduction in air pollution from inland shipping in Europe.

The effectiveness of a policy instrument depends, among others, on its transparency, its side-effects and the possibilities for enforcement.

Policy instruments that are intended to change the behaviour of either citizens or companies, like pricing policies, should be *transparent* in order to be effective. If they are not understood and accepted, they will fail to incite citizens or companies to change their behaviour. So simple instruments should be preferred to complex ones.

The effectiveness of policies can be hampered by negative *side-effects*, or enhanced by positive ones. While many side-effects will become clear in ex-ante evaluations, some are the result of intricate societal processes and may only become clear after a policy instrument has been implemented. So both in ex-ante and in ex-post evaluations, attention should be devoted to positive and negative side-effects.

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6 RIVM, CBS, 2004: Natuur en milieucompendium.

Policies that are not enforced, or that cannot be enforced, will not be effective. So, for example, emission charges are only effective if it is possible to identify the source of the emissions unequivocally. If not, other policies should be adopted to reduce emissions.

Feasibility
Whether or not a particular instrument can be used in practice, depends on legal considerations and on the perception of the fairness of the instrument. To start with the latter, in environmental policy, equity principles such as the User Pays and the Polluter Pays are widely accepted. Instruments based on these principles will often be considered as fair. In some cases, however, additional policy measures are needed to correct unintended and undesired distributional effects of environmental policy.

Policy instruments have to be either acceptable under current law or based on a new law. With respect to inland shipping in the Rhine estuary, the Mannheim Convention (see chapter 2) is of most relevance. The next chapter of this report is devoted to the legal feasibility of pricing policy for inland shipping.

Cost-effectiveness
Cost-effectiveness, the cost per unit of effect, is another key criterion. The most cost-effective instrument is an instrument that achieves a predefined target at least cost. Administrative and transaction costs are also important here.

Subsidiarity
Each level of government should deal with those issues with which it is most qualified to deal. A 'higher' level of government should be involved only if it is better suited to solving the problems than lower-level authorities. This is one of the basic principles of the policy of the Commission.

Subsidiarity affects the effectiveness, the feasibility and the cost-effectiveness of policy instruments. When policies are implemented at a level that is too low, the effectiveness of the policy may be reduced since actors affected by the policy may escape its consequences. For example, when high emission charges would be introduced in one mode of transport, but not in others, a modal shift will decrease the reduction in emissions. Similarly, is an emission charge is introduced in one waterway, but not in another, traffic may be diverted to the second waterway, again decreasing the effect of the charge. When the effectiveness decreases, so will the cost-effectiveness.
The introduction of a policy instrument that can be easily evaded may encounter more resistance than an instrument that is applied to all members of the targeted group. This affects the feasibility of a policy.
This is in fact the reason that this study focuses on European market based instruments rather than on national instruments. Subsidiarity relates not only to the Commission versus national governments, but applies also to the role of local and regional authorities.

1.5 Report structure

The structure of this report is as follows:

Chapter 2 discusses the current legal and policy context on the level of the CCR, the EU and the Netherlands.

In chapter 3, the essential design features of economic incentives are presented. This chapter also calculated the level of an adequate incentive.

Chapter 4 analyses three concrete incentives: fuel charges, waterway charges and harbour dues. The actual levels are calculated and the advantages and disadvantages of the different incentives are discussed.

Chapter 5 provides a concise, mostly qualitative overview of micro- and macro-economic effects of the incentives studied in this report.

Chapter 6 concludes.

2 Policy and legal context

2.1 Introduction

National policy should take supranational policy and intergovernmental treaties into account. This chapter analyses the most relevant policies and treaties that national governments in the Rhine area have to take into account when introducing financial incentives to reach environmental goals. Specifically, this chapter reviews:

- CCR and Mannheim Convention.
- Current and future CCR and EU emission standards.
- Oil duty within Convention on Waste.
- 1998 EU White paper on Infrastructure charging.
- 2001 EU White paper on the Common Transport Policy in 2010.

2.2 CCR and Manheim Convention

The Central Commission for Navigation on the Rhine (CCR) is the oldest intergovernmental organisation in the world. It was set up by the 1868 Mannheim Convention, and has the task of guaranteeing freedom of navigation on the Rhine and promoting the prosperity of navigation on the Rhine, while guaranteeing a high level of safety of navigation on the Rhine and on other rivers in the Rhine estuary. The CCR is made up of Belgium, France, Germany, the Netherlands and Switzerland.

It adopts binding regulations such as those on the construction of vessels and their equipment, the composition of crews, and the conditions for the issue of boatmasters' certificates for vessels operating on the Rhine.

Committee resolutions must be made unanimously. Thus, each member state has a veto right.

The articles 1 and 3 of the Mannheim Convention are the most relevant articles with regard to the legal feasibility of implementing economic incentives such as emissions charges or an emission trading system on inland shipping on the Rhine. Article 1 states that on the Rhine and other rivers that fall under the CCR jurisdiction, the only restrictions that can be imposed on shipping must be aimed at ‘general security’. Article 3 states that ships sailing on the Rhine and the other rivers will be free of duties that are exclusively based on shipping.

The Mannheim convention does not forbid port and lock dues. They exist in the Rhine area. So market based incentives, levied at ports and locks are possible within the Mannheim convention. Whether or not these points of levy are appropriate for reaching the environmental goals will be discussed in chapters 3 and 5.

Furthermore, the Mannheim convention does not seem to explicitly forbid a levy on NO_x emissions. NO_x 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 very costly. However, whether or not such a levy will hold in court, remains subject of discussion.

A levy on distance sailed will be hard to introduce if it is only applied to ships. However, when such a levy is also imposed on trucks, like for example in Germany, it can be argued that the levy is not exclusively based on shipping. In that case, it may be possible to introduce such an incentive. In the end, the legitimacy of a distance-duty will probably have to be decided in court.

In 1952, an additional protocol was added to the Mannheim Convention. This protocol states explicitly that fuels used in inland shipping shall be free of taxes, duties and levies. An economic incentive based on fuels seems therefore not to be feasible under the current law. However, it may be possible to circumvent this problem by signing a new treaty. This has been done in 1996, when a new convention was signed on the Collection, Depositing and Reception of Waste (see section 2.4). This convention includes a duty on diesel sold at bunkers by vessels. Member States avoided possible incompatibility with article 3 of the Mannheim Convention, by signing a *new* Convention on Waste. As long as all member States are included in the new Convention, it will prevail over an old one.

Establishment of a Convention on Waste independent from the Mannheim Convention shows that adaptation to the Mannheim Convention and the interpretation of it, depend to a large extent on political will in the Member States. Therefore, also incentives that are not legitimate under the current law, and incentives whose legitimacy is questionable, will still be analysed in this study. When they appear to be the best incentives, is may be better to try to amend the Mannheim Convention that to implement a suboptimal duty.

2.3 Current and future CCR and EU emission standards

Last decades the environmental performance of transport has changed a lot. Particularly emission standards have contributed to the reduction of emissions, setting a limit to the maximum emissions of new vehicles.

CCR emission standards

The CCR has set the first emission standards for inland shipping a few years ago, before the EU did. These CCR Phase 1 standards became effective at January 2002. CCR Phase 2 standards will become effective in 2007. The CCR standards are currently applied to new engines only, but they will be extended to existing engines in the coming decade.

Table 1 shows the levels of the CCR emission standards phase 1 and phase 2. The standards of phase 1 have limited effects on the emissions because they reflect more or less the current technology. In 2001, 70% of the German and 80% of the Dutch vessels already met the emission levels of phase 1[7]. (Average emissions of the Dutch fleet still exceed CCR phase 1 standards because of the long life of old, dirty engines).

Table 1 Emission standard of CCR phase 1 and phase 2

	Power (kW)	NO_x (g/kWh)	PM_{10} (g/kWh)
Phase 1	$37 \le P_N < 75$	9.2	0.85
	$75 \le P_N < 130$	9.2	0.70
	$P_N \ge 130$	n ≥ 2800 rpm: 9.2 500 ≤ n < 2800 rpm: $45 * n^{(-0.2)}$	0.54
Phase 2	$18 \le P_N < 37$	8.0	0.80
	$37 \le P_N < 75$	7.0	0.40
	$75 \le P_N < 130$	6.0	0.30
	$130 \le P_N < 560$	6.0	0.20
	$P_N \ge 560$	n ≥ 3150 rpm : 6.0 343 ≤ n < 3150 : 45 * n(-0.2) – 3 n < 343 rpm : 11.0	0.20

Source: CCR, 2001: *Report 1998/99*, Strasburg; CCR, 2001: *Report 2000/01*, Strasburg

EU emission standards

Directive 2004/26/EC regulates gaseous and particle emissions from internal combustion engines to be installed in non-road mobile machinery[8]. In contrast to previous EU regulation, this includes engines in vessels for inland shipping. In 2005, small engines will have to comply with the emission standards. Larger engines will follow in 2006 and 2007.

EU emission standards are not exactly compatible with CCR standards. The CCR standards regulate NO_x emissions as such, while the EU standards regulate combined emissions of nitrogen oxides and hydrocarbons. The reason for this combination is that the EU sought explicitly to introduce standards that were compatible with standards in other parts of the world, notably Japan and the USA[9].

Currently, the CCR and EU are trying to harmonise their standards. Both organisations do not intend to develop a common standard, but they seek a pragmatic solution. The EU already recognises engines that comply with CCR-1 standards. In 2005, the CCR will decide whether they will recognise EU emission standards. When this issue has been settled, engine manufacturers and shippers may freely choose between engines that comply with either the EU or the CCR standard.

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7 CBRB, annual report 2001.

8 Directive 2004/26/EC of the European Parliament and of the Council, 21 April 2004.

9 COM(2002) 765 final, 27.12.2002.

Since emissions of hydrocarbons are generally small compared to emissions of nitrogen oxides, the EU standards are probably tighter than the current Phase I standards set by the CCR, but lower than the planned Phase 2 emission standards of the CCR (expected to be set by about 2007/2008). Table 2 shows the EU standards.

Table 2 Limit values for new engines

Category: swept volume/net Power (SV/P) (litres per cylinder/kW)	Carbon monoxide (CO) (g/kWh)	Sum of hydrocarbons and oxides of nitrogen ($HC+NO_x$) (g/kWh)	Particulates (PT) (g/kWh)
V1:1 SV≤0.9 and P>37 kW	5.0	7.5	0.40
V1:2 0.9≤SV <1.2	5.0	7.2	0.30
V1:3 1.2≤SV <2.5	5.0	7.2	0.20
V1:4 2.5≤SV <5	5.0	7.2	0.20
V2:1 5≤SV <15	5.0	7.8	0.27
V2:2 15≤SV <20 and P ≤3300 kW	5.0	8.7	0.50
V2:3 15≤SV <20 and P>3300 kW	5.0	9.8	0.50
V2:4 20≤SV <25	5.0	9.8	0.50
V2:5 25≤SV <30	5.0	11.0	0.50

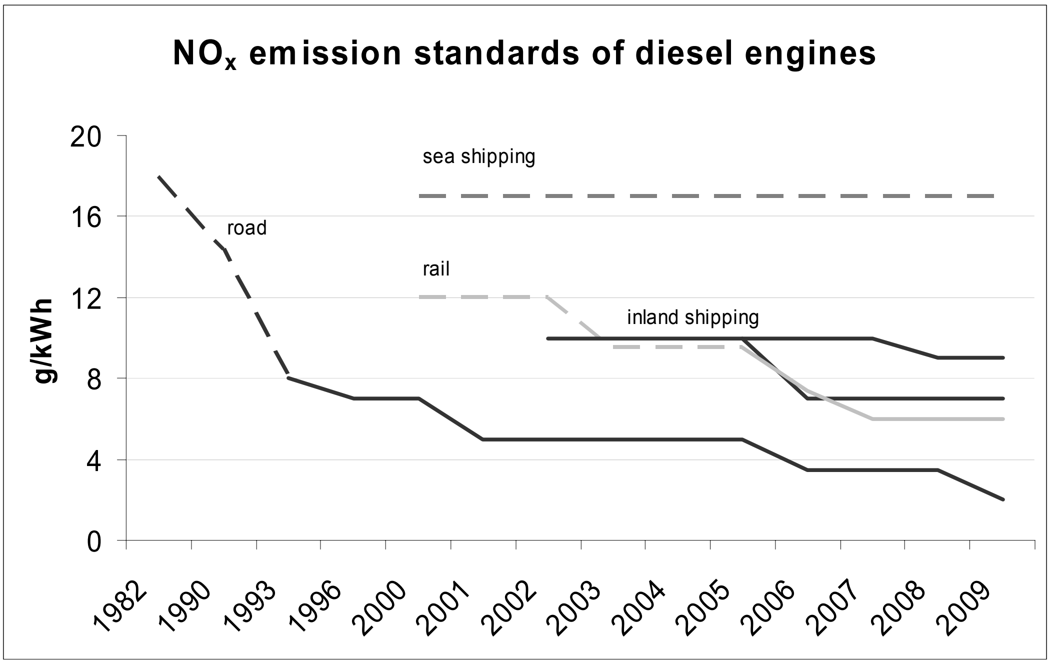
Table 3 Entry into force dates for emission limits for inland waterway vessels (placing on the market dates)

Category	Entry into force dates
V1:1	31 December 2005
V1:2	30 June 2005
V1:3	30 June 2005
V1:4	31 December 2006
V2	31 December 2007

Comparison of standards in different modes of transport

If we compare the EU or CCR emission standards with emission standards in other modes of transport, we see large differences. Figure 1 shows the emission standards for different types of diesel engines. Some of these standards are legal standards, others are voluntary or not yet consolidated in legislation.

