



Report 0513

*Edvard Thonstad Sandvik*

# **Environmental impacts of intermodal freight transport**



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*ENVIRONMENTAL IMPACTS OF INTERMODAL FREIGHT TRANSPORT*

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#### Summary:

This study is an input to the Northern Maritime Corridor on the environmental issues of establishing two new short sea cargo routes: 1) between Mid - Norway and Rosyth and 2) between Kristiansand and Eemshaven. The objective of this study is to compare different cargo routes with different means of transport, and different technologies (different speeds). Environmental impacts that are included in this study are divided into two parts: 1) energy consumption measured in KW/h and 2) emissions to air that is a direct result of the energy consumption. The emissions to air that are included are carbon dioxide (CO<sub>2</sub>) emissions, carbon monoxide (CO), nitrogen oxides (NO<sub>x</sub>) emissions, sulphur (SO<sub>2</sub>) emissions and particles (PM).

The planned fast conventional ferry service (23 knots) between Mid – Norway and Rosyth have higher emissions as compared to other means of transport. The planned fast conventional ferry service (28 knots) between Kristiansand and Eemshaven will also have relatively high emissions.

If this service is running at 18 knots instead it will have less emission than the base case (transport via Oslo Kiel). This is both with Norwegian and Danish electricity mix (including coal-generated power etc.). If the Mid – Norway and Rosyth services were running at a at a speed of 18 knots instead of 23/29knots, the differences between the different routes are significantly reduced, and the differences between the routes that goes via Rosyth and the base case becomes so small that it is not significant.

New and strict emission targets for road transport were put into place last year and even stricter targets will emerge. As we see in this report, emissions from the fast conventional RoRo fleet today cannot compete with emissions from road in the multi modal transport chains that we have investigated. New regulations for shipping for sulphur content in fuel and NO<sub>x</sub> emissions will reduce the future shipping emissions. We believe that the new regulations for the shipping industry will have an impact but not in the short run, due to much higher average age in the RoRo fleet than in the long distance HGV fleet.

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## Preface

Northern Maritime Corridor has commissioned Molde Research Institute to analyse environmental impacts of the planned Norway – Benelux ferry (Kristiansand -Eemshaven) service and the planned MINORO Ferry (Kristiansund- Rosyth) service. The main objects of interest were to investigate whole intermodal freight transport chains with respect to emissions to air impacts, to find the possible changes by changing the transport routes to longer sea legs. Another object of interest was to investigate the environmental effects of using fast conventional vessels (23-29 knots) compared to conventional vessels (16-18 knots) and to road transport.

Project leader for this research has been Research Economist Edvard Thonstad Sandvik. Contact person for Northern Maritime Corridor has been Roar Lervik. The report is written by Edvard Thonstad Sandvik. Chief Research Officer Svein Bråthen has been responsible for the internal quality control. We would like to thank Nor-Cargo Thermo, Attica Group, MARINTEK, Color Line, Fast Lane Cargo and The Norwegian Shipowners Association for data, information and advice.

Molde, November, 2005



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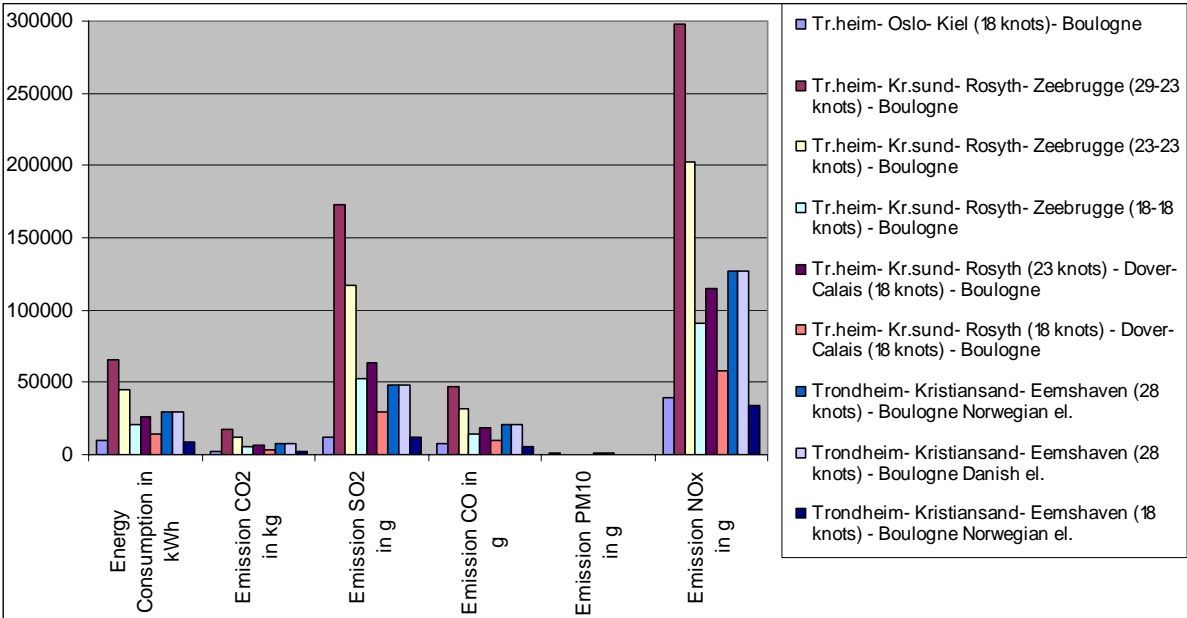
# Abstract

This study is an input to the NMC on the environmental issues of establishing two new short sea cargo routes: 1) between Mid - Norway and Rosyth and 2) between Kristiansand and Eemshaven. The objective of this study is to compare different multi modal cargo routes with different means of transport, and different technologies (different speeds).

Environmental impacts that are included in this study are divided into two parts: 1) energy consumption measured in KW/h and 2) emissions to air that is a direct result of the energy consumption. The emissions to air that are included are carbon dioxide (CO2) emissions, carbon monoxide (CO), nitrogen oxides (NOx) emissions, sulphur (SO2) emissions and particles (PM).

As we see clearly see in the table below, the planned fast conventional ferry service (23 knots) between Mid – Norway and Rosyth have higher emissions compared to other means of transport. The planned fast conventional ferry service (28 knots) Kristiansand and Eemshaven have relatively high emissions. If this service is running at 18 knots in stead it will have less emission than the base case (transport via Oslo Kiel). This is both with Norwegian and Danish electricity mix (including coal power etc.). If the Mid – Norway and Rosyth services were running at a at a speed of 18 knots instead of 23/29knots, the differences between the different routes are significantly reduced, and the differences between the routes that goes via Rosyth and the base case becomes so small that it is not significant. There is reason to conclude that the main factor affecting the emission levels are the choice of service speed for sea freight in the multi modal transport chains investigated.

**Figure 1 Energy consumption and emissions from all the alternatives from Trondheim to Boulogne (incl. production and transportation of fuel) per HGV**



New and strict emission targets for road transport were put into place last year and even stricter targets are coming. The relatively new HGV fleet has relatively low emissions and they are decreasing (per ton km). As we see in this report, emissions from today’s RoRo fleet cannot compete with emissions from road in those multi modal transport chains that have been subjected to research here. Emissions from shipping are regulated through the Marpol

convention and EU regulations. New regulation for shipping for sulphur content in fuel and NOx emissions will reduce the future shipping emissions. We believe that stricter regulations on NOx emissions and Sulphur content is needed for the short sea shipping to compete with rail and road on SO2 and NOx emissions.

The new regulations for the shipping industry may reduce emissions in the longer run. The average age of the Ropax and RoRo fleet is 3-5 times larger than the average age for the long distance HGV fleet in Norway. Another factor that also counts in disfavour of the short sea shipping, with respect to the environment, is the increased speed. As shown in this report the increased speed will in turn result in substantial increases in the energy consumption and the emissions.

# 1 Objectives

The main objective of this report is to find the environmental impacts of two new ferry services Kristiansund-Rosyth and Kristiansand-Eemshaven. The objective is to compare different multi modal cargo routes with different means of transport, and different technologies (different speeds) with respect to emissions and marginal external cost.

We have compared the environmental performance and marginal external costs of alternative transport chains between Trondheim and Boulogne-sur-Mer. We have done the same comparison with the different multi modal routes extended to Bodø. The comparison is based on emissions calculated in kg and g, energy consumption in kWh and marginal external costs in Euro.

We have in this report used the term “fast conventional ferries” for vessels running at 23-29 knots, because they are in the upper bound of the conventional ferry speed interval, and to distinguish between the vessels running at 18 knots and 23-29 knots.

