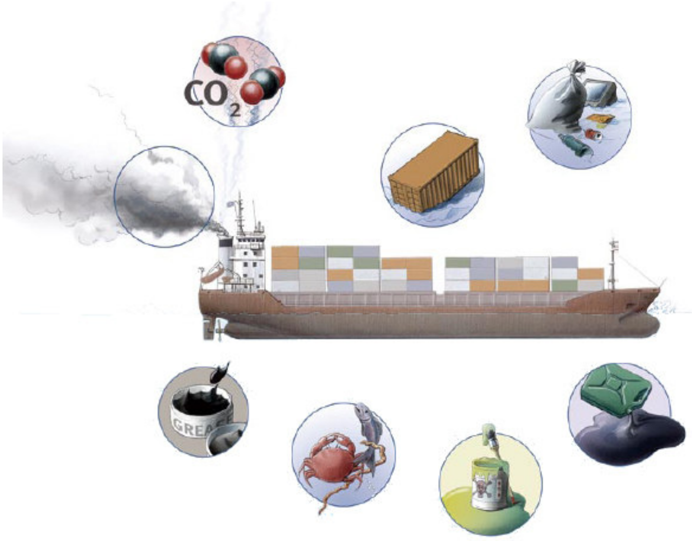
CLEAN SEA SHIPPING
("de Milieubalans")

Outline of a research programme based on an integral approach towards cleaner sea shipping

Final – September 2008



[1]

Maritime Knowledge Centre (MKC)

[1] Source: "Stichting Noordzee"

Disclaimer

The present text is meant as a proposal for a research programme based on an integral approach towards cleaner sea shipping, presumably carried out under the MIB or MIP programmes.

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0 SUMMARY

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1 BACKGROUND

1.1 Defining the problem

1.1.1 Political context

During the 2002 North Sea Ministers Conference (Bergen Declaration) the ministers acknowledged that new approaches and mechanisms are needed to minimize the impact of shipping on the environment, and agreed, a.o, to explore and develop the concept of vessels designed, constructed and operated in an integrated manner to eliminate harmful discharges and emissions throughout their working life (**the 'Clean Ship' approach**).

In the 2006 North Sea Ministers Conference (Stockholm Declaration) the ministers agreed to develop and implement the clean ship approach in their maritime and environmental policies. The Stockholm Declaration indicates that there is an urgent need for an integrated approach to address all the problems of the marine environment. This need for an integrated ecosystem approach will be met by, among other things, a European Marine Strategy and the broader EU Maritime policy.

The EU Commissions states in its Green Paper ('Towards a future maritime Policy for the Union: A European vision for the oceans and seas) that is essential to put all possible effort in the development of processes and methods (including risk assessment tools) for the provision of better information on maritime traffic, incidents and impact.

1.1.2 Shipping industry's vision and ambitions

The major actors in the shipping industry (designers, builders, ship owners and equipment manufacturers and providers) have indicated to pursue a policy to commit themselves to the "Clean Shipping" approach. The ultimate aim of this approach is to minimize the overall environmental impact of ships during all phases of shipping: designing, building, operating, accidents and end-of life stage.

With respect to the environmental impact of shipping the **operating phase** is dominant and the major focus of this project. As a consequence of this "Clean Shipping" approach, the main pathways to realize this concept in **ship operations** are:

- development and implementation of effective options and related technologies to minimize the environmental impact of shipping operations
- giving input in the formulation of realistic environmental shipping regulations, directives and guidelines.

1.1.3 Ship operations: target emissions/discharges for further reduction

During the last decades much is achieved in reducing the environmental impact of ship operations. However, on many environmental themes land-based emissions are reduced much further and sea-based emissions have grown relatively more important. Therefore it is generally accepted (e.g. in IMO framework) that further reduction is needed for:

- emissions to the air
- discharges to the sea
- wastes delivered to land

1.1.4 Environmental impact of shipping industry: emission and impact

As already stated, substantial reduction of environmental impact by the shipping industry is already achieved; often initiated and implemented in the IMO supra-national framework. Up to now the environmental impact is mainly quantified in terms of emissions or discharges, the latter being amounts or concentrations of harmful substances.

In the domain “environment” there is a growing tendency to take into account not only the emission/discharge but also the impact. This term covers the pollution as perceived, which can be translated to impact (or broader: the risk) of the emission. Acceptable impact depends on the vulnerability of the exposed or receiving environment. Introducing impact into the “environmental shipping domain” is recommendable.

1.1.5 Shipping compared to other transport modalities

Regulators and the shipping industry itself frequently express their interest in a sound comparison of the environmental impacts by the different transport modalities: road – rail –water – air.

This comparison has to be based on emission and impact (see above) as well as all-comprising pollution indexes (see below).

1.1.6 Quest for integral approach and all-comprising pollution indexes

Looking at the political context and the shipping industry’s ambitions and related actions as outlined above it is clear that there is a quest for:

- an integral approach to achieve the goals related to these ambitions; this means e.g. taking into account the complexity of shipping operations and the specific economic conditions
- identification and execution of effective actions to achieve these goals
- all-comprising pollution indexes to value the environmental and economic effectiveness of these actions
    - this index should enable comparison of various modalities in a uniform manner

1.2 Legal framework and constraints

For an overview of the present legislation and some current developments see appendix under 7.1. Most legislation applicable to the three streams, i.e. emissions to the air, discharges to the sea and wastes delivered to land, was developed under the IMO MARPOL convention and therefore is worldwide. The annexes, after being ratified, lead to legislation in the flagstates who then commit themselves to enforce these rules.

For the protection of the Marine environment in the North Atlantic the OSPAR treaty as the successor to the London Convention is relevant. They are instrumental in implementing IMO rule and also may take initiatives with respect to local implementation of IMO rules.

Apart from these international regulations there is a tendency to address local problems in ports and coastal waters on a national basis. Examples are the CARB regulations, US initiatives and EU directives. This means that ship operators are faced with a complex world and that all technical solutions proposed must be weighed against the possibility to operate in an undisturbed way everywhere in the areas that are dictated by the ships mission. Apart from being interested in technical solutions and the cost, ship owners also want to know how to take position in the international debate concerning upcoming regulations and how their operations are affected. Therefore this project has tasks addressing the technical and economical issues (chapter 5.4 to 5.11) as well as the legislative and operational issues (chapter 5.12).

