IVL report C346

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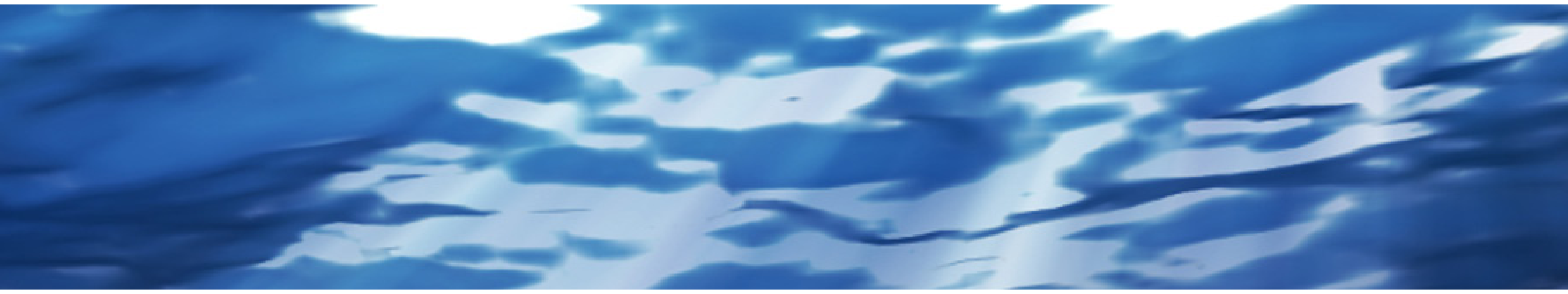
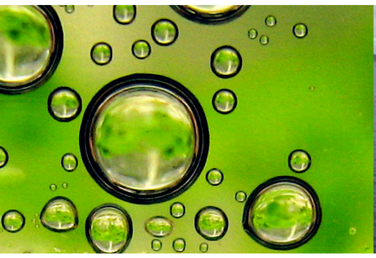
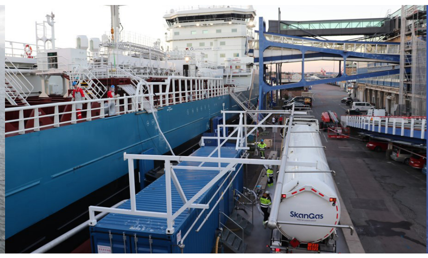


LIGHTHOUSE REPORTS

Low carbon marine freight

the possibility to introduce biobased fuels as marine fuels



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A feasibility study initiated by Lighthouse

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Low carbon marine freight

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Preface

This pre-study has been conducted within the Lighthouse cooperation by IVL Swedish Environmental Research Institute together with the School of Business, Economics and Law at University of Gothenburg.

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Summary

We have studied the possibility to introduce biobased fuels as marine fuels. A business model in which low carbon marine freight is offered to shippers is analysed. The model is in many ways similar to existing schemes in the energy sector ("green electricity", biogas and district heating). A fundamental principle of the model is that the cost increase in transportation when biobased fuels are used can be transferred to the end consumer.

Technical aspects, fuel supply issues, economic implications, and freight market aspects are all considered from a perspective of using liquid biobased fuel on ships. We find that both HVO and FAME/RME are suitable options to blend in fossil marine fuels. HVO comes with no special restrictions during operations, while the use of FAME/RME may need more close monitoring of fuel supply systems on board. However, price and availability are issues in large scale introduction on the market. Another option that is technically feasible is the replacement of LNG with liquefied biogas (LBG). From a sustainability perspective the use of palm oil as a source for HVO can be problematic due to unsustainable farming practices.

Several tests on biofuel use in marine engines have already been carried out. No technical issues are pointed out as the reasons for their short trial periods. We assume that the financial disadvantages have been the crucial aspects in these trials. There is also a recent example of a marine shipping service offering low carbon tonne miles to cargo owners.

In a continuation of this work, a project with real life tests is aimed for. In a workshop we therefore gathered stakeholders that have key roles in the proposed business model. A number of shippers that joined the workshop showed an interest in trying this model in cooperation with ship owners that provide their transports. Ship owners with bulk goods are less served by the suggested model, and alternative financial solutions are most likely needed in this segment.

Sammanfattning

Vi har studerat möjligheten att införa biobaserade bränslen som marina bränslen. En affärsmodell där sjöfart med låga koldioxidutsläpp erbjuds transportköpare analyseras. Modellen är på många sätt lik befintliga modeller inom energisektorn ("grön el", biogas och fjärrvärme). En grundläggande princip för modellen är att kostnadsökningen för transporter när biobaserade bränslen används kan överföras till slutkonsumenten.

Tekniska aspekter, problem med bränsleförsörjning, ekonomiska konsekvenser och marknadsaspekter studeras för att beskriva möjligheten att använda flytande biobaserat bränsle på fartyg. Både HVO och FAME/RME är lämpliga alternativ att blanda i fossila marina bränslen. HVO har inga speciella begränsningar under driften, medan användningen av FAME/RME kan behöva en utökad övervakning av bränslesystemen ombord. Pris och tillgänglighet är dock problem om biobränslet skulle börja användas i stor skala på marknaden. Ett annat alternativ som är tekniskt lättillgängligt är att ersätta LNG med flytande biogas (LBG). Ur ett hållbarhets-perspektiv kan användningen av palmolja som källa till HVO vara problematisk på grund av ohållbara odlingsmetoder.

Flera tester där biobränsle använts i marina motorer har redan genomförts. Inga tekniska problem påpekas som orsakerna till att försöksperioderna är korta. Vi antar att de ekonomiska nackdelarna har varit de avgörande aspekterna i dessa försök. Det finns också ett aktuellt exempel på en sjötransporttjänst som erbjuder transporter med låg fossilanvändning till lastägare.

