Potential fuel savings from operational measures in sea transport

- Study on general environmental improvements and specifically on fuel management

TRAFIKVERKET

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Preface

The Swedish Transport Administration, initiated a project regarding the potential fuel saving from operational measures in sea transport in 2011. The project has been financed by the Swedish Transport Administration.

The opinions, findings and conclusions expressed in this publication are those of the authors and not necessarily those of the Swedish Transport Administration.

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1. Executive summary

Sea transport includes various transport operation from shipper to consignee via ports. The operation is carried out by either dedicated vessels or transport operation through shared vessels. The dedicated sea transport services are often carried out by ships for general cargo or bulk cargo i.e. specially designed for the shipments. The shared sea transport services are often carried out by container ships and ferries (RoRo and RoPax). In the shared transport services, single shipments from various shippers are commonly consolidated through standardized cargo carrier units such as containers, trailers etc in order to coordinate goods flows i.e. achieve economy of scale.

The dedicated sea transport services are commonly negotiated and agreed between the cargo owner and the ship owner. In shared sea transport services the commercial agreement often involves an intermediary agent or forwarder that also may provide the cargo carrier unit and offer transport services to and from the port. Door to door sea transport service commonly requires feeding transport services that includes rail or truck transport to and from the port, i.e. a multimodal transport solution.

In general, the sea transport system consists of different sized vessels and various ports managed by people using information from supporting IT-systems. Overall the aim is to obtain efficient transport logistics. The sea cargo transport system also consists of different reload areas such as goods terminals for stuffing & stripping of the cargo carrier units (commonly containers).

Ships are apart from size divided in accordance with their use as ferries (RoRo, RoPax); general cargo for various types of goods, various tankers for bulk goods and the increasingly common container ships. The size of the ship is determined by the fairway capacity, for example Panamax[1] and transport demand, hence overall efficiency is determined by maximum allowed specifications regarding length, width, height and weight according to navigable fairways used and the ability to operate with balanced goods flows.

The objective of this study is to analyze some shipping companies and study what operational methods they have implemented with regards to their energy efficiency programmes. The results of the implemented methods are also analyzed and general recommendations are assessed when possible. This study is based on a Maritime Management degree thesis at Novia University of Applied Sciences in Åbo.

The carried out interviews with experts in the field of energy efficiency and literature studies was the major input to this report. A greater number of interviews would probably have lead to even more ideas on how to preserve energy and to more solid data regarding the methods described in this report. Even so, the expert opinion of the interviewees paints an adequate picture of what is at least possible, given time and resources, in terms of making energy use more efficient. The interviews were carried out during December 2011 and March 2012.

The fossil fuels used to propel the ships of today across vast oceans are a finite resource. In addition, the combustion of carbon based energy forms emits greenhouse gases and other air pollutants that are destructive to the environment. Shipping in general is an energy efficient way of transporting goods, even though it emits substantial amount of greenhouse gases in absolute numbers (see figure 5 in the introduction).

The sea trade is crucial to an ever growing global economy and is likely to grow at the same rate as international trade develops. Measures to reduce the shipping industry’s ecological footprint should therefore be a priority for everyone involved in sea transport as its legitimacy otherwise may be questioned among various stakeholders. Thus it is not just a question about the environment; it is a question of long term economic survival.

In this study, theoretical and suggested saving potentials were confirmed in the carried out interviews. It seems there are a number of relatively easy ways to reduce bunker consumption in sea transports. A lot of research has already been done and is only awaiting implementation. The possibilities seem so vast that it is amazing that more is not done in the field of reducing bunker consumption internationally and locally.

Overall business logic, aims at increasing profit margins where significant cost cut at short pay back time should rank high on the management agenda. In addition to increasing the profit margins, the emissions of green house gases would decrease by fuel saving programmes. This should be sufficient drivers to implement thorough fuel saving programmes for every ship owner. Still we see several saving activities not being carried out by the shipping industry in general. The activities themselves seem easy enough to carry out, but there are some severe hurdles that need to be addressed.

The most severe hurdle to overcome seems to be the assessment of a credible bunker consumption baseline, from where improvements can start. Assessing this baseline takes time and efforts without immediate gains. Therefore our observation throughout this study is a need for a strong and solid company culture that forms a long term commitment to assess a credible baseline of actual fuel consumption. From this baseline continuous improvement measures with regard to energy efficiency can be implemented. As new trials of fuel saving activities are carried out they must be evaluated and verified before implemented on other ships. The main problem really seem to be to measure bunker consumption accurate and the consequently uncertainty in what the real results are from various improvements activities.

Another issue is the difficulty to change old behaviours related to operation. Regarding the measuring problem it is evident that some investments are needed if the actual results are to be accurately measured. There is, however, the possibility to simply take advantage of research and measurements already made by others and trust that their energy conserving effects will bring monetary advantages in the long run. Substantial savings in fuel consumption can be made even though the measuring is not state of the art.

Another reason why more is not done seem partly to be the result of market failures e.g. the energy gap described by below examples:

- A significant reason for not improving energy effectiveness in the shipping industry might be that a large share of the fuel expenses is passed on to the customer. As much as 70% -90% of the bunker costs might not actually be paid by the shipping company[2] but by the end customer, e.g. bunker surcharges that passenger cruise companies sometimes levy.
- Another major reason for the non actions taken can probably be found in the parts of the shipping industry that involve a lot of bare boat and time charter contracts. Since the ship owner is the one responsible for improvements on the ship, but the charterer is the one paying for the fuel there is no incentive for the owner to invest in improvements (e.g. measuring equipment) onboard the vessel.

- A third issue is that second hand prices of vessels do not correlate with the investments made to increase their fuel efficiency. The ship owner who has invested money in bunker saving equipment will not see a fully corresponding increase in the price he gets once he sells the vessel.
- Shipyards are also not prone to change their ship designs at a reasonable cost or they simply do not have the capacity to do so. Therefore especially a smaller shipping company has little or no possibilities to affect the design of a “standard” ship.
- Finally, the initial investment cost for a new energy saving method might discourage a ship owner from initiating this development. Even though the investment is relatively sure to pay itself off in the long run, the owner might not be in the position, real or imagined, to make the investment.

If market failures exist it is part of the failure’s definition that the market itself cannot change them. In this case legislators could step in and provide the framework for modern energy efficient operations, essentially by forcing the shipping companies to operate with higher efficiency. This could serve as additional pressure to initiate change within the industry.

During the interviews it really became apparent that what is needed above all is the will to change the way we consider fuel efficiency. The unwillingness to change established patterns of operations is a significant hurdle. Resolving this challenge will need forming and developing the minds of the managers of the company. From there it should be communicated down through the ranks so that it finally is intrinsic within the whole company culture. Incentive programmes for crews also seems like a well working concept for coming up with new, energy saving, ideas. It is obvious that the people who operate a vessel have a great knowledge of how to maximize the output of the resources available. Their knowledge, experience and ingenuity are immaterial commodities that the company can take advantage of at no extra cost or through bonuses on good proposals. The company just has to elicit the new ideas by proper motivation.

There are numerous savings regarding fuel consumption to be made by operational measures alone. The fuel wasted in today´s shipping industry represents money that could be better spent elsewhere; it should therefore be in every ship owner’s interest to use that money more efficiently. The road to better fuel economy aboard is long and winding, so the sooner improvements are begun, the better.

2. Introduction

Sea transport includes various transport operation from shipper to consignee via ports. The operation is carried out by either dedicated vessels or transport operation through shared vessels. The dedicated sea transport services are often carried out by ships for general cargo or bulk cargo i.e. specially designed for the shipments. The shared sea transport services are often carried out by container ships and ferries (RoRo and RoPax). In the shared transport services, single shipments from various shippers are commonly consolidated through standardized cargo carrier units such as containers, trailers etc in order to coordinate goods flows i.e. achieve economy of scale.

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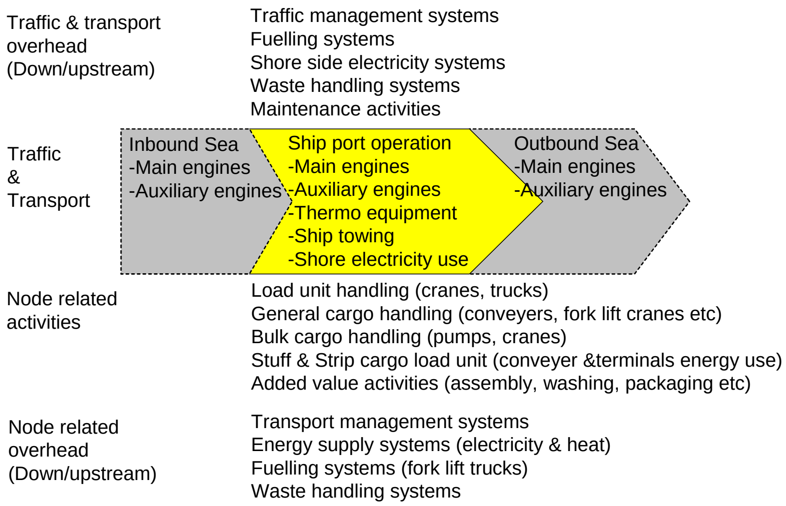

Figure 1. Operation of sea transport services requires substantial support from the ports in order to fulfil customer demands as well as enabling a resource efficient sea transport process.

Ships are apart from size divided in accordance with their use as ferries (RoRo, RoPax); general cargo including all types of goods, bulk and the increasingly common container ships. The size of the ship is determined by the fairway capacity[3] and transport demand, hence overall efficiency is determined by maximum allowed specifications regarding length, width, height and weight according to navigable fairways used and the ability to operate with balanced goods flows.

In essence, fuel efficient solutions has always been a priority within shipping in order to secure long term profitability, as fuel cost is a substantial part of the total cost in sea transport. Demands for more energy efficient transport solutions are continuously growing, today also driven by demands from legislators, customers and NGO´s. Therefore the focus on fuel consumption reduction is increasing. New technologies and innovations present a vast variety of possibilities in fuel consumption reductions in ship new buildings. However, a significant percentage of the world fleet will continue to consist of vessels with equipment designed for lowest short term cost rather than good fuel economy in mind. Thus, this fleet also needs fuel efficiency attention.

The life cycle cost (LCC) seems to have been of less importance than short term profit for shipping companies and investors when new ships have been explored. The good news in this respect is that increasing fuels costs will in evidently reshape the fuel consumption criteria's for new ships, increasing the focus on LCC. This new trend is already being seen in several new buildings.

As the life length of a ship may be 40 years it is of utmost importance to include present and future ships regarding more energy and emission efficient sea transport solutions. There are methods that can enable significant energy savings without the large costs of building new ships, such as retro-fit and upgrade projects. By changing the way vessels are operated, energy savings can be accomplished both in relative and absolute terms. The incentive for the shipping company to make these changes ought to be high due to short payback time. In other words, an investment in operational procedures will achieve financial break even in a short time since the investment costs are relatively low. After pay back of the investment, every cent saved will be a pure increase in the bottom line result.

A fairly well spread myth with regard to the sea transport mode is its outstanding energy efficiency. For several sea transport applications this is true. However, faster or less well utilized ships do not perform equally energy efficient.

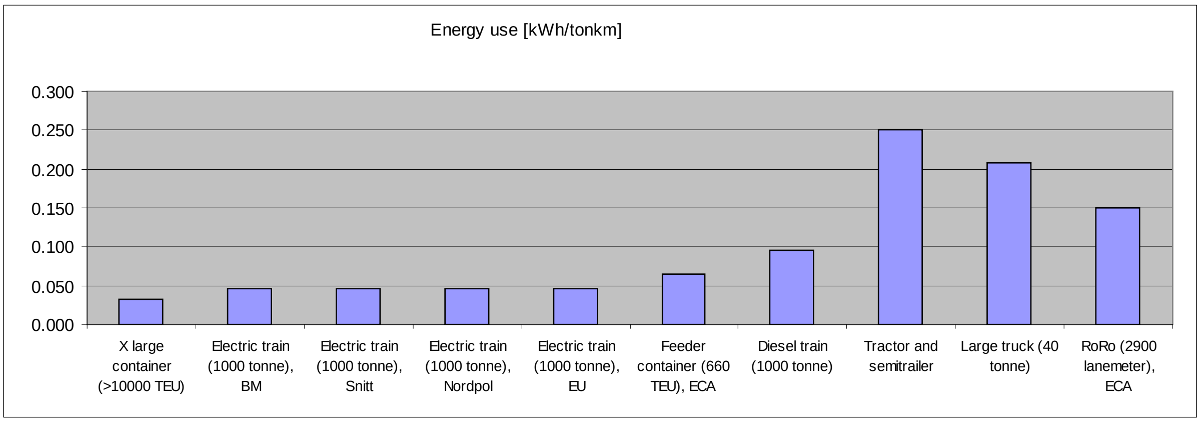

Figure 2. Benchmarking of energy efficiency for various modes of transport, assuming certain general fuel consumptions and load factors.[4]

Another type of comparison has been presented in a Karman-Gabrielli Diagram where a similar conclusion can be drawn regarding different modes of transport and their energy efficiency.