2 OBJECTIVES

2.1 Goal of the programme

This research programme aims at:

Identification of Best Available Technology for reduction of the environmental impact of operational shipping activities

This ultimate goal will be achieved by realizing the following sub-goals:

- Identification of interesting options and related technologies to minimize the environmental impact of shipping operations
- Technological, environmental and economic assessment of these options/technologies
- Development of all-comprising environmental indexes to be used in the assessment
- Provision of input in the formulation of realistic environmental shipping regulations, directives and guidelines, mainly within the IMO framework, but also local (in port and near coast) regulation of the EU, US or other states.

After successful completion of this project parties would be in a position to decide to proceed with the actual adaptation of ships and demonstration at sea of the positive-assessed options and technologies. The environmental impact is represented by the emission sources and related substances given in Table 1

Emissions to the air	**Discharges to the sea**	**Wastes to land**
Energy related: - CO_2 - SOx_x - PAH - NOx - Volatile Organic Components (VOC) - Particulate matter (PM)	*Hull related:* - Bilge water - Ballast water - Dirty oil - Tank residues - Antifouling - Cathodic protection	
System related: - Halons - CFC - HCFC	*System related:* - Sewage water - Propeller shaft lubrication - Fouled cooling water	*System related* - Sludge - Fouled cleaning water
Cargo related: - oil vapours - chemicals, mainly VOC	*Cargo related* - Cargo residues	
	Crew related - Garbage	*Crew related* - Garbage
	Dredging related - increased turbidity*	

Table 1 Overview of emission sources and related substances. *: although not directly related to ship or engine design; this was considered a very relevant issue for the dredging sector.

2.2 Scientific and technological challenges

- As far as known, integral assessment – which means economic as well as environmental – of options and related technologies for cleaner ships has not been done yet. Evaluation of options and technologies using an integral assessment on the basis of pollution or impact indexes is in line with the new EU Maritime Policy which focuses on an integrated ecosystem approach.
- This integral assessment needs all-comprising environmental indexes dedicated to shipping activities. These indexes will ensure sound comparison of environmental options and related technologies. The development of these indexes is new. Such indexes are currently in use for the (Norwegian) oil and gas industry (the EIF: Environmental Impact Factor) for discharges to water, sediment, air and incidental discharges. Integration of these impact factors to a single and overall environmental impact factor has been developed and currently being implemented.
- Although the offshore oil and gas industry has proven that the use of environmental impact indexes is effective in optimising the environmental performance of existing and new installations, these cannot be directly implemented in the shipping industry. The success of the use of these indexes, however, strongly motivates to develop in parallel a set of indicators to be used in the shipping industry.

  These indexes should become the basis of the formulation of realistic environmental shipping regulations, directives and guidelines.
- The development of pollutant indexes has a theoretical basis in the established concept of a transport efficiency. Relatively new is the idea of instantaneous index and a mean effective index for a certain mission profile.
- The definition of mission profiles and the actual measurement of these profiles requires new theoretical concepts. However work has been done already in the context of road transport. Anyway it is a method to deal with all non-linearities that are involved when dealing with real in-service environmental waste streams.
- The traditional pollution indexes based on emissions can be made more useful when translated into impact indexes as it does not express the potential environmental benefit (emissions) but the actual environmental benefit (impact) of cleaner technology. This is possible for those emissions that lead to local impacts (such as emissions to water and air emissions that are deposited in the direct vicinity).
- Knowledge of power and emissions at low ship speeds where auxiliary power could be dominant is scarce and well documented measurements could provide very useful insights. Integration of this knowledge of actual ship operation is another element in the challenge to "design for service".
- For most of the environmental problems the technology is available to make significant emission reductions. Most likely no single option on itself will suffice to reduce all impacts, so a combination of methods will be required. The challenge of this project lies in the integration and the overall impact on ship design and operation.
- In general the options for reduction of environmental impacts are known but most of these technologies are proven only in land-based application. These technologies should be adapted to on-board application and integrated in the existing ship systems.

2.3 Relevance to maritime stakeholders

The reduction of the environmental impact of shipping can not be solved by just a simple, technical innovation implemented by one smart company. The maritime industry is a complex sector with stakeholders engaging at all levels. These interdependencies between fuel suppliers, ship owners, cargo owners and financing and insurance companies make that the implementation of a concept like a Clean Ship requires not only technological, but also social and organisational changes. Realising clean shipping calls for a multi-stakeholder approach. Not just crew or ship owners: many stakeholders in the maritime industry have to be involved. When thinking about incentives or possible actions that are to be included in a Clean Ship approach, they have to be well targeted to actors that can and are willing to make a difference.

The proposed research and actions in this programme will support the stakeholders both in industry and in government in executing their tasks and duties and in achieving their goals.

