COMPETITIVE AND SUSTAINABLE GROWTH (GROWTH) PROGRAMME

ENVIRONMENT

Working Paper

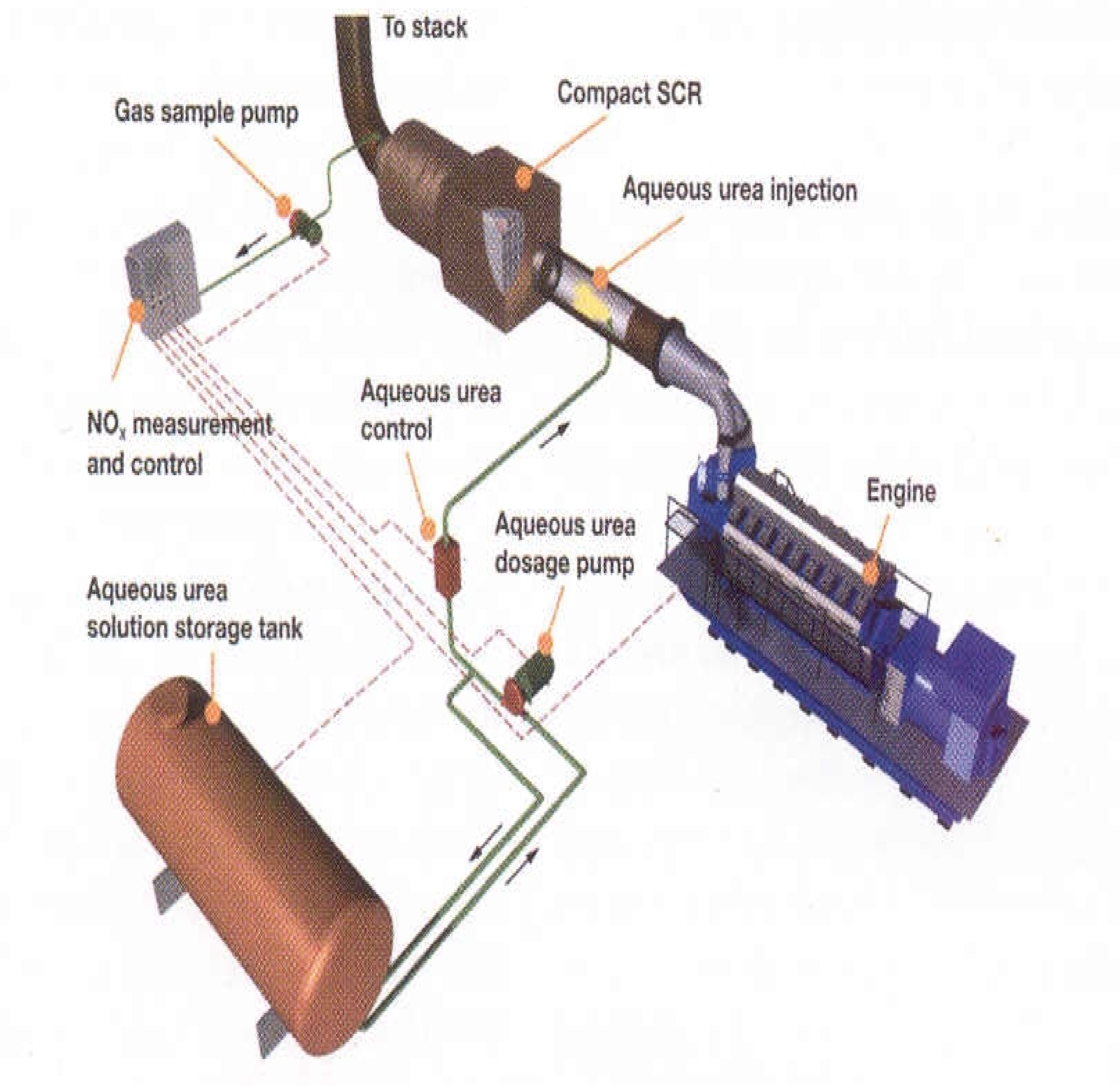
Project number:	**GTC2-2000-33036**
Project acronym:	**SPIN - TN**
Project full title:	**European Strategies to Promote Inland Navigation**
Work Package/ Working Group:	**WG6 Environment & Safety**
Author:	**Henk Blaauw, DLD**
Document version:	**1.0**
Date:	**15th December 2004**

DISCLAIMER - *The thematic network SPIN-TN has been carried out under the instruction of the Commission. The facts stated and the opinions expressed in the study are those of the consultant and do not necessarily represent the position of the Commission or its services on the subject matter.*

CONTENT

1 Introduction and Summary 4
1.1 Introduction 4
1.2 Summary 5
2 Emission regulations 7
2.1 Introduction 7
2.2 Survey of existing national and international regulations 7
2.2.1 Emissions of greenhouse gasses and CO_2 7
2.2.2 Emissions of Nitrous Oxides (NO_X), Hydrocarbons (HC) and Particulate Matter (PM_{10}) 8
2.2.3 Emissions of Sulphur Dioxide (SO_2) 8
2.2.4 Noise 9
2.3 Rules and regulations for other modes of transport 9
2.3.1 Road Transport 10
2.3.2 Short Sea and Deep Sea Shipping 10
2.3.3 Rail Transport 10
2.3.4 Air freight 11
2.3.5 Emissions at terminals and ports 11
2.4 Comparison between the transport modes 11
3 Optimising Ship Design 14
3.1 Introduction 14
3.2 Resistance 14
3.3 Drive mechanisms 15
3.4 Engines 16
3.5 Behaviour and awareness 17
4 Reducing NO_X 18
4.1 Introduction 18
4.2 In-process measures 18
4.3 End of pipe techniques 19
5 Reducing SO_2 21
5.1 Introduction 21
5.2 Lowering sulphur levels in gas oil 21
6 Reducing PM_{10} 22
6.1 Introduction 22
6.2 Steam Jet Aerosol Collector (SJAC) 22
7 Alternative fuels 23
7.1 Introduction 23
7.2 Carbon based alternative fuels 23
7.3 Non-carbon alternative fuels 24
8 All Electric Ship 25
8.1 Introduction 25
8.2 Aspects of the AES concept 25
8.2.1 Harmonisation of equipment and power sources 25
8.2.2 Integration of other electrical power sources 25
8.2.3 No unnecessary emissions 25
8.2.4 Efficiency 26
8.2.5 Costs 26

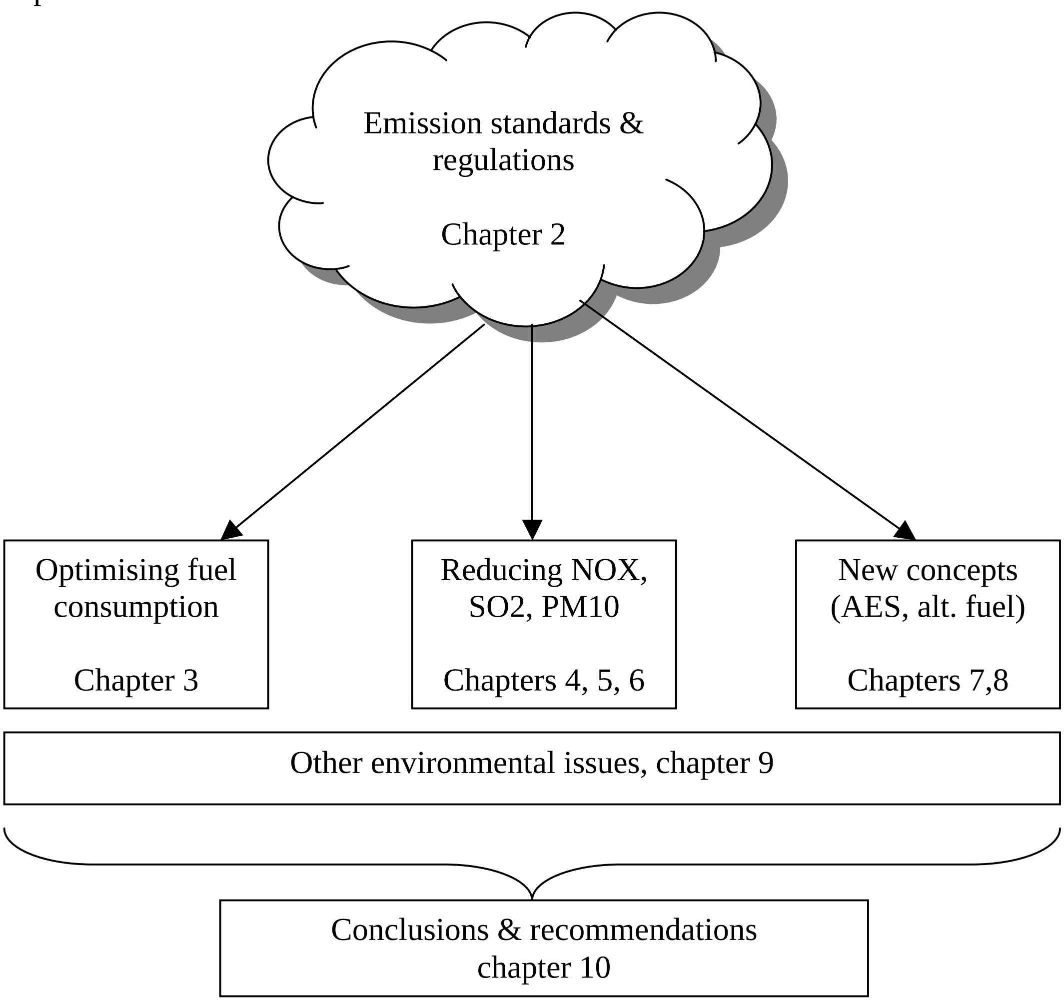
9 Waste and discharges to water 27
9.1 Introduction 27
9.2 Engine room waste, sludge and coolants 27
9.3 Cargo residues, cargo waste and ballast water 29
9.4 Discharge of gasses and vapours 30
9.5 Operational discharges to water 30
9.5.1 Grease 30
9.5.2 Anti fouling and PAH 30
10 Conclusions and recommendations 32
10.1 Introduction 32
10.2 Development in regulations 32
10.3 Required policy measures 33
10.3.1 Regulation 33
10.3.2 State-aid or European funding 33
10.3.3 Promotion and Education 34
10.4 Recommendations for future requirements 34