En tänkt fortsättning på detta arbete är ett projekt med verkliga tester. På en workshop samlade vi därför intressenter som har nyckelroller i den föreslagna affärsmodellen. Ett antal transportköpare som deltog visade intresse för att prova modellen i samarbete med redare. Den föreslagna modellen bedöms passa bättre för transporter av RoRo-gods och containertransporter. För redare med bulkvaror behöver en alternativ modell tas fram.

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1. Low carbon marine freight services

This study considers the potential driving force of end consumers. We assume that there are consumers willing to pay more for their goods if they know they have been transported with a low carbon footprint.

The business model under study is based on that ship owners partly replace the fossil fuel on board with biofuels or other low fossil carbon technology. Shippers can then be offered a low carbon marine freight service, in proportion to the transport work that can be produced by the non-fossil energy on board. The shippers have to pay an extra price premium that later can be transferred to the end customers of their goods. The aim of the study is to investigate technical, practical, financial, and market aspects related to such a business model. The perspectives of shippers and cargo owners, ship owners or ship operators, and fuel suppliers are all considered.

About 80% of worldwide trade by volume and 70% of its value is carried out by ships (UNCTAD, 2017). Marine freight is often a more favourable option from a climate perspective than land based transport, with low emissions of CO_2 per unit transport work. However, in a procurement process, shippers seldom prioritise high performance in environmental and climate concern before freight service price (Lammgård and Andersson, 2014). A combined cause for this, and consequence of, has resulted in that no low carbon sea transport service has historically been marketed. Hence, ships run on fossil fuels and the climate impact is only related to improvements in design and operation of the vessel, factors rarely known to the cargo owner or his/her transport purchaser. Shippers who aim at reducing the carbon footprint from their supply chain therefore have a low potential for decarbonisation of ship transport.

Environmental impact from shipping is often less regulated than land-based businesses. Regulations on emissions to air from international shipping directly or indirectly cover emissions of nitrogen oxides (NO_X), sulphur dioxide (SO_2), particles, and carbon dioxide (CO_2). Compared to European standards for land based transport the regulations allow higher emissions of NO_X per unit work from marine engines and higher contents of sulphur is permitted in marine fuels. Particle emissions are only indirectly regulated via the sulphur content in fuel. Emissions of CO_2 are regulated since 2014 via the Energy Efficiency Design Index (EEDI), which requires ship owners to prove that new ships are designed to emit less CO_2 per distance sailed compared to a reference level. The EEDI is part of the international convention of prevention of pollution from ships, MARPOL (International Maritime Organisation, 2011). The reference line of EEDI considers the size of the ship (dead weight tonne) and distinguishes between different ship types. Further, the requirements in the regulation become more demanding in three steps over time.

Although ambitions on CO_2 reduction from the sector have increased, there has long been a lack of driving force to transform shipping to a low carbon transport mode. There has not been a regulatory push and, with a high price premium on biofuels or low carbon propulsion technology, no pull from shippers. The EEDI regulation will not necessarily result in significant reductions of CO_2 emissions from ships in operation. After several years of negotiation and diplomatic pressure by among others the EU states, the IMO recently agreed to create an initial strategy for the reduction of CO_2 emissions from ships. At a Marine Environmental Protection Committee (MEPC) meeting in April 2018, it was agreed that shipping shall peak its total CO_2 emissions as soon as possible in order to reduce them by 50% in 2050, compared to levels in 2008 (IMO, 2018). International shipping is not included in the Paris agreement.

The continuation of this pre-study is a suggested pilot project where the business model is tested in real life conditions. Cooperation with industrial partners has been secured during this pre-study, clarifying how different segments of shipping, e.g. RoRo, RoPax, Tanker, and Container, could fit the business model.

Any low carbon energy source is a potential alternative to the fossil fuel used on board; however this study focuses on liquid biofuels in particular. Many types of biofuels can be used in marine engines without any installation work on board. If they are used as drop-in fuels in smaller portions, no changes of lubricants or bearings are needed. Further, liquid biofuels are available on the fuel market. By these arguments, the liquid biofuels are considered as low hanging fruits for a project like this compared to installations for wind propulsion or electric power trains.

Although shipping has a truly international character, our study takes Sweden as a starting point when investigating potentials to start a project, and next look to the European level. No efforts are therefore made to map the international differences on the fuel and bunker markets.

2. Technical and practical aspects

Technical and practical aspects of replacing fossil fuels with fuels of bio-based origin include combustion issues, and issues relating to the bunkering process, and existing standards. Different production processes and raw material results in different types and qualities of biofuels, which also needs special consideration.

2.1 Available fuels

Marine fuels are pre-dominantly heavy fuel oils (HFO), a residual product from refineries, from a global perspective. However, in specific areas the use of marine gasoil (MGO) is more common due to legislations on the sulphur content of marine fuels. The Baltic Sea and the North Sea and the English Channel are such areas. Marine gasoil is also sometimes used in smaller marine engines such as marine auxiliary engines and engines on smaller vessels. Another fuel that is supplied for the northern European market is so called low sulphur fuel oil (LSFO). This fuel is low in sulphur but can apart from that be similar to a heavy fuel oil.

The biofuel alternatives selected for further study are hydro-treated vegetable oil (HVO), fatty acid methyl esters (FAME) and liquefied biogas (LBG). These are all functionally comparable to the fossil derived alternative. During discussions with the engine manufacturer Wärtsilä on the use of non-processed crude biofuels for the marine market, it was made clear that it was not recommended to blend these oils with traditional fuels without engine modifications (Wärtsilä, 2018). There are examples of low grade biobased fuel qualities that could replace the heavy fuel oils (HFO) traditionally used for marine propulsion. However, this study focuses mainly on replacement of marine gas oil, and to a certain extent liquefied natural gas (LNG). This is done since alternatives to those products exist in larger volumes on the fuel market. The business model will not make a distinction between the renewable energy carriers as such, and the three selected fuels presented below are merely to be considered as plausible first step options. Blended fuels are often referred to as drop-in fuels. Literature on the matter mainly refers to blends with HVO as drop-in fuel, while biodiesel is the term used for FAME.