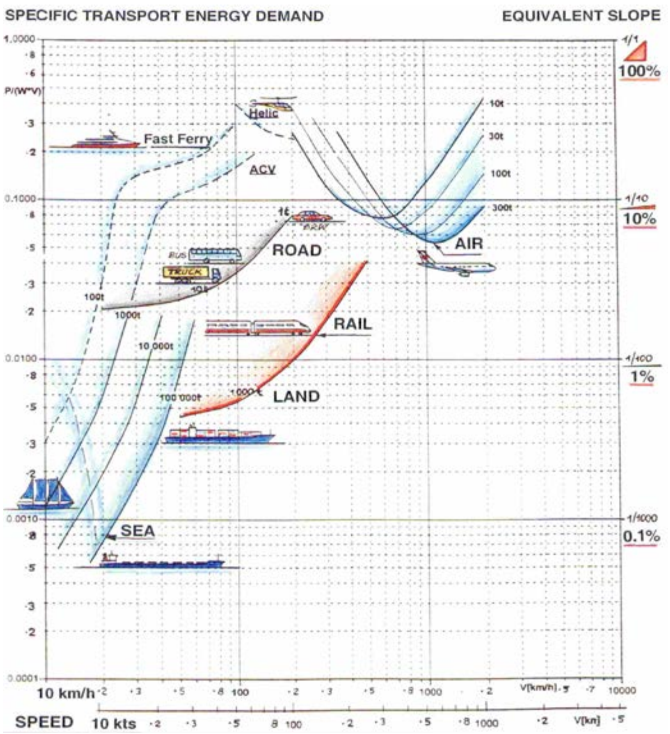

Figure 3. In this Karman-Gabrielli Diagram it is obvious that sea transport is the most energy efficient mode of transport if it is done at reasonable speed and in large units. Fast container- and RoRo-ships at 20 to 30 knots can however easily reach similar levels of energy efficiency as rail and road transport. Fast ferries at 40 to 50 knots can even reach the levels of air transport, but then at only one tenth of air speed.[5]

In conclusion it should be stressed that whatever level of energy efficiency a transport mode represents there are incentives and potentials for fuel saving programmes. The key driver is of course cutting short term costs. Other key strategic reasons are long term expected oil price and market credibility i.e. viability of the company.

The transport sector is on a global basis 96 % dependent on fossil fuels[6]. By burning fossil fuels in a an internal combustion engine in order to carry out transportation there are some significant second order effects occurring as described in the general combustion formula below.

Fuels + Oxygen => Exergy + Anergy + Carbon dioxide + Air pollutants + Water

Activity	Effects
Fossil fuel combustion	Propeller moving vessels (exergy)
	Losses in combustion and water/air resistance (anergy)
	Reduces present finite resources of oil
	Carbon dioxide emissions adding to GHG in the atmosphere[i]
	Emissions such as NOx, HC, PM, SO_2 etc

In summary there is, apart from cost saving gains to reduce fuel also environmental reasons to save fuel.

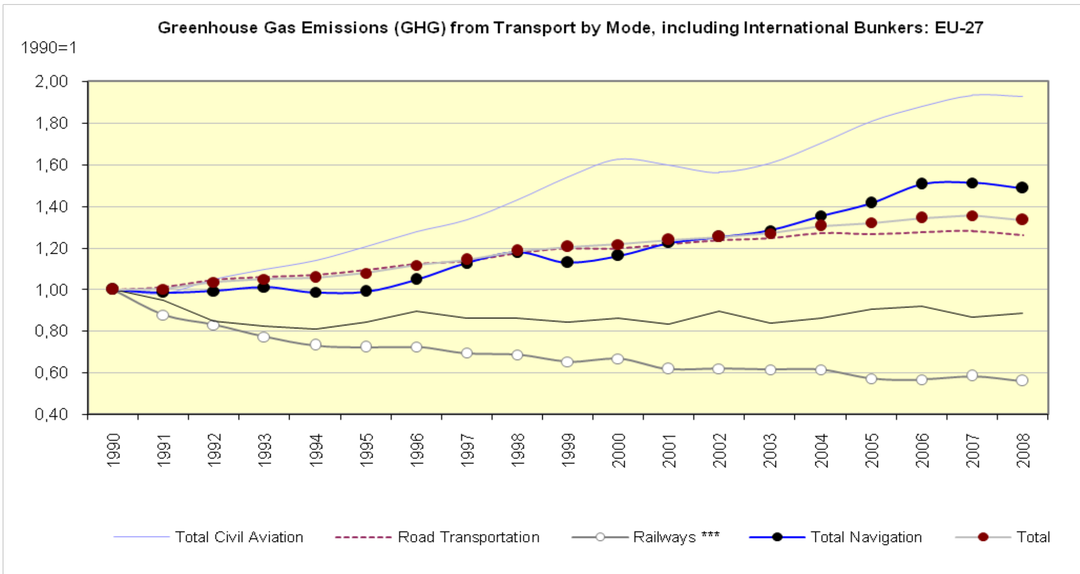

Figure 4. The transport industry development with regard to emissions of green house gases within the EU-27, including international bunker.[7]

[i] Total emission of CO_2 assuming 100% oxidation.CO_2 = carbon content (cc) x (mass weight CO_2)/mass weight C) x TFC (Total Fuel Consumption)

The general trend within the EU is an increase of transport related emissions of green house gases. Maritime transport is not an exception. Based on IEA, below the overall emissions of carbon dioxide emissions is somewhere between 2 and 4% of total global carbon dioxide emissions

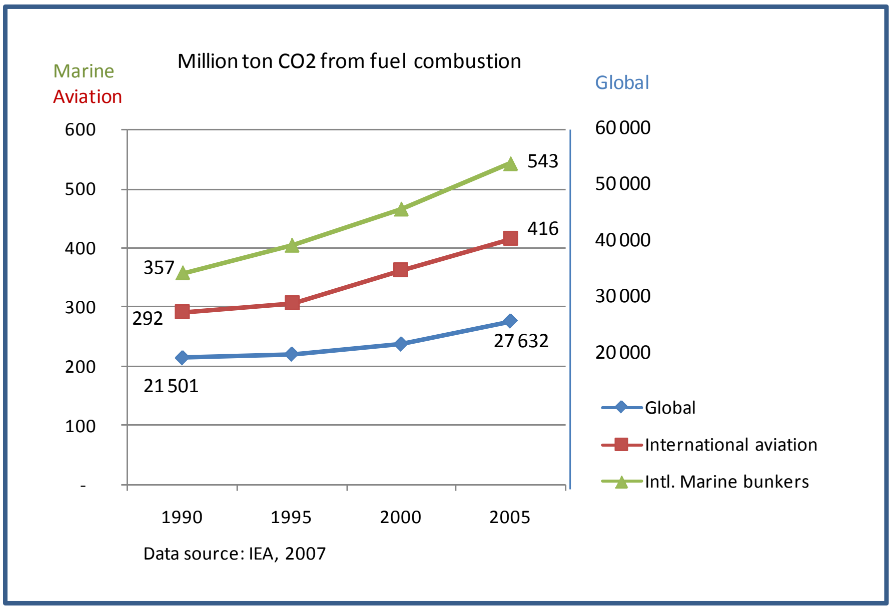

Figure 5. Emissions of carbon dioxide from the sea and air transport industry in comparison of total emissions. Later studies show that sea transport emissions in fact are higher than this graph indicates[8].The most important aspect of this graph is its trend, going in the wrong direction.

A long term strategic aspect of lowering fuel consumption is an improved ability to change towards renewable energy sources. In order to enable introduction of biomass based fuels, total fuel consumption needs to be substantially reduced, both from a cost perspective and from a resource availability point of view. An additional need for this cost cut need is coming bunker legislation aiming at lowering the sulphur content in bunker oils which in effect is predicted to increase bunker costs.

The aim of this report is mainly to introduce the reader to the practical and existing fuel saving programmes within sea transport operation. By adopting long term energy efficiency strategy we strongly believe that sea transport will evolve into an even more competitive mode of transport as well as improving its competitive edge with regard to low emissions and (green) market image.

In general, sea transport conditions seem at present to be the mode of transport with lowest general knowledge among authorities, politicians and traffic specialists. Therefore we hope this study will add to an increasing understanding regarding this mode of transport as one of several viable transport solutions for the future.

The report has been compiled by Andreas Slotte and Magnus Swahn at Conlogic.

2.2 Objectives

The objective of this study is to analyze some shipping companies and study what operational methods they have implemented with regards to their energy efficiency programmes. The results of the implemented methods are also analyzed and general recommendations are assessed when possible.

An assessment of the corporate culture regarding energy efficiency is also made in order to examine what it takes to make shipping company more energy conscious. The hypothesis of the study is that significant savings in fuel consumptions can be made relatively easily but it takes determination and focuses of the company and its employees, both ashore and aboard the vessels i.e. a mentality shift.

The study summarizes various fuel saving measures within sea transport that in effect has the potential to:

- Increase the energy efficiency
- Decrease emissions of green house gases (GHG) adding to global warming
- Decrease emissions of air pollutants with a negative impact on nature and health

2.4. Methodology

This study is based on relevant literature and interviews with leading personnel in the field of operations and the field environment in the shipping companies picked for the study. Furthermore this study is based on a Maritime Management degree thesis at Novia University of Applied Sciences in Åbo. The selection of companies in the study are based on of their size in the sector of shipping that they operate in and because of pre existing notion that they are considered, by active sea-farers, to be pro active in their work to improve energy efficiency.

The outcome of the literature studies and interviews formed a baseline which was compared with practical improvement programmes in order to identify potential discrepancies or supporting evidence with regard to practical and theoretical fuel saving programmes. This baseline of fuel saving effects is based on the estimates made by Wartsila in their Energy Efficiency Catalogue 2011[9]. It is important to point out that the numbers in the catalogue are only estimates made by Wartsila. Since Wartsila has been a well known actor in the world wide maritime cluster for a long time their estimates are however considered as relevant expert opinions. The numbers therefore served as a credible baseline for comparison of the findings of the interviews.

The study was conducted as qualitative research since obtaining large amounts of data about the energy efficiency work of shipping companies was difficult. This information is often regarded as confidential. Interviewing key personnel was therefore considered a sufficient way of discovering the possibilities of what energy efficient operational measures may obtain.

The interviews with the representatives from the shipping companies were carried out in December 2011 as well as in January and March 2012 in person. Follow up questions and/or clarifications were made through telephone conferences or via e-mail.

In chapter 7 the results from the interviews are presented. All statements concerning each company are the opinions the individual interviewee. In general it was fairly easy to assess general relevant information. More specific data and data capturing methodologies were however seen as confidential.

2.5 Delimitations

Assessing the environmental impact of a transport services typically includes the resource consumption of inputs, primarily fuel and electricity consumption and corresponding emissions generated by the transport activities. The amount of resource use and emission generating activities is determined by the system boundaries for environmental assessment. According to various studies[10] supportive and indirect activities of transport service can constitute a significant part of overall resource consumption and transport emissions. With a system boundary that includes various indirect activities more environmental factors and resource use are added. This will generally make the estimation more extensive and complex. Below is an overview of the various relevant systems boundaries for the transport system.

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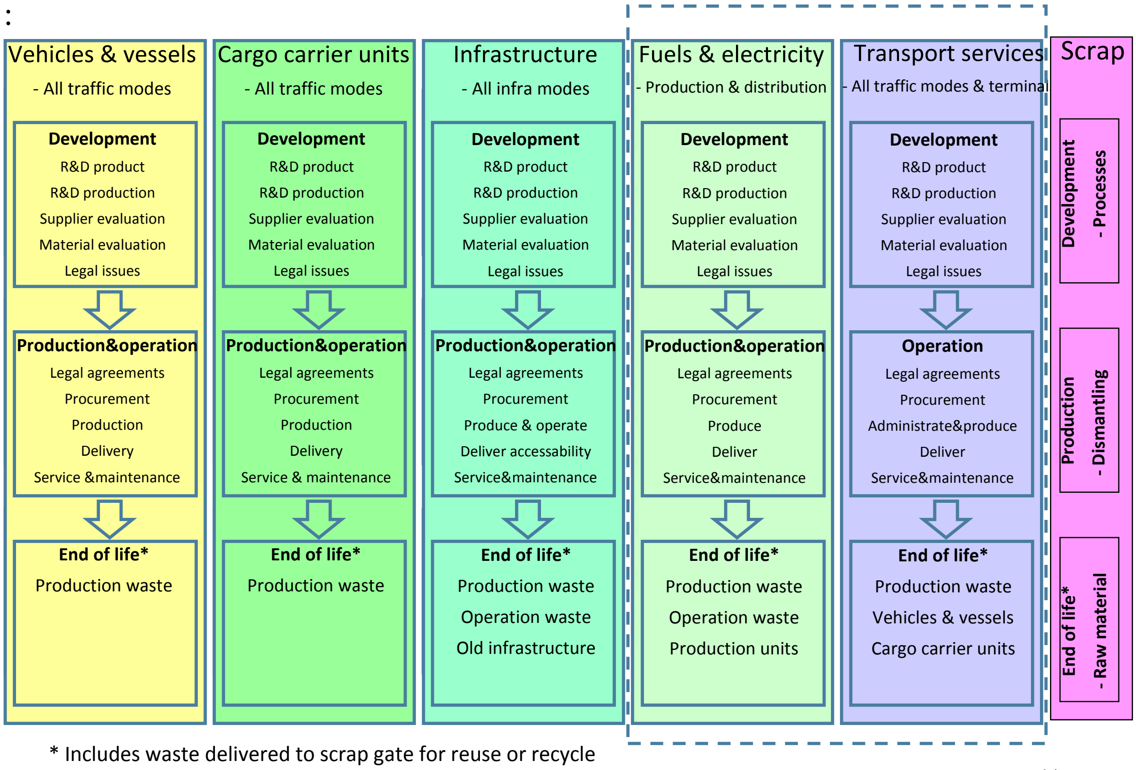

Figure 6. System boundaries for relevant areas in a "cradle to grave" approach.[11] *The dotted area represents the well to wheel system boundary that is the scope of the new CEN-standard for the assessment of transport energy use and emissions of green house gases. The above system boundaries should not be seen as mutually inclusive or exclusive, but rather as modules that can be added or subtracted, depending on the aim of the environmental assessment.*

Transport service, including traffic and transport related activities regarding engine operation for the propulsion and equipment for climate control of goods, and losses in fuel tanks and batteries. This system boundary is often referred to as tank to wheel, ttw.

Fuels & electricity, which includes the supply of energy from energy source to the tank, battery and electric motor (trains). This system boundary is often referred to as well to tank, wtt.

Infrastructure, development operation, maintenance and end of life
Cargo carrier unit, development operation, maintenance and end of life

Vehicle and vessel, development operation, maintenance and end of life

In addition the scrapping processes could be included.

