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When is Short Sea Shipping Environmentally Competitive?

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1. Introduction

Maritime transport is broadly accepted as an environmentally friendly mode of transport in terms of CO_2 emissions, and is also receiving government support for promotion and development, often based on presumed performance along environmental dimensions.

There is really no debate about the superior comparative efficiency of ships with respect to fuel consumption when calculated per deadweight tonne along routes of similar length. However, the emission figures calculated per deadweight tonne is only relevant for bulk transports, and fuel consumption per cargo tonne is quite different for typical short sea shipping services based on container or RoRo technologies. Further, other emissions to air, like sulphur dioxide, nitrogen oxides and particles, are typically very high for shipping – especially when no abatement technologies are applied.

The case for short sea shipping as an environmentally-friendly mode of transport is no longer self-evident under realistic assumptions, and needs deeper analysis.

The main competitors of such shipping services are rail and road transport. Considering realistic load factors – could the environmental friendly case for maritime transport still be made? This paper is based on the latest data for comparative environmental performance and presents a set of realistic European multimodal transport chains, and their environmental outputs, focusing on fuel consumption and CO_2 emissions. Through this comparative analysis we differentiate the common comprehension of shipping being the indisputable green mode of cargo transport, and analyze necessary actions that need to be taken for short sea shipping to maintain its green label. Finally, perspectives on both regulatory regime and technology are analysed.

2. When is short sea shipping environmentally competitive?

2.1 The competition between short sea shipping and land-based modes

Short sea shipping (SSS) plays an important role in the market for regional freight transport in many areas of the world. It's relative importance compared to alternative land-based

modes is, however, quite different in different regions. Whereas SSS along with inland waterways represents 40% of the intra EU27 transports and more than 60% of the total tonnekilometres in China, the equivalent market-share in the US and Russia is much smaller (Figure 1). To some extent such differences in market shares could be explained by geographical characteristics like the length of the coast-line compared to land area and population, or by the characteristics of natural inland waterways and coastal waters. Such factors may be a natural explanation for the low market share of SSS in Russia – and the equivalently high market-shares in Japan and China. However, it is harder to see how such factors could explain the very different market-shares of EU27 versus the USA. Both have a long coastline and some natural inland waterways. Differences in policy-regimes and the quality of alternative land-based infrastructure are factors that might explain the higher market-share of SSS in Europe compared to the USA.

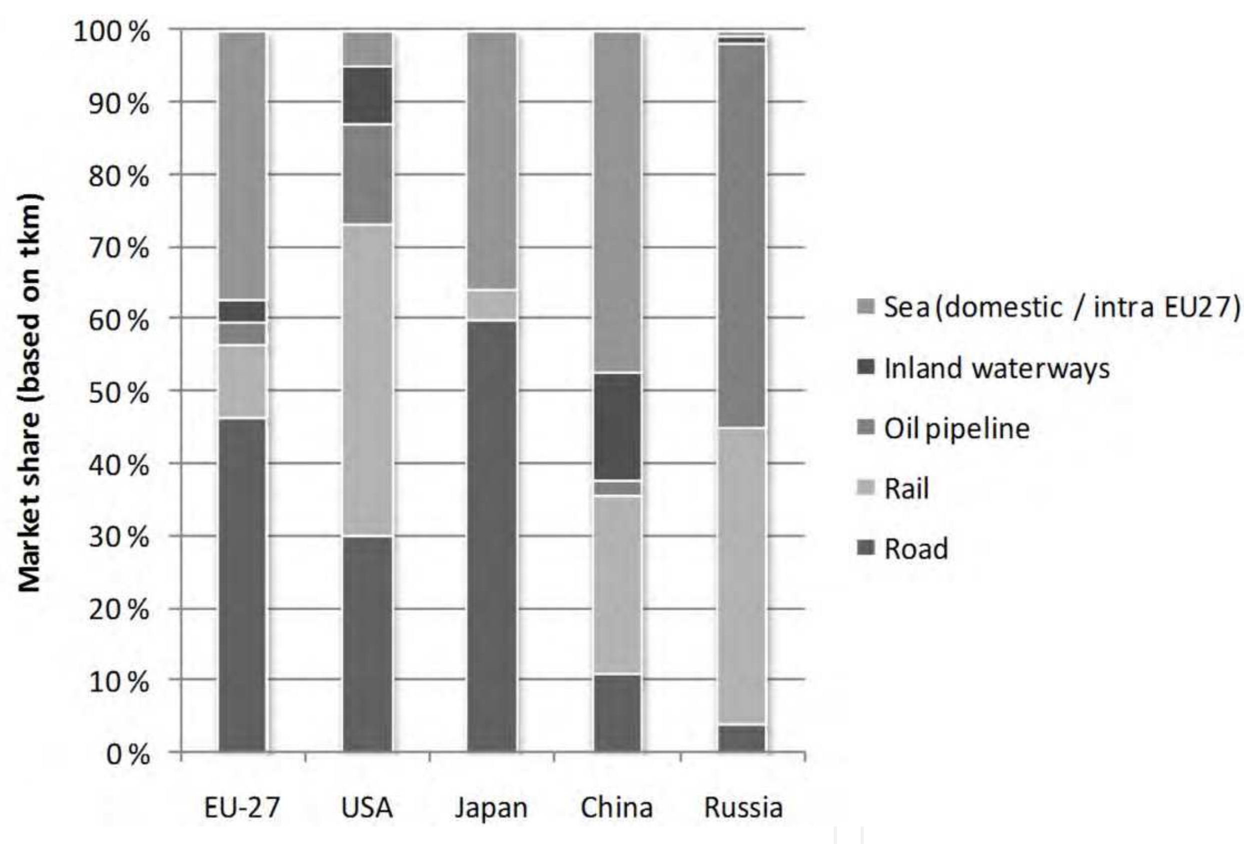

Fig. 1. Short sea shipping market-shares in 2006
Compilation: Eurostat 2009

From the mid 1990s to 2003 short sea shipping in Europe largely kept up with the growth rates of road transport (Figure 3), but in the years from 2003 to 2006 there has been a significantly lower growth in SSS relative to road transport (Figure 2). The average annual growth rates for road transport in EU27 from 1995 to 2006 was 3.5%, whereas the equivalent figure for SSS was 2.7%.