HVO is produced from a multitude of renewable sources and although the name implies a vegetable origin; this is not always the case. An abundant source in international production is palm seed oil accompanied with sustainability issues during production. Other sources of HVO placed on the Swedish market are crude pine oil and residuals from slaughter houses. HVO is considered a high quality non fossil fuel that can be used as drop-in fuel in minor quotas, or fully replace the fossil diesel fuel.

FAME produced in Sweden is exclusively made from rapeseed oil and is called RME for rapeseed methyl ester (Energimyndigheten, 2017). The European fuel quality directive regulates diesel oil to contain a maximum of 7% FAME; however member states may permit the placing on the market of diesel with FAME content greater than 7 % (The European Parliament and the Council of the Euopean Union, 2009). This limit has also been the basis for the update of the ISO standard for marine fuels that was published in 2017. Small ports may not be able to supply ships with the bunker quality demanded and might on occasions be required to supply road diesel as bunker to ships. In order to follow standards for marine fuel, it was important that also these standards allowed up to 7% of FAME (CIMAC, 2017).

The biogas that is produced and used in Sweden is to 98% originating from residuals and disposed material, primarily sewage sludge and domestic and industrial food residues (Energimyndigheten, 2017). Sweden has one facility producing LBG from biogas (Energimyndigheten, 2017).

2.2 Bunker storage and bunkering issues

Fuel tank layout on board differs from one ship to another. Some ships can store multiple qualities while others do not have this possibility. Using a fuel with a drop-in of bio-based origin does not require a consideration of the tank layout on board. There might be cases where a ship owner wants to keep biofuel in 100% grade in a separate tank on board. For example, one scenario could be that fuel for one auxiliary engine will be replaced by biofuel. In these cases the tank arrangement on board can propose challenges for fuel storage. For such situations, there are no solutions with general applicability.

While HVO and LBG are adequate replacement fuels in all aspects related to combustion and bunker storage, FAME is sometimes accompanied with issues of oxidation stability. When FAME blended fuel is used on board, the recommendations are to avoid storing for more than 6 months due to the potential oxidisation and condensation at biofuel storage and the risk of microorganism growth. An oxidised fuel may compromise fuel properties and engine performance. The storage time on board can be crucial for ships with long time periods between bunkering, typically a situation for ocean-going vessels. Some ships will also have dedicated tanks for lifeboats and emergency generators for which refilling are done more seldom than in other tanks. In large, however, the recommendations when using FAME blends up to 7% are similar to those applicable when using MGO (CIMAC, 2013; CIMAC 2017). At use of HVO or LBG, no extra precaution is needed compared to traditional fuels.

Ships are normally supplied with fuel from bunker ships or barges. It is expected that the existing infrastructure can be used for small scale introduction of biofuel in marine fuel although experiences of bunkering biofuel in Swedish shipping are from bunker supply with trucks. An example is the blended fuel used by the passenger and commuter vessels in the Gothenburg archipelago that uses road diesel with 5% rape seed methyl ester (RME), delivered and mixed in the truck before bunkering (Kållekärrs åkeri, 2018). Also governmentally owned Swedish road ferries are supplied biofuel, a pure HVO fuel, by truck.

2.3 Engine operational issues

Since April 2017, the ISO standard on marine fuels admits drop-in of biobased liquid fuels that are functionally equivalent to petroleum derived refined marine fuels (ISO, 2017; CIMAC, 2017). Up to 7% drop-in of FAMEs is in accordance with the standard. HVO is considered equal to petroleum derived fuel and there is for that reason no limit on drop-in percentage of HVO. HVO is however a low density product and might therefore require engine manufacturers' approval before use if used in high blends or pure (Energimyndigheten, 2016). Confirmed by the research department at Wärtsilä, there are no negative effects related to using HVO in marine engines, regardless of ratio between marine distillate oil and the HVO (Wärtsilä, 2018).

Specifications related to oxidation stability have been included in European EN 14214 and American ASTM D6751 biodiesel (FAME/RME) standards in order to avoid diesel engine performance and maintenance problems from oxidative degradation of biodiesel, particularly in the engine fuel system (Pullen and Saeed, 2012). According to the Wärtsilä research department, tests on marine engines show stable results at blends up to 10% FAME as long as the production has fulfilled the standard EN14214 (Wärtsilä, 2018). Another risk that is linked to the use of FAME blends is related to its high solvency compared to conventional marine diesel oils; they can wash out deposits from the fuel supply lining and thereby cause an increase in fuel filter clogging (CIMAC, 2017).

Further the viscosity of vegetable oils is highly temperature dependent. Under certain conditions, a polymerization can form insoluble polymers, which can clog fuel lines, filters and pumps. As an example, oil in a too cold environment may form wax and in too high temperatures the fuel may polymerize (Wärtsilä, 2007).

The International Council on Combustion Engines (CIMAC) recommends the following procedures when using FAME-blends (CIMAC 2013):

- All marine distillate oil tanks should have an effective drainage arrangement and be kept clean, kept away from heat sources and other sources that will encourage water accumulation. Regular draining of the fuel tanks at least twice daily as recommended for conventional marine distillate fuels.
- Monitor the fuel storage tanks for water content and microbial contamination. This is also recommended for conventional marine distillate fuels.
- Modern high pressure common rail (HPCR) fuel injection systems may exacerbate the issue of water in the fuel due to heating and cooling effects on the fuel releasing the water from the recycled fuel.
- Monitor fuel filter condition for any increased rate of clogging by checking for increased back pressure or any increase in the automated back-flushing cycles. Due to its greater solvency, biodiesel can dislodge fuel debris and other contaminants that have accumulated over time, in the storage tanks and through to the engine's fuel injection system.
- B100 biodiesel (100% FAME/RME) generally has a higher wax forming temperature than conventional diesel. In blends of B7 or less this should not be a problem as the cold weather parameters of the diesel fuel controlled in the specification should dominate. It is a good idea to take appropriate measures if B100 and/or biodiesel blends are exposed to outside conditions before entering storage on the ship. Measures that could be considered include; keeping the fuel temperature at least 10° C above the pour point and locating the fuel in storage tanks away from potential cold ambient

temperature interfaces. Ships operating in cold areas should include ship specific cold flow requirements in the bunker purchasing contract.