Figure 1 NO_x emission standards for diesel engines of different transport modes [RIVM, 2000], [CCR], [UIC][10]



Solid lines indicate compulsory standards. Dashed lines indicate standards without legal status, either voluntary standards or proposed standards but not yet consolidated in legislation. The bifurcation of the inland shipping emission standards is due to the existence of different classes of engines in EU directive 2004/26/EC

We conclude that the levels of the standards are very different for the different modes. For *road transport*, European emission standards have been in place since 1993. Because of these standards, the environmental performance of road transport has improved significantly in the last decades and is expected to improve even more. The emission standards for trucks in 2009 will have been reduced by 90% since 1982 for NO_x and even by 95% since 1993[11] for PM_{10}.

For *sea shipping* there are no EU emission standards. The International Maritime Organisation (IMO) has a standard for NO_x, which is not very restrictive[12].

For *rail transport* we need to distinguish between electric trains and diesel trains. The emissions of electric trains depend for a large part on the emissions of electricity plants. For diesel trains, directive 2004/26/EC prescribes standards in 2007 and stricter standards in 2010.

Comparison of the emission standards does not tell us everything about the real emissions, because standards only apply to new engines. Particularly for modes that make use of engines with a long lifetime, like inland shipping, the reduction of the real emissions will be much smaller.

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10 The standards for sea shipping and inland shipping depend on the engine speed. We used the following typical values: sea shipping 130 rpm, inland shipping 1800 rpm. For diesel trains we used the emission standards for >560 kW power and >1,000 rpm.

11 Before 1993, there were no EU standards for PM_{10} emissions by trucks.

12 *Verkeer en vervoer in de Nationale Milieuverkenning*, RIVM, 2000.

2.4 Oil duty under the CCR Convention on Waste

The Convention on the Collection, Depositing and Reception of Waste produced by Rhine and Inland Shipping, was signed on 9 September 1996 by six countries (all five CCR member states and Luxembourg)[13]. This Convention appears to be not of direct importance to this study on economic incentives to reduce engine emissions. However, there are two reasons for discussing the Convention on Waste in this report.

First, the Convention was developed distinct from the Mannheim Convention. One of the reasons for this was to avoid opening discussions on other issues in the Mannheim Convention. This example illustrates, assuming sufficient political support, that also provisions with regard to economic incentives to reduce engine emissions might be developed outside the Mannheim Convention. It also shows, that such a process may take a long time. Whereas the Convention was signed in 1996, it is still not ratified by all signatories[14].

Second, under the Convention on Waste, costs of collection and disposal of oily waste produced on board ships be financed by a duty levied on ships using diesel oil. For the first year that this system of financing will be in operation, the duty will be fixed at 7.5 Euro per 1,000 litres of oil bought[15]. Given the objective of this study, this existing provision of a fuel duty may also form a suitable levy point for e.g. a (differentiated) fuel related charge based on NO_x emissions standards. In chapter 4, we will elaborate on this possibility.

The amount of the waste disposal levy will be the same in all the contracting States. That is why provision has been made for a permanent and international financial redistribution between the States in which the proceeds of the levy are greater than the expenses incurred for waste disposal and the States whose expenses are greater than the sum collected. This financial redistribution will be carried out by an international Redistribution and Coordination body in which the national institutions responsible for handling waste from boats at the national level will be represented.

2.5 EU White paper on infrastructure charging

The EU White Paper on infrastructure charging, published in July 1998, constitutes the framework for the development of pricing policy in transport. The White Paper, *Fair payment for infrastructure use: A phased approach to a common transport infrastructure charging framework in the EU*[16]*,* supersedes a 1992 White paper, *The future development of the common transport policy: a*

[13] Centrale Commissie voor de Rijnvaart, 2002 Verdrag inzake de verzameling, afgifte en inname van afval in de Rijn- en binnenvaart, Straatsburg.

[14] The Convention is not in force yet as it has not been ratified by all signatory states. Switzerland is the first state to have ratified the Convention in November 1998. The Netherlands ratified the Convention in 2000. However, Germany, France, Luxembourg and Belgium still have to ratify the Convention.

[15] During the first phase and as an incentive to reducing the quantity of waste produced, a discount will be given to all boats equipped with an approved joint for propeller shafts.

[16] COM(1998) 466 final, 22.07.1998.

global approach to the construction of a community framework for sustainable mobility[17]*.* The 1992 White Paper was a turning point in EU transport policy. It changed the focus from the removal of restrictions to the enhancement of efficiency of the transport system in the EU.

In order to enhance the efficiency and sustainability of the European transport system, the 1998 White Paper calls for the introduction of a harmonised charging system for transportation. This should also encourage fair competition within and between modes of transport. The commission proposes to base the charges on the 'polluter pays principle', where charges are based on marginal societal costs. The proposals in the White Paper are not meant to create an EU charging system, but rather to establish a framework in which member states may set the level of infrastructure charges.

The Commission proposed an approach in three phases. In the first phase, running from 1998 to 2000, methods for determining marginal costs must be established, and an agreement has to be reached on levy points. In the second phase (2001-2004), implementation of a harmonised charging system should start. The third phase would see an updating of the Community framework in the light of experience gained during the first two phases.

The timetable set in the 1998 White Paper has not been met. Instead, a new White Paper has been published, which will be discussed in the next section.

2.6 EU White paper on Common Transport Policy for 2010

The EU White Paper *European transport policy for 2010: time to decide* (2001) asserts that the goals to open up the transport market have been met in the decade between 1992 and 2002. However, the different modes of transport have benefited unevenly from this development. Road transport has experienced a much larger growth than most other modes, resulting in congestion and air pollution.

In order to stimulate a balanced growth and ensure fair competition between the different modes of transport, the White Paper calls for the integration of external costs into the infrastructure charge. Charges should reflect both the costs for infrastructure maintenance and environmental impacts of transport. Furthermore, modes of transport should be treated equally, according to the White Paper. The Paper announces a framework directive, to be proposed in 2002, but this has not been done until now.

2.7 Conclusion

In principle, the CCR and the Mannheim convention could constitute a major barrier to the introduction of most pricing policies for inland shipping on the Rhine estuary. The Mannheim Convention only allows port and lock dues and charges

[17] COM(92) 494 final, 2.12.1992.

that are not exclusively based on shipping. However, these restrictions have been mitigated in, for example, the CCR convention on Waste. This example shows that any pricing policy may be introduced when the parties to the CCR can reach an agreement. This reduces the problem to political will. Given the fact that all but one party of the CCR are EU members, the political will may be present. After all, the EU clearly aims at the introduction of infrastructure charges based on marginal costs, and this is a pricing policy. So, while legal obstacles to pricing policy in inland shipping should not be nullified, they are not insurmountable. Therefore, in the remainder of this report, we will not devote too much attention to the legal aspects of pricing policy.

3 Design of economic incentives

3.1 Introduction

There are many different ways to shape economic incentives considered in this study. The design of the incentives determines their environmental impact, economic distortions, legal and institutional implications and distributional consequences. A well-balanced design should therefore seek to improve the environmental performance of inland shipping in Europe in an efficient manner, while at the same time giving ample consideration to practical feasibility of implementation.

The design of economic incentives has four determinants:

- The *aim* of the incentive is the policy goal for which the incentive is used. In this study, the incentives aim at reducing gaseous and particle emissions from inland shipping.
- The *incentive base* is the good that is charged or subsidised. The base has to be related to emissions from inland shipping. It can be emissions itself, or any other aspect of inland shipping that correlates to the relevant emissions.
- The *levy point* is the point at which the charge is collected. A kilometre charge, for example, can be combined with harbour or lock dues, or be collected directly from the operator of the vessel.
- The *incentive level* or the height of the charge.

This chapter discusses important choices with respect to the design of economic incentives. It evaluates possible instruments on the criteria set out in section 1.5: effectiveness, feasibility and cost-effectiveness.

The aim of this chapter is not to develop 'the best-designed economic incentive'. It merely presents alternative options and discusses their main advantages and disadvantages. This preliminary study does not pretend to be complete in analysing all the pros and cons and the feasibility of the options identified. The information provided however, should allow a discussion on the most promising variants which could be selected for further study.

3.2 Aim of the incentives

The incentive level depends on the aim of the incentive. Generally, we can distinguish three possible aims of an economic incentive (see chapter 1):

- Economic efficiency.
- To reach a certain policy target.
- Generate government revenue.

If the aim is *economic efficiency*, the marginal external and infrastructure cost should be taken as the basis of the incentive level. In this situation the incentive is aimed at limiting infrastructure maintenance, emissions and other external effects to an optimal level, at which the cost of further (emission) reduction becomes higher than the external benefits of these reductions. This approach is based on optimisation of total prosperity.

If the aim is *to reach a certain policy target* (in this study: implementation of the most cost-effective emission reducing measures), the incentive level should be based on the cost of the required measures. The incentive should be strong enough to ensure that these measures are implemented (in this study by the inland shipping companies).

If the aim is to *generate government revenue*, for example to cover infrastructure expenditures, the cost of these expenditures should be the basis of the incentive level.

A combination of different aims is sometimes possible.

This study looks for instruments to reduce emissions from inland shipping. So it aims at reaching a certain policy target, for reasons set out in the introduction. From an environmental policy perspective, the most relevant emissions from inland shipping are gaseous emissions of NO_x, SO_2 and CO_2, and emissions of particles.

It is important to note that the different emissions have different causes, although they all stem from the engine. Box 1 shows the factors that affect the different emissions.

BOX 1: emissions from inland shipping and their causes

NO_x

Oxides of nitrogen are formed when nitrogen and oxygen from the air combine under the high pressure and temperature that exist in an engine. The amount of NO_x does not depend on the amount of fuel burnt, but rather on the design and the state of the engine. As engines get older, they tend to emit more NO_x, for example because the combustion chamber has carbon deposits, or because the injected fuel/air mixture gets out of balance. Oxides of nitrogen emissions can be abated either by end-of-pipe measures, or by better engine design and maintenance.

PM10

Particulates emitted by engines are mainly carbon particles (soot). They are formed when the combustion of the fuel is not complete, i.e. when not all the fuel reacts with oxygen to form water and carbon dioxide. The formation of PM10 can be caused by lack of maintenance, by using fuels that are not suited for the engine or, especially with diesel engines, by sudden variations in the amount of fuel consumed, for example when accelerating.

SO_2

Sulphur dioxide is formed when sulphur combines with oxygen. Sulphur is naturally present in most diesel fuels, but the concentration of sulphur depends on the type of diesel fuel. Likewise, the SO_2 emissions are driven by the sulphur content of the fuel.

CO_2

Carbon dioxide is formed when hydrocarbons are burnt. The amount of CO_2 depends directly on the amount of fuel consumed, that is, when the fuel/air mixture is in balance and all the fuel is completely burned. However, even when this is not the case, fuel consumption is the main driver of CO_2 emissions.

Emissions of CO_2 and SO_2 are directly related to fuel consumption and the type of fuel used. Economic incentives to reduce these emissions can therefore be relatively straightforward. Emissions of SO_2 can be reduced by a differentiation of levies according tot the sulphur content of fuel. Emissions of CO_2 and SO_2 together can be reduced by raising fuel levies, thereby stimulating the use of fuel efficient engines, fuel efficient propulsion and fuel efficient operating modes.

Economic policies to reduce emissions of NO_x and PM_{10} are less straightforward, since their level depends not only on fuel consumption, but also on engine design, operating mode and the use of end-of-pipe technologies that reduce emissions. So the aim of the incentive could be to stimulate innovation in engine design, or to incite shippers to operate their engine to reduce emissions, or to promote the use of end-of-pipe technologies that reduce emissions.

In the remainder of this study, we will concentrate on emissions of NO_x. The choice of policies to reduce particle emissions is conceptually identical, but the possible technologies and the cost price of emission reductions may differ. We have decided to focus our analysis on NO_x emissions, because NO_x concentrations in the outside air exceed air quality standards considerably in several area's of Europe[18]. In most of these area's, inland shipping emits considerable amounts of NO_x and thus contributes to the problem. A reduction of NO_x emissions from inland shipping could contribute to a solution, though other sectors would also have to reduce their emissions in order to keep concentration below the current standards.

3.3 Incentive base

Once the aim of the charge has been established, the incentive base has to be chosen. The incentive base is the volume or unit on which the charge is to be levied. Ideally, the incentive base is either the emission itself or a factor that is directly related to the cause of the emission. When such an incentive base exists, the incentive is well targeted and the policy can be effective. Furthermore, the incentive base has to be easily and unequivocally measured. However, it may not be always possible to identify a good incentive base.

For NO_x emissions, the ideal incentive base would be the amount of NO_x emitted. However, this is not easy to determine. Therefore, suggestions have been made to base the incentive on fuel consumption by ships or on fuel sold at bunkers. In this case the charge to be paid is proportional to the volume of fuel consumed.

Finding an incentive base for PM_{10} is as hard as finding a base for NO_x, since both emissions cannot be determined easily. Below, we discuss in detail the merits and demerits of several incentive bases for NO_x. The arguments for an incentive base for PM_{10} run along the same lines, but they will not be elaborated upon.

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[18] Natuur en Milieu Planbureau, 2004: *Milieubalans 2004*, Bilthoven: RIVM.

For CO_2 emissions, it is possible to base the incentive not on the actual emissions, but on the amount and type of fuel consumed, since this is directly related to the emission. Such an incentive can be easily introduced, provided that the current legal framework of the CCR is adapted to enable fuel taxes.