1 Introduction and Summary

1.1 Introduction

The good environmental performance of the inland navigation sector has always been one of it's unique selling points. Other modes of transport however are closing the gap by improving their engines, reducing emissions of pollutants etc. It is of strategic importance to take the necessary steps to improve the environmental performance of inland navigation, since some policy makers are already starting to dismiss inland navigation as an option for sustainable transport developments.
The largest challenge of the inland navigation sector is to drastically reduce the emissions of pollutants to air. Therefore this report primarily focuses on this subject. Chapter 2 discusses the existing regulation, national and international, for emissions to air and noise emission, both for inland navigation and the other modes of transport.
Chapter 3 focuses on ways to prevent emissions by reducing the fuel consumption of inland vessels, largely by optimising ship and engine design. Chapters 4, 5 and 6 discuss specific options to reduce the emissions of the high priority pollutants. New concepts and developments that may aid the improvement of the environmental performance are discussed in chapters 7 and 8. Chapter 9 pays attention to other aspects of inland shipping and the environment, such as water pollution and waste. Conclusions and recommendations are given in chapter 10.



1.2 Summary

The environmental performance of inland navigation needs improvement. Other modes of transport are rapidly improving due to European regulations while inland shipping maintains it's status quo.
First steps have been taken with the introduction of emission standards by the Central Commission for the Navigation on the Rhine (CCNR) and the European Union. These standards will significantly improve environmental performance, however only for new engines and ships. To clean up the existing fleet, other measures are necessary. Promising developments are the introduction of catalytic converters for NO_X and filter systems for PM_{10}, however these need further development and testing. Alternative fuels and the All Electric Ship concept also look very promising. If there is any transport mode that can already benefit from the huge environmental benefits of the fuel cell concept, it is inland navigation.
On the short term, a quick win can be made by reducing the amount of sulphur in gasoil. This will reduce dangerous SO_2 emissions by 75% with little or no problems or investments costs. Further standardisation of emissions is necessary and effective. Setting more specific targets for high priority pollutants will further help this process.
Other environmental issues such as water pollution and waste seem to be under control, however two policy measures are necessary: implementing an international waste treaty for inland navigation and introducing a European prohibition for the use of anti fouling agents that contain dangerous Polycyclic Aromatic Hydrocarbons (PAH's).

The following policy measures are required:

Regulation

- Ongoing standardisation of emissions to air
- More detailed European targets for emissions of NO_X, SO_2, PM_{10} by inland navigation
- Additional regulation by the European Commission lowering the sulphur content of gasoil
- Refining emission standards for PM_5, $PM_{2,5}$, PM_1 and $PM_{0,1}$
- Implementation of the international waste treaty inland navigation or European alternative
- Obligation for the use of environmentally friendly lubricants in shaft seals
- Prohibition of the use of coal tar and other coatings containing PAH's

State-aid or European funding

- State-aid for R&D and demonstrators regarding hull design, friction resistance etc.
- assistance and possible funding of the introduction of voyage optimisation software and systems
- state-aid for introduction of catalytic converters
- state-aid for model testing and pilot for the plasma catalytic converter
- state aid for R&D and introduction of SJAC and other filtering techniques
- state aid for R&D and introduction of fuel cell powered barges
- state aid for the wider introduction of AES in inland navigation

Promotion and Education

- Support and possibly fund publicity campaigns for AES
- Integration of results and lessons learned in the TREMOVE
- Education and raising environmental awareness among barge operators concerning fuel consumption

Recommendations

- **Use the reduction potential of inland navigation**
  Given the present environmental performance of the inland shipping sector and possible improvements, a lot can be gained already at relatively low costs. In order to achieve this, specific targets have to be set on a European level and money needs to be invested. Standardisation of emission may result in a reduction of 50%-70% of the emissions of NO_X and PM_{10}, about 75% of the SO_2 emissions and approx. 25-30% of the CO_2 emissions. The timeframe for these reductions is 10-15 years. The larger part of these reductions and improvements will take place with little or no extra investments. However the so-called 'early adapters', that quickly embrace new technologies and regulations need financial aid. For the entire inland shipping sector in Western Europe an amount of € 150 million will suffice to initiate and support the required pilots, R&D programmes and demonstrators.

- **Pave the way for the fuel cell**
  If there is any transport mode that can already benefit from the huge environmental benefits of the fuel cell, it's inland navigation. There are however several problems to solve, regarding safety, availability of fuel for fuel cells, huge costs of current prototypes etc. Without the combined effort of the inland shipping sector, the CCNR and the European Union, these problems will not be solved. Furthermore a substantial investment of approx. € 75-100 million is required to not only build fuel cell powered ships, but also to facilitate the required infrastructure, research and promotion.

- **Co-operate**
  There are several international players in the field of inland navigation. The co-operation between these player needs optimisation. A zero-emission inland shipping sector can only be realised with the co-operation, joint efforts and support of the EU, the combined sector representatives (including ship builders and suppliers), the CCNR and the Danube Commission. The inland shipping sector has given some good examples of their willingness to co-operate by erecting the European Barge Union and the international promotion bureau Inland Navigation Europe. Now it is the turn for the governmental organisations to reach out to their colleagues in order to combine and optimise their efforts and support for inland navigation.
  Both sides, government and industry need to further improve the promotion of inland navigation both in policies and through active PR actions. The public perception and image of inland navigation is still far from optimal.

2 Emission regulations

2.1 Introduction

Of all available instruments, setting emission standards has proven to be the most effective policy measure. In sectors such as industry and transport standardisation of emissions has resulted in a dramatic improvement of the environmental performance of these sectors. This chapter focuses on the regulatory measures that are already in place for the inland navigation sector and on comparable regulations for the other transport modes.

In the following paragraph only the specific policies and regulations are discussed. That means that generic policies are not discussed in detail.
With respect to inland navigation two of these generic policy measures are relevant:

- **The Kyoto protocol**, setting targets for the reduction of greenhouse gasses. For the Netherlands the target for 2020 is a reduction of 6% relative to the situation in 1990. This target stands for all sectors of the economy. A specific target for the transport sector, e.g. a reduction target for inland navigation has however not been set. Inland navigation is responsible for 10% of the CO_2 emission by transport, while carrying about 40% of all cargo in the Netherlands. Inland navigation is therefore not a high priority sector for the reduction of greenhouse gasses.

- **The Nation Emission Ceilings**; the European directive 2001/81/EC, the so-called NEC directive, sets national emission ceilings for pollutants such as NO_X and SO_2.
  Here too only generic targets have been set for all sectors. In this case however inland navigation plays a more important role because the contribution of inland navigation in the emission of substances mentioned in the NEC directive is increasing. A more detailed set of targets for the various modes of transport is therefore desirable.

2.2 Survey of existing national and international regulations

2.2.1 Emissions of greenhouse gasses and CO_2

With respect to the emissions of CO_2 and other greenhouse gasses, there are no explicit regulations for the inland shipping sector. The emission of CO_2 is directly linked to the fuel consumption of a vessel. The specific fuel consumption[1] of ships is very low compared to other modes of transport. Improvements are possible and should be encouraged and supported, but setting specific targets or ceilings for the CO_2 emissions of the inland shipping sector is not a policy priority in the Netherlands.
Compared to the total annual emissions of CO_2 in the Netherlands[2] (180 Mton) the contribution of inland navigation (approx. 3 Mton) is rather insignificant.

[1] Specific fuel consumption: amount of fuel in kg, required to transport 1 tonne of cargo for 1 km; kg/tonkm
[2] In Annex 1 a survey of the exhausts in Hungary for 2002 is given in Tonnes.

Source	CO_2 *(Mton)*
Propulsion	2,2
Cargo heating	0,6
TOTAL Inland Navigation	**2,8**

Source: National Emissions Monitor, 2003

2.2.2 Emissions of Nitrous Oxides (NO_X), Hydrocarbons (HC) and Particulate Matter (PM_{10})

Since 1 January 2002 a first stage emission standard for NO_X, HC and PM_{10} entered into force for inland shipping. The first stage standards (chapter 8a) are part of the Rhine Vessel Inspection Regulations, governed by the Central Committee for the Navigation on the Rhine, and apply to all vessels that travel on the river Rhine and it's natural tributaries from Basel (Ch), via France and Germany to Rotterdam (NL).
The first stage equals a specific emission of approx. 9.2 g/kWh NO_X, 1.3 g/kWh HC and 0.6 g/kWh PM_{10}. The CCNR already agreed on an second stage, to enter into force in 2007, that equals approx. 6 g/kWh NO_X.
The first stage standard is derived from the MARPOL regulations for seagoing vessels, set by the International Maritime Organisation (IMO), and partially from the Directive 97/68/EC.