Liquefied biogas (LBG) can replace liquefied natural gas (LNG) without any need for technical amendments on board. Biogas can further be mixed with natural gas to any extent.

Many ships in the SECA use a low sulphur fuel oil (LSFO) which is offered on the market at lower price than the marine gas oil. Mixing either HVO or FAME with a LSFO involve small risks related to incompatibility, although it is likely that blending will cause no serious negative effects on engine operations (Wärtsilä, 2018).

2.4 Existing trials and developments

A number of trials with bio blended fuel in bunker have been done. Below are some examples of tests on specific ships and more comprehensive initiatives. There is a lack of available information on the reasons to why the initiatives in general are limited in time.

- Royal Carribean Cruises tested biodiesel on Carribbean based *Jewel of the Seas* in 2006-2007. Tests started on a 5 % blend and eventually fuelled their turbine engines with 100% biodiesel (Florentinus et al. 2012). Royal Carribean Cruises reported the project as successful with reduced soot emissions as a positive side effect, and the main obstacle being a lack of available biofuel.
- *Anna Desgagnes*, a 17 850 dwt freighter, was run on a 20% biodiesel blend (Florentinus et al. 2012) in 2006.
- *Maersk Kalmar*, a container ship of 88 669 dwt, was run on a FAME blended fuel for 160 hours in 2010-2011 (Florentinus et al. 2012).
- The multi-purpose vessel *Meri* was delivered in 2012 as a ship intended for 100% use of biofuel, with marine distillates as back-up fuel. *Meri* is a 105 m long, and 4 539 tonnes dead weight (Florentinus et al. 2012).
- A number of smaller ships, mainly intended for transport of passengers in the archipelago around Sweden, use biofuels to 100% or in blends. To mention three examples, the governmental *Färjerederiet* successfully runs their road-ferry between mainland and Hönö on the west coast on 100% HVO. *Styrsöbolaget*, with passenger transport in the archipelago outside Gothenburg uses blends with RME, and the archipelago traffic by *Waxholmsbolaget* in Stockholm uses a blend with 20% HVO.
- Maersk signed an agreement in 2013 with Progression Industry in order to develop a marine fuel from lignin. Maersk is committed to buy 50 000 tonnes of the fuel if it meets a set of specified conditions (Mofor et al., 2015).
- In 2015, Good fuels together with *Wärtsilä* and *Boskalis* (a dredging company) launched a two year initiative called the Sustainable Marine Biofuel Initiative (Good Fuels, 2018). *Boskalis* thereafter run ships on bioblended fuels.

3. Economic implications

Petroleum based fuels are accompanied with high price volatility. Accordingly, it is difficult to quantify the price premium range for biodiesels, LBG and HVO as bunker fuels. On average, the biodiesels (FAME and RME) appear to have approximately double the price that of MGO, and the RME price is slightly higher than the average FAME price. The fuel price fluctuations over time in the Amsterdam-Rotterdam-Antwerp-region in one year (1 Dec 2016 to 30 Nov 2017) for marine gasoil, low sulphur fuel oil, FAME and RME are shown in Figure 1. The price for low sulphur fuel oil is only slightly below the price on MGO for the year. HVO is more expensive than RME, as it is a higher quality drop-in fuel. The price on the Swedish market is at present approximately 1000 USD/tonne higher than that of MGO. Changes are expected following the upcoming regulation on reduction quotas (Backman, 2018). Since no taxes apply on international bunker sales, the market is less attractive as a maritime biofuel provider since it competes with domestic uses with tax incentives. Politically it is more sensitive to pay subventions than to give tax or fee deductions and particularly if the fuel is used outside the nation's territory.

