THE DOUBLE LOAD FACTOR PROBLEM OF RO-RO SHIPPING

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ABSTRACT

Maritime transport is regarded the most environmentally friendly mode of transport in many policy papers and has received a lot of government support for moving cargo transports from road to sea. Most assessments of energy use and related carbon emissions in mode-choice settings have been based on energy use per deadweight tonnage figures for the maritime modes, thus giving a very favourable picture for the sea-based alternatives. Whereas this may be relevant for bulk shipping, the situation is quite different for Ro-Ro shipping – which is the most relevant alternative for intra-continental transports.

The trucking industry has been subjected to a number of regulations, effectively cutting back on emissions per ton transported over the past decades. Through six generations of EURO-engine-standards and gradually stricter fuel quality regulations, much has been improved since the 1980s. In the same period much less has happened with respect to technical advances with environmental impact affecting Ro-Ro shipping. This could be attributed to the kind of regulatory environment these sectors have been subjected to, where the trucking industry is under control of national regulations – whereas the maritime shipping industry has comparatively fewer and looser environmental regulations, implemented through a slow moving international regime.

Through representation of a number of realistic intra-European multi-modal trade links, with different mixes of modes of transport – energy use and emissions from these various chains are presented. The outcome of these cases is not very favourable for the maritime transport alternatives. Apart from the factors related to the (lack of) technological progress mentioned above, the main problem seems to be “the double load factor problem” of Ro-Ro shipping. Half-full trailers on half-full decks may very well jeopardize the comparative advantage of maritime transport alternatives.

Keywords: Ro-Ro Shipping, Maritime Transport, Multimodal Freight Transport, Environment, Emissions, Load factor

INTRODUCTION

On the intra-continental transport arena, the relevant maritime transport solutions for general cargo comprise specialized container vessels, Ro-Ro (Roll-on-Roll off) or Lo-Lo (Lift-on-Lift off) vessels – or combinations of these. Ro-Ro vessels often comprise passenger capacity (with or without cabins) – and is then referred to as Ro-Pax vessels or ferries. There are few firm dividing lines here, - but generally the specialized container vessels have a higher market share on heavy transport links – between bigger ports with specialized container terminals. Still there are some container feeder vessels that have their own handling equipment and therefore could make calls in minor ports as well. Ro-Ro vessels are often promoted as an alternative to truck transport – as they typically carry trucks and trailers – and have very modest port infrastructure demands, thus making them very flexible. Programs like the EU Marco Polo programme and the Motorways of the Seas programme have focused on shifting cargo from road to sea – often by stimulating new Ro-Ro services. The main rationale behind such schemes has been an explicit or implicit assumption that maritime transport solutions would help relieving some of the environmental issues related to the emissions from road transport.

In many transport policy documents (EC, 2001, 2007), maritime transport is promoted as the "green mode" of freight transport – often without further references or justification. Whenever comparative figures for energy use or emissions to air are presented – the figures representing maritime transport is quite frequently based on energy use or emissions per deadweight ton (DWT). This may be relevant if the focus is on bulk transports like iron ore, crude oil or oil products, but not when the focus is on intra-continental transports of general cargo. Most policy papers focus on general cargo transports, because this is where alternative policies could affect the market share of the competing modes of transport. For deep sea transports of bulk cargo – there is usually no feasible alternative to maritime transport solutions.

This paper will challenge the common assumption that maritime transport solutions are generally more environmentally friendly than road transport alternatives through a comparative study of plausible Ro-Ro transport scenarios versus realistic pure road-based alternatives. Based on these concrete cases, we will analyse why Ro-Ro transport is very different to maritime bulk transport cases – and hence explain why comparative figures based on deadweight tonnage are quite irrelevant in most policy settings. We will also discuss the very different policy settings pertaining to international maritime transport and road transport – and illustrate how these different environments may have shifted the comparative environmental performance of these modes over the past decades. Finally we will show how the inherent technology of Ro-Ro transport also may be it's major challenge in the competition versus land based alternatives – this is what we may call the "double load factor problem of Ro-Ro transport".

THE ENVIRONMENTAL PERFORMANCE OF MULTIMODAL TRANSPORT CHAINS

The environmental performance of alternative modes of freight transport has to be analyzed in concrete and plausible settings. Information about relevant technical performance has to be put into a market context by assigning relevant speeds, distances and cargo volumes on both front-hauls and back-hauls. As will be shown in the consecutive case study, the set of market data are often more deciding for the environmental performance of the transport chain than the pure technical solutions.

Four different multimodal transport chains from Trondheim to Paris

We hav defined four different cases for trailer and Ro-Ro transport from Trondheim (Mid-Norway) to Paris, France. This is a typical transport leg for Norwegian export industries destined for European export markets.

The conceptual model applied is the same as described in Hjelle (2010), and briefly outlined in Figure 1. Vessel environmental performance has been based mainly on factors applied in the Sutranet model, documented in Sjödin et al. (2007). Vessel data from concrete relevant vessels is collected from Lloyd's Register (Lloyd's Register, 2008), and road distances are based on Google Maps. Emission data for HGV transport is based on Knörr (2008). The focus is on Ro-Ro or Ro-Pax vessels for the relevant sea transport legs.

