Possibilities for reducing fuel consumption and greenhouse gas emissions from inland navigation

Report by the Inspection Regulations Committee
for the 2012 Autumn Meeting

(Annex 2 to protocol 2012-II-4
of the Central Commission for the Navigation of the Rhine,
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CCNR report on the possibilities for reducing fuel consumption and greenhouse gas emissions from inland navigation

1. Justification/motivation for the report (project)

At its 2009 Autumn Meeting, the CCNR, taking up its responsibility for sustainable navigation on the Rhine and inland navigation elsewhere, set itself the target of cutting the greenhouse gas emissions generated by navigation of the Rhine in line with the emission reduction targets of its member states. This objective was made against the background that the international community of states is determined to take measures to prevent and reduce greenhouse gas emissions (mitigation), and combined with the finding that the inland navigation is a mode of transport, which causes low greenhouse gas emissions and yet can contribute to a reduction of greenhouse gas emissions from transport taken as a whole. To reach this goal, the CCNR has asked its Inspection Regulations Committee to provide a report, based on relevant studies and on contributions made by its member and observer states, and the international organisations and trade associations that cooperate with it, containing proposed and assessing measures and possibilities of reducing greenhouse gas emissions from inland navigation and to present a proposal for how they can be made accessible to the inland navigation operators as well as other potential users in an appropriate manner (CCNR, 2009).

The report's benefits go beyond the CCNR. Due to the compilation of the measures and options for reducing greenhouse gas emissions from inland navigation, it also offers a collection of data that can be used for future studies in the preparation of political decisions (e.g. emission reduction potential of inland navigation). In addition to this, the CCNR will also make this report available to PIANC, which is working on climate change and shipping at a global level (PIANC 2010).

The report and any additional work could contribute towards reliable and more accurate greenhouse gas balances for inland navigation such as those, for instance, which are necessary for reporting purposes in connection with the Kyoto protocol.

2. Reference range/contents of the report/the project

The report refers to the greenhouse gas emissions from inland navigation in the strict sense of the word, i.e. CO_2 emissions generated by the operation of inland vessels. With the exception of CH_4, the emissions of other pollutants apart from CO_2 are not taken into consideration, nor are emissions not resulting from the operation of the vessels. This limitation is primarily due to the lack of usable studies or data on other emissions generated by inland navigation than that of CO_2 due to the operation of the ships. This limitation is not detrimental to the objective of the report, since on the one hand CO_2 is the most significant greenhouse gas emitted by inland navigation by a long way, and on the other hand, other emissions apart from those resulting from operation of the vessel are negligible due to the low levels – at least initially.

Almost no CH_4, another of the most significant greenhouse gases, is currently emitted by inland navigation. This could change if LNG starts to be used as a fuel by a large number of inland vessels. CH_4 can either escape directly from the ships themselves, when bunkering, due to leaks or due to incomplete combustion, as well as during processing and transportation of the LNG. CH_4 emissions are therefore discussed in **section 11** of the report, which deals with the use of alternative energy sources and considers possible climate-harming effects of the use of LNG as a fuel.

The CCNR authorised the use of LNG as a fuel on a number of inland navigation vessels in 2012, for test purposes, and has already made a start on compiling general rules for authorising the use of LNG as a fuel in inland navigation. The impact assessment carried out in preparation for this provides an opportunity to examine these effects in more detail.

Emissions from the cargo, such as in tankers, should be attributed to the production chain of the cargo, rather than to the inland navigation.

However, in view of the large share of liquid goods in the total cargo volume of inland navigation, it seems useful to determine the quantity of greenhouse gas emissions from the cargo on tank vessels in a separate study, and to develop and implement measures for reducing them.

The processes of climate change are complex and it is difficult to compare the impact of the various different greenhouse gases (Solomon, Qin et al. 2007). CO_2 is, as shown in **Table 1**, the most significant greenhouse gas worldwide by a long way, far ahead of CH_4 (methane), nitrous oxide (N_20) and fluorochlorohydrocarbons. The proportion of CO_2 that contributes to the greenhouse gas emissions from the operation of inland navigation is far more than it is on average, worldwide. On average, the proportion of the total mass of exhaust gas from diesel engines, which are to be found on practically every inland vessel, accounted for by CO_2 is about 20% and the proportion of NO_x is significantly less than 0.1% ((Lenz, Illini et al. 2004) in accordance with (Geringer and Tober, 2010)). N_2O only constitutes a fraction of the total mass of NO_X (nitrogen oxides) in exhaust gases (Hausberger). This explains why the climate warming potential of N_2O from diesel engines used on inland vessels is estimated to be less than 1% of that of CO_2 (Verbeek, Kadijk et al. 2011). N_2O is thus irrelevant as a greenhouse gas emitted by inland navigation.

Table 1: Characteristics of key greenhouse gases (sources: (Laboratory: Houghton, Meira Filho et al. 1996; Solomon, Qin et al. 2007; Borken-Kleefeld and Sausen 2011)

Greenhouse gas / Criterion	Carbon dioxide (CO_2)	Methane (CH_4)	Nitrous oxide (N_2O)	Chlorofluoro-carbons
Primarily anthropogenic causes	Combustion of fossil fuels (transport-tation, heating, power generation, industry)	Processing of bio-material (farming, forestry, etc.), industrial pro-cesses, production of natural gas	Farming (keeping of livestock, fertilizer), power stations	Propellants, refrigerants, fire extinguishers
Primarily caused by inland navigation	Combustion of gasoil[1]	Leaks or incomplete combustion of LNG (to be used in the future)	Combustion of gasoil (NO_X)	Air conditioning systems, fire extinguishing systems
Global warming impact relative to CO_2	1	Approx. 25	Approx. 300	Some CFCs as high as 14,800
Proportion of the additional global warming due to anthropogenic causes	Approx. 60%	Approx. 20%	Approx. 5%	
Lifetime in the atmosphere	Varies, some as long as 100 years	Approx. 12 years	Approx. 115 years	Up to several 1000 years
Outlook	Accumulates in the atmosphere faster than other greenhouse gases	Relatively stable total amount in the atmosphere, accu-mulating at present	Continuous accumulation in the atmosphere	Some reduction due to international agreements & treaties

[1] In this report gasoil is understood as fuel for diesel engines on board of inland vessels, independently of the quality of the fuel that is actually used. In the EU the fuel used in inland navigation is specified by Directive 2009/30/EC.

Chlorofluorocarbons have a comparatively strong impact on climate. On inland vessels, apart from cargoes, they almost only occur in extinguishing agents of certain fire-fighting systems. The extinguishing agents are released into the atmosphere only in exceptional cases, when the systems are activated or leaks occur. For this reason, these greenhouse gas emissions are of minor importance in inland navigation[2] and are not considered further in this report. Nevertheless it seems reasonable that from now on only fire-fighting systems that operate without climate-harming substances are permitted on inland vessels.

The classic airborne pollutants resulting from the use of diesel engines, also promote global warming due to various complex mechanisms, but also have a cooling effect under certain conditions (Borken-Kleefeld and Sausen 2011). In the first few years of generation, their impact on the climate can be comparable to that of CO_2. However, these effects wear off quickly – in contrast to those of CO_2. The only exceptions to this are the pollutant emissions from maritime shipping, which stand out from the pollutant emissions originating from other modes of transport due to their very high sulphur content. The reduction in pollutant emissions from inland navigation already achieved in recent years has thus contributed to a reduction in greenhouse gas emissions. This should continue due to its contribution towards protection of the environment, although, for exactly these reasons, the reduction in pollutant levels should not increase the fuel consumption and thus the CO_2 emissions. Since most work on reducing pollutant emissions from inland navigation is now being done at the EU level, these emissions are only considered in this report where they are related to fuel consumption. The CCNR, which together with the US Environmental Protection Agency is the leader in the field of regulating pollutant emissions from inland navigation, has thus contributed to a reduction in climate change – if it is caused by inland navigation.

The greenhouse gas emissions resulting from the production of the vessels used in inland navigation, their maintenance and scrapping are not taken into consideration, as is also the case for those from other areas of inland navigation, in particular the building, operation and maintenance of the waterways and inland ports. **Annex 1** takes a closer look at these areas of inland navigation and outlines one possible way that these emissions could be dealt with.

From a geographical point of view, the report relates to navigation of the Rhine and inland navigation throughout the EU. Fundamentally, however, the conclusions reached are also applicable to inland navigation in other countries, as long as similar technologies are also used there and similar political and administrative conditions prevail. The former is presumably the case worldwide, the latter may, however, be the exception, especially in terms of the ambitious greenhouse gas emission reduction targets[3].

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[2] For inland navigation, no figures are available on the quantity of these emissions. For maritime navigation, their share is indicated as being significantly less than one percent, after conversion into CO_2 equivalents.

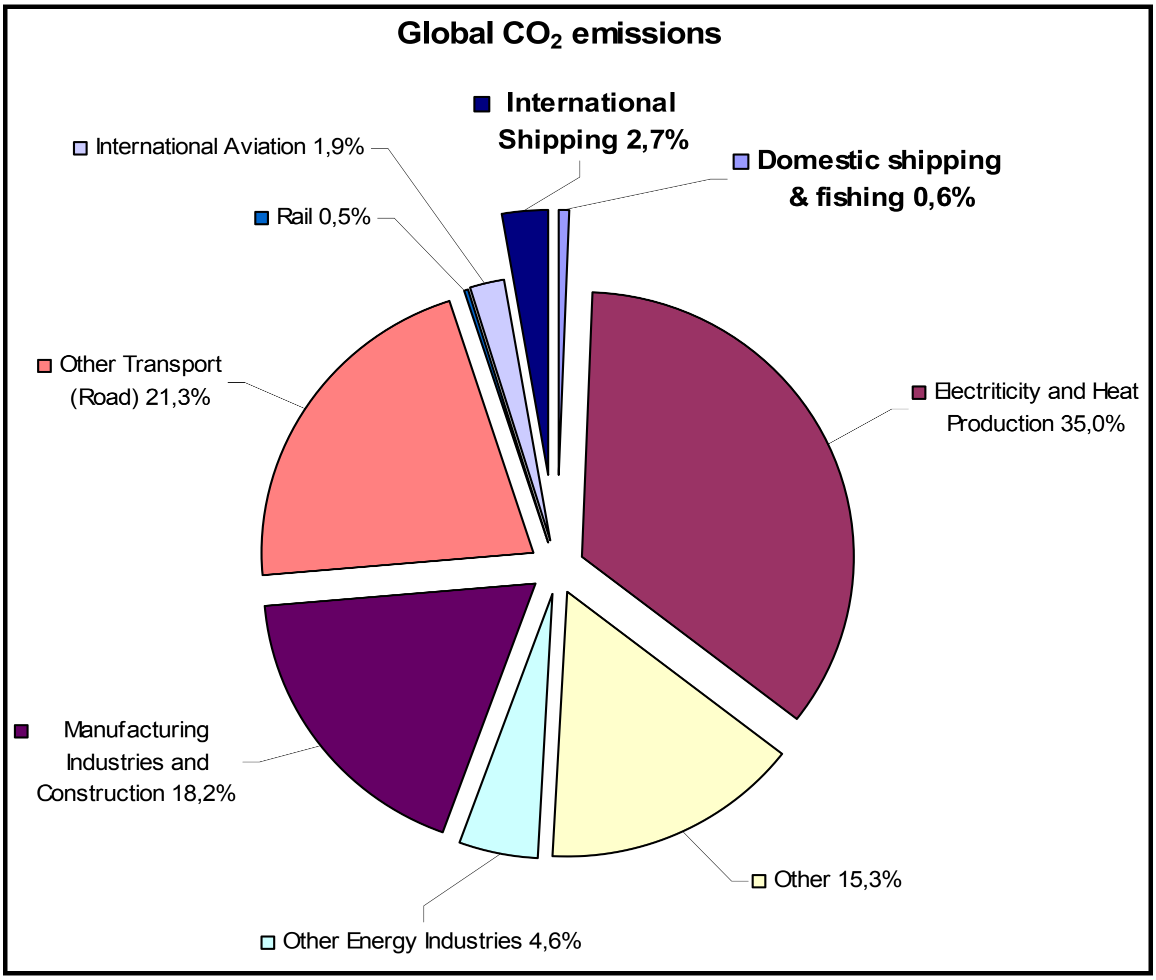
[3] The major inland navigation countries outside the EU, China, Russia and the USA, are far more sceptical of the need to reduce greenhouse gas emissions – at least when it comes to legally binding international agreements – than the member states of the CCNR and the EU.

3. The context of greenhouse gas emissions from inland navigation

In absolute terms, the greenhouse gas emissions due to inland navigation are very insignificant in comparison to the total amount of greenhouse gas emissions caused by transportation and even more insignificant in comparison to all anthropogenic greenhouse gas emissions. This is a result of the high energy efficiency of inland navigation and of its generally minor role in the traffic mix. However, the other carriers that compete with inland navigation are making advances in reducing their greenhouse gas emissions. If inland navigation wants to retain its competitive advantage as being “environmentally friendly”, it also needs to further reduce its greenhouse gas emissions.

It is difficult to establish the greenhouse gas emissions caused by transportation-related activities, which is why all of the details on this topic have inaccuracies (Miola, Ciuffo et al. 2010). The IMO’s second study of greenhouse gas emissions (Buhaug, Corbett et al. 2009) reached the conclusion that in 2007 about 27% of the total CO_2 emissions worldwide were due to transportation-related activities, with the emissions from shipping (marine, coastal and inland shipping) accounting for about 12% of this figure (see **Fig. 1**).

Figure 1: CO_2 emissions from shipping in comparison to total emissions worldwide (adopted from Buhaug et al. 2009)



It is impossible to derive the contribution towards CO_2 emissions made by inland navigation from the IMO's second study of greenhouse gas emissions. For the EU-27, the contribution made by inland navigation to total CO_2 emissions from land-based modes of transport is estimated to be less than 1% (Uherek, Halenka et al. 2010) The European Commission refers to a 1.8 % figure for 2008 (EU 2011d), with all modes of transport except the electric traction of railways serving as a reference.

It seems that the clear differences in the figures on the contribution towards emissions made by inland navigation (ranging from less than 1 % to 1.8 %) cannot be wholly explained by the different reference values used or the time periods considered.

The low proportion of emissions from inland navigation relative to the total emissions from transportation-related activities is due to its comparatively low contribution to transport service overall. Inland navigation is almost irrelevant for passenger transport and it only accounts for about 6% of all goods traffic in the EU-27 by land-based modes of transport (tkm). However, the contributions to transport service and thus to emissions vary considerably among countries. In the Netherlands, which is the leader in this respect, almost 40% of transport-related activities is accounted for by inland navigation (Eurostat 2009).

Whereas the absolute amount of CO_2 emissions due to inland navigation is uniformly presented as being extremely low in comparison to other carriers by all studies, this does not apply to the specific emissions (g/tkm). For instance, some studies consider electrified goods transportation by rail to be significantly cheaper than inland navigation (den Boer, Otten et al. 2011); (McKinnon and Piecyk 2010). But other studies here too indicate significantly lower values for inland navigation (PLANCO 2007). An in-depth comparison of the specific emissions from various modes of transport can be found in **section 5.2** of this report.

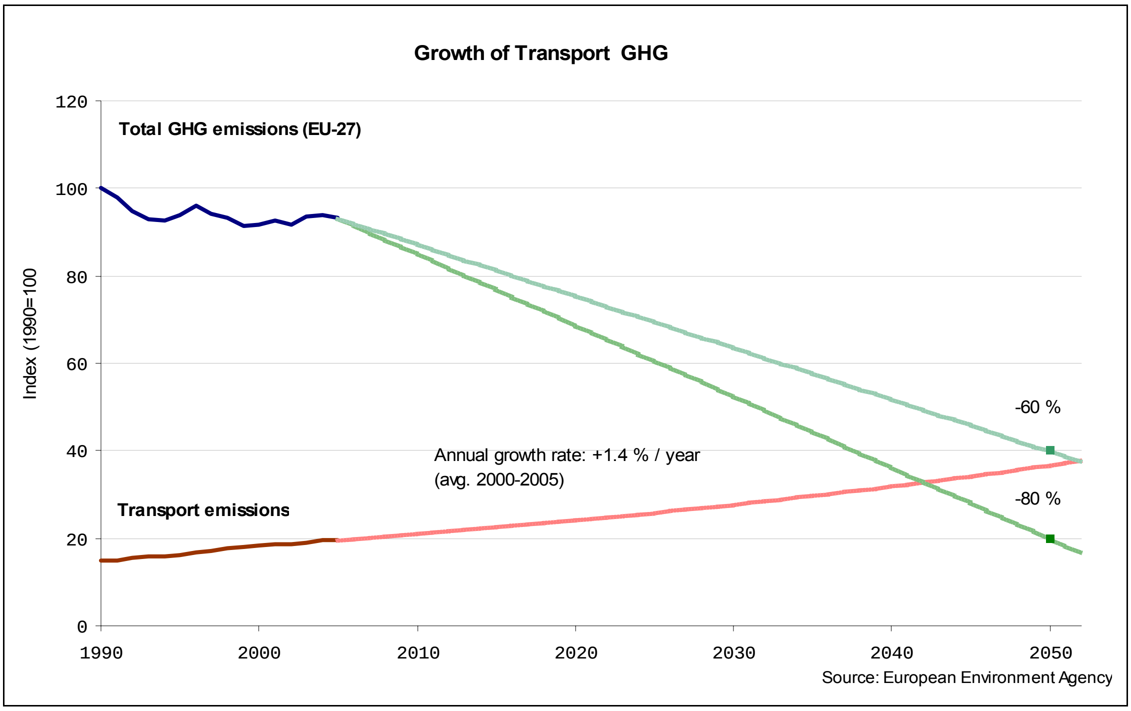
The other modes of transport that compete with inland navigation make use of ways of cutting greenhouse gas emissions that are not available to inland navigation. Railway companies, for example, can make use of electricity generated using wind or hydroelectric power plants, further cutting the CO_2 emissions of the railways (Essen, Rijkee et al. 2009). For example, with driver training and increased recuperation of train braking energy, the German national railway company (Deutsche Bahn - DB) aims to reduce its global CO_2 emissions by 20% between 2006 and 2020 (Müller-Wondorf 2012). Road vehicles are subject to rapid model changes, allowing them to rapidly implement new technical developments. Although road haulage has not yet been able to catch up with rail and inland navigation in terms of its specific emissions yet, it has nevertheless been able to significantly reduce the gap, making lorries increasingly competitive not only in terms of pollutant emissions, but also in terms of greenhouse gas emissions (Spielman, Faltenbacher et al. 2010).

When comparing various modes of transport, however, it is always necessary to take into account that the energy consumption resulting from transportation and the related emissions depend on a large number of factors, some of which are very specific to the case in point. This results in transport scenarios for every mode of transport for which these are better or less good. It is therefore not possible to draw meaningful comparisons based either on highly aggregated emission data, or on data for specific means of transport for unrealistic transportation applications. The former do not permit any worthwhile conclusions to be drawn for specific transportation applications, whilst the latter are misleading. They are also both no use for comparing traffic and environmental policy. It only appears worthwhile to draw comparisons between specific and real-life transportation applications. Such comparisons can be found both in studies (PLANCO 2007) as well as in quotations from shippers (Contargo 2011).

4. Objectives of the international community and the member states of the CCNR as well as the inland navigation industry with regard to the reduction of greenhouse gas emissions from the transport sector and from inland navigation

A continuous increase in greenhouse gas emissions from the transport sector would undermine the global emission reduction targets set by the EU, as shown in **Figure 2**. It is therefore necessary to take action to bring greenhouse gas emissions from transportation into line with the global climate protection goals. Such quantification is objective, especially due to the incomplete data on current emissions, the options for lowering emissions as well as overall the economic development of a complex undertaking. Such quantification of the targets would, however, be helpful for all those involved, as it would minimise uncertainty and allow them to bring the political, economic, technological and all other processes into line with this target. The need for quantification of the targets and the necessary methodology required for setting and achieving the climate protection goals have already been confirmed by the OECD at the ministerial level. Since the member states of the CCNR are responsible for about three quarters of the transport-related activities and thus the greenhouse gas emissions from inland navigation in the EU, it is obvious for these states to take a leading role, together with the CCNR, in drawing up concrete climate protection goals for inland navigation.

Figure 2: Progression of the total emissions in the European Union in comparison with extrapolated emissions from the transport sector



In its white paper “Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system” (EU 2011) the European Commission found that a reduction of at least 60% of the absolute quantity of greenhouse gas emissions from the transport sector is necessary by 2050, relative to 1990 (70% compared to 2008) . The 60% emission reduction target does not cover the maritime sector. The target for maritime shipping is therefore given separately.

The reduction target for EU CO_2 emissions from maritime bunker fuels is 40% by 2050 (50%, if feasible) relative to 2005. It remains unclear, from the white paper, whether each transport sector, i.e. including inland navigation, has to meet this target and whether this relates to the specific emissions, in other words in terms of the total traffic & transport volume, expressed in g of CO_2 per thousand km, or to the absolute amount of emissions. This is a matter of critical importance, especially given the significant increase in total traffic & transport volume accounted for by inland navigation assumed in the White Paper. In early 2011 the European Commission clarified this issue at the request of the Secretariat of the CCNR: The 60% emission reduction target refers to the absolute amount of emissions. This does not mean, however, that each mode of transport has to cut its emissions by 60%. In part due to the reasons outlined above, and also taking the peculiarities of each mode of transport into account, some modes of transport will have to cut their emissions more than others. Nevertheless, a significant contribution is required from every mode of transport. If the absolute amount of greenhouse gas emissions from inland navigation is to be reduced by 60%, in line with the general reduction target for the transport sector outlined above, and if one assumes that the traffic & transport volume accounted for by inland navigation continues to increase, then the specific emissions need to fall by more than these 60%. The additional amount by which the specific emissions need to fall by depends on the growth in the traffic & transport volume. If, for example, the traffic & transport volume in the period under consideration increases by 50%, then the specific emissions no longer need to decrease by 60%, but by over 70%. This interrelationship is shown in **Annex 13**, illustrated by a number of different scenarios.

The EU Transport Council basically welcomed the white paper published by the European Commission, but put some of the targets it contained into perspective. On the occasion of its meeting in June 2011 some members of the delegations described the targets as indicative and very ambitious (EU 2011).

In addition to the white paper, the EU has set a number of other targets for reducing greenhouse gas emissions in the transport sector. These are listed in the recitals of Directive 2009/33/EC[4] on the promotion of clean and energy-efficient road transport vehicles, as the basis for the adoption of legislation at EU level.

The member states of the CCNR are also pursuing the goal of reducing their anthropogenic greenhouse gas emissions, including those from the transport sector. In addition, some states have established quantitative targets for the transport sector as a whole. As these are developed further, they may specify application to inland navigation (see **Annex 2**).

The lack of quantification of the emission reduction targets set by the states is astonishing, since the Ministerial Council of the European Conference of Ministers of Transport already established in May 2000 that the first step towards an economic reduction in emissions requires an accurate quantification of the anticipated reduction in emissions resulting from the measures already initiated or proposed. The process for achieving this was reported to already have been initiated by most of the member states (CEMT 2000). The methods used for arriving at the climate protection goals in the transport sector, the quantification thereof and their implementation are given in Directives passed by the Minister for the Environment of the OECD (OECD 2002).

[4] Directive 2009/33/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of clean and energy-efficient road transport vehicles

The European shipping industry associations have, on contrast to the member states of the CCNR, quantified their target for reducing CO_2 emissions from inland navigation as 50 - 70% by 2050 (INE, EBU et al. 2011). It is safe to assume that this refers to the absolute amount of emissions. At the same time, the associations propagate an increase in the proportion of the modal split accounted for by inland navigation. In order to achieve the emission targets under these conditions, the shipping industry would have to cut the specific emissions (in relation to traffic & transport volume in tkm) even more drastically than the absolute amount. The objective does not provide any information on which year is to be taken as the basis year for the reduction target. Here one may assume that it is 1990, the year taken as the reference year in the white paper published by the European Commission, as the communication refers directly to the work done by the European Commission.

The scope of the emission reduction potentials for inland navigation also depends on the specific conditions on the waterway in question. Large waterways allow large vessels or convoys, which in turn generally lead to lower specific emissions. It should therefore be much easier to meet ambitious emission reduction targets on the Rhine and other large waterways of a comparable size than on waterways with a much narrower profile.

The Supreme Court of the USA has accepted a claim for damages due to greenhouse gas emissions. At present it impossible to predict whether the court will find the emitter liable for the damage caused by climate change (Eder 2011). If it does, this could have an impact far beyond the USA. In particular, such a judgement could be expected to give an additional boost to the reduction of greenhouse gas emissions, since the emitters would want to avoid the risk of claims for damages.

5. Carbon footprint and specific CO_2 emissions (CO_2 intensity) from inland navigation and other land-based modes of transport

This part of the report deals with the carbon footprint, the climate footprint of inland navigation. First of all, the current knowledge on the carbon footprint of inland navigation is explained, after which it is compared with other modes of transport. Finally, and in the light of current events, we will then look at the standardisation of the method used to calculate and declare greenhouse gas emissions generated by transport services.

5.1 Methods for calculating the carbon footprint and specific CO_2 emissions from inland navigation

For cargo transport, the CO_2 intensity of a given mode of transport can be presented via its CO_2 emissions in relation to its transport performance. This is largely done in g/tkm, but g/TEUkm can also be used. This ratio is often also referred to as the CO_2 emission factor. As is also the case for other modes of transport, the CO_2 intensity is the key element for determining the carbon footprint of inland navigation. Many studies have attempted to quantify the CO_2 intensity of inland navigation. However, the range of values resulting from these studies is so broad that they neither allow the carbon footprint of inland navigation to be determined reliably for the purposes of transport or climate protection policy, nor is it possible to accurately derive the CO_2 emissions of logistics chains. This raises the question of the quality of the output data used for calculating a model using emission factors. The emission factors available or to be re-developed should therefore be checked using the data from inland navigation companies on fuel consumption and the total transport performance of various vessel types in conjunction with the transport statistics recorded by the CCNR. On this basis it should be possible to draw up reliable and generally acceptable figures on CO_2 emissions from inland navigation.