Since SO_2 emissions depend directly on the sulphur content of the fuel, an ideal incentive base would be the sulphur content. The fuel tax could vary according to the sulphur content of the oil.

Since the choice of incentive base has a major impact on the environmental effectiveness of the instruments considered, we will use this criterion of environmental effectiveness as the starting point for the discussion of possible incentive bases. The choice of charge base also determines, to a large extent, legal complications. This issue has already been discussed briefly in section 2.2.

3.3.1 Actual emissions

The most appropriate incentive is one on actual emissions. This generates an incentive for abatement measures in the total chain of activities, ultimately influencing all the factors that determine the emission level: technological development, engine/ship purchase, operation and volume. At the same time, it generates an incentive to choose the most cost-effective package of measures over the whole chain.

However, measurement of emissions during all inland ship movements is currently not feasible on a large scale. With the present state of the art, such a measurement would be very costly, so this option would not be cost-effective. For this reason several second-best options will be investigated. The aim is to stay as close as possible to the ideal of an incentive based on emissions, but at the same time to find solutions that are acceptable in terms of the other criteria.

3.3.2 Distance sailed or cargo shipped

The distance that a vessel sails is proportional to the number of hours that an engine runs, fuel consumption and emissions. However, the correlation is specific to a certain engine in a certain vessel and does not apply to the entire fleet. The same holds for the amount of cargo shipped. The more cargo a vessel carries, the more fuel it consumes, but the relation has a different form for each vessel. So a kilometre charge or a cargo charge will not promote the use of emission-reducing technology, unless it is combined with other incentive bases.

A distance charge already exists for HGV's in several European countries (Austria, Switzerland and, starting in 2005, in Germany), while other Member States study the introduction of it (e.g. United Kingdom and the Netherlands[19]).

[19] CE, VU, 2004: *Onderhoud en beheer van infrastructuur voor goederenvervoer: Structuur en hoogte van kosten*, Delft.

Some systems differentiate between emissions levels. So the technical feasibility has been proven.
Also for rail infrastructure many Member States have a distance-based usage charge. Within the framework of the rail Directive 2001/14/EC, differentiation to environmental characteristics is possible.

A distance charge is a suitable instrument to charge users with variable infrastructure costs, which is in line with the policy of the Commission. A differentiation of user charges according to environmental damages is legally possible. So, the only obstacle to this incentive base seems to be the Mannheim Convention.

3.3.3 Engine

Instead of measuring actual emissions during a trip, the incentive base could be based on emission factors or categories. Engines can be classified in categories according to emission factor: the emission measured in a standardised test procedure[20]. Based on the test results, emission categories could be settled. These categories define the emission per unit of time or fuel.

Of course, emission factors per se are not a good incentive base, since their correlation with actual emissions is rather weak. However, emission factors multiplied by the amount of fuel consumed or the distance sailed (an approximation of the time that an engine has been running) give a good approximation of the actual NO_x emissions.

In order to define which category applies, vessel operators should periodically have to test the engines of their inland waterway vessels. For example at the moment of revision of an engine or every five years. This test procedure could be followed by certification of the engine which defines the emission category.

In order to reward operators that take abatement measures (e.g. retrofit), operators should have the possibility to ask for an extra test procedure which makes it possible to shift to a 'lower' emission category.

A possible classification for the certified emission performance of vessel engines may use the categories CCR Phase I and Phase II.

A disadvantage of this incentive base on *emission categories* is that it does not generate an incentive to choose the least polluting operating mode, including optimal maintenance management. Due to neglected maintenance, NO_x emissions may rise, but the engine stays within the same category. This is because an average performance (test procedure) is assumed.

[20] The internationally accepted test procedures according to ISO 8178-4, test cycles E2 and E3 could be applied. These procedures are also obligatory for the EU Directive 2004/26/EC.

Another disadvantage is the possibility of non-compliance. Reduction of emissions costs money, not only to install new engines or exhaust gas cleaners, but also to operate them. Engines can be maintained badly, which may drive up their emissions. End-of pipe technologies might be switched off or bypassed. Such non-compliance is beneficial to the shipper (it saves him money), so there is an incentive not to comply.

Non compliance cannot be prevented altogether, but it can be reduced by a combination of inspections and fines. Legal conditions in order to be eligible for a differentiated charge can comprise technical measures that make inspections easier (e.g. a seal on essential parts of the equipment) and verifiable logs of the use of technologies (e.g. a log on the use of urea in SCR). A rational fine can be set as the advantage of non-compliance divided by the chance of being detected.

3.3.4 Fuel

Another option is to base the incentive on fuel consumption. This has the advantage that, apart from legal obstacles, such an incentive is relatively easy to implement. Fuel consumption is directly related to emissions of CO_2 and SO_2 (depending on the sulphur content of the fuel). For these emissions, therefore, a fuel based instrument forms an adequate incentive.

However, the situation for NO_x emissions is different. NO_x emissions are not linearly correlated to fuel consumption but depend on specific circumstances of the combustion process. A fuel charge only stimulates the use of low-emission engines if these engines are also energy-efficient. Furthermore, it does not stimulate the instalment of end-of-pipe technologies.

Therefore, in order to be an incentive for NO_x emissions, the incentive has to be based on the product of fuel consumption and the emission category of the engine (the amount of NO_x emitted per unit of fuel consumed). This would mean that the fuel charge has to be differentiated according to motor type, which may makes it harder to implement.

3.3.5 Vessel

A fifth possible incentive base is the vessel itself. Examples of current per vessel charges are harbour and lock dues. In other transport modes, such charges are more common. Trucks and combinations are subject to a road tax for every vehicle. The per vessel charge can be varied according to the environmental management system that is applied.

An example of such an incentive base is a rebate system that started in Hamburg on 1 July 2001 by an amendment to the Hamburg Port Fees and Administration Regulations. The rebate is a contribution by the City of Hamburg to promotion of environment friendly equipment and operating on sea ships. It is granted by the Hamburg Port Dues Office from the time at which the conditions are met by submission of complete and valid documents in German or English. Under the

Hamburg incentive system vessels could receive a 6% or 12% rebate of existing port dues. Box 2 shows the structure of the management scheme in Hamburg.

BOX 2: Environmental management based incentive in Hamburg

A vessel is entitled to a rebate or *bonus of 6%* under the following conditions:

- Proof of successful external certification of the vessel to ISO 14001 Standards., **or**
- The vessel is certified in accordance with the Green Award Foundation (see box 3).

A vessel is entitled to a rebate or *bonus of 12%*[21] under the following conditions:

- If the bunker fuel oils used for operation have a sulphur content of not more than 1.5%, or
- If the certified exhaust gas emissions of its propulsion system are 15% below the exhaust gas standards of Annex VI of the MARPOL Convention; or
- If the vessel uses anti-fouling paint which does not contain tributyltin, or
- The operator could submit a statutory declaration of compliance with the Swedish system.

A major disadvantage of a management system-based incentive is that such an incentive is poorly related to the NO_x emission caused. No incentives are created with respect to length of trip, technical improvements with regard to NO_x or load factor. An advantage of the system described above is the proven experience and the possibility to apply it on a voluntary basis (e.g. similar to the Green Award system, see Box 3 below).

BOX 3: The Green Award

The Green Award Foundation in collaboration with the Port of Rotterdam and some ports in Portugal, Spain, the United Kingdom and South Africa offers reduced harbour dues for tankers of more than 20,000 DWT (Dead Weight Tonnes). During 1998 29 ships were certified, bringing the total quantity of certified ships to 92 at the end of the year. Most of these vessels are larger than 50,000 DWT and are not used in short sea shipping. Of the total number of tankers in the range of over 20,000 DWT calling at the Port of Rotterdam, the percentage of Green Award ships in 1998 was 14 per cent. They made altogether 172 calls at Rotterdam and received an average discount of 5.7 per cent on the harbour dues (Green Award Foundation, 1999).

The certification procedure consists of audits of crew and management procedures and technical provisions. The emphasis is on safe and environmentally friendly management and crew competence. A certificate is valid for three years. To earn the award, the ship owner and the vessel must comply with national and international laws and regulations. On top of this basic requirement the ship owner must demonstrate environmental and safety awareness in a number of areas affecting management and crew competence, as well as technical provisions. They include manning, maintenance systems, tank and hull arrangements, oil leakage prevention, vapour emission control, accidental oil pollution prevention, spill collection, bilge water treatment, waste disposal, tank cleaning and exhaust emissions. However, there are no specified requirements. Instead, it is the task of the Green Award Committee to assess whether the arrangements are in line with the general rules of the Green Award. The procedure is carried out in absolute confidentiality, which means third parties are not offered any insight. The committee consists of representatives of the Dutch Ministry of Transport, the Port of Rotterdam, the Dutch Pilotage Organisation and the Royal Association of Netherlands Ship owners.

[21] The bonus can be earned only a maximum of once per call in port, i.e. the maximum reduction in port dues is 12%. This regulation applies only for vessels which pay at least DM 50 per call in port.

3.3.6 Combinations of incentive bases

Except for actual emissions, all incentive bases seem to be weakly correlated to emissions, so the incentive to reduce emissions will be weak. However, a combination of two (or more) incentive bases might strengthen the incentive. Some of these combinations have been suggested above. A combination of a distance charge and an engine charge (differentiated according to emission factor of the engine) correlates strongly to actual emissions, so it will be a strong incentive. The same is true for a combination of a fuel charge and an engine charge. Also, a combination of a vessel charge and emission category correlates to emissions, as does a fuel tax that is differentiated according to emission factor. The correlation of these latter two combinations with NO_x emissions is weaker than the first, but might still be sufficient to induce the introduction of technologies that reduce emissions.

3.4 Levy point

Following the choice of incentive base, a levy point has to be selected. The levy point determines where the instrument is implemented, i.e. at what point the charge will be collected. Levy point may be existing charges, but new levy points are also considered. For inland shipping, the following levy points already exist:

- Harbour dues.
- Lock dues.

Other possible levy points include:

- Waterway charges.
- Cargo charge.
- Fuel tax.

This choice of the levy point has mainly practical implications and determines the feasibility, the effectiveness and the cost-effectiveness of the incentive. In general, it may be easier to differentiate charges at existing levy points than to introduce new ones. A modification of an existing charge is legally easier to introduce and may generate less societal resistance. However, it may be very hard to modify an existing tax to aim it at a policy goal that has nothing to do with the goal at which it was originally aimed.

Not every combination of incentive base and levy points constitutes a feasible design for economic incentives. For example, it makes no sense to collect fuel charges at locks; fuel charges are best collected at the point where the fuel is bunkered. Table 4 presents the possible combinations of levy points and incentive bases.

Table 4 Levy point per incentive base

	Harbour dues	Lock dues	New levy point
1 actual emissions			
2 distance sailed			
3 cargo shipped			
4 engine (differentiated by emission category)			
5 fuel			
6 vessel (differentiated by management system)			

3.5 Incentive level

This report focuses on incentives to reduce NO_x emissions. Therefore, the incentive level should be based on the cost of the NO_x reducing measures. They should be high enough to stimulate shipping companies to decrease emissions.

3.5.1 Cost effectiveness of the different emission reducing technologies

There are various technological measures to lower NO_x emission factors of a vessel engine. In this section we briefly describe the major ones including their costs and environmental effects. A more elaborate description is presented in annex C.

The most important technologies to reduce the NO_x emission factor of a vessel engine are[22].

- Improved combustion control: adjustment of fuel injection.
- Water injection.
- Fuel water emulsification.
- HAM (Humid Air Motor).
- SCR (Selective Catalytic Reduction).

Each option has different reduction potentials, as shown in Table 5. Improved combustion control, water injection and SCR are the most mature options. The other two options are still in a rather experimental stage. Furthermore, reduction potentials may be improved and cost prices may be reduced as technological development progresses. Currently, much work is done to improve the existing technologies and develop new ones[23].

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22 *Erarbeitung von* Verfahren *zur Ermittlung der Luftschadstoffemissionen von in Betrieb befindlichen Binnenschiffmotoren*, Energie- Umwelt- Berating e.V. and Germanischer Lloyd, 2001; *Entwicklungspotential von Binneschiffmotoren zur Reduktion von Schadestoffen*, Germanischer Lloyd, 1998; *Scheepvaart en milieu*, RIVM, 2002; *Study on the economic, legal, environmental and practical implications of a European system to reduce ship emissions of SO_2 and NO_x*, BMT Murray Fenton Edon Liddiard Vince Limited, 2000; *Vooronderzoek vervanging en retrofit scheepsdieselmotoren binnenvaart*, Senter, 2002.