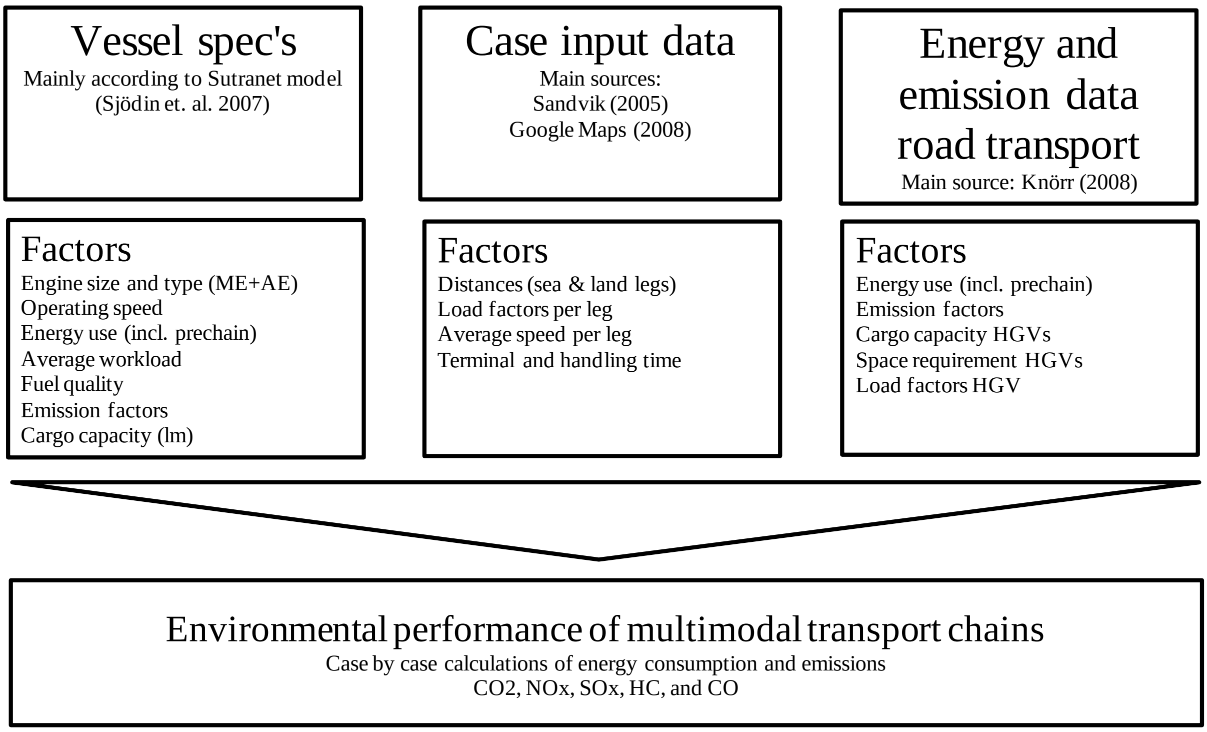

Figure 1 Conceptual model for the calculation of environmental performance (Hjelle 2010)

The four cases are:

1. A mainly road-based alternative with truck transport from Trondheim to Oslo, a Ro-Pax ferry connection from Oslo to Kiel, and road transport from Kiel to Paris. This case is based on an existing ferry service.
2. This is the case which is most dominated by maritime transport, as it includes a long Ro-Pax service from Trondheim directly to Zeebrügge in Belgium, and a short road trip from Zeebrügge to Paris. There is currently no such service – but such – or similar plans have been put forward on several occasions.
3. This is the pure road-based alternative – which crosses the Öresund bridge between Malmö and Copenhagen – and also the Storebælt bridge in Denmark, and then following a common route to Paris.
4. Finally, we have defined an alternative route including the relatively high speed monohull service between Kristiansand, Norway and Hirtshals, Denmark. Road transport is used for most of this route – as some rather long stretches from Trondheim to Kristiansand and from Hirtshals to Paris dominate this alternative.

As illustrated in Figure 1, the four alternatives varies in total distance, with alternative two, with it’s long ferry link, as the shortest one and the pure road alternative (3) the longest because of the deviation via the Öresund and Storebælt bridges.

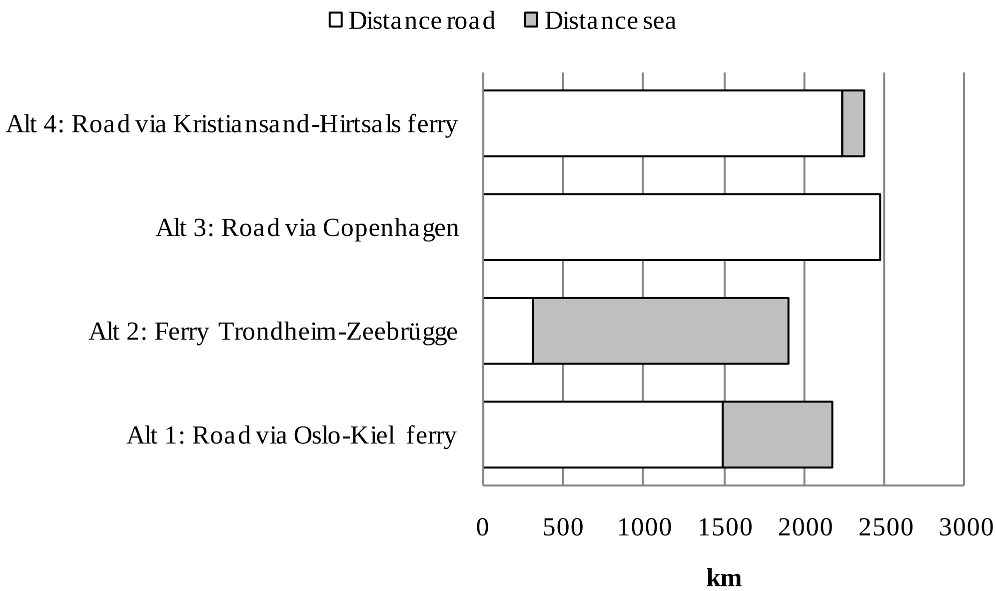

Figure 1: Transport distances for the four alternative transport chains

Vessel types and operating speed

Vessel operating speeds are critical to the environmental performance of the transport chains dominated by sea-legs as a doubling of the speed effectively will quadruple fuel consumption. This case study is based on existing or proposed actual services, and the operating speeds of the vessels represent actual or most relevant speeds. For the Oslo-Kiel link a speed of 22 knots has been assumed, based on reported operating speeds of current vessels (Lloyd's Register, 2008). The leg Trondheim-Zeebrügge is a potential new Ro-Ro connection where it is assumed that 22 knot vessels like the ones crossing the Irish Sea will be a relevant alternative. Kristiansand-Hirtshals is serviced by a relatively high speed mono-hull vessel (27 knots). For all services data has been collected from relevant actual vessels found in Lloyd's Register (2008).

Load factors – critical input factors with scarce empirical evidence

Cargo capacity utilization rates of the different vehicles and vessels enter into the case study in the form of load factors. These factors are critical when making comparative environmental studies like this one, but unfortunately empirical information on load factors is very scarce in published literature, possibly because such information is regarded as highly sensitive. Adding to this scarcity is the fact that the way such load factors are defined varies considerably. Sometimes an empty back-haul transport leg is not included in the roundtrip load factor reported, and sometimes cargo that is transported only on a sub-section of the route is included with the same weight as cargo transported between the origin and destination of the service.

For the ferries we have assumed a general load factor of 70% - defined as the average proportion of the available number of lanemetres occupied by trailers and trucks. Such a load factor would normally provide a viable service. Some services would be able to sustain operations with somewhat lower load factors, depending on the competitive pricing levels compared to operating costs. Actual load factors would vary over time and on respective routes. In Sandvik (2005) the Rosyth-Zeebrügge connection is reported to have an approximate load factor of 70%. Newer services will typically have a lower load factor while building up the market.

The assumed HGV load factor is 58% including empty back-haul driving – this is assumed to be an applicable average for Europe in Knörr (2008). Each trailer/truck is assumed to take up 16.5 lanemetres on the vessels deck and to have a capacity of 26 metric tons of cargo. The net cargo carried on the vessels is then calculated based on available lanemetres multiplied with the load factors of the vessels and vehicles, multiplied by the cargo capacity of the trailers.