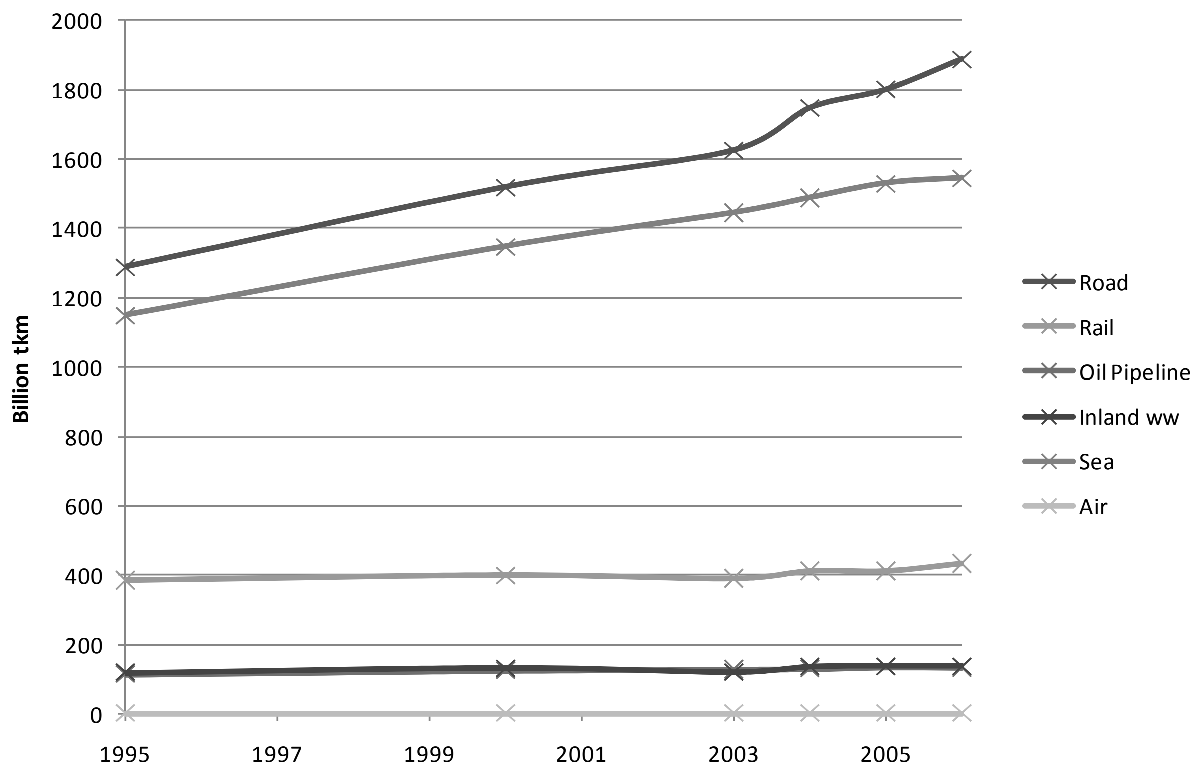

Fig. 2. Freight transport activity in EU27, billion tonne-kilometres
Source: DG Energy and Transport

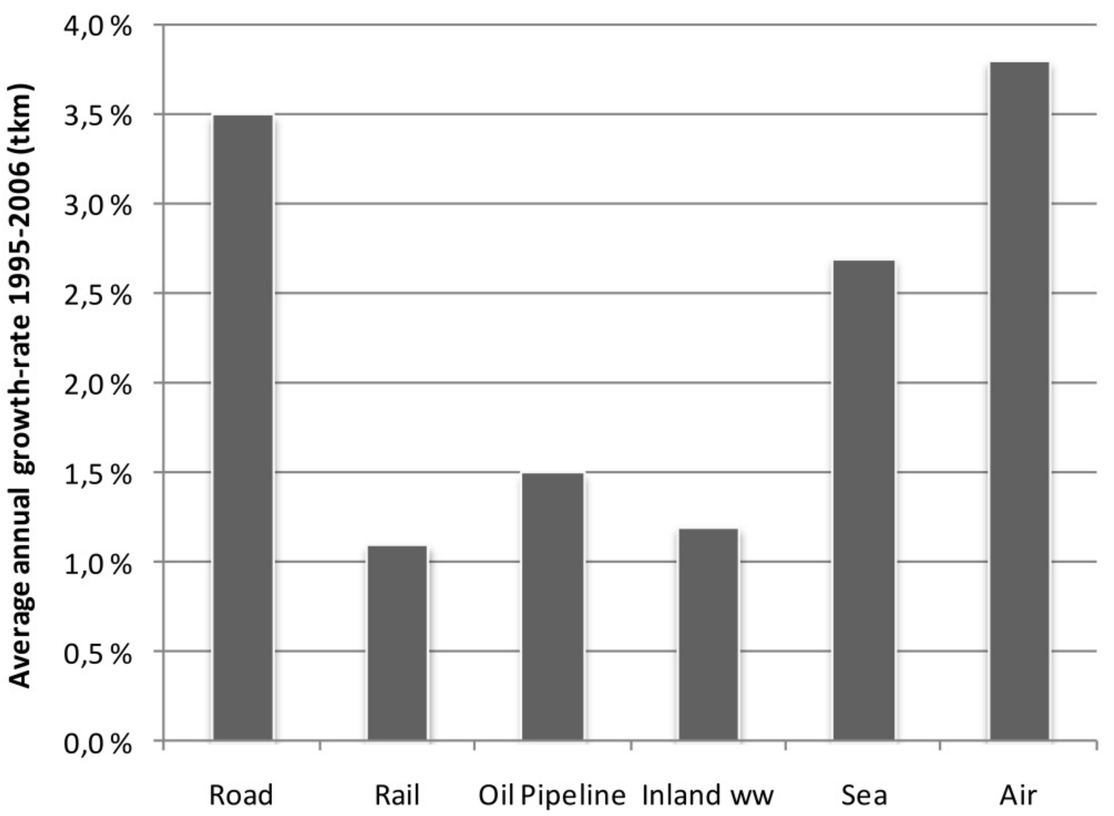

Fig. 3. Average annual growth rates of transport modes in EU27
Figures from Eurostat 2009

2.2 Short sea shipping as an instrument for greening freight transport

Since the 1970s European national and EU transport policy papers have had a relatively high focus on moving cargo from road to sea, inland waterways and rail. Partly the rationale for such a policy has been based on the environmental performance of SSS compared to road transport. In general shipping has been regarded "the green mode" of freight transport – often substantiated by empirical data on average energy use per tonne-kilometre and corresponding emission figures. Sometimes such figures have been based on energy use per deadweight tonne, calculated for big wet or dry bulk vessels. Such figures would typically show that shipping is 10-20 times more energy efficient than relevant road transport alternatives (IMO 2009) calculated per tonne-kilometre. This is why land-based modes like road and rail transport normally would not be competitive to maritime transport when it comes to the transport of commodities like iron ore or oil and chemicals, unless the sea leg is significantly longer than the land leg.

The relevant competition for the SSS industry is therefore not so much in the bulk markets, but in the markets for loose and unitized cargo (containers, trailers, pallets). The relevant vessels for such transports are general cargo vessels, container or RoRo vessels, partly in the business of feeding cargo to and from the deep sea, intercontinental, routes and partly transporting cargo within the continent. The environmental performance of these vessels is very different from the bulk vessels, mainly for three reasons. *Firstly*, the payload capacity relative to the size of the vessel is significantly lower than that of bulk vessels. *Secondly*, these vessels are typically designed for, and operated at, significantly higher operating speeds compared to the bulk vessels, and *thirdly* these vessels are operating in liner operations where average shipment sizes are much smaller than in the bulk market, necessitating a demanding consolidation activity in order to fill the available cargo capacity of the vessels. The latter factor normally means that the average load factor of such vessels may be lower than that of the bulk vessels. However, the scope for attracting back-haul cargoes – thus avoiding return trips in ballast – is definitely better for the general cargo, container and RoRo vessels than that of the bulk ships. This may mean that the average roundtrip cargo utilization does not have to be lower compared to bulk operations – which very often are operated with empty back-hauls.

For the RoRo and container industry there is an additional fourth factor – which may be called "the double load factor problem" of these modes (Hjelle 2010). The fact that containers and trailers transported are not always carrying cargo – and may be only partly filled – effectively means that the relevant load factor of such vessels is a multiple of two load factors. The number of containers / trailers compared to the container / trailer capacity – *and* the typical cargo load factor of containers and trailers. Statistics showing a 70% load factor of RoRo vessels often mean that on average 7 out of 10 available lanemetres are occupied by trucks and trailers. If these trailers have a load factor of 60%, then the relevant load factor of the RoRo vessel is not 70%, but 42%.

All of these factors (with the potential exclusion of the third one) contribute to a significantly lower fuel efficiency for relevant SSS vessels than for bulk vessels.

The level of CO_2 emissions will follow the fuel efficiency, but emissions of particles, SO_2 and NO_X are very different for trucks and ships. Under current regulations the shipping industry is allowed to use fuels with much higher sulphur content than the trucking

industry in Europe. The legal emissions of NO_X and particles are also much higher for shipping than for trucks. This could be attributed to the very different policy regimes for these alternative modes of transport.

2.3 The regulatory regime of shipping vs. land-based transport modes

The global nature of the shipping industry makes it harder to regulate than the trucking business. Regulation must be imposed on a supranational scale to be efficient. This is also true to some extent for road transport, but the degree of national control is much higher on the road networks than for international waters. In Europe this means that the environmental performance of trucks has been improved significantly over the past decades through a series of emission standards gradually reducing emissions of CO, NO, HC and particles (Figure 4). From 2013 the Euro 6 limits will apply with further cuts in NO_X, HC and PM emissions. Sulphur emission levels have also been significantly reduced through stricter regulations of the sulphur content of diesel oil. The reductions in fuel use and CO_2 emissions have not been as substantial.