The challenges to be overcome in determining the CO_2 emissions from inland navigation are addressed in the conclusions of the CCNR workshop on this topic held in Strasbourg on 12 April 2011 (de Schepper 2011):

- There is a broad range in CO_2 emission factors due to different parameters, values and methodologies.
- Current approaches still have limited scope due to knowledge gaps.
- It is a complex field in development.
- There is a need for 3 types of methodologies:
  1. Assessment of fuel consumption by ships (based on real values/EEOI[5]);
  2. Carbon footprinting for logistics decision-making (multimodal) and sector decision-making (intra-modal) – CEN standard;
  3. Method for policy development and decision-making.
- EU level expert exchange, research and neutral validation is needed for more detailed and accurate IWT emission relevant data and emission factors, which are generally accepted through stakeholder validation.

These results of the discussion are the starting point for the explanations in this report on the methods used to calculate the carbon footprint and the specific CO_2 emissions from inland navigation. The main focus of this report is the method used to determine the CO_2 emissions used for making political decisions. Nevertheless, the report also looks at the methods used for other use cases, which were identified at the CCNR workshop.

Accurate determination of the actual fuel consumption – and thus indirectly the CO_2 emissions – is probably the most important way in which ship owners can reduce their fuel consumption by optimising their operations. **Section 13.2** and, in particular, **Annex 11** of this report go into this in greater depth. Determining the actual fuel consumption allows ship owners to perform benchmarking within their own fleet and in comparison to other shipping companies. At the same time, knowing the actual fuel consumption acts as a basis for determining the CO_2 emissions in the context of logistical or political decision-making.

Determining the CO_2 emissions for logistical decision-making is of great importance to companies. For example, about two thirds of about 170 companies, with a total turnover of approx. 450 billion euros, including shipping agents and providers of services from every sector, surveyed in September and October 2009, said that recording (and reducing) CO_2 emissions was very important (Wittenbrink and Gburek 2009). Apart from that, the carriers' customers expect information on the CO_2 emissions that the transportation of their goods generate, in order to use this for their environmental or sustainability ratings. Take, for example, BASF, the world's largest chemical company and a very important customer of the inland shipping industry. BASF balances its greenhouse gas emissions along the entire value chain[6] and was thus able to discover that greenhouse gas emissions amounting to approximately 4 million tons of CO_2 equivalents are produced by the transportation-related activities that can be traced back to it.

[5] Energy Efficiency Operational Indicator, see Annex 11
[6] http://www.basf.com/group/corporate/en/sustainability/environment/climate-protection/bilanzierung-treibhausgasemissionen

Various automated methods are available for calculating the emissions from transportation. Perhaps the best known method in Europe for the transportation of goods is EcoTransIT[7]. This method, which was developed by the major European rail companies and is available to the public, makes it possible to calculate the emissions depending on the mode of transport used. This involves the various modes of transport entering a virtual ecological competition. The greater the importance of this method for making logistical decisions becomes, the greater the interest in the various transport sectors should be in keeping their emissions low and that the models reflect the emissions as accurately as possible. A precondition for this is having scientifically validated data and emission factors that are accepted by the various sectors of the industry. As was discovered at the workshop held by the CCNR, this is not yet the case from the point of view of the European inland shipping industry.

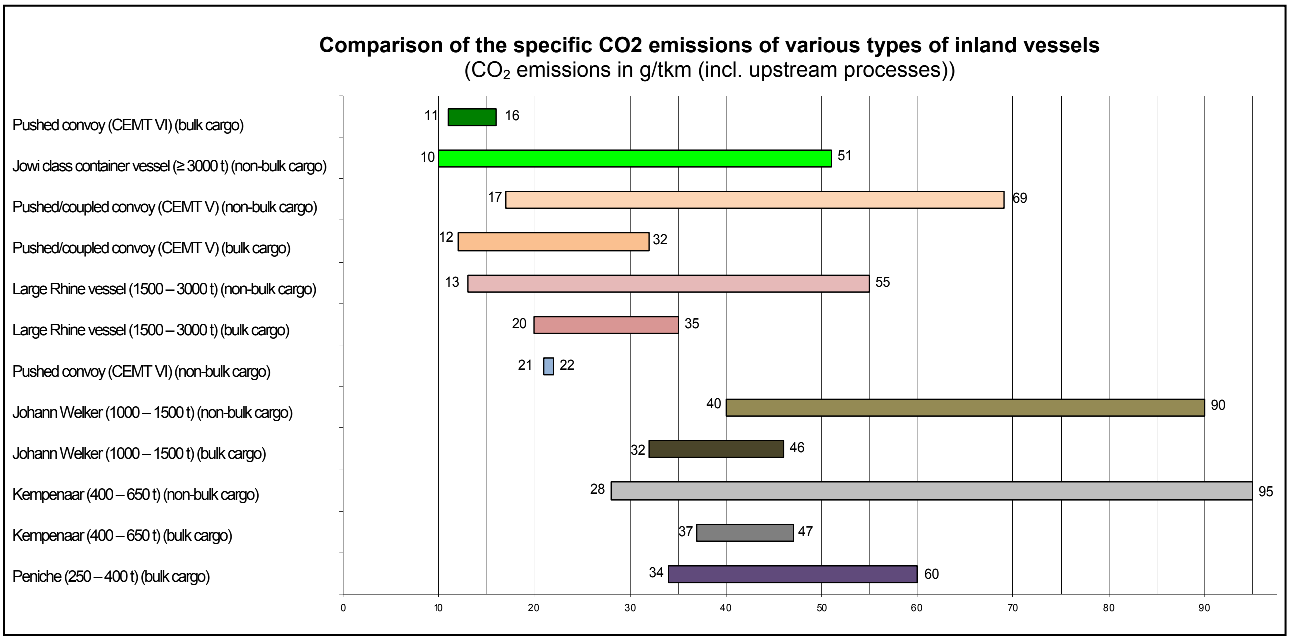
In terms of the calculation methods mentioned above, the standardisation of the method used for calculation and declaration of greenhouse gas emissions from transport services is currently underway. On the one hand, this standardisation is a big step in the direction of unified processes, although, on the other hand, it does not, in itself, provide any CO_2 emission factors. Rather, we need to generate artificial emission factors here, in order to be able to calculate and declare the greenhouse gas emissions from transport services. **Section 5.3** of this report deals with this standardisation in greater depth.

Many studies have attempted to determine the CO_2 emission factors and the CO_2 intensity of inland navigation. Studies that only give <u>one</u> average value appear to be fundamentally useless, unless this value is based on the actual fuel consumption of the fleet in question. Alternatively, it would also be possible, in theory, to determine the CO_2 intensity for each type of vessel and then to determine the total on the basis of the individual traffic & transport volume of the various types of vessel, but there are no such studies available.

Studies which derive the emission factors for as many types of vessel as possible – possibly even differentiating between the different areas in which they sail – are much more informative. **Figure 3** provides a summary of the CO_2 intensity (CO_2 emission factors) for various types of vessel, taking the upstream processes involved in producing fuel (well to wheel) into account. The figures given in this figure are taken from studies that provide a sufficiently differentiated view of the various vessel types. (An in-depth analysis of these and other studies as well as a much more detailed table can be found in **Annex 3**.) The very broad range of values for the CO_2 intensity (CO_2 emission factors), with some varying by as much as 5 times for an individual vessel type, and by as much as 10 times over the entire range of vessel types, is noticeable, however. This can be seen as an indication for the fact that different calculation methods were used and that there are still large gaps in knowledge and in the data.

7 http://www.ecotransit.org/

Figure 3: Figures for the CO_2 intensity (CO_2 emission factors) of inland navigation from selected studies, taking into account the upstream processes involved in producing fuel ((Schilperoord 2004; ADEME 2006; PLANCO 2007; den Boer, Otten et al. 2011)



This broad range of figures also means that it is impossible to derive a more or less reliable mean value for the CO_2 intensity of inland navigation from these figures. Details on the absolute carbon footprint of inland navigation based on the findings of these or other similar studies are thus unlikely to be very significant and should essentially be considered as rough estimates.

Is there a practicable way of determining the carbon footprint of inland navigation – not only for single transport operations, as has already been done (PLANCO), but in toto – with adequate accuracy? **Annex 3** describes one possible approach, which consists primarily of the following steps:

- Verification of the emission factors given for each vessel type for the relevant area;
- Determination of the total traffic & transport volume for each vessel category (all of the vessels belonging to one type) in the relevant area;
- Determination of the carbon footprint for each vessel category by multiplication of the total traffic & transport volume for the vessel category by the emission factor for the vessel type and with due regard to capacity utilisation;
- Addition of the carbon footprint of all of the vessel categories represented in a given area.

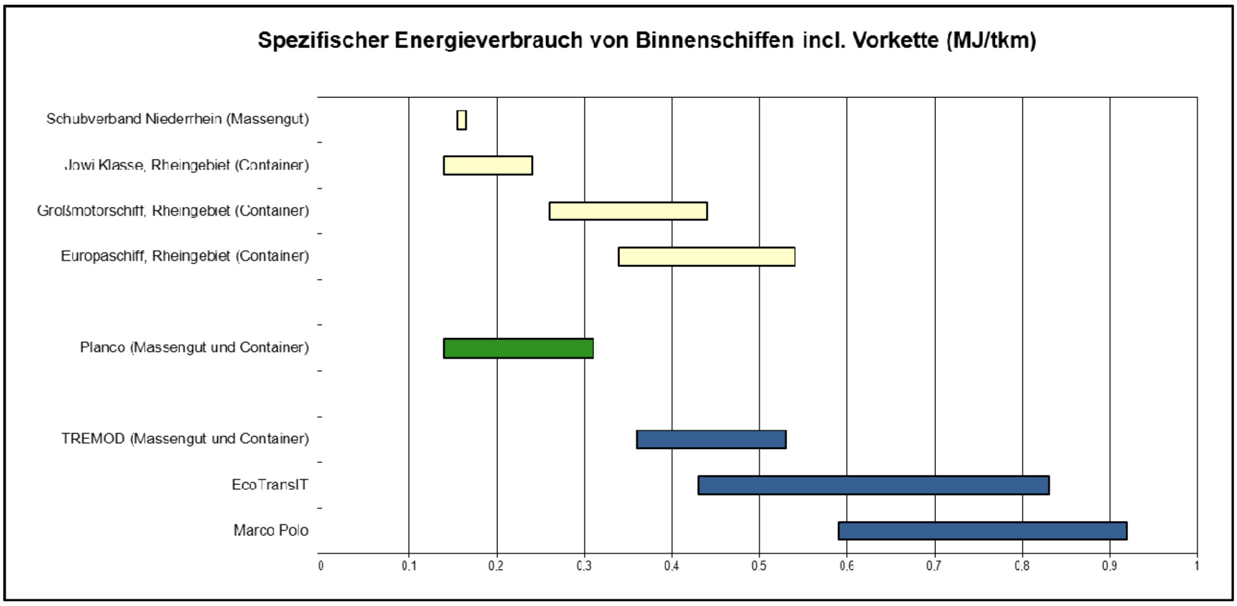
As was ascertained at the workshop held by the CCNR, this approach would need to incorporate all those involved and include neutral validation. The CCNR could play a fruitful role in this, as it, with its various bodies, can contribute technical expertise in every area of inland navigation, has the necessary working relationships with industry associations and companies and, in particular, has a plentiful supply of relevant statistics on traffic and fleets. In the broader sense, this could also be taken to include the data gathered in the context of the Convention on the collection, deposit and reception of waste produced during navigation on the Rhine and inland waterways (CDNI). It would need to be checked whether the emission factors and the overall fuel consumption of European inland navigation could be extracted from this data.

The United Nations Economic Commission for Europe (UNECE) is currently developing, as part of an ambitious project, an information and analysis tool (ForFITS) for modelling CO_2 emissions of all modes of inland transport. The tool should make it possible to report not only the scale of emissions but also to analyse scenarios and suggested strategies in transport policy[8]. In October 2012, UNECE submitted a comprehensive inventory on this (UNECE 2012). The document lists a large number of potential sources of data and models that could be relevant to this project. It was not however possible in this project to identify any procedure or study for determining the carbon footprint of inland navigation in Europe in keeping with the given premises. The project is scheduled for completion in 2013. It will then need to be checked whether the carbon footprint of inland navigation in Europe can be determined with an acceptable degree of accuracy using ForFITS, or at least whether ForFITS contains elements that can be used for this purpose.

Determining the carbon footprint and CO_2 emission factors for inland navigation is not just an end in itself. Political and business decisions are increasingly made on the basis of energy consumption and greenhouse gas emissions from the various modes of transport. For political decision-making, for example, mention may be made of the “Marco Polo Calculator” (Brons and Christidis 2011) and the TREMOD (Transport Emission Model) commissioned by the German Ministry for the Environment. The Marco Polo Calculator is used to compare the external costs of various modes of transport in the context of project proposals, with the results contributing to decisions on subsidies made by the European Commission. TREMOD is used for example in drafting legislation relating to the environment, and in meeting Germany’s international reporting undertakings in the field of energy consumption and transport emissions[9]. "EcoTransIT is aimed at company managers, logistics providers, advanced transportation planners, policy makers, normal customers, NGOs, shareholders and other interested parties for the calculation of the ecological impact of transportation via a particular route and the comparison of different transport solutions EcoTransIT"[10] (IFEU 2010). The emission data used by the Marco Polo Calculator, TREMOD and EcoTransIT are sometimes significantly higher than those determined in other relevant studies. The differences between these figures and real-life data provided by the shipping industry are even greater. **Figure 4** shows the reasons for this discrepancy: the Marco Polo Calculator, TREMOD and EcoTransIT are based on data for the specific energy consumption of inland navigation that has neither been verified in practice nor compared with a study based on real data. There is evidently an urgent need for action, if systematic penalisation of inland navigation due to inadequate data is to be prevented or at least reduced.

[8] http://www.unece.org/trans/theme_forfits.html
[9] http://www.ifeu.de/index.php?bereich=ver&seite=projekt_tremod
[10] http://www.ecotransit.org/

Figure 4: Example of comparison of data on the specific energy consumption of inland navigation vessels in studies and resulting from surveys carried out among companies (including upstream processes) (PLANCO 2007; IFEU 2011; Knörr, Heidt et al. 2011; Van Essen and den Boer 2012) (data provided by the companies)



5.2 Comparison of the specific CO_2 emissions from various modes of transport

Determining the specific emissions of a mode of transport is a complex matter involving a great deal of uncertainty. It is, therefore, even more difficult to compare with one another the emissions from different modes of transport. Yet, studies into the issue would appear to agree that the CO_2 intensity of inland navigation is of approximately the same magnitude as that of rail transport but far smaller than the one of road transport. At the same time it may be recognised that, under unfavourable circumstances, transport activities carried out by inland vessels or by rail can lead to higher levels of specific emission than certain types of transport provided by road vehicles.

Figure 5: Comparison of specific CO_2 emissions of various modes of transport (including upstream processes) (ADEME 2006; PLANCO 2007; den Boer, Otten et al. 2011)

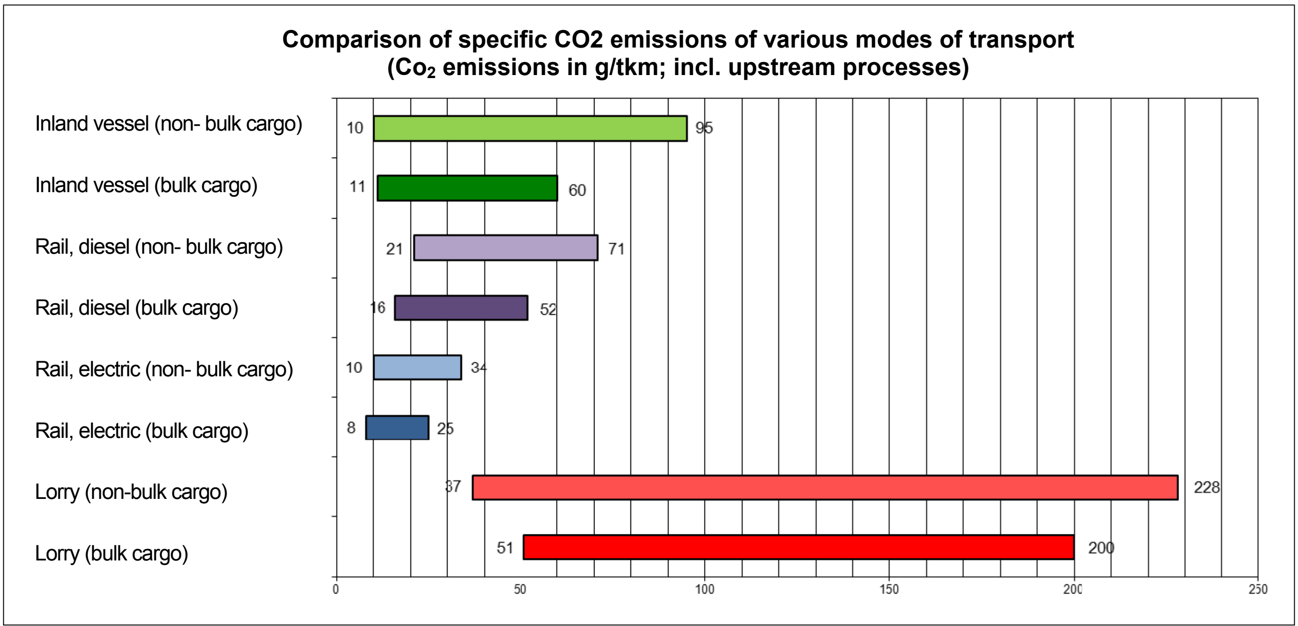


Figure 5 does not include rail transport using electric traction in rail networks where the electrical energy is generated almost exclusively by nuclear energy (which is the case in France). In that case the specific CO_2 emissions are even considerably smaller.

The facts presented above clearly show that shifting transport to waterway systems could contribute in general towards reducing greenhouse gas emissions, whereas individual cases need to be considered more closely to avoid shifts which might prove counter-productive. Refer in this connection to the details in **section 6** of this report.

5.3 Standardisation of the methods used to calculate and declare the greenhouse gas emissions of freight transport services

European standard EN 16258 : 2013 “Methodology for calculation and declaration on energy consumptions and GHG emissions in transport services (goods and passengers transport)” is to be published soon. It lays down a common methodology (general rules) for the calculation and declaration of energy consumption and GHG emissions in transport services. It applies to transport services of goods and passengers such as those provided by local public transport and rail companies or road haulage companies for their customers. The standard covers the terminology, guidelines, calculation methods and examples as well as specifications regarding declaration. It is based on a pragmatic and scientifically acceptable approach, which makes it applicable to a broad range of users. Potential users of this standard include individuals and organisations wishing to take recourse to a standardised methodology as the basis for quantification of the greenhouse gas emissions of a transport service, for example:

- Transport companies (passenger or goods transport),
- Transport service providers (logistics operators, travel agents), and
- Customers (loaders, passengers).

In principle, the calculation should be based on the actual fuel consumption. Where this is not possible, default values (emission factors in grams of CO_2 per ton-kilometre) may be used. These default values are not part of the standard, although sources on this subject are included in Annex I of the standard for information purposes. It may be that there are no sources cited in this annex which contain realistic default values for inland navigation or, in particular, navigation of the Rhine.

Only those emission factors that relate exclusively to the transportation process can be considered for inclusion in Annex I of the standard. Emission factors relating to transhipment or the initial and final journey, for example, cannot be taken into consideration.

An advance copy of the standard shows that Annex I includes sources with relatively high default values for inland navigation and in particular for navigation on the Rhine (ADEME 2006; Heidelberg, Öko-Institut et al. 2011). The inclusion of such values would be extremely disadvantageous for inland navigation, as stated in **section 5.1**.

The member states, and more particularly the associations of inland navigation operators, were given the opportunity to state their positionso that due attention would be paid to inland navigation in the final version of the standard. It would appear, however, that this opportunity was not taken up.

6. Fundamental strategies for reducing greenhouse gas emissions from transport

Basically, there are the following strategies for reducing greenhouse gas emissions from the transport sector (UNEP 2011):

1. Reducing traffic volume,
2. Shifting traffic to more environmentally friendly modes of transport,
3. Reducing specific emissions.

This present report only deals with the third strategic option, which is looked at in greater depth in the sections below. Option 1 may result in a restriction in demand for transportation by inland navigation. Option 2 would only be beneficial for the inland navigation industry if it could continue to achieve significant success in reducing its greenhouse gas emissions.

A reduction in traffic volume could be achieved by bundling shipments and by means of spatial planning measures that relocate the production of goods so that it is closer to the customer of those goods. Bundling of goods for shipping is generally good for the shipping industry, since it primarily has an advantage when it comes to transporting large quantities. However, bundling of goods would probably only be worthwhile for shipments in a close radius, for example for deliveries in urban areas, which is an area in which inland navigation only plays a very minor role.

Spatial planning measures that aim to move production closer to the end user could, on the other hand, have a greater impact on inland navigation. The rising cost of energy and the need to cut greenhouse gas emissions from maritime shipping significantly will drastically increase the cost of intercontinental transportation. This is likely to make international division of labour less attractive and will thus not be without consequences for the volume of goods handled by seaports. We anticipate that this would have a negative impact on the cargo volume of navigation on the Rhine, since the origins and destinations of the goods carried on the Rhine are primarily seaports.

Shifting traffic to more environmentally friendly modes of transport in order to protect the climate would, on the other hand, probably be generally good for inland navigation, since it is fundamentally more energetically favourable than other modes of transport. Regardless of this, each case should nevertheless be considered individually, as energy consumption is affected by very many factors, as illustrated in **Figure 8**. Even the application of an average value for the CO_2 emissions of inland navigation is not an effective solution, as the broad spread of specific CO_2 emissions of inland navigation vessels illustrated in **Figure 3** shows. In Germany, comparisons between various modes of transport have been carried out on selected transport routes. These show not only that there are of course types of transport for which inland navigation cannot make full use of its fundamental advantages because of the factors referred to above (Spielman, Faltenbacher et al. 2010), but also that even outside the Rhine basin inland navigation is often the best choice, particularly in comparison with road transport (PLANCO 2007).

Traffic shifting to protect the climate would depend on inland navigation keeping or even building on its current advantage when it comes to specific emissions, which can only be achieved if it continues to reduce its greenhouse gas emissions, as the other modes of transport that compete with it are making progress in cutting their emissions (see **section 3** of this report). Looking at the overall situation, the motivation for a switch in the mode of transport due to ecological considerations is likely to become less significant, as every mode of transport becomes "cleaner" and "safer" (Essen, Rijkee et al. 2009). Inland navigation would thus have to raise its profile as the environmentally sustainable mode of transport far more than it has been able to so far, in order to actually benefit from a switch in the mode of transport made for ecological reasons.

Possible ways of reducing the specific emissions from inland navigation - strategy option 3 – are described in **sections 9 - 11** of this report. A summary of this and other possible areas in which navigation on the Rhine and inland navigation can contribute towards a reduction in greenhouse gas emissions have already been presented by the CCNR in its Resolution 2008-I-12. An updated version of this summary can be found in **Annex 4**. The areas of influence identified there make it clear that it is not only technical measures involving the vessels themselves, i.e. their design and equipment as well as the operation of the vessels and the fuels used that have an influence on the greenhouse gas emissions from inland navigation, but that the design of the waterways and the ports also have an effect on the level of emissions. These aspects could be the subject of future study.

7. Potential for the reduction of fuel consumption and CO_2 emissions from maritime shipping

For maritime shipping, the intensive research that has been carried out in the past few years on the potential for reducing fuel consumption and CO_2 emissions (Buhaug, Corbett et al. 2009) has been much more comprehensive than has been the case for inland navigation to date. The IMO has found that there are a large number of ways of increasing energy efficiency and reducing emissions by changing ship design and ship operating procedures. A summary of the estimated potential for reducing CO_2 emissions is shown in **Table 2**.

Table 2: Estimated potential for reducing CO_2 emissions from maritime shipping by the use of known technologies and practices (IMO 2009)

Measures		**Savings CO_2/tkm**	**Combined**	**Combined**
Design (new ships)	Design, speed & performance/carrying capacity	2% - 50%[+]	10% - 50%[+]	25% - 75%[+]
	Hull & superstructures	2% - 20%		
	Power & propulsion systems	5 - 15%		
	Low-carbon fuels	5 - 15%*		
	Renewables	1% - 10%		
	CO_2 reduction of the exhaust	0%		
Operation (all ships)	Fleet management, logistics & incentives	5% - 50%[+]	10% - 50%[+]	
	Journey optimisation	1% - 10%		
	Energy management	1% - 10%		

[+] Savings on this scale would require a reduction in operating speed

* CO_2 equivalent, based on LNG

The Joint Research Centre (JRC) of the European Commission has looked at these measures in greater depth, from the point of view of regulating pollutant and greenhouse gas emissions (Miola, Ciuffo et al. 2010). Maritime and inland shipping operate under very different conditions in a number of ways, as explained below. It is therefore only possible to transfer the measures identified for maritime shipping and apply them to inland shipping after careful examination. Comparison with the estimated potential savings for inland navigation set out in **Table 3** shows that taken together the potential savings in inland and marine navigation appear to be broadly similar.

8. Operating conditions with regard to the ways of reducing fuel consumption and CO_2 emissions from inland shipping

In view of the options for reducing fuel consumption and CO_2 emissions, inland navigation is limited by special factors that play no or only a much more minor role in other modes of transport, including maritime navigation. These limiting factors need to be recognised and considered in determining or reducing levels of fuel consumption and CO_2 emissions in inland navigation.

Inland vessels navigate relatively shallow waters and are consequently subject to the laws of shallow water hydrodynamics. This fact determines to a large extent the power requirements of inland vessels and thus also the amount of fuel consumed and CO_2 emitted. The applicable laws are explained in the following by referring to examples:

- A vessel's power requirements are determined largely by the distance between the keel and the bottom of the waterway. The greater this distance, which is referred to as underkeel clearance, the lower the power requirements. To illustrate, when the water depth is increased from 4 m to 4.5 m, the power requirements of a large motor vessel of the kind typical for the Rhine decrease by about one third (vessel speed: 16 kph; loaded draught: 2.5 m) (PLANCO 2007).
- The speed of an inland vessel is a key determinant of the ship's power requirements. The large motor vessel cited above, with a loaded draught of 2.5 m, requires 500 kW in a water depth of 5 m in order to achieve a speed of 17 kph. When the speed is reduced by only about 15% to 14.5 kph, it requires only half as much power (Renner and Bialonski 2004). In other words, a minimal reduction in speed results in a substantial reduction of power requirements and subsequently of fuel consumption[11].
- If, on the other hand, the power used for the inland vessel is kept constant, the ship achieves a greater speed as the underkeel clearance increases. A large motor vessel with a loaded draught of 2.5 m achieves a speed of about 6 kph when powered by 200 kW in a water depth of about 3 m. Yet the speed increases to about 13 kph at a water depth of 5 m. These two effects become more pronounced as underkeel clearance decreases (PLANCO 2007).