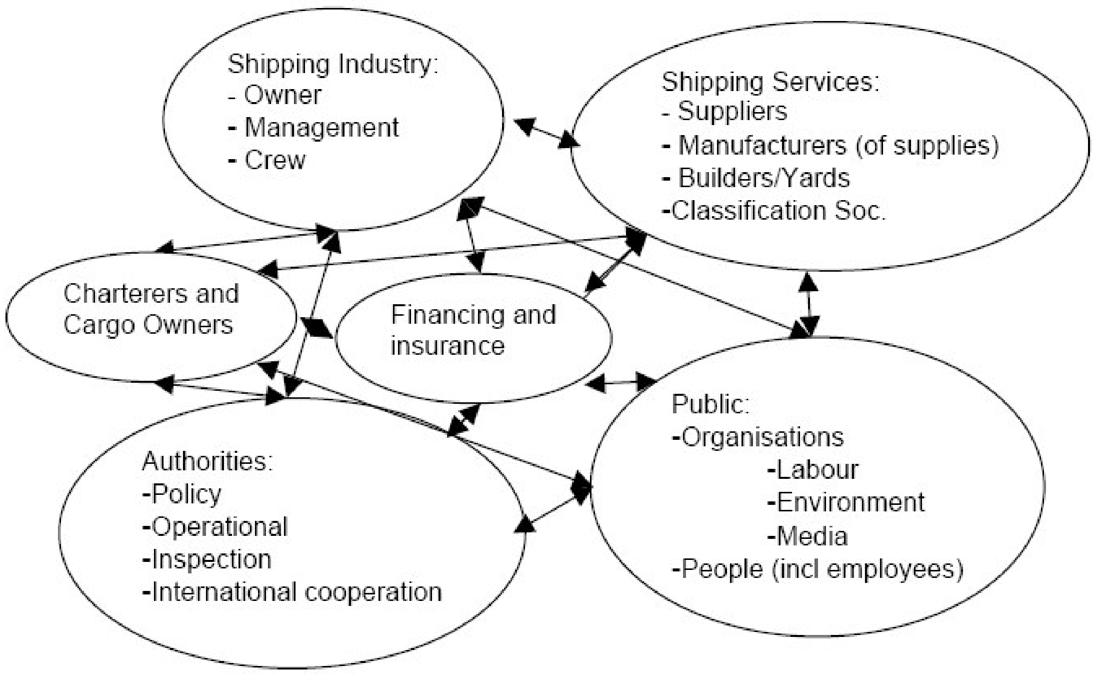

Figure 1 Picture of actors and stakeholders

2.3.1 Stakeholders in the maritime industry

Ship owners

It is likely that in the near future the shipping industry shall be further affected by new legislation and financial instruments to reduce or compensate for the environmental impact of shipping. These developments not only shall have an impact on the design of ships but are likely to bring in also the needs for new ways of operating these ships. Therefore, it becomes inevitable that in the business models of ship owners the importance of also taking in to account environmental considerations and related strategies shall increase. This project will provide information to the ship owners on how the environmental performance of present day shipping can be improved and what the effect will be on their economic performance.

Shipbuilders

New legislation on reducing the environmental impact of shipping shall have a major impact on ship design. New technologies are already available or are under development to contribute to the improvement of the environmental performance of shipping. However, it should be avoided that a technical solution to one problem should lead to others. In ship design all these solutions are integrated in to one ship. Therefore, shipbuilders should be more aware of not only the impact each solution has on the design but also how these solutions interact and how they contribute to the total environmental performance of the ship. This project provides the opportunity to shipbuilders to improve their knowledge on the environmental impact of present day shipping and to prepare themselves better for the near future needs towards cleaner ship transport.

Engine builders

Apart from causing some oily discharges to the sea and oily wastes to the land, the engines are seen as the main sources of the energy related emissions to the air. The latter are measured relative to the energy production of the engines (g/kWh) putting the engine manufacturers in the forefront of the actions to improve the situation with respect to emissions. The engine builders also can to a certain extent reduce these emissions (primary measures) and much is done under the EU 6^{th} framework Hercules project. The fuel quality and secondary measures however can also contribute to an optimum solution as well an improved design of the power plant as a whole. Last but not least emissions are affected by the way the ship is operated. This project will put the responsibilities of the engine builders in perspective and they will derive from the results of this project the necessary guidance to plan their new developments.

Equipment manufacturers and providers

Equipment can be both causing emissions as well as prevent or minimise emissions. Therefore equipment manufacturers and providers can be stakeholders in this project for several reasons. This project is aiming in particular to the manufacturers and providers of equipment that has the potential to reduce the emissions. The benefit for them could be that this project will systematically investigate the interactions between different solutions and therefore contribute to avoid unforeseen disharmony of technical solutions.

2.3.2 Governments as stakeholder

Global: A leading principle in the environmental performance of the shipping industry is the International Convention on the prevention of Pollution from ships (MARPOL 73/78) and its various annexes. As the current proposal directly relates to this Convention, the IMO should be considered an important stakeholder. The outcome of a project as described in this proposal provides significant input to IMO (and its member states) for further improvement of MARPOL 73/78 and related conventions.

Regional: Regional legislative organizations (such as OSPAR or HELCOM) are involved in the preparation and implementation of new and existing IMO conventions. Furthermore, strategies may be defined for regional implementation of global conventions. These organizations can therefore be considered as active areas for discussion of new developments and approaches, such as foreseen in the proposed project.

The European Union has an increasingly important role with respect to maritime activities, especially since the establishment of the Directorate General for Maritime Affairs. The EU should therefore be considered an important regional stakeholder in the scope of this proposal.

National: In the end, global conventions (and regional strategies or directives based on these conventions) need to be implemented and endorsed in national legislation. This would therefore involve ministries of economic affairs, transport and environment and the port authorities.

- **Port authorities:** The components in exhaust gases of ships - in particular SO_x, NO_x and Particulate Matter - contribute substantially to air pollution in sea ports. Worldwide port authorities strive for improving the air quality in ports by means of economic feasible measures. The port authorities are responsible for the supervision of compliance with international environmental regulations by seagoing ships. Clear and transparent regulations based on real-life situations will support the port authorities in this task. The port authorities will find in the results of this project some technical and economical constraints and can weigh these against the necessity to grow economically and simultaneously improve the air quality in the area.

- **Ministry of Transport**: One of the major goals of the Ministry of Transport is to improve the sustainability of the various transport modalities (road, rail, water and air). This means maximising the environmental performance without negatively affecting the economic performance. For this the indexing of emissions and immissions will be of great interest.

- **Ministry of Environment:** The goals of the Ministry of Environment match with those of the port authorities as well as of the Ministry of Transport. In particular the link between emission and immission is a major concern for which this projects will provide some answers.

3 OVERVIEW OF THE PROGRAMME

3.1 Integral ship emission balance

The idea underpinning the CO_2 index [Stapersma, 2002a] or a fuel index [Skjølsvik, 2002] is that the ship can be seen as a system and an emission balance can be drawn around it: all exhaust emissions originate from the combustion and thus from the fuel. Generalising this, the idea is that by looking to the input streams one can arrive at an integral approach of all output streams including the pollutant emissions. This process resembles the well known "Sankey" diagram for energy conversions. What is needed is some sort of a Sankey diagram for all three emission streams that were defined in 1.1.3 , i.e.