23 See for example http://www.innovatie.binnenvaart.nl.

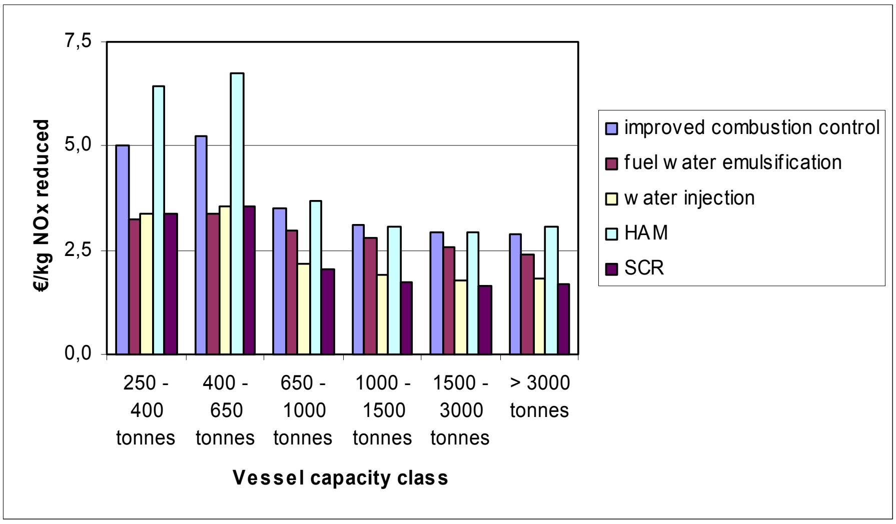
Table 5 Performance of several technologies to reduce emissions from inland shipping

Technical option for NO_x reduction	NO_x reduction		Corresponding CCR phase
	Max. reduction	Reachable level	
	in %	g/kWh	
Improved combustion control: adjustment of fuel injection	25%	9.0	CCR-1 (or CCR-2)[24]
Fuel water emulsification	30%	8.4	CCR-1
Water injection	50%	6.0[25]	CCR-2
HAM (Humid Air Motor)	70%	3.6	CCR-2 or more
SCR (Selective Catalytic Reduction)	90%	1.2	More than CCR-2

The cost-effectiveness of the different technologies varies with vessel size, distance sailed, engine characteristics, interest rate, oil price, et cetera. Below, we explore the determinants of the cost-effectiveness.

Figure 2 shows the price of a kilogramme of NO_x reduced per vessel class[26]. A description of the calculations and the data can be found in annex C. For most vessel classes, SCR is the most cost-effective option to reduce NO_x emissions. Only for the smallest vessels, fuel water emulsification seems to be a cheaper option.

Figure 2 SCR is the most cost effective technology for most vessel classes



Please note that these calculations are made for average vessel classes, with vessels sailing average distances for their class. The cost effectiveness is determined mainly by variations in engine power and sailing distance.

24 Due to technical progress, it seems to be possible to reach even lower levels of NOx emissions by improved combustion control. So CCR phase 2 might be reached without fundamentally new engine designs or end-of-pipe techniques.

25 For medium speed engines.

26 The calculations are made on the basis of average engine sizes, distances sailed, fuel consumption and engine efficiency per class. Detailed parameters are given in Appendix C. The interest rate is 8% and the investments are written down in three years.

This figure shows that the cost for the reduction of the NO_x emissions to the level of CCR 1 (improved combustion control, fuel water emulsification) is relatively more expensive than to reach the CCR-2 levels or even higher reductions. SCR and water injection are by far the most cost-effective technologies for most vessel classes.

In Table 6 details the cost-effectiveness for a vessel with a capacity ranging from 1,500 to 3,000 tonnes. It distinguishes investment costs from operating costs. Some technologies, like HAM, require large investments but have low operating costs. Others, most notably fuel water emulsification, require only very small investments but have relatively high operating costs.

Table 6 Capital and operating costs of NO_x reducing technologies for a 1,500 – 3,000 tonne vessel (Euro)

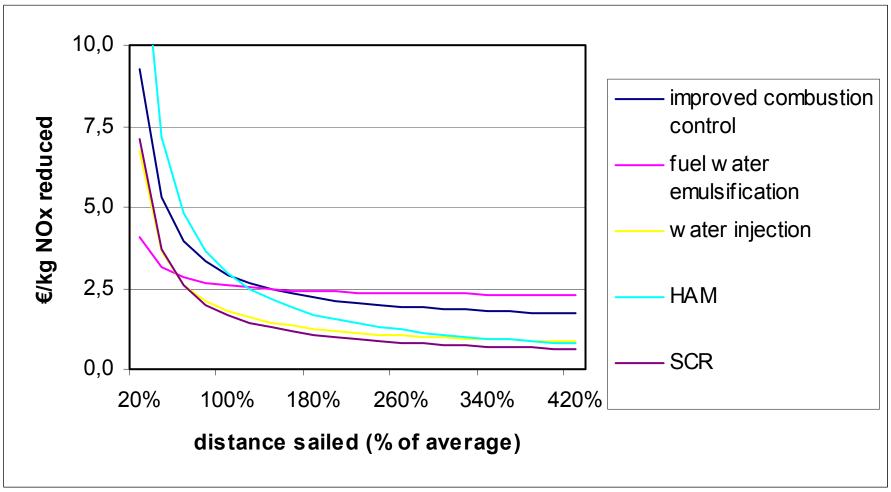
	Investment	**Annual capital cost (depreciation + interest)**	**Operations per year**	**Total cost**	**Cost per kg emission of NO_x reduced**
improved combustion control	15,584	5,599	4,653	10,252	2.92
fuel water emulsification	4,329	1,555	9,305	10,861	2.57
water injection	24,050	8,641	3,988	12,629	1.80
HAM	76,960	27,651	1,255	28,906	2.94
SCR[27]	48,100	17,282	3,766	21,048	1.66

Source: this study. A description of the calculations and the data is supplied in annex C

Figure 3 shows how the cost-effectiveness varies with the distance sailed. The figure is based on a vessel with a capacity of 1,500-3,000 tonnes, but for other capacity classes, the variation is qualitatively similar. The variation of the cost-effectiveness with the distance sailed has the highest value for HAM and the lowest for fuel water emulsification.

27 SCR can give the possibility for tuning the engine to minimum fuel consumption, because the engine does not need to be tuned to a certain NO_x level. The NO_x is reduced by the SCR, after all. This potential fuel consumption has not been included here.

Figure 3 The cost price decreases as a vessel sails greater distances



Other factors that determine the cost-effectiveness of NO_x reducing technologies have only a minor influence. Figure 4and Figure 5 show the variation with interest rate and oil price, respectively. The interest rate is positively correlated with the cost to reduce NO_x, since the investment costs rise as the interest rate becomes higher. The oil price is positively correlated with the cost price for most technologies because these technologies require extra fuel consumption.

Figure 4 The interest rate has only a minor impact on the cost-effectiveness

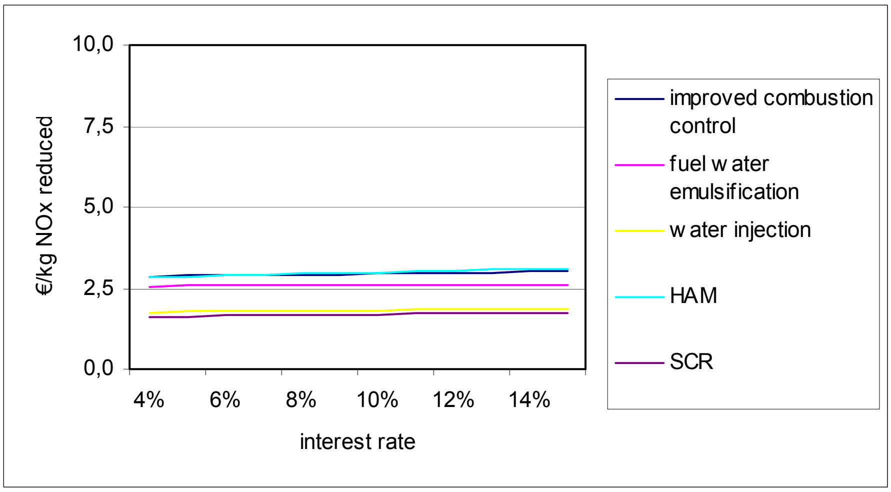
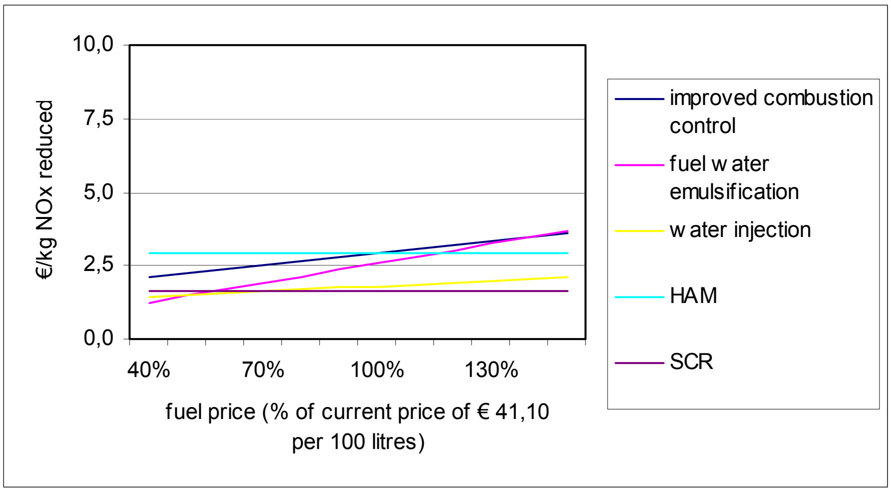


Figure 5 The oil price affects the cost-effectiveness of improved combustion control, fuel water emulsification and water injection



From the discussion above, it becomes clear that the cost-effectiveness of the different technological options differs substantially. In most cases, SCR is the most cost-effective technology, but for small ships and ships sailing small distances, fuel water emulsification becomes a cheaper option. The most important factor that determines the cost-effectiveness is the distance sailed. Other factors are less important.

3.6 Choice of the incentive level

In theory, an incentive that equals the cost of the least expensive measure to reduce NO_x emissions should result in the application of this measure. However, in practice, incentive levels need to be significantly higher. There are several reasons for this:

- A company has also other extra costs, like costs of time and organisation that is needed for selection, installation and maintenance of the equipment.
- The installation of equipment is not risk-free. The risk should be compensated for by the returns on the investment.
- Many companies will only be willing to install NO_x reducing equipment if the costs significantly *decrease*. This is because changes of any kind do always imply certain risks for a company (engine failures, unforeseen extra cost, etc.).

Furthermore, it may not always be possible to apply the least expensive technology in a specific vessel. An SCR installation, for example, uses a considerable amount of space, which some vessels may not have.

On the other hand, firms that introduce NO_x reducing technology improve their image which may result in an improved market position. This may constitute an incentive to introduce emission reducing technologies, even when they are not justifies on the basis of pure rational accounting.

Here, we consider the effect of three incentive levels on the installation of emission reducing technology:

1 Full internalisation of external costs.
2 An incentive based on the cost price of NO_x reducing technology for an average ship.
3 An incentive based on the cost price of NO_x reducing technology for the most active ships.

The first incentive level is based on the external costs of NO_x emissions, which are approximately € 8 per kg[28]. An incentive at this level would render several technical options to reduce emissions profitable for most vessels. Only the smallest vessels, and vessels that sail only very small distances will not be able to reduce their emissions in a profitable way.

BOX 4: Incentive levels based on external cost of NO_x-emissions

If the aim of an incentive is internalisation of external costs, the external costs should be the basis for the incentive levels. The external cost of a kilogram NO_x is € 8, according to the financial valuation of the emissions in an earlier study of CE-Delft ("De prijs van een reis", 2004[29]). This means that the external cost of the NO_x emissions per tonne-kilometre is about 0.5 to 0.8 €-ct. For a vessel of 2000 tonnes travelling 100,000 km/year the total external costs of the NO_x emissions are about € 540,000. The total costs of such a vessel are about 1.2 million Euro a year. This means that the external costs of the NO_x emissions are about 45% of the total annual operational costs of such a vessel. Consequently, if these costs would be totally internalised, the cost price of an average vessel-km or tonne-km would increase with almost 45%.

The second incentive level can be estimated on the basis of calculations presented in the previous subsection. Most active Dutch vessels can carry more than 650 tonnes. For these vessels, the costs of reducing NO_x are approximately € 2.04 per kg of NO_x reduced, assuming an interest rate of 8%, a full write-down in three years, and a sailing distance of 15,500 kilometres or more (the average sailing distance for this class). For vessels over 1,000 tonnes, the costs of reducing NO_x are approximately € 1.75 per kg NO_x. So an incentive of € 2.5 should incite at least all vessels over 650 tonnes which sail at least the average distance to introduce emission reducing technologies. Since the distance sailed is the most important determinant of the cost price of NO_x reductions, and since we do not know the distribution of sailing distances, we cannot estimate how many vessels will introduce an SCR. However, since larger vessels and vessels sailing large differences have even stronger incentives, we assume that the group of vessels that is responsible for the major part of emissions experiences a strong incentive to reduce emissions. Therefore, we estimate that emissions may be halved or reduced even further by this incentive.

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[28] CE, VU, 2004: *De prijs van een reis*, Delft.

[29] An English version entitled *The price of transport* is expected to become public by the end of 2004.

The third incentive level is lower than the second. The most active ships sail almost continuously. They may sail more than 90,000 km per year[30]. The cost price for NO_x reductions for vessels sailing five times the average distance of their class ranges from € 0.97 for the smallest vessels to € 0.56 for the largest. So for these vessels, an incentive of € 1 of even € 0.75 per kg NO_x will be a strong enough reason to introduce emission reducing technologies. However, at this level, only large ships sailing great distances will invest in emission-reducing technologies. The effect on aggregate NO_x emissions will remain small, unless technical progress leads to a significant reduction of the costs of emission reducing technology.

In the next chapter, we will use an incentive of € 2.5 per kg as a base for our calculations. At this level, about a third of the external costs are internalised, and many of the larger vessels will be able to earn back their investment in emission reducing technology within three years.

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[30] Naar een duurzame binnentankvaart", Stichting projecten binnenvaart and Erasmus University Rotterdam, October 2002.

4 Feasibility of specific incentives

This chapter discusses three possible charges that may act as an economic incentive to reduce emissions of NO_x from inland shipping. A charge is taken to be a combination of incentive base, levy point, and incentive level.