Transport service and fuels & electricity (well to wheel, wtw = wtt + ttw) are the minimum required system boundaries for performance comparisons between different modes of transport. This system boundary is supported by the new CEN standard presently being adopted in the EU.

- This study focus on transport services

- This study investigates potential fuel saving activities being carried out in various operational measures in the Baltic Sea and the North Sea. These measures are all equal or even more relevant in other sea areas. The ship types included are:
  - Passenger ferries
  - RoRo
  - RoPax
  - Container

- Inland water ways was only partly included in the study.

- The study includes only operational activities.

- The study excludes port activities. It is however recognized that port efficiency has a high potential to support fuel saving programmes in sea transport.

- Ports are a crucial interface pre requisite for sea transport in order to link sea based transport systems to land based transport systems. In order to address this important area there are several initiatives going on such as the EU project Mona Lisa, among other tasks aiming at presenting early port availability information to ships in order to adjust speed to an optimum with regard to arrival and fuel consumption.

- This study focus solely on the absolute savings that can be made using the different methods described.

- Other important decisive factors of whether to implement a new fuel saving procedure were not specifically analyzed. Examples of such factors are:
  - Penalty fees for late arrival in a port as a result of slow steaming
  - Revenue loss due to a slower cruising speed that could lead to a fewer trips being possible in a fiscal year.
  - Other direct and indirect costs

The complexity of the shipping industry makes the energy efficiency procedures an interesting object for further studies. The barriers to implement new methods and procedures in a shipping company could therefore be an interesting aspect to investigate further.

3. Overview of sea transport environmental challenges and solutions

This chapter presents a general overview of the environmental challenges facing sea transport operation. In principle these challenges summarizes into:

- Use of finite resources
- Emissions to air (GHG and air pollutants)
- Effluents to water and shore based facilities
- Solid waste to water and shore based facilities

In order to assess the fuel used and related emissions to air one has to understand the complexity of the propulsion system in ships. Below is a simplified figure describing a general configuration for a ship.

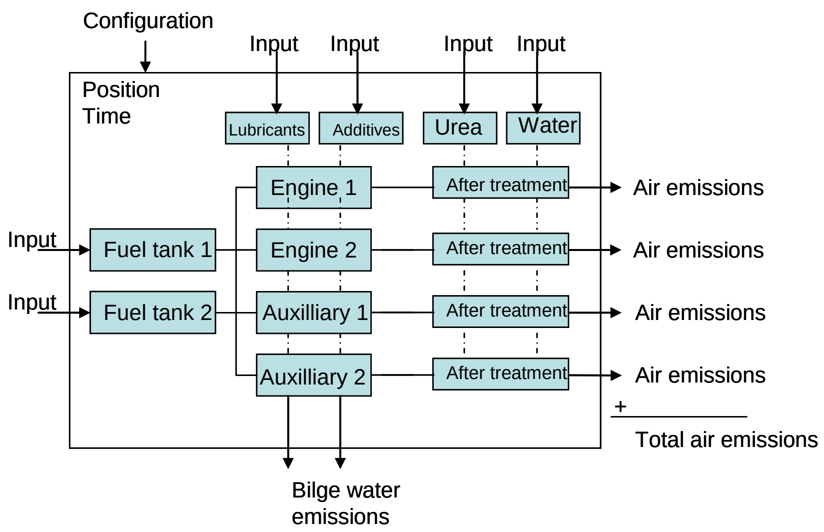

Figure 7. The ship propulsion system often includes several fuel qualities for a number of engines where some may be equipped with fume after treatment devices. The specific use of this system depends on several factors such as position, navigational conditions, weather, legal requirements, commercial aspects etc.[12]

Sea transport generates a number of various negative effects on the environment through its vast number of activities, in ISO 14001 named as environmental aspects. There are as well a number of mitigating measures. This overall picture is described in figure 8.

Environmental effect	Environmental impact	Environmental aspect	Delimitation measures	Efficiency measures	Technology measures
Scarcity of finite resources and damage on nature	Extraction and development of finite resources	Fuels combustion and upstream production, manufacturing and maintenance of vessels.	EC Renewable Energy Directive	Fuel saving activities (see chapter 7)	Cold ironing
Green house effect	Carbon dioxide	Combustion of fuels and their upstream production	EC Renewable Energy Directive	Fuel saving activities (see chapter 7)	LNG propulsion and cold ironing
		Shore land electricity consumption and its upstream generation	"	"	Renewable sources and efficient production
	Methane	Combustion of alternative fuels and their upstream production	"	"	"
	Laughing gas	Combustion of alternative fuels and their upstream production	"	"	"
	Cooling media	Use and release of CFC and HCFC for climate control	UN Montreal protocol	n/a	Soft Freons
Ozone layer depletion	Cooling media	Use and release of CFC and HCFC for climate control	UN Montreal protocol	n/a	Soft Freons
		Use and release of halons from old fire extinguishers	"	n/a	New techniques
Acidification	Nitrogen oxides	Combustion of fuels and their upstream production	EC engine emission standards & market based measures	Fuel saving activities (see chapter 7)	After treatment of fumes
		Shore land electricity consumption and its upstream generation	EC legislation	"	"
	Sulphur oxides	Combustion of fuels and their upstream production	EC Sulphur emission control area	"	Low sulphur fuels and scrubbers
		Shore land electricity consumption and its upstream generation	EC legislation	"	"
Overfertilization	Nitrogen oxides	Combustion of fuels and their upstream production	EC engine emission standards	Fuel saving activities (see chapter 7)	After treatment of fumes
		Shore land electricity consumption and its upstream generation	EC legislation	"	"
Negative impact on nature and health	Toxic emissions and effluents	Undelibetare and deliberate release of oil (bunkering and spills)	EC legislation	n/a	Spill protection decives
		Dangerous goods acidents	"	Precautionary procedures	n/a
		Release of toxic substances from use of various chemicals	"	Precautionary procedures	New techniques
		Toxic coating	"	Fuel saving activities (see chapter 7)	New bio based techniques
	Land erosion	Ship generated waves	Speed restrictions	"	New hull design
	Invasive species	Release of ballast water	EC legislation	Ballast water exchange procedures	After treatment of ballast water
	Solid and fluid waste	Scrapping of old ships and material	"	n/a	n/a
		Maintenance waste (oil, grease, etc.)	"	"	n/a
		Release of bilge, black- and grey water	"	"	After treatment of effluents
		General waste from operation	"	"	n/a
	Noise	Engine noise (main and auxiliary)	n/a	Reducing port hours	Insulation and cold ironing
	Vibrations	Engine vibrations (main and auxiliary)	n/a	"	"
	Particulate matters	Combustion of fuels and their upstream production	EC engine emission standards	Fuel saving activities (see chapter 7)	Fuel quality
		Shore land electricity consumption and its upstream generation	EC legislation	"	Renewable sources and efficient production
	Hydro carbons	Combustion of fuels and their upstream production	EC engine emission standards	"	Fuel quality
		Shore land electricity consumption and its upstream generation	EC legislation	"	Renewable sources and efficient production
Congestion and barrier effects	Sea ways and ports	Sea traffic work	n/a	Spatial planning	Larger vessels i.e. fewer sips needed

Figure 8. An overview of sea transport environmental challenges and a sample of related measures to reduce the negative environmental impact. Apparently, fuel saving activities should play a significant role in the maritime sector´s environmental improvement efforts.

4. Legal and policy demands

4.1 General EU transport policy

In 2001 the European Union published their first transport policy white paper, Time to decide[13]. This white paper was revised in 2006, as Keep Europe moving - Sustainable mobility for our continent Mid-term review of the European Commission's 2001 Transport White Paper[14].

According to the EU, sustainable mobility means allowing greater mobility while reducing the negative impacts of transport services. Hence, these two policy documents have been developed in order to be the overall framework of the EU´s Sustainable Development[15]. Environmental impact, climate change and energy policies are important aspects of these strategies.

The Commission has over the years put forward several different initiatives to make transport greener and more sustainable[16]. The aim has been to reduce air pollution and climate impact, and introducing the polluter pays principle in practice. In brief the various packages include initiatives such as:
- Internalize all the external costs of transport[17]
- Rail Transport noise reduction from rail freight trains by 50%
- Fuel taxation
- Include aviation in the EU´s Emissions Trading System

The new third European Transport White Book 2011-2020 concludes that transport is fundamental to economy and society. Mobility is considered vital for growth and job creation within the EU. It states that the transport industry directly employs around 10 million people and accounts for about 5% of gross domestic product (GDP).

Effective transport systems are according to the third white paper key to European companies' ability to compete in the world economy. Logistics, such as transport and storage, account for 10–15% of the cost of a finished product for European companies. The quality of transport services has a major impact on people's quality of life. On average 13.2% of every household's budget is spent on transport, goods and services.

As mobility increases the major future transport system faces challenges according to the European commission are:

- Oil will become scarcer in future decades, sourced increasingly from unstable parts of the world. Oil prices are projected to more than double between 2005 levels and 2050 (59 $/barrel in 2005). Current events show the extreme volatility of oil prices.
- Transport has become more energy efficient but still depends on oil for 96% of its energy needs.
- Congestion costs Europe about 1% of gross domestic product (GDP) each year.
- There is the need to drastically reduce world greenhouse gas emissions, with the goal of limiting climate change to 2ºC. Overall, by 2050, the EU needs to reduce emissions by 80–95% below 1990 levels in order to reach this goal.
- Congestion, both on the roads and in the sky, is a major concern. Freight transport activity is projected to increase, with respect to 2005, by around 40% in 2030 and by

little over 80% by 2050. Passenger traffic would grow slightly less than freight transport: 34% by 2030 and 51% by 2050.
- Infrastructure is unequally developed in the eastern and western parts of the EU. In the new Member States there are currently only around 4 800 km of motorways and no purpose-built high-speed rail lines; the conventional railway lines are often in poor condition.
- The EU's transport sector faces growing competition in fast developing world transport markets.

In order to meet these challenges the European Commission outlines strategies in the white paper "Transport 2050 Roadmap to a Single Transport Area that aims to introduce profound structural changes to transform the transport sector." The EU will move forwards in coming years (2011–14) with key measures regarding:

- A major overhaul of the regulatory framework for rail[18]
- Develop a core network of strategic infrastructure in order to create a real Single European Transport Area. The Commission will bring forward new proposals for a core European "multi-modal" network in 2011 with publication of TEN-T (trans-European transport network) guidelines, maps and financing proposals.
- Create a fully functioning multi-modal transport system by removing bottlenecks and barriers in other parts of the air network, inland waterway transport as well as paperless and intelligent shipping in order to create a real "Blue Belt" area, without barriers, for shipping. The Commission will also work to remove restrictions to road cabotage.
- To create a fair financial foundation to transport charges in the direction of an application of the "polluter pays" and "user pays" principle.
- Launch an EU Strategic Transport Technology Plan where the priority will be on producing clean, safe, quiet vehicles for all transport modes. Key areas will include: alternative fuels, new materials, new propulsion systems and the IT and traffic management tools to manage and integrate complex transport systems. The Commission will publish a clean transport systems strategy.
- Develop a strategy for transport in cities.
- For long distance modes, where air travel and maritime transport will remain dominant, the focus will be to increase competitiveness and reduce emissions through:

  - A complete modernisation of Europe's air traffic control system by 2020 (SESAR2).
  - Similar major improvements in traffic management are essential to the overall improvements in efficiency and lower emissions in all modes. That means the deployment of advanced land and waterborne transport management systems (e.g. ERTMS, ITS, RIS, Safeseanet and LRIT3).
- Other key measures for aviation and maritime includes the introduction of cleaner engines, design and shift to sustainable fuels.

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[2] Single European Sky ATM Research, cf http://ec.europa.eu/transport/air/sesar/sesar_en.htm.

[3] European Rail Traffic Management System, Intelligent Transport Systems (for road transport), River Information Services, the EU's maritime information systems SafeSeaNet and Long Range Identification and Tracking of vessels.

- The completion of the European Common Aviation Area of 58 countries and 1 billion inhabitants by 2020; as well as work with international partners and in international organisations such as ICAO (International Civil Aviation Organisation) and IMO (International Maritime Organisation) to promote European competitiveness and climate goals at a global level.
- For maritime, in particular, the target of reducing emissions by at least 40% from bunker fuels can be met by operational measures, technical measures, including new vessel design, and low-carbon fuels. Given the global nature of shipping, these measures need to be worked on in the international context of the IMO to be effective.
- In the short term, there will be a push to move ahead with the necessary EU measures to facilitate multi-modal integrated travel planning, as well as necessary legislative measures to ensure service providers have access to real time travel and traffic information.

The above list (shortened by the authors) aims to highlight some of the key measures which will move forwards in the period 2011–14 to introduce the major structural changes necessary to build an integrated Single European Transport Area.

4.2 Sea transport related environmental legislation

Internationally sea transport is legally controlled by UN,”The United Nations Convention on the Law of the Sea”; UNCLOS including operational aspects as well as emissions to air (part XII, article 212).

In addition the International Maritime Organisation”, IMO´s, Convention on the Prevention of Pollution from Ships (Marpol, annex VI) is controlling environmental performance of sea transport.

IMO MARPOL Annex VI aims at reduction of sulphur oxides and nitrogen oxides emissions from ships. This includes the European sea areas determined as Emission Control Areas where there is availability of the adequate fuels and the impacts on short-sea shipping are significant.

The EU Marine Strategy Framework Directive should ensure good environmental status in marine waters covered by their sovereignty or jurisdiction by 2020.

4.2.1 Air pollutants

Non-Road Mobile Machinery, NRMM, Directive 97/68/EC regulate exhaust emissions from different types of engines. The third directive, 2004/26/EC, covers diesel fuelled engines from 19 kW to 560kW for common NRMM and regulates the emission in 3 stages. The directive includes railcars, locomotives and inland waterway vessels. For the two latter categories there are no upper limits concerning engine power.