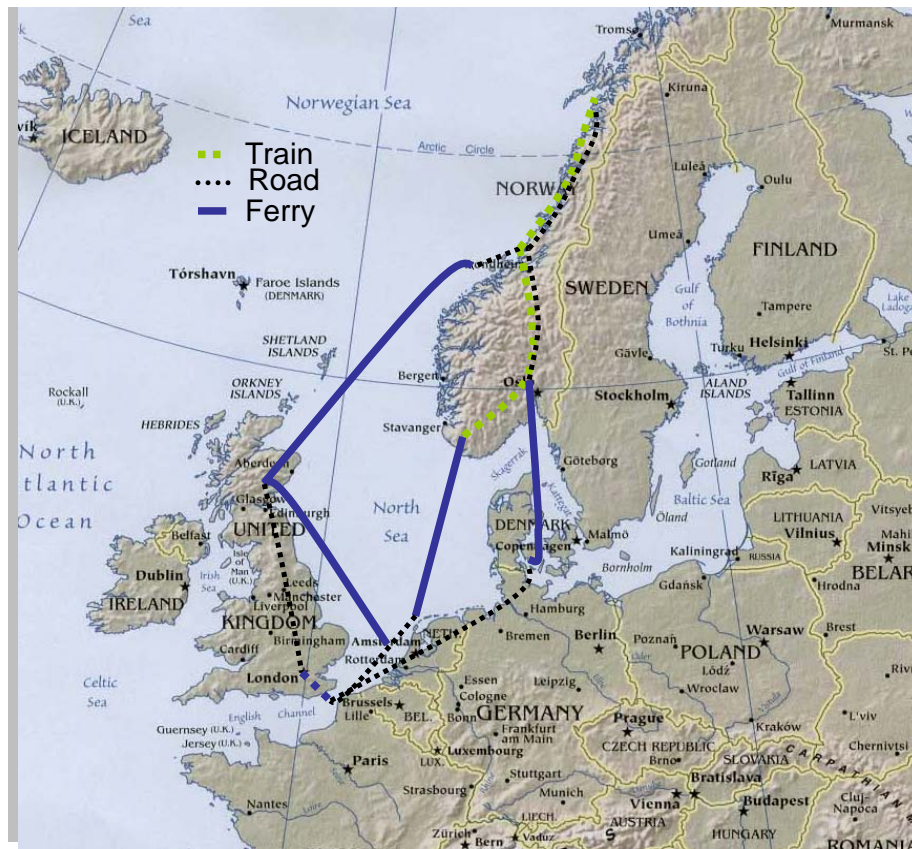
## 2 System boundaries

Transportation has various impacts on the environment. The following categories may be used: Greenhouse effect, depletion of the ozone layer, acidification, eutrophication, resource consumption, land use, eco- and human toxicity and noise. Transportation of cargo has impacts within all these categories. We have limited the selection of environmental values to a few parameters. The categories land use, noise, safety emissions to the sea (sludge, TBT and waste from cargo vessels) and nuclear risk were not taken into consideration. The selection was done according to the following criteria:

- Particular relevance of the impact
- Proportional significance of cargo transports compared to overall impacts
- Data availability
- Methodological suitability for a quantitative comparison of freight transport.

In this type of studies, the elicitation of energy consumption in construction and maintenance of infrastructure, production and maintenance of vehicles, production of petrol is possible only to a certain extent. It is desirable to at least include factors that are different for the different transport modes. We have chosen to include only those environmental impacts that are linked to the operation of vehicles and the fuel production. The production and maintenance of vehicles and the construction and maintenance of infrastructure are thus not included.

## 2.1 Descriptions of transport chains



We have chosen different transport chains to show environmental impacts of the two suggested new sea routes, Kristiansand- Eemshaven and Kristiansund – Rosyth. Hamre et al (2004) used the network split from NEMO in the computer model Cube to estimate the export routes from Norway. This shows that road based export from Mid - Norway goes to the Oslo area and then with ferries to Denmark and Germany. According to operators at Nor-Cargo, the most usual route is to use the Oslo – Kiel ferry, due to the fact that this fits very well with resting time regulations. According to what is mentioned above and the fact that the differences are small between this route and the other routes via Denmark, we have used Trondheim - Oslo - Kiel Boulogne as base case. Four routes start in Trondheim:

**Trondheim – Oslo (road) Oslo – Kiel (RoPax) Kiel - Boulogne-sur-Mer (Road)** is chosen as **the base case**. This route and other routes with more or less similar characteristics serve the road based cargo between these two regions today.

**Trondheim – Kristiansand (Rail) Kristiansand- Eemshaven (sea) Eemshaven - Boulogne-sur-Mer (road)** is chosen to show how the combination rail/sea compares with the base case.

**Trondheim – Kristiansund (Road), Kristiansund – Rosyth and Rosyth - Zeebrugge (sea) Zeebrugge - Boulogne-sur-Mer (road)**, is chosen to show the main transport alternative on the Kristiansund –Rosyth route, which is compared with the base case.

**Trondheim – Kristiansund (Road), Kristiansund – Rosyth (sea), Rosyth – Dover (road), Dover – Calais (sea) and Calais - Boulogne-sur-Mer (road)**, is chosen to show an alternative transport route through Britain, which is compared with the base case.

Two of these routes were also calculated with a starting point in Bodø (just north of the polar circle in Norway). This is done because one of the ideas behind the Kristiansund – Eemshaven project is to transfer fresh fish transport from northern Norway from road to rail and sea.

**Bodø – Oslo (road) Oslo – Kiel (RoPax) Kiel - Boulogne-sur-Mer (Road)** is chosen as the **base case**. This route and other routes with more or less similar characteristics serve the road based cargo between these two regions today

**Bodø – Kristiansand (Rail) Kristiansand- Eemshaven (sea) Eemshaven - Boulogne-sur-Mer (road)** is chosen to show how the combination rail/sea compares with the base case.

## **2.2 Functional unit**

The functional unit is the unit that decides the size of the energy consumption and pollution and marginal external costs from the system studied. All the results are related to this unit. It is of major importance that the functional unit is defined in a way that provides an equal basis for the comparison for all the transport chains. In studies of intermodal freight transport it is important that the functional unit reflects the main idea of the transport, which is to send something from A to B, regardless of the distance of the different transport chains.

This study has two main origins, Bodø and Trondheim, which will be handled separately. We have therefore ended up with two functional units; 1 average loaded (see chapter 3.1.1 and 3.1.2) HGV transported between Trondheim and Boulogne-sur-Mer with a HGV. We have done the same comparisons with the different routes extended from Trondheim to Bodø. This means that all marginal external costs emissions and energy consumptions are compared per average loaded HGV transported between these places. An alternative approach could have been to use ton/km. Ton/km would have favoured the shortest routes and not answered the main question of this study: how large the total emissions for the different routes are.



## 3 Descriptions of transport modes

### Load factor of the ships, HGVs and trains

The load factors of the different transport modes are vital for the environmental and marginal cost of the different transport modes. New technology, hub and spoke systems, and the deregulation of the transport markets have in the last decades increased the load factors on all the transport modes. How this will develop in the future depends on energy/emission costs, labour costs and future regulations of the transport market and the development of just in time production (Lea, 1998).

One factor that makes the questions around load factors easier is the fact that in almost all of the alternatives the idea is to transport trailer wagons by rail or sea. This is the case for the road and the RoPax and the RoRo services and also for the most of the rail transport within the Norway-Benelux project. The important load factors for this project are then 1) the load factors in the HGVs, 2) empty lane meters on deck for the sea legs, and 3) total number of empty railway-wagons for the rail legs.

### 3.1 Road

#### 3.1.1 Descriptions of the road transport characteristics

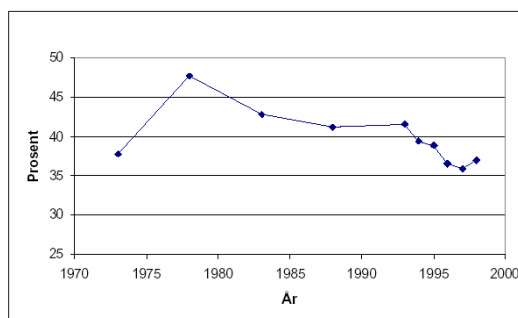
The following aspects are of significant importance for the energy consumption and the emissions from road transport:

- vehicle size and weight, vehicle type, engine power
- load factor
- driving pattern
- road characteristics such as vertical and horizontal gradients, lane width and the number of lanes.

The calculations are done with international long distance HGVs with a gross weight of 40 tons and with a load capacity of 22 ton.

#### 3.1.2 Load factor

Figure 1 Driving with empty Lorries in Norway, 1973 -98



Source: Lea (1998)

Until first quarter 1998

According to Lea (1998) around 32% of all HGV kms in Norway in 1994 were driving empty HGVs. The load factors on the HGVs over 13 tons and in 1993-1995 that had cargo on board was 72.4 % according to Holtskog and Rypdal (1998). This generates an average load factor of 49 % of their total weight capacity for the HGVs on the roads. However, we must keep in mind that some of the goods for example: flowers and vegetables do not fill up to the weight limit, but may use all the space.

According to Broken et al (2003), the average load factor in long distance road transport with HGVs was 50 % in 2001. These values also include empty vehicle-km. The share of additional empty vehicle-km in road traffic was about 17 %, and we have therefore used 50% for this report.

### 3.1.3 Emissions

Over the next years the emissions of NO<sub>x</sub>, CO, and PM<sub>10</sub> for road freight will be reduced as a result of the new Euro III, Euro IV and Euro V standards. In this study, we have chosen to take a snapshot of the average emission situation today. We contacted different operators in the Norwegian import and export market to find the average age of the fleet that are used in these kinds of operations. The average vehicle age that the operators have reported is lower than the average age used in the statistics (OFV 2005). This is because the newest vehicles are used on the longest distances. The operators unanimously stated that the average age for HGV for import and export to Norway is approximately 4 years. Nor-Cargo has an average age of 1.5 years for their long distance fleet.

The table below shows former, existing and future exhausts gas requirements for heavy vehicles engines categorized by Euro I, II, III etc. With an average age of 4 years we can assume that the average vehicle on the particular routes satisfies Euro III standard.