Trains can use either diesel or electricity. In the former case the situation is similar to that of trucks, although the specific emissions of NO_X and PM (per work of the engine) are somewhat higher for a modern train engine compared to a truck. From 2012 the emission limits in the EU will be similar to that of a Euro 5 truck. There are no direct emissions from an electric engine. However, for a fair comparison with other modes of transport one should consider the emissions that arise from electricity production. For CO_2 this means that the emissions vary significantly with the actual source of the electricity - from negligible for hydropower to relatively large for coal-power.

International shipping has not been subjected to similar regulations over the same period of time, but emissions to air was introduced to the global regulatory regime through the Annex VI of the IMO Marpol convention in 2007. Emissions of CO_2 from international shipping were exempted from the Kyoto protocol due to the complexity of allocating emission to the individual partner states. Lately, the Marpol Annex VI regulations have become stricter, especially in the so-called Environmental Control Areas (ECAs). These areas can be for either SO_2 (SECAs), NO_X (NO_X-ECAs) or both. Currently The Baltic Sea, The North Sea and The English Channel are SECAs and the North American coasts will be both SECAs and NO_X-ECAs in 2012. The sulphur content in the fuel is currently (2011) limited to 3.5% worldwide and to 1.0% in SECAs. The sulphur restrictions will be further tightened to 0.5% worldwide from 2020 and in SECAs to 0.1% from 2015. The regulation for NO_X is also gradually tightened, although through another regulatory instrument, - the NO_X-code, applying to marine engines. Engines delivered at present must comply with Tier 1 regulations. From 2012 Tier 2 regulations, giving a cut of about 20%, will apply. In NO_X-ECAs Tier 3 regulations apply from 2016, representing a cut in NO_X emissions of about 80% compared with Tier 1. The allowed emission for a slow-speed engine will then be 3.4 g/kWh. No specific regulations for particle emissions are implemented for marine engines.

Vessels have become more fuel efficient over the past decades, but the most significant advances were made in the late 1970s and the 1980s, triggered by significant increases in bunker prices. Some national regulations have been imposed, e.g. an environmentally differentiated fairway due system in Sweden and a NO_X tax in Norway. The European

Commission currently considers implementing emissions from the shipping industry into its cap and trade system of CO_2 emissions.

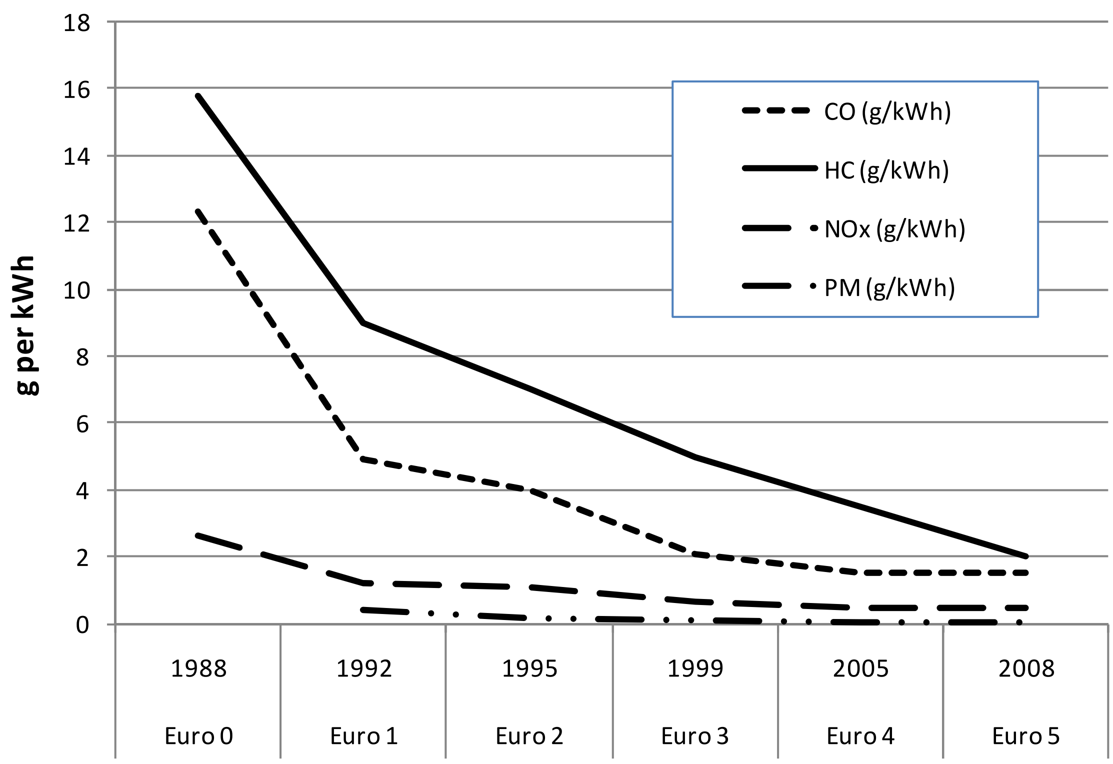

Fig. 4. Truck engine emission standards in Europe
Source: EC DG Energy & Transport

The international regulatory regime of maritime transport is moving quite slowly due to the demanding process of reaching the necessary consensus among nations. Adding to this sluggishness of new regulations is the fact that the penetration lead time of technological advances is much longer for ships than for trucks. The average age of a typical short sea vessel trading in European waters is probably around 15 years (Hjelle 2010), whereas a typical long distance truck in Western Europe has an average age of 4 years. This means that the Euro 5 standard, and in a few years Euro 6, will shortly be representative of the fleet of long distance trucks.

3. The environmental performance of vessels, trucks and trains

In order to compare different alternatives for transporting goods one needs to obtain emission factors expressed as mass of emitted substance per transported amount of goods and distance (functional unit), i.e. an emission factor with units like g/tonne-km. This requires knowledge of emissions per km for the specific vehicle/vessel and the mass of the cargo transported. The latter is often expressed as the maximum possible load multiplied with a load factor.

In this paper we compare the emissions of carbon dioxide (CO_2), sulphur dioxide (SO_2), nitrogen oxide (NO_X) and particulate matter (PM) for different transport alternatives. CO_2 emissions are directly obtained from the fuel consumption. The emitted SO_2 is formed from sulphur present in the fuel and can easily be obtained if the sulphur content in the fuel and

the fuel consumption is known. Nitrogen oxides are formed in the engine and the emissions will depend on the type of engine and on the presence of NO_X after-treatment systems. PM comprises a number of different types of particles and the emissions will depend on engine type, fuel quality and after-treatment system.

3.1 Empirical evidence on fuel consumption and emissions for short sea vessels

For shipping the tabulated emission factors are usually in the form of mass of emission per energy for propulsion from a specific engine. These are normally divided into slow speed, medium speed and high speed engines. Further, the emission factors depend on the type of fuel used; residual oil or gasoil and sulphur content (Cooper and Gustafsson 2004). The emission from a specific vessel thus depends on the engine power and fuel type. In reality the emissions per transported amount of goods and distance will vary significantly depending on the type of ship (tanker, container, general cargo, RoRo etc) and the ships' size. The emissions factor for CO_2, for a ship that carries cargo up to its payload, can vary from 1.2 g/tonne-km for a large tanker, to 250 g/tonne-km for a small RoRo ship. Once the emission factor for CO_2 is established, emission factors for other substances can be obtained through the relationship with fuel consumption. However, the emissions of NO_X, PM and HC may vary significantly from engine to engine depending on model and maintenance level.