Since Ro-Pax ferries also carry passengers and passenger cars – allocating energy use and emissions to freight transport activities is not straightforward. The passenger transport and the freight transport are truly joint products in this setting – and the choice of allocation procedure cannot be deducted from any clearly superior principle (Hjelle 2010). We have based our judgement on a review of the layout of the individual vessel – and the purpose of the various decks. Based on this we have allocated 35%, 50% and 80% of the energy use and emissions to the transport of HGVs respectively. The lower figure (35%) pertains to the

Oslo-Kiel link serviced by a ”floating hotel” with many decks allocated to pure passenger facilities. The medium figure (50%) represents the Kristiansand-Hirtshals link because this ferry has a lower (but still significant) emphasis on passenger facilities. The highest factor (80%) is allocated to the Trondheim-Zeebrügge link since such a service is likely to have a main focus on HGV transport due to it’s length. For reference - in DEFRA (2008) a Ro-Pax factor of 88% is applied in a study based on UK ferries, thus allocating more of the energy use and emissions to freight transport. One reason for allocating a smaller proportion in these cases is also the high emphasis on tax-free sales on these connections, since these are not intra-EU links.

Table 1 Overview over key factors applied in the case study

Load factor HGV	58%
Lanemeter utilization RoPax ferries	70%
RoPax factor[1] Oslo-Kiel	35%
RoPax factor Kristiansand-Hirtshals	50%
RoPax factor Trondheim-Zeebrügge	80%
Operating speed Oslo-Kiel	22 knots
Operating speed Kristiansand-Hirtshals	27 knots
Operating speed Trondheim-Zeebrügge	22 knots
Average main engine work-load	80%
Average auxiliary engine work-load	20%

Fuel types and emission factors

The sulphur content of the marine fuels applied will be critical for the calculated SOx emissions. All the relevant ferry links in this study operate within the ECA[2]s established by the IMO, effectively limiting the maximum sulphur content of marine fuels to 1.5%. Based on this 1.5% has been assumed on all links. The carbon content of the fuel is 87%.

The emission factors are based on Ship Defaults in the Sutranet model (Sjödin et al., 2007) for the relevant engine type and size. This model is mainly founded on the Artemis project (Sjöbris et al., 2005), updated with research conducted by IVL (Cooper et al., 2004a, b) and ENTEC (Whall et al., 2002). The average cruising workload is assumed to be 80% for the main engine and 20% for the auxiliary engine as assumed in the base scenario for open sea operations in the Sutranet model. This means that we have not considered the quite significant emissions from manoeuvring and mooring operations, nor have we considered the

[1] The RoPax-factor represents the proportion of energy use and emissions allocated to cargo transport.
[2] ECA means Environmental Control Area as defined in the MARPOL Annex VI convention. These are currently covering the North Sea, The Baltic Sea and the English Channel. In 2010 the east and west coast of North America will also be included in the ECAs.

much higher utilization of auxiliary engines typical on this type of ferries. The estimated energy use and emissions will therefore form a lower limit, considering these omissions.

The Sutranet model does not include pre-chain energy use and emissions related to the extraction, processing, conversion and distribution of energy products. This is included in the calculations based on an average efficiency factor of marine diesel oil of 79% reported in (Knörr, 2008). Primary emission factors for HGVs are based on average figures for hilly countries in Europe for vehicles with Euro 5 engines reported in *op.cit*. Euro 5 engines was implemented in 2008, and will soon be representative for the relatively new fleet of long-haul vehicles in Western Europe (average age is reported to be 4 years in Sandvik (2005)).

OUTPUT FROM THE CASE-STUDY – ENERGY USE AND EMISSIONS FROM MULTIMODAL TRANSPORT CHAINS

Based on the empirical evidence and assumptions made above, we have calculated energy use and emissions related to these four different cases of alternative transport chains from Trondheim to Paris. Alternative 2 is almost a pure Ro-Pax service with a small connecting road trip from Zeebrügge to Paris. This alternative is the shortest path and should therefore have a comparative advantage against the longest alternative – the pure road connection (Alternative 3) which is 30% longer. Even with this advantage it seems that the sea-based transport chains will have a very hard time competing with pure road transport when it comes to energy consumption and emissions to air. Figure 2 illustrates calculated energy use for these four alternative transport chains per metric ton cargo. The difference between Alternative 2 (mainly sea) and Alternative 3 (pure road) is quite significant. The sea transport alternative has an average energy consumption of 1134 kWh per ton cargo, whereas the pure road alternative needs 686 kWh. Alternative 2 thus has an energy consumption that exceeds the pure road alternative by 65% when calculated by the ton cargo transported. Alternatives 1 and 4 are mixed road / sea alternatives – and therefore fall in between the performance of alternative 2 and 3.

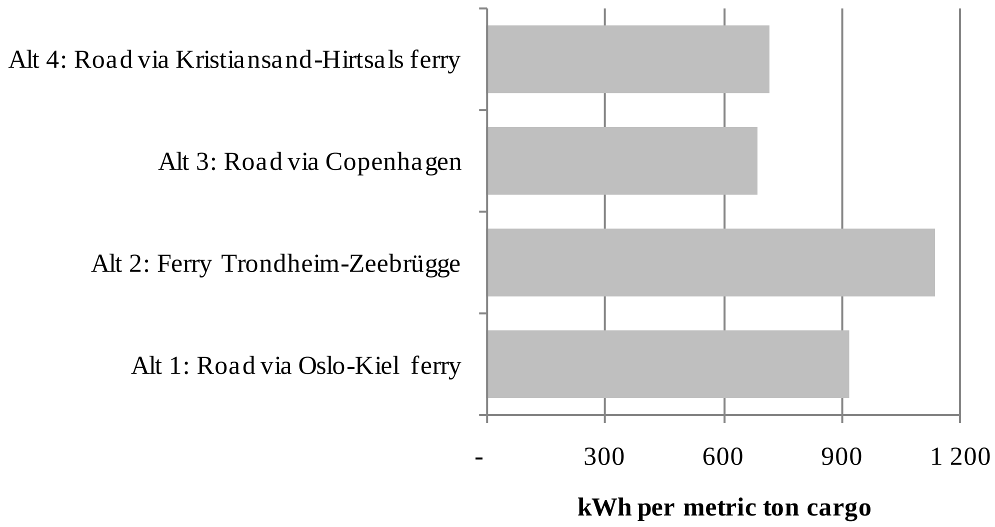

Figure 2: Energy use per ton cargo transported between Trondheim and Paris

When calculating energy use per cargo tonkm this picture becomes even more accentuated, as the comparative distance advantage of the maritime legs moderated the differences in Figure 2. The energy use per tonkm is 0.28 kWh for the pure road alternative (Alternative 3) and 0,60 for the Trondheim-Zeebrügge route. The comparative energy efficiency of road vs. Ro-Ro transport is thus very prominent.