**Figure 2 the Euro classes with when they comes into force and their emission requirements**

Level of aspiration	Comes into force	NO <sub>x</sub> (g/kWh)	Particles (g/kWh)
Euro II	1996	7,0	0,15
Euro III	2000	5,0	0,10
Euro IV	2005	3,5	0,02
Euro V	2008	2,0	0,02

The emission factors for the different Euro classes are shown in Figure 3 for HGV transport with HGV > 34-40 t on motorways with an average gradient for hilly countryside (Broken et al 2003).

**Figure 3 Total emissions factors (operation & prechain) for HGV transport (HGV >34-40 t, motorway, average gradient for hilly countries)**

Emission standard	EC (kWh/t/km)	CO <sub>2</sub> (g/t/km)	NO <sub>x</sub> (mg/t/km)	NMHC (mg/t/km)	Pm (mg/t/km)
<b>Euro 1 (1993)</b>	0,269	72	673	59	21
<b>Euro 2 (1996)</b>	0,258	69	746	39	10
<b>Euro 3 (2000)</b>	0,268	71	542	38	12
<b>Euro 4 (2005)</b>	0,260	69	343	44	2

Source: Handbook of Emission Factors (INFRAS 2004), IFEU estimations Heidelberg 2005

Factors for energy consumption and emissions for HGV transport in Norway (Figure 4) (Thune-Larsen et al., 1997) are for some factors as CO<sub>2</sub> quite different from the estimates done for the Euro III standard. The estimates given in Figure 4 are used because a large proportion of the road kilometres are driven in Norway.

**Figure 4 Total Energy consumption (kWh/ton km) and emissions factors (operation & prechain) for HGV transport (articulated HGV >20 t, for transport in Norway)**

Transport mode	kWh	CO <sub>2</sub> (g)	SO <sub>2</sub> (g)	NO <sub>x</sub> (g)	CO (g)	CH <sub>4</sub> (g)	NMVOG (g)	PM (g)
<b>HGV (&gt;20 ton)</b>	0,220	57	0,026	0,640	0,250	0,0010	0,080	0,045

## 3.2 Rail

### 3.2.1 Descriptions of the rail transport characteristics

Norway -Benelux is planned as a Rail/Ro-Ro route where the idea is to send trailer wagons by railroad.

### 3.2.2 Load factor

Western Norway Research institute uses a load factor of 74 % (Andersen 2001). Operators claim that this load factor is far too low for this kind of freight transport; they reported that the load factor may be as high as 85% to 90%. We have nevertheless chosen to use a load factor of 74 % in Norway, including empty trips because these data is the most reliable.

### 3.2.3 Emissions

The main energy carriers used in rail transport are diesel fuel and electricity. The emissions from the two are discussed in chapter 0

## 3.3 Sea

### 3.3.1 Descriptions of the sea transport characteristics

There are five different sea legs: Kristiansund–Rosyth, Rosyth–Zeebrugge, Oslo–Kiel, Kristiansand–Eemshaven, and Dover–Calais. On all of these the payloads and the kind of vessels that will serve this route in the future are uncertain. There are fast conventional vessels (29 knots) running Rosyth–Zeebrugge. Due to the currently high fuel prices they are running at 23.3 knots (Appendix 1). At the time of writing it was not yet decided upon

whether the same type vessel would be used for Rosyth–Kristiansund or if a more conventional vessel was to be applied.

For all the routes that use the Kristiansund–Rosyth sea leg we have calculated the impact using: 1) a fast conventional ferry service (23 knots) and 2) a conventional vessel (18 knots). For the Oslo- Kiel rout we use 18.3 knots (calculated from the time table), and for Dover-Calais 18 knots (calculated from the time table). For Kristiansand Eemshaven Fast Lane cargo informed us that they have planned the new route to use fast conventional ferry running at 28 knots. We have also calculated this with a service running at 18 knots.

### 3.3.2 Load factor

The load factor in the new ferry services is highly uncertain. Rosyth- Zeebrügge has a load factor of 70 %<sup>1</sup>. Fastlane Cargo which have planed to run Kristiansand Eemshaven service has calculated with a load factor between 65 % and 70 %. From this we have adopted a load factor of 70% for the new routes, as well as for the routes where the load factors have not been available. The Oslo-Kiel ferry route has a load factor of more than 90 %, due to the fact that they usually have 10-30 empty HGVs (without drivers) in a stand by queue at any given time<sup>2</sup>.

It is plausible that the load factor for Rosyth Zeebrugge will increase with a new ferry service Kristiansund Rosyth. Because of the uncertainty in the magnitude we have chosen not to increase the load factor on Rosyth Zeebrugge

### 3.3.3 Emission split between passengers and cargo on RoPax ships

One of the largest methodological challenges in this project is to find a robust way to split the emissions on the RoPax services between HGVs and cruise passengers. The ships are to a large extent purpose-built as cruise ships with hotel facilities, swimming pools and shopping and conference facilities. The modelling of the emissions from ferries is tricky because all vessels are quite different from each other. Different allocation methodologies: marginal contribution, weight, and space occupancy are proposed:

Marintek (Oftedal and Heimdal 1996) has investigated the proportions of vessel volume used for car decks compared to the volume used for passengers. For the MS Kronprins Haralds 46.4 % of volume is made up by a car deck. The ship-owners informed them that 60 % of the space on the car deck is occupied by heavy vehicles. The average number of heavy vehicles is 58, from which it can be inferred that each heavy vehicle is responsible for 0.48 % of the ship's total emissions. This adds up to total emissions equal to 1061 kg CO<sub>2</sub> and 22.2 kg NO<sub>x</sub> per HGV.

In the calculations by Bråthen and Foss (1997), passengers and freight are converted into transport units, such that one passenger is said to be one transport unit, one PBE (passenger vehicle unit) is said to equal three transport units (partly based on the set ticket costs for Norwegian public ferries). The capacity of the MS Kronprins Harald is 1400 persons and 700 PBE, which adds up to 3500 transport units. One HGV counts as 5 PBE or 15 transport units.

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<sup>1</sup> Fort Ports plc data

<sup>2</sup> Color line data

Based on a utilization of capacity on 70 %, Bråthen and Foss came up with a total emission of 1190 kg CO<sub>2</sub> and 25.5 kg NO<sub>x</sub> per HGV.

Color Line did not want to give fuel consumption or emission data for their new flag ship, the Color Fantasy. The Technical Director said that they had tried to find a methodology to split the emissions between cargo and passengers together with both MARINTEK and Norsk Veritas (Johansen and Fet 1999) without succeeding. In their opinion, RoPax ships for freight transport in environmental studies come out worse than they deserve because they are carrying the weight of “a hotel” on board.

Johansen and Fet defined the functional unit in a Life Cycle evaluation of M/V Color Festival as: (passenger \* km) + (car \* km) + (HGV \* km). The functional performance of Color Festival then becomes “transport of 550000 passengers, 55000 cars and 25000 HGVs, 263 km per year”. To make it a bit simpler to estimate the functional performance and to compare the results per functional unit for different transportation modes, the following average weights for passenger, cars and HGVs were assumed: One passenger equals 0,075 tons, one car equals 1 ton and one HGV equals 20 tons. The functional unit was defined as: Ton\*km per year. Johansen and Fet (1999) noted, however, that this functional unit is **not** representative if the estimated environmental impacts of Color Festival are to be compared with other transportation modes. This is because it is not the main function of the ship to transport maximum mass. This is a problem mentioned in Bråthen and Foss (1997) and others.

As we have seen, none of the methods mentioned has a general consensus on how to split the emissions from RoPax ships between passengers and HGVs. Unfortunately it is not possible to develop a new methodology within the constraints of this project that takes into account all the different aspects. We have therefore chosen to use estimations for RoRo ships emissions using OMIT (see 3.3.4) where RoPax ferries are used or are planned to be used. By using RoRo ships we will isolate the emissions from the freight. There are however probably some economies of scale by transporting passengers and freight in one ship, but this is impossible to find given the present knowledge about the split between passengers and freight on RoPax ferries.

### 3.3.4 Emissions

We used the OMIT computer program to calculate the energy consumption and the emissions for the sea legs. OMIT is a computer program that calculates environmental impact of different types of vessels. It was developed for the Danish Environmental Protection Agency in 2001 by the Institut for Transportstudier together with, among others, the Danish Trade Association of International Transport and the Institut für Energie- und Umweltforschung Heidelberg GmbH.

One of the difficulties with making a computer program to calculate emissions by vessels with different service speeds and different size is that vessels are custom-built or built in small numbers only. Knowledge about one ship’s emissions can not necessarily be generalised. To be specific about the real emissions requires emission testing or detailed knowledge about fuel consumption and information about the engine is needed.

Different general emissions models are based on the same emission tests from Lloyd’s ship register. Despite this, most of them give different emissions. The reasons for this are the numerous premises that define the consumption of fuel in the different models: the operating

conditions, different speed, cargo weight, engine type, fuel type and load factor. OMIT is also partly based on the emission tests from Lloyds, but it also allows the users to specify the most of these premises, thus producing a relatively reliable result. As mentioned, ships are often custom built or built in small series, and the energy consumption and emissions vary not only with the premises that is possible to specify in OMIT, so the results from Omit may not fully represent the actual situation.

