Biodiesel in car ferries

A feasibility study on the use of biofuels in Norwegian domestic ferries

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About ZERO

ZERO Emission Resource Organisation is a Norwegian organisation dedicated to working for solutions that provide zero emissions and no damage to the environment. ZERO is a non-profit foundation. ZERO are not consultants, the battle against climate change is ZERO's only mission. However ZERO participates in partnerships financed by third parties.

More info about ZEROs work is enclosed in Appendix 3 of this report and on our website; www.zero.no

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Preface:

This report aims to show how biofuels could be used in car ferries. The report is a result from ZEROs continuous work on biofuels in the marine sector which started with the report "Biofuels in Ships" in 2007. "Biofuels in Ships" addresses the potential in using biofuels in shipping. While working on the report ZERO made important relations with engine manufacturers. The conclusions of that report provided useful information on the use of biofuels in large marine engines. However, a more specific report on smaller ferry engines was desired to cover a wider range of marine engines. "Biodiesel in car ferries" is a direct follow up on "Biofuels in Ships" and can be seen as an additional project report. It aims to provide information particularly interesting for ferries in domestic operation.

The environmental NGO ZERO has made this report with financial support from Ruter AS and Tide ASA. ZERO would like to thank all those who have contributed to this report. We hope it will shed light on the possibility of using biofuels in Norwegian ferries as a measure to cut greenhouse gas emissions from the sector.

Oslo, 02.06.2008
Olav A. Opdal

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Abstract

Man made greenhouse gas emissions leads to global warming. The Intergovernmental Panel on Climate Change assess that global greenhouse gas emissions needs to be cut by 50-85 per cent to keep temperature from rising more than of 2 °C. Norwegian emissions are higher than the world average and needs to be cut by 90 %. To obtain such emission cuts, emission-free solutions has to be implemented. Greenhouse Gas emissions from the transport sector is a main source of greenhouse gas emissions. By switching to renewable fuels like biodiesel, these emissions can be cut.

In Norway, due to a sparsely populated coast and a long coastal line, there are a lot of ferry services, using fossil fuels. Altogether these ferries account for emissions of around 410 000 tonnes CO2-equivalents, thus representing about 10 per cent of total emissions from the Norwegian domestic fleet or about 1 % of the total Norwegian CO2 emissions. Greenhouse Gas emissions from norwegian ferries is equal to 150 000 cars, which is slightly more than the number of cars in Sør-Trøndelag county.

The total emissions from Norwegian ferries can be cut by implementing biodiesel. First by conventional biodiesel, but following development also new feedstocks such as wood or algae can be used. The total consumption of MGO is 129 000 tonnes per year. 100 000 tonnes of biodiesel will be produced at Uniols new production facilty.

ZERO recommends that the Public Roads administration set requirements for biodiesel operation in the announcement of tender. This will ensure that ferry owners can operate biodiesel on the same competitive levels.

The use of biodiesel in ferries has never been tested in Norway, but there have been some trials and tests around the world. Currently, Washington State Ferries in the USA have the most prominent program in the world for testing biodiesel in car ferries. Their different projects have generally good records, the most common problem reported being filter pluggings. This problem can however easily be taken care of. Norwegian ferries use marine gas oil (MGO), which is similar to auto diesel. Biodiesel is similar to auto diesel in many respects, and should therefore be a suitable replacement for MGO. The first diesel engine was originally designed to run on vegetable oil.

Biodiesel can be used in both new and existing ferries. However, introducing biodiesel in ferries can be challenging. Biodiesel has a higher acidity than regular marine fuels. This can result in slight problems for older engines that have poor rubber quality in hoses and sealing. In new engines with normal wear proof material, biodiesel according to the standard EN14214 should work fine. Before using biodiesel, storage tanks should be cleaned thoroughly.

Because biofuels are sulphur-free, using them will remove SO2-emissions from ferries. Further, emissions of particulate matter will be significantly reduced, resulting in reduced health risk. Only renewable CO2 will be emitted during combustion, and even though some greenhouse gases can be let out during biofuel production, the cut in emissions will be substantial when changing from fossil fuels to biofuels.

NOx-emissions may increase slightly though technology is available to deal with this problem. Carcinogenic Polycyclic Aromatic Hydrocarbons emissions are reduced, and so are emissions of Carbon Monoxide.

Biodiesel is available and can be bought on the Norwegian market, and several companies offer biodiesel. However, biodiesel is more expensive than regular MGO. The fuels costs will increase by around 55 per cent when switching to biodiesel on an average ferry. If biofuels are set as a requirement for ferry operation, the government could cover this extra expenditure.

Sammendrag

De store klimagassutslippene fra menneskelig aktivitet fører til global oppvarming. FNs klimapanel anslår at klimagassutslippene globalt må kuttes med 50-85% for å nå målet om maksimalt 2 °C temperaturøkning. Norske utslipp er høyere enn verdensgjennomsnittet og må derfor kuttes med 90%. For å oppnå slike utslippskutt er det essensielt å ta i bruk og utvikle utslippsfrie alternativer. Klimagassutslipp fra transportsektoren er en av de viktigste bidragsytere til menneskeskapte klimaendringer. Ved å bytte til fornybare drivstoff kan man fjerne disse utslippene.

På grunn av den tynt befolkede norske kyststripen finnes mange ferger. De fleste av disse benytter fossilt brennstoff. Til sammen slipper norske ferger ut ca. 410.000 tonn CO_2 i året. Det tilsvarer ca 10 prosent av utslippene til den norske innenriksflåten eller ca. 1 % av de totale norske CO_2-utslippene. Fergeutslippene tilsvarer de årlige utslippene til nærmere 150 000 biler. Det er flere biler enn i hele Sør-Trøndelag fylke.

ZERO mener at biodrivstoff på sikt kan kutte hele dette utslippet, først gjennom bruk av konvensjonelt biodrivstoff, på sikt kan man også se for seg å ta i bruk nye råstoff for biodrivstoff, så som skogsvirke eller alger. Det totale forbruket av MGO er 129 000 tonn per år. Ved Unioils nye fabrikk det produseres 100 000 tonn biodiesel i året.

ZERO oppfordrer myndighetene gjennom Statens vegvesen om å sette krav til bruk av biodiesel i anbudsutlysningen for norske ferger. På denne måten kan man sikre at det økonomiske grunnlaget for å ta i bruk biodiesel i norske ferger er tilstede og at ingen fergerederi får konkurransefortrinn ved å ikke bruke biodiesel.

Bruk av biodiesel i norske ferger har ikke tidligere bli testet i Norge, men det har vært et mindre antall tester rundt omkring i verden. Washington State Ferries i USA har for tiden det mest omfattende prosjektet for å i bruk biodiesel i bilferger. Resultatene fra dette og andre tilsvarende prosjekt har vært gode. Det mest kommenterte problemet synes å være tetting av filter. Dette problemet kan imidlertid med letthet taes hand om.

Norske ferger bruker marin gassolje (MGO), som tilsvarerer vanlig autodiesel. Biodiesel er tillaget for å ligne på autodiesel og skulle derfor også være godt egnet for å erstatte marin gassolje i ferger. Dieselmotoren ble opprinnelig laget for å bruke vegetabilsk olje.

Biodiesel kan brukes i nye og eksisterende fartøy. Noen utfordringer kan man imidlertid støte på. Biodiesel har høyere syrenivå en vanlig marin gassolje. Dette kan forårsake operasjonelle problemer for eldre ferger med dårlig gummikvalitet i slanger og tettinger. For nye motorer med normalt slitefast materiale skulle ikke biodiesel som oppnår standard, forårsake noe problem. Før man benytter biodiesel, bør også tanker rengjøres godt.

Biodrivstoff har ikke noe innhold av svovel, hvilket gjør at utslippene av svoveldioksid kuttes helt ved en overgang til biodiesel i ferger. Utslipp av svevestøv vil også bli drastisk redusert og gi et bedre arbeidsmiljø for fartøyets personell. Bare fornybar CO_2 slippes ut ved bruk av biodrivstoff, og selv om det kan følge noe drivhusgassutslipp med dyrking av biodrivstoff, vil utslippene av drivhusgasser reduseres betraktelig ved overgang fra fossile drivstoff til biodrivstoff. NO_x-utslippene økes sannsynligvis litt; teknologi er tilgjengelig for å behandle disse utslippene. Utslippene av polysykliske aromatiske hydrokarbon som kan forårsake kreft, blir kraftig redusert, det samme gjelder karbonmonoksidutslippene.

Biodiesel er i dag tilgjengelig og kan kjøpes på det norske markedet, flere selskaper tilbyr biodiesel i Norge. Biodiesel er dyrere enn vanlig marin gassolje; på en gjennomsnittlig ferge vil drivstoffutgiftene øke med ca 55 prosent ved overgang til biodiesel. Denne ekstrakostnaden vil staten kunne ta dersom bruk av biodrivstoff settes som krav i anbudsutlysningen.

1 Introduction

ZERO is an environmental NGO campaigning to reduce emissions of greenhouse gases. In this respect we have identified biofuels produced in a sustainable way as a good measure. Earlier ZERO has addressed several potential uses of biofuels in different projects, for example road transport and for generating turbines. Because greenhouse gas emissions from ships and boats are considerable and biofuels similar to marine fuels, we have found the use of biofuels in marine vessels interesting. The report “Biofuels in Ships” initiated our work in this field, while the current report “Biodiesel in car ferries” is an appendix of the former, aiming to investigate the compatibility of biofuels in car ferries.