The different engine stages in the 2004/26/EC directive are:
- Stage III A, 19 to 560 kW including constant speed engines, railcars, locomotives and inland waterway vessels. Effective from 1 January 2006 for certain types of engines.
- Stage III B 37 to 560 kW including, railcars and locomotives. Effective from 1 January 2011
- Stage IV covers engines between 56 and 560 kW. Effective from 1 January 2014.

For regular sea transport engines within the EU, NOx emissions are regulated through three tiers of engines.

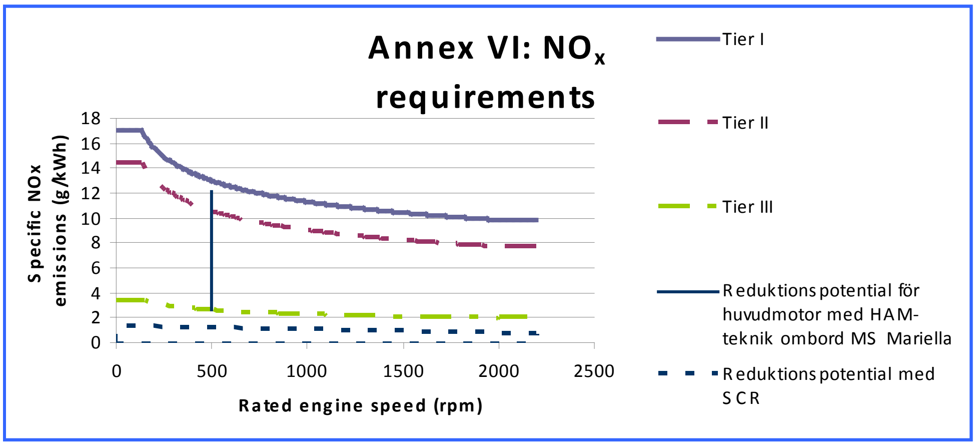


Figure 9. NOx emissions from sea transport engines in the EU are regulated through different engine standards:
Tier 1, until 2010, maximum 9.8 and 17 g/kWh depending on engine speed.
Tier 2, from January 1, 2011 maximum, 7.7 and 14.4 g/kWh depending on engine speed.
Tier 3, from January 1, 2016 maximum2 and 3.4 g/kWh depending on engine speed.

Environmentally adapted fairway and port dues are locally introduced in different geographical places. Since 1993 Sweden has environmentally adapted fairway dues, where costs depending on ship specific NOx emissions. In Norway there is since 2007 environmentally adapted port dues depending on ship specific NOx emissions.

The MARPOL Annex VI19 has in addition a progressive reduction in sulphur oxide (SOx) emissions from ships, with the global sulphur cap reduced initially to 3.50% (from the current 4.50%), effective from 1 January 2012; and then progressively reductions to 0.50 %, effective from 1 January 2020.

The limits applicable in Sulphur Emission Control Areas (SECA´s, as example the Baltic Sea) has been reduced to 1.00% (from the previous 1.50 %); and is being further reduced to 0.10 %, effective from 1 January 2015.

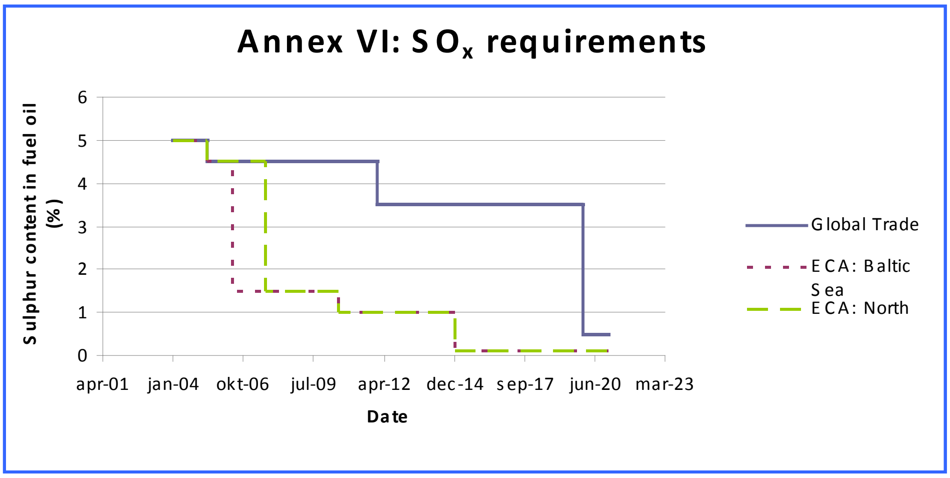


Figure 10. Regulations on sulphur content in bunker oil.

4.2.2 GHG emissions

United Nations Framework Convention on Climate Change (UNFCCC) has the objective to stabilize greenhouse gas concentrations in the atmosphere at a level that will prevent dangerous human interference with the climate system. The United Nations Framework Convention on Climate Change (UNFCCC) was adopted 1992.

The Convention is complemented by the Kyoto Protocol 1997 where 37 industrialized countries and the European Community have committed to reducing their emissions by an average of 5 percent by 2012 against 1990 levels. The Conference of the Parties (COP) is the "supreme body" of the Convention, that is, its highest decision-making authority. It is an association of all the countries that are Parties to the Convention. The COP meets every year, unless the Parties decide otherwise.

Abbreviation	Explanation	Comments
BFO	Bunker Fuel Oil	Also named MFO, HFO, IFO
HFO	Heavy Fuel Oil	Also named MFO, BFO, IFO
IFO 180	Intermediate Fuel Oil	IFO 180 means a viscosity of 180 cSt at 50°C.
IFO 380	Intermediate Fuel Oil	Sometimes mentioned as bunker. C. IFO 380 means a viscosity of 380 cSt at 50°C.
MDF	Marine Diesel Fuel	A distilled fuel that may contain small fractions of RO. Also named MDO.
MDO	Marine Diesel Oil	See MDF
MFO	Marine Fuel Oil	Also named BFO, HFO, IFO
MGO	Marine Gas Oil	A lighter and better quality fraction than marine diesel oil adapted to high speed engines. The fuel does not include any fraction of RO.
DMA	Standard for MGO	Maximum sulphur content of 1.5 percentage
DMX	Standard for MGO	Maximum sulphur content of 1.0 percentage
LS	Low Sulphur	Sulphur adapted to SECA[4]
RO	Residual Oil	After refinery of crude oil the remaining fraction is RO. Also named MFO, HFO, IFO or BFO.

Figure 11. Fuel qualities in sea transport.[20]

Directive on CO_2 emission trading (2003/87/EC, amendment 2009/29/EC). From transport sector, international maritime shipping and aviation are included in the directive. Electrified rail transport is already indirectly included in the emission trading, due to the inclusion of energy sector. In practice emission trade presently only includes air transport.

The EU Directive on Taxation of Energy Products and Electricity (2003/96/EC) sets the minimum tax levels on fossil fuels.

The directive on the promotion of the use of bio fuels or other renewable fuels for transport (2003/30/EC). Aims at 5.75 % for use of bio fuels calculated on the basis of energy content of all petrol and diesel for transport presented by 31 December 2010. Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing.

[4] Sulphur oxide Emission Control Area

Directives 2001/77/EC and 2003/30/EC sets the minimum target for transport purposes to10% in every Member State in 2020. The Commission policy is to increase the proportion of bio fuels up to 20 %, decrease the energy consumption by 20 % and decrease the CO_2 emissions by 20 % in 2020.

Based on the 1990 levels the Swedish environmental aims for 2020 are:

- 40 % reduction of GHG emissions for the non trading sector
- 50 % renewable energy
- 10 % renewable energy in the transport sector

For 2030, Sweden aims for a fleet of vehicles entirely independent of fossil fuels.

In summary it is obvious that the EU aims at developing the transport sector commercially meanwhile its negative impact will be reduced. These two objectives have several built in contradictions and challenges. The area of operational fuel efficiency improvements however has few drawbacks with regard to the overall policies proposed by EU and internationally.

5. General fuel efficiency

Saving fuel is not just a matter of protecting the environment; it is also a question of financial benefits. With every less tonne fuel consumed in propelling a ship forward, there is the monetary value of that tonne saved. In a case where fuel can be saved with little or small cost for the ship operator, the benefits are both environmental and economical. There are often no, or at least relatively small costs involved when operational saving measures are implemented. Therefore, operational measures are often the easiest bunker-saving activities to implement.

Oil and fuel prices are currently at a high level and there is no reason to believe that prices will drop in the future. Higher price on fuel will further increase the incentives to reduce bunker consumption. Every shipping company should realize that a tonne of saved fuel today will be worth even more in the future.

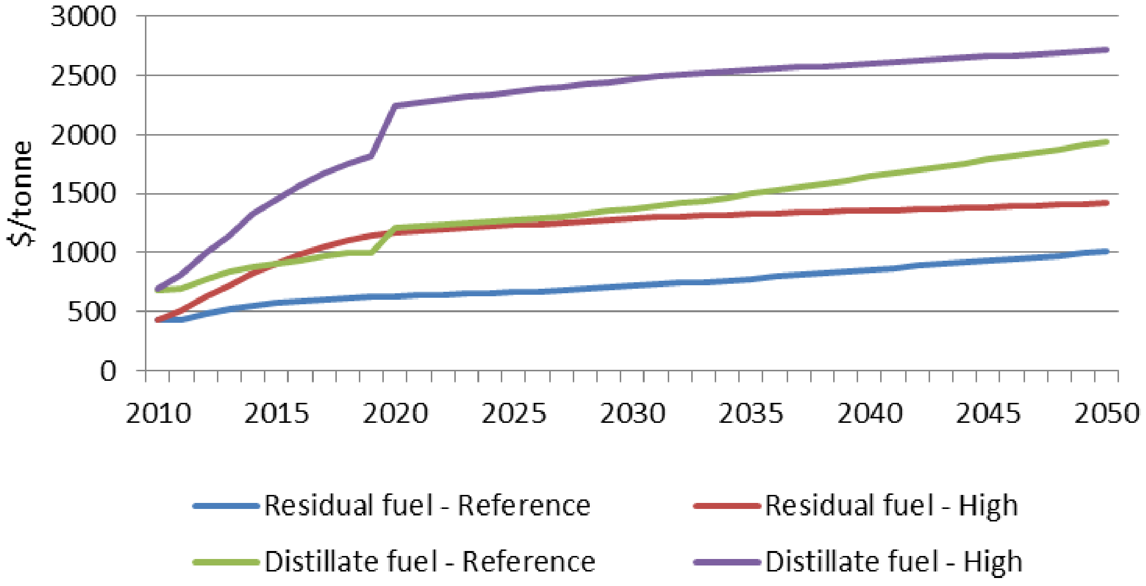


Figure 12. Predicted fuel prices 2010 – 2050[21]

In figure 12 above the IMO´s projection of potential fuel prices from 2009 until 2050 is presented. The reference price starts at 371/594 $/tonne for residual/distillate and peaks at 1008/1935 $/tonne in 2050. The high estimate starts at 371/594 $/tonne and peaks at 1416/2719 $/tonne in 2050. In the reference scenario the price almost triples for residual fuels and a little more than triples for distillates. The high estimate shows price increases that are almost four times as high for residual fuels and about four and a half times for distillates[22].

Commercial ships usually run on Heavy Fuel Oil (HFO) that is a residual fuel and/or Marine Diesel Oil (MDO) that is a residual diluted with distillate fuel. The bunker cost for an average vessel will therefore be the combined HFO and MDO bunker consumption times a weighted average that lies somewhere between the prices of the residual- and distillate fuels. This illustrates well that a tonne saved today will increase its cost cut over time and end up saving anywhere between about three and four times its present market value by 2050.

5.1 Possible saving due to operational measures

There are a number of operational measures that can be implemented onboard a ship with little or no investment cost. The actual savings in bunker consumption naturally depends on the actual measure implemented. Some studies also assess the possible monetary gaining in lowering carbon dioxide emissions at sea.

According to the new CEN-standard, the emission of CO_2e (ttw) is 3.15 kg/kg HFO and according to agreements within the IMO when developing the EEDI[5] the CO_2 emissions from one kg of HFO was set at 3.1144 kg/kg. Analyzing the emissions of CO_2 only we therefore use the number of 3.1144 kg/kg as it is also in line with the CEN data on CO_2e (including also methane and laughing gas)

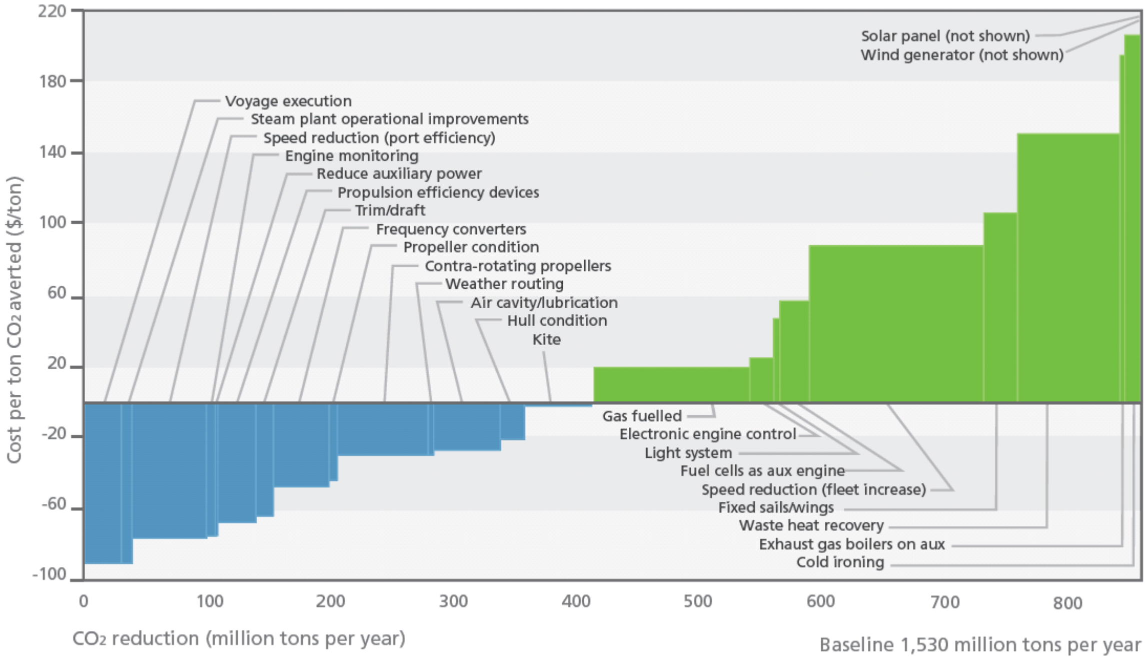


Figure 13. The marginal cost of carbon dioxide reduction by different measures.[23]

In figure 13 the marginal cost of different CO_2 reduction alternatives in the world fleet are shown. All the measures that show a negative marginal cost (blue bars in the figure) are measures that will save money from the moment of implementation. The opposite is also true; the green bars tell us that implementing that particular measure will generate a cost for each additional tonne of CO_2 not emitted. Given the assumption that one tonne of HFO emits approximately 3.1 tonnes of CO_2, the marginal cost of reducing one tonne of CO_2 can be divided by 3.1 to get the monetary value of reducing the bunker consumption by one tonne. The blue bars will show the profit made and the green bars the loss accumulated. If we also assume the price development of residual- and distillate fuels that IMO predicts, that monetary value can be multiplied by the price hike to estimate future savings or losses.