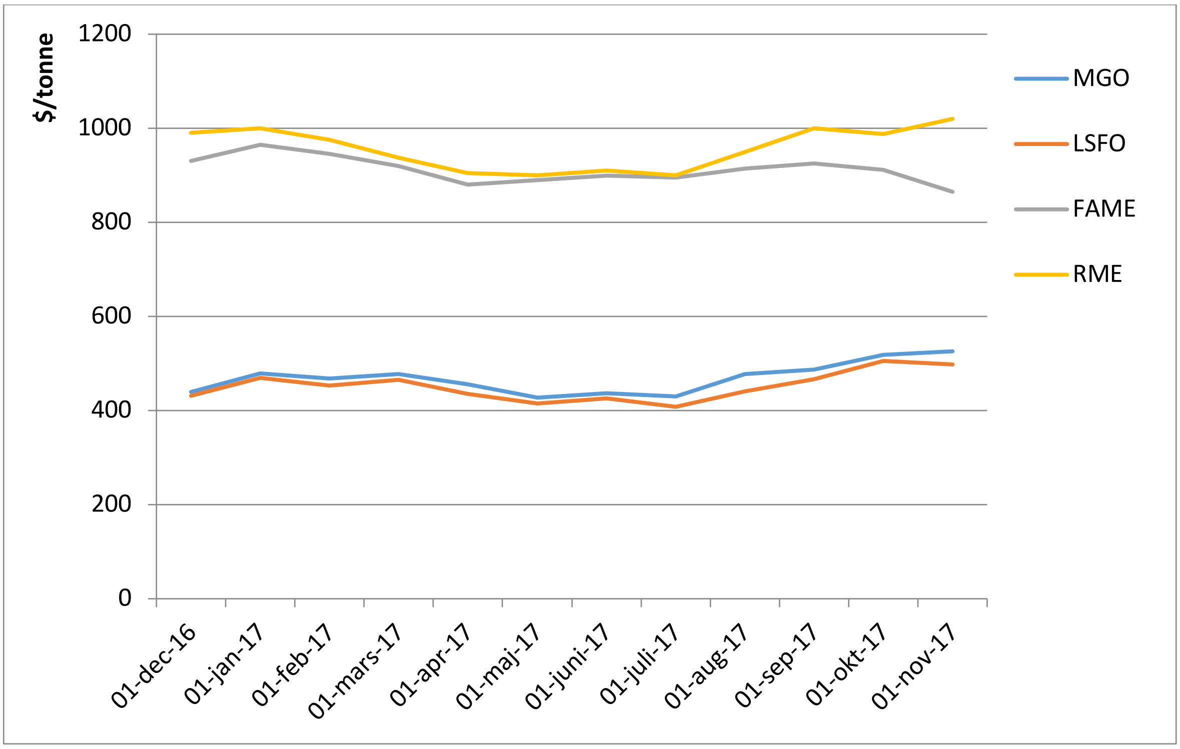


Figure 1. Bunker fuel, RME and FAME prices from 1 Dec 2016 to 30 Nov 2017, in the ARA region (Bunkerworld, 2017; Greenea, 2017)

Using biofuel as a drop-in fuel for the main engine or in an auxiliary engine will increase fuel costs, which are already a significant part of ships' total operational costs. Different segments of shipping would face different economic challenges in the proposed business model. A ship owner in the tanker segment would most likely not be able to transfer the whole cost increase to one customer. An example from discussions with a tanker ship owner with long-term contracts with a single customer suggests to split costs between own funding and increased fuel bills to the customer (shipper). Still additional support from rebates on other posts in the operational costs, such as port fees and fairway dues, are mentioned as crucial parameters in order to provide low carbon sea freight in the tanker segment.

Ship owners with ships for container or RoRo liner services are more likely to pass on the full cost increase for the biofuel to a cargo owner, which makes the suggested business model suitable for these ship owners.

The general rule in the industry is that all responsibilities for the fuel quality and quantity lie with the ship owners with little to no liability towards the fuel suppliers or bunker parties. The use of biofuels is since April 2017 included in the marine fuel standard (ISO 8217) and no specific legislation applies for biofuels (Florentinus et al., 2012).

Prices of LBG can be compared with LNG prices. The LNG prices are still to a much larger extent than oil prices made up by infrastructure related costs for the supplier. It is very difficult to quantify prices of LBG sold for marine bunker fuel. However, the price premium compared to LNG will most certainly remain high since the supply is small. Even the production costs for biogas exceeds the industry purchase price by approximately 2 to 2.5 times (Energigas Sverige, 2018).

4. Supply issues

Today's biodiesel market is predominantly determined by political decisions, and available biofuels cannot compete with fossil alternatives under the same market conditions. Subsidies and low-blend quotas control supply and demand, and market conditions are therefore directly influenced by policy decisions. In addition, the market is affected by regulations on tariffs in other parts of the world (Energimyndigheten, 2016).

An expected shortage of high quality biofuels is projected in Sweden by the summer of 2018 when regulations will require a 19% replacement of fossil fuels with bio based fuels in road traffic, a reduction quota. Representatives of the oil company Preem expects a shortage of HVO, with no potential to set aside any volumes for the ship industry. They expect that Sweden will import HVO from the whole European market. The fact that the demand will be high in the road sector, and that the fuel for land based transport are higher priced and accompanied by taxes, causes little interest in offering the HVO to the marine market.

FAME and RME is not expected to experience a similar increase in demand as HVO. According to Swedish law, diesel oil for light road vehicles is allowed to contain a maximum of 7% FAME. This restriction will favour the synthetic diesel fuels such as HVO when the 19% reduction quota becomes reality, since similar limits do not exist for HVO. Thus, as the target exceeds permitted levels of FAME there will be a favouring of the HVO drop-in fuel (Energimyndigheten, 2016).

The availability of liquefied biogas on the Swedish market is low. The total production of biogas 2017 was 2 TWh and the potential for 2030 is estimated to 15 TWh (SWECO, 2016). Today, there is only one unit for producing LBG in Sweden and the transport to terminals in ports by trucks can be assumed to be long and suboptimal for the cause of reducing climate gas emissions. It therefore needs to be considered if LBG should be used in applications closer to the source. As the LNG and LBG are equal from a combustion perspective, there is no new knowledge on operational practices to gain from adding the biogas on the ship. An example of a solution to a similar situation is the Finnish system for natural and biogas fuel. In Finland, biogas that is injected to their gas grid can be sold to customers as biogas in liquefied form under the condition that its origins are traceable. A detailed analysis of these conditions are however not part of this pre-study.

5. Freight market aspects

In a workshop with representatives from cargo-owners, ship-owners, bunker fuel suppliers, and refineries, the freight-market aspects were discussed in order to map potentials for a business model for a low carbon marine freight service, see summary in Attachment 1.

Low carbon energy sources for ship operations (i.e. all energy systems on-board - propulsion, auxiliaries, heating etc.) will impose an increased transport cost. While waiting for future regulations on carbon emissions from international shipping, any ship operator using alternative fuels risks to be priced out of the market. The increased cost for the low carbon fuel must therefore be carried from one or several of these sources: End customers through store price increases, cargo owners by lower margins (possibly motivated by climate ambitions or marketing benefits/brand development), forwarders by lower margins on transport prices, carriers/ship operators by lower margins on rates, vessel owners by lower margins on charters, fuel suppliers by lower margins on fuel supplies.

Some results from the workshop are presented below in the context of different actors with crucial roles to play in the suggested business model.