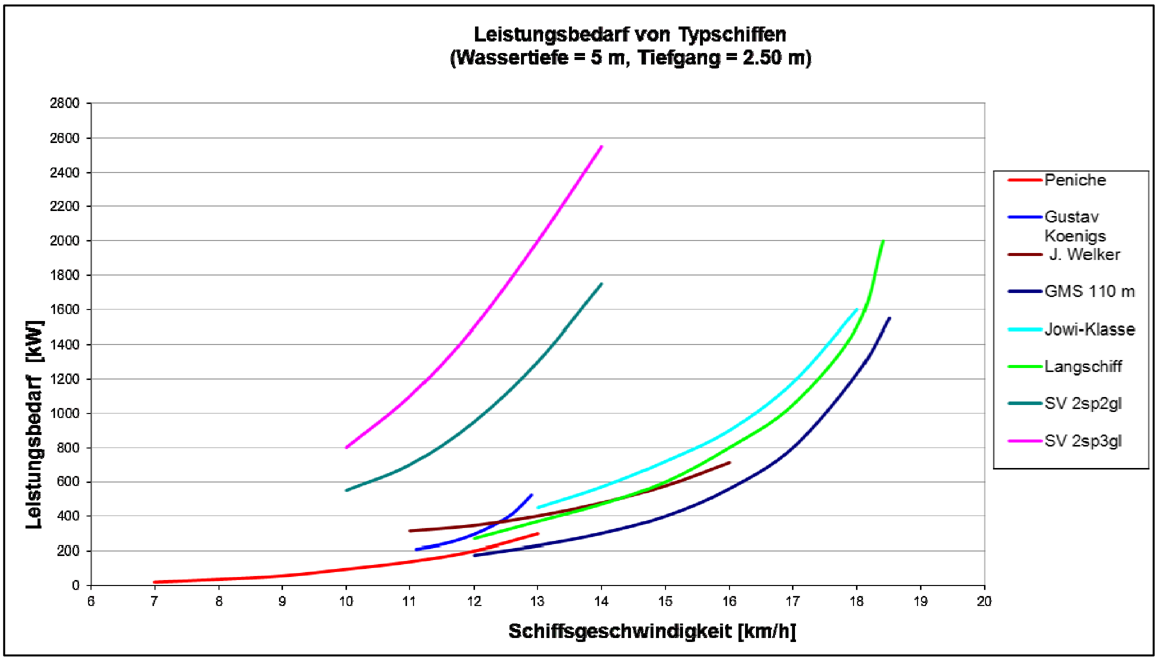
From the first law described above it is evident what a determining influence water depth has on fuel consumption as well as on CO_2 emissions in inland navigation. Deep waters and well-maintained waterways without shallow sections contribute towards inland shipping becoming more energy efficient and climate-friendly. The second law described above shows the disproportionately great influence of speed on fuel consumption, and consequently the lowest possible speed should always be selected in order to reduce fuel consumption. The third law described above defines the premises for selecting the speed of inland vessels in dependence of water depth in order to achieve optimum energy efficiency: slow speeds where only little underkeel clearance is given, and a speed that is great enough to allow the ship to just meet on schedule any specified arrival time with a large amount of underkeel clearance. There are practical limits, nevertheless. While free-flowing rivers with varying cross-sections and water depths offer considerable possibilities for optimum navigation in terms of energy, this is not so true of canals with a constant cross-section and water depth, and speed limits.

[11] The exaggerated influence of speed on power requirements becomes more marked as the vessel nears its maximum possible speed. The maximum possible speed of a given vessel depends more particularly on the water depth: the less the depth, the lower the maximum possible speed (in kph). Since inland navigation vessels, for economic reasons, try to make the best possible use of the water depth, this often results in in land navigation vessels operating at limited depths. Consequently, the effect described here is extremely important in practice.

The greater the vessel's carrying capacity, the lower are its power requirements per tkm as a rule. This law can be observed for all modes of transport. Yet, the following phenomenon can be observed only for inland navigation: where underkeel clearance is very high, the power requirements of a large vessel transporting a large amount of cargo can even be smaller in absolute terms than those for a smaller vessel. Specifically, a large motor vessel requires only 230 kW to transport a cargo of 1900 t in a water depth of 5 m at a speed of 13 kph, whereas a smaller ship, of the vessel type "Johann Welker", has a power requirement of 420 kW when transporting only 1250 t (Zöllner 2009).

Figure 6 illustrates the relationship between the power requirements – and hence the CO_2 emissions – of typical inland navigation vessels and vessel speed.

Figure 6: Power requirements of standard vessels in relation to vessel speed (Zöllner 2009)



The specific aspects mentioned above applying to inland navigation need to be considered when calculating the emissions it produces, be it greenhouse gases or air pollutants. If this is not done, the fact that in inland navigation the emissions are especially dependent on the size of the transport unit cannot be duly taken into account. Erroneous conclusions concerning the emissions from inland navigation would be the result.

For the reasons mentioned above, in order to reduce fuel consumption and CO_2 emissions it is important to use the largest possible transport units in inland shipping if there is sufficient demand for transport, even more than in other modes of transport. Yet, at least for European waterways, maximum permissible ship dimensions vary considerably. While on many canals in France only vessels with a carrying capacity of less than 400 t can be operated, pushed convoys with a maximum load capacity of more than 15,000 t operate on the lower Rhine. Even larger convoys are found on the Danube or on the waterways in the United States.

Waterway water levels often vary considerably, except in the case of canals and rivers regulated by barrages. At low water levels, large inland vessels (which generally have a deeper draught) are not able to utilise their enhanced efficiency, or only to a small extent. Where the water depth is limited, certain types of vessels, such as the Elbe pushed convoy (*Elbeschubverband*), offer advantages. In deeper waters, however, these types of vessels are much less energy-efficient (Renner and Bialonski 2004).

This fact has far-reaching implications for inland vessels which sail on waterways with varying water levels or which during one voyage sail on waterways with different water depths. If such vessels are to consume as little fuel as possible and produce the smallest possible amount of CO_2, the shape and dimensions can only be defined in terms of the best possible compromise.

Yet, as a result of the waterway profile there are limits not only to the length, width and draught of inland vessels but also to the their height, specifically to the load height. The latter factor accounts to a large degree for the specific fuel consumption and for the specific emissions of inland vessels carrying containers. Consequently, the specific emissions of container transports on the section of the Rhine to Basel, where containers can be stacked only three high, are much higher than for container transports downstream from Strasbourg, where inland vessels are able to be stacked in five layers due to the greater amount of vertical clearance under bridges. Compared with the free-flowing sections of the Rhine, the specific emissions of container transports are twice as high between Hamburg and Berlin, for example, where containers can be stacked in only two layers (PLANCO 2007). Besides vertical bridge clearance, other factors play only a minor role in container transport. This fact is revealed by a comparison of the specific emissions of bulk cargo transports within the same area. Specifically, the differences among specific CO_2 emissions within the same area are much more minor (PLANCO 2007). Stated in other terms, vertical bridge clearance limits to a great degree the potential for reducing specific CO_2 emissions in container shipping since this parameter is a determinant of maximum capacity utilisation.

In summary, it may be observed that waterway parameters have a crucial influence on fuel consumption and emissions from inland navigation. The largest possible vessel cross-section dimensions are required in order to achieve low fuel consumption. Where, in contrast, small waterway cross-sections exist, only limited potential is available for decreasing energy consumption. Of course, the waterway authorities and the shipping industry are familiar with these interrelationships and react to them with a number of different measures.

- The waterway authorities:
  - Enlarge locks or remove other bottlenecks so that the affected waterways can at least be navigated by the most energy efficient large motor vessels,
  - Allow larger vessels to navigate waterways without changing the waterway parameters, if necessary subject to technical or operational safety requirements,
  - Raise bridges in order to increase the number of layers of containers that can be transported on vessels.
- The shipping industry is increasingly adjusting the dimensions of vessels to suit certain regions or cargos, permitting particularly economic and energy efficient types of vessel, for example, vessels over 110 m in length. Although these vessels are unable to navigate all of the waterways in Europe, they are able to operate in the major shipping market, i.e., the Rhine watershed. It is ships of such a size that have dominated the new vessel market in recent years.

The details above make it clear that the importance of the “universal ships”, which are able to navigate almost any inland waterway in Europe due to their limited size, is on the decline. This also becomes clear from the constant rise in the average carrying capacity of inland vessels, as shown in **Annex 7**.

However, there may be a conflict of ecological targets with these larger vessels, as their use may increase the pressure on the aquatic environment. If waterways are constructed to allow the passage of these larger vessels, this will often have a serious effect on the natural environment. As a result, if the conditions for transport using larger vessels are to be created, an assessment of the ecological impact of the project must always be carried out. In the meantime, procedures have nevertheless been developed and have been partly implemented, so that the pressure on the aquatic environment is limited as much as possible and so that even the larger vessels used in inland navigation do not run counter to the targets of a sustainable transport system (Pauli 2010).

As stated above, using conventional fuels, climate-friendly transport cannot be achieved on waterways such as the traditional French canal system, where parameters are highly limited. In order to reduce CO_2 emissions on small waterways, it is particularly appropriate to use fuels such as highly developed biofuels, which produce low levels of greenhouse gas emissions, and to make use of renewable sources of energy. An example, albeit somewhat unorthodox, to illustrate this would be the so-called *Bierboot* (de Jong 2010).
This shows that for small inland vessels environmentally and climate-friendly technologies developed for other applications can be used. Especially hybrid propulsion systems as produced for large road vehicles, which have similar power requirements, seem to be predestined for this purpose.

The CCNR has not been insensitive to the economic and ecological advantages of larger vessels and has for example allowed the navigation of vessels with a length exceeding 110 m on the whole Rhine. Currently, the Rhine Police Regulation specifies that any craft operating separately on the Rhine must not be more than 135 m in length and more than 22.8 m in width. Permitting a vessel with a length of 150 m at a reduced width of 15 m could result in a substantial reduction in specific emissions, a fact illustrated by the so-called *Langschiff* (Zöllner 2009). This observation could serve as the occasion for the waterway authorities to examine the possibility of not only overall larger dimensions but also greater variability in maximum permissible vessel dimensions.

The network of inland waterway is much less closely linked than the network of rail lines or of roads. Inland vessels transporting cargo must consequently travel longer distances as a rule than would be the case if the same transports were carried out by road vehicles or by rail (PLANCO 2007). The same applies to transport links for which inland shipping traditionally holds a large market share. Ore transports from Rotterdam to Dillingen could be cited here as an example: the route for inland vessels is 30% longer than the route taken by other carriers (PLANCO 2007). This means that, even though inland shipping can be assumed to generate lower specific emission levels in general, this form of transport may produce a larger carbon footprint than other modes of transport, depending on the differences in specific emissions among modes and the added route needing to be travelled. However, this appears to hold true for hardly any transport links in Europe that are typically served by inland shipping (Schilperoord 2004; PLANCO 2007).

When, for transport chains that include inland shipping, the start and end points are not located directly on a waterway, pre- and post-river transport will be required, entailing additional transshipment of goods in each case. The effects specified above – i.e. added route, pre- and post-river transport and additional transshipment – have in part a substantial impact on specific emissions. These effects are not of key importance for identifying potential reductions in fuel consumption and CO_2 emissions in inland navigation, or for this report. They are, however, important when discussing any possible shifting of transport volumes to inland shipping (den Boer, Otten et al. 2011). Yet this does not mean that fuel consumption and CO_2 emissions are less favourable for transports by inland ship than for road or rail transports, when the effects described above are considered. Furthermore, even if for a certain transport link the carbon footprint created by inland shipping is larger than that of another mode of transport, it may not be subsequently concluded that this link should not be served by inland vessels. Transports by inland vessel are frequently to be preferred to other modes of transport from a macro-economic standpoint, even where an unfavourable level of greenhouse gases is emitted, especially when one takes into consideration for inland shipping the low noise emission levels and the low follow-up costs of accidents (PLANCO 2007). In view of the desired objective of shifting freight to inland ships, it would therefore seem advisable as a rule to consider individually the amount of emissions to be expected (den Boer, Otten et al. 2011).

9. Technical measures for the reduction of fuel consumption and CO_2 emissions involving the vessels themselves

There are many technical measures for the ship owners to reduce fuel consumption and CO_2 emissions of new vessels. They can choose the most economical and technically feasible of these options – for their ships and their applications. The potential savings that can be achieved by conversion of existing ships are significantly lower. The greatest potential savings can be achieved by using ships that are larger in size and have a greater load carrying capacity. This interrelationship required more in-depth consideration due to its overriding importance for future emissions trends. However, any quantification of the possible potential savings depends on a large number of factors, which can vary significantly from one type of ship to another and depend on the operating conditions.

There are no studies into ways of reducing fuel consumption and CO_2 emissions from inland navigation that are comparable in scope and depth to the aforementioned study for maritime shipping (Buhaug, Corbett et al. 2009). Mitigation measures identified in the course of the comprehensive research project EU Transport GHG: Routes to 2050? conducted by the European Commission on all modes of transport can be found in **Annex 5**. Measures for reducing CO_2 emissions from inland navigation were also the subject of the CCNR workshop held in Strasbourg on 12 April 2011. The possible measures identified by those at the workshop can be found on the CCNR website (www.ccr-zkr.og). These measures for reducing fuel consumption and CO_2 emissions were also assessed at the workshop (Croo 2011; Schweighofer 2011). The results of this assessment can be summarised as follows:

- In general the emission reduction potential is largely depending on the size, the state of the vessel, its equipment as well as the operational area and operational mode.
- Many vessels are already equipped with some reduction technologies and they have been designed using classical optimisation techniques, leaving only very little potential for reduction of CO_2 emissions of these vessels.

- The emission reduction potential of the existing fleet may be roughly estimated at 10% for the application of hydrodynamic measures alone.
- Measures for reduction of CO_2 emissions may be cost intensive and valuable cargo space or deadweight might be lost. Proper estimation of the emission reduction and the economic viability have to be considered case by case.
- When sufficient water levels are provided, shallow water effects (resistance) are reduced and larger vessels and amounts of cargo are possible, leading to a significant reduction of CO_2 emissions/tkm.
- The CO_2-reduction potential of engines is very limited.
- Diesel-electric propulsion offers a substantial CO_2-reduction potential.
- A combination of different measures is possible and needed.
- The greenhouse gas reduction targets postulated by the European Commission cannot be reached with propulsion related measures alone.
- Safety issues may arise with diesel-electric propulsion; therefore the CCNR's and EU's technical requirements for inland navigation vessels have to be modernised.

Annex 6 contains a summary and evaluation of these and other technical measures for reduction of fuel consumption and CO_2 emissions.

Both the research project Transport GHG: Routes to 2050? (Hazeldine, Pridmore et al. 2009) and the discussions held at the CCNR workshop identified an increase in the average load carrying capacity (size) as probably the most significant measure for reducing fuel consumption and CO_2 emission from inland navigation. **Annex 7** contains a simplified look at the trend in average ship size and the possible impact on CO_2 emissions. If the predicted increase in ship size of approx. 1.5% per annum (Ickert, Ulrike et al. 2007) actually comes about, it could certainly – at a rough estimate – result in a drop in specific CO_2 emissions by about the same order of magnitude. Taken over the space of a year this drop may seem negligible, but with an increase in vessel size and taken over a number of decades – which can be done retrospectively for navigation on the Rhine – a two-figure percentage drop could be expected. This means that the continuous increase in ship size would be of decisive importance for a reduction in fuel consumption and CO_2 emissions from inland navigation, at least on the Rhine and other waterways where the average vessel size is still substantially below the maximum authorised vessel size. It thus seems appropriate to verify the consideration reported in **Annex 7** and the results presented there.

10. Operational measures for the reduction of fuel consumption and CO_2 emissions

When it comes to the operational measures for reducing fuel consumption and CO_2 emissions there are fundamental similarities to the technical measures. There is a wide variety of possible options available which ship owners can choose from, depending on which are most economically viable for their ships and applications. In contrast to the measures involving the vessels themselves, there are no major differences between new ships and existing ships when it comes to the operational measures.

The greatest potential savings can be achieved by optimising the speed of the ships. This involves taking the specified time of arrival and the fairway conditions to be anticipated on the various sections of the route into consideration in order to choose the slowest possible speed. However, any quantification of the possible potential savings depends on a large number of factors, which can vary significantly from one type of ship to another and, in particular, depending on the operating conditions. Whereas ship owners and skippers generally determine the ship's fuel consumption and thus the emissions by their actions, several of the operational measures require the waterway authorities to create the right conditions.

The comprehensive study into ways of reducing fuel consumption and CO_2 emissions conducted by the IMO for maritime shipping includes such operation, too. Basically, these are also applicable to inland navigation. There are no comparable studies for inland navigation, however. Only a few mitigation measures for inland navigation were presented in connection with the comprehensive research project "*EU Transport GHG: Routes to 2050*?". Measures for reducing CO_2 emissions from inland navigation were also one of the topics addressed at the CCNR workshop held in Strasbourg on 12 April 2011. The measures identified by the workshop participants can be found on the CCNR website (www.ccr-zkr.org) and were evaluated at the workshop (ten Broeke 2011). The results of this evaluation can be summarised as follows:

- Operational measures offer great potential to reduce CO_2 emissions.
- Taking shallow water effects into consideration is of particular importance.
- The awareness of the mitigation measures is low, but is increasing.
- The use of simulators can help to boost awareness.
- Reduction of CO_2 emissions is already an integral part of training.

Annex 8 contains a summary and evaluation of operational measures for reduction of fuel consumption and CO_2 emissions. According to this, it is safe to assume that there is considerable reduction potential, primarily in connection with optimisation of the ship speed. The Dutch "Smart Steaming" programme, which is described in more detail in **Annex 9**, has the same objective. The proven success of this programme suggests extending it beyond the Netherlands' borders.

More and more computerised tools are being developed to do this, which are intended to help skippers decide on the best speed to travel at on each leg of a voyage. The "Tempomaat"[12] is one such example. Due to the very positive cost-benefit ratios which could be expected from investing in such tools at company as well as an economy-wide level, it would be appropriate to analyse the introduction of a legal obligation to equip inland vessels with such tools.

[12] http://ec.europa.eu/eu_law/state_aids/comp-2010/n264-10.pdf, and www.tempomaat.nl

European inland navigation is usually subject to speed limits for reasons of safety, to prevent damaging the floor of the waterway, and to limit the emission of harmful substances. The limits apply to short stretches of waterway, ports, or entire waterways. However, a general speed limit is not particularly efficient in achieving the target of reduced fuel consumption and hence emissions of greenhouse gases. The reasons for this are set out in **section 8** of this report. Speeds that are economical in terms of energy are very heavily dependent on water depth. Setting a particular maximum authorised speed would therefore only actually reduce fuel consumption for some types of vessel and for a specific underkeel clearance. For other vessels and different water conditions the speed would be either too fast or too slow to have the required effect. Consequently, for inland navigation, unlike marine navigation, what is needed is not a constant low speed (“slow steaming”) but an optimum speed (“smart steaming”).

11. Use of alternative energy sources (fuels) to reduce CO_2 emissions

At present, the only fuel used by inland navigation is gasoil. The combustion of gasoil generates considerable CO_2 emissions, which account by far for the largest share of greenhouse gas emissions from inland navigation. In addition to this, it is likely that from the middle of this century, mineral oil-based fuels will no longer be available for inland navigation or will no longer be available at a reasonable price. It is therefore essential for inland navigation to switch completely to alternative energy sources in the decades ahead. These alternative energy sources have to be low carbon or even carbon-free fuels and need to be available for a longer time or even indefinitely. Liquid biofuels are a possible logical successor to today’s mineral oils used as fuel, but it appears to be impossible to produce the required quantities sustainably.

A mix of fuels is therefore more likely to become established in inland navigation, consisting of liquefied natural gas (LNG) and CNG as well as liquid and gaseous biofuels. Electricity, stored on board in batteries or obtained by the conversion of hydrogen or synthetic methane, is likely to be used to power inland vessels, at least for certain applications. The use of these fuels calls for extensive preparations, including with regard to the laws and regulations governing inland navigation. In particular, it is necessary to ensure that the future energy mix makes it possible for the emission reduction targets for inland navigation to be achieved. A strategy for the switch by inland navigation to alternative fuels is therefore called for. This should be incorporated in a strategy covering all modes of transport and agreed at an international level, since inland navigation in Europe is operating internationally.

An important prerequisite for the economical use of alternative energy sources, apart from their availability at a reasonable price for inland navigation, is the development of quality standards. New propulsion systems for inland vessels will only be successful on the market if the energy sources they use are available at a good price and in sufficient quantities and at a consistent quality. New standards also need to be developed for the certification regulations for the propulsion systems themselves. At present, it is practically only gasoil that is approved as fuel due to current regulations. The process for approval of LNG as a fuel for inland vessels on the Rhine and inland navigation in general is already underway. Step by step, the certification regulations need to be changed so as to allow all energy sources that make sense to actually be permitted, without jeopardising the safety of shipping in the process. The CCNR has demonstrated that it is capable of promoting the increased use of eco-friendly fuels for inland navigation thanks to its technical know-how and its ability to develop and implement standards in the context of the introduction of sulphur-free fuels and of LNG for use in inland navigation. Since the member states of the CCNR are responsible for about three quarters of the transport-related activities and thus of the fuel consumption accounted for by inland navigation in the EU, it is obvious for these states to take a leading role, together with the CCNR – in coordination with and support of possible work to be undertaken by the European Commission –, in drawing up a strategy for the future energy sources that will be used by inland navigation and the development of the necessary standards.

In authorising LNG, the CCNR could draw on experience in the use of CNG acquired by smaller passenger vessels in limited areas. One company in Amsterdam has many years' experience of operating about ten excursion boats using CNG (de Wilde and Weijers 2008).

The European Expert Group on Future Transport Fuels has investigated the various energy sources for all modes of transport (Fuels 2011). A summary of their findings can be found in **Annex 10**. As is also the case for other sources (IEA 2011), the Expert Group highlights the fact that by the middle of the century, mineral oils will probably no longer be available for use as transport fuels. Not only do alternative fuels need to be found and used in order to meet the climate goals, but are also needed due to the world's oil fields running dry.

For the use of LNG in inland navigation, the total energy balance as well as the greenhouse gas emissions were investigated on the basis of the well-to-wheel classification, as was also the case for gasoil. A significant proportion of these emissions consists of CH_4. These emissions are converted to CO_2 equivalents. Taking these emissions into consideration, the CO_2 reduction potential resulting from the use of LNG in inland navigation is about 10%, in comparison to gasoil (Verbeek, Kadijk et al. 2011).

This value is in good agreement with the figure of 5 to 7% quoted by the European Expert Group on Future Transport Fuels (Fuels 2011) for Euro 5 diesel engines used in road vehicles. The CO_2 reduction potential figures for inland navigation are often given as varying between 20 and 25% (Consuegra and Paalvast 2010; Koopmans 2011). This corresponds to the theoretical figure for using LNG instead of gasoil without taking into account either the upstream processes (tank-to-wheel) or the possible negative effects of the CH_4 emitted (methane slip) on the climate. Due to the great significance that natural gas is likely to assume as a fuel for inland navigation in future, it seems desirable to state a practical value for the CO_2 reduction potential of LNG.

The European standard EN 16258 : 2013 contains specification values for greenhouse gas emissions for a good number of fuels, including CNG but not LNG. On the basis of this standard, the reduction potential of CO_2 equivalents for CNG – compared with gasoil – is about 20% (tank-to-wheel) or 25% (well-to-wheel). Since the manufacturing and transport of LNG and CNG are substantially different, the reduction potentials should at all events be applied without taking upstream processes into account.

It is not yet possible to produce liquid or gaseous biofuels in large quantities. It will still only be possible to meet a limited proportion of the demand for fuel from inland navigation's with biofuels in the future, too. On the one hand there are natural limits on the amount of biogenic fuel that can be produced, and on the other, inland navigation will have to compete for the biofuels against other, more economically competitive modes of transport. Also, in future the biofuels will have to meet ever stricter targets for the reduction of greenhouse gases. Also, it is safe to assume that the energy crops will trigger indirect changes in land use, and thus a predatory competition for land use. This could not only push the price of food up significantly, but also result in additional greenhouse gas emissions (Ahrens 2011). The production of biogas by the fermentation of maize is a particularly sensitive subject at present (Schuh 2011). Because of the intense criticism of the EU's promotion of biofuels, the European Commission was obliged in October 2012 to submit proposals for amending the relevant legal instruments (Directive 98/70/EC relating to the quality of petrol and diesel fuels and Directive 2009/28/EC on the promotion of the use of energy from renewable sources). The aim of these proposals is above all to limit the contribution of conventional biofuels (which carry the risk of emissions resulting from indirect changes in the use made of the land), to improve the greenhouse gas footprint of the biofuel manufacturing process (reducing the related emissions) by increasing the level of emission reductions to be achieved, and to promote the market penetration of advanced biofuels (with reduced indirect changes to the use made of the land) (EU 2012a). Regarding the industrial production of biofuel from waste, which the European Commission would like to promote even more with its proposal, important progress is currently being achieved; however, similar projects for manufacturing second-generation biofuels have not been successful (Trechow 2012). The International Energy Agency (IEA) assumes, in a roadmap that it has drawn up, that a good 25% of all fuels in use globally may be sourced from biomass by 2050 and that these should permit a reduction in greenhouse gas emissions of at least 50% in comparison to conventional fuels (IEA 2011b). It is to be expected that biofuels will mainly be used where no or only limited, sensible alternatives exist, particularly in aviation, maritime shipping and heavy goods road transport (Fuels 2011a).

The use of biogenic fuels on board inland vessels is more complex than on land (Arntz 2010)). For technical reasons, the engine manufacturers are cautious about the increasing use of biofuels in inland navigation. The complex technology used to reduce emissions of pollutants that can now also be found in the inland navigation industry, irrespective of whether this is achieved by changes made inside the engine or by the use of exhaust-gas aftertreatment systems, calls for consistently high quality fuels. The first step would be to define the technical quality standards that these fuels have to meet. The next step could then be the provision of these fuels. Engine manufacturers demand reassurance that there would not be any negative fluctuations in fuel quality as a result of long periods of storage on board under the conditions typically found on inland vessels (Scherm 2011).