It is easy to see from Figure 13 that many of the measures with a negative marginal cost are operational. On the other hand all of the measures with a positive marginal cost are technical and/or possible only in new built ships. Because of this correlation it seems as though the easiest and most profitable way to start reducing the bunker consumption in any company would be to go at it from an operational point of view.

[5] Energy Efficiency Design Index

The exponentially decreasing environmental performance curve shows us the same fact in a different context: when implementing measures that are aimed at preserving the environment, the investment cost buys a lot of result early on. The more work done, the harder it gets to continue showing positive results and the marginal cost for continued improvement increases exponentially.

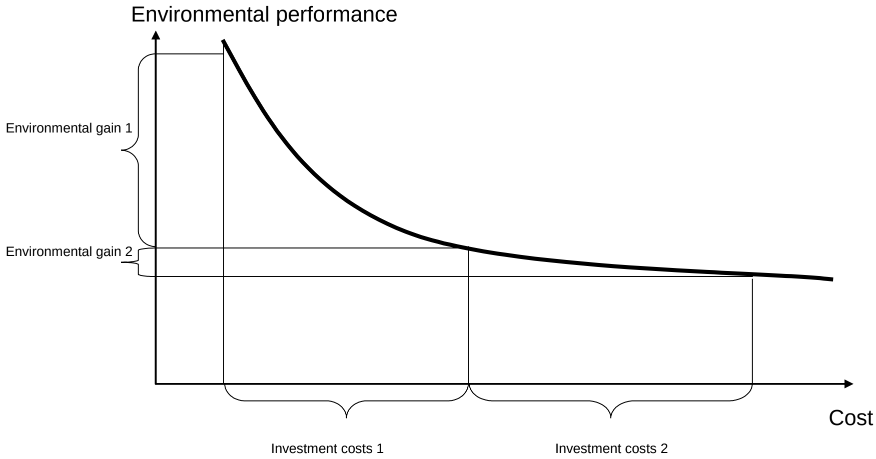


Figure 14. The exponentially increasing cost of environmental gain.[24]

In figure 14 the exponentially increasing marginal cost of environmental gain is evident. The first investment buys a significant amount of environmental gain. The second investment is larger than the first, but still only buys a fragment of the gain. The environmental performance curve fits perfectly into the theory that operational measures will buy a lot of bunker consumption reduction for a relatively small cost.

5.2 Why saving money on bunker consumption should be important to a company.

The basic concept of company operations tells us that a company needs to make a profit to survive long term. By saving money on operations the profit margins will increase which in turn will increase the shareholders return on investment. From a strictly financial point of view the environmental factors are just an added bonus (assuming no internalisation of external costs) even though the environmental savings probably are usable in the company's PR department, since ecological care currently is a hot and media sexy topic. There is however also a long term survivability issue that the company will benefit from.

Company's profitability is the difference between the amount of capital used on running the business and the revenues received from the customer. The customer pays a price for the company's product that is defined in theory by the law of supply and demand and it is reached in the equilibrium between the two.

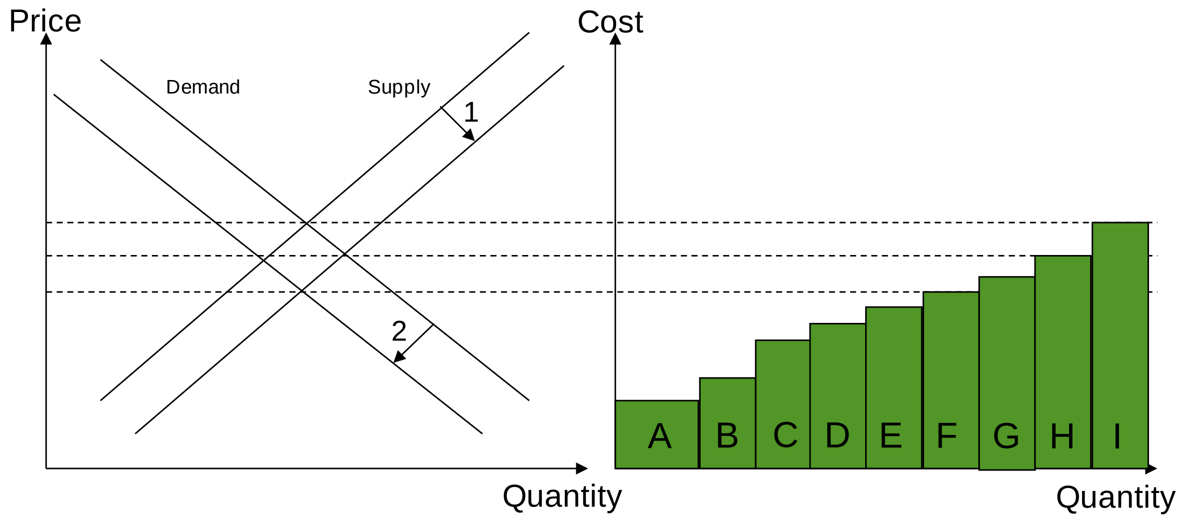


Figure 15. The Salter diagram describes the commercial effects of changing market supply and demand on company profitability.[25]

In figure 15 different supply and demand curves are shown in the left hand diagram and the effects of these on companies A-I on the right hand side. The green bars in the right hand diagram are the total operational costs of the companies and it is obvious that company A has the lowest and company I the highest total operational costs. The empty space between the top of each green bar and the equilibrium, represented by horizontal lines, represents the difference between revenue and cost, i.e. the operational profit. In the staring scenario companies A-H are profitable and company I just breaks even. In scenario 1) the supply grows (e.g. new companies enter the market that offers the same services as A-I) and therefore the market price equilibrium moves down and to the right (1). In this new scenario companies A-G are profitable, company H breaks even and company I loses money. In the third scenario 2) the demand decreases (e.g. as during a financial crises) and the market equilibrium price continues down but to the left (2). Now only companies A-E are profitable, company F breaks even and companies G-I are all losing money.

The above mentioned scenarios are simplified but still present the correlation between costs and profitability during the wide normal market changes that are out of control of the individual company. The company that has put the most effort into reducing costs will make the most profit and have the highest chances of long-term survival.

In above mentioned scenarios this company is company A. In the shipping business a company that purposefully works towards reducing its fuel consumption, and therefore its costs, could have significant advantages over its competitors if the market changes for the worse.

Figure 16. A modern crude oil vessel designed for the Baltic Sea with a maximum size and highest safety and ice standards. Length 182.9 m. Beam 40 m. 65 200 DWT. This concept illuminates one major measure to increase cost and fuel efficiency by maximizing the size of vessel.

5.3 Why more is not done already

Since many, if not all, of the operational measures described in this paper have been known for a significant period of time, the question of why they have not been more widely adapted rises. Adding that many of these measures are possible to implement at a small, or no cost to the ship operator, the answer is even more allusive. In theory this probably relates to the concept of the energy-efficiency gap[26], described through below sea transport examples.

A significant reason for not improving energy effectiveness in the shipping industry might be that a large share of the fuel expenses is passed on to the customer. As much as 70% -90% of the bunker costs might not actually be paid by the shipping company but by the end customer, e.g. bunker surcharges that passenger cruise companies sometimes levy[27].

Another major reason for the non actions taken can probably be found in the parts of the shipping industry that involve a lot of bare boat and time charter contracts. Since the ship owner is the one responsible for improvements on the ship, but the charterer is the one paying for the fuel there is no incentive for the owner to invest in improvements (e.g. measuring equipment) onboard the vessel[28].

A third issue is that second hand prices of vessels do not correlate with the investments made to increase their fuel efficiency. The ship owner who has invested money in bunker saving equipment will not see an increase in the price he gets once he sells the vessel[29].

Shipyards are also not prone to change their ship designs at a reasonable cost or they simply do not have the capacity to do so[30]. Therefore especially a smaller shipping company has little or no possibilities to affect the design of a “standard” ship.

Finally, the initial cost in developing a new energy saving method might discourage a ship owner from making the investment[31]. Even though the investment is sure to pay itself off in the long run, the owner might not be in the position, real or imagined, to make the investment.

During January, February and March 2012 we conducted a series of interviews with experts on energy efficiency. The experts were all employed by shipping companies that by seafarers are considered leaders in the field of energy saving. The aim of the interviews was to study the general process in the shipping company when working with energy conservation measures and to examine which of the more common operational measures were implemented and how.

We noticed that a common denominator among the experts was that they all seemed very proud of the amount of work their companies were putting into solving and developing energy related questions. The experts´ willingness and openness in sharing information about their companies and the work they are doing was also surprising.

As the individual interviews progressed it became apparent in each interview individually, that a whole-hearted commitment to energy efficiency and ecological thinking is of utmost importance if you truly want to make a change in the way the shipping industry is run. Mr Jivén of Maersk Line noted that being a leader in the field of energy efficiency, the path starts with top management saying so openly and officially. The questions that arise when trying to implement new measures are complicated and affect a lot of people; therefore effective communication within the company is crucial for success, said Mr Tunell of Wallenius Marine.

Figure 17. More spectacular ideas on fuel savings are continuously presented. This is a kite from the German company Beluga that will save fuels by 10-15 % in a first phase but later up to 30 – 35 %[32].

6. The measuring problem

Another common denominator in the interviews was that the respondents immediately turned to the problem of measuring. The effect of an implemented energy efficiency technique can only be assessed if you can accurately measure the effect of said technique. As it turns out, the most problematic aspect of the measuring difficulties is the measuring of the vessel's speed through water (STW), all of the shipping's company interviewees thought. Speed over ground (SOG) is fairly accurately measured today with the help of satellite navigation, but to find out whether or not you are saving bunker STW is crucial. If the vessel encounters strong currents the SOG might differ greatly depending on the direction of the current contra the heading of the vessel. The engine however is turning the propeller at constant speed with constant fuel consumption, regardless of the difference in SOG.

Since the ocean is never completely still the measurement must be made in STW. Because many of the techniques are only expected to save a fraction of a percent of bunker, the measuring of the ships STW should be made with an accuracy that is not attainable today. To measure hull and propeller performance Wallenius Marine have made several sea trials but still the results are conflicting.

To get as accurate data as possible Maersk Line retrofitted 8000 measuring points on its PS-class vessels. All the information gathered is followed in real time and the ships are benchmarked against each other. The information gathered is also of utmost importance when designing the next generation, Triple E, container vessels.

Stena Line has invested a lot of time and money in upgrading their measurement equipment with, amongst others, portable measuring equipment that easily can be moved to measure the quantity of current interest. The measuring results also made the switch to new frequency-controlled pumps an easy choice since it was noted that almost all pumps were operating with unnecessary high effect and the pay-off time of new control systems for the pumps would be short.

With eleven vessels with one hertz measuring techniques Per Tunell of Wallenius Marine still noted that frustration sometimes arises in the company when measuring data is not consistent. Performance can vary over time without apparent reasons by as much as tens of percentages. As of today Wallenius Marine are still trying to find the underlying explanations.

7. Operational and maintenance fuel saving potentials

In order to evaluate practical improvement programmes we used a summary made by Wartsila in their Energy Efficiency Catalogue 2011. This was done to benchmark practical and theoretical fuel saving programmes. It is important to point out that the numbers in the catalogue are estimates made by Wartsila. Since Wartsila has been a well known actor in the world wide maritime cluster for a long time their estimates are however considered as relevant expert opinions. The expected effects therefore served as a credible baseline for comparison of the findings of the interviews.

Action	General saving potential
Turnaround time in port	< 10%
Propeller surface finish/polishing	< 10%
Hull surface – Hull coating	< 5%
Part load operation optimisation	< 4%
Voyage planning – weather routing	< 10%
Ship speed reduction	< 23%
Vessel trim	< 5%
Autopilot adjustments	< 10%
Energy saving operation awareness	< 4%
Condition Based Maintenance (CBM)	< 5%
Hull cleaning	< 3%

Figure 18. Potential fuels saving activities according to Wärtsila [33]It should be noted that these rough numbers may be relevant for specific operators, ships, trade lanes but for others irrelevant as their operational conditions may be very different.

8. Practical fuel saving activities

Methods that are possible to implement onboard a vessel with little or no investment costs are deemed operational in this chapter. The included examples are a few elected examples of what the companies has implemented. In sub chapter 8.1 the term “Eco driving” also includes a measure of human attitudes towards environmental issues that strictly cannot be called operational but that are included anyway. The attitude towards change is of utmost importance when trying to establish whether a new measure has a chance of being successful or not.