First a general introduction of the Norwegian domestic ferries is given, followed by an overview of experiences with biofuels in ferries worldwide and a general review of the engine compatibility of biofuels in ferries. The market situation for biofuels is also reviewed, as well as the environmental impact of the switch from marine fuels to biofuels.

1.1 Ferries in the Norwegian transport sector

Due to the geography and sparse coastal population in Norway a lot of fjords are crossed and islands connected with the use of ferries. Transporting passengers and cars from islands and outskirts, the ferries provide connection and often considerable shortcuts for the coastal population. Ferries have been an integrated part of the life for coastal people for centuries. Today ferries are a vital part of the transport infrastructure in Norway.

There are about 200 ferries in Norway transporting cars and passengers (RLF 2008). Ferries are invaluable for the population on the outskirts of Norway. Although bridges are replacing several ferry services, ferries will play a major role in transport infrastructure in the foreseeable future.

Under the guidance of the Directorate of Public Roads, The Public Roads Administration is in charge of ensuring that passes are operated by ferries. The Directorate of Public Roads is a separate agency subordinated the Ministry of Transport and Communication (Statens Vegvesen 2008).

The Norwegian state buys services from the ferry owners to operate the ferry services. In theory the ferry services are part of the road network and a governmental affair. The ticket fair is set by the government. By the end of 2009 all ferry services will be subject for competitive bidding. The bidding process is connected with a lot of requirements for the operation. It is in theory possible to set requirements for biodiesel operations in these ferries. This makes ferries in Norway ideal as possible projects for biodiesel operation.

Ferries are generally propelled by a combustion engine. Traditionally, ferries have used fossil energy and thus contributed to greenhouse gas emissions and global warming. Ferries sometimes contribute to cutting total greenhouse gas emissions by reducing travelled distances. In this report the potential of changing fuel to renewables in ferries are reviewed in order to facilitate the reduction of greenhouse gas emissions from this sector.

1.2 Engines installed in Norwegian ferries:

There are around 200 ferries in Norway. Most of the ferries use Marine gas oil (MGO), however some use natural gas. There is a wide variety of different engines used in Norwegian ferries. Figure 1 shows the distribution of engines installed in the ferries.

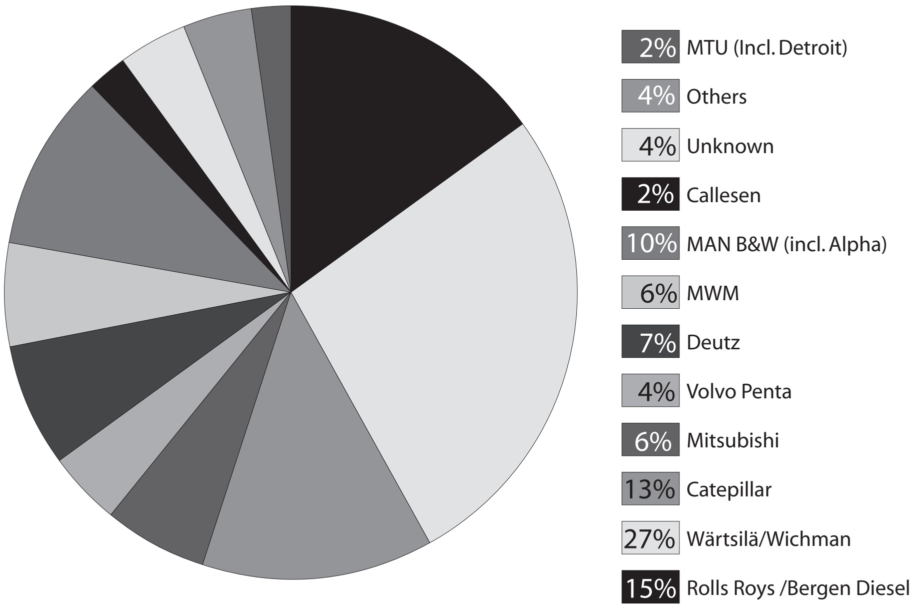

Figure 1: Engines installed in Norwegian ferries (RLF 2008)

As we can see from Figure 1, Wärtsilä with Wichman is the most important engine manufacturer for Norwegian ferries. Wärtsilä is also one of the manufacturers with most know-how on biofuels.

Most Norwegian ferries are operated on Marine gas oil (MGO). Most shipping vessels use HFO, a residue product for petroleum distillation. MGO is a product of distillation. This makes MGO a higher priced product than HFO, but also cleaner with respect to sulphur content and impurities. MGO is very similar to regular auto diesel used in land transport.

1.3 Global Warming

Concentration of global atmospheric concentration of carbon dioxide, methane and nitrous oxides has increased substantially as a result of human activity since 1750, carbon dioxide being the most important anthropogenic greenhouse gas. Based on this increase, the warming of the climate system is unequivocal, as is now evident from observations of increased global average air and sea temperatures (IPCC 2007).

The use of fossil energy like MGO results in greenhouse gas emissions and thus contributes to man made global warming. The Norwegian domestic fleet emits around 4 million tonnes CO2 eqv. each year (Statistics of Norway). According to national statistics, car ferries use 129 000 tonnes marin diesel annually. This leads to greenhouse gas emissions of around 410 000 tonnes CO2 equivalents, thus representing about 10 per cent of total emissions from the Norwegian domestic fleet or about 1 per cent of the total Norwegian emission (Statistics of Norway).

1.4 Biofuels

Biofuels are made from renewable energy sources. During the cultivation of resources, such as plants, the same amount of CO2 is taken up as is emitted during combustion of biofuels, thus no net CO2 is added to the atmosphere (IEA 2003). However, the use of fertilizer during cultivation may amount to some emission. In this study, only biodiesel will be evaluated, because of the current market situation of other biofuels and the compatibility of engines with biodiesel. Other possible future biofuels in ferries include ethanol, biogas, crude biooil, second generation biofuels and algae biofuels.

1.4.1 Vegetable Oils

Oil plants play an important role as sources of protein and fat for both humans and animals. A wide range of oil rich plants are grown and used for a variety of purposes. Plants like rapeseed, soybeans, palm, peanuts and sunflower cover most of our worldwide need for plant based fat. Vegetable oils are used as a separate ingredient as well as in numerous foodstuff products. Processed oils are used in products such as cosmetics, plastic, candles, soaps, paint, industrial adipose, leather tanning products, solvents, wax, rubber, biofuels – to name but a few.

Rapeseed (Europe) and Soya (USA) are the most common raw materials in biooil designated for fuel production, with oil content (seeds) of 40 per cent and around 20 per cent respectively. The rest of the seeds are converted to either food or livestock feed.

Basically all types of plant oils may be used in energy production; however, diverging characteristics lead to some oils being more suitable than others. Refined vegetable oils used for light and heating are one of the earliest forms of processed energy that have been identified.

Rapeseed oil is the most important vegetable oil in biodiesel production, the runner up being soy based diesel. Other important oil plants include sunflower, jatropha and palm oil. Below a table showing the yield potential for different oil plants is included:

Table 1: Oil yields from different oil plants

Plant	Latin	Kg Oil/hectare
Soy	*Glycine max*	375
Rapeseed	*Brassica napus*	1000
Jatropha	*Jatropha curcas*	1590
Oilpalm	*Elaeis guineensis*	5000

Although pure, processed vegetable oil can be used in diesel engines, the fuel specification suggests that the vegetable oil should be transesterified to biodiesel prior to use in domestic ferry engines.

1.4.2 Biodiesel

Biodiesel may be produced from plant oils or animal fat. In Europe rapeseed (canola) is the most frequently used product in biodiesel manufacturing.

The biodiesel is usually produced in a chemical process called transesterification, where alcohol (usually methanol) is added to the crude vegetable oil. Here the fat molecules in the oils are torn apart, leaving only combustible hydrocarbons.

The end result is a fuel called Methyl Ester or biodiesel. The word "Methyl" indicates the use of Methanol in the process; whereas the result from employing ethanol is called Ethyl Ester here the by-product is called Glycerine. The latter method was patented in 1940 when glycerine was crucial in the making of explosives.

Biodiesel is sometimes referred to as "Transesterified Vegetable Oil" and was initially used in heavy vehicles during World War II in South Africa. Figure 1 shows the steps in biodiesel production:

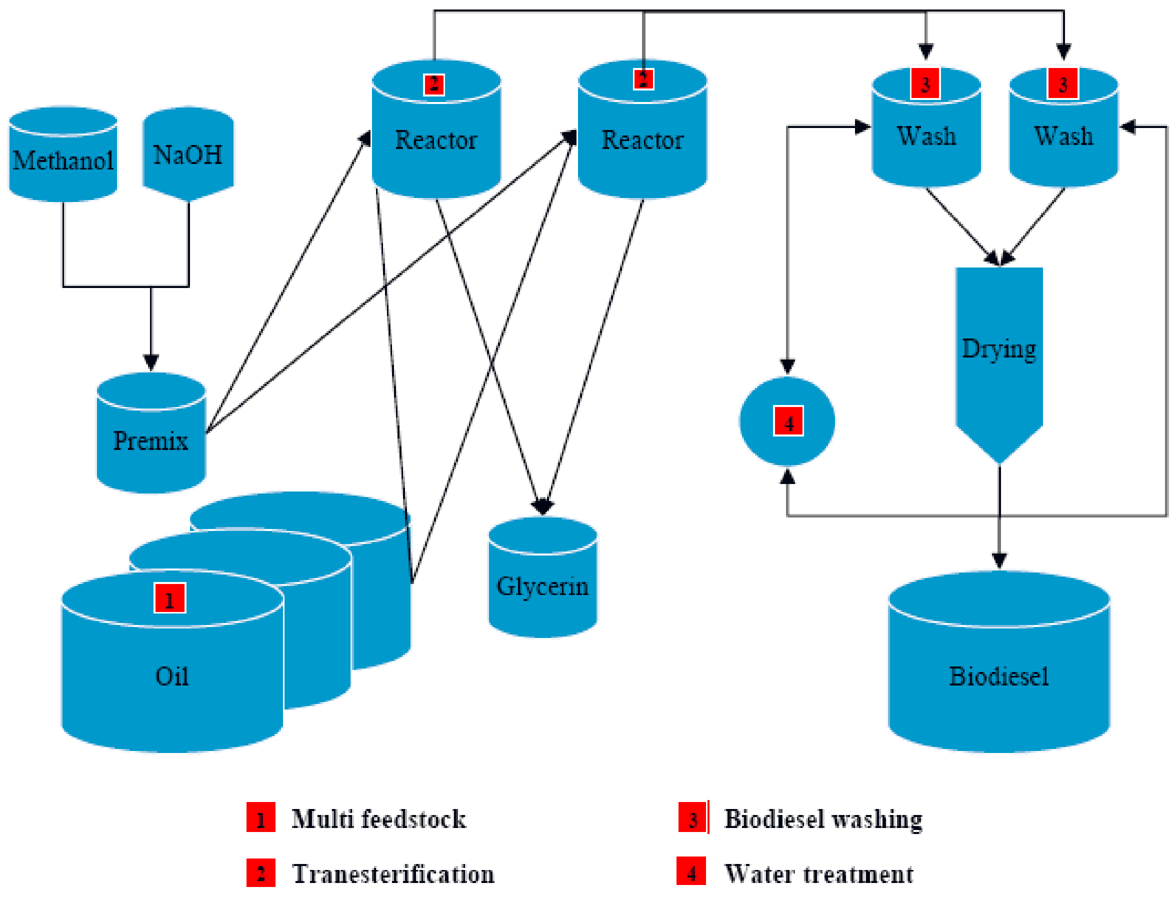

Figure 2: Biodiesel production process scheme

Biodiesel based on rapeseed is called Rapeseed Methyl Esther (RME) while biodiesel derived from soy is labelled SME. FAME (Fatty Acid Methyl Ester) is often used as a name for the entire group of biodiesels made from plant and animal fat.

1.4.3 Other remarks

Although vegetable food oils are the main feedstock for biofuels production today, this is not believed to be the case in coming years. As use of biofuels increase, research on new and better suited feedstock will result in a wide range of different biofuels feedstock. Norway and many other countries have big areas of unused forest which can be utilized for biofuels production. Also Algae have shown signs of being a promising feedstock for biofuels production. So-called second generation biofuels will bring about a sophisticated production mode. Here the only real requirement for producing biofuels is a biological feedstock input. Feedstock like switch grass in the USA has impressive yield and, may be very interesting, given a successful development of technologies for cellulosic biofuels.

1.5 Limitations of the study

This is a literature study only and no experimental work has been conducted during the work of this report. However, some of the information given is based on experimental work.

The study focuses on Norwegian ferries in domestic waters and some of the information may be irrelevant for international readers. However the findings are transferable also to international ferry transport.

Lastly, this is a technological feasibility study and does not consider other segments of biofuels use and production than climate and local pollution. Regardless of this, ZERO has been deeply involved with work to better understand the consequences of producing biofuels. In 2008 ZERO published a report on biofuels and poverty (Hole 2008). Unfortunately, this report is available in Norwegian only.

2 Experiences from around the world

Though the idea of using biofuels in the ferry fleet may seem new in Norwegian waters, it has been tested out several places, most prominently in Northern America. The objectives for using biodiesel in ferries have mainly been driven by local pollution in densely populated areas.

2.1 Washington State Ferries

In Washington, USA, an initial test project with biofuels on ferries has been launched. Washington State Ferries is the largest ferry company in the world based on the number of vehicles carried annually and burns annually about 64 million litres diesel fuel on its ferries. In 2004 Washington State Ferries started using biodiesel on trial in their ferries. Aiming for cleaner and healthier air in heavily polluted areas, biodiesel emerged as a viable alternative for the ferries administration.

Figure 3: Washington State ferries in operation (Washington State Ferries 2008)

Fauntleroy-Southworth-Vashon ferry route was chosen for the initial tests. The project used about 540 000 litres of biodiesel until the project was suspended in 2005 because of fuel filter clogging problems. Filter clogging is a returning issue when using biodiesel (Washington State ferries 2008).

In March 2008, phase III in the biodiesel program was launched, using low-blends of biodiesel. The three ferries Issaquah, Klahowya and Tillikum will all begin trials with 5 per cent biodiesel blended in petroleum diesel. As the project progresses, the mix will be increased to 20 per cent biodiesel. The testing of biodiesel in the ferries will continue until February 2009 and a final project report is to be finalized by June 2009. This report is to be made with recommendations for fuel quality specifications, test procedures and sampling protocols that could be applied both for land and marine based biodiesel users.

This project in Washington is based on several initiatives by state authorities to use biodiesel. The State governor of Washington, Chris Gregoire, issued an executive order for sustainability in 2005. 2006 legislation demanded state agencies to use at least 20 per cent biodiesel by the end of 2009 (Washington State Ferries 2008).

The project is funded by federal grant and financial contributions from Seattle City Light, the altogether budget is estimated to 875 000 US dollars.

2.2 Sydney biodiesel ferry program

Sydney Ferries is an old and important ferry company transporting passengers in Sydney. During 2005 and 2006 some company ferries were tested using biodiesel in blends varying from 20 per cent up to 100 per cent biodiesel.

The first vessel, the Borrowdale, was adjusted according to the list below:

- Lube oil and filter change
- Fuel and air filter change
- Fuel injector change
- Valve clearance change
- Non-invasive condition assessment including cylinder bore scope
- Fuel tanks drained, cleaned and dried

The trial results were not published, but by 2006 the trials were still ongoing. It has not been possible for ZERO to obtain more information on the project (Sydney ferries 2006).

2.3 Fanøfergen in Demark

During the summer of 2007 Pon Power tried 100 percent biodiesel (B100) on Fanøfergen (owned by Scandlines), transiting between Esbjerg and Fanø. This is one of the busiest ferry services in all of Denmark.

On the car ferry "Fanøfergen" (Scandlines) in Denmark, one Caterpillar 3412 engine (about 600 kW) was run on B100. The results of these test were positive and no adjustments was done prior to testing. The operation went smoothly until the ship was sold and the project stopped. However, the tests were helpful in building knowledge on biofuels used in ferries both for engine manufacturers and ship owners. According to Pon Power this was also the aim of these tests, and they where sad to abandon the project at an early stage (Jannik Stanger 2008)

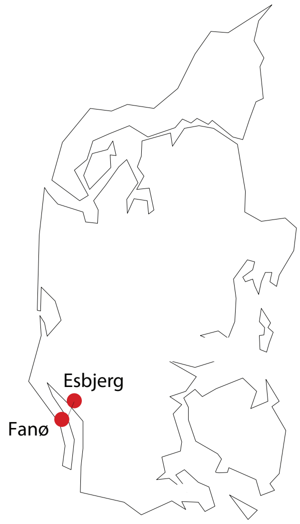

Figure 4: Esbjerg - Fanø

2.4 BioMer Project

Although the BioMer project did not involve car ferries, the boats involved are of considerable sizes and the project so comprehensive that it deserves further comment.

The BioMer project was a joint undertaking by Maritime Innovation Sine Nomine Group and Rothsay (a biodiesel manufacturer). The four Montrèal cruise companies Croisères AML, Bateau-Mouche, Lachine Rapid Tours and Lachine Canal Cruise provided 12 boats for biofuel trials (BioMer 2005).

The BioMer project ran from mid-May to mid-October 2004. The project's objectives were to:

- Test the use of pure biodiesel (B100) as an alternative fuel to tour boats of various sizes
- Assess the economic viability and benefits of biodiesel in routine operations of the marine industry
- Measure the environmental impact of biodiesel

The 12 boats used in the project were all passenger boats of which the biggest had a capacity of 750 passengers. The biofuel used was biodiesel made from offal and waste cooking oils. Biodiesel of this kind is of poor quality but could also potentially be very cheap.

Table 2: Fuel consumption results from the BioMer project (BioMer 2005)

	Difference in Biodiesel Energy Content per Unit Volume	Difference in Engine Perfomance	Difference in Fuel Consumtion
B5	-0.3%	+2.3%	-1.8%
B20	-1.4%	+2.3%	-0.8%
B100	-7.2%	+3.3%	+3.3%

As the above table shows, the biodiesel's superior burning properties lead to a generally improved performance, even though biodiesel has lower energy content than petroleum diesel.

One important finding worthy of comment originated from the project team tests of biodiesel's degradable properties. The tests were carried out in the St. Lawrence River environment. The result showed that biodiesel degraded 2.5 times as fast as petrodiesel.

The project report contains a few recommendations regarding the operation of biodiesel in boats, of which some of the most important are summarized below:

- In order to reduce release of build-up due to the biodiesel's solvent effects it is necessary to thoroughly clean onboard and dockside fuel tanks before switching from petroleum fuels to biofuels. Even at blends as low as 5 per cent biodiesel cleaning of tanks most be done. If the cleaning of storage tanks prior to the fuel switch is not possible, schedule three or four additional fuel filter changes during the cleansing period.

- Tune diesel engines e.g. by adjusting injection timing and duration, to optimise efficiency and performance before any use of B100. Note that after such tuning, the engine must run on B100 exclusively and should be readjusted before returning to petrodiesel.