5.1 Business model: Low carbon marine freight

The concept we aim to introduce in the shipping sector, is currently established in the road transport sector through e.g. DHL's ‘green tonnes’, and also in the energy sector (“green electricity”, biogas and district heating). For example, you can pay extra for biogas for your vehicle added to the natural gas network. Similarly, you pay more for a the service of ‘green tonnes’, corresponding to the amount of fuel needed to produce the amount of transport work (tonne*km) that is contracted. However, the biofuel is not necessarily used by the truck specifically transporting the cargo under the ‘green tonne’-contract. The total amount of transport work produced by the purchased biofuel is the maximum amount of ‘green tonnes’ that can be sold.

The purpose of the preliminary study is to clarify technical, practical, economic and market aspects relevant to carriers, shipping companies, fuel suppliers and transport customers. The study identifies issues to address in a continued, more extensive project, involving suggested pilot trials in Swedish shipping industry. The ambition is to cover RoRo, RoPax, tanker and container transport.

Thus the idea is to test a model in which a cargo owner pays for the extra cost of using a small amount of biofuel as a drop-in fuel (or higher blends of biofuel for auxiliary engines) for ship transport, instead of traditional marine fuels. The carbon neutral fuel is then mixed into the ordinary fuel (for main engine and/or auxiliaries) in an amount corresponding to the share of ‘green transport work’ purchased by the cargo owner. Another option can be to replace fossil energy with wind power, a solution which can also be fitted in the model.

A similar initiative started early 2018. The *Good shipping* program is a program with an aim to change the marine fuel mix to sustainable alternatives (Good Shipping, 2018). The program is linked to the bunker provider *Good fuels* that markets bio-blended marine fuels of ISO 8217 standard. *Good fuels* and *Good shipping* are active on a global scale with a base in the Netherlands. *Good shipping* has since December 2017 an agreement with *DHL*, and *DHL* offers their customers a service of low carbon marine transport on container ships. No container line is to date pronounced as linked to the offer.

5.2 Ship owner perspective

The marine sector needs to reduce its economic risks during the transition period from fossil to renewable fuels, which means that low carbon transport services should be introduced on the market using the existing fleet with minimal retrofit investments. One such solution is to use low carbon alternative fuels as drop-in fuels and offer a low carbon transport to climate ambitious cargo owners. The price premium for bio-fuel will in the suggested business model be transferred to the cargo-owner. A favourable scenario is of course if the customer requests the service, and the drop-in fuel is used in response to this demand.

The rate of introduction of these fuels is however slow in the shipping sector, due to concerns over increased fuel costs, supply and handling issues and an experienced lack of interest from cargo owners to pay price premiums for lower environmental impact from transport operations. At the same time, the introduction of renewable fuels has been substantial in the road transport sector, mainly in countries/regions with regulations combined with tax and levy reductions. These policy driven incentives have less potential in international shipping, at least from a shorter time perspective (5-10 years).

Ship owners in different segments see different challenges in using biofuel on board and with the proposed business model. Issues to overcome include fuel supply issues and technical issues related to long storage in tanks for ships in ocean-going service. From the workshop, the only ship owner with ships mainly in ocean going services were more hesitant to introduce biofuels on board due to fuel logistics and bunker storage issues, than present ship owners with ships in coastal service.

5.3 Shipper perspective

The energy needed for transport work, i.e. the transport of goods a certain distance (often in the unit tonne-km), will differ between type of goods and type of ship. In the suggested business model, bio-based drop-in fuel will be used in proportion to what is requested by the shipper. The energy needed to produce transport work will be calculated, and each goods assigned a share of the ship's total fuel consumption. The increased cost carried by the cargo owner could be justified by marketing arguments for a 'green' product (e.g. zero-emission vehicles, eco-food or premium products). In many markets and product segments, consumers are willing to pay more for branded products (e.g. electric cars - Tesla, mobile phones - iPhone) than for products with similar performance and the fuel premium could possibly be transferred to the end customer should they be willing to pay the low carbon supply chain as a high quality indicator.

Shippers identify issues related to the business model including the need for a certificate of the low carbon freight, and the increased fuel costs and potential to pass it on to end customers. These issues must be further explored in the proposed test project.

5.4 Fuel supplier perspective

The bunker fuel supplier will provide the customer the product requested. However, the expected shortage of HVO fuel and the low availability of LBG may cause constraints on the bunker market even for a small scale test project.

5.5 Case

In order to exemplify the discussion above, two theoretical cases were designed. In the first case, the principle of allocation is illustrated for containers transported on a feeder vessel. The second case shows how the increased price for bio-fuels entails for different stages of the value chain, we give an illustrative example of a supply chain of commodity transported from Shanghai to Gothenburg.

CASE 1 - Feeder ship between a continental hub port and Gothenburg

A 2 000 twenty-foot equivalent unit (TEU) container feeder is selected for the calculation of the case. Assuming a load capacity utilisation of 60% leaves us with a load of 1 200 TEU. This size of vessel typically consumes 40 ton MGO per day when operating at 19 knots speed in the emission control areas demanding low sulphur fuel. With an LCA CO_2 intensity of some 3 400 kg CO_2 per tonne MGO, the vessel will emit 758 g CO_2/TEU*nautical mile (NM), see figure Figure 2.