Omit allows definitions of different basic assumptions for the RoRo ferries: Capacity (lane metres), length of truck/trailer/container, weight of cargo on truck/trailer/container, speed, specific oil consumption (ton/h), reduction technology, NO<sub>x</sub> (g/kWh), sulphur content of oil, capacity utilization and average weight per lane metre. For all the basic assumptions there are default values.

The capacity of the vessels is encumbered with uncertainty. Fast Lane has reported that they have planed to use a RoRo vessel that has 840 lane meters on Kristiansand Eemshaven. The rest of the ferry services are operating with RoPax ferries or are planed to operate with RoPax, the size of this equivalent RoRo ferries are highly uncertain. We have therefore used the same size for all the vessels. This is probably a much too small vessel for Oslo Kiel. With a larger vessel this route will have reduced the emissions from the calculations.

**Table 1 The Basic assumption we used in Omit for the different sea routes**

	Dummy variabel	Oslo Kiel	Kr.sand Eemshaven	Kr.sund Rosyth	Rosyth Zeebrugge	Dover Calais
Capacity (lanemetres):	2000	840	840	840	840	840
Length of Truck (metre):	16,5	16,5	16,5	16,5	16,5	16,5
Weight of cargo on truck (ton):	16	11	11	11	11	11
Speed (knots):	18,9	18,3	28	18	23	18
Reduction technology, NO <sub>x</sub> (g/kWh):	12	10,2	10,2	10,2	10,2	10,2
Sulphur content of oil (percentage):	1,5	1	1	1	1,5	1,5
Capacity utilization (percentage):	75	90	70	70	70	70

Color Line and Fast Lane have stated that they are using/will use fuel with less than one percent sulphur. Attica uses fuel with 1.5 % sulphur content and we assume that also Dover Calais uses fuel with 1.5 % Sulphur content.

Attica has stated (Annex 2) that they have NO<sub>x</sub> emissions at 10.1 g/kWh. We have used the basic assumption option "low NO<sub>x</sub> fuel valve - 15 % reduction with 10.2 g/kWh". We know that also Color line have some sort of NO<sub>x</sub> reduction that at least reduces the emissions with 15 %. We assume that also Fast Lane and Dover Calais have 10.2 g/kWh.

The speeds of the vessels are generated using time tables and the distances generated by Cmap. For Rosyth Zeebrugge we used the speed given by Attica that they currently run at and the normal speed of the service (Appendix 2). Capacity utilization is discussed in chapter 3.3.2. The weight of the HGV is calculated using the numbers in chapter 3.1.1 and 3.1.2

### **3.4 Energy consumption from thermo transports cooling units**

A rather large share of the total HGV transport on the routes we studied is thermo transport. The energy consumption of the cooling units on the thermo transport is different on the different routes because of the time the transport uses, and thereby the number of hours the

cooling units has to run and also what their source of electricity is. While the HGV is on the road, the electricity will be produced by the generator of the cooling units. On the rail legs the cooling units will run on battery power, which is recharged by the generator of the cooling units. On the RoRo and RoPax ships however, the thermo wagons are plugged into the onboard electricity system. The cooling unit's generator runs when the wagon is not connected to the ship's electricity supply. Energy usage and emissions to air from cooling units on the thermo transport are as follows on the road/rail and onboard the ferry, according to Oftedal and Heimdal (1996):

Average effect of cooling unit generator	21 kW
Specific fuel consumption of cooling unit generator	0.245 g pr. kWh

With a NOx factor of 0.008 kg pr kWh and with 3.2 tons CO2 per ton of fuel

NOx cooling unit generator	$21 * 0.008 =$	0.168 kg NOx pr hour
CO2 cooling unit generator	$21 * 0.245 * 3.2 =$	16.464 kg CO2 pr hour

For the hours where the cooling unit is run on electricity from the vessel's engine we have used the same calculations that Oftedal and Heimdal (1996) did for MS Kronprins Harald. We have used the same NOx factor for the electricity from the main engines that we use in the rest of the report.

Average effect main engine	16.610 kW
Specific fuel consumption main engine	0.185 g pr. kWh

With a NOx factor on 0,0101 kg pr kWh and with 3.2 tons CO2 per ton fuel

NOx cooling unit	$21 * 0.0101 =$	0.212 kg NOx pr hour
CO2 cooling unit	$21 * 0.185 * 3.2 =$	12.464 kg CO2 pr hour

The difference between the cooling unit generators NOx factor and the main engines NOx factor exists because the main engine are optimised to generate as much as possible energy from the fuel while the generators take environmental consideration.



## 4 Data

### 4.1 Distances and time usage

The road distances used in this report are generated electronically from [www.visveg.no](http://www.visveg.no) [www.naf.no](http://www.naf.no) for distances in Norway and from <http://www.mappy.com/> for distances outside Norway. The railroad distances in Norway are generated electronically using [www.NSB.no](http://www.NSB.no). The sea distances are generated by Cmap.

The driving time on roads is generated by [www.naf.no](http://www.naf.no) for routes in Norway and <http://www.mappy.com/> for distances outside Norway. Resting time for the HGV drivers was supplied by different operators at Nor-Cargo. The transport time for rail is generated by time schedules for freight trains in Norway. Handling time is based on our own assumptions. The actual time usage is indeed uncertain, but for the environmental study this will only be of limited importance, because these numbers are only used to calculate the emissions from the thermo transport cooling systems.

Figure 5 and Figure 6 show the distances for each part of the different routes with their driving times and speed. These data, together with the energy consumption data and the payload assumptions contributes as the basis for the environmental and economic calculations we have done.

**Figure 5 Distances and time usage Trondheim - Boulogne-Sur-Mer**

Locations	Transport mode	Km	Hours	Minutes	Knots	Km/h
<b>Base case</b>						
<b>Trondheim - Oslo- Kiel- Boulogne-Sur-Mer</b>						
Trondheim Oslo incl. resting time	Road	499	8	0		62
Oslo terminal and handling time			1			
Oslo Kiel	Ferry	659	19	30	18,3	
Kiel - Boulogne-Sur-Mer incl. resting time	Road	897,6	14	0		64
<b>Total</b>		<b>2055</b>	<b>42</b>	<b>30</b>		<b>48</b>

Locations	Transport mode	Km	Hours	Minutes	Knots	Km/h
<b>Case 1: Trondheim- Kristiansund- Rosyth- Zeebrugge- Boulogne-Sur-Mer</b>						
Trondheim-Kristiansund	Road	193	3	20		58
Kristiansund terminal and handling time			1			
Kristiansund-Rosyth	Ferry	887	20	50	23	
Rosyth terminal and handling time			4			
Rosyth – Zeebrugge	Ferry	783	18	9	23,3	
Zeebrugge- Boulogne-Sur-Mer	Road	157	2	10		70
<b>Total</b>		<b>2020</b>	<b>52</b>	<b>00</b>		<b>41</b>

Locations	Transport mode	Km	Hours	Minutes	Knots	Km/h
<b>Case 2: Trondheim- Kristiansund- Rosyth - Dover - Calais- Boulogne-Sur-Mer</b>						
Trondheim- Kristiansund	Road	193	3	20		58
Kristiansund terminal and handling time			1			
Kristiansund- Rosyth	Ferry	887	20	50	23	
Rosyth - Dover incl. resting time	Road	823	10	30		78
Dover terminal and handling time			1			
Dover – Calais	Ferry	41	1	15	18	
Calais- Boulogne-Sur-Mer	Road	126	1	45		72
<b>Total</b>		<b>2070</b>	<b>42</b>	<b>50</b>		<b>48</b>

Locations	Transport mode	Km	Hours	Minutes	Knots	Km/h
<b>Case 3: Trondheim - Kristiansand- Eemshaven - Boulogne-Sur-Mer</b>						
Trondheim- Kristiansand	Rail	906	18	30		49
Oslo terminal and handling time			2			
Kristiansand terminal and handling time			2			
Kristiansand- Eemshaven	Ferry	561	10	50	28	
Eemshaven - Boulogne-Sur-Mer	Road	580	6			97
<b>Total</b>		<b>2047</b>				<b>42</b>

**Figure 6 Distances and time usage Bodø - Boulogne-Sur-Mer**

Locations	Transport mode	Km	Hours	Minutes	Knots	Km/h
<b>Base case</b>						
<b>Bodø Oslo- Kiel- Boulogne-Sur-Mer</b>						
Bodø Oslo incl. resting time	Road	1213	30	30		40
Oslo terminal and handling time			1			
Oslo Kiel	Ferry	659	19	30	18,3	
Kiel - Boulogne-Sur-Mer incl. resting time	Road	898	14	0		64
<b>Total</b>		<b>2770</b>				<b>43</b>

Locations	Transport mode	Km	Hours	Minutes	Knots	Km/h
<b>Case 1: Bodø- Kristiansand- Eemshaven- Boulogne-Sur-Mer</b>						
Bodø- Kristiansand	Rail	1595	32			50
Oslo terminal and handling time			2			
Kristiansand terminal and handling time			2			
Kristiansand- Eemshaven	Ferry	561	10	50	28	
Eemshaven - Boulogne-Sur-Mer	Road	580	6			97
<b>Total</b>		<b>2736</b>				<b>44</b>