Within the Greenhouse gas working groupof the IMO, a design index for CO_2 emissions are being developed for different types of ships (IMO 2009). These are expressed as functions of the deadweight tonnage (dwt) for emissions in g/tonne-nm, and are based on data from a large number of ships. In order to get emission factors for the transported cargo, the relationship between dwt and payload needs to be known as well as typical load factors. The former relationship has been presented in the Clean Ship index (The Clean Shipping Project).

In the calculations presented below we have used the specific emission factors presented by Cooper and Gustafsson (2004) as implemented in the model documented in NTM Working Group Goods and Logistics (2008) and NTM (2009). These are obtained from a large number of measurements and correspond well with other reports (see, e.g Whall et al.(2002)). The emission factors for SO_2 and PM are adjusted for the sulphur content in the fuel both inside and outside the SECA regions. However, to get the emissions from a specific ship the power used needs to be known. Here we have used the CO_2 indexes from IMO and then calculated the corresponding emissions for NO_X, PM and SO_2. The relationship between dwt and payload used (The Clean Shipping Project) are 0.95 for tanker, 0.8 for container ship and 0.5 for RoRo ships.

3.2 Empirical evidence on fuel consumption and emissions for road transport

The emissions from trucks for the transport of a specific cargo will depend on the size of the truck, the emission classification, the fuel used, driving conditions and the load factor. The emissions of NO_X and PM decrease significantly the newer the truck is (see Figure 4). The emission of SO_2 will depend on the sulphur content in the diesel which is now at a maximum of 10 wt-ppm in Europe. The CO_2 emissions are lower the larger the truck is, when considering emissions per mass of transported goods. The fuel consumption and thus the CO_2 emissions will also depend on the type of driving. Within the European Artemis project (Andre 2005) emission factors are available for a large number of trucks and driving

conditions. For example, the CO_2 emission per km for a typical Euro 4 truck of around 19 m length and capable of loading 26 tonnes of goods vary from 700 g/km (urban driving) to 580 g/km (rural) for an empty truck and from 1380 g/km to 1080 g/km for a fully loaded truck. In the calculations made here a load factor of 60% is used and the calculations are made for rural driving.

3.3 Empirical evidence on fuel consumption and emissions for rail freight

For diesel rail engines the data on fuel consumption is very limited and in this review the procedure of EcoTransIT was used to calculate emissions. In the case of electrical engines the CO_2 emissions depend on the source of electricity. For calculations an electricity mix for EU 25 obtained from EcoTransIT was utilized (Knörr 2008).

3.4 Realistic load factors and realistic speed are crucial elements in the comparative analysis

In Figure 5 the emissions per tonne-kilometre are presented for the alternative modes of transport included in this paper. These are estimated based on realistic load factors for the various modes as presented above. For the RoRo vessel a load factor of 44% is used, for the container feeder 48%, for the tanker 55%, for trains 50% and for the truck/trailer 60%. The load factor for the RoRo and container vessel represents the relation with the transported goods and the payload and takes into account both the weight of the trucks themselves and that containers are assumed to have a fill factor of 60%.

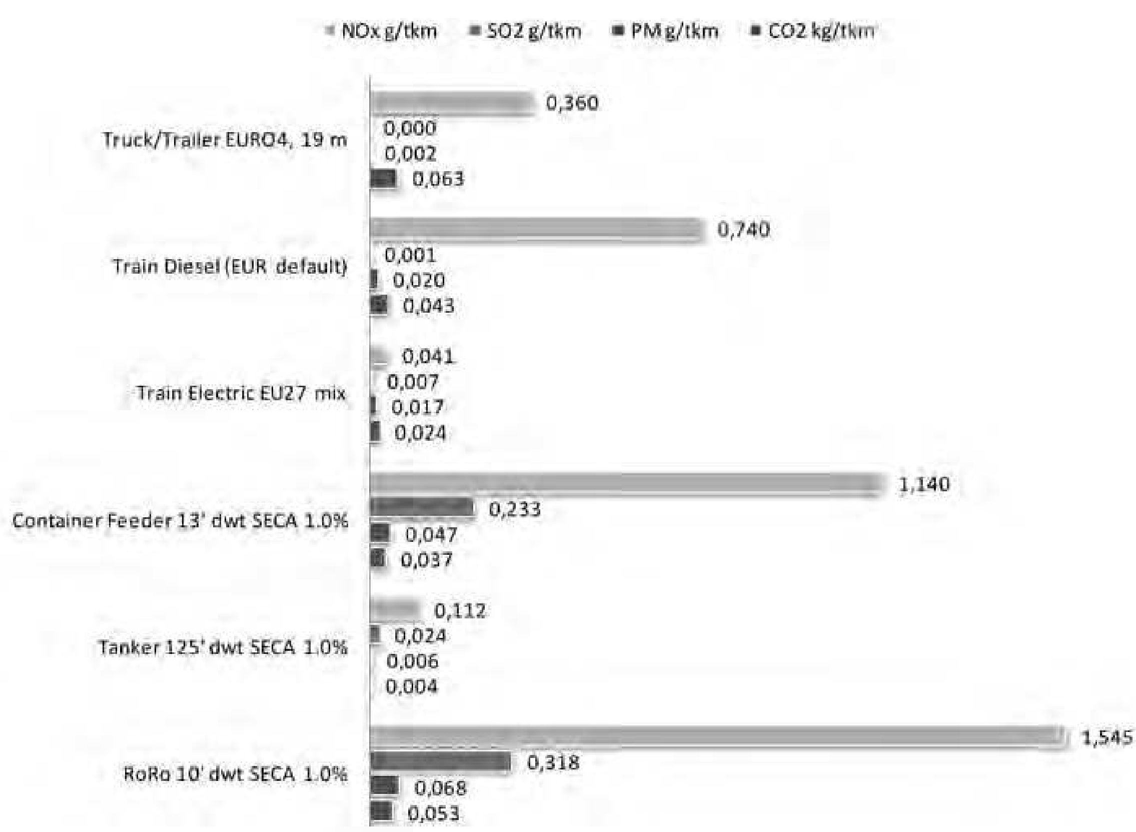

Fig. 5. Emissions per tonnekilometre for the alternative freight transport modes.
CO_2 emissions in kg/tkm. NO_X, PM, and SO_2 emissions in g/tonne-km.

CO_2 emissions are directly correlated with use of fossil fuels. The most fuel efficient among the cases in Fig. 5 is the big tanker vessel, with a CO_2 emission of 4 grams per tonne-km. At the other end of the scale is the truck/trailer combination with a CO_2 emission of 63 grams per tonne-km. The RoRo vessel is marginally better with an equivalent figure of 53 grams. The CO_2 emissions from the electric train with the EU25 energy mix is 24 grams per tonne-km. The container feeder vessel performs much better than the RoRo-vessel at 37 grams per tonne-km[1].

The comparatively very high SO_2 emissions from the vessels range from 0.024 grams for the large tanker to 0.32 grams for the RoRo-vessel while it is only 80 μg/tonne-km for the truck. This is despite the fact that we have assumed that the fuel quality is according to the SECA-regulations of 1.0% sulphur content. Future stricter limits for sulphur content will to some extent make short sea shipping SO_2 emissions come closer to those of the alternative modes, but not beat them.

European trucks (Euro 4 and Euro 5 standard) have relatively low particle emissions[2]. No other mode has lower PM emissions. NO_X emissions are also low for truck transport, only beaten by the large tanker and the electric train. Further, a Euro 6 truck would have an additional cut in NO_X emissions by around 90% compared with the Euro 4 truck.

Comparative figures like these are often presented in policy papers as a rationale for promoting short sea shipping as an alternative to land based modes of transport. Sometimes the figures presented are quite different from one setting to another. One late example is the figures presented in Chapter 9 in the IMO MEPC (IMO 2009) report. Here the CO_2 emissions of a wide range of vessels are presented along with figures for road and rail. As a benchmark for the figures presented in Figure 5, we present a subset of figures representing CO_2 emissions per tonne-km from this paper in Table 1.