- emissions to the air
- discharges to the sea
- wastes delivered to land

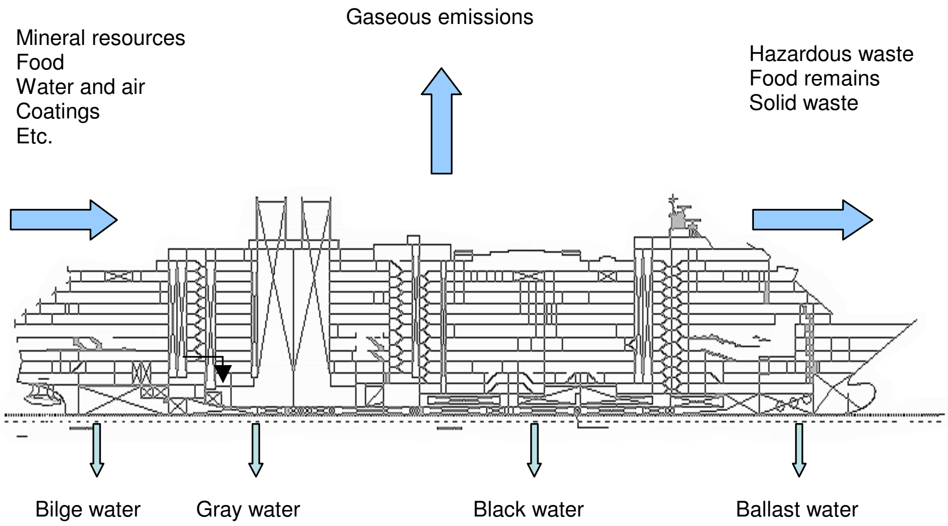

Figure 2: Ship as a system: overview of in- and outflow[2]

The following Table 2 is an example of an inventarisation of in- and outflows of a ship and can be seen as a further detailing of Table 1.

[2] TUD, "Implementing an Environmental Management System into a cruise company", thesis presentation B. Baan

Process	In	Out		
		to air	to seawater	to shore
Main and auxiliary diesel engines,	Fuel	Power dissipation Exhaust enthalpy Exhaust emissions Airborne noise	Power dissipation Underwater noise	
	Lube oil	Oil vapour Exhaust emissions		Dirty oil
	Cooling water		CW enthalpy flow	
Drinking water system	Drinking water		Grey sewage	
Food consumption	Food		Food garbage Black sewage	Food garbage
HVAC system	Air	fouled air		
Ballast system	Ballast water		Ballast water	
Tank inert gas system	Inert gas	Tank gases Fluid		Tank gases
Cargo	Bulk or packaged goods		Incidents*	
Paint system hull	Coating		Chemical flux hull area	Waste stream during docking
Cooling systems	Seawater		SW enthalpy flow	
Prop shaft bearing	Lube oil		Lube oil leak	
Deck wash	Seawater		Foul water	
Bilge system	Leaking water Leaking oil		Bilge water	
Hull protection	Anodes		Zinc oxyde	
Dry cleaning	Water			Foul water Fouled material

Table 2 In- and outflows of a ship

* incidents are excluded from this report

3.2 Approach and methodology

3.2.1 General approach

In order to identify the best available technology for reducing the environmental impact of operational shipping activities (the goal of the proposed project), we will follow a stepwise approach:

1. ***Selection of reference ships***
   This is a critical first step, as it is not possible to define a generic set of technologies that is applicable to all ships. Furthermore, the environmental impact already varies substantially among the different type of ships.

2. ***Definition of emission and impact indexes***
   The integrated approach, i.e. emission and impact of all waste streams, also requires an all comprising definition of indexes that can be used to compare the environmental effect of shipping activities and the influence of new technologies. that might reduce the environmental pressure.

3. ***Measurement of the current emission profile***
   A good reference situation needs to be established in order to arrive at realistic impact reductions that can be established with the efficiency of evaluated technology. It is important that this reference situation is representative for the mission profile of the specific type of ship. On the basis of the measured emission data, pollution and impact indexes will be determined according to the definitions developed in the previous task related to the specific mission profile.

4. ***Evaluation and integration of available technology***
   An inventory will be made of available, new and emerging technology, which will be evaluated on the basis of technical feasibility, economic aspects (CAPEX and OPEX) and environmental performance. Since fuel type is an all-determining factor for the applicability of many reduction techniques a separate study will be dedicated to fuel alternatives.

   Not all existing and proposed technologies can be combined or fit into existing or changing logistical infrastructure (such as fuel). A special task is foreseen to identify the most promising "packages", i.e. realistic and logical combinations of technologies.

5. ***Design of possible configurations for minimal environmental impact***
   The last step in the process is design of configurations of technologies, for each type of reference ship, that might be considered as Best Available Technology. For these configurations again an emission and impact index will be used as a tool for comparison with the reference (current) situation.

   A special design case is dedicated to near-coast and in-harbour shipping activities, aiming at full reduction of emissions (and thus impact) of these activities.

   A last important step will be to identify and discuss any consequences for the legislative framework that might come out of the research.

3.2.2 Emission to the air

It is imperative that new ships and new ship concepts must be:

- Suitable to fulfil existing legislation (i.e. NO_x and SO_x according to IMO Marpol Annex VI)

- Fit to cope with future legislation that has a high probability of coming into effect (i.e. North Sea, Baltic and Mediterranean becoming SECA's with stricter requirement on sulphur in fuel, as mentioned in IMO Marpol Annex VI, e.g..EU directives on sulphur in marine fuels)
- Able to support the intentions of the Kyoto protocol, i.e. have a lower CO_2 emission
- Pro-active to future legislation in particular with respect to particulates (particulate matter or PM). This in particular since IMO has announced to initiate a process to revise international standards on ship emissions and marine fuel quality and to consider regulating particulate matter for the first time.

Measures to achieve these aims are:

- High-efficient energy conversion processes, reducing fuel consumptions and associated emissions level.
- Low sulphur or alternative fuels (such as bio-diesel and natural gas) eliminating or reducing SO_2, NO_x and CO_2 emission levels.
- Pre-combustion emission control technologies on diesel engines (or other prime movers such as gas turbines)
- Combustion emission control technologies
- Post-combustion emission control technologies

The impact of low sulphur or alternative fuels will be addressed in task 5.4. The result of this impact study of course may affect the subtasks concerning the reduction control technologies.