As stated in the introduction to this report, it has not been the purpose of this study to design an ideal economic incentive to reduce NO_x emissions. Rather, its purpose is to provide policymakers with insight into the available options and their advantages and shortcomings. Therefore, we have chosen to discuss three types of incentives that are either based on the variation of current charges on inland shipping, or on charges that are applied in other modes of transport. These criteria have led to the following charges to be studied:

1 Fuel charges differentiated to NO_x emission classes.
2 Waterway charges differentiated to emission classes and vessel size.
3 Harbour- and lock dues differentiated to emission classes and vessel size.

The charges are evaluated on the following aspects:

- *The environmental effectiveness*: Is the charge likely to reduce NO_x emissions, and if so, by how much? Does it also affect other emissions?
- *Legal aspects*: Is the charge legally feasible, or does it require amendments to existing laws?
- *Feasibility*: Are there important practical obstacles for their introduction?
- *Economic impacts*: Will the charge affect the amount of transport? Will it change the modal distribution?

4.1 Differentiated fuel charges

When the Convention on the Collection, Depositing and Reception of Waste produced by Rhine and Inland Shipping will be ratified by all signatories, a modest fuel charge will be levied on inland shipping in the CCR area. The revenue of these charges are used to cover expenses on waste disposal. The charges are currently set at € 7.5 per 1,000 litres of oil[31].

Levy point

Differentiated fuel charges[32] can be designed in a number of ways. The incentive base is, of course, fuel, but there are two possible levy points. First, a charge on the amount of fuel bunkered, and second, a charge on the amount of fuel consumed. Both levy points have advantages and disadvantages.

A charge on the amount of fuel bunkered is relatively easy to implement, since the implementation can coincide with the implementation of the waste charge.

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[31] Centrale Commissie voor de Rijnvaart, 2002: *Verdrag inzake de verzameling, afgifte en inname van afval in de Rijn- en binnenvaart*, Straatsburg.

[32] The levy point for flat fuel charge is rather straightforward (amount of fuel bunkered). Here we only consider a *differentiated* fuel charge for which several options exist.

The Waste charge can in principle vary with the emission factor of the engine. However, it may be very difficult to ensure compliance with this system. For example, vessels with high-emission engines may take in fuel from vessels with low-emission engines, on which only a low charge has been paid. The shippers may share the savings on the fuel charge and benefit both from this non-compliance, which is almost impossible to detect. This means that the Waste charge system must be supplemented by something like a seal on the fuel intake, which can only be opened by a certified fuel vendor. Inspections of the seals should take place regularly and fines should be imposed that are proportional to the reverse of the chance of being caught.

A charge on the amount of fuel actually consumed may be harder to implement, but such a system could be less susceptible to fraud. It may be possible to measure actual fuel consumption in the most advanced engines by electronic means. Alternatively, it may be possible to estimate fuel consumption on the basis of engine properties and distance sailed[33]. But in that case, the difference between a fuel charge and a waterway charge is rather small.

Incentive level

In chapter 3, we established that a charge of € 2.5 per kg of NO_x emitted would constitute an effective incentive to reduce emissions from inland shipping. Here, we will assess how this incentive relates to the level of the differentiated fuel charge.

Although emissions of NO_x are not directly correlated to fuel consumption, it can be calculated that on average, the current Dutch fleet emits some 39 kilograms of NO_x per 1,000 litres of fuel consumed[34]. For engines that comply with CCR1 and CCR2 standards, the emissions are 34 kilograms and 22 kilograms of NO_x per 1,000 litres of oil, respectively, assuming the engines are turbo charged[35]. We have also calculated a hypothetical standard, called FRE (Further Reduced Emissions), that limits emissions to half the CCR phase 2 values. Such a reduction can be reached by applying technologies such as improved combustion control, water fuel emulsification of by using a humid air motor. Vessels that have installed an emission reducing end of pipe technology, such as an SCR, should get a discount according to the reduction in NO_x emissions. The corresponding fuel charges are summarised in Table 7.

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[33] Oonk, Hans, et al., 2003: 'Emissiefactoren voor de binnenscheepvaart', *TNO-rapport* 2003/437 versie 2, Apeldoorn.

[34] Emissions are on average 10.6 grammes of NO_x per kWh engine power. With an average fuel consumption of 232 grammes (273 millilitres) per kWh, it can be calculated that the average emissions amount to 39 kilograms per 1,000 litres of fuel consumed. See annexes A.

[35] Engines that are not turbo-charged have a higher fuel consumption per kWh, resulting in lower emissions of NO_x per amount of fuel consumed. The figures for conventional engines in compliance with CCR1 and CCR2 are 46 and 30 kilograms per 1,000 litres of fuel, respectively.

Table 7 Fuel charge for different emissions levels (incentive level of € 2.5 per kg NO_x)

	Current fleet average	CCR phase 1	CCR phase 2	FRE[36]
Fuel charge in € per 1,000 litres	113	98	64	32
With SCR	11	10	6	3
Percentage of fuel price[37]	27%	24%	16%	8%
With SCR	3%	2%	2%	1%
Percentage of Waste Deposal Charge	1,502%	1,303%	850%	425%
With SCR	208%	180%	118%	59%

From the last rows of Table 7 it is clear that a differentiation of the current waste disposal charge would not come near an effective incentive to reduce NO_x emissions. Instead, a new charge would have to be introduced.

Evaluation

Even though fuel consumption and NO_x emissions are not strictly correlated, it may be possible to design a differentiated fuel charge that acts as an incentive to lower emissions.

A fuel charge is not only an incentive to reduce NO_x emissions. It is an even stronger incentive to reduce fuel consumption, for example by installing turbo-charged engines or efficient propulsion techniques. This means that the fuel charge will also result in lower CO_2 and SO_2 emissions. Furthermore, since both EU and CCR standards prescribe simultaneous reductions of NO_x and PM_{10}, emissions of small particles will also be reduced by a fuel charge.

A fuel charge is explicitly prohibited under the Mannheim Convention. This prohibition has been relaxed somewhat by the subsequent adoption of the Convention on the Collection, Depositing and Reception of Waste produced by Rhine and Inland Shipping. The introduction of a differentiated waste charge would probably be possible. However, the introduction of a new and substantial fuel charge may require a change in the Mannheim Convention or even the abolishment of it.

The effectiveness of a differentiated fuel charge may be seriously hampered by non-compliance. It may be hard, if not impossible, to design a differentiated charge that cannot be evaded by transferring fuel from a low-NO_x vessel to a high-NO_x vessel. Also, a shipper may turn of his SCR off or limit its effectiveness by saving maintenance costs. It will be hard to detect this non-compliance. This will negatively affect the environmental effect of a differentiated fuel charge.

[36] FRE – Further Reduced Emissions. This is a hypothetical standard which reduce NO_x emissions of CCR phase 2 by 50%.

[37] Assuming a fuel price of € 41,10 per 100 litres.

Furthermore, the effectiveness may be reduced when vessels would start bunkering fuel in other countries that have not differentiated fuel charges.

From Table 7 it can be concluded that a mere differentiation of the Waste charge will not be an effective instrument to reduce NO_x emissions. So any effective fuel charge will result in a higher tax burden for inland shipping. A higher cost-price of inland shipping could in principle reduce the amount of transport and a modal shift away from inland shipping. However, these effects are hard to evaluate, even in a qualitative way. It may, for example, be possible that an increase in the load factor of vessels counterbalances the negative effect on transport: the amount of traffic may reduce, while the transport of goods will remain the same. This means that the effects of the introduction of a differentiated fuel charge on the modal distribution of transport can only be assessed using general equilibrium models, and even then, the current understanding of many relations may not be enough to generate robust results.

Furthermore, the effects on the modal shift depend largely on what happens in road and rail transport charges. If road and rail fuel charges would be raised at the same time that fuel charges would be introduced in inland shipping, the effect on the modal distribution could be negligible, depending on the relative charges.

4.2 Differentiated waterway charges

Waterway charges are levies on the use of waterways, for example a charge per kilometre sailed. Sweden levies waterway charges that are differentiated according to NO_x emissions (see Box 3), but these are not linked to distance sailed. Infrastructure charges exist for the use of roads by heavy goods vehicles in Switzerland, while other countries are currently introducing such charges or contemplating to do so. Some countries are also studying the introduction of waterway charges in order to finance infrastructure maintenance.

In order to stimulate the use of NO_x reducing technologies, the waterway charge should vary with NO_x emissions or emission categories.

Box 5: Differentiated fairway dues in Sweden

Sweden has long had a fairway due to cover costs of icebreaking and other shipping-related expenditures. Fairway dues are not linked to the distance travelled, but are imposed as a flat fee per vessel. They are based on two charging components. The first one is based on the gross tonnage (GT) of the ship, while the second component is based on the amount of goods loaded and unloaded in Swedish ports.

In 1998, the GT charge has been differentiated in order to reduce SO_2 and NO_x emissions[38].

The differentiation with respect to sulphur in the ships' bunker fuel is straightforward. A ship which certifies that it is only using low sulphur bunker fuel (< 0.5% S for ferries, <1% S for other ships) will be granted a discount of 0.9 SEK (approximately € 0.10) per GT. To receive rebate for low sulphur bunker fuel the ship owner has to provide a document certifying that the ship permanently and under all conditions is operated with bunker fuel containing less than 0.5% sulphur for ferries and less than 1% sulphur for other ships. Currently, more than 1,000 ships qualify for sulphur rebate. In case sulphur certificate exist the general random ship inspections involve control of sulphur content of fuel[39].

For NO_x emissions the differentiation scheme is slightly more complicated. Most ships, except tankers, pay at least a base rate of 3.40 SEK/GT (approximately € 0.37). If their NO_x emissions in standardised test cycles exceed 2 g/kWh, they pay 0.16 SEK/GT more for every gram of NO_x emitted per kilowatt-hour. The maximum charge of 5 SEK/GT (approximately € 0.55) is reached when a ship emits 12 g/kWh or more.

Currently, 37 ships qualify for NO_x rebate. Ships having NO_x certificates will have emissions measured at a regular basis in order to make sure that emission levels are in line with the certificate. Preliminary calculations show that with these 37 ships, NO_x emissions could be reduced by approximately 36,000 tonnes per year[40].

Levy point

A waterway charge could be collected in two distinct ways. First, it could be based on the exact distance sailed, measured by a GPS based electronic device. Second, it could be collected at locks, charging ships according to distance between locks or, in some cases, according to the average distance between a lock and the preceding locks.

The first system would be more precisely targeted and have no perverse effects on sailing distance: it would not be possible to take a detour to avoid paying charges. The second system would be easier to implement, since it does not require the setup of a new tax collection system and the installation of GPS systems. However, the latter objection could become irrelevant as the River Information System is being implemented and other, even more advanced electronic communicating devices are becoming more popular among shippers – and obligatory in some countries.

The second system would resemble the differentiated harbour and lock dues discussed in the next subsection. It differs from that system because the charge

38 Kågeson, Per, 1999: "Economic Instruments for Reducing Emissions from Sea Transport", *T&E Air Pollution and Climate Series* 11, T&E 99/7.

39 Commission Expert Group on Transport and Environment, Working Group III: 'Review of infrastructure charging systems', October 2003.

40 Sjövartsverkert, 2004: *Fokus på Östersjön: Sektorrapport om sjöfartens utveckling 2003*, Norrköping.

is levied at locks, but based on the distance between locks. As such, it is a new charge and not a differentiation of existing lock dues. However, such a charge would have a major practical disadvantage since there are no locks on the main west-east Dutch waterway, on which the majority of inland vessels sail.

Incentive level

In chapter 3, we established that a charge of € 2.5 per kg of NO_x emitted would constitute an effective incentive to reduce emissions from inland shipping. Here, we will assess how this incentive relates to the level of the differentiated waterway charge.

Since NO_x emissions not only depend on the distance sailed, but also on the characteristics of the engine, an effective waterway charge should be differentiated twice; it should vary both with the distance and with the vessel class.

Table 8 shows the waterway charge per kilometre for the different vessel classes and the different engine types. The top half of the table applies to engines without SCR, the bottom half to vessels with an active SCR installation.

Table 8 Waterway charge for different engine types and vessel classes (incentive level of € 2.5 per kg NO_x)

Euro/km	**Without SCR**			
	current fleet average	CCR1	CCR2	FRE
250 - 400 tonnes	0.36	0.30	0.19	0.10
400 - 650 tonnes	0.50	0.43	0.28	0.14
650 - 1,000 tonnes	0.74	0.65	0.42	0.21
1,000 - 1,500 tonnes	1.02	0.88	0.57	0.29
1,500 - 3,000 tonnes	1.86	1.48	0.96	0.48
> 3,000 tonnes	2.82	2.06	1.34	0.67
	With SCR			
250 - 400 tonnes	0.04	0.03	0.02	0.01
400 - 650 tonnes	0.05	0.04	0.03	0.01
650 - 1,000 tonnes	0.07	0.06	0.04	0.02
1,000 - 1,500 tonnes	0.10	0.09	0.06	0.03
1,500 - 3,000 tonnes	0.19	0.15	0.10	0.05
> 3,000 tonnes	0.28	0.21	0.13	0.07

The waterway charges vary from almost 3 Euros per kilometre by the largest ships in the current fleet to a few cents for small ships with a clean engine and an SCR installed.

To put these figures in perspective, the variable costs of waterway infrastructure management and maintenance in the Netherlands amount to approximately

53 cents per kilometre[41]. These costs are the outcome of a preliminary study and reflect mainly the cost for traffic control. Currently, studies are undertaken into the variability of waterway maintenance. Should it become clear that some maintenance costs are indeed variable, then the costs of waterway use would be higher than 53 cents.