Locations	Transport mode	Km	Hours	Minutes	Knots	Km/h
<b>Case 2: Bodø- Kristiansund- Rosyth - Dover- Calais- Boulogne-Sur-Mer</b>						
Bodø- Kristiansund incl. resting time	Road	907	26	0		35
Kristiansund terminal and handling time		0	0	1	0	
Kristiansund- Rosyth	Ferry	887	20	50	23	
Rosyth - Dover incl. resting time	Road	823	10	30		78
Dover terminal and handling time		0	0	1	0	
Dover – Calais	Ferry	41	1	15	18	
Calais- Boulogne-Sur-Mer	Road	126	1	45		72
<b>Total</b>		<b>2784</b>				<b>43</b>

Locations	Transport mode	Km	Hours	Minutes	Knots	Km/h
<b>Case 3: Bodø- Kristiansund- Rosyth – Zeebrugge- Boulogne-Sur-Mer</b>						
Bodø- Kristiansund incl. resting time	Road	907	26	0		35
Kristiansund terminal and handling time		0	0	1	0	
Kristiansund- Rosyth	Ferry	887	20	50	23	
Rosyth terminal and handling time		0	0	4	0	
Rosyth – Zeebrugge	Ferry	783	18	9	23,3	
Zeebrugge- Boulogne-Sur-Mer	Road	157,3	2	10		70
<b>Total</b>		<b>2734,3</b>				<b>38</b>

## 4.2 Fuel production

According to IFEU Heidelberg (2005) the energy consumption over the total energy chain depends on the efficiency of the individual steps of the chain. If electricity is used, between 11 % and 67 % (depending on the input mix) of the energy consumption is required for conversion and the upstream process steps, whereas for diesel fuel, the final energy use contributes about 90 % of the total primary energy demand.

### Diesel

The emission factors include all steps from exploration to refining of crude oil. The contribution of these process steps to the total impacts is low (less than 5 % of the full fuel chain). According to IFEU Heidelberg 2005 the contribution of diesel production to the energy consumption of the transport is less than 10%. The following table shows the specific figures for the emissions and the energy consumption for the prechain.

**Figure 7** Emission factors and energy consumption of diesel fuel for the conversion in refineries and transport to the filling station related to final energy (per kg fuel)

	kWh/kg	CO <sub>2</sub> g/kg	NO <sub>x</sub> g/kg	SO <sub>2</sub> g/kg	NMHC g/kg	PM g/kg
Diesel	13,58	438	1.3	2.0	0.72	0.06

Source: IFEU Heidelberg 2005

As we have shown earlier, Thune-Larsen et al., (1997) has calculated this emissions from HGV's >20 ton in Norway

**Figure 8 Emissions from HGV transport in Norway per ton km**

Energy use kWh	CO <sub>2</sub> g	SO <sub>2</sub> g	CO g	PM g	NO <sub>x</sub> g
0,22	57	0,026	0,183	0,078	0,682

With the values from Figure 7 and

Figure 8 we have generated figures for emissions from energy consumption of diesel fuel for all the steps from exploration to refining and transport to the filling station per ton km as shown in Figure 9

**Figure 9 Emissions from energy consumption of diesel fuel for the conversion in refineries and transport to the filling station per ton km**

Energy use kWh	CO <sub>2</sub> g	SO <sub>2</sub> g	CO g	PM g	NO <sub>x</sub> g
0,030	8,068	0,037	0	0,001	0,024

The total emissions including emissions from production and transportation of fuel and the direct emissions from the vehicles have then been calculated as given in the table below

**Figure 10 HGV transport in Norway >20 ton ton/km inc. consumption of diesel fuel for the conversion in refineries and transport to the filling station per ton km**

Energy use kWh	CO <sub>2</sub> g	SO <sub>2</sub> g	CO g	PM g	NO <sub>x</sub> g
0,250	65,07	0,063	0,183	0,079	0,706

## **Electricity**

To compare the environmental impacts of transport processes with different energy carriers, the total energy chain has to be considered:

- 1) The energy chain of electricity production: Exploration and extraction of the primary energy carrier (coal, oil, gas, nuclear etc.), transport conversion within the power plant and energy distribution (power loss).
- 2) The energy chain of diesel production: Exploration and extraction of primary energy (crude oil), conversion within the refinery and transport.

The emission factors of electricity production depend mainly on the mix of energy carriers and the efficiency of the production. The deregulation of the energy market has led to an international trade of electricity, making it difficult to determine a specific electricity mix. According to IFEU Heidelberg (2005) the most accepted method to estimate emission factors for electricity production is to take the average electricity split per year and country. Consolidating the energy split for electricity production, the respective emission factors and the conversion efficiencies for each country, gives the end energy related emission factors are listed in the table below.

**Figure 11 Primary energy consumption and emission factors of the electricity supply for railway transport in European countries**

	kWh/kWh	CO2 g/kWh	NOx g/kWh	SO2 g/kWh	NMHC g/kWh	PM g/kWh
<b>Belgium</b>	3,036	0,26	0,84	0,31	0,08	0,23
<b>Denmark*</b>	1,628	0,48	0,53	0,37	0,05	0,05
<b>France</b>	3,069	0,11	0,33	0,30	0,02	0,03
<b>Germany*</b>	3,083	0,66	0,60	0,67	0,04	0,03
<b>Luxembourg</b>	1,508	0,26	1,05	0,23	0,19	0,05
<b>Netherlands</b>	1,939	0,43	1,07	0,22	0,13	0,61
<b>Norway</b>	1,114	0,00	0,01	0,00	0,00	0,00

Source: IFEU Heidelberg 2005 (Remarks: \*railway mix)

It is, however, possible to argue that the marginal electricity in Norway is imported, and that it is the marginal electricity that is of interest here. We have therefore used both the Norwegian and the Danish numbers for primary energy consumption for the electricity supply for railway transport in Norway to check for sensitivity with respect to the results.

### 4.3 Marginal external costs included in the study

In comparing and calculating the marginal external costs of the different routes/ modes we have been asked to use the European commissions Marco Polo Program for assessing marginal external costs. For the transport on sea, the Marco Polo Program numbers for short sea shipping are a bit too inaccurate for this study. One of the effects we want to show is the differences between fast conventional ferries (29-23 knots) and conventional ferries (16-18 knots). As far as we know, there is no study that shows marginal external costs for different types of fast conventional RoRo ferries. The values for climate cost, pollutants costs and accident costs are too low for this type services. Even the noise costs may be too low. We could have included the climate costs based on our calculations of CO2 emissions but still would the rest of cost factors probably give a wrong picture. Within the constraints of this project it is not possible to estimate marginal external costs for different vessel types to a full extent.

**Figure 12 Marginal average external cost of transport by mode-€ 1000 t/km**

Road		Short sea shipping		Rail	
<b>Accidents</b>	5,44	<b>Accidents</b>	0	<b>Accidents</b>	1,46
<b>Noise</b>	2,14	<b>Noise</b>	0	<b>Noise</b>	3,45
<b>Pollutants</b>	7,85	<b>Pollutants</b>	2,0	<b>Pollutants</b>	3,8
<b>Climate Costs</b>	0,79	<b>Climate Costs</b>	Negligible	<b>Climate Costs</b>	0,5
<b>Infrastructure</b>	2,45	<b>Infrastructure</b>	Less than 1.0	<b>Infrastructure</b>	2,9
<b>Congestion</b>	5,45	<b>Congestion</b>	Negligible	<b>Congestion</b>	0,235
<b>Total</b>	24,12	<b>Total</b>	Maximum 4.0	<b>Total</b>	12,35

The marginal external cost of, for example, congestion, accidents and local air pollution is however not the same in rural Norway as in Germany. Since a large part of the transport (both road and rail) is in Norway, we have chosen to use values calculated by Eriksen et al. (1999) for calculations of the accident, noise, local emissions, greenhouse gases, road wear, congestion and infrastructure costs in Norway for freight transport on road and rail. For the other transport modes, the figures from The Marco Polo Program (2002) are used.

**Figure 13 Marginal external cost of transport by mode€/ t/km in Norway**

	<b>Greenhouse gases</b>	<b>Local emissions</b>	<b>Noise</b>	<b>Congestion</b>	<b>Accidents</b>	<b>Road wear</b>	<b>Total</b>
<b>Road</b>	0,012	0,006	0,010	0,010	0,006	0,015	0,057
<b>Rail</b>	0,001	0,002	0,001	0,000	0,003	0,009	0,015

Source: Eriksen et al. (1999)

#### **4.4 Environmental impacts included in the study**

Emission factors are based on average data valid for the transport means involved. We have chosen to analyse the following environmental impacts of the different transport routes:

**Energy consumption** (measured in kWh). Energy consumption was put on the agenda by the Brundtland commission, in “Our common future” (1987) The commission outlined the necessity of stabilising the worlds energy consumption, because of the environmental problems related to both, production, transport and use of energy. Energy consumption is a direct indicator for such problems. At the same time energy consumption is an indirect indicator for other types of usage of resources that are connected to environmental problems.

**CO2 carbon dioxide:** The increase of CO2 in the atmosphere contributes to global warming. Global warming, in turn, may cause changes in climate, such as changes in rainfall patterns, a rise in sea level, and a wide range of impacts on plants, wildlife and humans.

**NOx Nitrogen oxides** – has consequences on the global, regional and on the local level. NOx contributes to global warming through chemical processes in the atmosphere. The regional effects relate to acid rain and over-fertilization, on land, in lakes and in coastal and ocean areas. NOx emissions are also a major local environmental problem, and may result in health problems. In addition to this, NOx contributes to the formation of Ground Level Ozone which has impacts on both health and vegetation.