It is recognized that alongside of the existing technologies, many new developments take place elsewhere and therefore a limited number of the new technologies will be developed within CLEAN SEA SHIPPING project. Therefore some promising emission control technologies for reference ship concepts will be selected among both existing and new techniques. In so doing, the impact of any selected technology on the machinery installations and overall ship design will be established in terms of:

- Pollutant removal efficiency for all loads relevant to mission profile
- Energy requirements and supply
- Chemical requirements and additives
- Other interface requirements
- Weight, volume and dimensions
- Installation requirements
- First cost and cost of consumables
- Operational consequences
- Status of development and potential risks

3.2.3 Discharges to the sea

Operational shipping activities lead to a range of emissions to the sea, from slow release of anti-fouling substances from the hull to the discharges of tank sludges (see also Table 1). Such discharges may lead to environmental impact as a result of toxic substances, physical effects of oil and garbage or the introduction of alien species (ballast water)

Technological solutions reducing the environmental impact due to discharges to the sea may include:

- (improved) facilities for harbour collection
- on-board waste water treatment
- use of less toxic (so called ‘green-‘) chemicals
- new technologies preventing or reducing current emissions

- - ballast water management

3.2.4 Wastes delivered to land

Wastes delivered to land (to harbour reception facilities) are not included in this project (see 3.3 Scope).

3.3 Scope

3.3.1 Inside the scope

As already stated in 3.2, this programme aims at reduction of the environmental impact of shipping operations. The environmental impact is restricted to:

- Emissions to the air
- Discharges to the sea.

In principle, the focus is on environmental impacts directly related to the shipping activities. Effects up and down the chain (e.g., fuel production) are generally not included, although in some cases it might be worthwile to widen the scope to include some of these chain effects.

3.3.2 Outside the scope

The following topics definitely have a wider environmental impact but will nevertheless be outside the scope of the present project since they are not involved in the normal day-to-day operation of ships that is the main focus of this project (refer to 1.1.2):

- Wastes delivered to land

Wastes generated onboard and delivered to land are not included in this programme. The treatment and disposal of these wastes are subject of specific national regulations and are – in general - regarded as environmentally sound. However, harbour collection systems or other share based installations may contribute to a reduction of emissions to air of to sea. Such installations are <u>within</u> the scope of this programme.

- **Calamities**:

The general opinion is that reducing the (environmental) risk of ship accidents at sea is two-fold:

- prevention of the accident happening.
- minimizing the environmental effect if such an accident will occur

Both will be outside the scope of this project and their importance in fact warrant dedicated projects.

- **Maintenance and repair**

This topic lies outside the scope of normal ship operations and it is an in-harbour activity carried out at shipyards (with the exception of on-board maintenance and repair),. The environmental issues of ship maintenance and repair fall under yard management (not ship management) and they must be addressed under legislation for the land-based industry in the national states that it concerns.

- **End-of-life (demolition)**

This topic lies outside the scope of normal ship operations and it is an in-harbour activity carried out at specialised firms. The environmental issues must be addressed under legislation for the land-based industry in the national states that it concerns.

- **Propeller design, Hull design and reduction of resistance**

  No actual tasks and workpackages addressing these issues are foreseen in this project. It is acknowledged though that developments take place, some of which could be important (e.g. airfilm lubrication). The indexes that will be developed in this project however will have the potential to measure the effect of these hydrodynamic improvements.

4 DISSEMINATION OF RESULTS

The main target groups of this programme are the shipping industry stakeholders and the governmental bodies related to shipping and environment. To ensure effective dissemination and subsequent application and/or implementation of the results of this programme the following dissemination strategy will be applied.

To industrial stakeholders
The projects proposed in this programme will be carried out in close co-operation with major stakeholders from the shipping industry. Dependent on the specific project and the direct interest of stakeholders the following types of co-operation will be established. These types are reflected by the specific roles of stakeholders in the projects, like:

- “full partner” in a project
- subcontractor
- member of end users group or feedback panel.

This close co-operation will ensure a direct and ongoing transfer of experiences and results gained in the project to the industrial stakeholders.

Furthermore, dedicated workshops and seminars targeted on industrial stakeholders are foreseen.

To governmental bodies
Governmental bodies related to shipping and environment will be linked to the projects as:

- co-financer
- member of endusers group or feedback panel.

This linkage will ensure a direct dissemination route to the governmental bodies involved.

General
Furthermore, general, widely public dissemination will be done by, e.g:

- publications in authoritative journals
- presentations on conferences, seminars
- press releases.

This public dissemination – in particular the specific content of it – will be done after discussion and agreement with the stakeholders involved. Sensitive, and thereby confidential information will not be made public.

5 PROJECTS AND WORKPLAN

5.1 Definition of reference ships

5.1.1 Goal

In order to determine or estimate the effects of technologies to reduce the environmental impact a number of relevant ship types and operational profiles need to be selected. These ships can then be used to compare environmental indexes, the effects of fuel alternatives, the effect of existing and emerging emission reduction technologies, find promising new technologies, the effects of alternative power generation and heat recovery systems, etc.

5.1.2 Description of project

It is proposed to select the same ships and operational profiles which have been analysed in the report 'CO2 – emissions of various ship types, simulated in an operational year profile', [Brussen et al, 2006]:

- large container ship
- medium size container ship
- container feeder
- coastal general purpose / feeder
- large bulk carrier
- medium size bulk carrier

Complex specials (not in Brussen et al., 2006):

- yacht
- rescue vessel
- offshore vessel
- dredging facilities
- short sea ship
- patrol vessel

Further ship types to be included:

- ferry
- tug

Specific issues to be addressed are:

- Differentiation between deep sea and near-shore locations
- Manoeuvring and partial load conditions
- Alternative for using 'transport capacity' related to tugs and ferries

5.1.3 Expected results

For all ship types:

- Main data for ship and machinery

- General arrangement
- Machinery arrangement
- Mission profile
- Details of power generation system

5.2 Definition of pollution indexes for emission and impact

5.2.1 Goal

The objective of this part of the project is the development of a number of indices which can be used to make a quantitative description of the environmental performance of shipping activities. Both the potential effect (i.e., emission) and the actual effect (i.e., impact) on the environment need to be included. The indices should be developed in such a way that they can be used for comparison of shipping activities and for comparison of technologies that might reduce the environmental pressure.

5.2.2 Description of project

The figure below provides as schematic overview that provides the basis elements that link the emission of operational shipping activities to the impact indices that reflect the consequence of these activities for the environment.