A hypothetical waterway charge that would cover the variable costs of waterway management and maintenance would be at least € 0.53 per kilometre, and possibly somewhat higher. A comparison with the figures in Table 8 shows immediately that a differentiation of this charge according to NO_x emissions cannot create an effective incentive to reduce emissions.

The fixed costs of waterway infrastructure management and maintenance (costs that do not vary with the intensity of traffic) are much larger than the variable costs. One could introduce a waterway charge that generates revenue for both variable and fixed infrastructure costs and which is differentiated to load class. A preliminary calculation shows that such a charge would vary from € 2.48 for vessels with a capacity between 250 and 400 tonnes to € 8.64 for the largest vessels[42]. These figures are much higher than the NO_x kilometre charge.

This means that, in theory, it would be possible to introduce kilometre charges that have the dual aim of generating revenue for infrastructure maintenance and reduce NO_x emissions. However, whether it would be sensible to introduce such kilometre charges remains an open question, since both objectives may compete. For example, when a charge, designed to cover infrastructure expenditures, results in the installation of SCR, it would result in lower emissions but it would not generate enough revenue for infrastructure maintenance. Therefore, two separate charges could be preferable, one aimed at generating revenue for infrastructure maintenance, the other aimed at reducing NO_x emissions.

Evaluation

A differentiated distance charge could establish a well targeted incentive to reduce emissions. It would not have important perverse effects and its environmental effectiveness would be good. Of the two variants of waterway charges considered, the kilometre charge correlates better with NO_x emissions than distance based lock dues. Since emissions of NO_x are correlated with particulate emissions, a distance charge would most likely also reduce the latter emissions.

It is not clear whether waterway charges would have an effect on other emissions, notably CO_2 and SO_2. This depends on the effect of the charges on the amount of traffic on inland waterways. These are hard to predict, for reasons set out in the previous section.

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41 CE, VU, 2004: *Onderhoud en beheer van infrastructuur voor goederenvervoer: Structuur en hoogte van kosten*, Delft.

42 Ibid.

There could be major legal obstacles to the introduction of a kilometre charge. As stated in chapter 2, the Mannheim convention forbids charges that are exclusively based on shipping. This probably implies that a waterway charge can only be introduced when similar charges are laid on other modes of transport simultaneously.

The introduction of waterway charges by means of a differentiation of lock dues is legally less problematic, since lock- and harbour dues are permitted under the Mannheim convention. However, since there are no locks on the main Dutch east-west waterway (from Rotterdam to Germany), such a charge would only affect traffic to Belgium and traffic on minor waterways. Its environmental effects would therefore be limited.

Both variants of the waterway charge seem technically feasible. Kilometre charges are currently imposed on HGVs in some countries and will be introduced in other countries shortly. Differentiation according to environmental damage is legally possible and has indeed been proposed or applied in different modes of transport. Also, the amendment of the Eurovignette directive might result in differentiated charges for HGVs.

4.3 Differentiated harbour and lock dues

Almost every harbour and many locks charge dues. In sea-shipping, a differentiation of these dues has been applied successfully to reach environmental goals. Here, we will discuss whether differentiated harbour and lock dues can form an incentive to reduce NO_x emissions from inland shipping.

Levy point
The levy point of differentiated harbour- and lock dues is rather unproblematic. Harbour dues are charged by the harbour authorities, often public enterprises owned by the municipalities in which the harbours are located (see box 6). Lock dues are levied by the waterway authorities. However, on Dutch state waterways, no lock dues are levied.

BOX 6: Harbour and lock dues in the Netherlands

In the Netherlands, harbour dues are levied on a local basis. Every municipality, or in some cases, an independent port authority, sets its own pricing policy, leading to price levels and bases differentiating throughout the country. The Port of Rotterdam has been taken as an example to illustrate the price basis mechanism and price level determination. In Rotterdam, like in all other municipalities except Doetinchem in the Netherlands, lockage is included in harbour charges[43].

Lock dues on national waterways do not exist in the Netherlands. Only local waterways charge lock dues, but these waterways are mainly used for recreational shipping.

Collection & Amendment Authorities
In most municipalities, a municipal tax office (Bureau Gemeentebelastingen) collects the (locally set) charges under the authority of the local harbour installations (Gemeentelijk Havenbedrijf). Collected funds are transferred back to the Havenbedrijf. Changes to local pricing policies can be initiated only by the Havenbedrijf and must be proposed to the local council / Mayor & Aldermen (gemeentebestuur / College van Burgemeester en Wethouders) of the municipality. In some ports, like Rotterdam, the Havenbedrijf is independent and collects harbour dues itself. Suggested amendments are generally in line with European guidelines.

Incentive level

Port visits or lock passages correlate poorly with NO_x emissions. Some vessels may sail large distances over lock-free waterways, others may hop from harbour to harbour. The first type would require a very high incentive level in order to install emission reducing technologies, whereas the latter would need only a small incentive.

The variance in trips makes it hard to calculate adequate incentive levels. However, under some strict assumptions it is possible to calculate incentive levels. These assumptions are based on an analysis of statistics of inland shipping in the Netherlands (see box 5). We calculate incentive levels for ships that:

- Sail from Rotterdam.
- Sail to a destination abroad along the Rhine.
- Sail at least 400 kilometres between Rotterdam and their destination.

From the analysis in box 7 it can be inferred that ships that have these characteristics are responsible for a major part of NO_x emissions, and that an incentive that is strong enough for these vessels is even stronger for ships sailing to Belgium. Together, ships sailing to these destinations emit most of the NO_x that is emitted by inland shipping in the Netherlands.

[43] Personal communication with Mr. Van Houten of the Gemeentelijk Havenbedrijf Rotterdam, 22-01-2003.

Box 7: an analysis of inland shipping statistics

In 2002, in total some 374,000 trips were made on inland waterways by ships that had been laden in the Netherlands. Most of these trips (263,000 or 70%) has been unloaded in the Netherlands as well. This implies that these vessels visited two Dutch harbours. However, since national trips are typically shorter than international trips, national trips only account for 40% of the total distance sailed by vessels that had been laden in the Netherlands. Furthermore, they only account for 19% of the amount of cargo transported. Ships that are not laden but unloaded in the Netherlands show a similar distribution in the number of trips, distance sailed and cargo transported[44].

So international transport on inland waterways accounts for the major part of the distance sailed by inland waterway vessels. Very probably, vessels travelling internationally are larger. It is therefore safe to assume that the larger part of NO_x emissions is accounted for by vessels that are either laden in the Netherlands and unloaded abroad, or laden abroad and unloaded in the Netherlands.

International transport by vessels on inland waterways is mainly transport to and from Germany or Switzerland. Transport to and from Belgium makes up a substantial, but minor part. Ships sailing to Germany or Switzerland pass the Dutch border at Lobith. 60% of border transits are made here. Most of the ships sailing to Belgium cross the border either at the Kreekrak locks or at Sas van Gent. 22% and 10% of all border crossings are made there, respectively[45]. So together, these three routes account for 92% of all international inland shipping.

Looking at distances sailed by vessels crossing at these borders, vessels crossing at Lobith account for 77% of the total distances sailed, at Kreekrak locks for 12% and at Sas van Gent for 6%. Most of the vessels crossing these borders have been laden in either Rijnmond (where the major port is Rotterdam) or the North See Channel Area (where Amsterdam has the largest port)[46].

So differentiating harbour dues in Rotterdam and Amsterdam would probably be an incentive targeted at the most active vessels that are accountable for the major part of the NO_x pollution.

Since ships sailing to Belgium sail smaller distances on average than ships sailing along the Rhine, and since the major port of destination along the Rhine is Rotterdam, we calculate an incentive level for ships sailing from Rotterdam along the Rhine.

Vessels sailing from Rijnmond (Rotterdam) along the Rhine to Germany sail on average 413 kilometres per trip. We assume that they return to Rijnmond, so that the incentive of differentiated harbour dues should take into account a sailing distance of 826 kilometres. (We assume that the ports of destination have not differentiated their harbour dues). In the previous subsection, a kilometre charge has been calculated for different types of vessels. We can use this charge for the calculation of differentiated harbour dues, taking the sailing distance of 826 kilometres into account[47]. Table 9 summarizes the dues for different vessel types and emission factors.

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44 CBS, 2004: Goederenstromen in de binnenlandse en de internationale binnenvaart, Voorburg/Heerlen.

45 CBS, 2004: Gegevens over de internationale binnenvaart per grensovergang, Voorburg/Heerlen.

46 Ibid.

47 This calculation is a gross simplification out of necessity. In calculating the kilometre charge, we assumed that vessels of each class sailed the average distance of that class. It is probable that vessels sailing abroad sail larger distances than vessels sailing only to national destinations, so probably, vessels sailing abroad sail larger distances than the average vessel. However, it is not known how far vessels sailing internationally sail per year.
This simplification results in an incentive that is too strong. It will induce more vessels to install emission reducing technology than an incentive that is calculated on the basis of correct data on sailing distance.

Table 9 Harbour dues for different engine types and vessel classes (incentive level of € 2.5 per kg NO_x)

Euro	Without SCR			
	current fleet average	CCR1	CCR2	FRE
250 - 400 tonnes	297	246	161	80
400 - 650 tonnes	410	355	231	116
650 - 1,000 tonnes	614	537	350	175
1,000 - 1,500 tonnes	845	728	475	237
1,500 - 3,000 tonnes	1,540	1,219	795	398
> 3,000 tonnes	2,330	1,699	1,108	554
	With SCR			
250 - 400 tonnes	30	25	16	8
400 - 650 tonnes	41	35	23	12
650 - 1,000 tonnes	61	54	35	18
1,000 - 1,500 tonnes	85	73	47	24
1,500 - 3,000 tonnes	154	122	80	40
> 3,000 tonnes	233	170	111	55

The differentiated dues calculated in Table 9 are much larger than current harbour dues for inland vessels. The table shows the 2004 tariffs for inland vessels per 7 days in the port of Rotterdam. They amount to approximately one tenth of the differentiated dues that would be necessary to induce a reduction of emissions.

Table 10 Harbour dues for inland vessels, Port of Rotterdam, 2004

	Minimum tariff	Maximum tariff
250 - 400 tonnes	21.75	34.80
400 - 650 tonnes	34.80	56.55
650 - 1,000 tonnes	56.55	87.00
1,000 - 1,500 tonnes	87.00	130.50
1,500 - 3,000 tonnes	130.50	261.00
3,000 tonnes and more	261.00	

Note: The 2004 tariff amounts to 0.087 euro per dead weight tonne. Source: Port of Rotterdam

A differentiation of harbour dues as calculated in table 9 would constitute an incentive that is strong enough for ships sailing to Germany to invest in emission reducing technology. But what does it mean for other vessels? Below, we answer this question for three types of vessels: vessels that sail from Rotterdam to Belgium, vessels that sail to international destinations but only occasionally visit the Rotterdam Harbour and vessels that do not sail to international destinations.

Vessels that sail from Rotterdam to Belgium sail smaller distances on average than ships sailing from Rotterdam to Germany or Switzerland[48]. So these vessels emit less NO_x per trip. This means that the incentive, expressed in Euro per kg NO_x emitted, will be much larger. In fact, the incentive will be almost twice as

[48] CBS, 2004: Gegevens over de internationale binnenvaart per grensovergang, Voorburg/Heerlen.

large, inducing these vessels to install emission reducing technologies even faster.
Vessels that sail to international destinations but only occasionally visit the Rotterdam harbour will hardly experience any incentive to reduce their emissions, unless other harbours also differentiate their dues. However, since vessels laden in Rijnmond account for 40% of the distance sailed by inland vessels, and 50% of the cargo transport, the majority of ships visit Rotterdam regularly[49]. If the port of Amsterdam would also differentiate its dues, approximately two thirds of the cargo transport would originate in harbours that induce NO_x reduction. So the incentive would probably be effective.

Vessels that only sail to Dutch destinations would experience a much smaller incentive, mainly because they do not sail to the Rijnmond as often. However, since these vessels sail smaller distances and emit less NO_x, this would not seriously lessen the environmental effects of differentiated harbour dues.

Evaluation

Harbour visits or lock passages correlate poorly with NO_x emissions, so at first sight, the environmental effectiveness of differentiated harbour and lock dues is questionable. However, an analysis of Dutch shipping statistics shows that differentiated harbour dues may in fact be an effective incentive to reduce NO_x emissions, since many of the vessels with large emissions sail from and to one or two harbours.

To induce a reduction of emissions, differentiated harbour dues need to be considerably higher than current harbour dues. The current harbour dues amount to approximately one tenth of the differentiated dues that would be necessary.

A differentiation of harbour dues may be an equally strong incentive to sail larger distances between harbour visits as it is an incentive to reduce emissions. This may cause other emissions to rise. Furthermore, a differentiation of harbour dues in one or two ports may induce shippers to change their routes, passing by the ports with differentiated dues. Whether or not this is possible, depends on the commodity that is transported and the possibility to change the transport system. An analysis of this problem is well beyond the scope of this report.

There are no legal obstacles to differentiated harbour dues. Harbour dues are permitted under both national and international legislation.

An introduction of differentiated harbour dues in all Dutch harbours would require concerted action by a large number of local authorities. As their interests diverge, this is probably not feasible. An introduction of differentiated fees in the CCR region or the EU Member States would be even harder to achieve. However, a concerted action of the two largest ports in the Netherlands may be feasible, and may also be effective in bringing down NO_x emissions.

[49] CBS, 2004: Goederenstromen in de binnenlandse en internationale binnenvaart, Voorburg/Heerlen.