The use of electric propulsion in inland navigation, whether stored in rechargeable batteries or obtained from hydrogen generated by electrolysis, is currently still at an initial stage (Krijgsman 2010). These energy sources are however, with the exception of those currently under discussion, the only ones that can, in principle, by produced without any greenhouse gas emissions (zero-emissions). Their future importance in inland navigation will thus depend not least on the emission reduction targets. At present it is mainly smaller passenger vessels that use electrical energy stored in batteries. Interest appears to be increasing; in France, for example, an association for electrically propelled boats has been set up. Its Internet site[13] contains information on a number of passenger vessels powered by electric batteries. These are also used to propel two smaller cargo vessels operating into and out of the centre of Utrecht[14]. In Hamburg a passenger vessel commissioned in 2008 is propelled by fuel cells, using hydrogen as fuel[15]. As part of Germany’s national innovation programme for hydrogen and fuel cell technology (“NIP”), research is being carried out on the use of fuel cells for generating electrical and heat energy on cruise vessels[16]. Hydrogen technology, also in conjunction with fuel cells, is seen by leading automobile manufacturers as a sustainable prospect for long-distance journeys because of its power intensity (Reuss 2012). If these prospects were to be realised in the automobile industry, this could open the way – particularly with regard to cost – for numerically significant applications in inland navigation.

[13] L'Association Française pour le Bateau Electrique, http://www.bateau-electrique.com/

[14] http://www.binnenvaartkrant.nl/2/artikel.php?artikel_id=3807

[15] http://www.hysolutions-hamburg.de/index.php?id=26

[16] http://www.bmvbs.de/SharedDocs/DE/Artikel/UI/nationales-innovationsprogramm-wasserstoff-und-brennstoffzellentechnologie-nip.html

Hydrogen can be produced by converting wind power – “power-to-gas” technology. In Germany, the first power station of this type was commissioned in 2011. If the hydrogen produced in this way is converted into electric propulsion energy using fuel cells, the overall effect on the processes is in the order of 30%. This value is low, but if it is assumed that the hydrogen is manufactured when there are no other consumers for the wind power, the technology could nevertheless constitute a significant alternative to conventional energy storage processes (Schulze 2012).

A relatively new method for storing electrical energy uses methane as the storage medium. This method uses electrical energy to make methane from CO_2 and water. The first plant built on an industrial scale that converts excess wind energy into methane is scheduled to go online in 2013 (Reuss 2012). E-gas, as the synthetic methane produced by this plant is also known, has the advantage over hydrogen that it can practically replace natural gas 1:1. It does not, therefore, need any new technology or infrastructure, other than for production. Provided that unburnt methane is prevented from escaping (methane slip), it is climate-neutral to a significant extent, since only the same amount of CO_2 is released on combustion as was removed from the atmosphere to produce it. E-gas thus looks like a realistic alternative for climate-neutral operation of inland vessels.

Studies similar to those referred to above also need to be carried out for the use of other unconventional fuels in inland navigation, unless other similar studies for other modes of transport are applicable. To avoid counterproductive developments, these studies should be available before any decision on the promotion of alternative fuels is taken.

The change-over to alternative, low-carbon or carbon-free fuels will result in fundamental changes for all modes of transport. Consequentially, strategies for the change-over have been developed (e.g. by the German Federal Government in 2004) or announced. The European Commission plans to present a consistent long-term fuel strategy , but this had not occurred by the time this report was being drawn up[17]. A new fuel strategy is foreseen in Germany (DENA 2011). Specific recommendations are to be put forward at the end of 2012[18].

The future energy mix used by inland navigation will not be decided by the inland navigation industry itself. Rather, it will have to select those fuels that are available to it which are most suitable from a technical and – first and foremost – an economical point of view. In this sense it will be a “follower”, not a “driver” of developments. It will not, however, be possible for inland navigation to wait for developments in other areas and then follow them, since the operating conditions for inland navigation differ from those for road and rail transport. Therefore, a cross-transport-sector fuel strategy taking into account the special requirements of inland navigation is needed. A key cornerstone of this strategy would be the widespread disappearance of mineral oil-based fuels from inland navigation. Today, inland navigation uses almost exclusively gasoil. In 40 years these fuels will hardly be available for use in inland navigation. The reason for this is strongly expanding demand in China and other countries with large populations just as oil production is reaching its natural limits. As long as fuels based on mineral oil are still available, they will be sold in the marketplace at top prices, as could be expected for air travel. 40 years seems like a long time, but it is in actual fact shorter than the working life of an inland vessel being commissioned now. In other words, ships powered by diesel engines that are put into service now will probably need to be converted to use an alternative fuel before the end of their working lives.

[17] http://ec.europa.eu/transport/themes/urban/cts/future-transport-fuels_en.htm
[18] http://www.bmvbs.de/DE/VerkehrUndMobilitaet/Zukunftstechnologien/MKStrategie/HintergrundMKS/mks-hintergrund_node.html

Building on the findings of the studies conducted by the Expert Group (Fuels 2011) and the explanations above, a strategy for the future development of the energy sources in inland navigation could be based on the following main points:

1. The use of gasoil as long as it remains economically viable (rising supply costs, additional costs for exhaust gas after-treatment);
2. Gradual introduction of LNG (and e-gas), as in maritime and coastal shipping;
3. Introduction of electrical power, stored in rechargeable batteries, as for road transport;
4. Introduction of electrical power, stored as hydrogen, as for road transport;
5. Mixing/displacement of gasoil with liquid biofuels (depending on availability);
6. Mixing/displacement of LNG with gaseous biofuels (depending on availability);
7. Complete replacement of fossil fuels.

If the European Commission's future fuel strategies and those of the nations involved in inland navigation fail to pay adequate consideration to inland navigation, as is the case for the current German fuel strategy (German Federal Government 2004), the CCNR could fill the void and develop a fuel strategy of its own, especially for inland navigation, or at least the building blocks for one, that could then be integrated in the overall strategies.

12. Potential for the reduction of fuel consumption and CO_2 emissions from inland navigation

Sections 9 and 10 of this report, and in particular **Annexes 6 and 8**, list ways of reducing fuel consumption and CO_2 emissions from inland navigation. A summary of the estimated potential of these measures is shown in **Table 3**. Whether this potential is exploited depends on a number of different factors, not least on whether the supporting measures described in **section 13** are taken.

The "average" of the current fleet is taken as a comparative case or as a basis for the savings potential. The low figure shows the savings potential that can definitely be expected, while the higher figure shows the maximum potential. The figure 0% shows that some vessels already exploit this potential now, or that the measure in question is not applicable to all vessels for a particular reason. For the combination of measures, the lower figure shows the savings potential in comparison to vessels that are already built and operated very energy efficiently today. The higher figure shows the savings potential relative to modern vessels that are not very energy efficient.

Table 3: Estimated potential for reducing fuel consumption and CO_2 emissions from inland navigation by the use of known technologies and practices

Measures		**Savings CO_2/tkm**	**Combined**	**Combined**
Ship technology	Increase in engine efficiency	2% - 5%	10% - 25%	10% - 50%
	Diesel-electric propulsion	0% - 20%		
	Hybrid propulsion	0% - 20%		
	Waste heat recovery	0% - 5%		
	More efficient propulsion organs	5% - 20%	0% - 25%	
	Alternative propulsion organs	0% - 25%		
	Lightweight construction	0% - 5%	5% - 25%	
	Air lubrication	0% - 15%		
	Ship hull form optimisation	0% - 10%		
	Exhaust flow plate	0% - 10%		
	Adjustable tunnel apron	0% - 10%		
	Coupling point optimisation	0% - 15%		
Operation	Smart steaming, just in time	0% - 30%	5% - 30%	10% - 40%
	Speed optimisation using decision support systems	0% - 15%		
	Journey planning optimisation	0% - 20%		
	Automatic channel guidance optimisation	0% - 10%		
	Motor maintenance optimisation	0% - 5%	0% - 10%	
	Optimisation and maintenance of the propeller	0% - 5%		
	Optimisation and maintenance of the hull plating	0% - 5%		
	Optimisation of the ship's trim	0% - 5%	5% - 15%	
	Optimisation of locks/bridge passages	0% - 15%		
	Optimisation of vessel operation in ports	0% - 5%		
	Shore-side electricity	0% - 5%		

The above figures contain significant uncertainties with regard to:

- The savings potential of each individual measure for itself on a given vessel,
- The savings potential of possible combinations of individual measures on a vessel,
- The potential scope of realisation of the measures on all vessels, in particular the existing fleet.

These figures can therefore only be viewed as an educated guess, at best; a number of experts see much less potential for savings in the combination. It is therefore to be welcomed that this summary is already being discussed by specialists and is soon to be reviewed on a scientific basis. Also, the cost efficiency of the individual measures or combinations of measures is not taken into consideration, which means that the implementation of some of the measures or combinations of measures may be out of the question simply due to the cost.

In the past, various new regulations intended to increase safety or to protect the environment have led to an increase in power requirements and thus to higher fuel consumption by inland navigation, for example the requirements pertaining to on-board wastewater treatment plants.
Taking a holistic view of the safety and environmental protection measures in future could contribute to avoiding any negative effects on the energy efficiency of inland navigation resulting from such regulations to as great an extent as possible.

13. Supporting measures for reducing fuel consumption and greenhouse gas emissions

Supporting measures are measures that do not themselves contribute to a reduction in fuel consumption and greenhouse gas emissions, but which nevertheless promote the implementation of the operational and technical measures listed in the previous sections of this report. One elementary and fundamental supporting measure is the provision of relevant information. Other supporting measures may be of a voluntary nature, or may be prescribed by legal regulations, or subsidised.

13.1 Provision of information

The work by the CCNR on reducing fuel consumption and greenhouse gas emissions has shown that there is a wealth of relevant information available. Finding that information can be very hard work, however. Moreover, the information is also often only available in one language. In order to make information transfer easier, the Dutch shipping industry, with assistance from the Dutch administration, has published a number of publications, including an information brochure (de Grave), although it is now outdated. [19]) has been realised so far, as of April 2011. At the suggestion of the Secretariat of the CCNR, PLATINA has included measures in the Innovation Database[20], although these measures are limited to a few technical aspects and are only published in English. These examples clarify not only current gaps in information but also the possibilities of a user-friendly way of providing comprehensive and relevant information are and what needs to be taken into consideration in doing so:

1. Publication of a multilingual brochure describing the main operational and technical measures. This brochure could be based on the existing but outdated brochure published by the Dutch shipping industry;

[19] http://www.ccr-zkr.org/temp/workshop120411_en.htm
[20] www.naiades.info/innovations/index.php5/Innovation_database

2. Creation of a multilingual website to serve as an information platform for all of the key aspects relating to the reduction in fuel consumption and greenhouse gas emissions from inland navigation. This website could make use of this report as well as the CCNR's website on the workshop;
3. Creation of a user-oriented and multilingual database on the operational and technical ways of reducing fuel consumption and greenhouse gas emissions as part of the website mentioned above and using the dossier of measures that was drawn up for the CCNR workshop.

13.2 Voluntary supporting measures

The IMO has already drawn up a list of possible supporting measures for maritime shipping, of which the following are relevant here:

- Energy Efficiency Design Index - EEDI
- Energy Efficiency Operational Index - EEOI
- Ship Energy Efficiency Management Plan - SEEMP

A detailed description of these instruments, including the possibilities and limitations, can be found in **Annex 11**. The EEDI and the SEEMP are to be compulsory from 1 January 2013 for vessels with a gross tonnage of 400 t and over[21].

The EEDI is a system for **classification of the energy consumption** of ships. The classification of the energy consumption of ships has numerous benefits:

1. It helps ship owners when making decisions on investments, as the energy consumption classification reveals the energy or environmental efficiency that they will get for their investment. At the same time, good classification also increases the resale value of the ship.
2. It makes it easier for shipyards to sell new energy or environmentally efficient ships, as the advantages of the higher cost of investment are demonstrated by the favourable classification.
3. It gives economic incentive systems a simple and manageable basis. Ships with a good classification can be charged less for the use of ports and waterways than ships with a worse classification or no classification at all.
4. If the classification is taken into account, government subsidy schemes have a reference base that is broader and, first and foremost, independent of any measures. The subsidy could then be discontinued once a predetermined target is reached, the best energy consumption class, for example. It would then be up to the ship owner to choose the most suitable measures to implement in order to reach the target.
5. The classification of the energy consumption can also be adopted directly as a key element of an environmental certification system (such as the Green Label or Blue Angel) for inland vessels.

Such a classification system already exists for cars as well as for electrical consumer goods and houses. A comparative study of the various possibilities for energy consumption classification of inland vessels has also been carried out already (ECOFYS). Building on this study and the work of the IMO it would be possible to develop a special or adapted classification system for inland navigation.

[21] www.imo.org/MediaCentre/MeetingSummaries/MEPC/Pages/MEPC-64th-session.aspx

The EEOI allows comparison or **benchmarking of the energetically or environmentally efficient operation** of ships. This benchmarking also has several benefits:

1. Ship owners can compare the energy efficiency of operating a ship directly with other ships and thus identify where there is room for improvement.
2. It gives ship owners a solid basis for granting skippers bonuses to motivate them to navigate the vessels they are in charge of efficiently and economically.
3. The introduction of the EEOI generates valuable data on the fuel consumption of the fleet. This data is essential for good management. If it is made available to the administration, it would also make it possible to validate the emission factors using real emissions as well as monitor the success of climate protection policy in inland shipping in practice.
5. The existence of an Energy Efficiency Operational Index can also be adopted directly as an element in an environmental certification system for inland vessels.

Building on the work done by the IMO and initial application by the classification societies, it may be possible to develop a special or adapted Energy Efficiency Operational Index for inland navigation.

The SEEMP is a structured and transparent **tool for ongoing improvement of the energy efficiency of ship operation** and can thus be used to improve management. The progress made should be measurable using the EEOI. The existence of the SEEMP can also be included as an element in an environmental certification system for inland vessels.

Environmental labels can be used to document a **certification system for environmentally friendly ship design and environment-conscious ship operation**.
"The basic aim of the environmental label ... is to distinguish ships that go beyond the legal requirements in implementing measures to prevent or reduce their environmental impact.
Due to the sharp increase in environmental standards in the past few years, the gap between the mandatory regulations and what is technically possible voluntarily in terms of improvements has grown tighter. Nevertheless, further technical progress can still be expected in future, particularly in the area of energy efficiency. Environmental labels will also continue to be adjusted to suit the current legislation, meaning that new requirements are added to the existing ones.
Although the actual environmental benefits of individual ships meeting higher environmental standards are limited, this can help set a positive process in motion. It demonstrates that it is both practically and economically viable – be it by way of direct savings or indirectly by way of an improved environmental image – to go beyond the legal minimum when it comes to investing in environmental protection measures. This is intended to act as an incentive for the introduction of innovative technologies." (Seum, Bahlke et al. 2011)

Ship owners who make the necessary investment to obtain an environmental label want to protect the environment and the climate better, as well as improve their company's image but they also want financial recognition for their investment, for example, by qualifying for reduced harbour dues and preferential treatment by cargo shippers. Various countries have already introduced environmental labels for maritime shipping, such as the "Blue Angel"[22] in Germany, with one being awarded for eco-friendly ship design and one for environment-conscious ship operation.

[22] www.blauer-engel.de/en/blauer_engel/whats_behind_it/protection-goals.php?objective=3

More than 300 inland navigation vessels, mainly in the Netherlands, have already received the Green Award[23] environmental label. A vessel certified to the specifications of the Green Award must meet certain technical and operating requirements that serve to protect the environment not contribute to climate change in order to enjoy financial advantages such as reduced port fees in major Dutch and Belgian ports. State subsidies and bank grants provide financial support for building up the organisation and vessel certification. The Green Award label could, in principle, be a suitable instrument for supporting the implementation of voluntary climate protection measures in inland navigation. In terms of climate protection, however, the impact of this label could be even greater, if the requirements (the decisive criteria for certification) were to include other elements of climate protection, such as a certain classification of ships regarding their energy consumption.

The greater the recognition given to the environmental label, the greater the appeal of environmental labels and thus the incentive for ship owners to take environmental and climate protection measures. This speaks in favour of the creation of an environmental label that is recognised throughout Europe, or at least throughout the entire Rhine area. However, the creation of various environmental labels, for example at the national level, does not make sense for inland navigation, since this would mean that each vessel would need to go through several certification procedures. The organisation that awards the Green Award label is interested in developing this environmental label for use in the field of inland navigation. The Blue Angel environmental label for maritime shipping was revised in 2009, in particular to take climate protection into account (Seum, Bahlke et al. 2011). Building on this basis, it should be possible to arrive at a unified or harmonised environmental label for inland navigation in the Member States of the CCNR or beyond with a reasonable amount of effort.

13.3 Supporting measures based on legal obligations and subsidies

There are very many supporting measures of a legal and economic type (UNECE 2012). Directive 2009/33/EC is one example of how legal measures can be introduced, in this case offering financial incentives for the purchase of road vehicles. For inland navigation in Europe, legal obligations could be used as the basis for the following measures:

1. Taxation on fuel,
2. Inclusion of inland navigation in the European emission trading system,
3. Obligatory classification or certification of inland vessels based on *their* fuel consumption and their greenhouse gas emissions,
4. Emission-based port charges and navigation fees.

An investigation of the above measures would go beyond the scope of this report. Nevertheless, it seems worthwhile to at least take a closer look at the implementation of the 4th measure, alongside the compulsory energy classification of inland navigation vessels. For waterways for which a navigation fee is already payable, this could be revenue neutral. In other words, it could be introduced without increasing the overall cost of inland navigation, while nevertheless having an impact that could be significant. On the other hand, for waterways for which no navigation fee is currently payable, and above all the Rhine, the introduction of an emission-related navigation fee would be difficult or even downright impossible, for legal reasons.

[23] www.greenaward.org

This report also ignores subsidy schemes, whether run by governments or privately.

13.4 Summary

In conclusion, it can be said that the supporting measures can, on the one hand, make a decisive contribution towards encouraging those involved to actually implement the known measures for reducing fuel consumption and greenhouse gas emissions in practice and that the supporting measures, on the other hand, are already very advanced, in some instances, or are already in use, in others. In order to make sure that the supporting measures are as effective as possible in inland navigation, it is necessary to:

- conclude the development of the supporting measures, where this has not yet been done and to adapt measures in other fields – as necessary – to inland navigation in the process,
- help ensure that supporting measures that are already in use at a national level are implemented Europe-wide or at least for all navigation on the Rhine,
- set transparent and generally accepted standards, like the IMO, to which all those affected, including government agencies, for example, can refer in connection with direct or indirect subsidies.

Due to the extremely positive effects of the supporting measures and since they can also be voluntary, the tasks listed above should be given top priority and be addressed as soon as possible. The nature of these tasks calls for an overarching approach in several respects: The tasks need to be international, include all those affected and take both technical as well as operational aspects into consideration. Also, for informative or voluntary measures, political and legal powers do not play a role, since they do not result in any obligations, either for companies or for countries.

The effect of voluntary supporting measures should not be overestimated. A current study (Csutora 2012) shows that mere ecological awareness does not lead to a smaller carbon footprint. This would suggest that information and awareness-raising measures are not enough to achieve substantial reduction targets. Consequently, significant economic incentives or legal measures are also required.

14. Additional benefits of a reduction in greenhouse gas emissions

Measures taken to reduce greenhouse gas emissions can be accompanied by additional benefits:

- If the reduction in greenhouse gases results from a reduction in fuel consumption, then pollutant emissions[24] are almost always reduced as well.
- If the reduction in greenhouse gasses results from the use of LNG or the (indirect) use of electrical power from alternative sources, this leads to a significant or almost total reduction in pollutant emissions.
- Reducing fuel consumption also reduces the consumption of resources, specifically mineral oil. This enhances the sustainability of inland shipping and reduces its costs.

[24] "Pollutants" here refers to products that are harmful to humans and to the environment, and more particularly nitrous oxide (NO_X) and particles, in contrast to those products that contribute more generally to climate change.

- If the reduction of greenhouse gas emissions is achieved by reducing the propulsion power used for transport, this generally leads to less wash and consequently less impact on the currents in the surrounding body of water. This in turn will result in less of a burden on the river bed and on the bottom. The negative impact of inland navigation on aquatic ecology is reduced to a minimum.

The many benefits thus able to be achieved, i.e. through implementing measures aimed at reducing the greenhouse gas emissions from inland navigation, should serve to arouse the interest of policymakers and the shipping industry in the issue of climate protection in inland navigation, even though the potential contribution of inland navigation towards protecting the climate would appear, in absolute terms, to be negligibly minor.

Various studies have demonstrated the specific emissions of classical pollutants, in particular nitrogen oxides (NO_x) and particles (PM), from inland shipping to be comparable to or in some cases even substantially higher than those from rail transport. With certain qualifications, this also holds for long-distance road freight transport (PLANCO 2007; den Boer, Otten et al. 2011).

It is difficult to compare the macro-economic costs of pollutants – or, stated alternatively, the damage caused by such emissions – with the costs of greenhouse gas emissions, specifically because the various emissions need to be put into monetary terms. The results of the comparison thus depend not only on the magnitude of emissions but also on the estimated costs incurred by emitting one tonne of the particular substance. Whereas PLANCO (PLANCO 2007) estimates the macro-economic costs to be about the same for pollutants and greenhouse gas emissions from inland navigation, other studies have found the costs incurred by pollutant emissions to be about seven times as great.

The pollutants emitted by inland shipping originate from the same source as greenhouse gas emissions, i.e. the combustion of gas oil in the engines used to propel ships. Consequently, measures aimed at reducing the volume of greenhouse gases emitted by inland navigation through reduced fuel consumption generate an additional benefit: they also reduce the amount of pollutants emitted.

Decreased fuel consumption obviously entails the additional benefit of enhanced resource efficiency, through achieving more tonne-kilometres from the same amount of fuel. Resource efficiency is a relatively new policy objective (Commission 2011). For the industry, resource efficiency is one of the major means of controlling fuel costs, which, according to the internal estimates by the Secretariat of the CCNR, account for about a quarter of the total operating costs of a modern motor cargo vessel on the Rhine. Fuel costs in Rhine navigation have roughly quadrupled in nominal terms during the past ten years[25]. Moreover, they are rising faster than others, thus becoming increasingly important, as was pointed out by representatives of the shipping industry during the consultation organised by the CCNR for this report on 6 March 2012.

While sailing, ships cannot avoid generating waves, currents and pull in the surrounding body of water. The shallower the vessel's underkeel clearance and the narrower the cross-section of the waterway navigated in comparison to the cross-section of the vessel, the greater the negative impact of waves and currents on the waterway ecosystem and on the river bed. Reducing the ship's engine power and vessel speed are especially effective ways of limiting this negative impact (Söhngen, Knight et al. 2008).

25 www.rhinecontainer.com/de/gasolpreise/?area=

Both measures are normally accompanied by a reduction in fuel consumption. The preceding explanation relates in highly simplified terms the complex factors that are actually involved. Nonetheless, it clearly shows how measures aimed at reducing greenhouse gas emissions through a reduction in fuel consumption can also contribute towards reducing the negative impact of inland navigation on the ecosystems as well as on the beds and shores of the waterways affected. The latter effect results in turn in reduced costs for maintaining the waterways.

The multiple benefits provided by reducing fuel consumption entail important implications for public policy:

- In order to keep climate change to a minimum, to improve air quality, to enhance resource efficiency and to reduce the potential negative impact on the body of water navigated, in general such measures need to be supported which reduce fuel consumption in inland navigation, as these result in multiple benefits. An example is the computer-based device referred to as a cruise control, which supports the skipper in selecting the optimum speed for navigation. Use of this device results in less fuel consumption, and the amounts of pollutants as well as greenhouse gases emitted are consequently reduced. When navigating waterways with a limited cross-section, the system recommends a slower speed, which reduces the waves generated and the currents induced by the vessel. An additional effect is reduced operating costs, so that the shipping industry can provide users with more cost-effective transport services.
- Conversely, such measures should be avoided if possible which allow only one of the objectives mentioned above to be achieved, particularly when at the cost of another objective. An example for this is the use of certain kinds of biofuels, which potentially contribute towards a reduction in greenhouse gases yet upon combustion generate more pollutants in total and do not help reduce costs.

The comments above describe in very simple terms a highly complex phenomenon. Still, they make it clear that reducing the greenhouse gases emitted by inland navigation can entail additional benefits which in terms of significance for society at large go far beyond the scope of the original intention. For this reason policymakers and public administration should devote more attention to reducing greenhouse gas emissions from inland navigation than would appear warranted when considering the minor impact, in absolute terms, of inland navigation on climate change. It should also be clear to the shipping industry that reducing fuel consumption not only helps control costs but is a concern that needs to be at the focus of all efforts towards greening inland navigation.

In the new European programme for the promotion of inland navigation – NAIADES II – the European Commission also proposes measures to reduce emissions of harmful substances (EU 2012). They refer mainly to the further development of legislation on the limitation of emissions of harmful substances, and more particularly Directive 97/68/EC[26]. The following measures are also proposed (Panteia, PLANCO et al. 2012):

1. Promotion of the use of LNG as a fuel for inland navigation;
2. Promotion of or obligation to use Decision Support Systems (Tempomaat, Econometer);
3. Promotion of emission-related port charges and navigation fees;

[26] Directive 97/68/EC of the European Parliament and of the Council of 16 December 1997 on the approximation of the laws of the Member States relating to measures against the emission of gaseous and particulate pollutants from internal combustion engines to be installed in non-road mobile machinery

4. Information and awareness-raising with regard to selecting optimal vessel speed (smart steaming);
5. Long-term support of an environment label (Green Award);
6. Development of classification or certification of inland navigation vessels with regard to their environmental properties, similar to the EEDI for marine vessels;
7. Campaign in support of selecting reasonable – i.e. not oversized – propulsion engines.

These additional measures rely largely on reducing fuel consumption, and hence emissions of harmful substances, and using LNG as a more environment-friendly fuel. Implementation of these measures would therefore constitute a further contribution to reducing greenhouse gas emissions in inland navigation, and it is therefore only logical that these measures should be considered from this point on view in the present report. If the measures are carried out as part of NAIADES, it would not be necessary for them to be followed up in the context of further work on reducing fuel consumption and greenhouse gas emissions, as set out in section 17 of this report. On the other hand, if the measures are not taken into account in NAIADES, they could be dealt with as suggested in section 17.