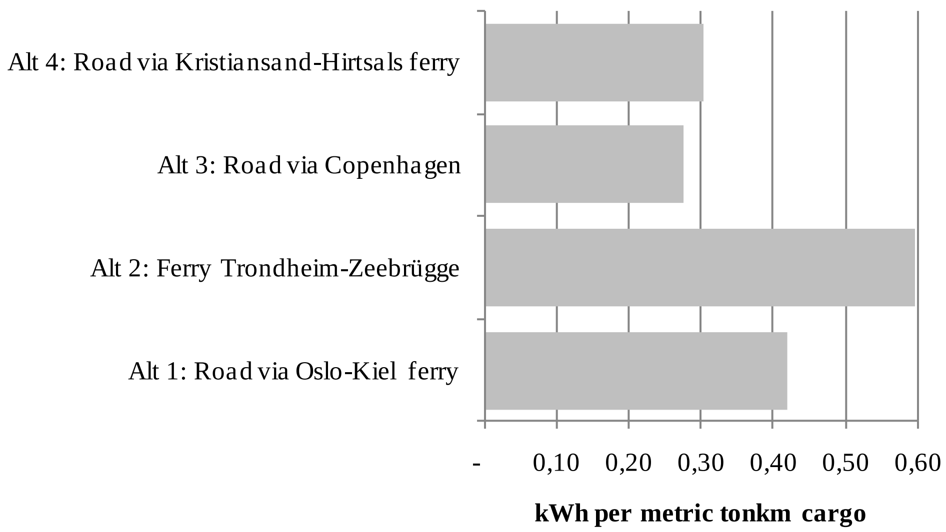

Figure 3: Transport chain average energy use per cargo-tonkm

CO2-emissions for these four alternative transport chains will to a large extent follow the energy consumption figures presented, somewhat dependent on fuel types applied. If the

Ro-Ro ferries use heavy fuel oil, this will mean 5-6% higher CO2-emissions per energy unit for the maritime transport legs compared to the autodiesel-based mode.

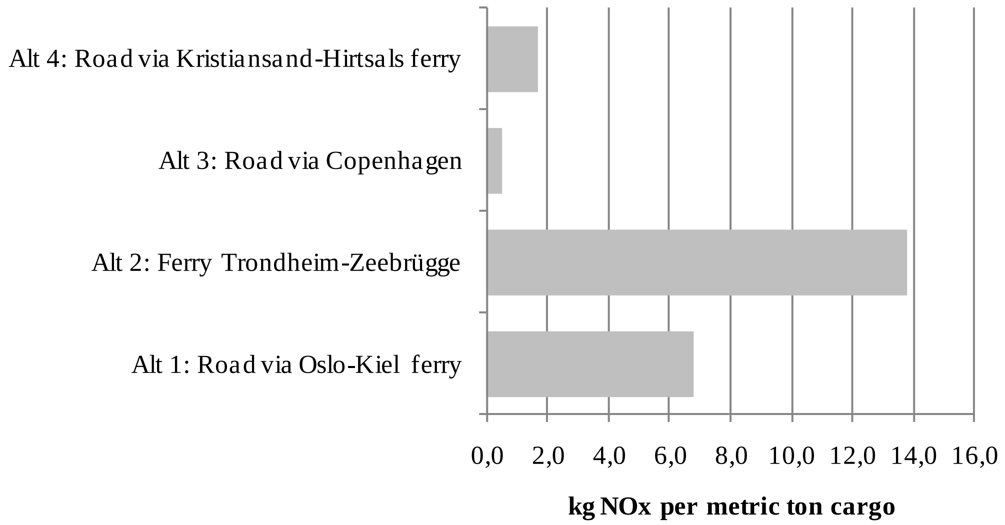

Figure 4: NOx-emissions per ton cargo

Based on the Sutranet NOx-emission factors for the vessels, assuming no abatement technology is applied, is presented in Figure 4. If abatement technologies are in operation, this will reduce NOx-emissions on the maritime legs by 60-95% (Sjödin, Henningsson et al. 2007). Even with the most efficient NOx-reducing technology, the vessels will not fall below the road-based alternative. Without such technology in operation NOx-emissions from the ferries are in the area of 30 times that of the trucks with Euro 5 engines.

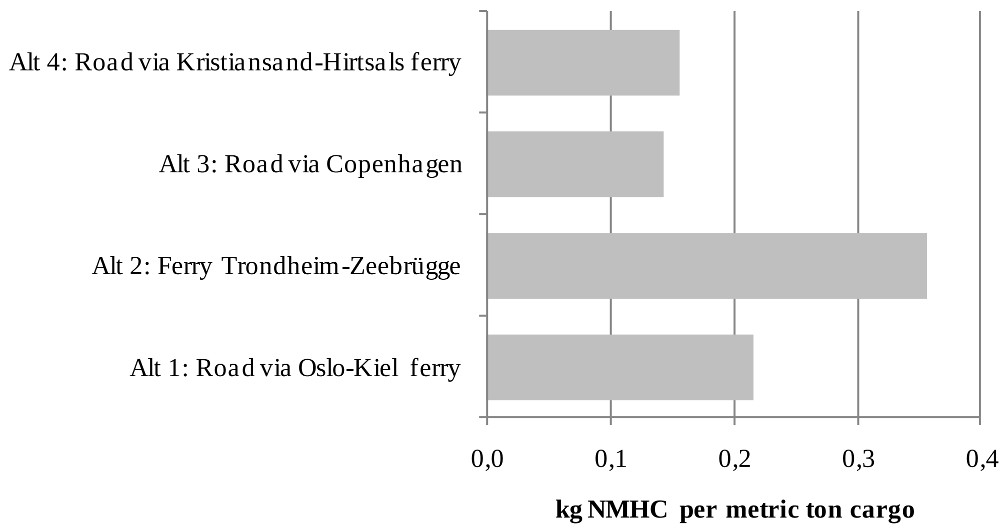

Figure 5: NMHC emissions per ton cargo

Non-Methane Hydrocarbon (NMHC) emissions (Figure 5) are also higher for maritime transport than for trucks with modern engines. However, vessels with SCR[3]-technology installed may reduce these emissions by 50-80% (Sjödin, Henningsson et al. 2007), which could make such emissions from Ro-Ro vessels fall below the level of modern Euro 5 trucks.