The CCNR regulations were quickly followed by EU directive 2004/26/EC, that changed the mobile non-road machinery directive 97/68/EC in such a way, that between 1-1-2006 and 1-1-2007, depending on the power levels, all engines for inland shipping and diesel locomotives that are put on the European market have to apply to stage III emission levels. These levels equal approx. 4.5 g/kWh NO_X emissions.
The CCNR and the European Commission have agreed upon mutual recognition of the standards for inland navigation. Furthermore, both parties will co-operate to set standards for stage III (CCNR) and IV (EC), to enter into force around 2012.

Further limitation of the emissions of NO_X, HC and PM10 is a policy priority in the Netherlands, because the relative contribution of inland shipping to the national emissions of these pollutants is increasing (from 10% in 1990 to 15% in 2000). This increase is not caused by an absolute increase of emissions by inland shipping, but a dramatic decrease of emissions by trucking, due to ongoing European regulation.

Source	NO_x *(kton)*	PM_{10} *(kton)*	HC *(kton)*
Propulsion	35	1,8	2,1
Total Inland Navigation	**35**	**1,8**	**2,1**
Total Netherlands	**400**	**40**	**280**

Source: National Emissions Monitor, 2003

2.2.3 Emissions of Sulphur Dioxide (SO_2)

The emissions of sulphur dioxide are directly linked to the levels of sulphur in the fuel (gasoil) that is used in inland shipping. The sulphur levels are regulated by the EU directive 99/32/EC, changing Council Directive 93/12/EEC of 22 March 1993 relating to the sulphur content of gasoil. The directive states, that as off January 1st 2008 the sulphur content of gasoil should be lower than 0,1%. The present sulphur concentration is 0,2 %.

Recent consultation of engine manufacturing industry representatives in the Netherlands has learned, that modern engine design already allows sulphur concentrations as low as 500 ppm (0,05%). Furthermore, it is expected that the engines already in use will also run on gasoil with only 500 ppm sulphur.
Early adaptation of more stringent regulations with respect to sulphur concentrations in gasoil could significantly contribute to a EU-wide decrease of SO_2 emissions by inland navigation by as much as 75%.

Source	**SO_2** ***(kton)***
Propulsion	2,4
Total Inland Navigation	**2,4**
Total Netherlands	**100**

Source: National Emissions Monitor, 2003

2.2.4 Noise

Contrary to other modes of transport, noise from inland shipping is not perceived as a problem by the public. Due to safety regulations a minimum distance is kept between the waterways and the adjoining houses and buildings. These safety distances may be as large as 50 meters. As a result, noise levels around waterways are already low. Furthermore, ships often produce low frequency noise which is perceived differently from high frequency noise from e.g. trains or trucks.
Even though the safety margins are not always respected by local governments, and as a result the number of house built closely to waterways is increasing, still little or no complaints regarding noise emissions from inland vessels are heard.
Chapter 8.08 of the Rhine Vessel Inspection Regulations states that noise levels at 25 meters from the ship should not exceed 75 dB(A) while in motion and 65 dB(A) while loading and unloading.

2.3 Rules and regulations for other modes of transport

Looking at the entire transport sector, inland navigation plays an important role as a mass transporter, that takes care of 30% of all national transport in the Netherlands, and 60% of all international transport from and to the Netherlands. In Western Europe inland navigation is responsible for 10% of all freight transport. This percentage is significantly higher when only the ‘typical’ inland navigation countries are considered. For these countries inland navigation accounts for approx. 30-40% of all freight transport.
So far inland navigation has played a minor role in environmental discussions, because of the relatively low environmental impact and very low fuel consumption. As a result regulatory measures have focussed on the other transport modes, especially road transport. Because of these regulations, the other modes **are now gaining on inland shipping with respect to environmental performance.**
The main emission regulations of the other modes of transport are discussed in this paragraph.

For each mode, only the regulations regarding high priority emissions and prominent environmental issues are discussed. Therefore the structure of the subparagraphs differs from those in paragraph 2.2.

2.3.1 Road Transport

Already in 1970 the EEC started to regulate the emissions of road vehicles with the directive 70/220/EEC for light vehicles and in 1988 for heavy vehicles, directive 88/77EC. These directives have set standards for NO_X, volatile hydrocarbons and carbon monoxide. Stage III of these so-called EURO-standards entered into force in 2000 and equals 5.0 g/kWh NO_X , 0.78 g/kWh HC and 0.16 g/kWh PM_{10}. This stage is followed by EURO-IV in 2005 and EURO-V in 2008, which will finally result in levels as low as 2.0 g/kWh NO_X.

Sulphur Dioxide emissions are controlled via standards for the sulphur content of diesel fuel for road transport. European regulation will lower the sulphur concentration to 50 ppm in 2005 and 10 ppm in 2009. In the following table a survey of these regulations is given.

	NO_X g/kWh	**HC (non-methane)** g/kWh	**HC (methane)** g/kWh	**PM_{10}** g/kWh	**CO** g/kWh
Stage III (2000)	5.0	0.78	1.6	0.16	5.45
Stage IV (2005)	3.5	0.55	1.1	0.03	4.0
Stage V (2008)	2.0	0.55	1.1	0.03	4.0

Noise emissions of road cars (including trucks(are regulated by directive 1970/157/EEC, last revision 99/101/EC. The allowed noise levels are 84 DB (A) for trucks weighing less than 3,5 tonnes and 89 DB (a) for trucks weighing more than 3,5 tonnes.

2.3.2 Short Sea and Deep Sea Shipping

Seagoing vessels have to apply to the Marine Pollution Convention (MARPOL) of 1973/1978. The MARPOL Annex IV regulations for propulsion engines set a standard of approx. 9.2 g/kWh NO_X emissions. These standards do not include the pollutants HC and PM_{10}. The MARPOL act also provides rules for ship waste treatment, storage and disposal.

2.3.3 Rail Transport

As far as electrical traction of freight trains is concerned, there are only indirect emissions of the power plants that supply the electrical power. These emissions are well regulated by national and international industry standards.
Diesel locomotives are regulated by the aforementioned directive 2004/26/EU, starting 2006.

The Dutch government has taken measures to reduce the noise emission of rail cars, both passenger cars and freight cars. These national measures - noise emission ceilings enforced by the Law Modernising Noise reduction instruments - are necessary because there is no European regulation regarding noise emission from rail cars, while 800.000 freight rail cars operate freely in the European Union.
The European Commission is preparing a directive[3] that deals with - among others - technical specifications for interoperability (TSI) of rail cars. Noise emissions from rail cars will be addressed in these TSI's. It is unknown when the directive will enter into force and when noice reduction measures for rail cars will take effect.

The European authorities recently (Mid. 2004) officially launched the ‘Railway Agency’, based in Lille (France) which is responsible for interoperability, safety and a number of other environmental issues mentioned in this paper.

2.3.4 Air freight

National and international policy measures for airborne transport primarily focus on noise pollution. Although the other emissions of airplanes are considerable, these emissions are often not taken into account in policy targets (e.g. Kyoto protocol). This is due to the fact that aircraft and seagoing vessel travel the larger part of a voyage in international airspace and international waters respectively. The emissions of the vessels are therefore not allocated to a member state, so no national measures can be taken. There are however considerable local emission, especially due to take-off exhausts, emissions during air-queuing and sometime also kerosene is dumped in mid-air on approach routes to airfields.

2.3.5 Emissions at terminals and ports

It can be argued that special attention needs to paid to emissions at terminals where e.g. trucking and inland shipping meet. At these location emissions and noise of many vehicles accumulate, especially because here vehicles and vessel manoeuvre or wait with engines running idle, sometime causing very high concentrations of hazardous substances and pollutants.
Many governments however do not regard ports and terminals as environmental issues, because the emissions of the modes that meet in ports or at terminals are themselves already standardised. This position may however change when public resistance against these focal points of pollution increases.

2.4 Comparison between the transport modes

Ever since the European emission regulation started in the seventies, policy makers, environmentalists and representatives of the various modes of transport have compared road, rail and waterborne transport for various reasons. The outcome of these comparisons is never the same and often tends to confirm certain assumptions and biases of the party that orders a research project regarding the differences between the modes.

The last three years the Ministry of Transport in the Netherlands has studied the various methods for comparing transport modes and has also updated the emission monitoring protocols for inland shipping.

[3] Draft directive amending directive 2001/16/EC.