15. Scenarios for the development of greenhouse gas emissions from inland navigation

There are a wide range of measures open to inland navigation by which it can reduce greenhouse gas emissions from shipping operations. These measures include, on the one hand, the operation, construction and equipping of vessels. On the other hand, there are also a large number of measures aimed at "decarbonisation" of the fuel, i.e. the use of fuels with lower CO_2 emissions. The widespread implementation of the former measures in future could be described as a conservative scenario, since these measures have already found their way into inland navigation and have basically been accepted. Measures in the latter group have, at best, only been applied in isolated cases to date, however. Implementation of these measures, over and above the former measures, could thus be seen as an optimistic scenario in terms of the reduction of greenhouse gas emissions. What both scenarios have in common, and what is of particular importance, is increasing the average carrying capacity of the vessels as a result of the progressive modernisation of the inland navigation fleet. A model calculation of the greenhouse gas emissions for these scenarios reveals that, according to the conservative scenario, the total emissions would remain more or less constant, even with an increase in the total traffic & transport volume, and could be reduced by about two thirds according to the optimistic scenario. The following conclusions from this seem most relevant, particularly for transport and environmental policy:

- Widespread implementation of the various existing technical and operational energy-saving measures as well as a continued increase in the average size of vessels will enable the operational greenhouse gas emissions from inland navigation to be kept more or less constant, even with a steady increase in the total cargo volume.
- A significant reduction in the absolute amount of operational greenhouse gas emissions from inland navigation accompanied by a simultaneous increase in the total cargo volume will be possible, if biofuels and fuels produced using renewable energy are used on a large scale, alongside LNG.

These conclusions have to be seen as provisional, since the scenarios and the calculation model both need to be validated. This should be within the possibilities of the CCNR and the trade associations that cooperate with it. Once this has been completed, the model could be very useful to business and administrative organisations, for example in developing strategies and in connection with political decision-making.

Annex 12 contains a detailed presentation of the calculation model and the scenarios.

16. Costs and barriers to reducing fuel consumption and greenhouse gas emissions

Well-founded decisions regarding measures to reduce fuel consumption and greenhouse gas emissions call for adequate knowledge of the associated costs. It seems remarkable that some of the measures presented in this report would contribute to cutting costs, but, in spite of this, have only found very limited use in inland navigation to date. This section will therefore examine the costs and barriers to *reducing* fuel consumption and greenhouse gas emissions in greater depth.

16.1 Costs of reducing fuel consumption and greenhouse gas emissions

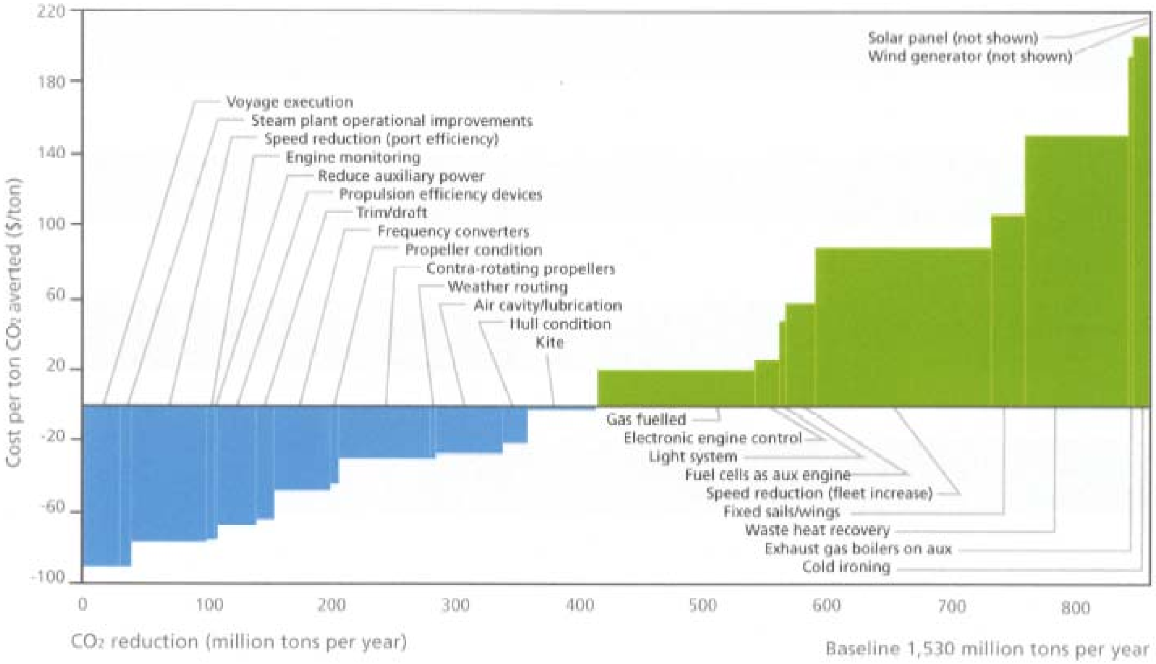
The various technical and operational measures for reducing fuel consumption and greenhouse gas emissions incur different costs. Investments in technical measures increase the cost of inland navigation, unless they are offset by a reduction in operating costs. Operational measures generally result in savings, i.e. the cost of the measures is negative.

The various measures have different reduction potentials. Measures that contribute to a reduction in the power consumption of a vessel’s main propulsions have a significantly higher reduction potential than measures that only have an impact on the power consumption of a vessel’s auxiliary functions. This means, for example, that the reduction potential of what is known as “smart steaming” is very much higher than that of heat recovery for heating purposes.

Marginal Abatement Cost Curves (MACCs) are used to represent these interrelationships graphically, i.e., on the one hand the costs and on the other hand the reduction potentials of the various measures. In general, a MACC shows options for reducing emissions of pollutants or greenhouse gasses in the order of their associated reduction costs. MACCs can be used in any branch of industry within an economy, either globally, or just to represent options for a single branch of industry. MACCs are particularly of interest for political decision-making processes due to their comprehensive representation of the costs and reduction potentials, as they show in a very compact way how reductions can be achieved at what cost, and where it is possible to take political action in order to cut emissions.

Various MACCs have been developed for maritime shipping (Faber, Behrends et al. 2011). **Figure 7** shows a MACC that is based on a model of the anticipated quantitative and qualitative growth of the global merchant shipping fleet up until 2030 and the application of 25 different options for cutting CO_2 emissions (Jahn 2010). The measures on the left of the graph result in a reduction of the life cycle costs, and those on the right to an increase, in particular of the investment costs and fuel costs for the vessels. There are no known MACCs for inland navigation, however. The MACCs for maritime shipping cannot be applied to inland navigation as they are – primarily due to the very different operating conditions of the vessels and the fuel costs – although the curves should tend to be quite similar for inland navigation, since many of the measures listed are also applicable to inland navigation.

Fig. 7: Average marginal CO_2 reduction cost per option – world shipping fleet in 2030 (Alvik, Eide et al. 2010)[27]



The benefits and costs of reduction measures from the point of view of ship owners and the affected companies are relatively obvious. The benefits result from fuel savings (negative costs) and the costs (expenditure), primarily due to additional investment. From the point of view of society, the situation is rather more complicated. From the point of view of society, the amount of fuel saved translates not only into a reduction in greenhouse gas emissions, as shown in the MACC, but also into a reduction in pollutant emissions, in particular NO_X and particulates. This additional social benefit is – when the external costs of the various emissions are taken into account – even more significant than the reduction in greenhouse gas emissions. What is "merely" a reduction in fuel consumption for the companies thus has multiple benefits for society. A social consideration of the MACCs for maritime shipping, taking the reduction in pollutant emissions into account, would therefore shift the zero point of the costs to the right, as some of the measures that incur additional costs for the operators result in savings from society's point of view.

[27] "How to read the abatement curves?
The abatement curves illustrated in Figure 7 summarise the technical and operational opportunities to reduce emissions from the shipping fleet sailing in 2030. The width of each bar represents the potential of that measure to reduce CO_2 emissions from the world fleet compared to a baseline scenario.
The height of each bar represents the average marginal cost of avoiding 1 ton of CO_2 emissions through that measure assuming that all measures to the left are already applied. In Figure 1 the marginal cost shown is the average cost for all ship segments. The graph is arranged from left to right with increasing cost per ton CO_2 averted. The effect of the remaining measures decrease as one measure is implemented, and the most cost-effective measures are implemented first. Where the bars cross the x-axis, the measures start to give a net cost instead of a net cost reduction. Any future carbon cost is not included in the illustration, but will in principle improve the cost-effectiveness of the measures."

The MACC in **Figure 7** also takes the use of liquefied natural gas (LNG) as a possible measure into account and identifies this option as incurring positive marginal costs.

From the current work on the approval of LNG as a fuel for navigation on the Rhine it is known that for large-capacity inland vessels that operate around the clock, the use of LNG as a fuel would probably cut costs and result in savings. For smaller vessels, on the other hand – at least at present – only used for daytime operation, the cost of investing in on-board LNG systems would exceed the potential savings resulting from lower fuel consumption. In such cases, it is worth considering what the MACC takes into consideration: Is it only intended to represent the use cases which cut costs – and thus have a low emission reduction potential overall – or all use cases, which would then result in positive marginal costs overall? The MACC in the example also fails to show the above-mentioned benefits of LNG in terms of the reduction of air pollution and does not take into account how fast the fleet could switch over and thus how soon the desired benefits could start to take effect.

The explanation above shows that MACCs can tempt one to see things as being simpler than they actually are. Therefore, and as a result of the great importance that MACCs have assumed in the last few years, they were examined in-depth and very critically. From the results of this examination, one thing that really stands out is that the models and scenarios on which a MACC is based need to be transparent, so that the user is not misled by the MACC in such a way as to cause them to take the wrong decisions. Also, MACCs can only be one, albeit very important tool of many for analysing the known emission reduction options. Additional information on the uncertainties of the assumptions made and the scheduled implementation of the options taken into consideration is also needed as well as information about the interdependence of the various options. (Elkins, Kesicki et al. 2011; Vogt-Schilb and Hallegatte 2011)

These factors should be taken into consideration when developing and using a MACC for inland navigation. This is relatively simple for the reduction measures for inland navigation, since there are a limited number of practically relevant measures and the implementation of the measures is at least less complex than for maritime shipping, for example. In other words, the models and scenarios on which a MACC for inland navigation is based should be relatively manageable. Of course, the assumptions made for this would also need to be shown transparently. Experience from the creation of MACCs for maritime shipping (Faber, Behrends et al. 2011) should make the creation of MACCs for inland navigation easier.

Even taking the critical comments into account, it is apparent that it would be useful in a number of ways, both for companies as well as for policy makers, to develop a MACC for the greenhouse gas emissions from inland navigation with the underlying scenarios and models. The extensive groundwork on the various MACCs for maritime shipping and the analyses in the paragraphs above should help to minimise the required effort.

16.2 Barriers to reducing fuel consumption and greenhouse gas emissions

Various options or measures for reducing fuel consumption and greenhouse gas emissions cut cost and result in savings, but are nevertheless only implemented to a limited extent in inland navigation. There are thus barriers limiting the implementation of these measures. For maritime shipping there are already studies (Faber, Behrends et al. 2011), which identify these barriers. Potential barriers in the context of inland navigation and possible ways of overcoming them are outlined below.

Technological barriers

Many of those affected, first and foremost the ship owners, are not familiar with or aware of all of the relevant technologies. This limited familiarity with these technologies may be due to the structure of the inland shipping industry in Europe. The European inland shipping industry is highly fragmented, even though the inland shipping industry is internationally oriented due to that fact that most of the traffic is cross-border traffic. This fragmentation is primarily a result of the very piecemeal ownership structure of the inland shipping fleet.

The shipbuilding and equipment industry is similarly fragmented. This fragmentation is also compounded by language barriers in the European inland shipping industry. Technologies are developed and introduced in one language area, but remain more or less unknown in other language areas.

If a new technology is developed, information about it is made available by the supplier of the technology, but there is often a lack of independent information – which is thus generally accepted as being reliable – on the benefits of the technology in practice. Ship owners and financial institutions are thus liable to overestimate the risk associated with an investment due to a lack of information.

It is evident that many technological barriers can be overcome by improving transparency. In practical terms, this could be achieved by providing the relevant information to a few central contact points in a number of languages and by targeted exchange of experience. It would also be desirable for there to be some kind of manufacturer-independent validation of the benefits of the new technologies, for example by the publication of first-hand reports from users or from independent testing institutes.

Institutional barriers

Institutional barriers arise in cases where the body that has to bear the cost of fuel-saving investments or proposes these investments has no advantage to gain as a result of these investments, but must bear the disadvantages. Shipyards that propose fuel-saving technologies may have cause to fear a loss of orders because the ships they build are more expensive and thus harder to sell than those from other shipyards that don't use these technologies. Ship owners who invest in fuel-saving technologies face lower profits if– although they have to pass on the savings achieved due to the lower fuel costs to their customers – the higher investment costs are not covered by them or the shipping companies. Skippers would not be likely to have much interest in navigating efficiently and economically, since on the one hand this would be more demanding on them, in terms of the attention required, and may also result in increased journey times, whereas efficient operation benefits the ship owners. Waterway and port authorities that make investments to facilitate fuel-saving navigation, on the other hand, have no direct influence on whether the opportunities they create are accepted by the skippers.

Institutional barriers can also be overcome, but perhaps not as easily as others, as shown by the following examples. If inland vessels were to be classified according to their fuel efficiency, like cars or houses, this would boost the resale value of vessels fitted with fuel-saving technologies, thus giving the ship owners at least some return on their investment. If skippers received a bonus based on the fuel savings they achieve, they would be motivated to drive in a fuel-saving manner.

Financial barriers

Financial barriers prevent the provision of finance for investments in fuel-saving technologies. Decision-makers, ship owners and financial institutions may underestimate the future cost of fuel and not give sufficient consideration to the fact that that cost of fuel used for inland navigation may rise significantly over the working life of the vessels, making investments in fuel-saving technologies more worthwhile than they may initially seem. The same may apply to the managers of waterways and ports.

In conclusion, it can be said that there are significant barriers to the implementation of measures to reduce fuel consumption and greenhouse gas emissions. Equally, it is clear that there are ways of overcoming these barriers. It seems that it is necessary for all those involved to meet, identify the barriers, and then analyse potential mechanisms for overcoming them.

For most of the barriers this should require relatively little effort, since most of the barriers and potential solutions are already known. Only the institutional barriers would seem to call for more extensive effort in order to be overcome.

17. Proposals for further work

In this section, the needs for further work that were pointed out in the report will be summarised, including additional proposals for specific action and an evaluation of the actions. Particularly in view of its currently very limited resources, the CCNR is only able to actively support a small part of this work. It will therefore focus preferentially on:

- tasks for which the CCNR has data or knowledge that is not otherwise available in the same scope or quality;
- tasks that contribute to the development of strategies and consequently to the objectives of the CCNR's work in the medium and long term.
- tasks that represent necessary groundwork for measures to be taken by others, in particular by the shipping industry, or for later actions by the CCNR.

Correspondingly, tasks have also been listed below in which the CCNR ought to play no or only a minor role.

The evaluation will also involve a rough estimate of the effort needing to be contributed by the parties involved in these tasks. Effort is rated as low, medium or high. Low effort signifies that only a few individuals will be involved, who will require only a few working days to complete each of the tasks. High effort signifies that complex modifications to regulations or similar measures are required.

None of the further work proposed entails any significant investments. Nor will the proposed measures affecting legal regulations necessarily require investments. Rather, the proposed measures make accessible to ship owners options that are currently not available. They could potentially even help reduce the costs incurred to the shipping industry.

The proposals set out below may be used in various ways. They may:

- serve as a basis for discussions among the stakeholders, particularly the navigation and shipbuilding industries;

- be used to develop a CCNR strategy for reducing fuel consumption and greenhouse gas emissions in inland navigation;
- form part of the CCNR's work programme.

17.1 Proposals for further work which the CCNR would be suited to leading

A. Supplementary report on passenger shipping

Content	Addition of specific details on passenger shipping to this report
Benefits	Creation of a basis to inform all those affected and for further work
Effort	Moderate, as it is only an addendum to this report
Risks	Inaccuracies in the estimates required; possibly a lack of details from the shipping industry
Procedure	Preparation by the CCNR Secretariat, completion jointly with the shipping industry
Appropriate leader	CCNR (Secretariat)
Possible partners	EBU, ESO (shipping industry companies), CESA

B. Supplementary report on Rhine shipping

Content	Presentation of the particularities of navigation on the Rhine in relation to reducing fuel consumption and greenhouse gas emissions
Benefits	Creation of a foundation for targeted information for the CCNR and its delegations
Effort	Only slight effort, as it would merely supplement the present report, without requiring additional data collection
Risks	None
Procedure	Set up by CCNR (Secretariat)

C. Determine the carbon footprint of inland shipping

Content	Determine the greenhouse gas emissions arising from inland navigation on the Rhine and in Europe, both in absolute terms and relative to traffic and transport volume (tkm)
Benefits	Create a common foundation for a large number of activities, hence minimise uncertainties particularly in the area of: – political objectives – emissions calculators – voluntary or compulsory information by the shipping industry on greenhouse gas emissions – obligation of countries to report as specified in the Kyoto Protocol Verification of inland navigation's "green" image
Effort	Medium effort, due to the familiar and relatively simple methods and to the figures already available in part from market observation
Risks	Inaccuracies of required estimates; shipping industry could fail to provide information on actual fuel consumption
Procedure	Preparation by the CCNR Secretariat, completion jointly with the shipping industry
Appropriate leader	CCNR (Secretariat)
Possible partners	European Commission, EBU, ESO (shipping industry companies), VBW, INE

D. Determine fuel consumption by evaluating data from the Convention on the collection, deposit and reception of waste produced during navigation on the Rhine and inland waterways (CDNI)

Content	Evaluation of CDNI data to determine fuel consumption of inland navigation vessels, both in absolute terms and as far as possible also relative to traffic and transport volume (tkm)
Benefits	Precise knowledge of vessels' fuel consumption makes it possible to decide on absolute values for the industry's emissions of harmful substances and greenhouse gases and deduce emission factors.
Effort	Relatively low effort with regard to fuel consumption, as the methods are likely to be simple; moderate effort with regard to link to traffic and transport volume
Risks	Inaccuracies caused by demarcation problems and possible required estimates; it may not be possible to produce link to traffic and transport volume
Procedure	Preparation by the CCNR Secretariat, completion jointly with the CDNI instruments/organs and possibly also the shipping industry
Appropriate leader	CCNR (Secretariat)
Possible partners	CDNI organs, EBU, ESO (shipping industry companies)

E. Adapt technical requirements for inland navigation vessels to allow approval of alternative energy sources (fuels)

Content	Adapt technical requirements for inland navigation vessels to allow approval of alternative energy sources (fuels)
Benefits	Allows shipping companies to use other energy sources (fuels) besides gas oil
Effort	High effort, due to comprehensive amendments to technical requirements
Risks	Certain alternative energy sources (e.g. LNG, hydrogen) entail a greater potential risk than gas oil
Procedure	Develop proposals for amending the RVIR and Directive 2006/87/EC on the basis of a fuel strategy; issue recommendations for trials / exemptions; initially amend requirements for electrical equipment incl. propulsion systems, later for the approval of LNG etc.
Appropriate leader	CCNR (Inspection Regulations Working Group)
Possible partners	European Commission, EBU, ESO, CESA, Euromot

F. Generally examine the mandatory introduction of the Energy Efficiency Design Index (EEDI) for inland navigation

Content	Generally examine the mandatory introduction of the Energy Efficiency Design Index (EEDI) for inland navigation or another energy classification
Benefits	Mandatory basis for determining whether the design of a new ship is energetically favourable; provides ship owners with a means of benchmarking
Effort	An Energy Efficiency Design Index (EEDI), already developed for maritime shipping (termed the "CO_2 Design Index") and accepted by the IMO this July as a legally binding measure for reducing CO_2 emissions from maritime shipping, could, in principle, also be used for inland shipping; low effort, since only an examination of suitability is needed
Risks	No risk, since only an examination of suitability is required initially
Procedure	Consult with the classification societies mainly responsible for developing and using the Index and with shipyards and ship owners; subsequently, prepare a proposal for a general decision and possible further procedure (Introduce a classification after a positive decision)
Appropriate leader	CCNR (Inspection Regulations Working Group)
Possible partners	European Commission, EBU, ESO, IACS, CESA

G. Generally examine a mandatory standard for the Energy Efficiency Operational Indicator (EEOI) for inland navigation

Content	Generally examine a mandatory standard for the Energy Efficiency Operational Indicator (EEOI) for inland navigation
Benefits	Reliable basis for determining whether a ship is operated in accordance with energy efficiency standards; provides ship owners with a means of benchmarking
Effort	Energy Efficiency Operational Indicator (EEOI) has been developed for marine shipping and corresponding provisional regulations have been adopted by the IMO; could, in principle, also be used for inland shipping; low effort, since only an examination of suitability is needed
Risks	No risk, since only an examination of suitability is required initially
Procedure	Consult with the classification societies mainly responsible for developing and using the Index and with shipyards and ship owners; subsequently, prepare a proposal for a general decision and possible further procedure (Introduce the standard after a positive decision)
Appropriate leader	CCNR (Inspection Regulations Working Group)
Possible partners	European Commission, EBU, ESO, IACS, CESA

H. Generally examine any possible significant measures to be further taken by the CCNR to reduce fuel consumption and greenhouse gas emissions from inland vessels

Content	Generally examine any possible significant measures to be further taken by the CCNR to reduce fuel consumption and greenhouse gas emissions from inland vessels
Benefits	Besides the measures previously described in detail, other possible steps are known or could be conceived; this includes measures that reduce both CO_2 emissions and pollutant emissions (i.e. a central goal of the CCNR)
Effort	Depends on the number of measures to be examined; medium effort at most is expected, since only a general examination will take place
Risks	No significant risks
Procedure	Measures pre-selected by the CCNR Secretariat will be subsequently defined in detail jointly with specialised trade associations
Appropriate leader	CCNR (Inspection Regulations Working Group)
Possible partners	EBU, ESO, CESA, Euromot, IACS

I. Prepare scenarios for the development of greenhouse gas emissions from inland navigation

Content	Prepare scenarios for the development of greenhouse gas emissions from inland navigation
Benefits	Scenarios are an effective tool for the development of climate protection objectives and of strategies, e.g. for the fuels to be used by inland shipping in future, or of programmes to promote climate-friendly inland shipping
Effort	Depends on the depth of detail and the quantity of scenarios; relatively low effort, if the available calculation model is used or expanded to a minor extent
Risks	Inaccuracies of required estimates
Procedure	Preparation by the CCNR Secretariat, completion jointly with the shipping industry
Appropriate leader	CCNR (Secretariat)
Possible partners	European Commission, EBU, ESO (shipping industry companies), CESA, INE

J. Provision of relevant information for the inland navigation sector

Content	User-friendly provision of comprehensive relevant information on the main aspects of greenhouse gas emissions from inland navigation and the reduction of these emissions
Benefits	Overcomes one of the main barriers preventing the implementation of measures by the shipping industry and other bodies
Effort	Relatively low, due to major preliminary work
Risks	Insufficient acceptance of the information instruments
Procedure	Publication of a multilingual brochure; creation of a multilingual website to serve as an information platform; creation of a user-oriented and multilingual database on the operational and technical ways of reducing fuel consumption and greenhouse gas emissions
Appropriate leader	CCNR (Secretariat)
Possible partners	EBU, ESO, CESA, Euromot, IACS, INE, European Commission

17.2 Proposals for further work to be led by the CCNR or other institutions

K. Develop quantitative objectives for reducing greenhouse gas emissions from inland shipping

Content	Develop quantitative objectives for reducing greenhouse gas emissions from inland shipping
Benefits	Aligns political, economic, technical and other processes; creates a common foundation for a large number of activities, hence minimises uncertainties; contributes towards maintaining inland navigation's "green" image
Effort	Relatively low, due to major preliminary work (OECD, European Commission, INE/EBU/ESO, this report)
Risks	Incomplete knowledge of current emissions, of options for reducing emissions and of the overall development of the economy; diverging national objectives
Procedure	Examine and define in detail the objectives of the European Commission and the shipping industry; prepare a joint proposal
Appropriate leader	CCNR or European Commission
Possible partners	European Commission, EBU, ESO, INE

L. Prepare a cross-transport-mode and cross-border strategy for future energy sources (fuels) used in inland navigation or alternatively a fuel strategy for inland navigation

Content	Prepare a detailed strategy for future energy sources (fuels used in inland navigation) as a means of reducing greenhouse gas emissions and of ensuring supplies
Benefits	Aligns economic, technical and other processes; creates a common foundation for other activities such as those involving the technical requirements for inland vessels, hence minimises uncertainties; contributes towards maintaining inland navigation's "green" image
Effort	Relatively low, due to major preliminary work (European Commission, trade associations, this report)
Risks	Limited knowledge of market developments and of overall economic development in the medium and long term; potentially diverging national objectives
Procedure	After presentation of the announced strategy of the European Commission and of the states examine and supplement them if necessary with regard to the needs of inland navigation
Appropriate leader	European Commission or alternatively CCNR
Possible partners	European Commission, EBU, ESO, CESA, Euromot, CONCAWE/EUROPIA, INE

M. Europe-wide introduction of a common environmental label for inland navigation

Content	Europe-wide introduction of a common environmental label for inland navigation, either identical or similar to the Dutch “Green Award”
Benefits	Promotion of the adoption of measures by the inland navigation industry to reduce greenhouse gas emissions and protect the environment
Effort	Low amount of effort to develop the environmental label, as extensive preliminary work has been done and experience gathered; low effort for individual users; overall a large amount of effort required to introduce it throughout Europe, as it could potentially involve a lot of parties
Risks	Low level of acceptance by bodies that could recognise vessels with environmental labels, e.g., ports, shipping agents, financial institutions
Procedure	Fundamentally adoption of the Dutch Green Award system by the appropriate institutions in other countries or the establishment of an international system; International standardisation (evaluation criteria etc.) by the CCNR possible
Appropriate leader	INE, VBW, (CCNR – if no other institution can be found)
Possible partners	EBU, ESO, EFIP, national waterway administration authorities