Vessel / Vehicle	Total CO_2-efficiency (g/tonne-km)
Crude oil tanker 120'-200' dwt	4.4
Container 1000-1999 TEU	32.1
Container 0-999 TEU	36.3
RoRo 2000+ lm	49.5
Road freight	150 (80-180)
Rail	10-119

Table 1. CO_2 emissions per tonne-km for alternative freight transport modes according to IMO MEPC (2009). Compiled from the text and various tables.

The data for the oil tanker used here is 3.7 g/tonne-km, as compared to 4.4 g/tonne-km in the IMO MEPC-report. The latter is an average for tankers between 120 000 and 200 000 dwt, whereas the tanker considered in this paper is a 125 000 tonner. This discrepancy may be partly explained by the fact that the model used yields a load factor of 55% for crude tankers, whereas the IMO MEPC-report applies 48%.

[1] The container feeder vessel performs better than the RoRo vessel, but it should be noted that the weight of the container itself is included when the calculations have been made.
[2] This applies to exhaust PM. Trucks will also generate resuspended particles from road dust and wear.

The two container vessels from the IMO MEPC-report yields a CO_2 emission level of 32.1-36.3 g/tonne-km. The 13 000 dwt container vessel included in our analysis would typically carry 1000 TEUs, and emits 37.3 g/tonne-km – which is somewhat higher than the IMO MEPC figures. According to the text in the IMO MEPC-report the cargo capacity of the container vessels is based on an assumed 7 tonnes per container. The 70% load factor applied in the IMO MEPC-report is probably calculated as a percentage of this figure, meaning that the assumed net cargo on a 1000 TEU vessel would be 4 900 tonnes. This is similar to our assumption which is based on a cargo capacity of 10 400 tonnes for the 13 000 dwt container feeder vessel, and a load factor of 48%, yielding 4 992 tonnes of cargo.

In our case study we have included a RoRo vessel of 10 000 dwt, emitting 52.7 g/tonne-km. This is slightly higher than the 2000+ lm RoRo-vessel in the IMO MEPC-figures above – which yields 49.5 g/tonne-km. We have applied a load-factor of 44%. This is a combination of the truck load factor and the "lanemeter loadfactor" – see Hjelle (2010) on the double load-factor problem of RoRo shipping. We have also corrected the net cargo carrying capacity of the vessel for the difference between the gross and payload weight of the truck/trailer (40 tonnes vs 26 tonnes).

The IMO MEPC figures are based on an assumption of a cargo capacity of 2 tonnes per lanemeter for the RoRo vessels. The IMO report does not state weather the term "cargo" means net cargo, or a gross term in the form of the combination of truck/trailer and cargo. A plausible interpretation would be that one has assumed only unaccompanied trailers with a payload of 26 tonnes and a lanemeter footprint of 13 meters, which yields 2 tonnes per lanemeter as the maximum net cargo capacity. In most operations one would have a mix of accompanied and unaccompanied trailers. One will also have to allow some extra space for stowage, which means that a more plausible figure probably would be in the area of 1.6 tonnes per lanemeter as a maximum capacity limit. The 2 tonnes applied in the IMO MEPC figures implies that the average lanementer capacity of the 2000+ lm category is 2577 lanemeters. According to the calculations above this corresponds to a cargo carrying capacity of 4123 tonnes. If 70% of the lanemeters are utilized on average, and the truck has an average load factor of 60%, the combined loadfactor of 42% means that this vessel category on average carries 1732 tonnes of cargo.

In our calculations we have applied the IMO GHG group's CO_2 index for a 10 000 dwt RoRo ship which is 15.1 g/tonne-km when it is full. Such a vessel is assumed by us to have a payload of 5000 tonnes (including the own weight of the trucks and trailers, 3250 tonnes without). As indicated above, we have applied a combined load factor (representing both lanemeter utilization and truck payload utilization) of 44%. Based on this we end up with a CO2 emission factor that is close to the one reported in the IMO MEPC-report.

For road freight the IMO MEPC (IMO 2009) report refers to seven different sources/studies, and concludes with an average figure of 150 g/tkm and a range from 80 to 180 g/tkm. Based on the Artemis model we end up with 63.1 g/tkm for our 19m truck/trailer combination with a load factor of 0.6. Since the IMO publication only briefly refers to external sources, it is not quite clear which settings all of these figures stem from, neither the implied load factors. It is clear though, that some of the referred sources include figures representative for smaller trucks and trucks operating in more urban

environments. In a setting where truck transport is compared to short sea shipping such settings are not very relevant as the maritime transport alternatives would compete against long haul truck/trailer combinations rather than distribution vehicles in urban settings. This might explain the fact that our figure lies below the lower bound of the IMO MEPC figures.

Our rail alternatives yield CO_2 emission figures between 24.3 (electric) and 42.6 (diesel) g/tonne-km. The IMO MEPC (2009) study refers to six different studies, yielding a range between 10 to 119 g/tonne-km. The lower figure stems from the long and slow moving bulk trains in the USA, and the upper limit stems from a top-down calculation based on data for the EU region provided by Eurostat. Our data based on the EcoTransIT (Knörr 2008) model lie within these limits, but are significantly lower than the top-down calculations based on Eurostat data. Among the sources cited by the IMO MEPC-report, our figures are quite close to the ones based on US container trains (35-50 g/tonne-km). Further, it can be pointed out that an electric train using exclusively hydro electricity would in our calculations have a CO_2 emission of 0.004 g/tonne-km with a load factor of 0.5.

4. Comparing alternative modes on typical short sea legs

4.1 Four cases and seven modal alternatives

We have chosen four typical intra-European trade links which are quite different with respect to the comparative distances for alternative modes of freight transport (Figure 6). The first case is Gothenburg (Sweden) to Rotterdam (The Netherlands), which is a relatively short distance by sea, and somewhat longer by road and rail. The second case, Helsinki (Finland) to Genoa (Italy) is the longest one, and a case where the sea-link is significantly longer than the road and rail alternatives. Rotterdam to LeHavre (France) is a link where the sea-leg is almost parallel to the road and rail alternatives, which means that this third case will mainly be affected by differences in emissions per tonne-km for the alternative modes. Finally, the last case is Gothenburg to Aberdeen (Scotland). This case represents an alternative where short sea shipping has a very significant comparative advantage distance-wise. Road and rail alternatives for this case are three times as long as the maritime transport alternative.

These four geographical cases are then combined with alternative modes, also with some different varieties within the broad modal categories of sea, road and rail transport. The sea transport alternatives included in this analysis are a 10 000 dwt RoRo-vessel, a 6000 dwt container feeder vessel and a 125 000 dwt tanker. The latter one would typically be used for shuttle transports from offshore oil production sites to refineries, and thus road and rail transport is no realistic alternative to the tanker. We have included this vessel here more as a reference to illustrate how typical calculations of emissions per dwt for large bulk vessels will be very different to such figures for typical short sea cargo vessels. For rail transport, we have included one diesel train alternative, and one electric train with a typical mix of electricity production for the EU. Finally, we have included one typical long distance truck/trailer combination (19 meter) with a Euro 4 engine. As the average age of such trucks in Western Europe will in the area of 4-5 years (Sandvik 2005), this will be a representative engine type.