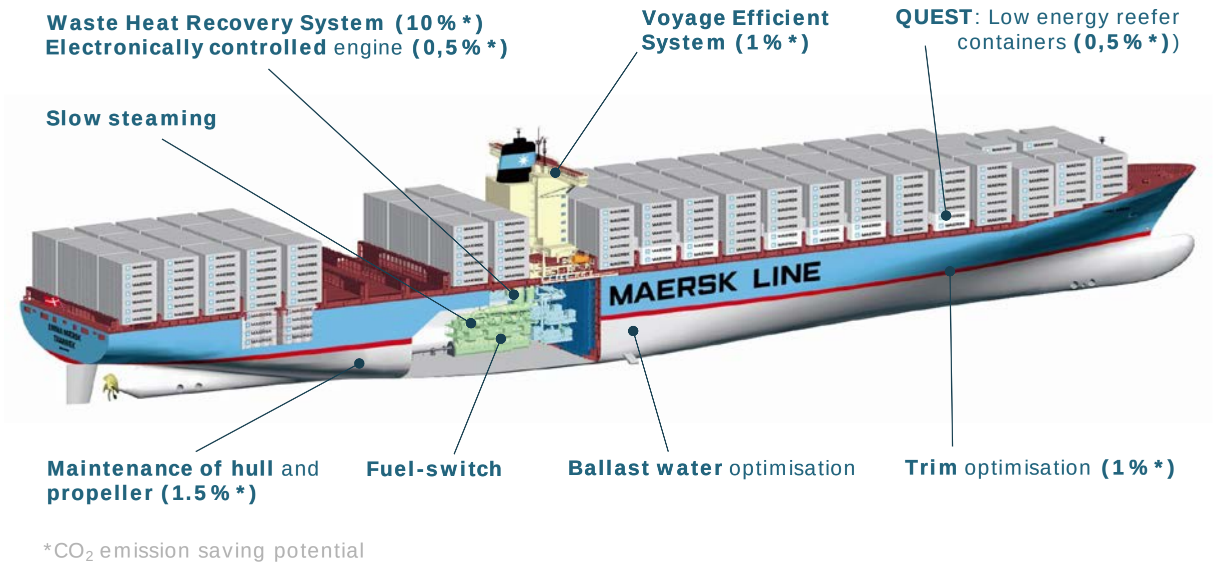


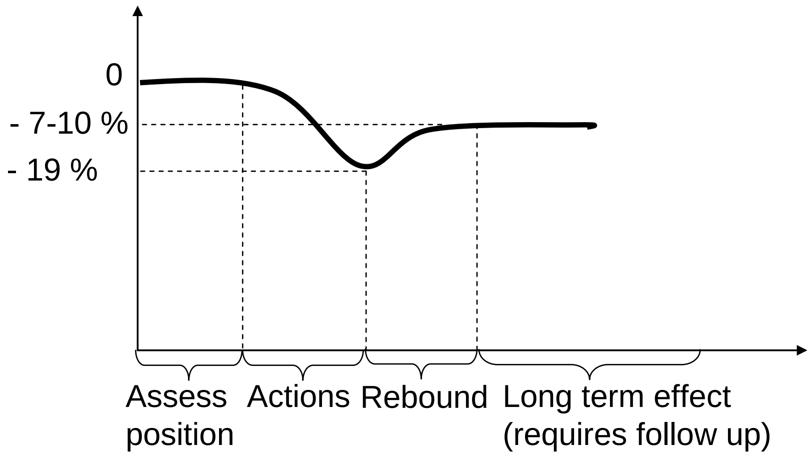
Figure 19. Maersk line and their PS type vessels[34].

8.1 Eco driving

The term “Eco driving” can mean a number of things. Usually in the maritime industry the term is used to describe the operational use of the main propulsion during a sea voyage. We have chosen to include the mindset of the individual person in which this person regards changes in operational routines and how the person is motivated to perform more fuel efficiently.

The way in which any given ship is to be operated for maximum energy efficiency is always individual, due to the unique layout concerning main- and auxiliary engines, hull form, route, autopilot settings and multiple other variables of each ship. Some general guidelines can however hopefully be drawn up for use onboard various types of vessels.

Figure 20. Viking Energy, a Norwegian gas fuelled supply vessel. In its operation significant differences in fuel consumption in comparison to its sister ship has been identified[35].



F*igure 21. Rebound effects on eco driving are a well known fact. This graph comes from lessons learnt in road transport[36]. The key challenge in sea transport is to assess a credible baseline where external factors affecting the result are eliminated.*

8.1.1 Expected gains

According to Wartsila Marines Energy Efficiency Catalogue a culture and mind set among the crew onboard could alone generate as much as a 10% reduction in fuel consumption. Adding a slower cruise speed, autopilot adjustments and other operational factors the fuel consumption savings can be even greater.

8.1.2 Measures carried out

Maersk Line

According to Maersk Line, shipping crew knowledge about fuel consumption reduction is crucial for any gains to be made. Their crews are continuously educated, mainly through the masters and chief engineers of the vessels, to improve performance. All sister ships fuel efficiency performance is continuously benchmarked against each other for ease of comparison between ships. The masters and chief engineers receive an annual appraisal in which fuel consumption plays a major part. Other parts of the appraisal include safety onboard and crew well being.

Stena Line

Stena Line educates their officers once a year ashore and once a year with a visit from technical shore personnel onboard all the vessels. A concern within Stena Line is the reluctance of some officers to change the way they operate their ship and to implement new routines. This problem can to some extent be conquered by training and education but accuracy in recruiting and incentives for current crews are also important in continuously improving performance.

Stena Line has implemented a program called Stena Innovations that includes monetary bonuses to every employee that comes up with an energy- and/or cost saving idea that is implemented. A price for “best vessel” is also presented every year as a way of promoting the energy saving way of thinking.

Crew members that show interest in developing the company’s energy saving plans are selected to help with or run new projects outside the boundaries of their usual jobs. This provides an incentive for the individual as well as promotes energy efficiency thinking.

Stena Line has completed approximately 100 fuel efficiency projects since 2005 and estimates the total saved fuel since then at a quantity of 16.000 tonnes. Mr. Hellring also noted that Stena Line without delay implements all bunker saving ideas that can be shown to have a pay off time of 2 years or less.

Figure 22. Windmills onboard Stena Jutlandica. The interesting effect of this solution is that it delivers electricity meanwhile it reduces the wind drag from the ship building[37].

Wallenius Marine
Wallenius Marine focuses on training their vessel crews with officers' conferences twice a year as well as computer-based environmental training aboard the ships. There is high focus on training existing crews to be more energy efficient but the interest in environmental questions is already screened during the recruitment of officers.

Wallenius has a "Proposal committee" to which all improvement initiatives can be sent. Implemented initiatives are rewarded. In addition an Energy Efficiency competition was held 2011 within the fleet with a high rate of participation.

Neste Oil
Neste Oil has produced an operational manual for their energy efficiency techniques. The manual is soon to be updated as the work towards ever more efficient energy use continues. An incentive program that, amongst other factors, measures the vessels energy efficiency is also in use and it rewards captains and chief engineers. Improvements and new operational measures are usually implemented when freight rates are low so as not to lose business opportunities.

8.2 Weather routing

Weather routing or route optimizing are terms used for route planning that includes other factors than the traditional route plan, i.e. the shortest, safe route between two given points. In optimal conditions the least amount of fuel consumed by a ship would be by travelling the shortest possible distance between two points. In theory this always means using a great circle but a rhumb line is often used on many shorter distances since the difference is negligible. It is considered good seamanship to take weather forecasts into account for reasons of safety, but to do it for the sake of bunker economy is not as widespread.

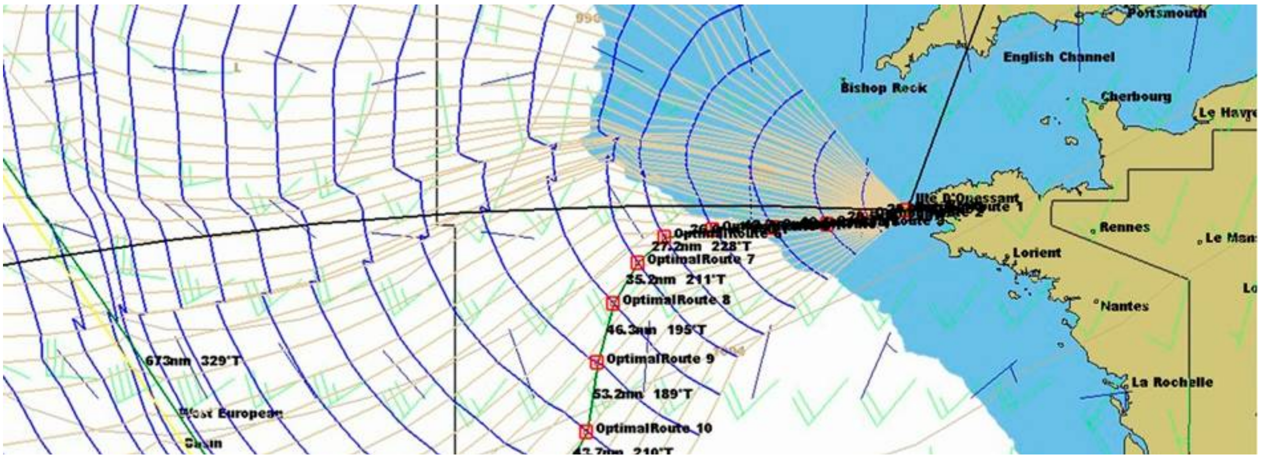


Figure 23. Optimising the route with help from various advanced forecasts on wind and current development[38].

Since weather and currents greatly can affect the speed over ground (SOG), or the speed at which the vessel is actually approaching its goal, there can be an advantage in choosing a route that uses the weather conditions to improve the SOG or at least minimizes the loss in SOG in unfavourable conditions. A route optimizing service will expectedly be more effective the longer the route is. Crossing an ocean can be done in a multitude of ways whilst crossing a bay or navigating in archipelago conditions might only have a few viable route options.

Many different types of weather routing services are available, ranging from the deck officers making their own judgement based on weather maps to complex systems where expert meteorologists give recommendations based on sophisticated data from a number of weather services. A company's vessels´ automated communication between each other, sharing information about current and wind, speed and direction is a modern weather routing service.

8.2.1 Expected Gains

The gains expected by using weather routing are higher the longer the journey is. This is because the ship is exposed to the weather for a longer time and the possibilities for different route choices are greater. The expected gain can be up to a 10% reduction in fuel consumption given a scenario with a long journey, for example an ocean crossing in foul weather (Wartsila, 2011). It is, however, noteworthy that also on short routes there are consumption savings to be made, especially if the conditions are such that strong currents and/or heavy winds are often encountered.

8.2.2 Measures carried out

Maersk Line

Weather routing has been a tool for Maersk Line in reducing bunker consumption for a long time. The newest system in use uses a wide variety of factors when determining the most effective route between two points. The vessels in the fleet automatically communicate the weather and current information they currently are experiencing to all the other vessels and therefore a database of weather information from around the globe is created and continuously updated. The system is also implemented on all vessels that are chartered by Maersk. The effects on bunker consumption are considered substantial.

Neste Oil

For 6-8 years Neste Oil used weather routing services sporadically. Weather routing services were bought on a trip-by-trip basis only when the vessel had an ocean crossing or other longer trip ahead. The positive effects on bunker consumption did, however, inspire the implementation of a fleet-wide weather routing system. Since the autumn 2011 a weather routing service is permanently available to all the vessels in the fleet. Factors taken into account in the system are currents, wind and wave height prognosis. The information is then analyzed by a team of experts at a meteorological institute and a route recommendation is constructed. Neste Oil estimates the bunker savings to be in the range of Wartsila´s Energy Efficiency catalogue.

Stena Line

Since Stena Line operates on shorter routes than the other companies interviewed in this report, the expected gains from weather routing are naturally smaller. However, I found it very interesting that Stena Line uses weather routing on the route between Oslo and Frederikshavn (a distance of just under 160 nautical miles). The bunker saved with the implemented weather routing is estimated at 1 – 1.5 %.

8.3 Slow steaming

Slow steaming is a bus word that aims at describing the operational measure of reducing the vessel speed in order to save fuel. It is however difficult to define slow steaming. In general it can be said that a reduction of speed reduces bunker consumption per nautical mile. There are, however, nuances, mainly because of different engine room layouts, that need to be accounted for. When s vessel designed for 20 knots operates in 13 is either poorly designed or it is used to buffer market fluctuations. The general note that a reduction of speed reduces bunker consumption per nautical mile is true down to a certain speed where the consumption for electricity will make the curve turn up again. Hence slow steaming will generally improve fuel efficiency to a certain degree and the way it should be done depends on the technical characteristics of the actual vessel.

8.3.1 Expected gains

The bunker saving can be significant if the speed is reduced drastically, but already a modest decrease in speed of 1 knot can reduce bunker consumption by 11%. (Wartsila, 2011)

The layout of a given vessel's engine room greatly affects the actual bunker reduction for a number of reasons:

- A vessel with only one main engine will probably gain the most from a speed reduction if the engines load program is also modified for the new speed, even if just a speed reduction in itself also will reduce bunker consumption. (Wartsila, 2011)
- A vessel with more than one main engine can probably use a lesser number of main engines if travelling at a smaller speed than if travelling at full speed. A smaller number of engines in use also means less bunker consumed.
- If the operating speed of a ship is reduced, other fuel savings might also be possible, for example changing the propeller to better suit the new speed range might give additional savings.

One shipper remarked on this topic that fuel savings were not so big as expected due to present ships were designed for another speed.