These studies resulted in a model that allows comparison between transport modes for e.g. a certain cargo package. As the project turned out, there are many restrictions when comparing modes. Actually, there are so many variables and influences concerned, that a generic comparison for e.g. policy decisions can not be made. There are more differences within one transport mode then there are differences between the transport modes.
Two recent research projects have proven just this proposition. A study ordered by the Ministry of the Environment, “To Shift or not To Shift, that is the question” tried to prove that inland navigation was no longer a clean mode of transport, so therefore the modal shift policy of the European Commission should be abandoned. In response, the Dutch inland navigation industry[4] ordered a study “Environmental performance of Inland Shipping” by Royal Haskoning that proved, that the primary assumptions of the To Shift or not To Shift-report were faulty. Both studies used the updated emission monitoring protocols, but used very different assumptions and bases for comparison.
In reaction to the abovementioned opposing reports, the ministries of Transport and the Environment agreed not to use these intra-mode comparisons anymore in policy documents. Both ministries agreed that all modes of transport should improve their environmental performance and furthermore, that inland navigation is a mode that can still significantly improve it’s performance.

Given the various European standards described in the paragraphs above, it seems easy to compare the environmental performance by the emission levels of the pollutants in g/kWh. It appears that this unit describes the emission performance independent from the kind of vessel or mode. It however does not take into account the transport effort or transport performance that was made by the vessel. The emission standards in g/kWh only describe the emission performance of the engines.
Looking at these engines, it can be seen that the trucking sector is quickly renewing its machinery, resulting in cleaner engines. Engines used in ships are not only much larger, but also run considerably longer. On average ship engines in Western Europe are 23 years old, whereas trucks engines last between 5 to 10 years. It is anticipated that new engines in ships will probably not last longer than 10 years, because it will become more economical to place a new engine than to repair it.
The conclusion is that the European focus on environmental issues in inland navigation is insufficient.

Pollutant	**Road**	**Short Sea**	**Inland Navigation**	**Rail (1-7-2005)**	**Inland Navigation (1-1-2007)**
Nitrous Oxide (NO_x)	5,0	9,2	9,2	avg. 4,5	avg. 4,5
Hydrocarbons (HC)	0,66	-	1,3		
Particulate Matter (PM_{10})	0,1	-	0,6	avg. 0,35	avg. 0,35

Looking at these emission levels (the Table is constructed on basis of existing rules and regulations) , it may be concluded that inland navigation is currently lagging behind (technically speaking), but will - due to CCNR and EU regulations - catch up with the technical development with respect to engines and emissions.

A European model for – among others - calculating emissions of the transport modes and compare the environmental performance of these modes is being developed at this moment. It is advisable that the developments of the standardisation of emissions, as well as the results

[4] Central Bureau for Rhine and Inland Shipping (CBRB) and Royal Schuttevaer

and lessons learned from the Dutch studies regarding intra-mode comparison are integrated in this European model, TREMOVE.
The same can be advised for other models and studies, e.g. the EU project ‘REALISE’ that deals with Statistics, Environment impacts, and Multi-modal transport pricing and costing comparisons.

Policy measures

- more detailed European targets for emissions of NO_X, SO_2, PM_{10} etc.
- new EU regulation lowering the sulphur content of gasoil
- continue lowering emission standards
- R&D by governments
- Integration of results and lessons learned in the TREMOVE

3 Optimising Ship Design

3.1 Introduction

The environmental performance of ships can be improved significantly by optimising the ship's design. Improvements can be made with respect to the friction resistance of ships in the water, propulsion and the engines used to drive the propulsion line. Another important factor is behaviour. Better voyage planning and improving the environmental awareness of the crew can significantly improve the environmental performance. The possible improvements and the expected effects are discussed in the following paragraphs.

3.2 Resistance

The resistance of ships in the water can be reduced by optimising the hull shape of the vessel. A sharper hull shape will often reduce both the friction resistance as well as the wave making resistance of a body moving through water. So far, barge design focussed on optimising the cargo hold size while maintaining a reasonably economical shape. New design techniques and new light weight materials allow both a large cargo hold and a low friction hull shape. There are currently 3 ships in operation with lightweight hulls and low friction hulls. These vessels run considerably faster than regular ships, while consuming relatively less energy.

A new development in this field is the use of air bubbles to lower friction on the hull-water surface, and also catamaran shaped ships. Catamaran shapes have been used successfully in ship design for seagoing passenger vessels throughout Europe. About 10 smaller catamarans now also operate on passenger lines on the inland waterways in the Netherlands and elsewhere.
The air lubrication technique has been applied to a barge, but the results were unsatisfying as yet. Further testing of this friction reduction option is required.

A new invention that was primarily designed to improve safety proved to have environmental benefits as well: the light-weight Schelde impact hull. The light-weight hull that was especially designed to absorb the energy of an impact by another vessel allows ship designs that are much lighter than the standard tankers, thus lowering the fuel consumption and emission of pollutants. The invention of the Schelde-hull has stimulated other designs of hulls made of composite materials, like for instance a composite 'Peniche' chemical tanker. Plans and designs are being made to construct a small light-weight chemical tanker especially for freight traffic between the Netherlands and the North of France.

A study by the CCNR regarding possibilities for low or zero emission barges predicts that composite materials and light-weight hull will be introduced in inland shipping, especially in special markets such as transport of chemicals. The CCNR is however sceptical with respect to (radical) changes in hull shapes and predicts only minor changes for the benefit of fuel economy.

Predictions for the effects of reducing the resistance of barges have not yet been made. The emission monitoring protocols for inland navigation however show a dependability of more than 50% of the fuel consumption on friction resistance. This implies, that even subtle changes in hull design or hull-water interaction may result in significant reductions.

3.3 Drive mechanisms

Ships are historically propelled through the water using a propeller or screw. A propeller may not be the most efficient way to propel a ship, it has however proven to be the most reliable and robust drive mechanism.
New materials and control mechanisms however allow new designs for drive mechanisms:

- The Whale Tail drive
  This drive mechanism copies the highly efficient stoke of a whale's tail in the water. A horizontally positioned paddle wheel holds several independently operated wing shaped blades that move through the water like a fish tail. The combined actions of the blades produces a very effective thrust, that may be up to 50% more efficient than a regular propeller.
  There are however disadvantages to this mechanism: the current design has proven to be fragile, especially in the harsh conditions of a fast flowing river like the river Rhine. Furthermore, there are significant limitations in manoeuvrability.

- Counter-rotating propellers
  The rotating movement of a propeller in water causes the water to swirl. This swirling water harbours a significant amount of energy, but the swirling motion does not contribute to the forward thrust of the propeller. If a counter-rotating propeller is installed close to the forward propeller, the swirl-energy can be transformed back into thrust-energy. The use of a counter-rotation propeller also allows smaller propeller design, because the combined surface of the two smaller propellers equals the surface of a larger single standard propeller. The smaller size of the counter-rotating propeller gives more flexibility in engine-propeller design and decreases the draught of a barge, thus increasing it's load capacity. Another benefit of the counter-rotating propellers is the low level of noise and vibrations. The overall gain in thrust and propulsion efficiency amounts up to 15%.

- Propeller optimisation
  There are other means to reduce the loss of thrust and energy caused by the swirling action mentioned above. It is e.g. possible to add small fins to the propeller hub, to optimise the flow of water on the propeller blades. The flow of water on the propeller blades may also be improved by strongly curving the tips of the blades. Placing a nozzle shaped ring around the propeller decreases the losses of water moving sideways away from the propeller, thus increasing thrust.
  These measures to optimise the propeller's efficiency can reduce fuel consumption by as much as 15-20%.

- Azimuth thrusters (Z-drive)
  About 95% of all inland vessels have the same standard design of a fixed propeller and rudders. This design may be optimal for traffic on rivers and canals, but it is not so optimal when manoeuvring in ports. Especially when ships move sideways or backwards, the fixed propeller is far from efficient. To counteract this inefficiency, the azimuth thruster was designed. This propeller in mounted on a vertical shaft which allows it to rotate 360° around it's axis, thus being able to deliver maximum thrust in any direction. Especially when equipped with a nozzle ring, these propellers are as efficient as regular propellers. How the increased manoeuvring efficiency influences the fuel consumption is

not yet know. It is known that highly skewed propellers in nozzles perform up to 7 % better than regular propellers.

3.4 Engines

Ever since the invention of the diesel engine, it has been applied in inland vessels. Today, the diesel engine is still the most reliable and fuel efficient primary mover. Various alternatives for the diesel engine have been studied and some are even in production today, but for various reasons they have not been able to end the reign of the diesel engine.
The alternatives themselves will be discussed in the following chapters. The reason why the diesel engine is still the dominant primary mover is the topic of this paragraph.

The typical behaviour if inland vessels largely contributes to the popularity of the diesel engine. Barges move at a relatively constant speed through rivers and canals, for a long period of time. Diesel engines are at their most efficient, when operated at approx. 90% of their maximum load, with little fluctuation in engine speed. Herein lies the strong connection between the two. No other prime mover, neither the fuel cell powered electric engine, nor the petrol (Otto) engine has such a performance optimum that fits so well the typical behaviour of inland vessels.
Furthermore, diesel fuel is cheap, safe and easy to handle aboard a ship. This advantage rules out other engines that e.g. run on natural gas or other gaseous fuels. Taking large quantities of liquefied gas aboard a ship is intrinsically dangerous, apart from the loss of space that otherwise could be use to hold cargo.
Only one alternative might be able to compete with the diesel engine: the all-electric ship. This option will be discussed in chapter 8.