N. Support of the Europe-wide introduction of a programme to promote energy-saving operation of inland vessels (smart steaming)

Content	Europe -wide introduction of a programme to promote energy-saving operation of inland vessels, either identical or similar to the Dutch “Smart Steaming” programme
Benefits	Promotion of energy-saving operation of inland vessels as a key element in the reduction of greenhouse gas emissions and to protect the environment
Effort	Moderate effort to develop the programme, as on the one hand extensive preliminary work has already been done and experience gathered, and on the other hand it would involve a bundle of different measures; low effort for individual users; large amount of effort for introduction at the national level
Risks	Low level of acceptance by the shipping industry; experience in the Netherlands indicates that acceptance should be high
Procedure	Fundamentally adoption of the Dutch programme by the appropriate institutions in other countries or the establishment of an international programme; Exchange of information and experience for national bodies via the CCNR possible
Appropriate leader	States, INE (alternatively the CCNR – if there is demand for an international programme)
Possible partners	EBU, ESO, national administration authorities

17.3 Proposals for further work without the CCNR or with no more than minimal involvement

O. Develop measures for waterways and ports aimed at reducing greenhouse gas emissions from inland shipping

Content	Develop measures, not involving the building or equipping or operation of vessels, aimed at reducing greenhouse gas emissions from inland navigation
Benefits	Reduces greenhouse gas emissions from the overall system
Effort	Depends on the degree of detail; medium to high
Risks	Limited possibility of generalising the proposed measures and/or of representing reduction potential
Procedure	Expand the mandate of the existing PIANC Permanent Task Group on Climate Change
Appropriate leader	PIANC
Possible partners	EFIP, EBU, ESO, VBW, national waterway administration authorities

P. Develop quality standards for future energy sources (fuels) used in inland navigation

Content	Develop quality standards for future energy sources (fuels) used in inland navigation
Benefits	Prerequisite for safe operation of ship engines and specifically of complex exhaust-gas aftertreatment systems, when the particular energy sources (fuels) are used
Effort	For individual energy sources (fuels), low to medium, since standards could be adopted, in part at least, from other industrial sectors; for all energy sources, high
Risks	Difficulty in reaching agreement due to the large number of parties involved, some of whom have widely diverging interests
Procedure	Incrementally for individual energy sources (fuels)
Appropriate leader	Industry or the European Commission; CCNR could initiate tasks or moderate discussions
Possible partners	European Commission, EBU, ESO, CESA, Euromot, CONCAWE/EUROPIA

Q. Examine CO_2 reduction potential through the use of LNG and other alternative energy sources (fuels) in inland navigation

Content	Examine CO_2 reduction potential through the use of LNG and other alternative energy sources (fuels) in inland navigation
Benefits	Focuses on energy sources (fuels) that could substantially contribute towards reducing CO_2 emissions from inland navigation; avoids contra-productive developments
Effort	For individual energy sources (fuels), low to medium, since results of studies could be adopted, in part at least, from other transport sectors; for all energy sources, high
Risks	Difficulty in reaching agreement due to the large number of parties involved, some of whom have widely diverging interests
Procedure	Incrementally for individual energy sources (fuels)
Appropriate leader	European Commission, Member States; CCNR might possibly compile the results of studies conducted on behalf of the European Commission and the Member States and of the industry (CCNR Secretariat observatory)
Possible partners	Research institutions

R. Study in greater detail technical measures for the reduction of fuel consumption and greenhouse gas emissions from inland vessels involving the vessels themselves

Content	Study in greater detail technical measures, including those involving propulsion systems, for the reduction of fuel consumption and CO_2 emissions from inland vessels involving the vessels themselves, particularly with regard to implementation
Benefits	Reduces fuel consumption and CO_2 emissions from inland navigation
Effort	Varies for the individual measures; high especially for studies involving propulsion systems using alternative energy sources
Risks	Measures are studied that have little prospect of practical application
Procedure	Incrementally for individual measures
Appropriate leader	European Commission, Member States; CCNR might possibly compile the results of studies conducted on behalf of the European Commission and the Member States and of the industry (CCNR Secretariat observatory)
Possible partners	Research institutions

S. Study in greater detail operational measures for the reduction of fuel consumption and greenhouse gas emissions from inland vessels

Content	Study in greater detail operational measures for the reduction of fuel consumption and CO_2 emissions from inland vessels, particularly with regard to implementation
Benefits	Reduces fuel consumption and CO_2 emissions from inland navigation
Effort	Varies for the individual measures; low to medium in total
Risks	Measures are studied that have little prospect of practical application
Procedure	Incrementally for individual measures
Appropriate leader	European Commission, Member States; CCNR might possibly compile the results of studies conducted on behalf of the European Commission and the Member States and of the industry (CCNR Secretariat observatory).
Possible partners	Research institutions

T. Determine reduction in fuel as result of increasing average capacity of inland navigation vessels

Content	Determine reduction in fuel consumption and greenhouse gas emissions of inland navigation vessels on the Rhine and European waterways as a result of increased average capacity of vessels, both in absolute terms and in relation to traffic & transport volume (tkm)
Benefits	The increase in average capacity (size) is an important factor in reducing fuel consumption and CO_2 emissions in inland navigation, and one of decisive importance; more precise knowledge of the factor would also be helpful as support for setting policy targets
Effort	Relatively little effort, as the method would probably be simple, and some of the data is already available from work on observation of the market
Risks	Inaccuracies in the necessary evaluations; possibility of inadequate information from the shipping industry on actual fleet developments
Procedure	Initiation through national administrations
Appropriate leader	National administrations
Possible partners	EBU, ESO (companies in the shipping industry), VBW

Annex 1

Greenhouse gas (GHG) emissions from inland navigation – Emissions others than from ship operation

Knowledge gaps regarding certain aspects of GHG emissions from inland navigation

The EU research project *EU Transport GHG: Routes to 2050 II*[28] looks at – among others – inland navigation GHG emissions others than from ship operation. It shows that there are enormous knowledge gaps regarding those emissions.

Scope of the possible activity

The goal of the activity is to develop sufficient understanding and tools to determine the GHG emissions from the entire inland navigation system. With those tools it should be possible to estimate the GHG emissions for all phases of the life cycles of waterways, inland ports / terminals and vessels.

The possible scope of the activity, the individual tasks and the main stakeholders are summarized in the following table.

		Construction	**Operation**	**Maintenance**	**Decommissioning**
		1	2	3	4
Waterways	A	Waterway administration	Waterway administration	Waterway administration	Waterway administration
Ports / terminals	B	Waterway administration, port administration / operators	Port operators	Port administration / operators, waterway administration	Waterway administration, port administration / operators
Vessels	C	Shipbuilders	Shipowners	Shipbuilders / shipowners	Shipbuilders

With regards to the waterways, water management not related to navigation does not need to be included in the foreseen activity. For PIANC, it may be of interest to also cover recreational navigation. However, that is not so for the EU research project, as it concentrates on transport.

For the ports / terminals, only waterside activities need to be taken into account, e.g. loading and unloading of vessels including necessary infrastructure and equipment. (All the other port activities are attributable to rail or road transport and separate logistical activities.)

Obviously, whereas PIANC members would most likely be able to generate the necessary knowledge for the tasks related to the waterways, for all other tasks it would rely heavily on contributions from the relevant industry (associations).

[28] www.eutransportghg2050.eu

The scope of the activity is vast and therefore priorities need to set. The table on the right gives priorities for the different tasks. The priorities are assigned to each of the tasks according to their assumed share of overall GHG emissions from inland navigation.

Priority		Task
High	I	A2, A3, B2, B3, C2
Medium	II	A1, B1, C1,
Low	III	A4, B4, C3, C4

Structure of the possible PIANC activity

Because the scope of the activity is vast, it seems wise to design work packages, taking the different stakeholders and the above priorities into account.

WP1.1: A2+A3, WP1.2: B2+B3; WP2:1 A1+A4, WP2.2: B1+B4, WP2.3: C1+C3+C4

No work package is needed for the emissions from the operation of inland navigation vessels as this task is already covered in this report by the CCNR.

The activity would require the classification of objects for each of the task. Obviously, vessels would be categorized according to their type and size. Similar categories would have to be developed for the waterways and the ports / terminals.

Inputs and outputs

It seems unlikely that a deductive approach can be found to generate the necessary knowledge. Rather, real world data on GHG emissions and energy consumption will have to be collected. Information about the energy or carbon intensity for the production of construction material will also be needed.

At least for the time being, it is not possible to develop exact figures for the GHG emissions from transport. This is also true for inland navigation. Further, inland navigation produces in absolute terms much less GHG emissions than road or rail. Therefore, the desired output of the activity will be sufficient knowledge to substantiate educated guesses of the emissions rather than exact calculations.

It is to be expected, that the operation of the vessels will be the main source of GHG emissions in inland navigation. The activity should establish the magnitude of the GHG emissions of the other tasks in comparison to the GHG emission from vessel operation. If it can be established that the GHG emissions of some of the other tasks amount only to few percentage points, these tasks do not warrant an in-depth examination.

Ideally, one of the main outputs of the activity would be values for emission coefficients or emission intensity, such as grams of CO_2 per ton kilometre. This would allow applying the findings of the work in the most general and easiest way. The values of these coefficients will be given as a range of likely values, as exact figures will neither be possible nor really needed.

Developing the emission coefficients will require a sound understanding of the factors that determine the GHG emissions for each task. Developing this understanding and describing it in a way that is comprehensible for decision makers in all fields of inland navigation, including operation managers and policy designers, will be the other main output of the activity.

Annex 2

CCNR Member States' targets for the reduction of anthropogenic greenhouse gas emissions

Table 4: CCNR Member States' targets for the reduction of anthropogenic greenhouse gas emissions for all sectors and for transport

Country	Climate protection goals		Sources
	All sectors	Transport	
Belgium	Target outside the Emission Trading System: reduction in greenhouse gas emissions by 15% by 2020 (relative to 2005), with linear reduction path	Still in preparation	EU decision (Effort Sharing Decision)
Germany	Reduction in greenhouse gas emissions by 40% by 2020, by 55% by 2030, by 70% by 2040 and by 80-95% by 2050 (all figures relative to 1990)	Decrease in final energy consumption by approx. 10% by 2020 and by approx. 40% by 2050 (relative to 2005)	Energy Concept for an Environmentally Sound, Reliable and Affordable Energy Supply (BMWi 2010)
France	Reduction in greenhouse gas emissions by 23% by 2020 and by 75% by 2050 (both figures relative to 1990)	Return to the greenhouse gas emissions level of 1990 by 2020 (after an increase by 19% between 1990 and 2004), additional reduction by 65% by 2050	French climate plan, updated in 2011 Climate and energy efficiency policies Summery of France's commitments and achievements, 2011
Netherlands	Reduction in greenhouse gas emissions by 20% by 2020 (relative to 1990). Conditional target of -40% by 2030.	The 20% reduction target corresponds to a maximum quantity of 35.3 million tonnes in 2020. No sectoral target for 2030 yet. Starting point of -60% by 2050.	Government strategy on climate policy to 2020 (June 2011). Climate Brief 2050 (18 November 2011)
Switzerland	Reduction in greenhouse gas emissions by 20% by 2020 (relative to 1990)	Sectorial targets are being defined in the context of the implementing regulations. These regulations will enter the consultation process in May 2012. Sectoral targets can only be given once the regulations have been passed into law by the Federal Council.	Federal Law on the Reduction of CO_2 Emissions (Law on CO_2), 23 December, 2011

Annex 3

Establishing the carbon footprint and the specific CO_2 emissions (CO_2 intensity) of inland navigation

The CO_2 intensity of a given mode of transport can be presented via its CO_2 emissions based on its transport performance. This is largely done in g/tkm, but g/TEUkm can also be used. This ratio is often also known as the CO_2 emission factor. The CO_2 emissions are due to the combustion of gas oil which is virtually the only fuel used for inland navigation. Owing to the chemical processes caused by combustion there is a constant relationship between the amount of fuel burnt and the resultant emissions of CO_2. This generally happens regardless of the age or make of the vessel.

CO_2 intensity is therefore clearly to be determined by pinpointing the fuel consumption of a vessel or fleet in relation to transport performance

The studies and procedures cited in **table A5** tend to draw on a **theoretical approach to establishing CO_2 intensity**. A number of parameters are deployed to determine the average energy consumption for specific vessels or an entire fleet and are then compared to the transport performance which these vessels of fleets achieve or could potentially achieve.

Table 5: Selected studies establishing figures of the CO_2 intensity (CO_2 emission factors) of inland navigation

Study/Procedure	Date of publication	Additional information	Inclusion of upstream processes
INFRAS; *External Costs of Transport, Update Study* (Schreyer, Schneider et al. 2004)	2004	Underlying data tenuous; many simplifications	Yes
Haskoning; Schilperoord, H.A., *Binnenvaart voortdurend duurzaam – Environmental Performance of Inland Shipping* (Schilperoord 2004)	2004	Various emission factors for different vessel types (vessel dimensions) and transport operations	No
ADEME/VNF; *Etude sur le niveau de consommation de carburant des unites fluviales francaises* (ADEME 2006)	2006	Determination of fuel consumption on the basis of a survey of skippers / shipping companies	No
PLANCO; *Verkehrswirtschaftlicher und ökologischer Vergleich der Verkehrsträger Straße, Bahn und Wasserstraße* (PLANCO 2007)	2007	Various emission factors for different vessel types (vessel dimensions) and transport operations	Yes
DST; *Strömungstechnische Möglich-keiten zur Reduzierung des Kraftstoffverbrauchs und der CO_2-Emissionen von Binnenschiffen* (Zöllner 2009)	2009	Various emission factors for different vessel types (vessel dimensions) under standard operating conditions	No
TTI; *A Modal Comparison of Domestic Freight Transportation – Effects on the General Public* (Kruse 2009)	2009	Average figure for inland navigation in the USA; Calculation model was checked against actual transport performance and fuel consumption	

Study/Procedure	Date of publication	Additional information	Inclusion of upstream processes
Gent University; *Improving the efficiency of small inland vessels* (Geerts, Verwerft et al. 2010)	2010	Average value for 3 classes of vessel; taking the total traffic & transport volume for various classes of waterway into account	No
IFEU/TREMOD; *Fortschreibung und Erweiterung "Daten- und Rechenmodell: Energieverbrauch und Schadstoffemissionen des motorisierten Verkehrs in Deutschland 1960-2030* (TREMOD, Version 5) Endbericht (Knörr 2010)	2010	Broad, unrefined assessment	Yes
CEFIC; Measuring and Managing CO_2 Emissions of European Chemical Transport; Alan McKinnon, Maja Piecyk (McKinnon and Piecyk 2010)	2010	Based on emission factors published by INFRAS, TRENDS, Tremove and IFEU; an average value only	Yes
Seine-Schelde study; External and infrastructure costs of freight transport Paris-Amsterdam corridor (Schroten, van Essen et al. 2010)	2010	Different emission factors for different vessel types (dimensions) and transportation; highly differentiated; emission data correspond more or less to STREAM	
EcoTransIT World; Ecological Transport Information Tool for Worldwide Transports; Methodology and Data (IFEU 2010)	2010	Little distinction as regards vessel type and kinds of waterway	Yes
STREAM; STREAM International Freight 2011 – Comparison of various transport modes on a EU scale with the STREAM database (den Boer, Otten et al. 2011)	2011	Various emission factors for different vessel types (vessel dimensions) and transport operations, highly differentiated	Yes
Marco Polo; External cost calculator for Marco Polo freight transport project proposals (Brons and Christidis 2011)	2011	Various emission factors for three size classes (independent of vessel type) and one average value	Yes
NEA; Medium and Long Term Perspectives of IWT in the European Union (NEA, PLANCO et al. 2012)	2012	Emission data from STREAM	Yes

One project that is interesting in this connection calculated the theoretical energy consumption of inland navigation vessel types according to speed and other relevant parameters and then compared this with the actual consumption data of a small number of vessels (Georgakaki and Sorenson 2004). If the parameters, including speed, are known, the data from this project can be used to calculate energy consumption and extrapolate CO_2 emissions. The study does not, however, include any CO_2 emission factors.

The most reliable and apparently the simplest **method for establishing the CO_2 intensity in practise** would be to measure the fuel consumption of a vessel or fleet and correlate this with the transport performance of the vessels or fleet in the observation period. This method does give rise to some fundamental problems:

- When surveying entire fleets there are often serious problems of delimitation when it comes to establishing the quantity of fuel consumed, and perhaps also with regard to their transport performance. These problems have been evident in a number of studies (Denier van der Gon and Hulskotte 2010; Knörr, Heidt et al. 2011) and as a result these studies have not been taken into account any further in this report.
- When surveying entire fleets the research results for certain aspects are rather tenuous if the fleets, their operating conditions, or routes are very heterogeneous. This would, however, not be significant when determining the carbon footprint for inland navigation in a country or a region.
- Research covering a limited number of vessels is not reliable – conversely research projects encompassing many vessels with different operating conditions and/or routes are highly expensive.

The TTI study is the only one which refers to a research project where the actual fuel consumption of a fleet is compared to its transport performance. PLANCO took account of research on individual vessels and indeed assessed the results of various studies on the power requirements of inland navigation vessels before interpolating and extrapolating these results using a mathematical procedure. TTI and PLANCO therefore made practical use of research results to check on the theory underpinning the figures for fuel consumption and thus also those for CO_2 intensity.

Key parameters to be borne in mind when establishing the CO_2 intensity (and potential use of emission factors) for inland navigation

The **average energy consumption** of an inland navigation vessel depends on a host of **parameters**. The most relevant are:

- Type of vessel and its dimensions,
- Vessel speed,
- Vessel capacity (cargo loading factor),
- Number of unladen runs,
- Dimensions of the waterway used (especially depth of water),
- Kind of waterway used (free-flowing river, impounded river, canal),
- Direction of current.

In this light, those studies or procedures which take complete account of these parameters or which take most of them on board, should be superior to those which only use a few parameters or which rely on unverified average figures for these parameters to avoid a more in-depth analysis.

Many studies also examine **energy consumption for transshipment** plus **initial and/or terminal road haulage,** particularly when establishing CO_2 emissions for container transport. However, this only makes sense if the study covers transport operations involving a modal switch or seeks to compare modes of transport where the consignor and the recipient of the cargo do not enjoy direct access to the waterways. However, there is still room for discussion as to whether energy consumption for transshipment plus initial and/or terminal road haulage is to be taken account of in determining the carbon footprint for inland navigation. These activities were not taken into consideration in this report.

When establishing emission factors, many studies also consider **the energy used to produce fuel**. Since this energy input (upstream processes) is also often taken into consideration when calculating the carbon footprint of other modes of transport, this is also done for the calculations below. If the upstream processes were not taken into consideration in certain studies, the upstream processes are taken into consideration for the emissions at a rate of 11.8 g CO_2 per MJ (den Boer, Otten et al. 2011). In the as yet unpublished European standard EN 16258 : 2013, a value of 15.9 g CO_2 per MJ is given. It would exceed the scope of this report to analyse the reason for the difference between the two values. Since the difference corresponds to a mere 5% of total emissions (per MJ), this discrepancy would seem to be acceptable both for the purposes of this report, and for determining the fuel consumption and greenhouse gas emissions of inland navigation in Europe.

The age of the engines fitted to the vessels also affects the emission factor. This is because older engines use more fuel than newer engines to provide the effort they supply (to propel the vessel), expressed in kWh, For example, studies on engines built prior to 1975 show a specific fuel consumption of 235 g/kWh and a figure of 200 g/kWh for engines manufactured after 2002 (Denier van der Gon and Hulskotte 2010; Knörr, Heidt et al. 2011). According to this, the spread of the value for specific fuel consumption is less than 20% of the absolute values, which could imply an inaccuracy of 10% at most in the choice of a suitable average value. Even this possible inaccuracy ought to be acceptable for the purposes of the report and for determining fuel consumption and greenhouse gas emissions for inland navigation in Europe.

Use of the figures on CO_2 intensity (emission factors) of inland navigation cited in the studies and procedures

It might seem a good idea to conduct a kind of meta-study with a detailed comparison of the methods used in the procedures and studies on establishing CO_2 intensity (emission factors) listed in **table 5**, and then go on to set figures for the CO_2 intensity of inland navigation. Nonetheless, it will only be feasible to do this in the CCNR report on possibilities for reducing fuel consumption and CO_2 emissions for inland navigation to a limited extent.

Furthermore, a simple comparison of the studies and procedures is enough to show the different weight given to the various parameters. Basically, some studies and procedures tend to consider only certain parameters and those which are taken account of are subjected to simplistic or sweeping assumptions, without the authors verifying beforehand whether the simplifications and generalisations performed had any substantial effect on the results. The problem concerning the average figures for the CO_2 intensity becomes apparent by comparing inland navigation with road transport. The smallest vessels (peniches) have a carrying capacity of less than 400 t, which is approximately 1/40 of that of a large pushed convoy. Applied to road transport, this is approximately the ratio of the load capacity of a delivery van relative to that of a large articulated lorry.

Table 6 lists the studies that only give one average value for the CO_2 intensity, which is not backed up by a differentiated consideration of the emissions from the various classes of vessel or by comparison with the actual fuel consumption of all of the ships in a specific area. These studies, with the exception of the studies by Gent University and the TTI, are not given any further consideration due to the reasons stated above. Although the study by Gent University does calculate the average taking the total traffic & transport volume for various classes of waterway into account, the study is limited to 3 small vessel types in a relatively small area. The CO_2 intensity determined in this study could thus by all means be significant, after all, albeit only for the discussion of the emissions of small vessel types. The study conducted by the TTI gives an average value for inland navigation in the USA, with the computational model having been verified with actual traffic and transport volume and fuel consumption figures. Since shipments via inland waterways in the USA are generally performed by large pushed convoys, the values for the CO_2 intensity arrived at by this study can indeed be compared with those for large pushed convoys in Europe.

Table 6: Selected studies which establish figures for the CO_2 intensity (CO_2 emission factors) of inland navigation in an undifferentiated manner

Study/Procedure	CO_2 intensity (CO_2 emission factors)
CEFIC	31 g/tkm
Gent University	32 g/tkm
IFEU/TREMOD	31.8 g/tkm
INFRAS	31 g/tkm
TTI	11 g/tkm

It would seem that the only realistic and refined research with due regard to the key parameters is to be found in the Stream/Shift, Haskoning and PLANCO studies. The Stream/Shift and Haskoning studies also cover very small vessels, which have, of course, the largest specific emissions. In 2007 cargo vessels with a capacity of less than 650 t made up about a third of the European fleet in numerical terms, for about 10% of total tonnage and about 15% of total installed capacity (CCNR and EC 2009). This makes it clear that these very small vessels are of relatively minor significance in the overall European context.

Table 8 shows figures on the CO_2 intensity (CO_2 emission factors) for inland navigation that were determined by various different studies in a differentiated manner, taking the upstream processes involved in producing fuel (well to wheel) into account. The broad spread between the minimum and maximum values is striking, even for the various individual vessel types and even more so when looking at all vessel types. For the individual vessel types, the highest values are five times as high as the lowest, in some cases, and when comparing all vessel types it can be as much as ten times as high. The highest values are primarily for light loads on vessels with a low carrying capacity. However, they are rather insignificant in the context of inland navigation in Europe and, in particular, navigation on the Rhine. It is therefore safe to assume that, basically, the minimum values are closer to the real emission levels than the maximum values.

No generalisation, let alone calculation of an average, is possible on the basis of the figures reported by these studies alone, in order to determine the carbon footprint of inland navigation, due to the wide range of values. In order to be able to determine the carbon footprint of inland navigation for a specific area, such as for navigation on the Rhine, for example, or for inland navigation in Europe, reliably, the following procedure seems appropriate:

- Verification of the emission factors given for each vessel type for the relevant area;
- Determination of the total traffic & transport volume for each vessel category (all of the vessels belonging to one type) in the relevant area;
- Determination of the carbon footprint for each vessel category by multiplication of the total traffic & transport volume for the vessel category by the emission factor for the vessel type;
- Addition of the carbon footprint of all of the vessel categories represented in a given area.

The individual shipping areas could be subdivided further, according to whether they are free-flowing or regulated rivers or canals, as this has a significant effect on specific fuel consumption and hence on the emission factors (Knorr, Heidt et al. 2011). The verification of the emission factors could be performed by the use of data on the actual fuel consumption for various vessel types. The total traffic & transport volume for each vessel category can also be determined on the basis of real-life data. Together with the statistical data on the number of vessels per category, it is thus possible to determine the total traffic & transport volume per category.

The Secretariat of the CCNR has obtained initial provisional values of the emission factors from individual inland navigation operators; these are reproduced in **Table 7**.

Table 7: Values for CO_2 intensity (CO_2 emission factors) in inland navigation based on real fuel consumption for selected vessel types and shipping areas (including upstream services)

Vessel types/shipping areas	CO_2 intensity (CO_2 emission factors)
Pushed convoys consisting of 4 or 6 barges / Lower Rhine	11,6 g/tkm
Johann Welker / container transports Rhine area	24,9 ... 40,0 g/tkm
Large motor vessel / container transports Rhine area	19,1 ... 32,6 g/tkm
Jowi / container transports Rhine area	10,3 ... 17,6 g/tkm

It is interesting to note that the emission factors determined on the basis of the figures provided by the shipping industry are at the lower end of the range of values reported in the studies and remain significantly below the values used in the framework of EcoTransIT and Marco Polo for decisions on subsidies by the European Commission and for company decisions.

In view of the great political significance as well as the increasing commercial significance that greenhouse gas emissions have for inland navigation, it seems appropriate to continue this work. and the intensive participation of the shipping industry is indispensable for this, in order to ensure that real-life data, the necessary statistics and the technical & operational aspects are all brought together. Furthermore, it would be worthwhile coordinating with the European Commission, in order to enable the work to gain EU-wide acceptance and be taken into account in the development of European transport policy.