8.3.2 Measures carried out

Tallink Silja

In 2012 Tallink Silja decided to increase the travel time for its ferries travelling between Stockholm and Helsinki via Mariehamn on their eastbound leg during the months when ice conditions were expected. The arrival time in Helsinki was moved 35 minutes forward but the departure time from Stockholm and the arrival- and departure times in Mariehamn were unchanged. This effectively increased the travel time on the leg from Mariehamn to Helsinki by 35 minutes whilst the distance obviously was unchanged. The first numbers gathered by M/S Silja Serenade showed that a saving of approximately 6 tons of fuel oil was made every trip from Mariehamn to Helsinki. The savings for one vessel during one month amounted to about 80 tons. The direct reason for the savings in fuel consumption was that one main engine less was used for a period of about 5 hours on each trip.

The CO_2 not emitted by this change in schedule can, according to section 5.2 in this report, be estimated to approximately 232 tonnes per vessel per month. The money saved on bunker can equally be estimated to approximately 56.000 Euros, given a current bunker price of about

700 Euros per tonne. For the two ships operating on the Helsinki – Mariehamn – Stockholm line the total savings where, therefore, just under 500 tonnes of CO_2 not emitted at the “cost” of saving the company over 100.000 Euros every month.

Stena Line
One ship was moved to a new route with a new timetable that only required a cruising speed of 18 knots instead of the 26 knots that is the ship’s maximum speed. A change of propeller to a design more suitable for the new speed resulted in a fuel saving of approximately 16 %. The old propeller is kept in store, awaiting possible future use and the cost of the new propeller was quickly paid off by the bunker savings.

Maersk Line
Maersk Line has been trying different ways of slow steaming and the results have been a distinguishable reduction in bunker consumption. In the beginning, engine manufacturers objected to the idea due to imagined risks of the engines taking damage, but a test program was carried out on 120 vessels. That test showed no negative effects. The Maersk Line vessels slow steam as low as 5 knots but the normal cruising speed within the new speed scheme is usually around 15-17 knots. The total bunker consumption reduction because of slow steaming in the Maersk fleet is approximately 7%. A concept of so-called super slow steaming is also being planned; the concept will lower the cruising speed to 12-14 knots, saving even more bunker.

Slow steaming had some operational problems that had to be addressed by the company. A decision was made that the Maersk Line ships will continue to slow steam even if a shortage of capacity is noticed. A concentration of ports in which cargo was loaded and unloaded was also implemented to shorten the total time needed for a voyage with increased travelling time at sea with the slower speed.

Lessons learned from the implementation of slow steaming also affected the design of the new Triple E container ship series. A reduction in the maximum speed of the Triple E series to 23 knots from the previous standard of 25 knots in the PS-series, the Triple E hull is now being built in a more box like shape than its predecessors. A more boxed hull equals more boxed like cargo compartments and therefore a higher number of containers that can be loaded, which in turn means lower relative fuel consumption per cargo unit.

Because of the reduction in top speed, the Triple E series is also fitted with 19% smaller main engines than the PS series whilst loading 16% more containers. The combined advantages of the design features will give the ships of the Triple E series a 20% better fuel consumption than the one generation older PS series.

Neste Oil
During the low freight rates of the summer and autumn 2008, Neste Oil decided that all the vessels of the fleet where to cruise at 80% of the engine capacity. The bunker savings were in line with what Wartsila´s Energy Efficiency Catalogue 2011 predicts.

8.4 Trim

The trim of a ship is the difference between the draft at the forward- and aft perpendiculars (PP). If the drafts at both perpendiculars are equal, the ship is considered to be on even keel. If the draft at the forward PP is greater than at the aft the ship has a negative trim and if the forward draft is lesser than the draft at the aft PP the ship has positive trim.

At what trim a vessel is most energy efficient is individual to the vessel type and sometimes even sister ships might have different optimums. The common conception amongst seafarers is that a ship should always be floating on even keel or with a slight negative trim to be most efficient. The most efficient trim should, however, always be measured on the ship to avoid speculation and possible negative fuel consumption consequences.

Factors like the shape of the hull i.e. draft and cruising speed all affect the optimum trim and therefore it is impossible to give a general answer as to what the optimum trim for a vessel is[39]. Wartsila´s Energy Efficiency Guide, however, speculates that the difference between the least effective and most effective trim with a given hull shape with a given draft and speed might be as high as 20%.

8.4.1 Expected gain

Because of the reasons mentioned in the trim explanation an estimate of fuel savings is difficult to give. The gain could however be as big as 5% (Wartsila, 2011) but it is more likely that, at least on a ship with an experienced crew that already trim their vessel according to acquired experience, the gain would be smaller.

8.4.2 Measures carried out

Maersk Line

Measurements onboard the PS class vessels have concluded that optimal trim saves Maersk approximately 1% in bunker consumption. The difficulty in trimming the ship to the optimal, without using ballast water with its added weight, used to be that the cargo weight of the containers loaded was not exactly known. The vessel had to rely on the weight information provided by the freight consignor. That piece of data was outside the control of the company and many times turned out to be wrong. The aggregated errors could therefore be substantial on a vessel with a 15.000 TEU capacity. Maersk Line now demands that all containers are weighed before loading and that data is then processed in a load computer program to achieve optimal loading for an optimal trim.

Wallenius Marine

The results of measuring fuel consumption in different ballast conditions concluded that an optimally ballasted vessel would use approximately 3% less fuel than on a benchmark voyage. An add-on to the loading computer now optimizes the ballast distribution, within set conditions, to achieve higher energy efficiency.

Thun tank

At present Thun tank is in the process of assessing a relevant fuel consumption baseline that will be their benchmark for evaluation of trim improvement measures. The expected gains are 2% savings on the fuel consumption.

9. Conclusions

The interviews carried out as a part of the research for this report were done with experts in the field of energy efficiency. A greater number of interviews would probably have lead to even more ideas on how to preserve energy and to more solid data regarding the methods described in this report. Even so, the expert opinion of the interviewees paints an adequate picture of what is at least possible, given time and resources, in terms of making energy use more efficient.

The fossil fuels used to propel the ships of today across vast oceans are a finite resource. In addition, the combustion of carbon based energy forms emits greenhouse gases and other air pollutants that are destructive to the ecological environment.

Shipping in general is an energy efficient way of transporting goods, even though it emits substantial amount of greenhouse gases in absolute terms. The sea trade is crucial to an ever growing global economy and will grow at the same rate. Measures to reduce the shipping industry's ecological footprint should be a priority for everyone involved. It is not just a question about the environment; it is a question of economic survival.

In this study, theoretical and suggested saving potentials were confirmed in the carried out interviews. It seems there are a number of relatively easy ways to reduce bunker consumption in sea transports. A lot of research has already been done and is only awaiting implementation. The possibilities seem so vast that it is amazing that more is not done in the field internationally.

Overall business logic, aiming at increasing profit margins where significant cost cut at short pay back time should rank high on the management agenda. In addition to increasing the profit margins, the emissions of green house gases would decrease by fuel saving programmes. This should be sufficient drivers to implement thorough fuel saving programmes for every ship owner. Still we see several saving activities not being carried out by the shipping industry in general. The activities themselves seem easy enough to carry out, but there are some severe hurdles that need to be addressed.

The most severe hurdle to overcome links to our observation throughout this study that there is a need for a strong and solid company culture that continuously strives for improvements with regard to energy efficiency. This culture must be based on solid and continuous measurements in order to assess a credible assessment of actual fuel consumption. As new trials of fuel saving activities are carried out they must be evaluated and verified before implemented on other ships.

The main problems really seem to be the measuring and the consequent uncertainty in what the real results are. Another issue is the human weakness of accepting change related to fuel saving measures. Regarding the measuring problem it is evident that some investments are needed if the actual results are to be accurately measured. There is, however, the possibility to simply take advantage of research and measurements already made by others and trust that their energy conserving effects will bring monetary advantages in the long run. The instant effect of a certain implemented method is only relevant if the aim is to continuously improve operations. If the ambition level is lower, smaller investments are needed. Substantial savings in fuel consumption can still be made even though the measuring is not state of the art.

Another reason why more is not done seem partly to be the result of the energy gap described by below examples:

- A significant reason for not improving energy effectiveness in the shipping industry might be that a large share of the fuel expenses is passed on to the customer. As much as 70% -90% of the bunker costs might not actually be paid by the shipping company but by the end customer, e.g. bunker surcharges that passenger cruise companies sometimes levy.
- Another major reason for the non actions taken can probably be found in the parts of the shipping industry that involve a lot of bare boat and time charter contracts. Since the ship owner is the one responsible for improvements on the ship, but the charterer is the one paying for the fuel there is no incentive for the owner to invest in improvements (e.g. measuring equipment) onboard the vessel.
- A third issue is that second hand prices of vessels do not correlate with the investments made to increase their fuel efficiency. The ship owner who has invested money in bunker saving equipment will not see an increase in the price he gets once he sells the vessel.
- Shipyards are also not prone to change their ship designs at a reasonable cost or they simply do not have the capacity to do so. Therefore especially a smaller shipping company has little or no possibilities to affect the design of a “standard” ship.
- Finally, the initial cost in developing a new energy saving method might discourage a ship owner from making the investment. Even though the investment is sure to pay itself off in the long run, the owner might not be in the position, real or imagined, to make the investment.

If the energy gap remains there may be a need to provide a framework for modern energy efficient operations that should be aimed at by all shipping companies.

During the interviews it really became apparent that what is needed above all is the will to change the way we consider fuel efficiency. The unwillingness of humans to change established patterns of operations is a significant hurdle. Resolving this challenge will need forming and developing the minds of the managers of the company. From there it should be communicated down through the ranks so that it finally is intrinsic within the whole company culture. Incentive programmes for crews also seems like a well working concept for coming up with new, energy saving, ideas. It is obvious that the people who operate a vessel have a great knowledge of how to maximize the output of the resources available. Their knowledge, experience and ingenuity are immaterial commodities that the company can take advantage of at no extra cost. The company just has to elicit the new ideas by proper motivation.

There are numerous saving regarding fuel consumption to be made by operational measures alone. The fuel wasted in today´s shipping industry represents money that could be better spent elsewhere; it should therefore be in every ship owner’s interest to use that money more efficiently. The road to better fuel economy aboard is long and winding, so the sooner improvements are begun, the better.

10. Abbreviations and nomenclature

Abbreviation	Explanation
Bare boat	An arrangement of hiring a ship whereby no crew or provisions are included as part of the agreement
Bilge water	Bilge is the lowest compartment on a ship where water and other spills are gathered. This fluid often contains various toxic substances.
Black water	Toilette sewage
CCU	Cargo Carrier Unit
CH_4	Methane
CO	Carbon oxide
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CFC	Chlorine Fluor carbon
CDM	Clean Development Mechanism (Kyoto agreement)
CRT	Continuous Regenerating Trap
CH_4	Methane as biogas or natural gas
Cold ironing	Land shore electricity
Diesel	Fuel and engine principle (Rudolf Diesel)
DME	Dimetylether
Displacement	The actual total weight of the vessel
DWT	Dead weight tonne is the displacement at any loaded condition minus the lightship weight. It includes the crew, passengers, cargo, fuel, water, and stores
EEA	European Environmental Agency
EMAS	Eco Management and Audit Scheme
EPA	Environmental Protection Agency (e.g. US EPA)
EPD	Environmental Product Declaration
EGR	Exhaust Gas Recirculation
Emission allowances	One of the flexible mechanism suggested by the Kyoto agreement
Euro class	EU heavy vehicle emission standards
ETA	Estimated time of arrival
F-T diesel	Fischer Tropsch (Diesel) i.e. synthetic diesel
GWP	Global Warming Potential
GHG	Green House Gas
GT	Gross tonne, a function of the volume of all ship's enclosed spaces
Grey water	All sewage apart from toilette sewage
HAM	Humid Air Motors (also SAM and Wetpac)
HSD	High speed diesel engine
Hybrid	A mix of two techniques e.g. electric/diesel engine
HFC	Hydro Fluor carbon
HC	Hydrocarbons
H_2	Hydrogen
NH_3	Ammoniac
NMHC	Non-methane Hydro Carbons

Abbreviation (cont.)	**Explanation**
ICE Classification	Ships with an Ice Class have a strengthened hull and additional engine power to enable them to navigate through sea ice
ISO	International Organisation for Standardization
ISO 14 001	Environmental management system
ISO 9001	Quality management system
ISO 50 001	Energy management standard
JI	Joint Implementation, One of the flexible mechanism suggested by the Kyoto agreement
IMO	International Maritime Organisation
LNG	liquefied natural gas
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
Abbreviation (cont)	Explanation
LCI	Life Cycle Inventory
Lm	Lane meters (ferry cargo capacity)
NO_2	Nitrogen dioxide
N_2O	Laughing gas
NOx	Nitrogen oxides
N	Nitrogen
NTM	Network for transport and environment
MAUT	German road toll system
MSD	Medium speed diesel engine
Motor alcohols	Ethanol and methanol
Market based measures	Economical incentives in order to favour a specific behaviour
Otto	Petrol engine principle
ODP	Ozone Depletion Potential
O_2	Oxygen
O_3	Ozone
PM	Particulate matters
PCR	Product Category Rules
PSSA	Particularly Sensitive Sea Areas
Renewable fuels	Fuel based on renewable primary biomass
RME	Rape seed oil
Regulated emissions	Emissions to air being regulated by engine standards
RoRo	Roll on/roll off (cargo)
RoPax	Roll on/roll off (cargo and passenger)
Rhumb line	
SO_2	Sulphur oxides
SQAS	Safety & Quality System Assessment within the chemistry industry
SCR	Selective Catalytic Reduction
ST	Steam turbine engine
SSD	Slow speed diesel engine
Slow steaming	
SOG	Speed Over the Ground is the speed of the vessel relative to the surface of the earth
STW	Speed Through Water (STW) is the speed of the vessel relative to the water.