Differentiated harbour dues, being considerably higher than current harbour dues, will impose an extra burden on inland shipping. However this needs to be valued behind the background of the introduction of road pricing systems and rail infrastructure charges in an increasing number of European countries.

As discussed in the previous sections, it is hard to evaluate the effects of a higher cost price of inland shipping. Much depends on the policy with regard to other modes of transport. When charges on rail and road transport are differentiated and raised as well, total transport may diminish, but the modal distribution may not be affected.

5 Economic impacts of differentiated charges

Because at present inland shipping is exempt from many taxes and charges, the introduction of a differentiated charge that aims at reducing emissions will inevitably result in a higher tax burden for inland shipping. This will affect both the micro and macro-economic aspects of inland shipping. The micro-economic impacts, or effects on the cost structure, are discussed in section 5.1. Macro-economic aspects, such as efficiency improvements, demand side response and modal shift, are discussed in section 5.2.

5.1 Direct impact of incentives and abatement cost on total operational cost

Table 11 shows a crude estimation of the cost structure of the average Dutch inland vessel. It is based on the financial statistics of Dutch businesses in inland shipping, under the assumption that companies have on average 1.36 ships[50].

Table 11 Cost structure of an average Dutch inland vessel, 2002 (1,000 Euro)

Debit			**Credit**	
Purchasing value of turnover	22.63		Income	293.38
Labour costs	57.84			
Depreciation of permanent assets	34.16			
Personnel	9.01			
Transport (including fuel)	61.19			
Energy	2.10			
Housing	3.77			
Machinery and equipment	5.45			
Sales costs	4.40			
Communication	2.93			
Services by third parties	11.11			
Other costs	20.33			
Operating results	58.05			

Calculations based on CBS, 2004: Kerncijfers transport per SBI, Voorburg/Heerlen; CBS, 2004: Geregistreerde en actieve binnenvloot, Voorburg/Heerlen

An average inland vessel in the current fleet (2002) emits 7,666 kg NO_x per year (see annex A). An incentive level of € 2.5 per kg NO_x means an extra tax burden of approximately € 19,000 per year. Relative to operating results, this is a considerable amount. Relative to total costs, this is 8%.

50 The total number of companies in 2002 was 3510. In that year, the active fleet numbered 4,772 vessels, so, on average, companies owned 1,36 vessels. CBS, 2004: Kerncijfers transport per SBI, Voorburg/Heerlen; CBS, 2004: Geregistreerde en actieve binnenvloot, Voorburg/Heerlen.

Vessels complying with CCR phase 1 standards have NO_x emissions that are 15% to 20% lower than the current fleet average (see appendix A). Therefore, their extra tax burden is also lower. CCR phase 2 vessels have NO_x emissions that are between 45% and 52% lower. An SCR can bring emissions down by 90%. After the installation of an SCR, the extra tax burden is on average reduced to € 1,900 per year. Add to this the operating costs of an SCR of approximately € 3,000 per year for an average ship, and the total extra costs will amount some € 5,000 per year, or a little more than 2% of total costs.

It is unlikely that the total costs of the extra tax burden (or the sum of the tax burden and operating costs of a SCR) will be borne by shipping companies alone. At least some of the costs will be passed on to the customers, while a part may also be mitigated by efficiency gains in business operations. A precise calculation of the effect of the incentive on shippers profits is beyond the scope of this study, but some qualitative estimates will be given in the next section.

5.2 Other reactions

The primary impacts of the incentive are the impact of the charges and/or discounts themselves and of the abatement cost. However, there can also be other market responses determining the total economic impact. In this section we discuss the following reactions:
- Efficiency improvements.
- Demand side responses.
- Fare adjustment behaviour.

The effects of these responses are discussed in the following sub-sections.

5.2.1 Efficiency improvements

Shipping companies can also react to an economic incentive by improving their efficiency. The type of improvements depends on the design of the incentive.

In general, small ships and ships sailing small distances will not be able to react to the introduction of incentives by investing in emission reduction, since cost-effective technologies do not exist for these vessel categories. For the inland shipping sector, this probably will result in a decrease of the number of small ships, and an increase in average sailing distances. Furthermore, ships that are at present only marginally profitable, will be driven out of business, while the most profitable ships will be able to invest in emission reducing technologies and expand their market share.

Distance related waterway charge
Shipping companies that are charged per travelled kilometre will try to reduce the number of vessel-kilometres that is needed for each shipped tonne-km. Thus, this is an incentive to improve the load factors of vessels.

Differentiated fuel charge
Shipping companies that are charged per litre of fuel that is bunkered will try to reduce the total fuel consumption that is needed for each shipped tonne-km. This, can be reached in several ways:

- Higher fuel efficiency of the vessel.
- Improvement of the load factors of vessels.

Thus, this is an incentive for higher fuel efficiency and higher load factors. The fuel consumption of a vessel (per km) can be improved by improving the engine energy return or by a more efficient use of the engine (more economic way of sailing, just like 'eco-driving'). Consequently, a shipping company has more possibilities to respond than in the case of a distance related waterway charge.

Harbour dues
Shippers that are confronted with higher harbour dues may limit their number of visits to the harbour, for example by ameliorating their load factor (only sailing when fully laden). They may also evade ports that have introduced differentiated dues, but this limits the environmental effects of the measure.

5.2.2 Demand side response

Because of the higher cost for shipping companies because of the economic incentives, the demand may decrease. The price elasticity for inland shipping is -0.3 to -1.2[51]. This means that a 1% increase in the cost price will result in a decrease in inland shipping between 0.3% and 1.2%.

If we assume that the cost of inland shipping would increase with 8%, the transport volume of inland shipping would decrease with 2.4% to 9.6%. This decrease is partly caused by a drop in total transport demand and partly by a substitution by other transport modes. The drop in total transport demand is usually much larger than the modal shift effect. After the installation of an SCR, total costs would rise by 2% and transport volume would decrease by 0.6% to 2.4%.

In the market for tankers and chemicals, quality and safety play an important role. In these markets, the economic incentives will probably not lead to large changes in the shipped transport volume. Also in the market for dry bulk, the modal shift will probably be limited.

In the container market, however, the competition between different modes of transport is very strong. Therefore in this market the modal shift to other modes can be substantial.

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[51] *Beter aanbod, meer goederenvervoer?*, CE-Delft 1999.

5.3 Mitigating undesired effects

Some of the undesired effects of economic incentives, such as the decrease in demand for inland shipping, and especially the modal shift away from inland shipping, may be reduced by ploughing back revenues into the sector. One very attractive option might be to use part of the revenue to subsidise investments in emission reducing technologies, and to use another part to subsidise R&D into more effective and efficient ways to reduce emissions.

6 Conclusions

It is possible to design economic incentives to reduce emissions of oxides of nitrogen (NO_x) and particles (PM_{10}) from inland shipping. However, there are important legal restrictions.

Incentives might reduce inland shipping and even cause a limited modal shift away from inland shipping. However this strongly depends on developments in the pricing of other modes, particularly road and rail, for which distance based infrastructure charges (sometimes also differentiated to environmental characteristics) are implemented in an increasing number of European countries.

The most important legal restriction is the Mannheim convention, which explicitly forbids fuel duties and charges that are exclusively based on shipping. Many types of incentive would therefore require a change of the Mannheim convention or a new international agreement, similar to what has been done with the Convention of Waste. Within the current legal framework only differentiated harbour dues and differentiated infrastructure charges are allowed, if applied simultaneously to other modes of transport.

The effectiveness of an economic incentive depends on its design. The most important design features are:
- Aim of the incentive.
- Incentive base.
- Levy point.
- Incentive level.

When the aim of the incentive is to reduce NO_x emissions from inland shipping, the ideal incentive base would be actual emissions. However, since these are hard to determine, other bases like fuel, distance sailed, engine emission factor and vessel size are considered. We conclude that neither of these bases correlates well with emissions, but combinations of different bases will. Therefore, adequate incentive bases are a combination of fuel and emission factors, or distance sailed and emission factor, or vessel size and emission factor.

The levy point chosen depends on the incentive base.

An incentive level of € 2.5 per kg of NO_x emitted will induce vessels that together are responsible for the major part of emissions from inland shipping to invest in emission reducing technologies. At this level, about a third of the external costs are internalised, and many of the larger vessels will be able to earn back their investment in emission reducing technology within three years.

A *fuel charge, differentiated with emission factors* and levied together with the Waste charge, could in principle constitute an adequate incentive to reduce NO_x emissions. Such a charge would vary from € 113 per 1,000 litres of fuel for the average ship in the current fleet to € 3 for vessels that meet the most advanced standards in engine technology and have introduced exhaust cleaners.

A differentiated fuel charge has the advantage that it not only induces a reduction of the emissions of NO_x (and the correlated emissions of PM_{10}), but also of the emissions of SO_2 and CO_2. However, the introduction of a fuel charge is not possible under current international law. A modification of international treaties, which may take a long time, seriously reduces the feasibility of this incentive. However, feasibility and speed of overcoming legal modifications do mainly depend on political will.
Another disadvantage of a differentiated fuel charge is the potential for non-compliance. Vessels may bunker fuel in other countries, or take in fuel from other vessels that have less emissions and that have therefore paid smaller charges.

A *waterway kilometre charge*, differentiated with emission factor and vessel class, could also constitute an effective incentive, since the distance travelled correlates rather strongly with emissions of NO_x for a specific vessel. Such a charge would vary from almost € 3 per kilometre for the largest vessels in the current fleet to a couple of cents for vessels with advanced engines and end-of-pipe emission reducing installations.

The legal feasibility of differentiated waterway charges remain unclear. When they are introduced only for inland shipping, they will not be permitted under current international law. When they are introduced simultaneously with a road and rail charge, they may be permitted, although this issue deserves further study.

Differentiated harbour dues may at first sight not constitute an effective incentive, since harbour visits are not correlated to emissions at all. However, in the Netherlands most inland shipping originates in only two harbours, the ports of Rotterdam and Amsterdam, and exports cargo to Germany and Belgium. These facts make it possible to calculate average total emissions per trip of ships sailing out of Rotterdam or Amsterdam, and base incentives on these emissions.
To induce a reduction of emissions, differentiated harbour dues would need to vary from € 2,330 for the largest vessels in the current fleet to € 8 for small vessels with advanced engines and end-of-pipe emission reducing installations. The current harbour dues amount to approximately one tenth of the differentiated dues that would be necessary.

The main advantage of a differentiation of harbour dues is that there are no legal obstacles and they do not require the introduction of a new tax. A problem might be that an introduction of differentiated harbour dues in all Dutch harbours would require concerted action by a large number of local authorities. As their interests diverge, this would probably not be feasible. An introduction of differentiated fees in the CCR region or in the EU Member States would be even harder to achieve. However, a concerted action of the two largest ports in the Netherlands may be feasible, and this report shows that this may also be a powerful incentive to reduce NO_x emissions. But in that case, differentiated harbour dues would be a strong incentive for the most polluting ships to find other routes and bypass the harbours with differentiated dues.

All economic incentives will result in a higher tax burden or higher operational costs for inland vessels. However this needs to be valued behind the background of the developments in pricing of other modes, e.g. the introduction of road pricing systems and rail infrastructure charges in an increasing number of European countries.

Economic incentives might depress demand and cause a modal shift away from inland shipping. These effects might be diminished when at least part of the revenue would be ploughed back into the sector, for example by subsidising investments in emission reducing technologies. Moreover, the effects of a higher cost price of inland shipping are hard to evaluate. Much depends on the policy with regard to other modes of transport.

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Charges for barges?

Preliminary study of economic incentives to reduce engine emissions from inland shipping in Europe

Annexes

Final report

Delft, December 2004
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A Statistics on the Dutch fleet

All calculations in this report are based on the characteristics of the Dutch inland shipping fleet. Therefore, some statistics of the fleet are presented below.

Table 12 Characteristics of the Dutch active fleet (2002)

Size class	Number of vessels	Average distance sailed (km)	Average speed (km/h)
250 - 400 tonnes	373	7716	13.2
400 - 650 tonnes	695	8291	13.2
650 - 1,000 tonnes	927	1,5643	14.4
1,000 - 1,500 tonnes	986	1,9796	15.9
1,500 - 3,000 tonnes	1,127	1,8855	15.8
> 3,000 tonnes	165	1,6413	15.2

Source: CBS, AVV

Table 13 emission and fuel characteristics of the Dutch fleet

Size class	NO_x emissies (g/kWh)	PM emissies (g/kWh)	fuel consumption (g/kWh)
250 - 400 tonnes	10.7	0.55	229
400 - 650 tonnes	10.2	0.60	234
650 - 1,000 tonnes	10.1	0.60	234
1,000 - 1,500 tonnes	10.3	0.59	234
1,500 - 3,000 tonnes	11.2	0.56	230
> 3,000 tonnes	12.2	0.46	218

Source: TNO

Table 14 Average emissions NO_x per ship per year

Size class	Number of ships in class	Emissions per ship per year (kg)	Emissions per class (kg)
250 - 400 tonnes	373	1,110	413,952
400 - 650 tonnes	695	1,644	1,142,926
650 - 1,000 tonnes	927	4,648	4,309,079
1,000 - 1,500 tonnes	986	8,103	7,989,694
1,500 - 3,000 tonnes	1,127	14,061	15,846,928
> 3,000 tonnes	165	18,517	3,055,378

Source: CBS, TNO

The weighted average emission per vessel is 7,666 kg NO_x per year.

B Cost structure of an inland vessel

Table 15 shows the cost-structure of a large tanker, sailing almost continuously between Rotterdam and Karlsruhe. Such a ship is exceptional, so the cost structure deviates from the average cost structure for Dutch vessels given in table 15.