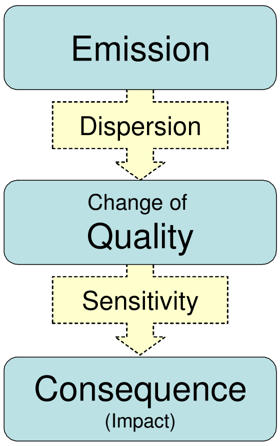

Figure X. Schematic overview of the process of determining the consequence of shipping activities for the environment

In order to arrive at the development of a set of suitable emission and impact indices, the following elements need to be covered:

1. **Emission indices – air**
   Further development of the emission index for emissions that are related to fuel use. Questions that need to be answered include the coverage of all relevant emissions and how to quantify and structure emission profiles.

2. **Emission indices – other**
   Methods developed for air emissions will need to be modified, such that for non-air emissions comparable emission indices can be derived. This comprises answering questions such as the unit of expression to use and the relation between emissions and representative shipping parameters.

3. **Impact indices**
   Development of an impact index for each type of emissions, requiring the development of a relationship between the emission levels and the severity of the environmental impact (‘dose-response relationship’)

4. **Integrated environmental impact index**
   Integration of the individual impact indices into an overall environmental impact index. Main effort is expected to go into the development of a weighing procedure, taking into account economic, social and environmental aspects.

5.2.3 Expected results

Main deliverables from this part of the project are expected to be methods for calculating emission indices, impact indices and a method to determine an overall environmental impact index. It is envisaged that apart from publishing these methods in a technical report, articles will be drafted for publication in peer reviewed scientific journals. The latter will strengthen the acceptability of the developed indices.

5.3 Measurement of the state-of-the-art of emissions to air

5.3.1 Goal

General

Emissions to air are considered to be amongst the main environmental impacts of sea-shipping. As increasingly stringent controls are placed on land-based sources of atmospheric emissions, there is mounting pressure to bring ship emissions more closely within land air quality policy. Ship emissions have not been as tightly controlled as many land-based emission sources and the international transboundary context of the shipping sector posed specific difficulties to achieving progress in improving environmental performance.

Ships activities can be divided into two main groups:

Location oriented:

- High seas (transit or other operational modes)
- Near coast (slow speed)
- Harbour entrances
- Harbours
- Dockside operation (auxiliary power only)

Activity oriented:

- Steady state sailing
- Manouvring (slow speed and start/stop manoeuvres)
- “Dead” ship (mooring or in-harbour)

Emissions during sea-going operations are relatively well understood. However, the emissions during inland navigation, manoeuvring and dockside operation are less well known than sea-going emissions, because the engine settings are unclear and emission factors might not apply at low engine loads and during more transient operations. It is the objective of this project to generate information that might close this gap in knowledge.

5.3.2 Description of project

Performance database

When considering engine emission measurements, the application of its results is of importance. The primary goal is the realisation of an emission factors database (focussing on the reference ships indentified in §5.1), for the air pollutants nitrogen oxides (NO_x), sulphur dioxide (SO_2), hydrocarbons (HC) and particles (PM) and for the greenhouse gas carbon dioxide (CO_2).

Measurements

In case of an emission factors database which is not complete, general engine emissions measurements can be done. Engine emission measurements can be assessed in a few ways:

- from direct measurements in the exhaust
- by interpretation of more remote plume measurements (on-ship or on-shore)
- from engine settings (rpm, power) and the engines emission map

When the engine emission map is known, e.g from factory acceptance tests, the third method will be just as accurate as the first two methods. This is most likely the case in sea-going operations, where engine settings and emission characteristics are fairly well known. However during manoeuvring and dock-side operations the engine static emission data might not be applicable, so additional measurements are possible.

5.3.3 Expected results

1. Identification of major lacks in knowledge and existing sources of information.
2. Specification of a measurement programme
3. Performing measurement programme
4. A final report, summarising the above with conclusions and recommendations how to assess emissions of seagoing vessels.

5.4 Measurement of the state-of-the-art of emissions to water

5.4.1 Goal

General

Emissions from shipping activities to water is very diffuse: many minor and major sources contribute to the total emission to water (e.g., ballastwater, bilgewater, anti-fouling biocides, etc.) Little data is available on the actual levels of these emissions, as most attention is paid to emissions to air. This project aims at quantifying all possible (operational) emissions to water and, where possible and usefull, categorizing these emissions to the main groups of reference ships. If there is relation with a ships location or activity, this should be indicated (see categorization in 5.3.1)

5.4.2 Description of project

When considering emission measurements, the application of its results is of importance. The primary goal is the realisation of an emission factors database (focussing on the reference ships indentified in §5.1), for the main emissions to water. The primary source for such information is the general (scientific and 'gray') literature.

In case of an emission factors database which is not complete, dedicated emissions measurements can be done in order to yield data on the most relevant emissions to water (see Table 1, chapter 2).

5.4.3 Expected results

5. Identification of major lacks in knowledge and existing sources of information.
6. Specification of a measurement programme
7. Performing measurement programme
8. A final report, summarising the above with conclusions and recommendations how to assess emissions of seagoing vessels.

5.5 Comparative evaluation of fuel alternatives

5.5.1 Goal

The starting point for reduction of air emissions is the energy source for propulsion and auxiliaries. As it is agreed that great improvements might be achieved, an in depth evaluation of all related elements is required. This project aims to obtain a matrix to show advantages and disadvantages of existing and future fuel alternatives for ship propulsion, auxiliaries and other energy users onboard.

5.5.2 Description of project

The matrix of fuel alternatives to be developed in this project will be designed taking into account the following aspects:

- Fuel alternatives to be considered include at least: heavy fuel oils (HFO) with different sulphur content, diesel oil (DO) with different sulphur content, natural gas in gaseous and liquefied forms, blends (including biodiesel and biofuels), hydrogen (including options of its supply in ready form or its production onboard with use of renewable energy sources, such as wind)

- Fuel treatment cost associated with its production onboard (if applicable), preparation for use, and treatment and disposal of wastes

- High/Low heating value per ton or cubic meter

- Average efficiency of fuel-to-energy (mechanical, electrical, heating/cooling) conversion processes (with use of the known and new equipment and with regard to expected improvements in its performance)

- Safety of fuel supply and use (stability of fuel supply, safety of handling and storage)

- Average fuel cost in last decade, in last 2 years, in last 12 months, expected evolution of costs in short, medium and long terms

- Maintenance costs associated with the use of different fuels

- Integral appraisal of fuel alternatives with regard to level of untreated emissions (SO_2, NO_x, CO, CO_2, soot, PM) in marine engine exhaust

In addition a life cycle analysis (LCA) for (a selection of) the fuels will need to be performed. The scope of the LCA will include all stages from fuel production through the fuel supply chains to engine combustion products (emission).