The study concludes that the BioMer project yielded very promising results for using biodiesel in maritime transport (BioMer 2005).

2.5 Aquabus Vancouver

Small ferries in Vancouver have just started using a vegetable mix and biodiesel in their vessels. The vessels usually ship tourist and commuters between various parts of the city. In the beginning of the trials with pure biodiesel, the fuel filters clogged, making the operation difficult. It can be noted that the vegetable oil mix was applied to prevent clogging of filters (Metro Vancouver 2008.)


Figure 5: Metro Vancouver (2008)

3 Biodiesel compatibility

The engines onboard most Norwegian ferries have installed diesel engines. The most common fuel is Marine Gas Oil (MGO). Biodiesel is a product similar to regular marine fuel oils. Actually, the diesel engine was originally designed for vegetable oils. Rudolf Diesel wrote in his patent application in 1912:"The use of vegetable oils for engine fuels may seem insignificant today, but such oils may become in the course of time as important as petroleum and the coal tar products of the present time."

In recent years, many of the biggest engine manufacturers in the world have started testing and commercial production of engines for biofuel use in stationary energy production. The subsidizing of green energy production in the EU has increased the energy production based on biofuels. Marine engines differ from these engines; however, the differences are not overwhelming.

Based on the report "Biofuels in Ships" and more specific information on Norwegian ferries an investigation with engine manufacturers has been conducted. Its results are summarized below.

3.1 Wärtsilä

It is interesting to note that Wärtsilä, one of the most important engine manufacturers in shipping, also has a lot of knowledge on the use of biofuels in their engines. Since the 1980s Wärtsilä have been working on alternative fuels. In 1995 rapeseed oil was tested and approved as a viable fuel for Wärtsilä engines, and the first commercial vegetable oil fuelled power plant with a Wärtsilä engine was installed in 2003 in Germany (Juoperi et al. 2007).

There has been less research within the marine division, due to the economical situation of fuels for world shipping. Due to the minimum of regulation of world shipping, marine fuels are not taxed and relatively cheap. Unlike land transport there is obviously not much room for tax relief on biofuels (Kai Juoperi).

Wärtsilä are eager to follow any trial projects that would emerge on biodiesel in ferries. On a general basis they are positive towards using biodiesel in marine engines, and eager to know more about the potential long term effects of biodiesel on the engine system (Mats Lagström)

When asked for a specific engine in a Norwegian ferry, Wärtsilä approved for biodiesel use in M/V Bastø III, however a technical check has to be made and some converting may be necessary. The ferry M/V Bastø III is equipped with two Vasa LN32 engines (Kai Juoperi).

3.2 MAN diesel

MAN B&Ws experiences with biodiesel date back to 1994. Although their research has been focused mainly on non-marine applications, the company has a great deal of knowledge on biofuel compatibility in their engines.

They commenced research and tests on of a wide variety of biofuels in order to figure out which were most suitable. A pilot plant for biofuels with an installed power of 750 kW was delivered in 2001. Since then the company has gained a lot of know-how on how to operate low and medium speed engines using biofuels (MAN B&W Diesel press release 2007).

A new milestone was reached in 2007 for MANs biofuels efforts when a large 2007 cogeneration plant, employing a biofuel version of the highest powered four-stroke medium speed engine in MAN Diesel's range, commenced operation at Mouscron in Belgium. The Belgian plant is based on an 18 cylinder configuration type 18V48/60 engine.

MAN B&W has provided engines to a number of biofuel plants. For the engines used in ferries biofuels operation could also be possible, but the main obstacle for introducing biofuels is the difference in price with MGO.

3.3 Caterpillar

Chapter 2.3 described the test on Caterpillar engines running on biodiesel in a ferry in Denmark. The tests showed that biofuels could be used on ferries. However, according to Pon Power Norway the trials ended too early to allow any conclusions on potential long term effects of using biodiesel in marine engines (Jannik Stanger).

3.4 Rolls Royce/Bergen Diesel

Lutz Liebenberg of Rolls Royce Norway states that they have had no experience with biofuels in their marine engines, but that they are planning to give it more attention after having received several enquiries from customers. On a general basis Rolls Royce says biofuels should be well suited for use in ship engines (Lutz Liebenberg).

4 Technical consideration – the engine and the fuel system

Ferries in the Norwegian fleet display a variety of engines and age. Old engines may have a fuel system with components of poor rubber quality; this may prompt the necessity of some changes on the engine and the fuel system. For smooth operation on biofuels, cavitation resistant material may be needed. A typical engine and fuel system for a car ferry is described below, and adjustments to the engine are commented. As the fuel treatment system varies from one installation to another, the following description may also vary.

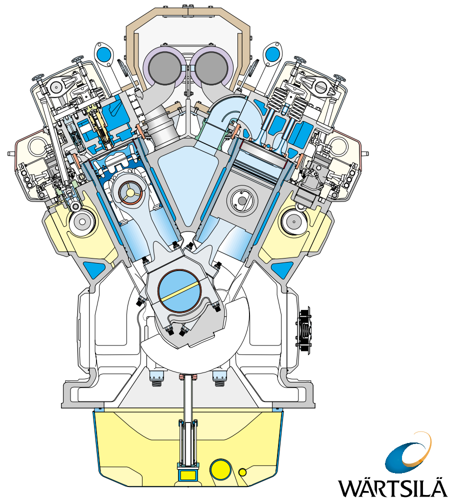

Figure 6: Vasa 32 Low NoX engine (Wärtsilä 2002)

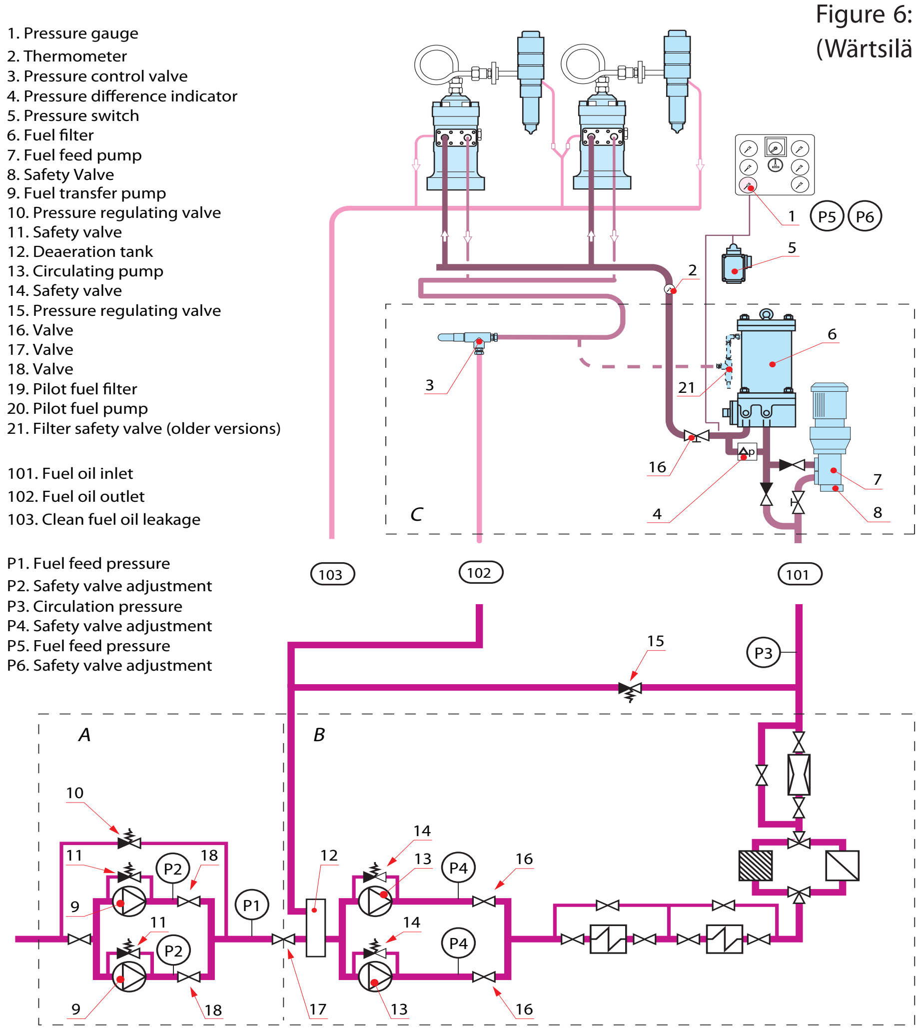

Figure 7: Fuel system for Vasa 32LN (Wärtsilä 2008)

This engine is somewhat large for a normal ferry; the installed power varies from 1480 kW to 7380 kW. The smallest engines installed in Norwegian ferries are only a few hundred kW, while the biggest engines are about 7000 kW (RLF 2008).

According to Wärtsilä, biodiesel operation on Vasa 32LN should go smoothly on biodiesel according to specification EN14214. This is the type of engine installed in Bastø III, owned by Bastø-Fosen A/S. The ship operates between Moss and Horten in south-eastern Norway (Kai Juoperi, 2008).

The biodiesel standard EN14214 is attached in appendix 1, the ISO standard for distillate marine fuel is attached in appendix 2.

4.1 Injection pump

When using vegetable oil in engines, one relevant problem tends to be the cavitation in injection pumps. Cavitation in injection pumps is mainly due to increased fuel temperature, which reduces the viscosity and causes the fuel to boil locally. Cavitation in most cases is very isolated, but deep. Most probably due to the fact that power plants are running continuously with the same load. In contrast to land based power plants, marine engines often run on different loads, due to shifting of running speed, for instance when entering a harbour. When using biodiesel, cavitation may also be a problem, although not as serious as when using vegetable oil (Wärtsilä 2007).