Given the fact that the diesel engine will still play a significant role in the future of inland navigation, it is wise to consider possibilities to optimise both the energy consumption and the emission characteristics of this engines. For some pollutants, this proves a problem.
Ever since the oil crisis in the seventies, engine manufacturers have developed new techniques to further improve fuel efficiency of the diesel engine. A lower fuel consumption also means lower emissions of CO_2 and SO_2. It however does not always mean a reduction of the emissions of NO_X and PM_{10}. As far as NO_X is concerned, there is a counter-productive relationship between fuel consumption and NO_X emissions. A compression-ignition engine such as the diesel engine is most efficient, when it operates at high ignition temperatures and pressures. These are also perfect condition for the formation NO and NO_2. Lowering NO_X emissions by changing the engine parameters alone, will always result in higher fuel consumption. Nowadays, there are add-on techniques to lower NO_X either during combustion or by reducing it end-of-pipe in the exhaust, but apart from these measures, the so called NO_X Paradox will always be a challenge for engine builders.
Recent developments have also introduced such a paradox for particulate matter (PM_{10}). The introduction of new fuel injection system, such as the well known 'common rail', has led to an increase in emissions of very small particles, even smaller than 10 microns. These even smaller particles are more dangerous to human health than their larger predecessors.

Ongoing standardisation of emissions will ultimately drive engine manufacturers into the arms of manufacturers of in-process reduction techniques or end-of-pipe reduction systems. These systems will be discussed in the following chapters.

3.5 Behaviour and awareness

The most important variable in the equation of the environmental performance of inland navigation is still the human being that controls the vessel and especially the throttle of the engines. Especially in inland shipping there is an interesting relationship between speed and fuel consumption. It is obvious, that the fuel consumption increases with the speed of the vessel through the water, because the resistance increases (rapidly). Both engine and propellers however are designed to operate at their optimum when the ship cruises at 80-90% of the maximum speeds and engine power. Lower speeds mean lower fuel consumption but not necessarily optimal performance of engine and propellers.
There is a certain balance point between the two factors, and this point changes constantly as the vessels moves through different waters with different water depths and draughts.
Most bargemen adapt their behaviour accordingly, often based on years of experience with those waters. Experience also comes into play when planning a voyage. Many bargemen can precisely indicate how long a voyage from point A to B will take.
However, optimising the combination of voyage planning, local influences of the waterway and speed is very difficult and almost an impossible task for a human being.

There are however computers that can perform this difficult task. The Ministry of Transport in the Netherlands has sponsored and aided in the development of a computer system that advises the bargemen about the optimal speed and setting of the throttle regulators.
The results of this pilot project are promising: about 10-15% of fuel is saved when the instructions of the system are followed. Such a percentage is not only interesting from an economic point of view, but also from an environmental viewpoint. Less fuel consumption means less CO_2, NO_X, SO_2 and PM_{10}. A wider implementation of such systems is therefore highly advisable.

Policy measures

- state-aid for R&D and demonstrators in field of hull design, friction resistance etc.
- education and raising environmental awareness among barge operators
- assistance and possible funding of the introduction of voyage optimisation software and systems

4 Reducing NO_X

4.1 Introduction

Nitrous oxides are pollutants that effect both the environment and human health. In the environment, NO_X attributes largely to acidification of the soil, thus causing damage to trees, plant life etc. Nitrous oxides also cause respiratory diseases in the lunges of humans and animals. Together with PM_{10}, NO_X is responsible for 3000 cases of premature death in the Netherlands every year. Reducing NO_X, from any possible source is a high priority.

There are basically two methods for reducing NO_X emissions from ship engines:
1. Prevent it from forming during combustion, and;
2. Take it out of the exhaust gas.

The first option sounds easier than it really is. All engines use air as a supply of oxygen for combustion. Air contains 80% nitrogen. Under pressure and high temperatures it reacts with oxygen to form NO or NO_2. High pressures and temperatures are always present in diesel engines, so it takes some special measures to prevent NO_X from forming, while maintaining the working principles of an engine.

Taking NO_X out of the exhaust gas is also difficult. Every modern car has a catalytic converter that changes the dangerous NO_X into harmless nitrogen. This type of catalytic converter can however not be used with diesel engines, because diesel exhaust has a different composition that prevents the common 'oxycat' from doing it's work.

4.2 In-process measures

The following techniques prevent the formation of NO_X during combustion:

- <u>Engine Management</u>
  State of the art diesel engines are controlled by a computer that monitors and adjust the engine parameters and settings. This electronic control allows precision injection of fuel, valve timing, ignition timing etc. By this, the ignition and combustion parameters, pressures and temperatures can be adjusted in such a way that the engine still produces enough power, while lowering pressure and temperature to avoid the formation of NO_X. This is generally done by retarding the combustion timing. The reduction that can be achieved by this is not endless. About 25% of the NO_X emissions can be reduced by engine management.

- <u>Exhaust Gas Recirculation</u>
  A Exhaust Gas Recirculation (EGR) system reduces NO_X formation by recirculating small amounts of exhaust gases into the air intake. These gasses replace some of the air that goes into the combustion process. By doing so, the concentration of oxygen is lowered, which results in a combustion with lower pressure and temperature and less NO_X formation. There is however a downside to this: if the oxygen levels are lowered, the engine will run less efficient. A benefit of EGR over retarding the ignition timing of the

engine is that the ignition can still take place at the most effective moment, while still lowering combustion pressure and temperature.
About 20-30% reduction of NO_X can be achieved with EGR.

- Water injection
  Another way of reducing NO_X is the introduction of water into the combustion process. With this technique neither the ignition timing nor the oxygen concentration is affected, but the ambient conditions in the engine just before the ignition point and during combustion are altered. By jetting very small droplets of water into the cylinder - either by direct injection or by injection of a water-fuel mixture though the regular fuel injectors - the combustion pressure and temperature remain lower, because a portion of the combustion energy is used to evaporate the water droplets. It is also possible to jet water droplets into the cylinder while compression is still taking place. The quick evaporation or flash evaporation that occurs in this situation lowers the temperature and also makes it easier for the piston to compress the air. As a result, not only NO_X is reduced, but the engine performance also increases.

  It needs no further explanation, that there are significant risks to the introduction of water directly into an engine. If the system does not work perfectly, engine damage may occur. Overall, the reduction of NO_X that can be achieved by water injection is 15-20%.

4.3 End of pipe techniques

At present, there are two techniques to reduce NO_X when it is already in the exhaust pipe. Both the SCR and Plasma Catalytic Converter work by changing NO_X chemically into less dangerous nitrogen and CO_2.

- Selective Catalytic Reduction (SCR)
  In a SCR catalytic converter, the NO_X molecules are ripped apart and turned into nitrogen and CO_2. To do so, two ingredients are required: a catalytic material, on which the chemical reaction takes place and a chemical agent, in most cases urea. When properly dimensioned, a SCR catalytic converter can reduce NO_X by 90-95%. There are two disadvantages:
  1. the process consumes urea, and;
  2. when the dosage of urea is incorrect, another dangerous substance, ammonia, is formed.

  The second problem, the so-called ammonia slip, has been solved by introducing an adaptive control system that injects the right amount of urea at the right time. Only the urea consumption remains as a disadvantage of this system. Although urea is a very common product (industrial fertiliser) that is not very expensive, still it introduces extra operational costs and problems with distribution, because it is not yet a common 'consumable' for inland vessels.

- Plasma Catalytic Converter
  A new technique that is still under development is the plasma catalytic converter. This catalytic converter uses high voltage electricity to transform NO_X and hydrocarbons into nitrogen, water and CO_2. The huge advantage of this system is, that it reduces both NO_X and PM_{10} and uses no reduction agent like the SCR does. Disadvantage at this moment is, that it is only a lab scale set up. An operational version that is able to purify the exhaust

flow of an average 1000 kW inland shipping engine does not yet exist.

It is uncertain whether the operation parameters, such as consumption of electrical energy, will be suitable for operation in inland vessels.
The reduction potential of this technique is 90% for NO_X and PM_{10}.

Policy measures

- state-aid for introduction of catalytic converters
- state-aid for model testing and pilot for the plasma catalytic converter

5 Reducing SO_2

5.1 Introduction

Sulphur dioxide is a strong acidifying pollutant that is responsible for the destruction of forests, plant life and also the acid erosion of precious buildings and monuments.
SO_2 originates from the organic sulphur that is present in crude oil and therefore also present in gasoil.
For passenger cars and trucks, low-sulphur diesel fuel is already available and will be obligatory in the next few years. Gasoil (chemically nearly identical to diesel) still contains a significant amount of sulphur, approx. 0,2 %.

5.2 Lowering sulphur levels in gas oil

According to some, it is absolutely impossible to lower the sulphur levels in gasoil any further. Inherent damage to the engine is feared, because sulphur functions in gas oil as a lubricant. Engine manufacturers and the petrochemical industry differ in opinion. According to the leading manufacturer of diesel engines that are used in the Dutch fleet, it is possible to lower the sulphur concentration to 500 ppm, without problems, neither for the new engines, nor for the engines that are already in use in the fleet. In addition, a large manufacturer of gasoil confirms, that the sulphur may be replaced by other lubricants that have little or no negative effects on the environment, at very little costs[5].
The European directive 99/32/EC will reduce the sulphur concentration of gas oil in 2008 to a level of 1000 ppm. It is possible to already lower it to 500 ppm on short notice. It is advisable that the European Commission takes additional measure to do so, because a reduction 75% of the SO2 emissions by inland navigation may thus be achieved with little of no disadvantages neither technical nor financial for the inland navigation sector.