Table 8: Selected studies which establish figures for the CO_2 intensity (CO_2 emission factors) of inland navigation in a differentiated manner, taking the upstream processes involved in producing fuel (well to wheel) into account

		CO_2 intensity (emission factors), in g/tkm									
Waterway class (CEMT)		**I**	**II**	**III**	**IV**		**V**		**VI.**		**Minimum/ maximum in study**
Vessel type		**Peniche**	**Kem-penaar**	**Gustav Koenigs**	**Johann Welker**	**Pushed convoy**	**Large Rhine vessel**	**Pushed/ coupled convoy**	**Jowi class container vessel**	**Pushed convoy**	
Carrying capacity (t)		**250 - 400**	**400 – 650**	**650 – 1000**	**1000 - 1500**		**1500 - 3000**		**≥ 3000**		
Study	**Goods transported**										
Haskoning [29]	Bulk goods	43.2	47.2		40.0		22.8[30]	14.4	23.1[31]	10.6[32]	10.6 - 47.2
	Non-bulk goods		28.2[33]		47.0		14.7		17.0		
ADEME / VNF[34]		51.4	50.4	45.0	42.1		34.8	25.0			25.0 - 51.4
Planco	Bulk goods					15.8	19.6; 22.8	12.0 - 21.1		14	10.3 - 23.2
	Containers[35]					21.1; 21.9	13.0	17.4	10.3		
DST2009[36]		(47.1)		(31.3)	(17.6)		(6.4)	(11.6)	(7.7)	(11.9)	(6.4 - 47.1)
Marco Polo[37]	Bulk goods				(68.5)		(64.3)	(43.21)			
EcoTransit[38]	Bulk goods	(60.6)					(37.7)				(31.5 - 60.6)
	Containers	(52.7)					(31.5)				

29 Converted values (emission factors incl. upstream processes approx. 1.16 * emission factors excl. upstream processes)
30 3500 t tanker
31 6000 t tanker
32 4-barge pushed convoy
33 Neokemp
34 Converted values (emission factors incl. upstream processes approx. 1.16 * emission factors excl. upstream processes)
35 Converted values (1TEU ~ 10.5 t)
36 Values not comparable, as the logistical operating conditions such as unladen runs are not taken into account; these values are therefore not taken into consideration.
37 Own calculations on the basis of Van Essen and den Boer (2012); only 3 vessel types; values therefore not taken into account any further
38 Values not comparable, as they are averaged for several vessel types; these values are therefore not taken into consideration

		CO_2 intensity (emission factors), in g/tkm									
Waterway class (CEMT)		**I**	**II**	**III**	**IV**		**V**		**VI.**		**Minimum/ maximum in study**
Vessel type		**Peniche**	**Kem-penaar**	**Gustav Koenigs**	**Johann Welker**	**Pushed convoy**	**Large Rhine vessel**	**Pushed/ coupled convoy**	**Jowi class container vessel**	**Pushed convoy**	
Carrying capacity (t)		**250 - 400**	**400 – 650**	**650 – 1000**	**1000 - 1500**		**1500 - 3000**		**≥ 3000**		
Study	**Goods transported**										
STREAM Internat. Freight 2011 [39]	Light breakbulk and bulk cargo	41 - 56	41 - 46		40 - 46		32 - 34	27 - 32 19 - 20		14 - 16	14 - 56
	Medium breakbulk and bulk cargo	36 - 54	39 - 41		34 - 40		29 - 30	23 - 29 17 - 19		12 - 15	12 - 54
	Heavy breakbulk and bulk cargo	34 - 60	37 - 42		32 - 40		27 - 32	23 - 28 17 - 20		12 - 16	12 - 60
	Light containers		74 - 95		75 - 90		39 - 43 45 - 55	51 - 69	51 - 36		36 - 95
	Medium-sized containers		53 - 64		49 - 60		29 - 33 25 - 33	37 - 49	24 - 35		24 - 64
	Heavy containers		44 - 53		40 - 50		20 - 27 24 - 29	32 - 35	19 - 30		19 - 53
	Minimum/ maximum shipments	34 - 60	37 - 95		32 - 90		24 - 55	17 - 69	19 - 51	12 - 16	12 - 95
Minimum/ maximum for all studies	Bulk goods	34 - 60	37 - 47		32 - 46	16	20 - 35	12 - 32	23	11 - 16	11 - 60
	Non-bulk goods		28 - 95		40 - 90	21; 22	13 - 55	17 - 69	10 - 51		10 - 96
	All goods	34 - 60	28 - 95	45	32 - 90	16 - 22	13 - 55	12 - 69	10 - 51	11 - 16	10 - 95

[39] Given data for the year 2009

Annex 4

Basic ways in which inland navigation can reduce greenhouse gas emissions

For inland navigation several technical, operational and logistical measures for reducing fuel consumption and thus CO_2 emissions have been identified and, in many cases, implemented already. This report only takes into account those measures that affect the vessels themselves and their operation. To illustrate the overall context, and since in some cases measures relating to vessels and infrastructural measures are interrelated, the table below shows a summary of these measures, although it makes no claim to be complete.

Table 9: Overview of identified and implemented measures

Area of influence		**Measures**	**Remarks**
Infrastructure	Waterway - Buildings - Navigation channel	Design for optimum ship size	Since the waterway infrastructure is already defined to a significant extent, only very minor changes are possible or logical in this area
		Minimisation of the manoeuvres required	
		Prevention of unfavourable currents and flow conditions	
	Waterway information	Provision of information on waterway parameters	Cross sections, water conditions, flow conditions
		Provision of information on traffic conditions	Traffic density and currents, closures
	Vessel traffic management	Traffic management	Ideal ship speed
		Operation of the hydraulic structures (locks)	Preventing waiting times, switching off engines
	Ports and moorings	Minimisation of the manoeuvres required	Cf. Waterway
		Shore side power	Electricity supply from renewable sources
		Equipment for energy efficient loading and unloading	
Vessels	Design and equipment		
		Optimisation of ship design using pilot projects and computer simulation	Hydrodynamic properties (optimisation of the main dimensions, ship hull form, speed, propulsion organs)
		Optimisation of conventional propulsion systems	Energy efficient design, prevention of over-dimensioned engines, electric propulsion systems

Area of influence		Measures	Remarks
		Diesel-electric propulsion	Combination of a diesel engine operating in the optimum speed range with an electric generator and an electric engine for driving the vessel
		Hybrid propulsion	Buffering of the propulsion energy as electrical energy, possibly in combination with a diesel-electric propulsion system
		Energy efficient equipment	Auxiliary drives, loads
		Energy recovery	Heating, air conditioning, additional propulsion power
		More efficient or alternative propulsion organs	E.g. “whale-tail” jets
		Weight reduction	Lightweight construction, smaller engines
		Reduction of resistance	Air lubrication, ship hull form optimisation, exhaust flow plate, adjustable tunnel apron, coupling point optimisation
	Fuels	Use of biogenic fuels (liquid and gaseous)	Questionable ecological & social impact; Storage on board may be problematic; only available in limited quantities
		Use of gaseous fuels	Production, storage on land, distribution, and storage on board are difficult
		Use of fuels that can be produced using renewable energy, e.g. hydrogen	Long term development; probably only available in limited quantities
	Operation	General speed reduction	Possibly the most effective single measure in conjunction with appropriate speed
		Adjustment of speed to the navigation channel dimensions / water depth (smart steaming)	In principle, the larger the navigation channel dimensions, the lower the resistance of the vessel
		On-board information systems for fuel efficiency	Econometer, journey planning
		Optimised journey planning	Selection of most suitable routes, consideration of limitations
		Automatic channel guidance	Prevents unnecessary movements of the rudder
		Optimised maintenance	Skin, propeller, engine
		Avoiding engine idling	E.g. before or in locks

Area of influence		**Measures**	**Remarks**
		Optimising the trim	Load, ballast
		Train skippers in using the operational measures	Measure of major importance
	Maintenance	Optimally configures and maintained engines	Maintenance according to manufacturer’s instructions
		Undamaged propulsion organs	Damage can reduce efficiency
		Clean, undamaged underwater bodies	Fouling and serious distortion can increase resistance
Transport management		Prevention of empty voyages	
		Making full use of the carrying capacity	As far as permitted by waterway conditions
		Avoiding waiting times	E.g. in ports

The measures listed above incur different costs with regard to their emission reduction potential. Many of the measures should even cover their own costs due to the potential fuels savings.

Emission reduction measures can also have an impact on the safety and the easy flow of shipping traffic as well as on the environment. Any reduction measures that may have a negative impact on the safety and the easy flow of shipping traffic must be ruled out. There is a positive interrelationship between a reduction in fuel consumption and environmental impact. In general, a reduction in fuel consumption results in lower emissions of pollutants such as nitrogen oxides and soot particles. Ships with lower fuel consumption often cause less wash and have less impact on the currents in the surrounding body of water, which in turn means less of a burden on the river bed and the sole.

Annex 5

Technical Options to reduce GHG for non-Road Transport Modes

(Reproduced from (Hazeldine, Pridmore et al. 2009))

Table 10: GHG emissions reduction potential of the technical inland navigation options

Technical option	Current reduction potential on ship level where applicable	Current payback time
Powertrain		
More efficient engines	15 – 20 %	> 10 years
Diesel-electric propulsion	10 %	> 10 years
Reduction of required propulsion		
Larger units (economy of scale)	Up to 75 % depending on difference in scale	No general conclusion possible
Improved propeller systems	20 – 30 %	Short payback time
Improved hull design	10 – 20 %	Short payback time
Computer assisted trip planning and speed management	5 – 10 %	< 1 year
Lightweight hulls	5 - 15 %	> 10 years (experimental)
Air lubrication	10 %	Unknown (experimental)
Whale tail/experimental propulsion systems	25 %	Unknown (experimental)

(Author's comment: This table is only to provide information on the *EU Transport GHG: Routes to 2050?* research project. The measures and their potential are considered in greater depth in **Annex 6** to this report.)

Annex 6

Technical measures for the reduction of fuel consumption and CO_2 emissions of inland vessels involving the vessels themselves

Table 11 contains a summary and evaluation of technical measures for reduction of fuel consumption and CO_2 emissions. The details given and the evaluation are based on studies of maritime shipping (Buhaug, Corbett et al. 2009; Miola, Ciuffo et al. 2010), the project EU Transport GHG: Routes to 2050? (Hazeldine, Pridmore et al. 2009), the database of measures for reducing CO_2 emissions on the CCNR website (www.ccr-zkr.org), lectures at the Workshop on *CO_2 emissions from inland navigation, How to measure them? How to reduce them?* held by the CCNR on 12 April 2011 (Andersen 2011; Christophel 2011; Guesnet 2011; Scherm 2011; Shuto 2011; van Terwisga 2011) and other sources (PLATINA 2009; Zöllner 2009). Where no figures on the reduction potential were available, the CCNR Secretariat estimated them.

Table 11 shows that several technical measures that allow a reduction in fuel consumption and thus in CO_2 emissions from inland vessels are already available for use. The various reduction potentials are given as a proportion of the fuel consumption (in %). In principle, there are not cumulative, since the amount of fuel that is saved by one measure cannot then be saved again by another measure. Instead, the proportions of the fuel consumption remaining after a reduction measure should be multiplied (the mathematical principles are shown in **section 15** of the report).

The evaluation is, by necessity, subject to a number of restrictions:

- Not all of the measures have yet been studied scientifically.
- Some of the measures have not yet been tested at all, whereas others have only been tested in isolated instances on commercial ships.
- Several of the details on which the evaluations are based were provided by the developers and manufacturers, which must be presumed to cast the measures they propagate in a positive light, in order to be economically successful.
- Some of the measures are only suitable for certain types of ship, such as the optimisation of the coupling point, for example.
- In many instances it is not very technically or economically viable to implement the proposed measures on a ship.
- The details on the reduction potentials are often only rough estimates or are only applicable under certain conditions.

At the same time, it must be said that the list of measures cannot be considered to be comprehensive. There are many other measures, many of which have not been tested, however, on which there is no reliable information or which offer very low energy or emission reduction potential.

The details given in **Table 11** should therefore be treated with a certain degree of caution. They should be helpful in estimating the global energy and emission reduction potential from inland navigation and to get any indication on decisions for their adoption in public funding programmes, however.

Nevertheless, it is safe to assume that there is reduction potential, primarily in connection with the propulsion systems. Fundamentally, we conclude that there are a number of possible measures, of which ship owners can choose the most economical and technically feasible for their vessels and applications.

Studies of the ship design using CFD (computational fluid dynamics) are helpful in making this selection. These allow possibilities for optimisation of the design to be identified by using simulations on powerful computers and also allow changes to be analysed theoretically (Guesnet 2011; Meij 2011), reducing the need for costly tests using models in test tanks. Another way in which ship owners can identify whether the design of a new ship is energetically favourable is using the Generic Energy System (GES) simulation developed by TNO, which can be used to analyse a vessel’s energy consumption while taking the predicted operating scenarios into account and to optimise it while validating a wide variety of parameters, in particular the equipment (Veen 2012). These procedures do not themselves reduce a vessel’s energy consumption, but make it possible to simulate the known ways of reducing fuel consumption in advance and to optimise the vessel.

Some of the measures mentioned above were implemented on the tanker Amulet, which is used to supply sea-going vessels. On this ship, fuel savings, and thus CO_2 emission reductions of up to 45%, in comparison to a conventional ship, were achieved (Jansen, Jansen et al. 2010). This savings potential may be seen as the upper limit of CO_2 reduction potential using a combination of technically tested measures. In so doing, it should be borne in mind that the tanker Amulet is a ship used for a very specific application.

Several of the measures listed in **Table 11** can also be realised by conversion or retrofitting of existing ships. However, the possibilities are limited in such cases, for economic and technical reasons, resulting in a lower reduction potential (Renner 2005). The most significant savings in fuel consumption would appear to be achieved by the following measures: replacing main drive units, replacing and supplementing propulsion organs (propeller / jet), adapting vessel extremities to the coupling configuration. There are also technically significant combination of measures such as adapting stern shaping in conjunction with replacing and supplementing the propulsion organs. These measures are also taken into account in **Table 11**.

Table 11: Summary and evaluation of the technical measures for the reduction of fuel consumption and CO_2 emissions of inland vessels involving the vessels themselves

Measure	Energy/CO_2 reduction potential	State of development	Area of application	Efficiency	Comments/evaluation
Measures involving propulsion					
Increase in engine efficiency	2 % to 5%	Ready for market	In principle, all ships	Yes	Future reduction potential low, as the legally prescribed measures for reducing pollutant emissions can result in higher fuel consumption; economic measures for the replacement of older engines with high specific consumption; reduction potential then more than 10%
Diesel-electric propulsion	0 % to 20%	Ready for market	In principle, all ships	Yes	Promising measure, although the reduction potential is lower relative to state of the art conventional propulsion engines; efficiency depends a lot on the operating conditions of the vessel and the number / type of electrical loads
Hybrid propulsion	0 % to 20 %	Ready for market	Currently for yachts		Promising for ships that need to manoeuvre a lot, such as consolidation/distribution traffic in ports, ships used for day trips and excursions
Higher-efficiency propulsion organs	5 % to 20%	Ready for market	In principle, all ships	Yes	Various promising measures (counter-rotating propellers, skew propellers)
Alternative propulsion organs	0 % to 25%	Research & development			Currently impossible to predict whether alternative propulsion organs (e.g. Whale Tail) will succeed on the market
Waste heat recovery	0 % to 5%	Ready for market	In principle, all ships	Amortisation in approx.. 5 years	Promising measure for ships that normally carry heavy loads; for idle vessels, not possible in conjunction with shore-side electricity

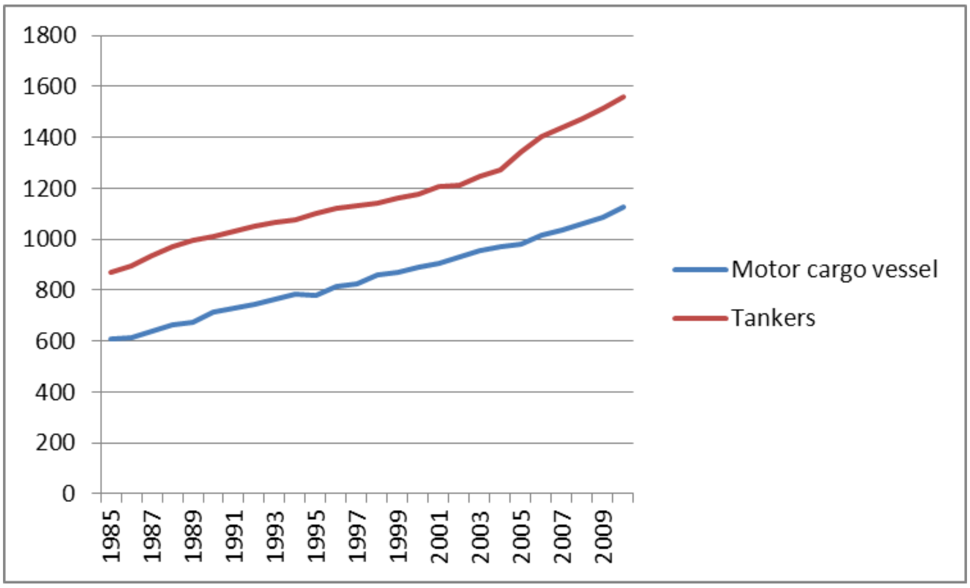
Measure	Energy/CO_2 reduction potential	State of development	Area of application	Efficiency	Comments/evaluation
Measures involving the hull					
Lightweight construction	0 % to 5%	Ready for market	Already common in some applications such as for day cruisers		Lightweight construction is currently hardly used for cargo vessels; lightweight construction can lead to higher repair costs
Air lubrication	0 % to 15%	Ready for market	In principle, for all ships	Yes	Currently impossible to predict whether this measure will succeed. Air chambers reduce the cargo hold space, which reduces the cargo capacity at medium and low water levels
Ship hull form	0 % to 10 %	Ready for market	In principle, for all ships	Yes	Further optimisation possible in future
Exhaust flow plate	0 % to 10 %	Research & development	In principle, for all ships		Successful pilot schemes
Adjustable tunnel apron	0 % to 10%	Research & development	Motor vessels (bulk and tanker)	Yes	Successful pilot schemes; initial application scheduled
Optimisation of coupled pushed barge trains	0 % to 15%	Ready for market	Pushed and coupled barge trains	Yes	Already common for coupled barge trains that are permanently connected
Optimisation of all technical measures involving the vessels themselves					
Computer-aided simulation CFD		Ready for market	In principle, for all ships	Yes	Promising measure for the optimisation of ship design with regard to hydrodynamics, already used in some instances
Energy analysis		Ready for market	In principle, for all ships	Yes	Promising measure for the optimisation of ship design with regard to energy requirements, already used in some instances

Annex 7

Consideration of the trend in average ship size in Europe and the possible impact of this on CO_2 emissions

Perhaps the greatest potential for reducing fuel consumption and CO_2 emissions from inland navigation lies in the increase in the average load carrying capacity (size) of the vessels (Hazeldine, Pridmore et al. 2009; Schweighofer 2011). Between 1991 and 2010, the average load carrying capacity of inland vessels in Western Europe grew by approx. 20 tons each year for dry cargo vessels and that of tankers grew by approx. 25 tons each year, as shown in **Figure 5**, which equates to an annual increase of about 1.8% or 1.6%, respectively. As can be seen from the graph, the average load carrying capacity of dry cargo vessels in 2010 was about 1130 tons and that of tankers was about 1560 tons.

Figure 5: Average load carrying capacity (in tonnes) of motor vessels of the West European fleet (source: Statistical surveys and calculations performed by the Secretariat of the CCNR)



The specific CO_2 emissions basically decrease proportionally as the load carrying capacity increases. This correlation is presented in detail in **section 5.1** of the report. Below is a rough estimate of the variation in specific emissions due to the increase in the average load carrying capacity of inland vessels in Western Europe, performed using emission figures determined under predefined conditions (maximum loaded draught: 2.5 m; water depth: 5 m; vessel speed: 12 kph) (Zöllner 2009) and thus reasonably comparable. The figures are given in **Table 12.**

Table 12: Illustration of the influence of load carrying capacities on specific CO_2 emissions of inland vessels under specified limiting conditions (Zöllner 2009)

Vessel type	dW [t]	CO_2 [g/tkm]
Peniche	366	47.1
Gustav Koenigs	935	31.3
Johann Welker	1272	17.6
Motor cargo vessel	1900	6.4
Jowi class container vessel	3335	7.7

On the basis of the figures given in **Table 12**, a simplified averaging produces the assumptions shown in Table **13**.

Table 13: Assumed mean specific CO_2 emissions from inland vessels

Vessel category	dW [t]	CO_2 [g/tkm]
Dry cargo vessel	1130	25
Tanker	1560	12

For dry cargo vessels we also assume the simplification that ships with, mean specific emissions of 40 g/tkm, and a mean carrying capacity of 700 t will be taken out of service and, as far as tankers are concerned, it is safe to assume that the ships that are taken out of service will be larger than the dry cargo vessels. The assumed mean carrying capacity for these is thus 1000 t, with mean specific emissions of 27 g/tkm. For both categories, we assume that the new ships entering service will have mean specific emissions of 7 g/tkm and a mean carrying capacity 3000 t. With these values it is, in turn, possible to deduce the mean change in the specific emissions relative to the increase in the mean carrying capacity. The results are shown in **Table 14**.

Table 14: Assumed changes in the mean specific CO_2 emissions from inland vessels relative to mean carrying capacity

Vessel category		dW [t]	CO_2 [g/tkm]	Δ CO_2 [g/tkm] per dW [t]
Dry cargo vessel	Old	700	40	0.014
	New	3000	7	
Tanker	Old	1000	27	0.01
	New	3000	7	

If the mean changes in specific emissions are multiplied by the annual increase in mean carrying capacity, the result for dry cargo vessels is a reduction in mean specific emissions of 0.28 g/tkm per annum and of 0.25 g/tkm per annum for tankers. Relative to the figures shown in **Table 13**, this thus results in a pro rata change of about 1.1% per year for dry cargo vessels and of about 2.1% per year for tankers.

If the above estimates for the improvement in specific emissions is right due to the increase in the mean carrying capacity, this would serve as confirmation that the ship size is indeed of decisive importance for a reduction in CO_2 emissions from inland navigation. The improvements achieved by this also agree approximately with the increase in the total traffic & transport volume accounted for by inland shipping (Ickert, Ulrike et al. 2007; ITP and BVU 2007). If the growth in the mean carrying capacity of inland vessels seen in recent years continue in future, the resulting reduction in the specific CO_2 emissions may be able to make up for any increase in emissions due to a possible increase in the total traffic & transport volume accounted for by inland navigation. This would mean, to put it simply, an increase in traffic & transport volume without an increase in greenhouse gas emissions.

PLANCO has also investigated the CO_2 emissions resulting from the increase in carrying capacity of the vessels and arrived at the conclusion that the energy required by the inland navigation fleet decreases proportionally to the increase in average carrying capacity (PLANCO 2007). However, PLANCO's calculations are based on an annual increase in size of only approx. 0.5% p.a., as opposed to the figure of approx. 1.5% assumed by the CCNR, as shown in **Figure 5.** This difference could be due to the fact that PLANCO only considered the German fleet, whereas the Secretariat of the CCNR also included other fleets that are growing faster. The evolution of average vessel size may also depend on the navigation area. On waterways which only relative small vessels are able to us, it is to be expected that average vessel size will scarcely increase. An example of this is the narrow canals in France. In contrast, the Rhine still has potential for increasing average vessel size.

The considerations below are a very simplistic analysis of the relationship between the fleet structure and greenhouse gas emissions. To verify the results of this analysis, it would be desirable to not only consider the average size of the ships, but to also look at each ship size class separately. These size classes have already been defined. There is also information on the trends regarding the number of ships in each size class. The calculations should not only be based on values for specific CO_2 emissions from a single study, as was the case above, but should use figures from various sources. It would also be desirable to be able to determine the proportion of the total transport-related activities by inland navigation accounted for by all of the ships in each of the size classes. Then it would be possible to confirm the impact of the change in the mean carrying capacity or the ship size on the CO_2 emissions reliably.

Annex 8

Operational measures for the reduction of fuel consumption and CO_2 emissions of inland vessels involving the vessels themselves

Table 15 contains a summary and evaluation of operational measures for reduction of fuel consumption and CO_2 emissions. The details given and the evaluation are based on studies of maritime shipping (Buhaug, Corbett et al. 2009; Miola, Ciuffo et al. 2010), the project EU Transport GHG: Routes to 2050? (Hazeldine, Pridmore et al. 2009; Kampman, Rijkee et al. 2009), the database of measures for reducing CO_2 emissions on the CCNR website (www.ccr-zkr.org), lectures at the CCNR Workshop on *CO_2 emissions from inland shipping "How can CO_2 emissions be measured and how can they be reduced?*" held on 12 April 2011 (Kammertöns 2011; Koopmans 2011; Lutz and Gilles 2011; Savelkoul 2011) and other sources (PLATINA 2009; van Kempen 2010). Where no figures on the reduction potential were available, the CCNR Secretariat estimated them.

Table 15 shows that several operational measures that allow a reduction in fuel consumption and thus in CO_2 emissions from inland vessels are already available for use. The various reduction potentials are given as a proportion of the fuel consumption (in %). The evaluation of the measures and, in particular, the reduction potential figures, are basically subject to the same restrictions as those determined in **Annex 6** for the technical measures involving the vessels themselves. The details given in **Table 15** should therefore be treated with a certain degree of caution. They should be helpful in estimating the global energy and emission reduction potential from inland navigation and to get any indication on decisions for their adoption in public funding programmes, however.

Nevertheless, it is safe to assume that there is considerable reduction potential, primarily in connection with optimisation of the ship speed. This can be achieved more particularly on waterways with varying cross sections and current conditions, such as the Rhine, and less so on canals with relatively uniform conditions. The Smart Steaming programme in the Netherlands has shown success in using this potential. There is also a remarkable number of computerised tools that have already been developed to do this, some of which are already on the market. The "Tempomaat" is a tool of this kind, which has already found its way into various programmes (This is described in detail in **Annex 9**). Since their reduction potential for fuel consumption and thus for greenhouse gas and pollutant emissions is evidently generally recognised and since the investment in such tools have very short amortisation periods, it would also be possible to make their installation and use mandatory on the Rhine or for inland navigation in Europe. An impact assessment would very probably yield very positive results.

Some measures call for the support of the waterway operators, such as a "green wave" for locks and movable bridges. For container shipping, an optimisation of the operation of the terminals at the seaports could contribute towards a significant reduction in emissions. The fewer terminals a ship has to call at and the less manoeuvring that is required, the lower the emissions will be. This is particularly significant for large container ships. (For travelling between terminals, ships with a hybrid propulsion system or even fully electric propulsion are possible solutions.) Fundamentally, we conclude that there are a number of possible measures, of which ship owners can choose the most economical and technically feasible for their vessels and applications.