In Figure 8 the injection pump used in Vasa 32 LN is showed. This pump is equipped with anti-cavitation helix suitable for biodiesel.

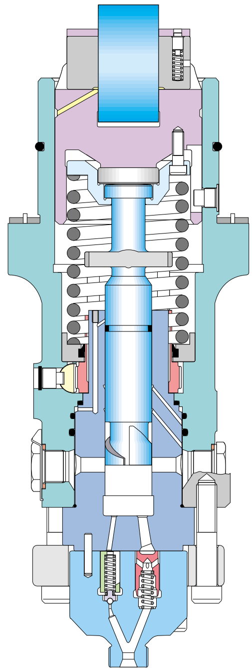

Figure 8: Typical Injection pump (Wärtsilä 2002)

4.2 Rubber seals in system

The acidity of liquid biofuels is highlighted as a potential problem in relation to biofuels in diesel engines. Wärtsilä has a limit of total acid number (TAN) of 5 mgKOH/g (Juoperi et al.2007) whereas MAN specifies a TAN limit of 4 mgKOH/g (MAN Diesel 2006). The EN14214 biodiesel standard limits to 0.5 mg KOH/g, well below the limits set by engine manufacturers. All new Wärtsilä engines use seals made from cavitation resistant material Viton (FPM). This means that biofuels of EN14124 quality should not pose problems when applied in these engines (Mats Lagström, 2008).

Old fuel systems in ferries may have poor rubber quality seals, and long term effects of biodiesel on these seals may be serious. Providing seals made from cavitation resistant materials may be considered.

4.3 Filters and fuel lines

The most frequently reported problem with biodiesel in fuel systems is the potential clogging of filters in a start-up phase when switching to biodiesel. Biodiesel's solvent properties can potentially cause clogging of fuel filters from HFO deposits in the storage tanks. This is normally only reported to happen in a start-up phase when switching from petroleum fuels to biodiesel. In order to prevent this from happening, it is important to thoroughly clean onboard storage tanks before use. Filter cartridges should be changed regularly, as is the case when using petroleum fuels.

Wärtsilä reports that the fuel lines in their new engines are made of mild carbon steel running on raw palm oil of considerable higher acidity on stationary thus operation on biodiesel should pose no problem (Mats Lagström, 2008).

4.4 Storage tanks

Normal acid proof storage tanks can be used for biodiesel. Nevertheless, by switching from HFO, deposits in the storage tanks can cause clogging of filters as mentioned in the previous section.

The fact that biodiesel combines with water from the environment has been raised a potentially cumbersome point. The biodiesel standard EN14214 (Appendix 1) sets a limit of 500 mg/kg. Wärtsilä informs that moisture should not pose a problem if the biodiesel is according to standard. They add that they have used biodiesel in backup systems for the vegetable oil stationary energy production in Italy. Using these systems in occasional cold weather, biodiesel has not caused operational problems. In this respect, the operation on engines should not be more problematic (Kai Juoperi, Wärtsilä).

4.5 Other challenges

Microbial growth is mentioned as a problem when using biodiesel in boats and ships. This is also a problem occurring when using regular petroleum diesel. Biodiesel's solvent properties can detach microbial growth bacteria from the inside of storage tank and block filters. To prevent this from happening, tanks should be cleaned before using biodiesel (von Wedel 1999).

Biodiesel will degrade faster than conventional diesel. Ageing and oxidation of biodiesel can lead to increased TAN value, increased corrosion activity and formation of sediments that could clog filters. High temperatures, sunlight and atmospheric oxygen can speed up the ageing process (NREL, 2004). Ferries are in traffic most of the year and make continuous use of fuel. This should keep the TAN number well below the 4 mg KOH/g at all times.

Due to the somewhat poorer cold flow properties of biodiesel, its use in cold temperatures has been listed as problematic. For biodiesel at sea this is worth mentioning. The fuel temperature has to be kept 10-15°C above cloud point/CFPP, which should not be a problem. Cold flow properties should thus not hinder the use of biodiesel in ferries (Wärtsilä 2008). Biodiesel with additives can manage temperatures below minus 25°C.

Temperature control is important when operating biodiesel. It should be kept at the correct temperature in the fuel system to ensure proper viscosity. The fuel feed system may then be equipped with extra components like heaters, coolers, additional trace heating etc. in order to ensure correct fuel temperature (Niklas Haga).

5 Effects on the environment

The main reason for implementing biodiesel in ferries is to reduce greenhouse gas emissions. Currently there are no available measures to cut emissions from ships and boats substantially. However, biodiesel could without major difficulty be used in Norwegian ferries.

Although biodiesel is derived from renewable material, the use of hydrocarbons in a combustion engine will always cause emissions of some sort.

Combustion results in a number of very complicated reactions and the products formed depend on many factors. The degree of mixing of the biofuel and air can regulate the reactions occurring once the biofuel is ignited. In an ideal scenario with complete combustion there would be no emissions of carbon monoxide or unburned hydrocarbons, but this would increase emissions of NOx which is heavily influenced by the combustion temperature (Moran & Shapiro 2000).

5.1 Greenhouse Gas Emissions

The total GHG-emission from Norwegian ferries is estimated to 410 000 tonnes CO2, corresponding to about 1/10 of the total domestic sea transport emissions in Norway (Statistics of Norway).

Under the Kyoto protocol Norway has agreed to stabilize its greenhouse gas emissions on one percent above 1990 level. Figure 9 shows the emissions of greenhouse gases by source 1990 – 2006. Emissions from ferries sort under fishing vessels and coastal traffic.

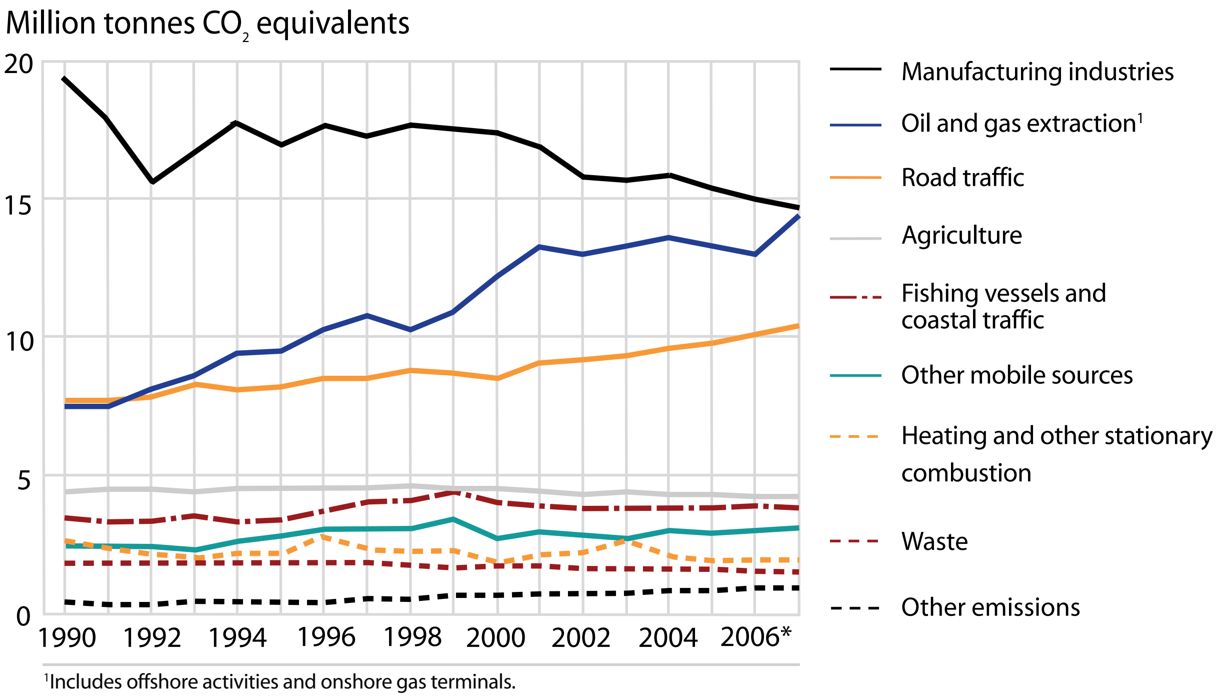

Figure 9: Emissions of greenhouse gases by source 1990 - 2006 (Statistics of Norway)

Biofuels should be considered a renewable energy source because the same amount of CO2 that is released from combusting biofuels has previously been taken up from the atmosphere by the growing plant, whereby net increase in the concentration of CO2 in the atmosphere is prevented (IEA 2003).

However, some fossil-fuel energy is used when producing raw material for biodiesel. The picture is further complicated by the fact that the fertilizer used to produce biodiesel crops itself releases nitrous oxide, a very potent greenhouse gas. Consequently it is necessary to consider the greenhouse gas emissions for biodiesel in a broader perspective.

A joint research study conducted by the European Council for Automotive R&D (EUCAR), The oil companies' European association for environment, health and safety in refining and distribution (CONCAWE) and The Institute for Environment and Sustainability of the EU Commission's Joint Research Centre (JRC) compares conventional automotive fuels and biofuels (EUCAR, CONCAWE, JRC 2007). According to this study rapeseed based biodiesel could save 53 per cent of greenhouse gas emissions compared to conventional diesel. This includes nitrous oxides (N2O) and fossil fuels used in production. Figure 10 is derived from the aforementioned study. The black lines on the graphs outline the possible error margin of the study.