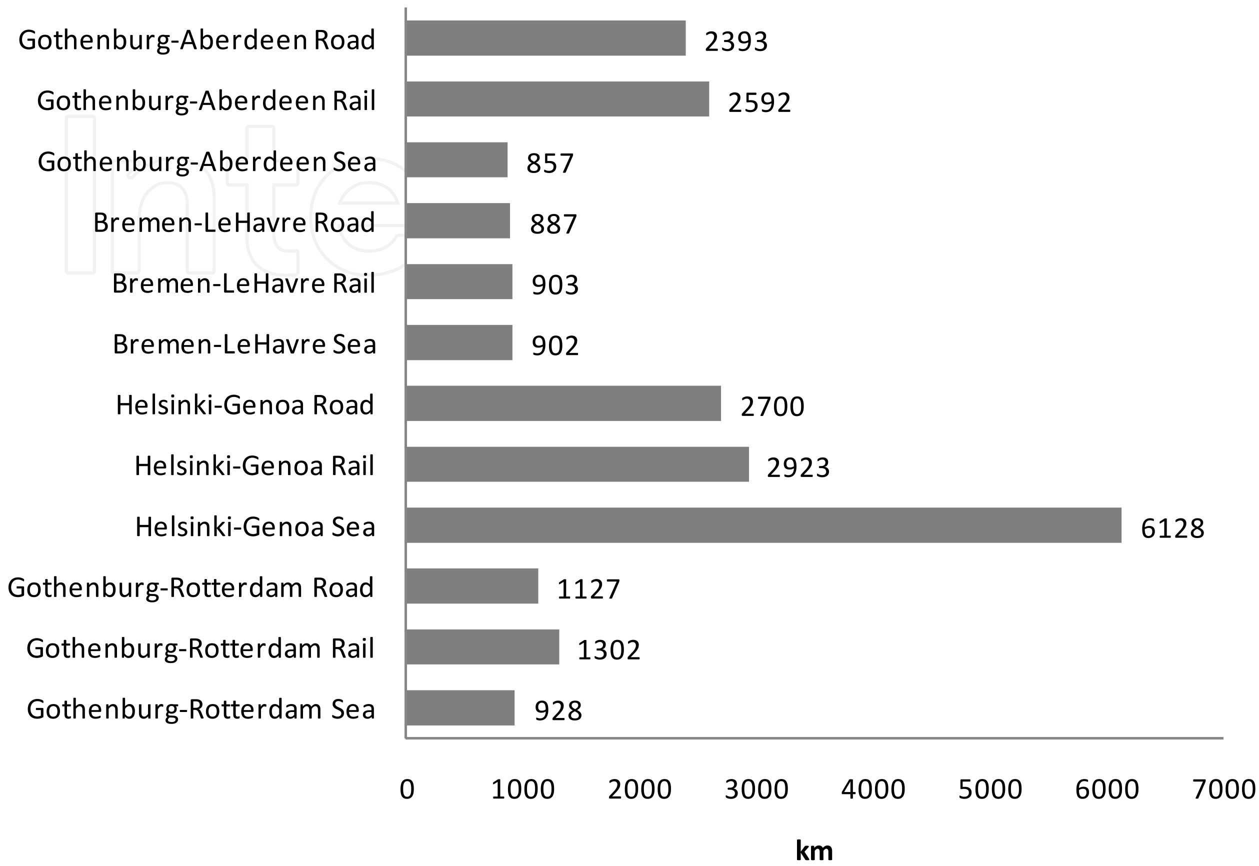

Fig. 6. Distances for alternative OD-pairs and modes (kilometres)

4.2 Emissions to air for the alternative cases

Putting these alternative modes into realistic settings, differences in relative distances also comes into play. In Figure 7 the environmental performance of the alternative modes are presented for the Gothenburg-Rotterdam link. This is a link where the sea-leg is somewhat shorter than the road and rail alternatives. This makes the RoRo and container liner alternatives the winners along with the electric train, regarding CO_2 emissions. The truck/trailer combination yields CO_2 emissions that are more than twice as high as those of the RoRo-vessel, and 4-5 times that of the container vessel.

Even with the distance advantage for the shipping alternative – the emissions of SO_2 are significantly higher from the SSS alternatives than for road and rail. The picture is more mixed for NO_x and PM emissions. The container feeder performs much better than the diesel-train regarding NO_x, whereas the RoRo alternative is comparable to the diesel train. Regarding PM-emissions both train alternatives are of the same order of magnitude as the container vessel, but yield a lower emission level compared to RoRo transport. As we have pointed out earlier, European trucks have very low particle emissions compared to alternative modes.

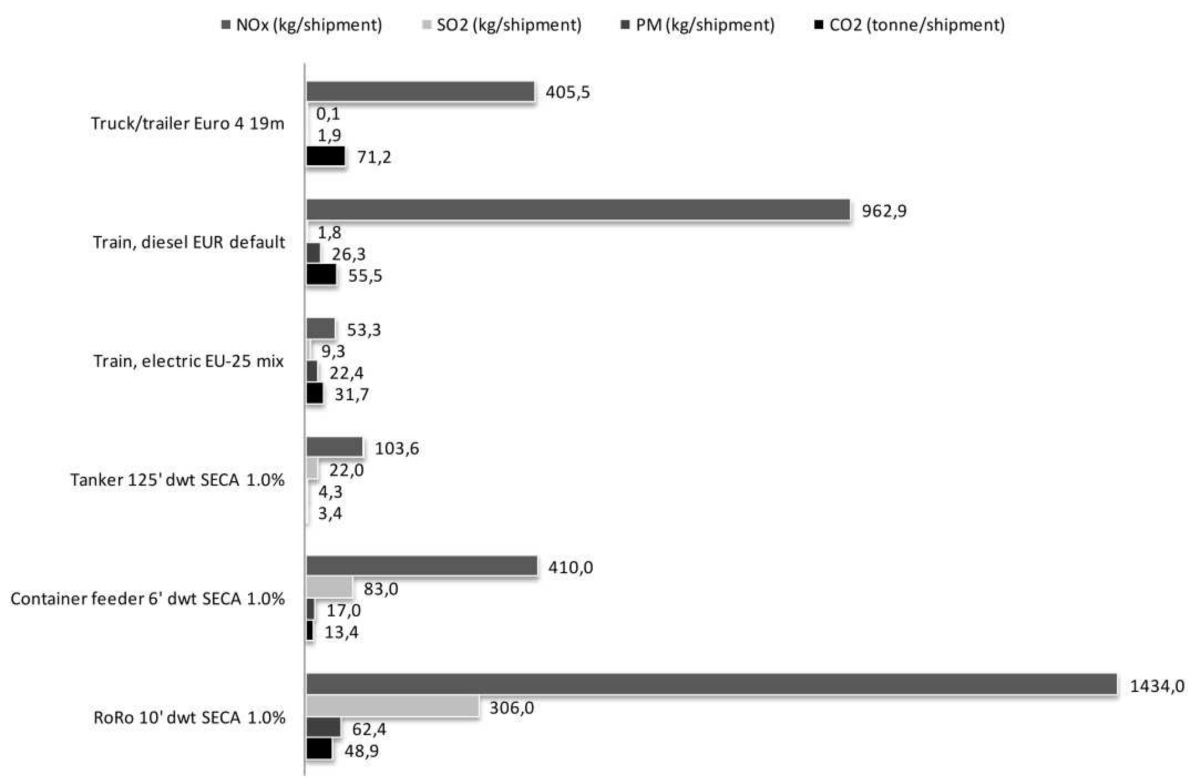

Fig. 7. Emissions of alternative freight transport modes.
One shipment of 1000 tonnes from Gothenburg to Rotterdam