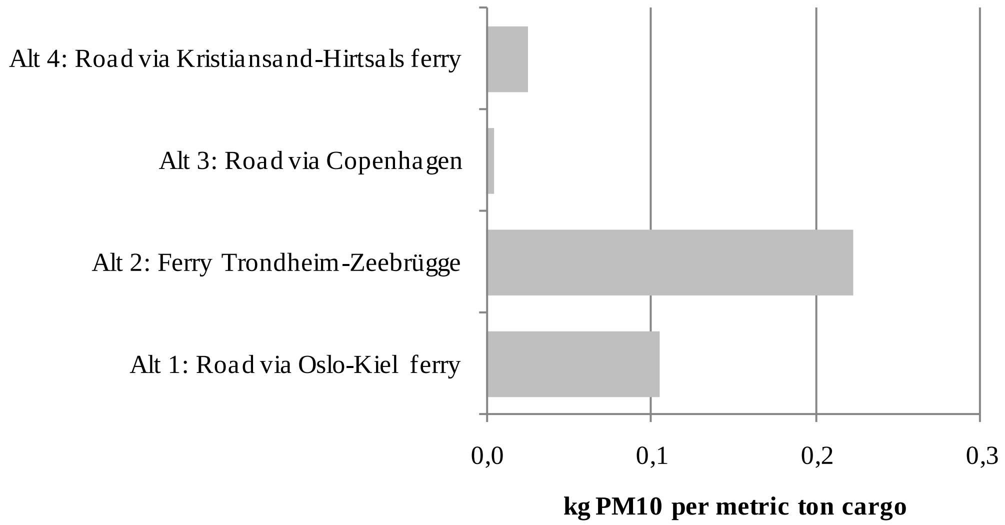

Figure 6: Particle (PM10) emissions per ton cargo

Without abatement technologies, particle emissions from Ro-Ro vessels are extremely high compared to modern trucks. Scrubber technologies may have a potential of reducing these emissions by as much as 80%.

[3] SCR - Selective Catalytic Reduction

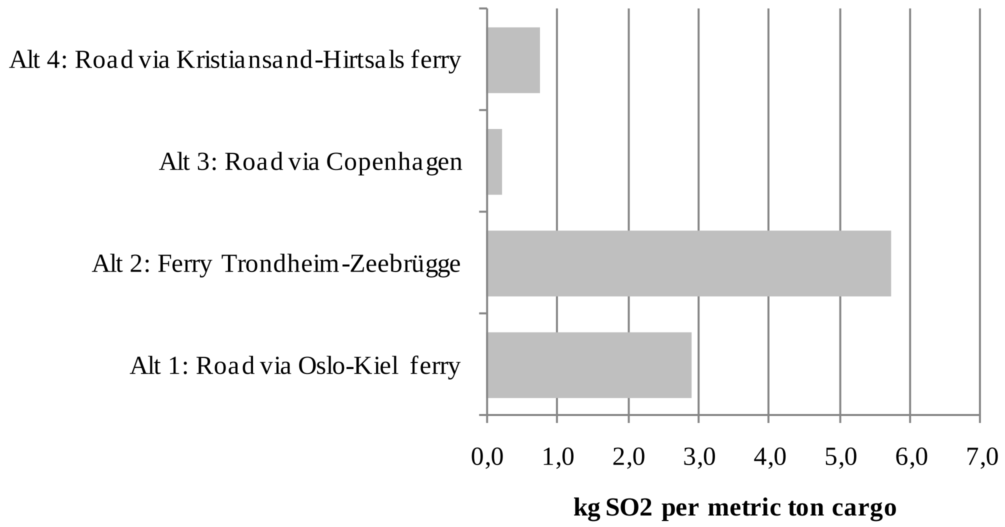

Figure 7: Sulphur (SO2) emissions per ton cargo

Sulphur emissions from vessels depend heavily on the sulphur content of the fuel applied. In our case study we have assumed a sulphur-content of 1.5%, equivalent to the current (2010) limit for North-Sea operations. Even with the relatively ambitious reductions of the sulphur content inherent in the plans for the ECAs under the Marpol annex VI convention, sulphur emissions from shipping will still exceed that of HGVs.

Our case-study illustrates that Ro-Ro shipping is quite far from being the obvious choice based on environmental performance. Even in cases like these where the shipping routes are the shortest path between origin and destination, it is hard to make the case for moving cargo from trucks to Ro-Ro shipping services, purely based on environmental aspects. To some extent this is due to the inherent nature of Ro-Ro shipping, but the situation for Ro-Ro shipping's comparative environmental performance has also changed for the worse over the last decades. This can be attributed to the very different policy environments that Ro-Ro shipping and the trucking industry faces.

THE ENVIRONMENTAL POLICY REGIMES FOR RO-RO SHIPPING VS. THE ROAD HAULAGE INDUSTRY

The road haulage industry will have to relate very closely to national and regional government regulations related to emissions from their vehicles. The shipping industry is, on the other hand, mainly governed by global agreements under International Maritime Organization (IMO), which are subsequently implemented in the national legislation of the flag states. These regimes are very different when it comes to the scope for enforcement. It is generally much easier to evade regulations in maritime transport than in land-based modes where the national control regimes are more efficient.

Having a new regulation adopted through the IMO-system can be a very lengthy process (Mitropoulos, 2007), because it builds on a modified consensus principle that requires a substantial number of underwriters to come into effect. To achieve the necessary consensus the regulations also often turn out to be relatively unambitious.

Over the past 20 years, the road haulage industry has been subjected to a long range of stricter emission standards in Europe. The so-called Euro-standards for heavy vehicle engines have effectively reduced the per unit environmental hazards from the trucking industry significantly (Figure 8).