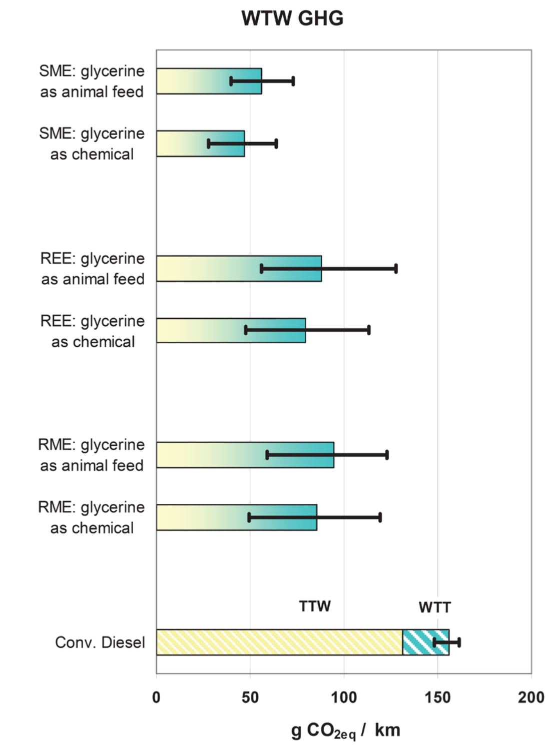

Figure 10: Well-To-Wheels greenhouse gas emissions from different pathways of biodiesel and conventional diesel (EUCAR, CONCAWE, JRC 2007)

Combusting most marine fossil fuels produce about the same amount of CO2, namely about 3.17 tonnes CO2 per ton of fuel, the same as for fossil diesel. This leaves the EUCAR report as a satisfactory baseline for comparison (EUCAR, CONCAWE, JRC 2007).

As seen from figure 10, RME (rapeseed based biodiesel) generates more greenhouse gas emissions than does SME (soy based biodiesel). Rapeseed based biodiesel is, however, the most common type of biodiesel in Europe and Norway. As indicated in figure 10, the fate of the by-products is of high importance for the final GHG-balance.

The level of uncertainty in the study presented in figure 10 is due to nitrous oxides (N2O) emissions from cultivation of the vegetable oil plants used for biofuels production, which is not well accounted for. The nitrous oxide emissions also vary with different feedstock. Crutzen et al. suggest that production of palm oil may lead to lower emissions than would rapeseed oil and soybean oil (Crutzen et al. 2007). Ligno-cellulosic second generation biofuels lead to a considerably lower level of N2O-emissions during production (EUCAR, CONCAWE, JRC 2007).

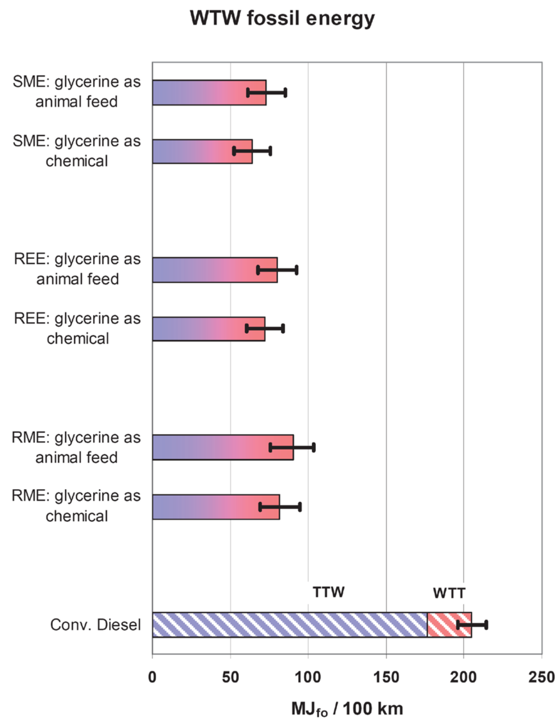

Figure 11: Fossil energy inputs to biodiesel production (EUCAR, CONCAWE, JRC 2007)

While the fossil energy inputs to the production of biodiesel is higher than for production of petroleum fuels, as can be seen from figure 11, still the fossil energy inputs in production is less than half of energy output (EUCAR, CONCAWE, JRC 2007).

5.2 NOx-emissions

Nitrogen monoxide (NO) and nitrogen dioxides (NO2) are by-products of the combustion process. NOx gases are not greenhouse gases but contribute to acidification that causes eutrophication and acid rain, the latter being a major environmental problem for Scandinavia and Northern Europe. .

The NOx-emissions from biofuels in engines are generally slightly higher than NOx-emissions from fossil fuels. Several theories exist as to why this is the case. One explanation is that the increased flame temperature caused by reduced concentration of carbon soot is believed to increase emissions of NOx. However, several factors affect the NOx-emissions.

In 2002 the US Environmental Protection Agency released a report based on a number of tests of engines using biodiesel. Large truck engines were used with both soy-based biodiesel and petroleum diesel. Figure 12 shows the results of the comparison:

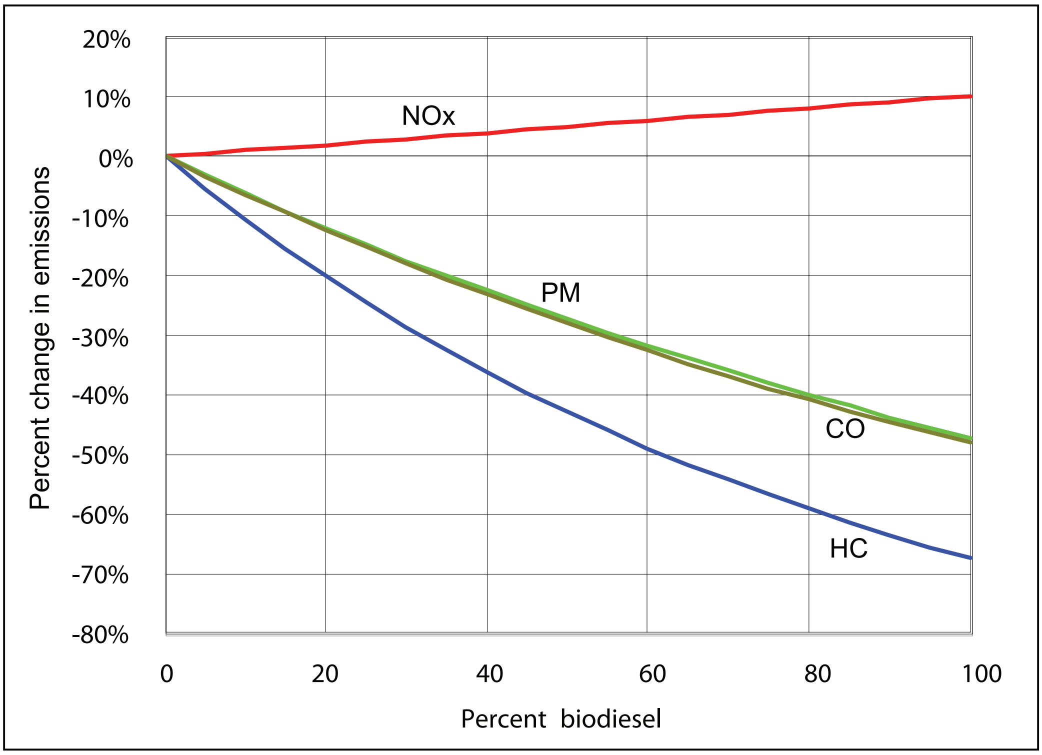

Figure 12: Emissions related to different blends of biodiesel in autodiesel on a truck engine (EPA 2002)

In Norwegian inshore waters a tax on NOx was introduced 1st of January 2007 for many NOx-emitters, including vessels whose installed power exceeds 750 kW. There are several ways of dealing with the NOx problem, the most widely used for ships engines being Selective Catalyst Reduction (SCR), but also HAM-technology and water emulsion are potential solutions (Det Norske Veritas 2007).

Wärtsilä wet pack humidification is a new NOx-reduction concept developed by Wärtsilä. By injecting pressurized water into the combustion process, the NOx-formation is reduced. The idea is to lower the combustion temperature by adding the pressurized water into the combustion process after the turbocharger. This leads to lower formation of NOx. Wärtsilä claims this measure can reduce NOx-emissions by up to 50 per cent. The wet pack humidification principle is shown in figure 13 (Wärtsilä 2008).

Most new engines installed in ferries have installed different types of NOx-reducing equipment. Using biofuels in these engines is not documented to affect the level of NOx-reduction when using these technologies (Juoperi et al. 2007).

5.3 Sulphur emissions

Introducing biodiesel in ferries will significantly reduce emissions of sulphur compounds such as sulphur dioxide (SO2) from ships because of the minimal presence of sulphur in biofuels.

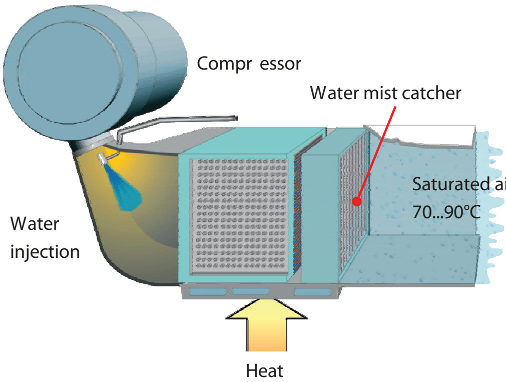

Figure 13: Wärtsilä wet pack humidification (Wärtsilä 2008)

Table 3: Sulphur content of different fuels (MAN B&W Diesel, 2006)

	Vegetable oil, treated, non trans-esterified	**Biodiesel** EN14214	**Marine Diesel** ISO 8217	**DMB Heavy** Fuel Oil ISO 8217 RM
Sulphur content (PPM)	<10	<10	< 20 000	<50 000[1]

[1]MARPOL Annex VI limit the max permissible sulphur content to 45.000 ppm

SO2 reacts with atmospheric water and creates a weak solution of H2SO4 (Sulphuric acid) which in turn leads to the formation of acid rain. This acidifies water bodies such as lakes and rivers and soil, leading to serious environmental damage.