**CO carbon monoxide** has an immediate effect on health by reducing the capacity to circulate oxygen in the blood. Low concentrations may result in drowsiness and reduced reactivity. CO oxidizes to CO2 and thereby contributes to global warming.

**Sulphur dioxide** has mainly regional effects and is the largest contributor to acid rain. High concentrations of sulphur dioxide can have an impact on health by worsening respiratory diseases.

**Dust in suspension** are particles suspended in the air for some time and are the air pollution component that generates the greatest local air pollution problems besides NOx. PM10, particles under 10 µm, have the largest health impacts.

# 5 Analyses

## The distance Trondheim-Boulogne

Figure 14 show that the planned new fast conventional ferry service (23 knots) Kristiansund-Rosyth and (29 knots) Rosyth Zeebrugge has high energy consumption and high emissions. The route Kristiansund- Rosyth (23 knots) Dover- Calais (18 knots) has energy consumption and emissions much lower than the Kristiansund-Zeebrugge route but still much higher than the base case (Trondheim-Oslo-Kiel-Boulogne). The figure also shows that the planned new Norway-Benelux route with rail transport to Kristiansand and a fast conventional RoRo ferry to Eemshaven (28 knots) have energy consumption and emissions at the same level as Kristiansund- Rosyth (23 knots) Dover- Calais (18 knots).

**Figure 14 Energy consumption and emissions from the four main alternatives from Trondheim to Boulogne (incl. production and transportation of fuel) per HGV**

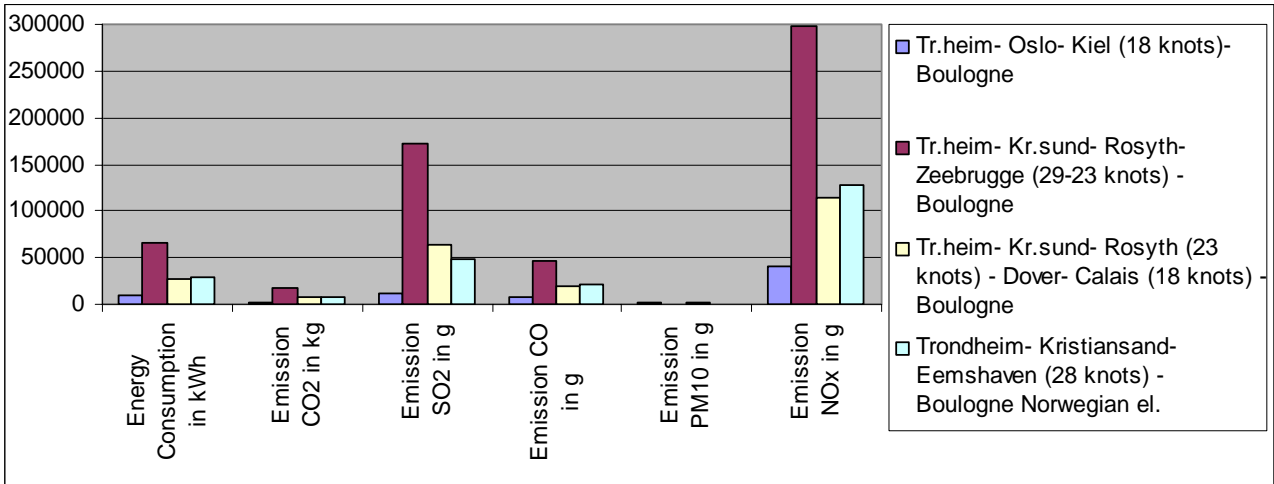
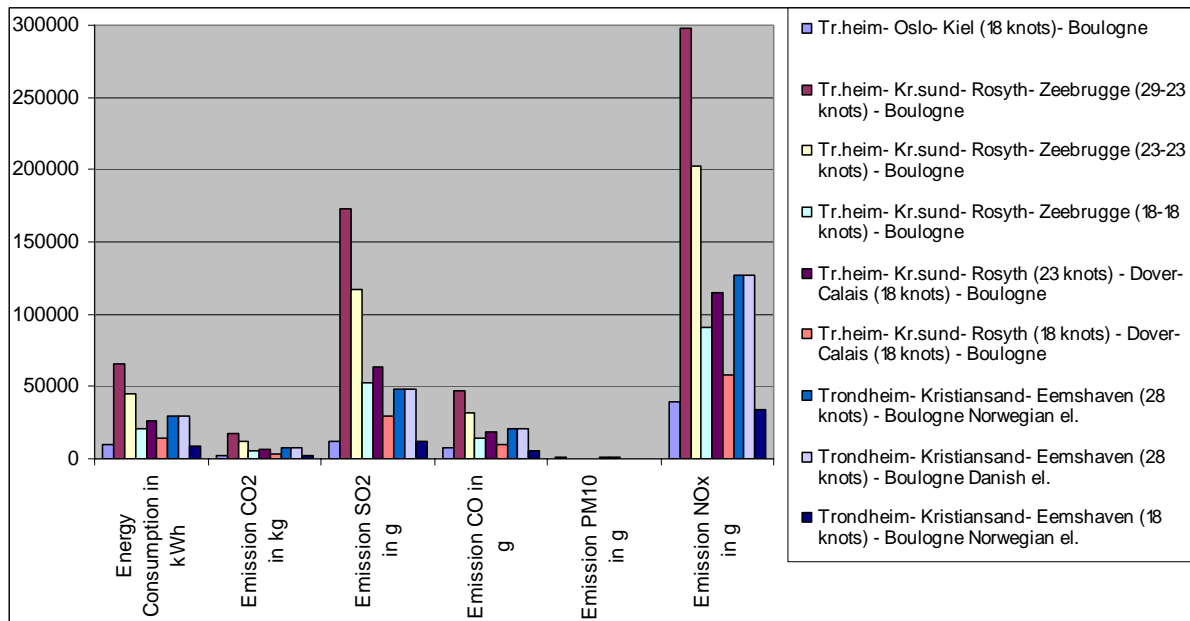


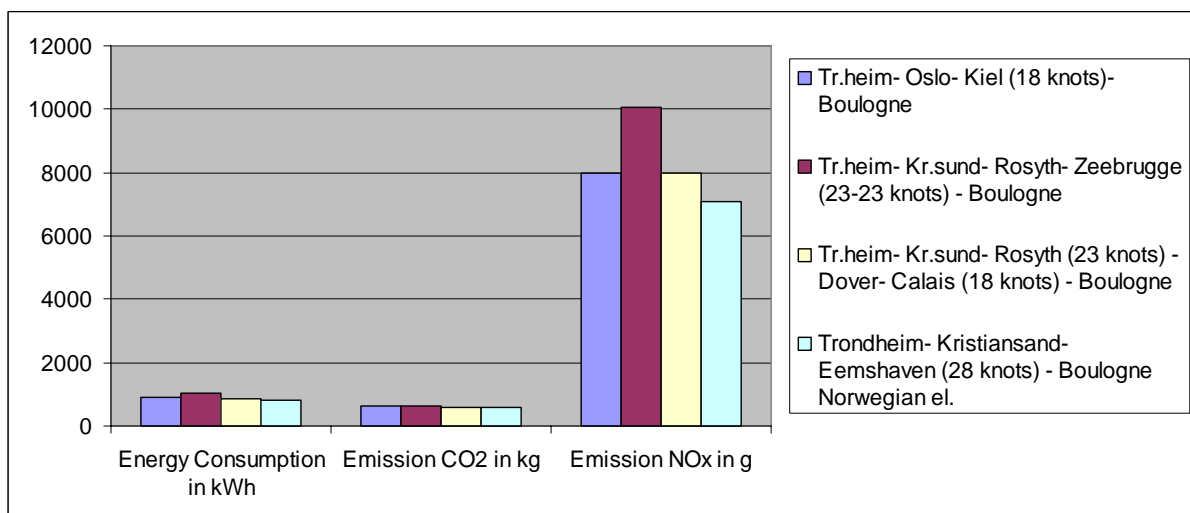
Figure 15 shows the connection between speed of the ferries and the environmental impacts. Regardless of some uncertainties in the results from the computer generated energy consumptions and emissions (especially for the highest speeds), this figure shows that it is the speed on the Superfast ferries that constitutes an environmental problem. Another key result is that there is almost no difference between The Norway Benelux route calculated with Norwegian energy mix (hydro electric power) or Danish electricity mix.