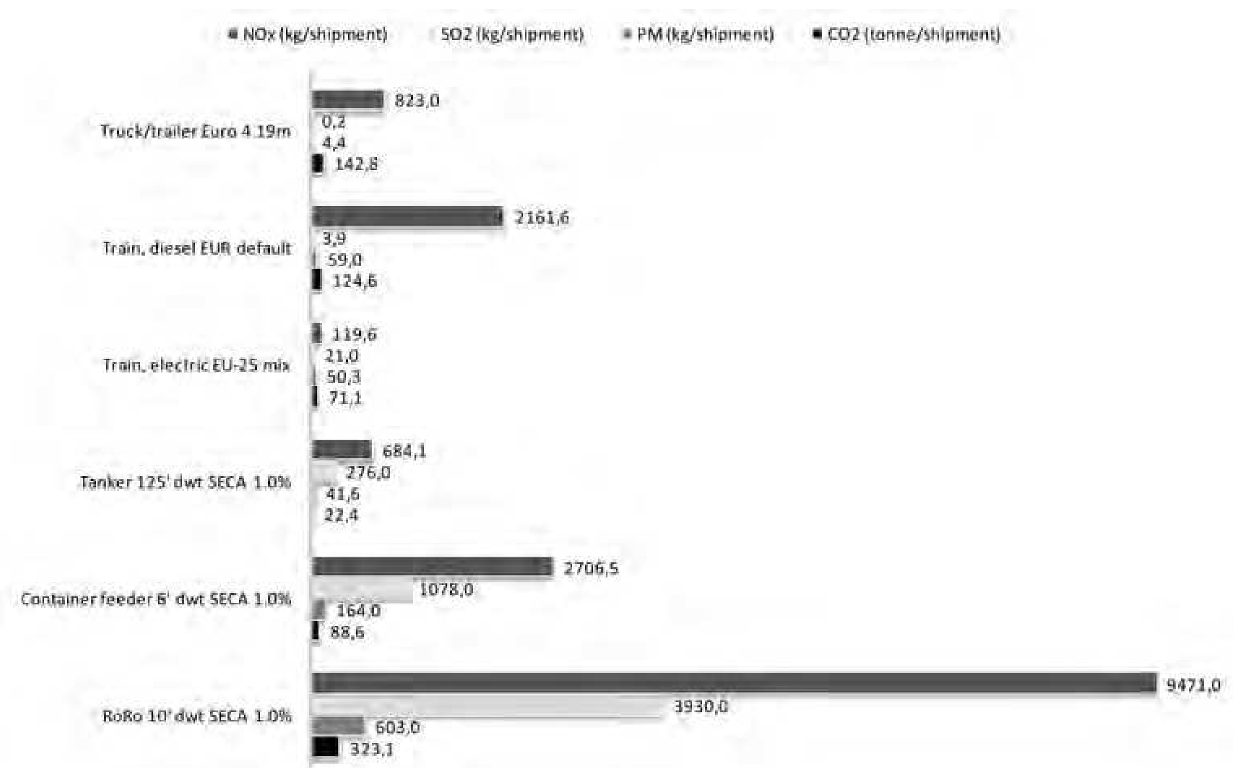

Fig. 8. Emissions of alternative freight transport modes.
One shipment of 1000 tonnes from Helsinki to Genoa

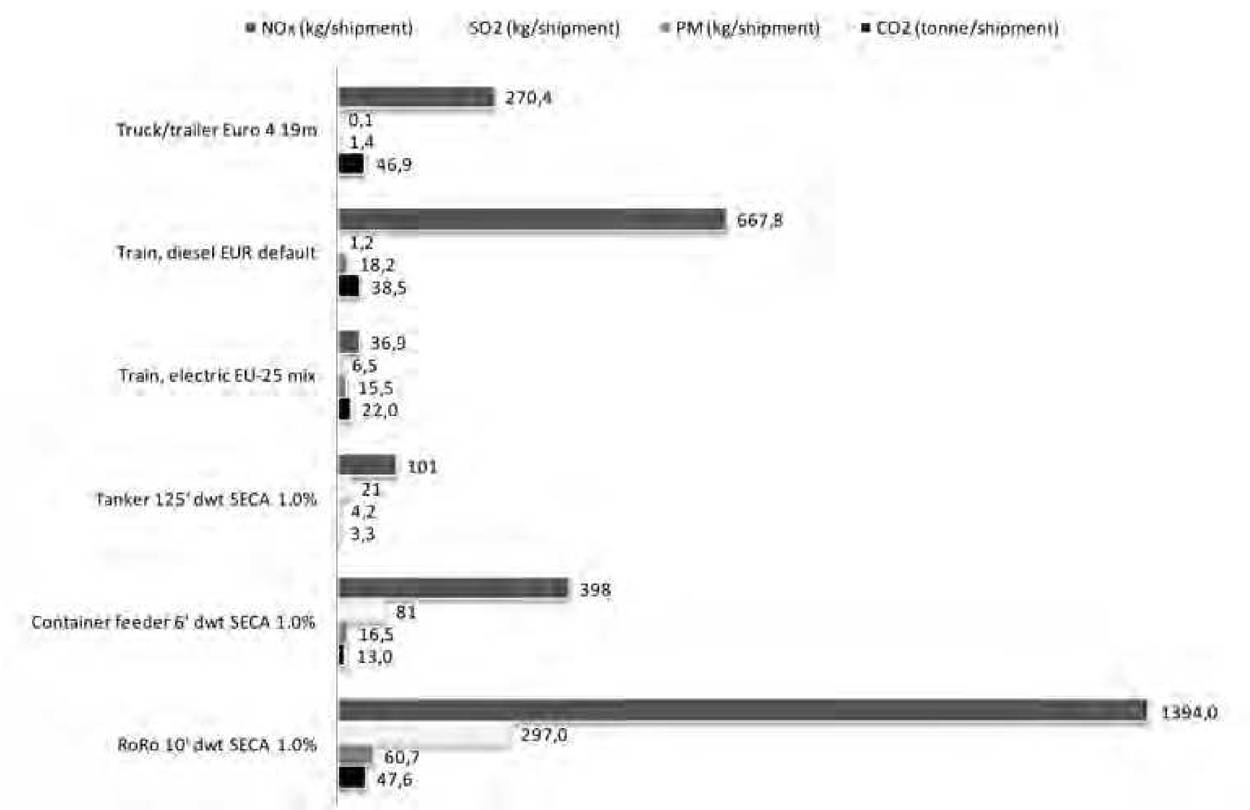

Fig. 9. Emissions of alternative freight transport modes.
One shipment of 1000 tonnes from Bremen to Le Havre

The Helsinki-Genoa case illustrates the effects of cases where the sea leg is significantly longer than the land-based alternatives. With such a big distance-disadvantage the SSS modes will lose along all environmental dimensions. Still, it may be interesting to note that our "reference" tanker vessel is more energy efficient than the land based modes even with such a huge difference in distances. The train alternatives are preferable to the truck alternative with respect to CO_2 emissions, but the picture is more mixed for other emission types.

The Bremen-Le Havre case (Figure 9) would be a typical project for the Motorways of the Seas programme of the EU, since this would be a service that might relieve traffic congestion on parallel road (and rail) networks. Would it also be good case along pure emissions-to-air dimensions? As always the maritime transport alternatives performs poorly with respect to SO_2 emissions – and also with respect to NO_X and PM when compared to truck transport. The container feeder emits much less CO_2 than the two rail alternatives, whereas the RoRo vessel emits more CO_2 than the electric rail alternative and somewhat less than the diesel train. Both SSS services perform better with respect to CO_2 than the truck/trailer combination.

Finally, our Gothenburg-Aberdeen case represents the other extreme, compared to the third case. Here the SSS-alternatives have a very large distance advantage compared to road and rail. Even with this advantage SO_2 emissions are high for the container and RoRo-alternatives. This is also true for the NO_X emissions for RoRo relative to the road transport alternative. The energy use is of course much lower for the vessels than for the road and rail alternatives.