When no sulphur is present in the fuel, there will not be any SO2 from combustion, so this problem does not arise when using biofuels.

Norway has a tax on fuels for domestic use containing sulphur. For each 0.25 weight percent sulphur in the fuel, the tax is 0.07 NOK/litre fuel (Lovdata 2007).

5.4 Particulates

Particulates are mainly PM10s and PM2.5. PM10s being of maximum 10 micrometers in aerodynamic diameter and PM2.5 being of maximum 2.5 micrometers in aerodynamic diameter. The particulates can cause serious health problems to the respiratory system of human beings.

A reduction of particulate matter emissions is documented when using biodiesel instead of automotive diesel. According to an American study, soy based or rapeseed based biodiesel could reduce particulate emissions by 35 per cent compared to automotive diesel (Strong et al. 2004).

Levels of PM in Oslo and Trondheim have been higher than set limits, mainly due to heavy traffic. High levels increase risk of health problems and authorities are trying to use different measures to cut emissions, such as reduced speed limits in periods of high concentrations.
.

The emitted particulates from engines consist of organic and inorganic constituents. Organic compounds include unburned fuel, while inorganic constituents include soot, sulphates and metallic compounds (Krahl et al. 2005). In biofuels, these inorganic constituents are not present. As a result there are minimal PM emissions from these engines which use biofuels.

The results from the BioMer project showed substantially better local air quality for passengers, probably due to reduced emissions of particulates (Biomer final report 2005).

5.5 Carbon Monoxide

CO-emissions derive from incomplete combustion of the fuel. CO is oxidized to CO2 in the atmosphere or eliminated by soil bacteria. In spite of this, carbon monoxide is not considered as important a polluting substance as particulates, SO2 or NOx (Krahl et al. 2005).

From figure 12 we learn that emissions of CO are reduced substantially by using biodiesel instead of automotive diesel.

5.6 Polycyclic Aromatic Hydrocarbons (PAH)

There are over 500 different PAH-compounds, and usually PAH exist in mixtures of substances.

PAH is found in crude petroleum. Incomplete combustion of organic material is the most important source of PAH. Inhaling air polluted with PAH can cause serious health problems such as cancer, a lowered immune system and increased risk of skin diseases (Norwegian Institute of Public Health, 2007).

A study conducted by the U.S. Environmental Protection Agency shows a reduction of PAH in the region of 75 per cent to 85 per cent when petroleum is substituted with biodiesel (National Biodiesel Board, 2007).

5.7 Marine environment

Huge spills of oil from ships have proven disastrous for marine environment.

In 1989 the oil tanker Exxon Valdez spilled an enormous amount of crude oil in the Prince William Sound in Alaska, creating the one of the worst environmental disasters the world has ever seen. This and other oil spills represent a continuing environmental threat all over the world.

Because they are biodegradable, a spill involving biofuels would be much easier to cope with. The US Environmental Protection Agency concludes that biofuels have less impact on aquatic and marine organisms than do petroleum oils. A study conducted in Idaho, United States, examined the biodegradability of biodiesel and petroleum diesel in water. The study found that rapeseed biodiesel was 95 per cent degraded after 23 days while petroleum diesel was only 40 per cent degraded.

Biodiesel is classified as food in many countries and the demands for handling and transport are less strict.

Low blends of biodiesel could also improve biodegradability of the petroleum based fuel; this is another reason for using low blends of biofuels in marine fuels (Von Wedel, 1999).

In the BioMer project in Canada the findings were that biodiesel degraded 2.5 times as fast as petrodiesel (BioMer 2005.)

6 The market situation for biodiesel

The production of biodiesel is a relatively young industry, and biodiesel is more expensive than regular marine fuels. As the global market for conventional marine fuels is not heavily regulated, a good way to implement biodiesel in the marine sector would be by introducing it in a more regulated market like the Norwegian ferry system.

6.1 Biodiesel production

The majority of global biodiesel production is based in the European Union, where 4.9 million tonnes of the world's total 6.4 million tonnes of biodiesel are produced (2006 figures). This is equivalent to 77 per cent of global production.

The EU has been producing biodiesel on an industrial scale since 1992. From 1998 there has been a rapid growth in biodiesel production, with a 54 per cent increase in growth between 2005 and 2006.

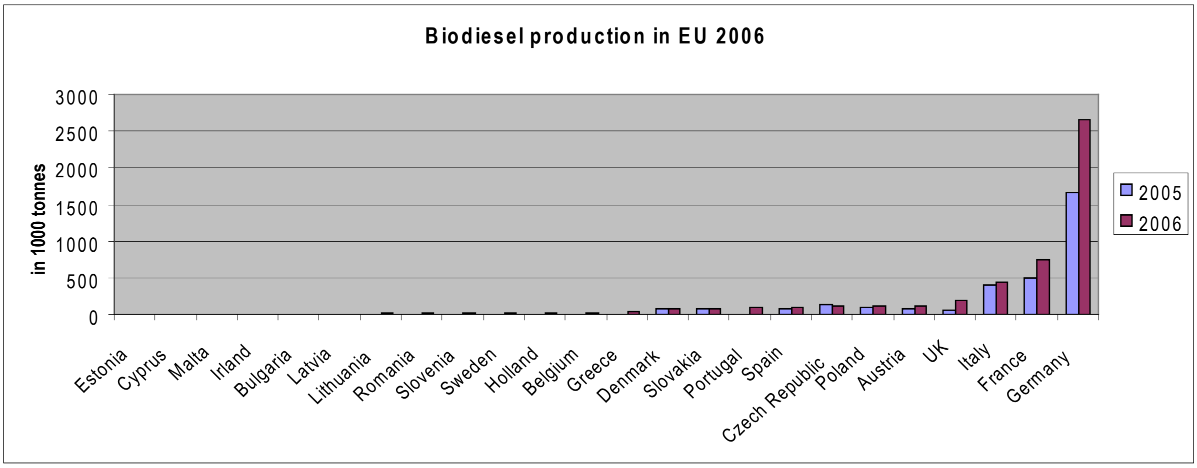

Figure 14: Production in the EU 2006 (European Biodiesel Board 2007)

Biodiesel production is rapidly increasing, and there is sufficient spare capacity to allow for higher levels of production in case of increased demand. By 2007 the European Biodiesel Board (EBB) reported a production capacity of 10.3 million tonnes in the EU only. This illustrates the great potential for increased production. Biofuel Market Worldwide predicts a 30 per cent annual growth from 2006 and an estimated global biodiesel production in the region of 11 million tonnes by 2010 (RNCOS 2006).

The International Energy Agency (IEA) expects a doubling of annual biofuel production by 2011 (International Energy Agency 2006). Biodiesel production correlates with demand, higher demand triggering higher production as the production capacity is in place.

There is a huge amount of fallow land in the EU, amounting in 2005 – 2006 to 7.7 million ha (Eurostat 2005). This land can be used to produce biofuels and substantially increase production.

Vegetable oil is the raw material for biodiesel production. Global vegetable oil production is in excess of 100 million tonnes, and biodiesel therefore only composes about 6 per cent of global production volume of vegetable oils (Fediol 2006).

6.2 The cost of biodiesel

An average ferry uses about 700 tonnes of fuel each year, leaving fuel costs at around 4 million NOK. A switch to biodiesel will increase the fuels costs by around 55 per cent to around 6.3 million NOK. These calculations are based on present day prices and regulations, whereas political incentives can change the profitability of using biodiesel instead of regular marine fuels. Also, the price of petroleum based diesel has continued to increase during the last few years. This trend shows no signs of weakening and may further increase the competitiveness of biodiesel.

6.3 Availability of biodiesel

Several companies offer biofuels in Norway, and together these producers can provide big quantities for the Norwegian market. Most traditional oil companies can provide bulk volumes of biodiesel on demand.

Biodiesel is currently not produced at a large scale in Norway, but there is some import from the European spot market. The biggest Norwegian actor BV Energi went bankrupt in April 2008, leaving Norway without major biodiesel manufacturers. Nevertheless, the company Uniol is currently building a large biodiesel plant.

Habiol

Hadeland Bioolje AS (Habiol) was established in 1994 and connects to the agricultural environment of Hadeland. Since its founding Habiol has distributed small quantities of biodiesel imported from its German partner ADM Connemann.

The company will distribute the biodiesel produced at Uniol's new factory. Currently Habiol operates two filling stations for biodiesel in Norway.

Uniol

In June 2006 Habiol, Unikorn AS, Borregaard Industrier AS and Østfoldkorn founded the company Uniol AS. Uniol is currently building a factory that will be finished by the end of 2008. This factory will have a production capacity of about 100 000 tonnes biodiesel. The factory is flexible as to which feedstock is being used and is located next to a pressing facility for soy beans. Uniol will make use of great parts of the already existing infrastructure from this pressing facility. Soy oil will be an important raw material for the biodiesel processed at the facility.

StatoilHydro

StatoilHydro is a big Norwegian oil company with a vision of becoming an important provider of biofuels. StatoilHydro's first biodiesel filling station in Norway for B100 biodiesel was opened in April 2008.

YXenergi

YX Energi provides B100 biodiesel. Currently YX sells biodiesel from eight filling stations for the same prize as petroleum diesel.