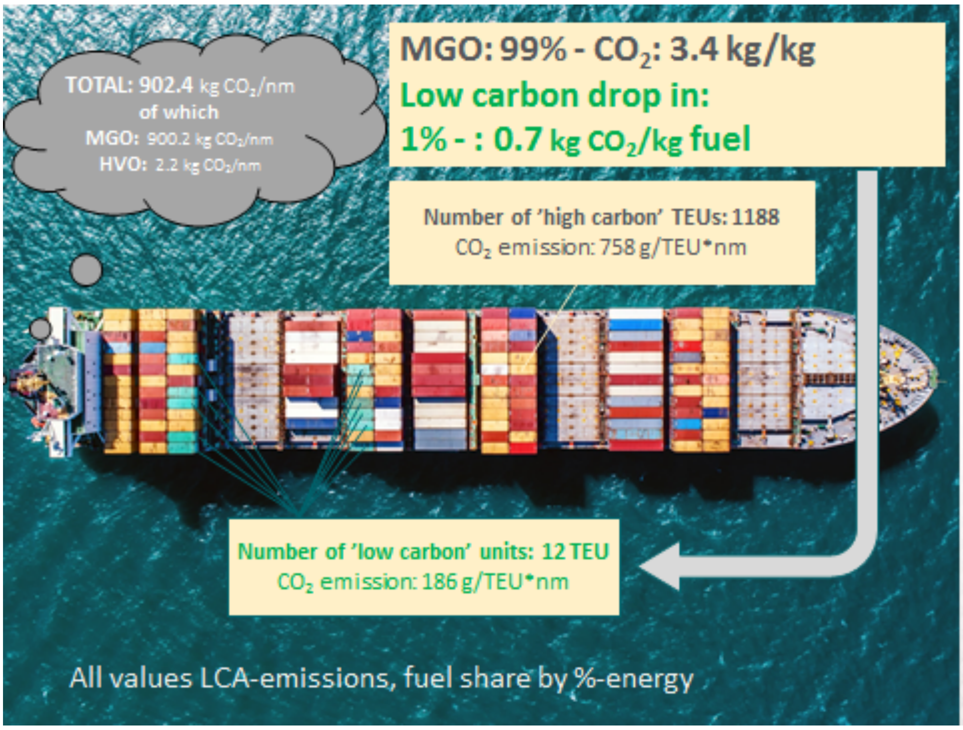
Figure 2. Illustration of container feeder vessel.

If the vessel was to use a biofuel as a drop-in fuel, the total CO_2 reduction would decrease. For example, by substituting 1% of the fuel energy by a bio-oil, the total Life cycle CO_2 emission will be reduced by 0.75%. For the vessel in the example, the emissions per NM will drop from 909 to 902 kg/NM, of which 900 kg emanates from the MGO and 2 kg from the HVO drop in fuel. This reduction in emissions can now be allocated to the transported cargo in two different ways.

The first option is to let all shipments benefit from the reduction, yielding an average emission of 752 g CO_2/NM, i.e. a reduction by 6 gram per TEU/NM.

A second approach is based upon the argument that if a transport customer pays a premium in order to cover the increased bunker cost of a drop in fuel, the related emission reduction should be allocated to this customer's goods. In the case of 1% of the fuel energy substituted by a low-carbon fuel, 12 of the 1 200 TEUs will be connected to the reduced emissions, thus yielding an average emission of 186 g CO_2/NM. The remaining 1 188 TEUs are then connected to the emissions caused by the MGO fuel, thus with a constant emission of 758 g CO_2/TEU*NM. The concept is illustrated in Figure 3.

Figure 3. Illustration of the concept of low carbon sea transport by drop-in fuels.



CASE 2 – Direct call at Gothenburg with trans-ocean vessel

In this case, the price premium for a low carbon sea transport of one TEU is calculated for a passage from Shanghai to Gothenburg. The unit is transported on a 9 000 TEU vessel, which calls a total of 20 ports during a rotation of its route. For illustrative purposes a load and unload pattern was made up and a total produced transport work of 169 250 000 TEU*NM was assumed during the rotation. The vessel was assumed to have a daily consumption of 100 tonnes of HFO and 3.7 tonnes of MGO, the MGO assumed to be used when cruising in emission control areas. The average emission intensity is then calculated to 134.5 g CO_2/TEU*NM (72.63 g CO_2/TEU*km).

We then assume that 25% of the MGO is substituted by bio-oil as a drop-in fuel. This will reduce the total CO_2 emissions for one rotation by 182 tonnes. Split evenly between all units transported, this will reduce the average CO_2 intensity to 133.4 gCO_2/TEU*NM. If we instead allocate the reduction to a customer with units transported between two of the ports along the route, e.g. from Shanghai to Gothenburg, the substituted fuel energy would cover the energy utilised for 142 TEU. The CO_2 intensity for these units would then amount to 31.5 gCO_2/TEU*NM, while the others remain on 134.5 gCO_2/TEU*NM.

The price premium for this decreased emission could be calculated accordingly. Prices for marine bunkers fluctuate over time, why no definite value can be given. For illustrative purposes the price premium were calculated using the following fuel prices, representative for the situation 2017:

HFO: 300 USD/tonne, MGO: 450 USD/tonne and bio-oil: 960 USD/tonne. With these prices the use of bio oil for the 142 TEUs above will lead to a price premium of 234 USD/TEU. The total price for a passage could then rise from some 1000 USD to 1230 USD, an increase by 23%.

This price premium could be compared to the store value of the content of the unit. This value can of course vary greatly, however a guiding value for retail goods (as store price) could be some 15 000 USD/TEU. In such a case, the low fossil carbon sea transport from Shanghai to Gothenburg would increasee the consumer price by 1.5%. The increase would of course vary with type of commodity, lower for smart phones and higher for beer.

6. Concluding remarks

Aspects of technical and practical character exist but are mainly related to an expected shortage of HVO as a bunker oil alternative. While LBG and HVO are high quality products and similar to their fossil counterparts, they are both expected to be available in limited quantities for some time ahead. RME seem to be a more accessible choice, but comes with a few technical drawbacks unless fulfilling the specified quality standards. RME however has a favorable price compared to HVO. At the workshop, the only ship owner with ships mainly in ocean going services was more hesitant to introduce biofuels on board due to fuel logistics and bunker storage issues, than present ship owners with ships in coastal service.

The proposed business model suggests that economic concerns for high fuel price premiums are transferred to end-customers. This model suits supply chains for goods ending the chain as retail commodities. The case presented indicates that for high priced and low weight goods (e.g. smart phones and clothes), the price premium for consumers will be of less concern. A number of shippers that joined the workshop showed an interest in trying this model in cooperation with ship owners that provide their transports. Ship-owners with bulk goods are less served by the suggested model, and alternative financial solutions are most likely needed in this segment.