**Figure 15 Energy consumption and emissions from all the alternatives from Trondheim to Boulogne (incl. production and transportation of fuel) per HGV**



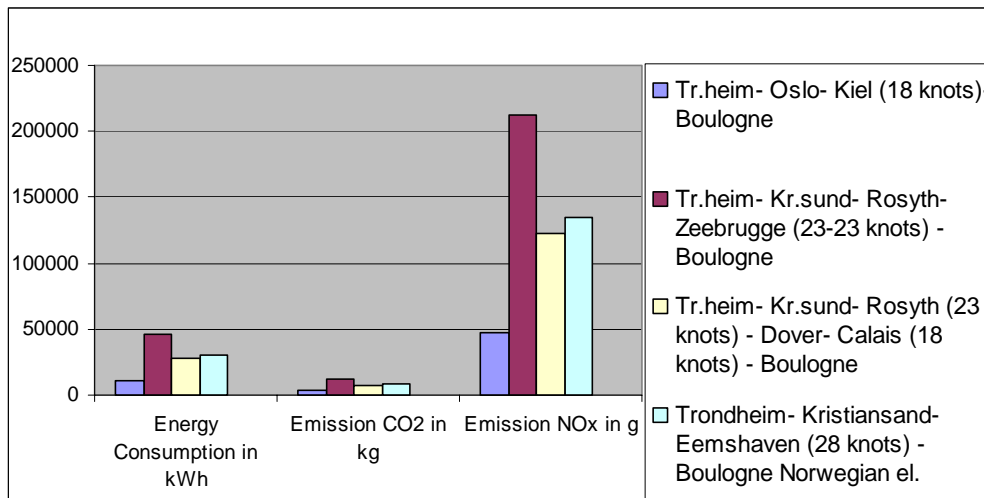
Based on the lead time on board the ferries (were the plugged into the vessel’s electricity supply), on the road and on the terminals (where the cooling units aggregates are running), we have found that cooling contributes to emission as shown in Figure 16, for the different transport routes. The routes with the least time usage also have the lowest emissions. The reason for the relatively high NOx emissions for the Kristiansund- Rosyth –Zeebrugge route is that when the HGVs are on board the ferries, they are connected to the electricity supply of the vessel, and this has high NOx emissions.

**Figure 16 Emissions and energy consumption, from cooling units and from cooling onboard the ferries, between Trondheim- Boulogne.**



The total figures for the Thermo transport shows some small fluctuations between the different alternative routes, but it is still the rail alternative, together with Oslo Kiel, that has the lowest energy consumption and the lowest emissions.

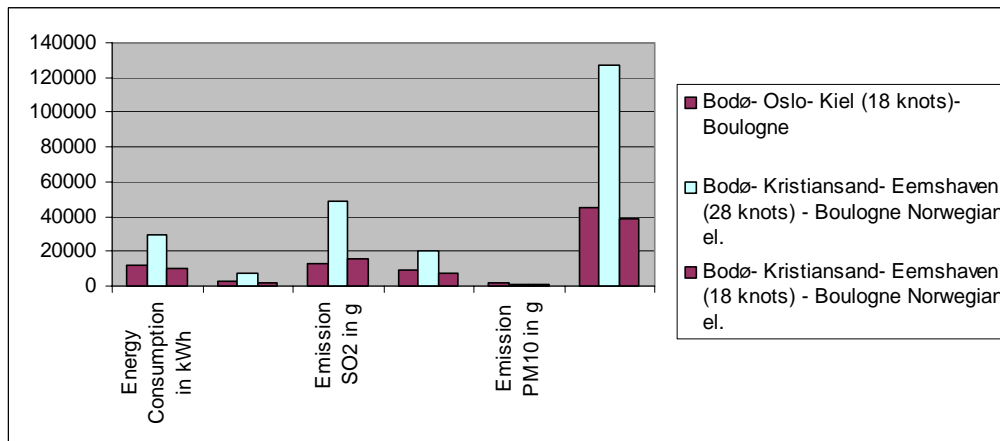
**Figure 17 Total emissions and energy consumption from transportation, cooling units and cooling onboard the ferries between Trondheim- Boulogne per HGV.**



We see that the difference in energy consumption between the Kristiansund Rosyth Dover Calais Boulogne and the base case is lower for thermo transport than ordinary transport due to shorter transport time.

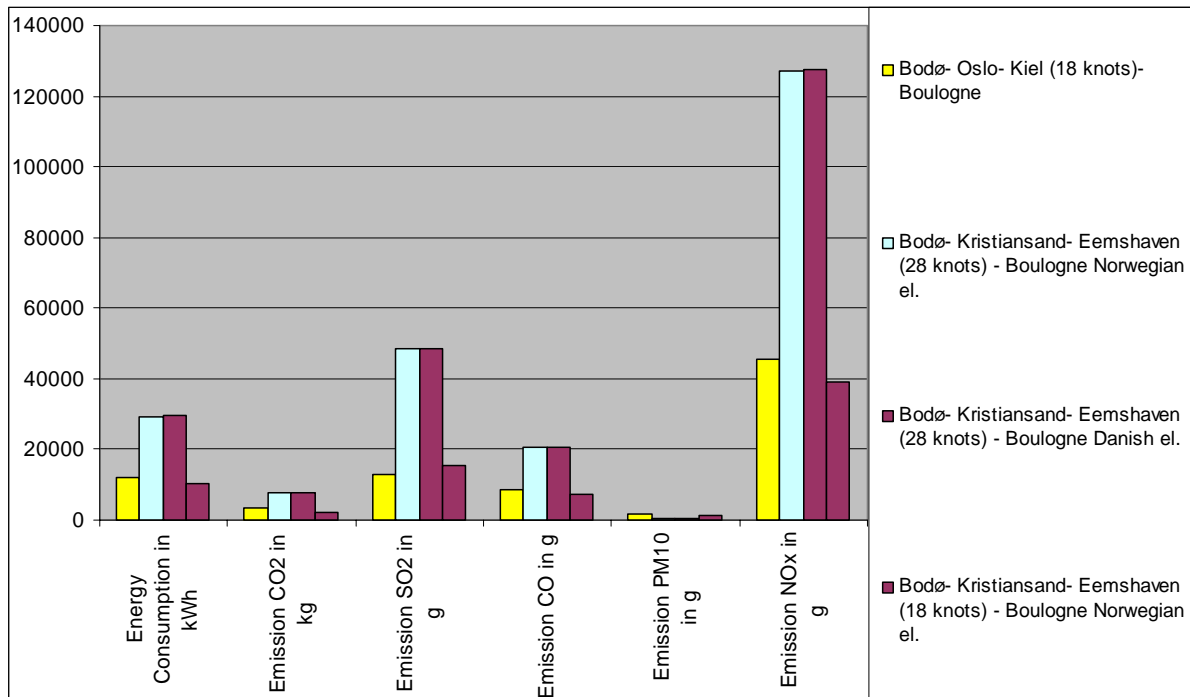
**The distance Bodø Boulogne**

**Figure 18 Energy consumption and emissions from the four main alternatives from Bodø to Boulogne (incl. production and transportation of fuel) per HGV**



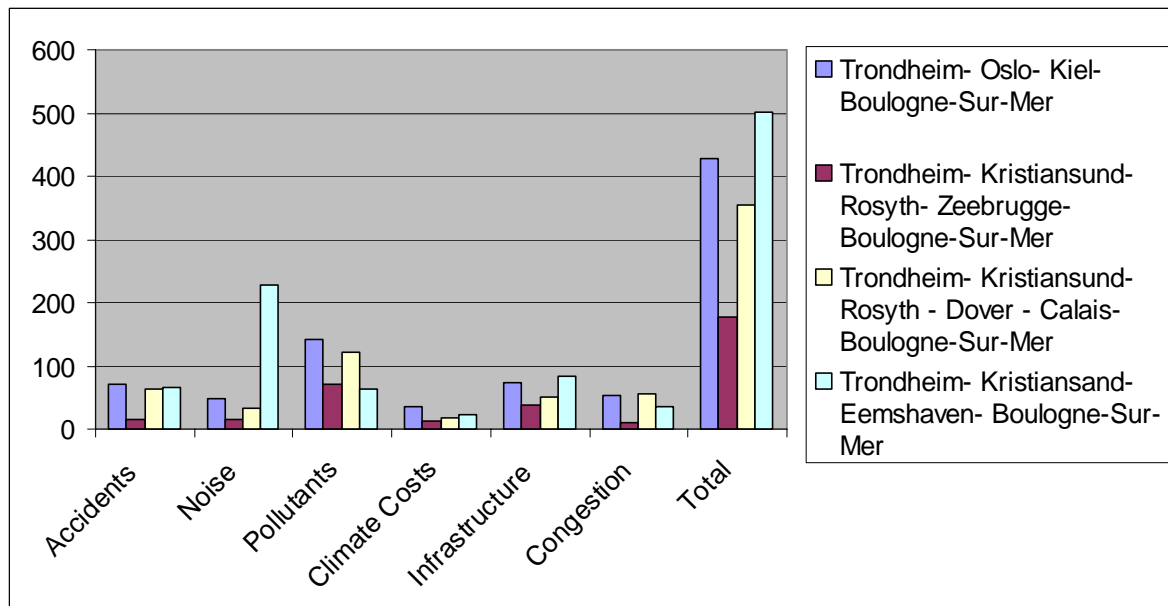
The routes of interest here are Bodø Oslo Kiel Boulogne and Bodø Kristiansand Eemshaven Boulogne. The routes via Kristiansund are not possible from Bodø with HGV without a 9 hours brake. As we clearly see in Figure 18 the rail alternative over Kristiansand with a fast conventional ferry running at 28 knots uses much more energy and has larger emissions than the base case. An alternative with a ferry running at 18 knots uses less energy and has less emission than the base case. Figure 19 shows that this is the case also if we use a Danish energy mix for the electric railroad between Trondheim and Kristiansand. North of Trondheim is the railroad not electrified.

**Figure 19 Energy consumption and emissions from all the alternatives from Bodø to Boulogne (incl. production and transportation of fuel) per HGV**



**Marginal external costs**

**Figure 20 Marginal external cost from the four main alternatives from Trondheim to Boulogne in Euro per HGV mainly based on the Marco Polo figures.**



As we see in Figure 20, the marginal external cost calculated with the Marco Polo and Eriksen et al. (1999) figures. The fast conventional ferry service Kristiansund -Rosyth -Zeebrügge has the lowest overall value. It is also lowest when it comes to climate costs.