Skippers are at the focal point of implementing the operational reduction potential. Training them, if possible using appropriate simulators, should be given top priority for reducing fuel consumption and CO_2 emissions from inland navigation. All of the measures listed in **Table 15** can also be realised by existing ships.

Table 15: Summary and evaluation of the operational measures for the reduction of fuel consumption and CO_2 emissions of inland vessels

Measure	Energy/CO_2 reduction potential	State of development	Area of application	Efficiency	Comments / evaluation
Optimisation of the ship speed by the skipper					
Smart steaming, just in time	0% to 30%	Publicly-funded programmes in the Netherlands; commonplace in many companies	All ships	Very economical due to the minimal costs	Simplest and most economically viable measure for the reduction of fuel consumption and CO_2 emissions
Measures using computerised tools					
Optimised speed using decision support systems	0% to 15%	Ready for market, already the subject of subsidy programmes	All ships, perhaps with the exception of ships used for day trips and excursions		Conflation of data from various sources on the transportation application, fairway conditions, use of our own experience and experience with other ships
Optimisation of voyage planning	0% to 20%	Ready for market	All ships, perhaps with the exception of ships used for day trips and excursions		Use of Inland ECDIS and Notices to Skippers
Optimisation by the use of automatic channel guidance	0% to 10	Prototypes	All ships, perhaps with the exception of ships used for day trips and excursions		Selection of the optimum route in terms of the water depth and currents; Reduction in the number of control commends (rudder deflections)
Measures involving ship maintenance					
Optimisation and maintenance of the propulsion engine	0% to 5%	Normal	All ships		Regular inspection/maintenance work will be necessary to maintain the efficiency of the exhaust gas after-treatment systems (and the reduction in pollutant emissions) anyway

Measure	Energy/CO_2 reduction potential	State of development	Area of application	Efficiency	Comments / evaluation
Optimisation and maintenance of the propeller	0% to 5%	Normal	All ships		
Optimisation and maintenance of the hull plating	0% to ≤ 5%	Normal	All ships		Probably not as significant for inland navigation as it is for maritime shipping
Other operational measures					
Optimisation of the ship's trim	0% to 5%	Normal	All ships		
Optimisation of lock/bridge passages	0% to 15%		Waterways regulated by locks, and canals		The operators of locks/bridges could provide a “green wave” for passage of the ships; Realisation with the assistance of RIS
Optimisation of port operations	0% to 5%		Freight navigation		The specific emissions from container ships, in particular, can rise considerably if a ship needs to visit numerous terminals
Shore power	0% to 5%	Already common at a lot of moorings	All ships		Commercially operated inland vessels have very short periods at anchor, making the potential savings very limited
Optimisation of the operational measures overall					
Training using simulators		Suitable simulators are already available or will be soon	All ships		Training in a simulator teaches awareness, understanding and ability to select the optimum speed, depending on the transport application, water depth and currents

Annex 9

Smart Steaming

The following details are based on personal information (de Vries 2012). Further information is available through the Foundation for Navigation Projects ("SPB") and the Expertise and Innovation Centre for Inland Barging (EICB)[40].

Introduction

The Smart Steaming programme was started in 2007 by the Dutch Ministry of Infrastructure and the Environment. The main goal of the program is to create a reduction of CO_2 emissions in the inland water transport by changing the behavioural aspects of sailing. Reducing the emissions of CO_2 also has a positive effect on the costs for the small and medium sized enterprises involved by reducing the fuel consumption. From 2011 onwards the Expertise and Innovation Centre for inland Barging (EICB) took over the program from the Dutch government.

Results

For the period 2007 to 2010 a monitoring study was made on the results of the first years of the program. The yearly result of 6.7% exceeds the original target of 5% CO_2 reduction per year. In **Table 16** you can find an overview of the results per year:

Table 16: Results per year based on the established 6.7% savings

	NO_x	NMVOS	PM	CO_2
	mln kg	mln kg	mln kg	mln kg
Savings compared to 2007	1.742	0.241	0.0744	119.6
Savings in euros compared to 2007	€ 18 465 200	€ 602 298	€ 3 049 170	€ 2 989 875

	Social benefits	Benefits companies	Total
Savings minus cost of program	€ 21 916 881	€ 27 180 682	€ 49 097 563
Savings in euros compared to 2007	€ 25 106 543	€ 27 180 682	€ 52 287 225

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40 www.spb.binnenvaart.nl / www.eicb.nl

Programme content

The “Smart Steaming” programme includes various content, training offers, a CO_2 comparison tool, a competition, and communication measures.

Training

Teaching skippers how to sail in the most efficient way to reduce the fuel consumption is the backbone of the programme. The basic ideas of Smart Steaming are imbedded In the regular education program for skippers. For the population of more experienced skippers there is a special course, at which the participants learn the subtleties of economic sailing.

CO_2 comparison tool

The CO_2 comparison tool gives shipping companies a clear indication of the amount of CO_2 their vessels produce. In addition to historical overviews of fuel consumption and CO_2 production, the tool gives users the possibility of comparing their ships with the (sector of the) market. The tool can be used by inland navigation companies to give their customers more details on CO_2 production. The tool will be developed in 2012, and is scheduled for roll-out in February 2013.

Competition

Which ship is the cleanest ship? This is the basic idea of the Inland Waterway Fuel Competition. Ships and their crew compete against each other. It is proven that it is a great motivation to sail as economically as possible when you have competitive surroundings. The first year ships enter the competition their fuel and CO_2 reduction is approximately 20%. The coming years the tool will be further build into a benchmark tool where participants can see their consumption in comparison with the whole market.

Communication

The central idea of “Smart Steaming” is to change the behaviour of skippers in a more economic and environmental friendly way. Communication on the way a skipper can accomplish that target is of great importance. The following aspects are actively communicated toward the target groups:

- Tips and tricks on economic sailing;
- Pre calculating the economic benefits;
- Usage of technical aids.

Smart Steaming stakeholder platform

The measures for achieving efficient behaviour are to be communicated via a stakeholder platform, comprising inland navigation companies and other relevant interest groups. The platform must promote the Smart Steaming programme by attracting media attention and organising events.

European rollout

The results of the “Smart Steaming” programme are so positive that it would be of great benefit to other European countries to introduce the programme. In a European perspective the contents of the programme can be upgraded to a higher level so it will be also interesting for the current users of the programme. The main focus in the other countries will be the educational aspects of “Smart Steaming”.

Annex 10

Future Transport Fuels
Report of the European Expert Group on Future Transport Fuels, January 2011

Executive Summary

(Reproduced from (Fuels 2011))

Transport fuel supply today, in particular to the road sector, is dominated by oil …, which has proven reserves that are expected to last around 40 years …. The combustion of mineral oil derived fuels gives rise to CO_2 emissions and, despite the fact the fuel efficiency of new vehicles has been improving, so that these emit significantly less CO_2, total CO_2 emissions from transport have increased by 24 % from 1990 to 2008, representing 19.5 % of total European Union (EU) greenhouse gas emissions.

The EU objective is an overall reduction of CO_2 emissions of 80 - 95 % by the year 2050, with respect to the 1990 level …. Decarbonisation of transport and the substitution of oil as transport fuel therefore have both the same time horizon of 2050. Improvement of transport efficiency and management of transport volumes are necessary to support the reduction of CO_2 emissions while fossil fuels still dominate, and to enable finite renewable resources to meet the full energy demand from transport in the long term.

Alternative fuel options for substituting oil as energy source for propulsion in transport are:

- **Electricity/hydrogen,** and **biofuels (liquids)** as the main options
- **Synthetic fuels** as a technology bridge from fossil to biomass based fuels
- **Methane (natural gas and biomethane)** as complementary fuels
- **LPG** as supplement

Electricity and **hydrogen** are universal energy carriers and can be produced from all primary energy sources. Both pathways can in principle be made CO_2 free; the CO_2 intensity depends on the energy mix for electricity and hydrogen production. Propulsion uses electric motors. The energy can be supplied via three main pathways:

- **Battery-electric**, with electricity from the grid stored on board vehicles in batteries. Power transfer between the grid and vehicles requires new infrastructure and power management. Application is limited to short-range road transport and rail. The development of cost-competitive high energy density batteries and the build-up of charging infrastructure are of the highest priority.
- **Fuel cells powered by hydrogen**, used for on-board electricity production. Hydrogen production, distribution and storage require new infrastructure. Application is unlikely for aviation and long-distance road transport. The development of cost-competitive fuel cells, on-board hydrogen storage, and strategic **refuelling** infrastructure is of the highest priority.
- **Overhead Line / Third Rail** for tram, metro, trains, and trolley-buses, with electricity taken directly from the grid without the need of intermediate storage.

…

Biofuels could technically substitute oil in all transport modes, with existing power train technologies and existing re-fuelling infrastructures. Use of biomass resources can also decarbonise synthetic fuels, methane and LPG. First generation biofuels are based on traditional crops, animal fats, used cooking oils. They include FAME biodiesel, bioethanol, and biomethane. Advanced and second generation biofuels are produced from ligno-cellulosic feedstock and wastes. They include bioethanol, HVO, higher alcohols, DME, BTL and biomethane.

The production of biofuels from both food and energy crops is limited by the availability of land, water, energy and co-product yields, and sustainability considerations, such as the life-time accountancy of CO_2 emissions. Second generation biofuels from wastes and residues are also limited by the availability of these materials.

The development of feedstock potential and of optimised production processes is of the highest priority. A supportive policy framework at the EU and State level and harmonised standards for biofuels throughout the EU are key elements for the future development of sustainable biofuels.

Synthetic fuels, substituting diesel and jet fuel, can be produced from different feedstock, converting biomass to liquid (BTL), coal to liquid (CTL) or gas to liquid (GTL). Hydrotreated vegetable oils (HVO), of a similar paraffinic nature, can be produced by hydrotreating plant oils and animal fats. Synthetic fuels can be distributed, stored and used with existing infrastructure and existing internal combustion engines. They offer a cost-competitive option to replace oil-based fuels, with the perspective of further improved system performance with engines specifically adapted to synthetic fuels. The development of industrial scale plants for the production of cost-competitive synthetic fuels derived from biomass is of the highest priority, while efforts should be continued to improve the CO_2 balance of GTL and particularly CTL. DME (Di-Methyl-Ether) is another synthetic fuel produced from fossil or biomass resources via gasification (synthesis gas), requiring moderate engine modifications.

Methane can be sourced from fossil natural gas or from biomass and wastes as biomethane. Biomethane should preferentially be fed into the general gas grid. Methane powered vehicles should then be fed from a single grid. Additional refuelling infrastructure has to be built up to ensure widespread supply. Propulsion uses internal combustion engines similar to those for liquid hydrocarbon fuels. Methane in compressed gaseous form (CNG) is an unlikely option where high energy density is required. Liquefied methane gas (LNG) could be a possible option in these cases. Harmonised standards for biomethane injection into the gas grid and the build-up of EU-wide refuelling infrastructure are of the highest priority.

LPG (Liquefied Petroleum Gas) is a by-product of the hydrocarbon fuel chain, currently resulting from oil and natural gas, in future possibly also from biomass. LPG is currently the most widely used alternative fuel in Europe, accounting for 3% of the fuel for cars and powering 5 million cars. The core infrastructure is established, with over 27,000 public filling stations.

Single-fuel solutions covering all transport modes would be technically possible with liquid biofuels and synthetic fuels. But feedstock availability and sustainability considerations constrain their supply potential. Thus the expected future energy demand in transport can most likely not be met by one single fuel. Fuel demand and greenhouse gas challenges will require the use of a great variety of primary energies. There is rather widespread agreement that all sustainable fuels will be needed to resolve the expected supply-demand tensions.

The main alternative fuels should be available EU-wide with harmonised standards, to ensure EU-wide free circulation of all vehicles. Incentives for the main alternative fuels and the corresponding vehicles should be harmonised EU-wide to prevent market distortions and to ensure economies of scale supporting rapid and broad market introduction of alternative fuels.

The main alternative fuels considered should be produced from low-carbon, and finally from carbon-free sources. Substitution of oil in transport by these main alternative fuels leads then inherently to a decarbonisation of transport if the energy system is decarbonised. Decarbonisation of transport and decarbonisation of energy should be considered as two complementary strategic lines, closely related, but decoupled and requiring different technical approaches, to be developed in a consistent manner.

The different transport modes require different options of alternative fuels:

Road transport could be powered by electricity for short distances, hydrogen and methane up to medium distance, and biofuels/synthetic fuels, LNG and LPG up to long distance.

Railways should be electrified wherever feasible, otherwise use biofuels.

Aviation should be supplied from biomass derived kerosene.

Waterborne transport could be supplied by biofuels (all vessels), hydrogen (inland waterways and small boats), LPG (short sea shipping), LNG and nuclear (maritime).

(Author's comment: The fuels report, given here in summary form, provides a good foundation for future discussion in the inland navigation industry on fuels used and for devising a fuel strategy for all modes of transport. The report appears, however, to take only limited account of developments in the industry, such as the exclusion of LNG for inland navigation in the foregoing summary. The report should therefore be used in conjunction with **section 11** of this report, which takes account of the particularities and current evolution of inland navigation.)

Annex 11

Regulatory measures for climate protection in maritime shipping: EEDI, EEOI, SEEMP

The General Assembly of the International Maritime Organization (IMO) commissioned the Marine Environment Protection Committee (MEPC) with resolution A.963 (23) from 2003 to develop mechanisms to reduce emissions from ships. The agreed work schedule for this went up to 2011. The MEPC also developed the following technical and operational regulatory instruments on this topic in 2008:

- The Energy Efficiency Design Index (EEDI) as a compendium of the technical measures to reduce emissions,
- The Energy Efficiency Operational Index (EEOI) as a compendium of the measures for low-CO_2 operation,
- The Ship Energy Efficiency Management Plan (SEEMP)

A provisional methodology for calculating the EEDI and the creation of the SEEMP were passed in 2009, but not conclusively agreed upon. At the MEPC's 60th meeting in 2010 it was agreed that the EEDI and SEEMP should be introduced as mandatory measures under MARPOL Annex VI.

The EEDI is a way of expressing the greenhouse gas efficiency of a ship design. It compares the emissions generated by a ship, calculated from the propulsion power and the specific fuel consumption relative to the transport capacity (= cargo capacity x speed), and uses the dimensions g CO_2/tsm capacity (generally expressing the capacity as carrying capacity). It is augmented for individual ships by the addition of factors to the numerator to take the operating conditions, special design elements and the availability of innovative energy efficiency technologies into account:

$$EEDI = \frac{\text{Power} * \text{spec. fuel cons.} * \text{Emission factor}}{\text{Capacity} * \text{Speed}}$$

The EEDI is a way of expressing a ship's emissions under very specific operating conditions as a draft EEDI, which is determined during the classification process and is only changed if changes are made to the design. The IMO plans to determine a mandatory "Baseline EEDI" by evaluating the data on the existing fleet for the various types of vessel as a regression curve. The baseline will then be lowered in stages in the future. ...

It does not cover the wide variety of vessel types adequately. The possibility of improving the EEDI for a ship at the expense of safety also raises questions (e.g. insufficient performance reserves, reduced steel weight). All in all, it is seen as having the potential to be a good indicator of the design's energy efficiency, although it is not yet mature and requires further trials. ... The first EEDI certificate was issued in June 2010 by Germanischer Lloyd for a container vessel owned and operated by Hapag-Lloyd. ...

The use of the EEDI is only mandatory for new ships, but it does not apply to the majority of the fleet. ...

The Energy Efficiency Operational Index (EEOI) is based on the same idea of the cost (emissions) to benefit ratio as the EEDI. It is defined as follows:

$$EEOI = \frac{\sum_i FC_i \times C_{carbon}}{\sum_i m_{cargo,i} \times D_i}$$

FC_i – fuel consumption on journey i;
C_{carbon} – carbon content of the fuel;
$m_{cargo,i}$ – quantity of cargo on journey i;
D_i – length of journey i

The units of the EEOI are g CO_2 per ton-km of transported cargo (normally t, other units are also possible). The value of the EEOI depends to a considerable degree on how well the ship's carrying capacity is actually exploited and is thus subject to fluctuations due to the economic situation of the shipping industry. The properties and composition of the load also cause considerable fluctuation in the index, meaning that the calculation of an obligatory limit seems almost impossible. Another problem arises from the fact that the emissions from the operation of the ship are governed by decisions made by the charterer and not by the ship owner. The IMO therefore recommends that the EEOI should be used by ship owners and operators as a voluntary means of evaluating the performance of a ship ...

The Ship Energy Efficiency Management Plan, SEEMP is intended to be a structured framework for energy efficient ship operation and for monitoring ship performance as well as for identifying potential improvements. SEEMP includes the following measures to enable this:

- Weather, current and tide-optimised routing
- Trim optimisation
- Hull and propeller monitoring and care
- Real-time monitoring and optimisation of the ship parameters etc.

In so doing, the SEEMP adheres to the principle of a continuous improvement cycle including the following phases:

1. Planning (plan);
2. Implementation (do);
3. Performance monitoring and self-evaluation (check);
4. Improvement (act).

The EEOI can be used for the monitoring phase in SEEMP. The SEEMP ties in with the mechanisms put forward in the ISM Code (International Management Code for the Safe Operation of Ships and for Pollution Prevention) ... There are plans for a mandatory requirement for such documentation to be kept, but no mandatory reporting requirements when it comes to the content.

The potential effectiveness of these regulatory options is estimated to be as follows:

- A binding limit of the EEDI for new ships is a cost-effective solution with a limited impact on the growth of the global merchant shipping fleet (see the criticisms above);
- Mandatory or voluntary reporting on the EEOI will only become effective in combination with incentive schemes.
- Mandatory or voluntary use of an SEEMP is a useful instrument for raising awareness of cost-effective measures of reducing emissions, but does not reduce emissions in itself;
- Obligatory limits for the EEOI in combination with sanctions could be very effective, but are technically extremely difficult to implement ..." (Jahn 2010a)

Annex 12

Scenarios for the development of greenhouse gas emissions from inland navigation

Politicians set targets for the reduction of greenhouse gas emissions, for instance the European Commission, as well as the European shipping industry. Experts have identified a large number of measures that can contribute to a reduction in energy consumption and greenhouse gas emissions. However, is the reduction potential of these measures sufficient to reach the proposed emission reduction targets?

In order to arrive at an initial provisional answer to this question, a simple mathematical model is used to estimate the absolute amount of greenhouse gas emissions from the operation of inland vessels. The model allows the reduction in emissions due to various groups of measures to be taken into account. In a second stage, it then proceeds to present and discuss various reduction potentials of possible scenarios for the future development of greenhouse gas emissions from inland navigation on the basis of rough estimates. The model is limited in the first instance to freight navigation. Fundamentally, however, it is hoped to extend the data to include passenger shipping, in order to be able to estimate its contribution to the total emissions from inland navigation reliably.

The model used to estimate the total emissions from inland freight shipping operations, which reflects the actual situation in a very simplified way, takes the following parameters into account:

- Development of the total traffic & transport volume (exponential),
- Reduction potential for energy consumption by means of technical measures (summary rough estimate),
- Reduction potential for energy consumption by means of operational measures (summary rough estimate),
- Reduction potential for energy consumption by means of an increase in the average carrying capacity of the vessels (summary rough estimate),
- Reduction potential for greenhouse gas emissions by the use of LNG,
- Reduction potential for greenhouse gas emissions by the use of biofuels (summary rough estimate),
- Reduction potential for greenhouse gas emissions by the use of electrical energy, including hydrogen and e-gas (summary rough estimate).

The calculation model and the scenarios only take CO_2 emissions into account. Other greenhouse gases are converted to CO_2 equivalents (this applies in particular to methane). The model is shown below and the operators and terms are explained in **Table 17**

$$C_{Future} = L_{Baseline} * (1 + x)^n * c_{Baseline} * (1 - r_T) * (1 - r_O) * (1 - r_{CC}) * [(1 - r_{LNG}) * G_{LNG} + (1 - r_{Bio}) * G_{Bio} + (1 - r_{EE}) * G_{EE} + (1) * G_{Oil}]$$

Table 17: Operators and terms used in the model for the emission scenarios

Indices		
	Stands for	**Explanation**
T	Technology	To identify the reduction potentials
O	Operation	
CC	Carrying capacity	
Oil	Oil (diesel, gasoil)	To identify the reduction potentials and the proportion of the total amount of energy consumed
LNG	Liquefied natural gas	
Bio	Biofuels	
EE	Electrical energy	
Baseline	Starting value, starting year	To identify the original total traffic & transport volume
Future	Target value, target year	To identify the total emissions in the target year

Operators			
	Subject matter	**Units**	**Explanation**
L	Traffic & transport volume	tkm	Total cargo volume of inland navigation per annum
C	Mass of greenhouse gas emissions	t	Total CO_2 emissions per annum
c	Specific greenhouse gas emissions	g/tkm	
r	Reduction factor		Used to specify the potential reductions; e.g. 10% lower emissions means r = 0.1
G	Standardised total amount of energy used in the course of shipping operations		Used to describe the contribution that the various different energy sources make to the energy consumption. The sum total = 1
x	Average annual increase in the traffic & transport volume		Used to specify the average rate of growth; e.g. a 2% increase in the traffic & transport volume means that x = 0.02
n	Number of years		The Number of years between the reference year (starting year) and the year under consideration (target year)

This model is used to describe two scenarios for inland navigation in Western Europe, one representing a conservative estimate of the reduction potential and the other representing an optimistic estimate. Both of the scenarios are modelled assuming a modest increase in the total traffic & transport volume accounted for by inland navigation and assuming a greater increase. The modest increase is set at 1% per annum, which corresponds well with the forecasts for the development of the traffic & transport in Germany (Progtrans 2007) (ITP and BVU 2007). The greater increase is set at 3%, which basically reflects the European Commission's objective to increase the proportion of the modal split for inland shipping (EU 2011). The baseline or reference year used is 2010 for each scenario, and the year under consideration or target year is 2050.

The following values are used for the constants in the two scenarios: $L_{Baseline}$ = 120 bn. tkm; $c_{Baseline}$ = 25 g/tkm; n = 40. The traffic & transport volume that is assumed as the baseline is based on the most recent data available for the major west European countries which have an interest in inland navigation. The value for the specific emissions is a rough estimate that needs to be verified (see **section 5.1**. for details).

The scenarios use the values shown in **Table 18** for the variables. The estimates of the potential savings reflect the conclusions drawn in **sections 8, 9 and 10** of this report. In addition to this, it is also assumed that the increase in the size of the fleet will continue for about 2 more decades before meeting its limits. These limits result from economic/logistical aspects as well as from the dimensions of the waterways and the permitted size of the vessels. Furthermore, it is also assumed that an increase in the demand for transportation by inland waterway, the mean carrying capacity of the vessels will increase, as the improved economic situation will permit greater investment in new and thus overall larger vessels.

Table 18: Variables used in the various scenarios

	Conservative scenario		**Optimistic scenario**	
	Low growth	**High growth**	**Low growth**	**High growth**
X	0.01 (1%)	0.03 (3%)	0.01 (1%)	0.03 (3%)
r_T	0.2 (20%)		0.4 (40%)	
r_O	0.1 (10%)		0.3 (30%)	
r_{CC}	0.2 (20%)	0.4 (40%)	0.2 (20%)	0.4 (40%)
r_{LNG}	0.1 (10%)		0.1 (10%)	
r_{Bio}	0.35 (35%)		0.6 (60%)	
r_{EE}	0.7 (70%)		0.9 (90%)	
G_{LNG}	0.5 (50%)		0.5 (50%)	
G_{Bio}	0.15 (15%)		0.4 (40%)	
G_{EE}	0.05 (5%)		0.1 (10%)	
G_{Oil}	0.3 (30%)		0 (0%)	

Table 19 shows the results of the model calculations. The emissions for the initial situation (baseline, 2010) and the target year are given as absolute amounts. For the target year a value is also given for each scenario for the percentage change relative to the baseline. Due to the simplicity of the model and the rough estimates of the input quantities the results can hardly be seen as more than trends, however.

Table 19: Rough estimate of the total emissions of the operational CO_2 emissions from inland shipping in Western Europe for various scenarios

			Total operational CO_2 emissions	
Scenario		**Growth rate**	Tons per annum	Change relative to the baseline
2010	Baseline		3,000,000	
2050	Conserv-ative	Low	2,220,000	- 26%
		High	3,650,000	+ 22%
	Optimistic	Low	930,000	- 69%
		High	1,529,000	- 49%

The results of the model calculation given in Table 19 reveal that, according to the conservative scenario, emission reductions would result above all from the introduction of LNG and the increase in average vessel capacity, while total emissions would remain more or less constant, even with an increase in the total traffic & transport volume. In the event of less increase in traffic & transport, the reduction measures overcompensate for the increase in emissions and total emissions fall by about a quarter. In the event of greater increase in traffic & transport, the compensation is not enough and emissions increase by nearly a quarter. According to the optimistic scenario, however, in which gasoil is completely replaced by alternative fuels, emissions would be reduced by about two thirds for a slight increase in traffic & transport; in the event of a greater increase in traffic & transport, emissions would be almost halved. The following conclusions would thus seem appropriate:

- Widespread implementation of the various existing technical and operational energy-saving measures, including the use of LNG as a fuel, as well as a continued increase in the average size of vessels will enable the operational greenhouse gas emissions from inland navigation to be kept more or less constant, even with a steady increase in the total cargo volume.
- A significant reduction in the absolute amount of operational greenhouse gas emissions from inland navigation accompanied by a simultaneous increase in the total cargo volume will be possible, if biofuels and fuels produced using renewable energy are used on a large scale, alongside LNG.

The above calculation model is very simple and the scenarios are based on rough estimates. It is therefore worth working to validate the model with the assistance of experts, including scientists and, in particular, the affected economic sectors. Once this has been done, the model could be a useful tool for the development of environmental protection objectives and of strategies such as on the fuels to be used by inland navigation in future or for programmes to promote environmentally-friendly inland shipping.

In this case the model has been used to develop scenarios for inland navigation in western Europe. By adjusting the input parameters it can also be used for selected navigation areas or small fleets. For example, in creating scenarios for waterways that only permit small vessel dimensions, the starting point would be less or no increase in vessel capacity,

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