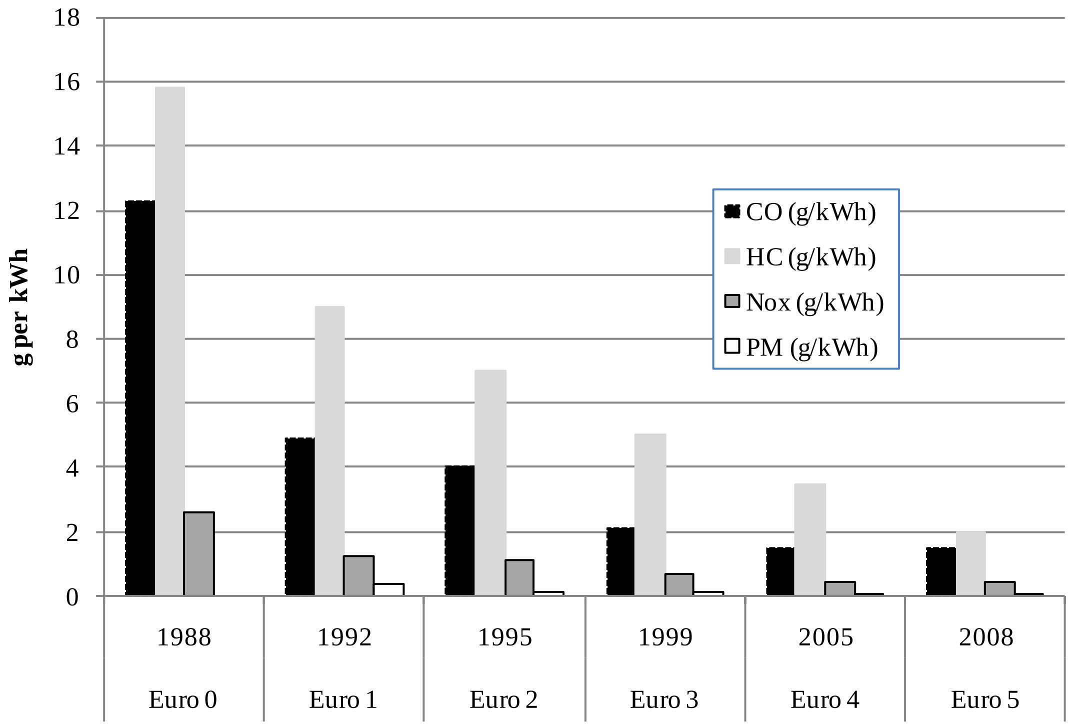

Figure 8: The environmental performance of European HGV engine standards

Other policy elements, e.g. related to road user charges that are differentiated by the environmental performance of the HGV (like the German HGV road tax), have contributed to a generally greener road haulage sector. In Figure 8 the changes in emission standards in the 20-year period from 1988 to 2008 is illustrated. The most significant impacts came with the early standards that were established in 1992, but there has been a continuous improvement since then, resulting in very low emission levels for new vehicles.

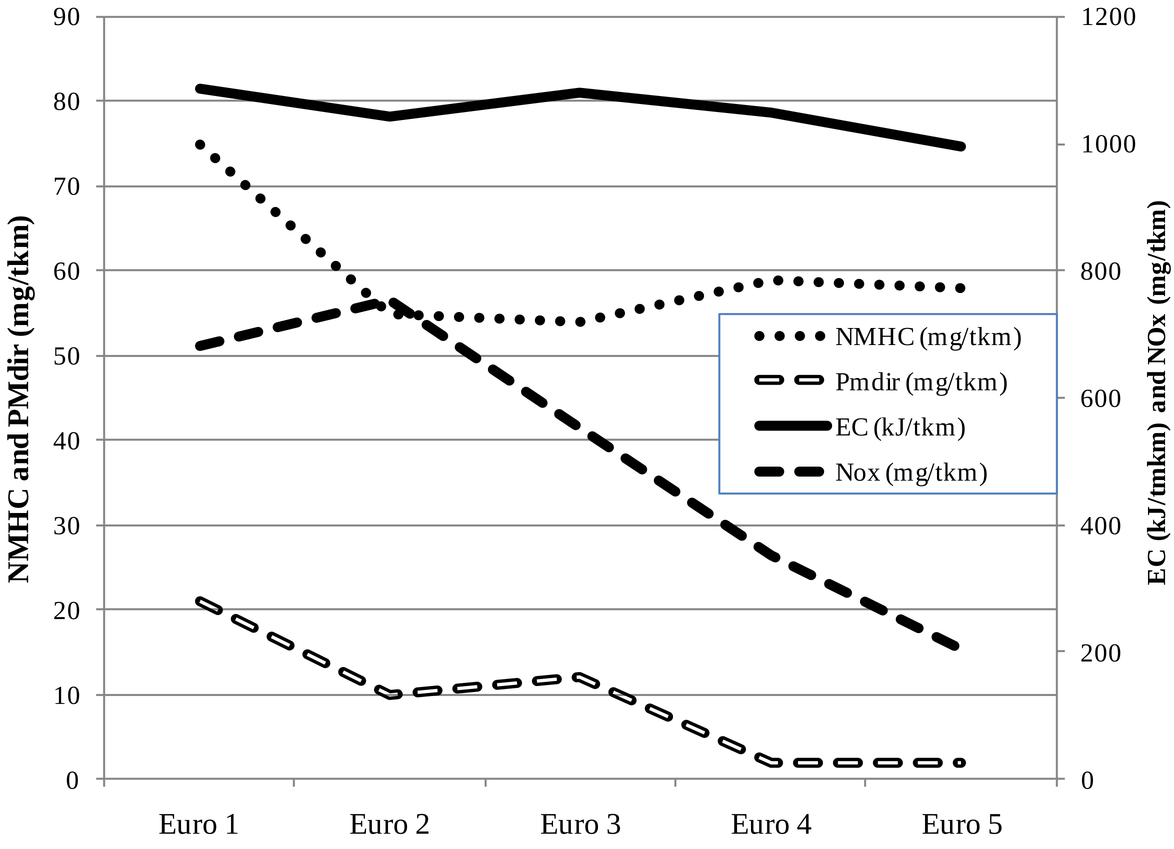

Figure 9: Emissions to air from European HGV engine standards, including prechain emissions
Based on Knörr (2008)

In Figure 9 the development in energy consumption and CO2-emissions per tonkilometre is added to the picture, as are prechain emissions from producing and distributing fuel. Over these years there has also been some gain in HGV fuel efficiency calculated per tonkilometre, but this improvement is not very significant compared to the achievements related to other emissions to air.

The international regulatory regime for maritime transport has not put the same momentum on the technical development of vessels and their engines and exhaust systems. Over the last years we have seen the first international regulations with respect to fuel quality and emissions to air, but these have not been very ambitious so far.

Still, the IMO has put emissions from shipping on the international agenda for many years through the development of the International Convention for the Prevention of Pollution From Ships (MARPOL). Over the last years Annex VI to this convention has been developed, ratified and entered into force, setting a cap on the sulphur content of marine fuels, 4.5% globally and 1.5% in Sulphur Emission Control Areas (SECAs), now Emissions Control Areas (ECAs). There are no direct regulations of NOx emissions, but these are treated through reference to a NOx technical code which sets standards for NOx-emissions for different generations of machinery. A so-called “Tier II-engine” which is mandatory on ships built after 2010 will have a maximum NOx-emission of 14.4 g/kWh. Some countries have added extra NOx-reducing measures like a NOx-tax (Norway) and NOx-differentiated port and fairway dues (Sweden).

A global cap of 4.5% sulphur content of fuels is not very ambitious, since the average sulphur content of marine fuels is estimated at 2.6% (2006) as monitored by the IMO. However, The Marine Environment Protection Committee (MEPC) of IMO has decided on a gradual reduction of the sulphur content in bunker fuel. The general limit of 4.5% will be reduced to 3.5% and in the emission control areas (ECAs), the limit will be 1.0% from July 2010 and 0.1% from January 1 2015. The Baltic Sea, the North Sea and the English Channel are ECAs with a current limit of 1.5%. In 2010 the North American coast is also included as an ECA. Stricter NOx limits will also apply to the so-called “Tier III-engines” for ships constructed after 2015 (3.4 g/kWh) when operating in an Emissions Control Area.