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Attachment

List of participants on workshop - Low carbon marine freight

Name	Surname	Organisation
Maria	Arnholm	Swedish Oriental Lines
Fredrik	Backman	Preem
Steve	Barter	EFO
Åsa	Burman	Lighthouse
Sebastian	Bäckström	IVL Swedish Environmental Research Institute
Laura	Daugnoraite	Logistics Purchasing Development at Volvo Group
Carl	Fagergren	Wallenius Marine
Erik	Fridell	IVL Swedish Environmental Research Institute
Rashmi	Hahn	IKEA Supply - Inter IKEA Group
Scott	Hemphill	IKEA Supply - Inter IKEA Group
Dick	Höglund	Tärntank shipping
Eija	Kanto	Wega Advisors
Jens	Kjellerup	Clean Shipping Index
Andreas	Kron	Lighthouse
Martin	Larsson	DFDS
Erik	Lewenhaupt	Stena Line
Tryggve	Möller	Tärntank shipping
Per	Nilsson	Tetra Pak
Nikolai	Nymoen	Wallenius Wilhelmsen
Daniele	Saba	Volkswagen Konzernlogistik
Arja	Salo	Scania CV
Frida	Sjölin	Scania CV
Sara	Sköld	IVL Swedish Environmental Research Institute
Astrid	Sonneveld	Goodfuels
Roger	Strevens	Wallenius Wilhelmsen
Sebastian	Tamm	EFO
Mario	van der Bussche	Volvo Group Logistics Services
Hulda	Winnes	IVL Swedish Environmental Research Institute
Carl-Johan	von Sydow	Topoil
Poul	Woodall	DFDS

Summary of workshop - Low carbon marine freight

2017-04-11 at IVL Swedish Environmental Research Institute, Gothenburg

Will 2018 be the turning point?

Background and result from pre-study – presentation by Sebastian and Hulda from IVL

The Paris agreement included no limits or targets for international shipping, but there is a clear trend from regulators to reduce CO_2 emissions. The IMO MEPC meets this week to decide on possible targets to reduce CO_2 emissions. Shippers want to be able to highlight the environmental credentials of their supply chains and have shown interest to reduce dependence on fossil fuel in all parts of the supply chain. Low carbon shipping solutions today include:
1. higher energy efficiency
2. alternative propulsion options
3. low carbon alternative fuels.

When looking into possibilities to use biofuel for shipping there are a number of factors to consider, such as quality of fuel, practical issues on board, price compared to MGO (2-4 times higher) and possible conflict with food supply and nature conservation. During last year a pre-study was done together with Lighthouse Swedish Maritime Competence Centre and University of Gothenburg on biofuels and one of the results is the workshop today. The idea is to substitute a part of the traditional fossil bunker with low carbon alternatives. Instead of reducing the average CO_2 intensity per cargo unit transported (e.g. grams CO_2/tonne*km) ***the entire CO_2 reduction will be allocated to a number of 'low fossil' cargo units.*** The number of low carbon units is proportional to the share of fossil energy substituted by renewable energy. The low carbon cargo units could then be charged with a price premium related to the cost of the selected renewable fuel. When using bio drop-in fuels, this requires no retrofitting which is a low risk option, less complicated to implement and retract. A number of calculation examples were showed, together with the idea of a green supply chain for environmentally conscious customers.

Input from invited participants

Tryggve Möller from Terntank presented their strategy to lower NO_X and CO_2 emissions from their tanker operations. Currently Terntank develops environmentally adapted supply chains with their clients and starts a biofuel project to test a blend of marine gasoil with 10-20 % renewable content in existing vessels. Tryggve argued that incentives are needed as this is an additional cost for shipping. "If we all work together we will be able to reduce the environmental footprints in the transport chains."

Roger Strevens from Wallenius Wilhelmsen presented a ship owner's views on decarbonisation. The criterion that WW have for adoption of new solutions is that there is a technical, operational, financial and commercial feasibility. The challenge as WW sees it when it comes to biofuels is finding the right quantity and quality for deep sea shipping, problems with storage and that the usage of biofuels need more experience. Roger called for more collaboration between all actors in order to include bio-fuels in the shipping decarbonisation agenda.

Scott Hemphill from IKEA presented their strategy for sustainable transports. IKEA transport purchasing is dedicated to tackle climate change. For the fiscal years 2017-2019 IKEA aim to be recognized for true leadership in driving the sustainability agenda in global transportation by society and IKEA's supply chain stakeholders. IKEA shared their 6 standpoints on alternative fuels and the plan for sustainability beyond compliance for ocean transport.

Future project proposal by IVL

A project proposal prepared by IVL was shared with the group. The suggestion is to include practical tests and evaluate experiences on a specific route or trade lane. ***Several shippers and carriers present in the room expressed an interest in participating in a case, however some technical issues on quality and quantity of biofuel remains to be solved. The worries shared on technical issues could also be*** recognized from the discussion when the fuel LNG was introduced in the shipping industry 7-8 years ago. The fuel providers in the workshop stated that suitable biofuel blends are already available.

It was also recognized that container carriers are needed to participate in the project and are not present at the workshop. All cargo owners are welcome to assist with contacts from carriers that could be potential project partners or participants in any way.

Several cargo owners were interested in participating in the project. Some needed to discuss further internally and some wanted to know more about the pricing and cost model – what will the price premium be, also with the upcoming 2020 sulphur cap in place.

The general sense from the discussions is that there is an opportunity to act now, and there are possibilities for a successful case in many shipping sectors. There are issues to be solved on the technical side, financial and also on availability. This is something positive, as it shows there is a need for this project. IVL will continue to develop the project proposal and communicate with all participants interested.