Table 15 Annual costs per vessel

Category	Costs	Annual costs	Share in total costs
Capital costs		*345,000*	*28,3%*
Purchase	4,000,000		
Economic life (years)	25		
Residual value	800,000		
Interest rate	0.07		
Depreciation		128,000	10.5%
Interest costs		112,000	9.2%
Insurance costs		40,000	3.3%
Maintenance costs		65,000	5.3%
Operational costs		*502,800*	*41.2%*
Fuel		448,800	36.8%
Fuel costs per loaded km	6.00		
Fuel costs per empty km	3.60		
Number of km	550		
Charges for locks and bridges		2,000	0.2%
Cleaning costs (2 times a year)	26,000	52,000	4.3%
Crew		*366,200*	*30.0%*
Gross salary – captain	43,000		
Gross salary – skipper	31,000		
Gross salary – navigation officer	28,000		
Gross salary – first seaman	21,000		
Gross salary – ordinary seaman	14,000		
Number of shifts	2		
Salary costs crew		356,200	29.2%
Education costs crew		10,000	0.8%
Administrative costs		*7,000*	*0.6%*
Travel data			
Number of outward voyages	85		
Load factor per outward voyage	0.90		
Number of return voyages	85		
Load factor per return voyage	0.20		
Vessel capacity	2,000		
Number of shipped tonnes	187,000		
Transport volume (x1,000 tonne-km)	102,850		
Total costs		**1,221,000**	
Total costs per tonne		**6.53**	

Source: “Naar een duurzame binnentankvaart”, Stichting projecten binnenvaart and Erasmus Univeristy Rotterdam, October 2002.

We can conclude that for tankers that sail almost continuously, the fuel costs are a large part of the total costs (36.8%), while the charges for locks and bridges are relatively very small (0.2%).

The share of different test of costs in the total costs is not for all vessels the same. Therefore, in addition to the average cost distribution, Table 16 gives the cost distribution for several types of vessels.

Table 16 Cost structure per type of vessel in 2000

Type of vessel	**Share of cost elements in total costs (%)**			
	Labour	*Capital*	*Fuel*	*Other*
Dry cargo				
Motor vessels < 450 t	56.5	9.5	8.6	25.4
Motor vessels 450-1200 t	45.5	10.5	14.5	29.5
Motor vessels > 1200 t	37.4	18.4	15.3	28.9
Pushing tugs < 5000 t	20.5	14.4	23.1	42.0
Pushing tugs > 5000 t	9.8	13.5	29.0	47.7
Tankers				
Motor vessels < 1200 t	46.8	12.6	14.1	26.5
Motor vessels > 1200 t	45.6	16.2	11.9	26.3
Container shipping				
Container vessels	41.4	16.6	18.6	23.4
	30.0	19.7	36.8	

Source: http://www.europa.eu.int/comm/transport/iw/nl/iv_nl/iv_1a_nl.html

In the data of Table 16, the share of fuel costs is lower than in the data of Table 15, though still substantial (between 8.6% and 29%). Apart from large pushing tugs, the share of labour is much higher. For all types of vessels, the share of ‘other costs’ is relatively high. The major explanation of these differences is the relatively high annual travelling distance that is assumed for the cost structure presented in Table 15.

C Cost effectiveness calculations

In chapter 3, the cost-effectiveness of several technologies to reduce emissions of NO_x has been calculated. This annex described the methods and data sources used in these calculations.

C.1 Basic framework

The cost-effectiveness is defined as the cost per kg of NO_x emissions reduced. This is the sum of the annual depreciation and the operating costs.

The annual depreciation is based on a total write-down of the investment in three years, leaving no rest value. Interest is calculated in advance, and future costs are not discounted. The standard interest rate is taken to be 8% per year. This leads to a conservative estimation of the annual depreciation.

The calculation of the operating costs differs for the different technologies, as described in annex C. Three technologies, notably improved combustion control, fuel water emulsification and water injection, result in higher fuel consumption, so the operating cost are a mark-up on the average annual fuel costs. Two technologies, HAM and SCR, have operating costs that are proportional to the engine power.

The calculations of NO_x emission reductions are taken from the available literature on the different technologies, as described in annex C. Emission data can be calculated directly from the data sources.

C.2 Data sources

All data refer to the Dutch fleet. Data were used as much as possible for 2002. When these data were not available, data for the most recent year was used. The only exception it the fuel price, where data from September 2004 were used.

Most data are from Statistic Netherlands' Statline service.

Data on maximum engine power per vessel class and the fuel consumption per ship kilometre are taken from [CBS, 2002][52].

Data on emissions are calculated from [TNO, 2003][53]. Since the vessel categories in the TNO report do not match the vessel categories used in this report, we have estimated that each capacity class consists of motor vessels for 70% and of other types of vessels for 30%, each vessel having the same relative

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52 CBS (2002): 'Energieverbruik door binnenschepen 1997-2000', *Maandstatistiek Verkeer en vervoer*, jaargang 64, december 2001, CBS, Voorburg/Heerlen.

53 Oonk, Hans, et al., 2003: 'Emissiefactoren voor de binnenscheepvaart', *TNO-rapport* 2003/437 versie 2, Apeldoorn.

weight within its category. Although this is a crude approximation, the errors will not be large, since emission factors only differ by 20% maximum. Attributing different weights to the different vessel types will change the average emissions per class by a few percent at most.

Data on the distance sailed for the different ship types have been supplied by the AVV, the Transport Research Centre of the Dutch ministry of Transport, Public Works and Water Management.

Sailing speed is calculated on the basis of data on speed in the Waal river, assuming that downstream 30% of the ships in each class is carrying cargo, and upstream 90%. In order to calculate speeds for the different classes used in this report, the same method is used as in the calculation of emission factors per class.

Data on fuel efficiency of engines is based on specifications of Caterpillar engines for inland vessels. For the smallest engines (maximum power 170 kW), efficiency is assumed to be 36,5%, for the largest engines (maximum power 1,3 MW) 39%.

C.3 Emission reduction technologies

C.3.1 Improved combustion control: adjustment to fuel injection

With adjustments to the engine, the NO_x emission level of many engines can be reduced. The most important adjustments are electronic combustion control and adjustment to the fuel injection. These methods are based on the fact that different types of fuel nozzles have various impacts on NO_x emission levels, as does the intensity of the fuel injection. Different studies give different estimations for the cost of this measure and for the reduction of the NO_x emissions factor that can be obtained with it. Table 17 gives an overview.

Based on this information, we assume that this measure can reduce exhaust gas NO_x emissions by 25% and thus only be used to meet the CCR phase 1 requirements. Due to technical progress, it seems to be possible to reach even lower levels of NOx emissions by improved combustion control. So CCR phase 2 might be reached without fundamentally new engine designs or end-of-pipe techniques[54].

This measure is applicable for all vessel engines, however only useful for certain engine types.

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[54] *Vooronderzoek vervanging en retrofit scheepsdieselmotoren binnenvaart*, Senter, 2002.

Table 17 Possible NO_x reduction and cost of *improved combustion control (adjustment of fuel injection)* according to several studies

Source	**NO_x reduction**	**Cost**
RIVM, 2002	20 - 30%	Cost about the same as for water injection (see below) 10-15% higher price for new engine
Germanischer Lloyd, 2001	10 - 30%	3-5 % higher fuel consumption
BMT, 2000	20%	3.5% higher fuel consumption
Used in this study	25%	12% higher price for new engine and 3.5% higher fuel consumption

To calculate the cost of this measure, we need to know the price of a new engine. Table 18 gives an indication of the costs of a new engine. These prices of an engine that meets the CCR phase 1 requirements[55]. The prices of vessel engine depend a lot on the type of engine and on the power. These prices have been quickly checked with a dealer in ship diesel engines (Geveke, the Netherlands)[56].

Table 18 Indication of cost of a new engine

Max. power	**Load capacity**	**Price of a new engine CCR phase 1**	**Price of a new engine per kW**
kW	*tonnes*	*€*	*€ per kW*
500	1,000	75,000	150
1,000	2,000	135,000	135
1,500	> 3,000	175,000	117

The larger vessel engines (>kW) have a very long life-time of usually more than 20 years even up to 40 or 50 years. Every five to ten years these engines need to be reconditioned which costs € 45,000 to € 75,000. Mostly, the engine is taken out of the ship and replaced by an engine of the same type that just has been reconditioned[57].

C.3.2 Fuel water emulsification

Fuel water emulsification changes the input factor of the engine. It involves adding up to 50% or more water to fuel. While new-buildings can be designed to accommodate additional throughput, standard engines may not accommodate more than 20% water at full load, without retrofitting.

55 *Schoon schip in de Nederlandse binnenvaart*, CE-Delft, 1997.

56 Geveke gave an indication of € 130,000 for an engine of 1,100 kW, but very much depending on the type of engine.

57 Hans Kraaij, Dutch Ministry of Transport.

This technology has been tested in practice, but is not yet commercially available. It is applicable in the near future and can be applied to all type of engines. A disadvantage is that water supply is needed on the vessel[58].

Fuel Water emulsification is applicable for all vessel engines.

Table 19 Possible NO_x reduction and cost of *fuel water* emulsification according to several studies

Source	**NO_x reduction**	**Cost**
RIVM, 2002	30%	No data about the cost
Germanischer Lloyd, 2001	20 - 30%	No installation costs 5-10% higher fuel consumption
BMT, 2000	25%[59]	No data about the cost
Senter, 2002	50%	Installation: € 4,500 per MW Operations: € 1,600 per MW
Used in this study	30%	Installation: € 4,500 per MW 7% higher fuel consumption

C.3.3 Water injection

Water injection is a technology that changes the input factor of the engine. It involves adding water to the combustion chamber through separate nozzles. It is similar to water emulsification, but tends to consume more water.

This technology is applicable in the near future and can be applied to all type of engines. A disadvantage is that water supply is needed on the vessel[60].

Table 20 Possible NO_x reduction and cost of *water injection* according to several studies

Source	**NO_x reduction**	**Cost**
RIVM, 2002	20 - 50%	Installation: € 25,000 per MW Operations: 4-5% fuel costs
BMT, 2000	30 - 50% (to 7 g/kWh)	Installation: $ 27,500 Operations: $ 1 Euro/MWh (is about 1.2% of the fuel costs[61])
Senter 2002	50%	No data about the cost
Used in this study	50%	Installation: € 25,000 per MW Operations: 3% fuel costs

58 *Vooronderzoek vervanging en retrofit scheepsdieselmotoren binnenvaart*, Senter, 2002.

59 When 50% water is added.

60 *Vooronderzoek vervanging en retrofit scheepsdieselmotoren binnenvaart*, Senter, 2002.

61 Assuming 231 g fuel/kWh (CBS (2002) Energieverbruik door binnenschepen 1997-2000, Maandstatistiek Verkeer en vervoer, jaargang 64, december 2001, CBS, Voorburg/Heerlen) a fuel price of € 330 per 1,000 litre and an engine energy return of 35%.

C.3.4 HAM

Just like water injection, HAM (Humid Air Motor) changes the input factor of the engine. It uses combustion air that has been modified and chilled, powered by waste heat and cosuming only water. Engine efficiency is not adversely affected. HAM is still in a rather experimental phase but could be an effective way to reduce the NO_x emissions of an inland vessel.

Table 21 Possible NO_x reduction and cost of *HAM* according to several studies

Source	NO_x reduction	Cost
RIVM, 2002	70 – 80%	Installation: € 29 per kW (the Annex of this report gives a different figure: € 80/kW) Operations: much lower than SCR (the Annex of this report says: € 0.01 per kg NO_x)
BMT, 2000	70% (< 2 g/kWh)	No data about the cost
Used in this study	70%	Installation: € 80 per kW Operations: € 1 per MWh

Remark: we assumed € 1.00 = $ 1.00.

C.3.5 SCR

An SCR is an end-of-pipe technique. In a SCR, the NO_x emission are highly reduced by letting it have a chemical reaction with another substance like urea or ammonia. It is a very effective way to reduce the NO_x emissions of an inland vessel and is already commercially available. To work properly, an SCR needs urea or ammonia, which should be bunkered together with the gas oil.

Not all vessels are suitable to be equipped with an SCR. The current SCR's require a large space (about 3 meters) in the vessel behind the engine room and also space for storing the urea or ammonia. In many vessels this space is not available, which makes it impossible to equip them with an SCR. In the future new types of SCR's might be developed that tackle this problem.

Table 22 Possible NO_x reduction and cost of *SCR* according to several studies

Source	**NO_x reduction**	**Cost**
RIVM, 2002	90 - 95%	Installation: existing ship € 29-46.5 per kW; new ship € 29 per kW (the Annex of this report gives a different figure: € 55/kW) Operations: 2.07 Euro/MWh (the Annex of this report says € 0.29 per kg NO_x)
Germanischer Lloyd, 2001	80 - 90%	Installation: € 40 - $ 50 per kW
Germanischer Lloyd, 1998[62]	85 - 95%	No data about the cost
BMT, 2000	max. 99% (< 2 g/kWh)	Installation: € 55 per kW Operations: € 3.5 per MWh
Senter, 2002	70 - 95%	Installation: € 25 - € 85 per kW Operations: € 14 - 15 per kW (for an engine running 4000 hours/year)
Used in this study	90%	Installation: € 50 per kW Operations: € 3 per MWh

Remark: we assumed € 1.00 = $ 1.00

62 Entwicklungspotential von Binnenschiffmotoren zur Reduktion von Schadestoffen, Germanischer Lloyd, 1998.