5.5.3 Expected results

- A comprehensive matrix based on an exhaustive collection and treatment of data related to the much-used and prospective fuels and power generation technologies in the short and medium terms

- Report, elaborating on the analysis performed to construct the matrix

- LCA report for (a selection of) the fuels included in the matrix

5.6 Specification of emission reduction technologies - Air

5.6.1 Goal

An inventory needs to be made of all technology (existing and emerging), to be evaluated on the basis of technical feasibility, economic aspects (CAPEX and OPEX) and environmental performance. The objective is to obtain a widely accepted list of Best Available Technology to reduce emissions to air.

5.6.2 Description of project

A set of functional specifications need to be developed for existing and emerging technologies controlling emissions to air. Table 1 (chapter 2) should be regarded as the starting point for the inventory of the existing technology. Each technology needs to be described including at least the following topics:

- general description of the principle including a system assessment comprising the following elements: chemical requirements and additives; interface requirements; weight, volume and dimensions; installation requirements.
- technical feasibility of implementation on the respective reference ships (see project 6.1)
- economic aspects (CAPEX, OPEX) related to the reference ships
- Performance, where possible demonstrated with actual data. The performance assessment should, be where possible, be based on measurements, specified in work package 6.3 and comprise the following elements: effectiveness in achieving lower emissions for all loads relevant to the mission profile; energy requirement and supply; operational consequences.

5.6.3 Expected results

- A prioritised list of existing technology to be referred to as BAT-Air
- A prioritised list of emerging technology
- A database containing all the results of the inventory

5.7 Specification of emission reduction technologies - Water

5.7.1 Goal

An inventory needs to be made of all technology (existing and emerging), to be evaluated on the basis of technical feasibility, economic aspects (CAPEX and OPEX) and environmental performance. The objective is to obtain a widely accepted list of Best Available Technology to reduce emissions to water.

5.7.2 Description of project

A set of functional specifications need to be developed for existing and emerging technologies controlling emissions to water. Table 1 (chapter 2) should be regarded as the starting point for the inventory of the existing technology. Each technology needs to be described including at least the following topics:

- general description of the principle including a system assessment comprising the following elements: chemical requirements and additives; interface requirements; weight, volume and dimensions; installation requirements.

- technical feasibility of implementation on the respective reference ships (see project 6.1)

- economic aspects (CAPEX, OPEX) related to the reference ships

- Performance, where possible demonstrated with actual data. The performance assessment should, be where possible, be based on measurements, specified in work package 6.3 and comprise the following elements: effectiveness in achieving lower emissions for all loads relevant to the mission profile; energy requirement and supply; operational consequences.

5.7.3 Expected results

- A prioritised list of existing technology to be referred to as BAT-Water
- A prioritised list of emerging technology
- A database containing all the results of the inventory

5.8 Power generation and heat recovery systems

5.8.1 Goal

An inventory needs to be made of existing or emerging power generation and heat recovery systems, to be evaluated on the basis of technical feasibility, economic aspects (CAPEX and OPEX) and environmental performance. Where such information is not available it should be based on educated and documented estimations.

5.8.2 Description of project

A set of functional specifications needs to be developed for available (and emerging) power generation systems and heat recovery systems. These systems will include (but not be limited to) gas engines, batteries (lead acid, zebra, etc.) and fuel cells; as well as waste heat recovery from exhaust gas in conjunction with steam systems (Schmid 2004). Each technology needs to be described, including at least the following topics:

- General description of the principle including a system assessment comprising the following elements: chemical requirements and additives; interface requirements; weight, volume and dimensions; installation requirements.

- Technical feasibility of implementation on the respective reference ships (see project 6.1)

- Economic aspects (CAPEX, OPEX) related to the reference ships

- Performance, where possible demonstrated with actual data. The performance assessment should, be where possible, be based on measurements, specified in work package 6.3 and comprise the following elements: effectiveness in achieving lower emissions for all loads relevant to the mission profile; energy requirement and supply; operational consequence

5.8.3 Expected results

A prioritised list of power generation systems and waste heat recovery systems to be referred to (as candidates) for BAT

A database containing all the results of the inventory (following the format of the database referred to in 5.5)

5.9 Integration of technologies

5.9.1 Goal

This work-package aims to evaluate all possible measures for emission reduction and to define a limited number of integrated technology packages that reduce emissions. The activities in this phase comprise

- the identification of all individual measures
- combination of measures in integrated packages
- selection of most promising packages

Activities will be performed in discussion with suppliers of equipment who have best knowledge on conditions required for proper performance of unit operations.

5.9.2 Description of project

In the previous tasks a number of measures to reduce emissions are identified. These measures however are not independent of each other. Some measures are easier combined than others. In some cases one measure might facilitate the second measure, while combination of others are less likely.

When evaluating the feasibility and effectiveness of measures, it is therefore advisable to evaluate integrated packages of measures

- the measures are dependent of each other. The feasibility and effectiveness of a single measure depends on the other measures in place;
- evaluating integrated packages of emissions reduces the evaluation task. Instead of ship-design and evaluation for all measures, a limited number of design of implementation of integrated packages is required, followed by evaluation
- thinking in integrated packages is in line with the way engine companies and suppliers of other equipment think.

We foresee the following main elements of this project:

1. Collecting relevant information of individual measures e.g. required working conditions (temperature window, poisoning components and inhibitors, moisture), other requirements (heat, steam, co-reagents, electricity) and expected product exhaust gas composition.

2. Identifying logical combinations, based on the consultants own technological knowledge and continuous discussions with suppliers of equipment

3. Model development and simulation, to evaluate the identified combinations on overall environmental effect, costs, cost-effectiveness and technological feasibility (demonstrated technology or concept in the lab, other risks).