The slow moving international regulatory regime for shipping has meant that the shipping sector has been more or less left to market forces which may also be efficient regulators of fuel consumption and environmental performance, but not necessarily so. Endresen, Sørgård et al. (2007) presents a very interesting reconstruction of the past century when it comes to bunkers consumption and emissions from the world ocean-going fleet. From figures presented in this study we may calculate the development in fuel efficiency and emissions from 1970 to 2000. This is presented in Figure 10. Obviously the major gain in fuel efficiency took place in the 1970s, partly resulting from the OPEC1 (1973) and OPEC2 (1979) oil price shocks which had a very severe effect on the oil tanker market and the world economy as a whole. These figures are not directly comparable to developments in the HGV sector presented above, as there may be other explanations than technological improvements that contribute to the development in shipping fuel efficiency figures, notably the average speed of the fleet which usually goes down when rates are low. Endresen et al. (2007) has also calculated historical figures for the average speed of the fleet, and there seems to have been only a marginal increase in average speed from 13.9 to 14.4 knots since 1970. The severe drop in international trade levels lately may very well have brought this average figure back to the 1970s level.

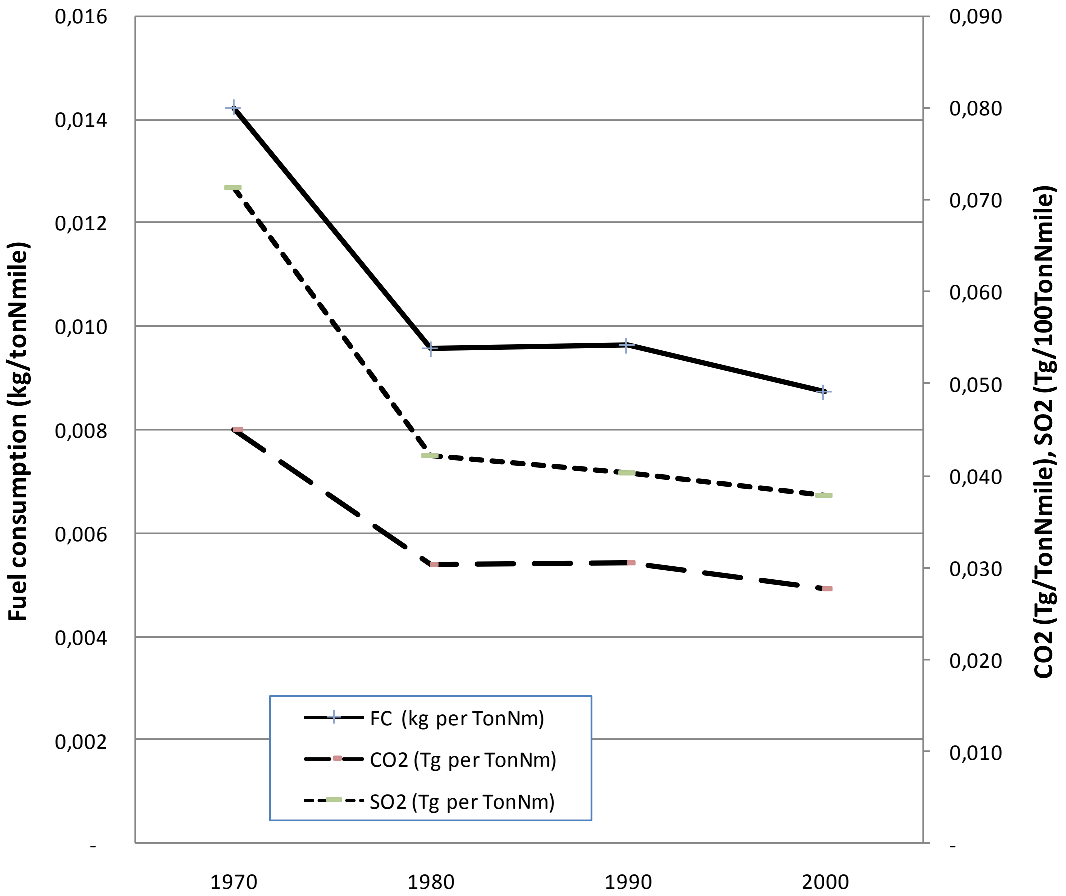

Figure 10: Fuel efficiency and emissions from international shipping 1970-2000.
Based on figures from Endresen et al. (2007)

Another important factor is the increasing average ship size. This development has also been driven by substantial economies of ship size with respect to fuel consumption per deadweight ton, and the resulting development of hub-and-spoke networks which are designed to consolidate large cargo volumes on the trunk routes. However, judging from the data compiled by Endresen et al. (2007), the potential gains in fuel economy per ton transported may have been partly offset by a drop in tons transported per fleet ton. Another possible explanation mentioned by Corbett et al. (2007) is the fact that the average installed power of vessels also has increased over this period.

The average age of long-range HGVs in Europe is probably 4-5 years (Sandvik, 2005). In 2010, the average long distance truck would therefore meet Euro IV-standards, and soon Euro V. Unit emissions from the road haulage industry is therefore significantly lower than it was 20 years ago. Comparatively, the average age of short sea vessels calling at European ports would probably be 12-15 years, referring to an assumed economic life of 25 years and a corresponding renewal rate of 4% (Proost et al., 2006), and an average age of all active Ro-Ro vessels of 18.7 years (Lloyd's Register, 2008). Even though there are few effective regulations bringing the engine technology forward, the economic rationale for having more fuel efficient engines and ship designs means that a newly built vessel performs significantly better than a 15 year old one. The longevity of the vessels effectively means that shipping is lagging further behind the road haulage industry because of the low penetration rate of new technology.

THE ENERGY EFFICIENCY OF BULK AND RO-RO SHIPPING VS ROAD TRANSPORT

The misconception that maritime transport always is environmentally superior may stem from the widespread use of emissions per deadweight tonnage, calculated for bulk vessels. Such figures are not very relevant when comparing Ro-Ro transport solutions to truck-based alternatives. There are three reasons why this turns out to be wrong. Firstly, the cargo carrying capacity of a bulk vessel is much higher relative to the size and weight of the vessel, than for a Ro-Ro or Ro-Pax vessel. Secondly, the typical cargo utilization rate will also be different for these two types of vessels. Finally, the typical operating speed of a bulk cargo ship is much lower than that of a typical Ro-Ro or Ro-Pax operation. The former would typically have an operating speed of 12-14 knots, whereas the Ro-Pax ferries used for illustration in this article will have an operating speed of 22 to 27 knots.