Policy measures

- additional regulation by the European Commission lowering the sulphur content of gasoil

[5] Shell Refineries Netherlands indicates approx 2% raise of market prices for low-sulphur gasoil.

6 Reducing PM_{10}

6.1 Introduction

Particulate matter, also called particulates or fine sooth is a pollutant that seriously damages human health. The mostly carbon particles are so small that they remain suspended in air and are inhaled by humans. The particles contain not only carbon, but al kinds of hydrocarbons, acids and other harmful substances. These harmful substances accumulate in the lungs and seriously raise the risk of cancer. Furthermore, these substances cause respiratory syndromes such as bronchitis and asthma.
Particulate matter is typically formed in diesel engines. Their formation is mainly affected by the injection of diesel fuel into the engine.

Emission standards have been set for PM_{10}. That is all particulate matter with a diameter of 10 microns or less. Due to these standards, engine manufacturers have altered their injection systems. As a result, even smaller particles are now formed. Because they are smaller and lighter, the overall mass of PM_{10} is lower. However, as it turns out, these smaller particles are even more dangerous to human health, because they can penetrate the lungs even deeper.
It is therefore crucial, that the emissions standards are refined to also limit the emissions of PM_5, $PM_{2,5}$ and even particle as small as PM_1 or $PM_{0,1}$.
Luckily, techniques for reducing PM_{10} are being developed at this moment. One technique, the plasma catalytic converter, has already been discussed in paragraph 4.3. The other technique is the Steam Jet Aerosol Collector or SJAC.

6.2 Steam Jet Aerosol Collector (SJAC)

The SJAC technology uses steam to capture the small particulate matter. By injecting steam into the exhaust gasses the small particles are captured in the water droplets that condensate in the exhaust gas stream. These droplets are significantly larger than the captured particles and are easily separated from the exhaust gasses.

The Dutch Energy Centre (ECN) has developed a SJAC system that can be applied aboard inland vessels. At present the scale of the system is suitable for a small engine of 15 kW. A SJAC for a >500 kW engine is under development and will be available in 2006.

The SJAC technology is very effective in reducing not only the larger particles in the PM_{10} range, but also the smaller particles, even PM_1 and $PM_{0,1}$. With an efficiency of 90% the SJAC technology is a very promising development in reducing the PM_{10} emissions of inland navigation.

Policy measures

- refining emission standards for PM_5, $PM_{2,5}$, PM_1 and $PM_{0,1}$
- state aid for R&D and introduction of SJAC and other filtering techniques

7 Alternative fuels

7.1 Introduction

Ever since the oil crisis in the seventies, the automotive industry and transport industry have been searching for alternative sources of energy and fuel. The main drive for this quest was the dependability on oil and gas. Nowadays, the search for alternative fuels is also driven by environmental arguments. Some of these alternatives allow nearly zero-emission propulsion or the use of very sustainable energy sources.
The alternative fuels can be divided into two groups: the carbon based fuels and the non-carbon fuels.

7.2 Carbon based alternative fuels

Although carbon based alternative fuels can also be used to power fuel cells, their primary purposed will be to replace gas oil in an internal combustion engine. The following fuels can be considered

- Natural gas and other gaseous carbon based fuels
  Natural gas and other gaseous fuels are being used more and more in semi-industrial and industrial environments. Busses that run on methane or LPG are very common these days and many industrial generators are powered by gas engines.
  The advantages are the low NO_X output, approx 1,5 g/kWh, and nearly no emissions of PM_{10}. A disadvantage however is the large amounts of liquefied gas that mobile installations need to carry. An average 1000 kW engine would require several tonnes of liquefied gas to make a regular round trip from Rotterdam to Karlsruhe. Such an amount of compressed gas not only takes up a large amount of space, but also brings safety risks, especially in case of collisions. Engines powered by natural gas instead of diesel fuel may be an intermediate option for some waterborne applications. Widespread application in the entire inland navigation sector is not very probable.

- Bio fuel and other liquid carbon based fuels
  Bio fuel is derived from other sources than petroleum. Often Cole seed is used to produce an oil-like fuel, whereas other bio mass can be used to produce gaseous fuel or electricity. Bio fuel have a considerable advantage over petrol based fuel because the so-called CO_2 balance is not affected when these fuels are burned. About the same amount of CO_2 that is formed when burning these fuels also went into the fuel because it is derived from organic material that absorbs CO_2 in order to grow. These are however some downsides:
  - it takes a considerable amount of energy and land to grow, create and distribute biofuels;
  - when burned, e.g. in a diesel engine, still NO_X and PM_{10} are formed;
  - there is not enough bio fuel to power the entire transport industry.
  Despite these disadvantages, bio fuel is still an interesting option to further reduce the emissions of CO_2, although CO_2 is not a high priority problem for the inland navigation sector.

  In recent years there have been experiments with other carbon based liquid fuels to replace diesel. One of these was Di-Methyl Ether or DME. In it's natural form, DME is a gas, but mixed with regular diesel, the mix behaves like a liquid. Having nearly the same burning characteristics as gas oil, but considerably less formation of PM_{10}, DME looked promising as a replacement for diesel or gas oil.

However, the costs of producing DME were considerably higher than the production costs of gas oil and other problems arose, such as loss of viscosity of the fuel mix etc. Experiments are still running, but for the moment DME is not a high priority development area.

7.3 Non-carbon alternative fuels

Apart from one possible other application of hydrogen, the field of non-carbon fuels revolves around the fuel cell. A fuel cell transforms fuel directly into electrical energy while producing only water or another harmless substances. The electricity can be used to power electric motors that propel ships, cars, tucks etc. The most commonly known fuel for use in fuel cells is hydrogen. Hydrogen is expected to become the future's primary energy carrier. Some people already speak of the future hydrogen economy. There are however some disadvantages to hydrogen, one of which is the fact that it is highly flammable and combustible. Another problem is, that it is a gas that is very difficult to compress, unlike e.g. LPG. Research into the field of hydrogen bearing substances and other means of safely and compactly transporting hydrogen is taking place at this moment.
The advantages are obvious. Hydrogen is 'as clean as it gets' when used as fuel to power fuel cells. Hydrogen can be produced by 'splitting' water molecules by means of electricity or by treating natural gas. Whichever method is used, even if it is produced with electricity from coal burning power plants, it still is a lot cleaner than any other fuel.
Recent developments in fuel cell design and research have resulted in fuel cells that might already be powerful enough to operate in ships. Furthermore, the fuel that these cell stacks use is not necessarily hydrogen. Depending on the type of cell, these can also be powered by e.g. urea or ammonia. If fuel cells could indeed operate on urea and the size of the fuel cell stack would be suitable for a barge, it would mean a breakthrough in developing a zero emission ship for use in inland navigation.
Despite the possibly huge environmental gains, projects to actually build a fuel cell powered barge have not been undertaken due to very high costs. A prototype would cost as much as € 15-20 million, whereas a regular barge costs € 3-4 million. Private parties are not (yet) willing to commit to such a project.
Perhaps an intermediate form of fuel cell application may be attempted. Fuel cells can also be powered by regular carbon based fuels by means of a reformer. Although this process is less efficient compared to the use of pure hydrogen or other substances such as urea, it still has significant advantages for the environment, one of which being that during the reforming stage, only water and CO_2 are produced, no NO_X. The reformer can operate on regular gas oil, so no change of fuel is required.
A barge powered by fuel cells with reformer would not only be cleaner than a regular barge, but also much more quiet. This benefits not only the environment, but the crew as well. Serious plans to build such a barge have not yet been made.
At present, state aid seems to be the only option to create leverage in the development of a fuel cell powered barge.

Policy measures

- state aid for R&D and introduction of fuel cell powered barges

8 All Electric Ship

8.1 Introduction

The concept of the All Electric Ship or AES is simple: use electric motors and other electrically powered systems throughout the ship and supply the electric power from one point, using one or more generators. This concept has many advantages over the use of direct drive by diesel engines. The introduction of AES is an indispensable stepping stne on the introduction of fuel cells and from this point of view extremely important. However it proves to be hard to determine and quantify the advantages of AES compared to conventional installations. These calculations are of the utmost importance to persuade the entrepreneurs involved to invest in AES. In the Netherlands a working group is active on these aspects of AES. They expect to report at the middle of 2005.

8.2 Aspects of the AES concept

8.2.1 Harmonisation of equipment and power sources

At first, the question arises whether the use of direct power transfer from diesel engines to e.g. the propellers would be more efficient. Considering the fact that many ships have several electric systems already aboard, such as pumps, winch motors and also rudder control (electro-hydraulic), navigational equipment, computers etc., it becomes more obvious to harmonize the power systems aboard. When the average load and typical peak loads of some of the combustion engines are considered, especially engines that drive equipment that is only used for a small period of time, such as bow thrusters or anchor winches, it seems all the more obvious to switch from direct drive to electric drive with central generators.