4. Selection: A small set of combinations of technology needs to be selected for further elaboration. This activity will be performed in consult with all stakeholders within the programme.

5.9.3 Expected results

- Data-base with relevant information. (for internal use only)
- Models developed for evaluation of selected technology combinations

- Report with a summary of all possible combinations of technology and a description of procedures of the evaluation, its results and the underlying arguments.
- Documented choice for a small set of possible systems for further elaboration

5.10 Bringing near-coast and in-harbour emissions to zero

5.10.1 Goal

The consequences of emissions are considered to be highest in near-coast and in-harbour situations. A reduction of emissions might in these situations be insufficient . It is the objective of this project to identify (feasible) solutions to realise a zero-emission (or at lest to zero impact) configuration for near-coast and in-harbour shipping.

5.10.2 Description of project

This project requires a 'visionary approach' as conventional technology and configurations are expected not to meet the objective of zero-emission. This project may be based on the following elements:

- Identification of possible solutions, covering at least (for as far as the information is available) the following topics:
  - General description of the principle including a system assessment comprising the following elements: chemical requirements and additives; interface requirements; weight, volume and dimensions; installation requirements.
  - Technical feasibility of implementation on the respective reference ships (see project 6.1)
  - Economic aspects (CAPEX, OPEX) related to the reference ships
  - Performance, where possible demonstrated with actual data. The performance assessment should, be where possible, be based on measurements, specified in work package 6.3 and comprise the following elements: effectiveness in achieving lower emissions for all loads relevant to the mission profile; energy requirement and supply; operational consequence
- Assessment of the efforts required to actually implement these solutions to reach zero emission for near-coast and in-harbour shipping.

5.10.3 Expected results

- Report concluding the most feasible solutions for zero-emission, documented with the identification and assessment as described above.

5.11 Technical and economical synthesis of solutions in reference ships

5.11.1 Goal

All preceeding projects focussed on the identification and description of existing and emerging technology for reducing (or preventing) emissions to water and air. The objective of this project is to evaluate the technical and economical feasibility of implementation of the best (BAT) solutions on the identified reference ships. This should be presented in the perspective of the integral environmental benefit of the evaluated solutions.

5.11.2 Description of project

The basis for this project is the implementation of the reference ships in vessel design simulation software. After implementation of the basis information of the reference ships, scenarios need to be defined based on the technology combination with the highest perspective (see also project 6.8). Simulation of the various scenarios (i.e., technology combination and specific mission characteristics) should provide information on technical and environmental performance.

5.11.3 Expected results

Report describing, for each reference ship, the most feasible solutions for emission (impact) reduction and zero-emission (or zero impact) in near-coast and in-harbour situation. Include at least 1 option with the maximum environmental benefit and 1 option with the best cost – (environmental) benefit ratio.

5.12 Consequences for legislative framework and operations at sea, near coast and in harbour

5.12.1 Goal

Increasing the environmental performance of sea shipping mainly requires technological solutions. However, modification to the current legislative framework may provide incentives to stimulate innovation. The objective of this project is to is to identify and discuss such modifications and consequences with the aim of maximising the progress towards clean sea shipping.

5.12.2 Description of project

As a basis for evaluating consequences for the legislative framework, an overview will be made of all relevant legislation; highlighting the issues that are considered most relevant in this context. A series of workshops with national and international stakeholders is expected to provide the means for discussing the legislative consequences and formulate recommendations for modification of current legislation.

5.12.3 Expected results

- Report with recommendations
- A series of national and international workshops; with a report of each workshop as documentation of the final recommendations

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7 APPENDICES

7.1 Overview of legislation

7.1.1 Emission to the air

Present legislation

- IMO International Convention on the prevention of Pollution from ships (MARPOL 73/78).
  - Annex VI (Exhaust emissions). Entry into force date: 19 May 2005.

Current thoughts and developments:

- IMO Sub committee on Bulk Liquids and Gases (BLG): Review of MARPOL Annex VI and the NO_x Technical Code:
  - Terms of Reference of the BLG sub-committee on the revision of MARPOL Annex VI and the NO_x Technical Code.
  - BLG 10/14/2: MARPOL Annex VI revision: Proposal for future emission limits and issues for clarification, submitted by Norway, 23 Dec 2005.
  - BLG 10/14/5: MARPOL Annex VI revision: The shipping industry perspective, submitted by ICS, BIMCO, Intercargo, ICCL and Intertanko, 20 Jan 2006.
  - BLG 10/14/13: MARPOL Annex VI revision: Limits of shipping emissions of air pollution, submitted by Friends of the Air International, 26 Jan 2006.
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- EU Directive 2005/33/EC: Sulphur content of marine fuels.
- EU Recommendation of 8 May 2006: Promotion of shore-side electricity by ships at berth in Community ports.

7.1.2 Discharges to the sea

Prevailing legislation

- IMO International Convention on the prevention of Pollution from ships (MARPOL 73/78):
  - Annex I: Prevention of pollution by oil. Entry into force date: 2 Oct 1983.
  - Annex II: Control of pollution on by noxious liquid substances. Entry into force date: 2 Oct 1983.
  - Annex IV: Control of pollution by sewage from ships. Entry into force date: 27 Sept 2003.
- IMO International Convention for the control of Management of Ships' Ballast Water and Sediments. Adopted: 13 Feb 2004. Status: to be ratified.
- IMO International Convention on the control of harmful Anti-fouling systems. Adopted: 5 Oct 2001. Status: to be ratified.
- OSPAR 1992 Convention for the protection of the Marine environment of the North-East Atlantic. Entry into force date: 25 March 1998.
  - Annex I: prevention and elimination of pollution from land-based sources.
  - Annex II: prevention and elimination of pollution by dumping and incineration.
  - Annex III: prevention and elimination of pollution from off-shore sources.
  - Annex IV: Assessment of the quality of the marine environment.
  - Annex V: protection and conservation of the ecosystems and biological diversity of the maritime area.

7.1.3 Wastes delivered to land

Legislation

- IMO International Convention on the prevention of Pollution from ships (MARPOL 73/78):
  - Annex III: Prevention of pollution by harmful packages. Entry into force date: 1 July 1992.
  - Annex V: Prevention of pollution by garbage from ships. Entry into force date: 31 Dec 1988.