To illustrate how these moderating factors affect the comparative environmental performances, we have compared the energy consumption per cargo-tonkm of maritime transport alternatives to the truck transport alternative in Figure 8. For all these examples we have allocated 50% of the energy-use of the Ro-Pax vessel to cargo transport.

The energy use of a slow steam (14 knot) Ro-Ro vessel if one could load it like a bulk vessel (i.e. with cargo tonnage equal to the deadweight tonnage) is 0,05 kWh per tonkm, which is one fifth of the “benchmark” energy efficiency of a truck with an average load factor of 58% (0,27 kWh/tonkm). Increasing the speed to 21 knots effectively doubles the energy use – which then becomes 0,11 kWh per tonkm.

The actual cargo-carrying capacity of a Ro-Ro or Ro-Pax vessel could be calculated by the cargo-carrying capacity of the maximum number of truck/trailer combinations that it could accommodate. This also halves the cargo carrying capacity compared to the deadweight tonnage of the vessel. Operating at slow steam (14 knots) – and considering the actual Ro-Ro cargo capacity, yields an energy efficiency of 0,11 kWh per tonkm. Increasing the speed to normal operational speed (21 knots), makes the energy efficiency drop to 0,22 kWh per tonkm – approaching the “benchmark” HGV performance, but still lower. This far, the Ro-Pax figures are based on a 100% cargo utilization rate (load factor).

This is where the “double load factor problem” of Ro-Ro shipping enters the picture. Not only will we have to adjust for the fact that only a fraction of the available lanemetres will be utilized under normal operations, adding to that we also must consider the fact that the trailers themselves are not fully loaded. Indeed, they will quite often return empty. This double load factor problem means that if the decks are half full and the trucks are half full on average – then the relevant load factor for Ro-Ro shipping is 25%. In our cases we have assumed a load factor of the available lanemetres of 70% and a 58% load factor of long distance trailers. The combined load-factor for the Ro-Ro vessel is then 41%. A slow-steaming (14 knot) Ro-Ro vessel will then yield 0,28 kWh per tonkm, comparable to the HGVs performance. Operated at typical speed the vessel's energy efficiency turns out to be in the area of 0,55 kWh, which is 104% higher than that of the HGV combination under typical operating conditions.

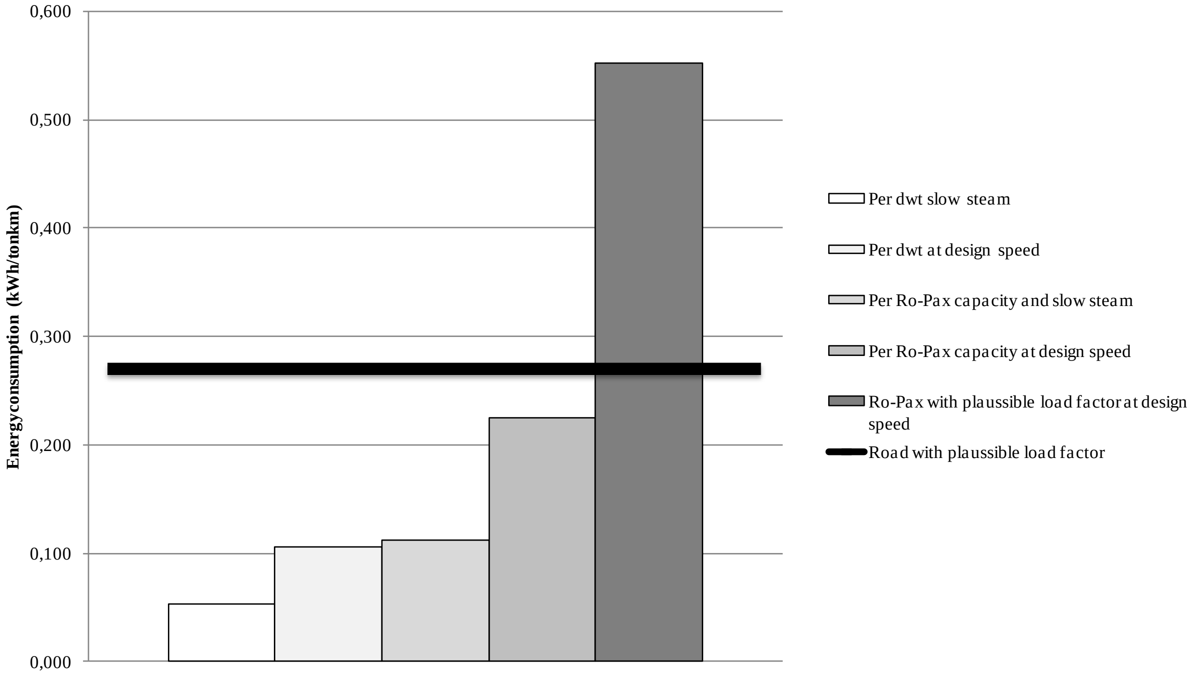

Figure 8: Energy use per tonkm for Ro-Pax vessel vs. Road Transport

Figure 8 illustrates that one would have to assume quite favourable operating conditions for the Ro-Pax vessel to make it compete with the energy consumption per tonkm of a HGV. The most effective measure would be to reduce the operating speed. Better cargo utilization would also be helpful, but is not always possible.

CONCLUDING REMARKS

Through a set of case studies and a review of the different policy environments of Ro-Ro shipping and the trucking industry, we have demonstrated that Ro-Ro transport, under typical conditions, probably is not an attractive alternative to road freight transport from an energy use and emissions perspective. We have also illustrated that although sea transport could be much more energy efficient than road transport, this comparative advantage could be severely reduced, and even disappear, due to the lower cargo carrying capacity of Ro-Ro vessels compared to bulk vessels, the lower actual load factor and the higher speed of such services compared to typical bulk operations.

Such a comparative analysis will inevitably rely upon a number of assumptions – and to some extent the results of this analysis could be affected by alternative assumed vessel speeds, installed abatement technologies on ships and different load factors. For further illustration of the effect of such factors, see the sensitivity analysis conducted in Hjelle (2010). However, according to our analysis, even if the vessels switch to low sulphur fuel and install the latest abatement technologies – the comparative picture will not change, unless the Ro-Ro vessels are operated well below their design speeds. To some extent higher Ro-Ro load-factors could help, but operators will have to run a very efficient service to exceed the postulated 70% load factor as a roundtrip average.

European transport policies include schemes for the promotion of short sea shipping vs. road transport. In the light of the analysis presented above, one could raise the question weather this policy is justifiable. However, before such a conclusion is drawn one will have to consider factors like the differences in impacts from emissions at sea vs. emissions in the proximity of residential areas. Other externalities related to road freight transport (accidents, congestion) should also be considered. These elements all tend to go in favour of the maritime transport alternatives, so it may still be possible to make the case for promoting efficient Ro-Ro services, albeit not with a pure environmental rationale.

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