8.2.2 Integration of other electrical power sources

There are more benefits to the AES concept: other sources of electrical energy can be integrated into the power grid, e.g. solar cells, wind energy (not during regular operation, but during stops in ports) and of course electric power from fuel cells. So far, the large surface of a regular barge with a covered cargo hold of approx. 1000 m^2 is not used to produce electricity by means of solar panels. Considering the fact that solar energy harbours 1 kW/m^2 and new solar panels are reaching efficiency levels of 30%, it is interesting to consider the possibility of integrating solar energy into the AES concept for barges, despite the high costs of solar panels. Special attention need to be paid to the fragility of solar panels: during the loading and unloading of the ship it is not uncommon that a crane spills 5-10 tons of e.g. rocks or steel rods, which will inevitably result in damage to solar panels.

8.2.3 No unnecessary emissions

Although barges operate on a 24 hour basis these day, there are still many ships that stop at night and/or wait for several days for the next cargo to be loaded. During these waiting hours, almost all of the ships use diesel powered generators that run at very low loads, close to idle,

to supply electrical energy for household purposes. If these ships were to use batteries and/or solar energy, a considerable amount of unnecessary air pollution would be avoided.
In fact, many more unnecessary emission during regular operation could be avoided too, because regular non-AES ships also use these generators while cruising, for little more than household purposes. Only a very small number of ships use a drive shaft generator that takes it's power from the main engines. All other ships have diesel generators running idle most of the day.

8.2.4 Efficiency

A very important aspect of the AES concept is energy efficiency. It is generally know, that every power coupling and every power transformation loses energy.
Generating electrical energy and using electric motors to propel a ship is less efficient than direct propulsion via a propeller shaft connected to the engine (via a gearbox). However, this in only true under optimal conditions at 90% of the maximum power output. Especially when ships are moving at lower speeds and with changing engine loads, the electrical alternative becomes more efficient. Furthermore, one needs to realise that power and efficiency are also lost in the gearbox of a direct drive system consisting of engine, gearbox and propeller shaft. Electric motors do not need such a gear box and can also rotate both clockwise and counter clockwise, whereas 90% of all diesel engines need a gearbox to do that. Furthermore, electric motors can be applied with much more flexibility that fixed engine - propeller shaft combinations.

All together, the benefits of the AES concept are larger than the loss of efficiency. According to the AES Platform, a co-operation between Dutch ship builders, suppliers and ship owners that promote the application of AES concepts, an All Electric Ship is about 10% more fuel efficient and emits 15-20% less pollutants.

8.2.5 Costs

Despite all the benefits of the AES concept, still no inland AES vessels have been built. The main reason for this is the aspect of costs. The AES concept requires a considerable investments in both diesel generators and electric motors and systems. The costs are considerably higher than those of conventional propulsion and power systems. Although technological advancements are lowering the price of the required AES components, still an All Electric Ship costs about twice as much compared to a regular ship.
Even though the higher efficiency of the AES system and the flexibility in ship design will recover these investments, still many entrepreneurs are scared off by the high initial costs. Therefore, state funding may be necessary to set up the first inland AES and to take away preconceptions and bias towards the AES concept.

Policy measures

- support and possibly fund publicity campaigns for AES
- state aid for the wider introduction of AES in inland navigation

9 Waste and discharges to water

9.1 Introduction

Compared to other modes of transport, the shipping sector - inland as well as sea shipping - has a unique problem: cargo waste. Because almost all bulk goods are transported by barge or seagoing vessel, almost all the problems related to cargo residues and cargo waste are concentrated in the shipping branch.
Also unique is the fact that ships interact with tree compartments: air, land and especially water. Operational and accidental discharges of various substances to water are an environmental issue. Being in and moving through water also creates another waste problem: contaminated water in the cargo hold and the engine room. Finally, there is the issue of contaminated ballast water. The major problems and solutions regarding waste and discharges to water are discussed in the following paragraphs.

9.2 Engine room waste, sludge and coolants

Due to the scale of their engines inland vessels create considerable amounts of waste from lubricants, coolants, grease etc. As far as these substances are contained in e.g. the engine, they can be transferred to a sludge tank (oil) or separate containers (grease and coolants). There are however also leakages of oil, coolants and grease. These substances accumulate beneath the engine room floor and engine foundation and in the space adjacent to double bottom and hull, the so-called bilge. Especially coolants (often containing di-ethylene glycol) may seriously contaminate the bilge when leaking from the engine's heat exchangers. Coolant water has a very high (bio)-chemical oxygen demand, is therefore very dangerous to the aquatic environment and is also expensive to treat. In the bilge space also water leaks into the ship via the propeller shaft bearings and seals. Although modern propeller shaft seals are completely water tight, about 70% of all motorized inland vessels in Western Europe still have seals that may leak water into the bilge. The mixture of water, oil and grease is called bilge water and constitutes the bulk of all engine room waste flow.

Along the river Rhine, in the Netherlands, Germany, France and Switzerland there are waste disposal facilities that collect the bilge water and other waste from inland shipping. About 70.000 tonnes of bilge water is collected by these facilities every year, along with 7.000 tonnes of sludge (oil) and approx. 4.000 tonnes of grease, rags, filters and engine coolants.

In 1996 the major inland shipping countries in Europe, Belgium, Germany, France, Luxemburg, the Netherlands and Switzerland signed the international Convention on the Collection, Disposal and Reception of waste from Rhine and Inland Shipping. This convention provides rules and guidelines for handling and treating waste from inland navigation and also regulates the distribution of costs between involved parties. This means, that each ship will have to pay (indirectly) a waste disposal fee for the waste reception facilities, while the cargo owners will have to pay the costs of cleaning the ship from cargo residues and cargo waste.

The international waste convention will enter into force once all member states have ratified and implemented the convention into their national legislation. So far Switzerland, Luxemburg, the Netherlands and Germany have done so.
Because the implementation of the international waste convention still - after 8 years - takes considerable time, and can easily be brought to a halt by just one of the participating countries, it is necessary to study alternative regulatory frameworks such as an EC-directive. Germany, Switzerland and the Netherlands have agreed to undertake such a study.

In the Danube countries the awareness for necessary regulations and further actions related to an environmentally sound collection and disposal of ship waste also exist.

For example, legislative regulations have been established in Austria and recommendations have been passed by the Danube Commission. Furthermore the implementation of an EU compliant and regionally co-ordinated waste disposal system for the Danube is seen as an important issue.

9.3 Cargo residues, cargo waste and ballast water

When bulk goods are unloaded, a portion of the cargo stays behind in the cargo hold. By scooping, sweeping and vacuuming (dry bulk) or pumping and 'stripping' (liquid bulk) these cargo residues are removed.
Depending on the type of cargo that is transported next, these techniques are not effective enough to clean the hold or tank in such a way that new product may be loaded without contaminating this new cargo. In such a case the hold or tank needs to be washed. Naturally this creates a considerable amount of waste water. There are several waste reception facilities in the major ports along the main waterways where this waste water can be treated. In some cases however the ship operator chooses to illegally dump this waste water. This may cause severe water pollution. The Dutch authority for the monitoring of surface water quality (RIZA) reports an annual discharge of approx. 1.700 tonnes of mineral oil into the surface waters due to illegal waste and bilge water discharges by inland shipping.
In the Netherlands and most other European countries it is forbidden by law to discharge any waste in the water. In the Netherlands, this prohibition is written down in the Surface Water Pollution act. This act will be changed as soon as the international waste for inland navigation enters into force, because this treaty introduces a new set of rules for waste water treatment. Some substances are totally harmless to the water environment. According to the treaty the washings from these substances may indeed be discharged into the surface waters. A special annex to the treaty describes the way waste water and cargo residues should be treated and/or discharged either in the surface waters or the sewage system.
A different type of waste, that is also cargo related, is ballast water. Sometimes barges take in ballast water for example to be able to pass under low bridges. Depending on the presence and capacity of the ballast tanks, the cargo hold is sometimes used to store ballast. This phenomena especially occurs in Germany when ships return from the German Canals without cargo. If the hold was clean before taking in the ballast water, one is allowed to discharge this water into the surface waters. When the ballast water is however polluted by cargo residues, a considerable amount of light contaminated waste water is produced. Annually the Dutch waste reception facilities collect about 50.000 tonnes of ballast water.

The network of waste reception facilities in ports and on the river banks is effective and efficient. When the international waste convention inland navigation enters into force, the policy framework concerning ship waste is also adequate.

Enforcement and co-ordination of the international waste convention inland navigation
When the international waste convention inland navigation enters into force, a system of rules and regulations will have to be enforced. The participating member states agreed to the following:

- regulations are enforced by national authorities;
- each member state will facilitate and fund a co-ordinating 'national institute' (NI);
- an international Conference of treaty parties (CTP) will co-ordinate operational and organisational issues, and;

- a separate international equalisation and co-ordination body will co-ordinate the equal distribution of finances between the treaty parties.

9.4 Discharge of gasses and vapours

A large part of all liquid bulk that is transported by inland navigation consists of volatile fuels and chemicals. When these substances are unloaded a large amount of vapour - up to 3 tonnes in an average total tank volume of 2.000 m^3 - stays behind in the tanks. Unless the next cargo is compatible with this product, the vapours need to be purged from the tanks. This is normally done by ventilating the tank with outside air. This situation in undesirable from both a safety and environmental viewpoint, because during the process of ventilating a highly explosive air-fuel mixture is formed and furthermore a large amount of environmentally dangerous substance is discharged in the atmosphere.
The Dutch and German governments have set up regulations that prohibited the discharge of vapours from gasoline and petroleum products alike, to enter into force by 1-1-2006. This reduces the emission of approx. 70% of all volatile substances that are transported by barge. Further regulation is however required, especially with respect to highly toxic of carcinogenic substances. These substances are still being discharged into the atmosphere.