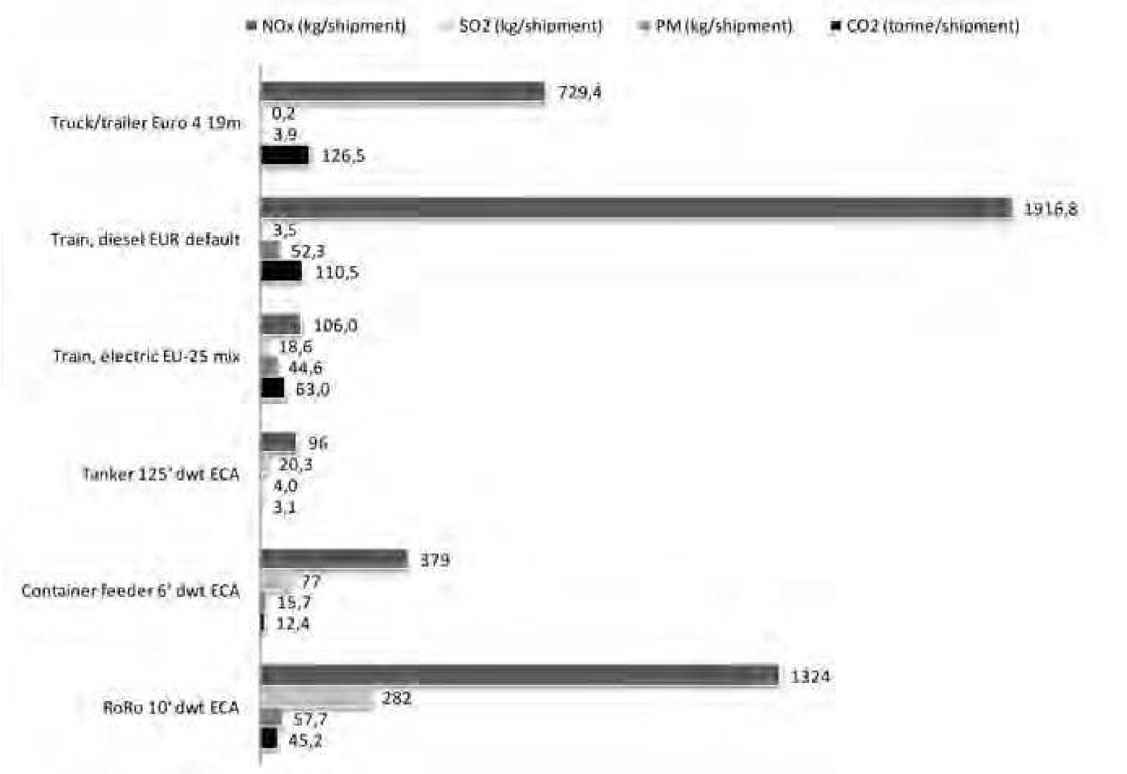

Fig. 10. Emissions of alternative freight transport modes.
One shipment of 1000 tonnes from Gothenburg to Aberdeen

5. Technological and political perspectives on green shipping

5.1 The scope for technology-based reductions of emissions from short sea shipping

The picture presented here will be altered in the future as new engine and exhaust conversion technologies are introduced. If we look at regulations already in place we can note that a Euro 6 truck would reduce the emissions of NO_X by 90% and by PM with 50% compared with the truck used in our calculations. For the ships most of the routes we studied are already within SECAs. Here the emissions of SO_2 will be reduced by 67% by 2015 compared with today. Also the PM emissions are then probably reduced by about 80% by 2015 in SECAs. If the ship were to have Tier 3 engines the NO_X emissions would be reduced by about 80%. The use of natural gas as fuel would give even further reductions in all three substances. The train with diesel engines will show better performance as the new emission regulations are put in place.

When it comes to CO_2 emissions all three transport modes have the potential for reductions through increasing the load factors. For the ships, significant improvements can be obtained through reducing the ships' speed, since the fuel consumption is strongly dependent on speed. All three modes also have the possibility to use alternative fuels. Natural gas should give a 25% reduction in CO_2 emissions but may increase the emissions of methane which is a powerful green-house gas.

The Second IMO Greenhouse Gas Study (IMO 2009) points to a number of technology-based options for improving the energy efficiency of vessels. Partly these are related to improved design (concepts, hull and superstructure, power and propulsion systems) and improved operations (fleet management, logistics, incentives, voyage optimization, energy management). The combined potential for reductions of CO_2 emission from these technologies is estimated to be between 25 and 75%. To reach the upper bound of this range, reductions in operating speed would be necessary.

5.2 The potential impact of future regulatory actions

Some of the technological options mentioned above will be financially attractive to the ship-owners, and theoretically there should be no need for regulatory actions to put them to work. Other technologies need regulatory support in the form of regulations or incentives. Such policies could be categorized into market-based instruments, command-and-control instruments and voluntary measures (Table 2). Within these categories one could think of different concrete instruments and ways of benchmarking environmental performance. Currently benchmarks like the Energy Efficiency Operational index (EEOI) and the Eneregy Efficiency Design Index (EEDI) are candidates for benchmarking the CO_2 emissions of vessels within the IMO discussions.

	Market-based instruments	**Command-and-control instruments**	**Voluntary measures**
Maritime GHG emissions	Emissions trading, e.g., METS.* Emissions levy, e.g., ICF.†		
Operational efficiency	EEOI levy. EEOI levy/benefit scheme.	Mandatory EEOI limit. Mandatory EEOI reporting. Mandatory SEMP.	Voluntary agreement to improve EEOI. Voluntary agreement to implement SEMP.
Design efficiency	EEDI levy. EEDI levy/benefit scheme.	Mandatory EEDI limit for new ships.	Voluntary agreement to improve EEDI, meet voluntary standards.
Fuel life-cycle carbon emissions	Differentiated fuel levy.	Fuel life-cycle carbon emissions standard. Biofuel standard.	

* METS - Maritime emissions trading scheme.
† ICF - International Compensation Funf

Table 2. Overview of policies to limit or reduce emissions of greenhouse gases from ships Source: IMO (IMO 2009)

As noted above, such global regulatory regimes are to a large extent dependent on achieving consensus among many nations which makes the international regulatory regime related to shipping more sluggish than the equivalent regimes applied to land based modes. This is one of the reasons why the EU “threatens” to take unilateral action by including CO_2 emissions from international shipping into the EU trading regime for CO_2-quotas.

6. Conclusions

Our case studies illustrate that short sea shipping operations, represented by RoRo and container services may very well deserve their “green label” when compared to alternative modes with respect to CO_2 emissions. This conclusion is valid under what we consider realistic operating environments with respect to vessel operation speeds and achieved load factors, and when the shipping leg is not much longer than the distances of the land based modes. This conclusion holds at least for the container vessels, but the advantage of RoRo operations versus truck transport may be marginal – and is highly dependent on the prevailing market situation and the resulting load factors achieved.

The short sea shipping alternative does generally *not* deserve a “green label” when SO_2, NO_X and PM emissions are considered. Although some improvements are in the pipeline through the stricter Marpol Annex VI regulations, the maritime transport alternatives will still not be able to compete with road transport along these dimensions unless new fuels (LNG) are introduced or abatement technologies are installed.

We have applied quite large feeder vessels, a 10 000 dwt RoRo vessel and a 13 000 dwt container vessel, in our case studies. Smaller vessels will generally yield higher emissions per tonne-km and may therefore be less competitive.

We have illustrated that the use of realistic load factors is crucial in a comparative analysis like this. Applying load factors related to the cargo *capacity* of the vessel measured in tonnes will not yield a realistic setting, especially for RoRo vessels. All emissions should be attributed to the net cargo transported – as is the intention of IMOs proposed Energy Efficiency Operational Index (EEOL).

The recent work of the IMO MEPC points out that there is a very significant potential for reductions of CO_2 emissions from ships – but that many of the possible technological and organizational measures are dependent on efficient policy regimes to come into play.

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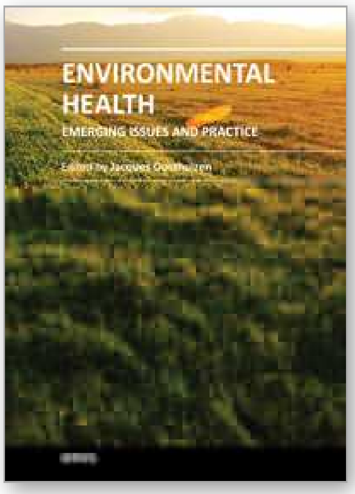

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Environmental health practitioners worldwide are frequently presented with issues that require further investigating and acting upon so that exposed populations can be protected from ill-health consequences. These environmental factors can be broadly classified according to their relation to air, water or food contamination. However, there are also work-related, occupational health exposures that need to be considered as a subset of this dynamic academic field. This book presents a review of the current practice and emerging research in the three broadly defined domains, but also provides reference for new emerging technologies, health effects associated with particular exposures and environmental justice issues. The contributing authors themselves display a range of backgrounds and they present a developing as well as a developed world perspective. This book will assist environmental health professionals to develop best practice protocols for monitoring a range of environmental exposure scenarios.

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