YXenergi also claim they can provide biodiesel for ferries. However, as they have not previously provided biodiesel to ferries, each project will have to be evaluated (Odd Sahlberg 2008).

EcoFuel AS

EcoFuel is a Norwegian company specializing on trading biofuels and also doing consulting in this area. EcoFuel aims for an international market with products that comply with international demands and certifications. The main focus have been import of biofuels produced in Asia, Africa and America.

Energilotsen (Sweden)
Energilotsen is a Swedish trading company which deals biooils to larger heating centrals. The company offers straight vegetable oils, animal oils and marine oils based on byproducts from the food industry. Energilotsen offers biooil-blends of different qualities, some of which may be suitable for use in ferries. Currently they are only offering biofuels for the Swedish market, but may also deliver to Norway if there is demand for it.

Happy Biofuels
Happy Biofuels is a Norwegian company based in Kristiansand, founded in 2007. Currently they operate two fillings stations and import biodiesel from rapeseed oil.

MBP
MBP Norway is located in Greåker, focusing on biological by-products from different industries. Their most important business venture is delivering a biooil by-product from fish-oil production. Whereas their feedstock is in Norway, most of their business is related to Sweden, as the market for biofuels is much larger there.

BioFuel AS / BioDiesel Norge
This Norwegian company aims to produce biofuels from jatropha nuts grown in Ghana. The goal is to produce the first quantities of jatropha oil for commercial sale by the end of 2008. In eight years BioFuel AS hopes to produce 25 000 barrels of jatropha oil per day.

The company is mainly focusing on upstream activities connected to jatropha oil, but they also operate two pumps in Norway. Biofuel AS offers bulk volumes to big contractors and may also sell to major and serious buyers in Norway (Steinar Kolsnes).

BV Energi
This company produced biodiesel from a factory in Hurum previously used for producing glue. The plant had a production capacity of 300 000 tonnes per year, equivalent of 15 per cent of the Norwegian consumption of auto diesel oil (1.7 million tonnes diesel). The feedstock for the production was rape oil imported from Europe. BV Energi has also built the most extensive net of biodiesel filling stations in Norway. After the company went bankrupt in April 2008, the owners are now trying to sell the production facility and the extensive net of filling stations.

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8 Appendices:

Appendix 1 European biodiesel standard EN14214

Property	Units	lower limit	upper limit	Test-Method
Ester content	% (m/m)	96,5	-	pr EN 14103d
Density at 15 °C	kg/m^3	860	900	EN ISO 3675 / / EN ISO 12185..
Viscosity at 40°C	mm^2/s	3,5	5,0	EN ISO 3104
Flash point	°C	> 101	-	ISO CD 3679e
Sulfur content	mg/kg	-	10	-
Tar remnant (at 10 % distillation remnant)	% (m/m)	-	0,3	EN ISO 10370
Cetane number	-	51,0	-	EN ISO 5165
Sulfated ash content	% (m/m)	-	0,02	ISO 3987
Water content	mg/kg	-	500	EN ISO 12937
Total contamination	mg/kg	-	24	EN 12662
Copper band corrosion (3 hours at 50 °C)	rating	Class 1	Class 1	EN ISO 2160
Thermal Stability	-	-	-	-
Oxidation stability, 110°C	hours	6	-	pr pr EN 14112k
Acid value	mg KOH/g	-	0,5	pr pr EN 14104
Iodine value	-	-	120	pr pr EN 14111
Linolic Acid Methyles-ter	% (m/m)	-	12	pr pr EN 14103d
Polyunsaturated (>= 4 Double bonds) Methy-lester	% (m/m)	-	1	-
Methanol content	% (m/m)	-	0,2	pr pr EN 14110l
Monoglyceride content	% (m/m)	-	0,8	pr pr EN 14105m
Diglyceride content	% (m/m)	-	0,2	pr EN 14105m
Triglyceride content	% (m/m)	-	0,2	pr EN 14105m
Free Glycerine	% (m/m)	-	0,02	pr EN 14105m / pr pr EN 14105m / pr EN 14106
Total Glycerine	% (m/m)	-	0,25	pr EN 14105m
Alkali Metals (Na+K)	mg/kg	-	5	pr pr EN 14108 / pr / pr EN 14109
Phosphorus content	mg/kg	-	10	pr EN14107p

Appendix 2 Fuel specification – Distillate marine fuels

ISO 8217:2005(F) fuel quality standard for distillate marine fuels.

Parameter	Unit	Limit	DMX	DMA	DMB	DMC
Density at 15 °C at 15 °C	kg/m^3	Max	-	890.0	900.0	920.0
Viscosity at 40 °C	mm^2/s	Max	5.5	6.0	11.0	14.0
Viscosity at 40 °C	mm^2/s	Min	1.4	1.5	-	-
Micro Carbon Residue at 10% Residue	% m/m	Max	0.30	0.30	-	-
Micro Carbon Residue	% m/m	Max	-	-	0.30	2.50
Water	% V/V	Max	-	-	0.3	0.3
Sulphur [1]	% (m/m)	Max	1.0	1.5	2.0	2.0
Total Sediment Existent	% m/m	Max	-	-	0.10	0.10
Ash	% m/m	Max	0.01	0.01	0.01	0.05
Vanadium	mg/kg	Max	-	-	-	100
Aluminium + Silicon	mg/kg	Max	-	-	-	25
Flash point	°C	Min	43	60	60	60
Pour point, Summer	°C	Max	-	0	6	6
Pour point, Winter	°C	Max	-	-6	0	0
Cloud point	°C	Max	-16	-	-	-
Calculated Cetane Index		Min	45	40	35	-
Appearance			Clear & Bright		-	-
Zinc [2]	mg/kg	Max	-	-	-	15
Phosphorus [2]	mg/kg	Max	-	-	-	15
Calcium [2]	mg/kg	Max	-	-	-	30

1: A sulphur limit of 1.5 % m/m will apply in SOx Emission Control Areas designated by the International Maritime Organization. In addition, ports and port states may specify more stringent requirements.

2: The Fuel shall be free of ULO (Unused Lube Oil).
A Fuel is considered to be free of ULO if one or more of the elements are below the limits. All three elements shall exceed the limits before deemed to contain ULO. The above table is taken from ISO 8217 Third Edition 2005-11-01 Petroleum products - Fuels (class F) - Specifications for marine fuels is reproduced with the permission of the International Organization for Standardization, ISO. This standard and any other referenced ISO standard can be obtained from any member body or directly from the Central Secretariat, ISO, Case postal 56, 1211 Geneva 20, Switzerland. Copyright remains with ISO.

Appendix 3 ZERO Emission Resource Organisation

www.zero.no

Our vision

A world where carbon emissions cause no threat to nature and environment.

Our mission

ZERO will contribute to limiting the threat posed by climate change by promoting carbon-free energy solutions. In our view, emission-free alternatives exist for all energy use, and ZERO works continuously for their realisation.

We therefore:

- urge companies to choose carbon-free energy solutions and cooperate to put them into use
- seek contact with policy makers to favour such solutions
- collect and distribute information to contribute to their realisation.

Our method

In order to make emission-free solutions prevail, ZERO pursues a constructive role in the fight against climate change: Instead of negative campaigning, we prefer to advocate the solutions which we support.

ZERO aims to possess first class knowledge of carbon-free energy technology. We co-work with companies and industrial researchers to secure the know-how necessary to maintain that position.

ZERO views environmental problems from a broad perspective. Our technological and political knowledge enables us to identify areas where renewable energy solutions should be preferred to polluting ones, thereby acting as meddlers between companies, policy makers and industry researchers.

ZERO seeks influence wherever decisions affecting climate change are made. We seek contact with policy makers, whilst protecting our integrity to ensure that our advice is reliable and our information is to be trusted.

ZERO also acts as guardian and watchdog when carbon-free energy solutions are abandoned or framework for use of such technology is weakened.

Finally, in addition to lobbying towards industry and policy makers, ZERO informs the general public of renewable and carbon free energy solutions. We aim for our website www.zero.no to be a preferred source for news and information on the subject.

Our position

…towards companies

ZERO is a non-profit foundation.

ZERO is an environmental organisation. We are not consultants, the battle against climate change being our only mission. However, we participate in partnerships financed by third parties.

ZERO cooperates with companies who are polluters, in order to urge them to choose non-emission solutions, and with companies who make such solutions, in order to widen their use.

…towards other organisations

ZERO is the only Norwegian environmental organisation solely committed to fighting climate change. We never accept the use of fossil fuels without carbon dioxide burial.

As environmentalists, we demand that Norway cut carbon emissions by a minimum of 90 per cent. Still, ZERO's role is to be constructive and pragmatic, cooperating even with big polluters, if it can help obtain our goals.

We do not believe in moralization. Rather than urging people to reduce their standard of living, ZERO advocates solutions that enable people to maintain their current way of life.

…towards researchers
ZERO is not a research institute. We work with industry researchers to help develop and promote new carbon-free technology.

Our income

In addition to general sponsors, ZERO's sources of income include financial support for specific projects, as well as endowments. Contributions come from companies, individuals and Norwegian authorities.

ZERO is a foundation with no supporting members.
Neither are we paid consultants for companies or authorities.

ZERO has full intellectual property rights to its work. Sponsors to our reports and publications are highlighted.

Our fields of focus

ZERO works with a wide range of sources for greenhouse gas emissions. Below follows a list of our major fields of focus:

- CO2-capture and storage
- Electric power for the offshore sector
- Biofuels for road transport, ships and heating
- Wind energy
- Hydrogen
- Electric vehicles
- Other renewable energy

www.zero.no

ZERO