9.5 Operational discharges to water

Operational discharges of substances to water by barges are caused by regular wear and tear of the coated outer hull and the lubrication of the propeller and rudder shaft seals. The two relevant substances are 'grease' and 'anti fouling'.

9.5.1 Grease

Almost all rudder shaft seals and many propeller shaft seals are lubricated with grease. Although environmentally friendly and safe lubricants that have a high level of biodegradability are already on the market, still 95% of all these seals is filled with petrol based grease that often has a high concentration of mineral salts (potassium, sodium) and also heavy metals such as zinc and lead.
Depending on the type and condition of the shaft seals, an average amount of 0,5 - 1 kg per ship per day is discharged into the water. This means that in the Netherlands alone no less than 1.000 tonnes of grease is discharged every year. The Dutch authority for the monitoring of surface water quality (RIZA) estimates that approx. 300 tonnes of mineral oil is discharged to water due to these losses of lubricants, along with 6 tonnes of heavy metals and 18 tonnes of aromatic substances such as benzene and toluene. There is no regulation that forces ships to use a more environmentally friendly type of lubricant. **Such a measure is highly advisable**.

9.5.2 Anti fouling and PAH

Despite regulation that prohibits the use of environmentally dangerous anti fouling coating in the Netherlands, still 60% of the inland navigation fleet uses coal tar to coat the outer surface of the ship. This coal tar contains so-called Polycyclic Aromatic Hydrocarbons or PAH's. These substances are dangerous to the aquatic environment but also to human health, because these substances are toxic, often carcinogenic and persistent[6] but certainly bio-accumulative,

[6] Persistent substances are not easily broken down by chemical processes or bacteria. Therefore these substances remain dangerous to the environment and animal and human health for a long time.

which means that animals and humans store these substances in the body. On the top of the food chain human take in all the accumulated PAH's that cause genetic mutation and cancer.

In Germany and Belgium there is no prohibition to sell, store or use coal tar. Such a policy measure, a European prohibition of the use of coal tar an other PAH based anti fouling coatings, is highly advisable.

Policy measures

- implementation of the international waste convention inland navigation or an European alternative
- obligation for the use of environmentally friendly lubricants in shaft seals
- prohibition of the use of coal tar and other coatings containing PAH's

10 Conclusions and recommendations

10.1 Introduction

In the preceding chapters existing regulation, new developments and possible technical solutions have been discussed. This final chapter will combine these findings in three paragraphs: development in regulations, required policy measures and recommendations on future requirements.

10.2 Development in regulations

Emissions to air
With the publication of the directive 2004/26/EC the European Union has taken an important step in regulating and improving the environmental performance of inland navigation. With this directive also came a technical co-operation between the EC and the CCNR. If this fruitful co-operation is maintained, the inland navigation will certainly catch up from it's present arrears in environmental regulations. There are however some difficult problems to be solved. First of all, both parties have to think of a way to enhance the environmental performance of the existing fleet. The ongoing standardisation of emissions will only effect new engines, while the engines already in use last very long.
A joint German-Dutch study has already shown, that enforcing standards for these existing engines is very difficult if not impossible. It seems, that end-of-pipe measure, as discussed in chapter 4 might provide a solution for this problem, however enforcing the introduction of these measures by regulation will probably not work. Techniques like the SCR and plasma catalytic converter are still too expensive to allow a widespread implementation. State aid or even better: a European aid programme is more likely to succeed.

Waste
The international waste convention inland navigation will be an effective and efficient policy measure to solve several problems (environmental and financial) concerning ship waste. However, the convention has not yet entered into force. Although France has recently announced that it is now ready to implement the convention, it may still take several more years before all parties involved are ready with the implementation.
Meanwhile the European Union has successfully implemented a very similar policy measure for seagoing vessels. Following the example of the co-operation in the field of emission regulation, it might be wise for the CCNR, the Danube Commission and the EU to consider a comparable European solution to the waste management problems, especially now that the Union has welcomed new member states that do have inland navigation, but are not part of the international waste convention.

Emissions to water
Co-operation between the CCNR, the inland shipping sector and the EU is certainly crucial when it comes to emissions to water. The implementation of the Water Framework Directive will have a very significant influence on inland navigation, while inland navigation plays an important role in water quality issues in the EU.

Extra attention needs to paid to the issue of the economical impact and interests of inland navigation versus the ecological impact. Inland navigation is only one of the many parties in light of the Water Framework Directive. It is not always recognised that this 'minor' role in term of water use is linked to a very important role in the European transport system.
A perfectly sound policy measure from a viewpoint of water quality improvement might thus have a serious effect on the transport economy and also on the overall ecology, for still inland navigation is a clean and safe partner in the transport network.

10.3 Required policy measures

At the end of every chapter a policy measure block has already indicated possible and required measures. In this paragraph these measures are grouped by type.
Basically these are three types of policy measures are suggested in this paper:

1. **Regulation**, aimed at enforcing new standards and lowering environmental impact. Sometime regulation also forces a new technical development of conceptual breakthrough.
2. **State aid** or otherwise funding of improvements that are difficult to enforce by law. These improvements are often experimental techniques and systems that are too expensive too demand autonomous adaptation by the market. As state aid is bound by limits, European aid programmes are necessary when such a technique needs to implemented on a large scale
3. **Education**, aimed at increasing the environmental awareness of ship owners. This may be in the form of publicity programmes, either by governments or private parties, but also by means of software, web sites etc. that provide information on certain themes.

10.3.1 Regulation

- Ongoing standardisation of emissions to air
- More detailed European targets for emissions of NO_X, SO_2, PM_{10} by inland navigation
- Additional regulation by the European Commission lowering the sulphur content of gasoil
- Refining emission standards for PM_5, $PM_{2,5}$, PM_1 and $PM_{0,1}$
- Implementation of the international waste convention for inland navigation or European alternative
- Obligation for the use of environmentally friendly lubricants in shaft seals
- Prohibition of the use of coal tar and other coatings containing PAH's

10.3.2 State-aid or European funding

- State-aid for R&D and demonstrators regarding hull design, friction resistance etc.
- assistance and possible funding of the introduction of voyage optimisation software and systems
- state-aid for introduction of catalytic converters
- state aid for R&D and introduction of SJAC and other filtering techniques
- state aid for R&D and introduction of fuel cell powered barges
- state aid for the wider introduction of AES in inland navigation

10.3.3 Promotion and Education

- Support and possibly fund publicity campaigns for AES
- Integration of results and lessons learned in the TREMOVE
- Education and raising environmental awareness among barge operators concerning fuel consumption

10.4 Recommendations for future requirements

When looking at inland navigation in the future, it's role in the transport system and it's contribution to a sustainable of Europe, the following recommendations are in place:

- **Use the reduction potential of inland navigation**
  Given the present environmental performance of the inland shipping sector and possible improvements, a lot can be gained already at relatively low costs. In order to achieve this, specific targets have to be set on a European level and money needs to be invested. Standardisation of emission may result in a reduction of 50%-70% of the emissions of NO_X and PM_{10}, about 75% of the SO_2 emissions and approx. 25-30% of the CO_2 emissions. The timeframe for these reductions is 10-15 years. The larger part of these reductions and improvements will take place with little or no extra investments. However the so-called ‘early adapters’, that quickly embrace new technologies and regulations need financial aid. For the entire inland shipping sector in Western Europe an amount of € 150 million will suffice to initiate and support the required pilots, R&D programmes and demonstrators.

- **Pave the way for the fuel cell**
  If there is any transport mode that can already benefit from the huge environmental benefits of the fuel cell, it's inland navigation. There are however several problems to solve, regarding safety, availability of fuel for fuel cells, huge costs of current prototypes etc. Without the combined effort of the inland shipping sector, the CCNR and the European Union, these problems will not be solved. Furthermore a substantial investment of approx. € 75-100 million is required to not only build fuel cell powered ships, but also to facilitate the required infrastructure, research and promotion.

- **Co-operate**
  There are several international players in the field of inland navigation. The co-operation between these player needs optimisation. A zero-emission inland shipping sector can only be realised with the co-operation, joint efforts and support of the EU, the combined sector representatives (including ship builders and suppliers), the CCNR and the Danube Commission. The inland shipping sector has given some good examples of their willingness to co-operate by erecting the European Barge Union and the international promotion bureau Inland Navigation Europe. Now it is the turn for the governmental organisations to reach out to their colleagues in order to combine and optimise their efforts and support for inland navigation.
  Both sides, government and industry need to further improve the promotion of inland navigation both in policies and through active PR actions. The public perception and image of inland navigation is still far from optimal.

ANNEX 1: Survey of exhausts of Hungary, 2002

		Emissions transport Hungary 2002					
			(in Tons)				
		CO	**CH**	**NO2**	**SO2**	**PM**	**CO2**
passengers transport		409.634	56.148	102.076	1.078	20.438	10.420.163
road transport		851	278	3.893	250	34	180.200
rail transport		128	93	259	23	10	72.308
Inland navigation		3.239	2.267	9.421	259	703	542.210
Total		413.852	58.786	115.649	1.610	21.185	11.214.881