Figure 14 shows that the same route is the one with the largest emissions when it comes to the green house gases CO<sub>2</sub> and NO<sub>x</sub>. As we mentioned in chapter 4.3 the Marco Polo numbers for short sea shipping is not precise enough and they can not be used for fast conventional ferry service. It is possible to calculate the price for climate costs based on the emission numbers used in this report, but probably should also the pollutants costs, accident costs also be particularly investigated for this type of services. This is not possible within the limits of this project. This is a quite comprehensive task and recent research on this matter is scarce. The Norwegian Ministry of Transport and communication has recently launched a research project on marginal cost of sea transport. We will therefore conclude that the figures shown in Figure 20 are unreliable.



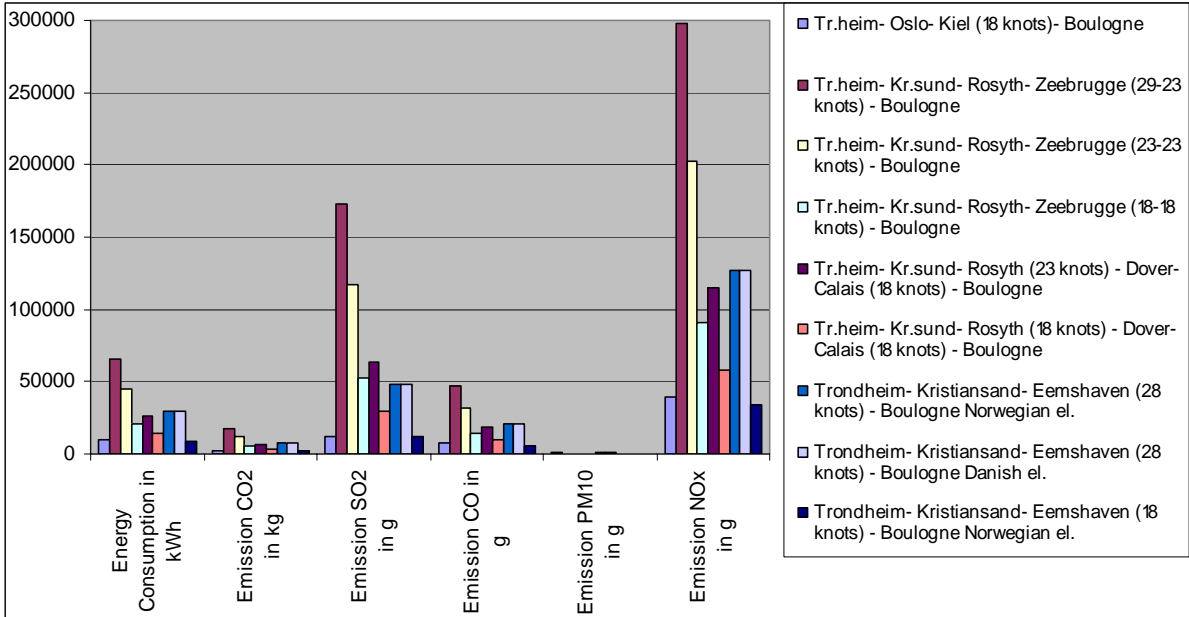
# 6 Conclusion

As we see clearly see in the table below, fast conventional ferry vessels have high emissions compared to other means of transport. The calculations for the emissions for the sea freight are based on the computer program Omit. The results from this program are connected to some uncertainties because of that ships often are custom made with different characteristics when it comes to energy consumption and emissions. The Norway - Benelux service appears to have higher emissions as compared to the base case (transport via Oslo Kiel). This is both with Norwegian and Danish electricity mix (including coal power etc.).

If all the RoRo services were running at a speed of 18 knots, the differences between the different routes are significantly reduced, and the differences between the two routes that go via Rosyth and the base case becomes insignificant. The route over Kristiansand Eemshaven will have had slightly lower emissions than the base case.

We were asked to calculate marginal external costs by using the Marco Polo figures. As discussed in chapter 4.3 and 5 they are clearly too low when it comes to fast conventional ferry services. The recent research on these matters is scare so we did not manage to find alternative marginal external cost data.

**Figure 21 Energy consumption and emissions from all the alternatives from Trondheim to Boulogne (incl. production and transportation of fuel) per HGV**



It is reason to conclude that the main factor affecting the emission levels are the sea freight's choice of service speed in the multi modal transport chains investigated.



## 7 The future

New and strict emission targets for road transport were put into place last year and even stricter targets are coming. The relatively new HGV fleet has relatively low emissions and they are decreasing (per ton km). One reason for the new regulations is the Gothenburg protocol. To comply with the emission reductions agreed on, Europe's NO<sub>x</sub> emissions must be cut by at least 41% compared to 1990. One of the ways to achieve this is to cut the emissions from the transport industry.

At present, emissions from the RoRo fleet cannot compete with the emissions from road transport. Emissions from shipping are regulated through the Marpol convention and EU regulations. The current regulation through Annex VI of Marpol 73/78 limits the generation of NO<sub>x</sub> from ship engines up to 12,9gr/KWh.

For SO<sub>x</sub> emissions, the key is the regulation of the sulphur content of the fuel. The current Marpol regulation allows 4.5 % sulphur (the global average is 2.7). SO<sub>x</sub> emissions are covered by the EU Directive, which makes it compulsory for all ferries which call at EU ports to burn fuel with a maximum 1.5% sulphur content, beginning in April, 2006. The Marpool regulation for the North Sea basin comes into force 22.11.2007 and has also a limit on 1.5 % sulphur content in the fuel. The new requirements when the ships are in harbour are 0.1 %.

As we see in this report, emissions from today's RoRo fleet cannot compete with emissions from road in those multi modal transport chains that have been subjected to research here. We believe that stricter regulations on NO<sub>x</sub> emissions and Sulphur content is needed for the short sea shipping to compete with rail and road on SO<sub>2</sub> and NO<sub>x</sub> emissions. New regulation for shipping for sulphur content in fuel and NO<sub>x</sub> emissions will reduce the future shipping emissions reduce emissions in the longer run. The average age of the Ropax and RoRo fleet is 3-5 times larger than the average age for the long distance HGV fleet in Norway. Another factor that also counts in disfavour of the short sea shipping, with respect to the environment, is the increased speed. As shown in this report the increased speed will in turn result in substantial increases in the energy consumption and the emissions.



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Cmap

## 9 Appendix 1

**Figure 22 Energy consumption and emissions from all the alternatives from Trondheim to Boulogne (incl. production and transportation of fuel) per HGV**

	<b>Energy Consump- tion in kWh</b>	<b>Emission CO2 in kg</b>	<b>Emission SO2 in g</b>	<b>Emission CO in g</b>	<b>Emission PM10 in g</b>	<b>Emission NOx in g</b>
Tr.heim- Oslo- Kiel (18 knots)- Boulogne	10268	2712	12319	7364	1215	39870
Tr.heim- Kr.sund- Rosyth- Zeebrugge (29-23 knots) - Boulogne	66209	17632	173113	46920	305	297337
Tr.heim- Kr.sund- Rosyth- Zeebrugge (23-23 knots) - Boulogne	45152	12023	117322	32005	305	202255
Tr.heim- Kr.sund- Rosyth- Zeebrugge (18-18 knots) - Boulogne	20532	5464	52089	14566	305	91080
Tr.heim- Kr.sund- Rosyth (23 knots) - Dover- Calais (18 knots) - Boulogne	26627	7074	63017	18935	994	114920
Tr.heim- Kr.sund- Rosyth (18 knots) - Dover- Calais (18 knots) - Boulogne	14014	3714	29600	10001	994	57969
Trondheim- Kristiansand- Eemshaven (28 knots) - Boulogne Norwegian el.	29330	7656	48410	20419	510	127233
Trondheim- Kristiansand- Eemshaven (28 knots) - Boulogne Danish el.	29586	7656	48594	20419	530	127498
Trondheim- Kristiansand- Eemshaven (18 knots) - Boulogne Norwegian el.	8724	2167	12196	5824	530	34451

## Appendix 2

**Fra:** Katras Marilia [mailto:katras@attica-group.com]

**Sendt:** 7. oktober 2005 14:45

**Til:** edvard.sandvik@hiMolde.no

**Emne:** RE: Contact Form

Dear Mr. Sandvik

Thank you for your inquiry. The Superfast vessels, all built after 2001, employ the latest technology so that the impact on the environment is minimised. With regards to NOx emissions our engines comply with the demands of international regulations and are certified to that effect. Annex VI of Marpol 73/78 limits the generation of NOx from ship engines. All engines installed on the Superfast Ferries fleet fully comply with the above regulation, and they even produce 20% less than permitted. Superfast Ferries measured on average 10,1gr of NOx per KWh, whereas current international regulations would allow up to 12,9gr/KWh.

SOx emissions: Superfast Ferries has adopted the use of special low sulphur fuel oil, which contains not more than 1.5% sulphur. SOx emissions are covered by the EU Directive which makes it compulsory for all ferries which call at EU ports to burn fuel with a maximum 1.5% sulphur content, beginning April, 2006."

Superfast IX and Superfast X which serve the North Sea route currently cruise at 23.3 kn.

Thank you for your interest in Attica Group.

Yours sincerely

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