Abbreviation (cont.)	**Explanation**
Stuffing & stripping	The packing and unpacking of containers or other cargo carrier units
TEU	Twenty Foot Equal Unit (container)
THC	Total hydro carbons
ttw	Tank to Wheel
TEN	Trans European Network
Time charter	The vessel is hired for a specific amount of time. The owner still manages the vessel but the charterer gives orders for the employment of the ship.
Vetting system	A process of examination and evaluation of performance
VOC	Volatile organic compounds
VLCC	Very large crude carrier
wtw	Well to Wheel
wtt	Well to Tank
UREA	Ammoniac based reduction liquid

11. Interviewees

Mr. Karl Jivén
Sustainability Manager, Maersk Line
Located in Gothenburg

Mr. Lars-Erik Hellring
Superintendent, Project Manager, Energy Saving Programme, Stena Line
Located in Gothenburg

Mr. Hannes Johnson
Doctoral student, Chalmers Maritime Environment
Located in Gothenburg

Mr. Per Tunell
Head of Environmental Management, Wallenius Marine
Located in Stockholm

Mr. Sami Niemelä
Technical Manager, Neste Oil
Located in Helsinki

Mr. Ola Bengtsson
Senior Captain, M/S Silja Symphony
Located in Stockholm

Mr. Henrik Källsson
Technical department, Thun Ship Management AB
Located in Lidköping

Mr Fredrik Backman
Vettting coordinator, Preem AB
Located in Stockholm

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1. Executive summary

Sea transport includes various transport operation from shipper to consignee via ports. The operation is carried out by either dedicated vessels or transport operation through shared vessels. The dedicated sea transport services are often carried out by ships for general cargo or bulk cargo i.e. specially designed for the shipments. The shared sea transport services are often carried out by container ships and ferries (RoRo and RoPax). In the shared transport services, single shipments from various shippers are commonly consolidated through standardized cargo carrier units such as containers, trailers etc in order to coordinate goods flows i.e. achieve economy of scale.

The dedicated sea transport services are commonly negotiated and agreed between the cargo owner and the ship owner. In shared sea transport services the commercial agreement often involves an intermediary agent or forwarder that also may provide the cargo carrier unit and offer transport services to and from the port. Door to door sea transport service commonly requires feeding transport services that includes rail or truck transport to and from the port, i.e. a multimodal transport solution.

In general, the sea transport system consists of different sized vessels and various ports managed by people using information from supporting IT-systems. Overall the aim is to obtain efficient transport logistics. The sea cargo transport system also consists of different reload areas such as goods terminals for stuffing & stripping of the cargo carrier units (commonly containers).

Ships are apart from size divided in accordance with their use as ferries (RoRo, RoPax); general cargo for various types of goods, various tankers for bulk goods and the increasingly common container ships. The size of the ship is determined by the fairway capacity, for example Panamax[1] and transport demand, hence overall efficiency is determined by maximum allowed specifications regarding length, width, height and weight according to navigable fairways used and the ability to operate with balanced goods flows.

The objective of this study is to analyze some shipping companies and study what operational methods they have implemented with regards to their energy efficiency programmes. The results of the implemented methods are also analyzed and general recommendations are assessed when possible. This study is based on a Maritime Management degree thesis at Novia University of Applied Sciences in Åbo.

The carried out interviews with experts in the field of energy efficiency and literature studies was the major input to this report. A greater number of interviews would probably have lead to even more ideas on how to preserve energy and to more solid data regarding the methods described in this report. Even so, the expert opinion of the interviewees paints an adequate picture of what is at least possible, given time and resources, in terms of making energy use more efficient. The interviews were carried out during December 2011 and March 2012.

The fossil fuels used to propel the ships of today across vast oceans are a finite resource. In addition, the combustion of carbon based energy forms emits greenhouse gases and other air pollutants that are destructive to the environment. Shipping in general is an energy efficient way of transporting goods, even though it emits substantial amount of greenhouse gases in absolute numbers (see figure 5 in the introduction).

The sea trade is crucial to an ever growing global economy and is likely to grow at the same rate as international trade develops. Measures to reduce the shipping industry's ecological footprint should therefore be a priority for everyone involved in sea transport as its legitimacy otherwise may be questioned among various stakeholders. Thus it is not just a question about the environment; it is a question of long term economic survival.

In this study, theoretical and suggested saving potentials were confirmed in the carried out interviews. It seems there are a number of relatively easy ways to reduce bunker consumption in sea transports. A lot of research has already been done and is only awaiting implementation. The possibilities seem so vast that it is amazing that more is not done in the field of reducing bunker consumption internationally and locally.

Overall business logic, aims at increasing profit margins where significant cost cut at short pay back time should rank high on the management agenda. In addition to increasing the profit margins, the emissions of green house gases would decrease by fuel saving programmes. This should be sufficient drivers to implement thorough fuel saving programmes for every ship owner. Still we see several saving activities not being carried out by the shipping industry in general. The activities themselves seem easy enough to carry out, but there are some severe hurdles that need to be addressed.

The most severe hurdle to overcome seems to be the assessment of a credible bunker consumption baseline, from where improvements can start. Assessing this baseline takes time and efforts without immediate gains. Therefore our observation throughout this study is a need for a strong and solid company culture that forms a long term commitment to assess a credible baseline of actual fuel consumption. From this baseline continuous improvement measures with regard to energy efficiency can be implemented. As new trials of fuel saving activities are carried out they must be evaluated and verified before implemented on other ships. The main problem really seem to be to measure bunker consumption accurate and the consequently uncertainty in what the real results are from various improvements activities.

Another issue is the difficulty to change old behaviours related to operation. Regarding the measuring problem it is evident that some investments are needed if the actual results are to be accurately measured. There is, however, the possibility to simply take advantage of research and measurements already made by others and trust that their energy conserving effects will bring monetary advantages in the long run. Substantial savings in fuel consumption can be made even though the measuring is not state of the art.

Another reason why more is not done seem partly to be the result of market failures e.g. the energy gap described by below examples:

- A significant reason for not improving energy effectiveness in the shipping industry might be that a large share of the fuel expenses is passed on to the customer. As much as 70% -90% of the bunker costs might not actually be paid by the shipping company[2] but by the end customer, e.g. bunker surcharges that passenger cruise companies sometimes levy.
- Another major reason for the non actions taken can probably be found in the parts of the shipping industry that involve a lot of bare boat and time charter contracts. Since the ship owner is the one responsible for improvements on the ship, but the charterer is the one paying for the fuel there is no incentive for the owner to invest in improvements (e.g. measuring equipment) onboard the vessel.

- A third issue is that second hand prices of vessels do not correlate with the investments made to increase their fuel efficiency. The ship owner who has invested money in bunker saving equipment will not see a fully corresponding increase in the price he gets once he sells the vessel.
- Shipyards are also not prone to change their ship designs at a reasonable cost or they simply do not have the capacity to do so. Therefore especially a smaller shipping company has little or no possibilities to affect the design of a “standard” ship.
- Finally, the initial investment cost for a new energy saving method might discourage a ship owner from initiating this development. Even though the investment is relatively sure to pay itself off in the long run, the owner might not be in the position, real or imagined, to make the investment.

If market failures exist it is part of the failure’s definition that the market itself cannot change them. In this case legislators could step in and provide the framework for modern energy efficient operations, essentially by forcing the shipping companies to operate with higher efficiency. This could serve as additional pressure to initiate change within the industry.

During the interviews it really became apparent that what is needed above all is the will to change the way we consider fuel efficiency. The unwillingness to change established patterns of operations is a significant hurdle. Resolving this challenge will need forming and developing the minds of the managers of the company. From there it should be communicated down through the ranks so that it finally is intrinsic within the whole company culture. Incentive programmes for crews also seems like a well working concept for coming up with new, energy saving, ideas. It is obvious that the people who operate a vessel have a great knowledge of how to maximize the output of the resources available. Their knowledge, experience and ingenuity are immaterial commodities that the company can take advantage of at no extra cost or through bonuses on good proposals. The company just has to elicit the new ideas by proper motivation.

There are numerous savings regarding fuel consumption to be made by operational measures alone. The fuel wasted in today´s shipping industry represents money that could be better spent elsewhere; it should therefore be in every ship owner’s interest to use that money more efficiently. The road to better fuel economy aboard is long and winding, so the sooner improvements are begun, the better.

2. Introduction

Sea transport includes various transport operation from shipper to consignee via ports. The operation is carried out by either dedicated vessels or transport operation through shared vessels. The dedicated sea transport services are often carried out by ships for general cargo or bulk cargo i.e. specially designed for the shipments. The shared sea transport services are often carried out by container ships and ferries (RoRo and RoPax). In the shared transport services, single shipments from various shippers are commonly consolidated through standardized cargo carrier units such as containers, trailers etc in order to coordinate goods flows i.e. achieve economy of scale.

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In general, the sea transport system consists of different sized vessels and various ports managed by people using information from supporting IT-systems. Overall the aim is to obtain efficient transport logistics. The sea cargo transport system also consists of different reload areas such as goods terminals for stuffing & stripping of the cargo carrier units (commonly containers).

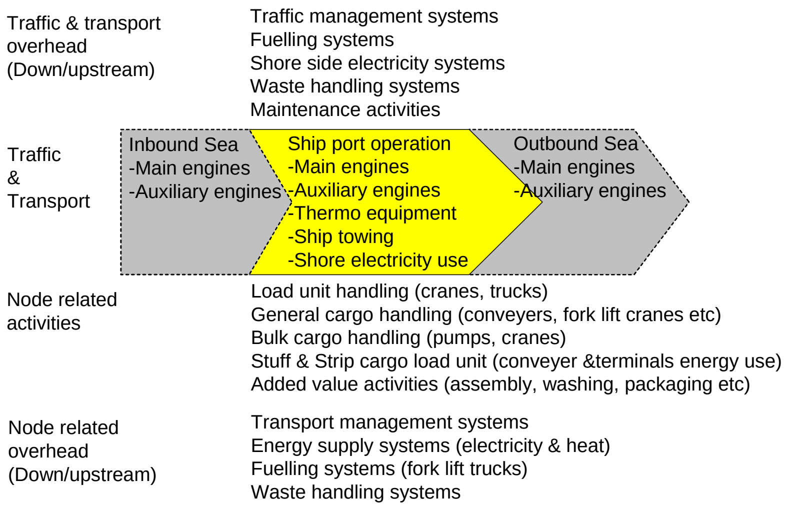

Figure 1. Operation of sea transport services requires substantial support from the ports in order to fulfil customer demands as well as enabling a resource efficient sea transport process.

Ships are apart from size divided in accordance with their use as ferries (RoRo, RoPax); general cargo including all types of goods, bulk and the increasingly common container ships. The size of the ship is determined by the fairway capacity[3] and transport demand, hence overall efficiency is determined by maximum allowed specifications regarding length, width, height and weight according to navigable fairways used and the ability to operate with balanced goods flows.

In essence, fuel efficient solutions has always been a priority within shipping in order to secure long term profitability, as fuel cost is a substantial part of the total cost in sea transport. Demands for more energy efficient transport solutions are continuously growing, today also driven by demands from legislators, customers and NGO´s. Therefore the focus on fuel consumption reduction is increasing. New technologies and innovations present a vast variety of possibilities in fuel consumption reductions in ship new buildings. However, a significant percentage of the world fleet will continue to consist of vessels with equipment designed for lowest short term cost rather than good fuel economy in mind. Thus, this fleet also needs fuel efficiency attention.

The life cycle cost (LCC) seems to have been of less importance than short term profit for shipping companies and investors when new ships have been explored. The good news in this respect is that increasing fuels costs will in evidently reshape the fuel consumption criteria’s for new ships, increasing the focus on LCC. This new trend is already being seen in several new buildings.

As the life length of a ship may be 40 years it is of utmost importance to include present and future ships regarding more energy and emission efficient sea transport solutions. There are methods that can enable significant energy savings without the large costs of building new ships, such as retro-fit and upgrade projects. By changing the way vessels are operated, energy savings can be accomplished both in relative and absolute terms. The incentive for the shipping company to make these changes ought to be high due to short payback time. In other words, an investment in operational procedures will achieve financial break even in a short time since the investment costs are relatively low. After pay back of the investment, every cent saved will be a pure increase in the bottom line result.

A fairly well spread myth with regard to the sea transport mode is its outstanding energy efficiency. For several sea transport applications this is true. However, faster or less well utilized ships do not perform equally energy efficient.

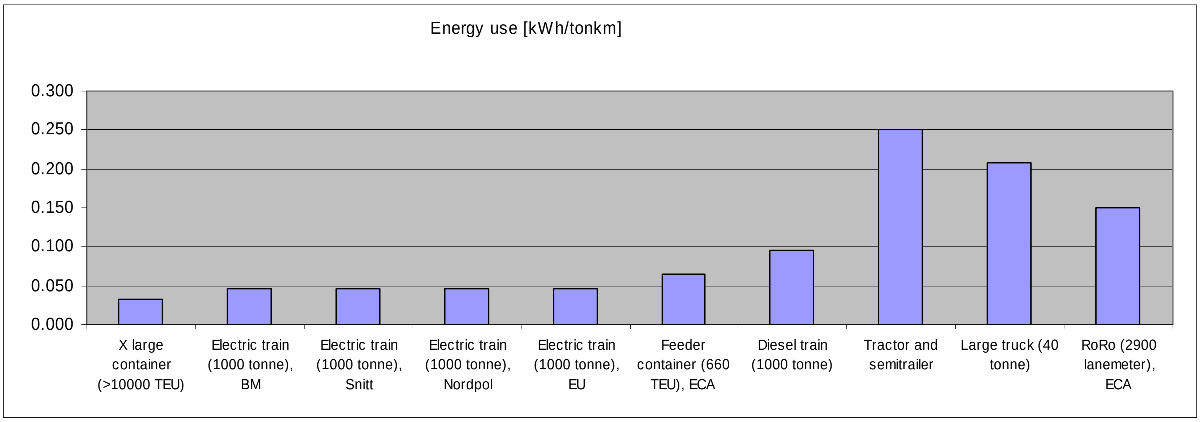

Figure 2. Benchmarking of energy efficiency for various modes of transport, assuming certain general fuel consumptions and load factors.[4]

Another type of comparison has been presented in a Karman-Gabrielli Diagram where a similar conclusion can be drawn regarding different modes of transport and their energy efficiency.

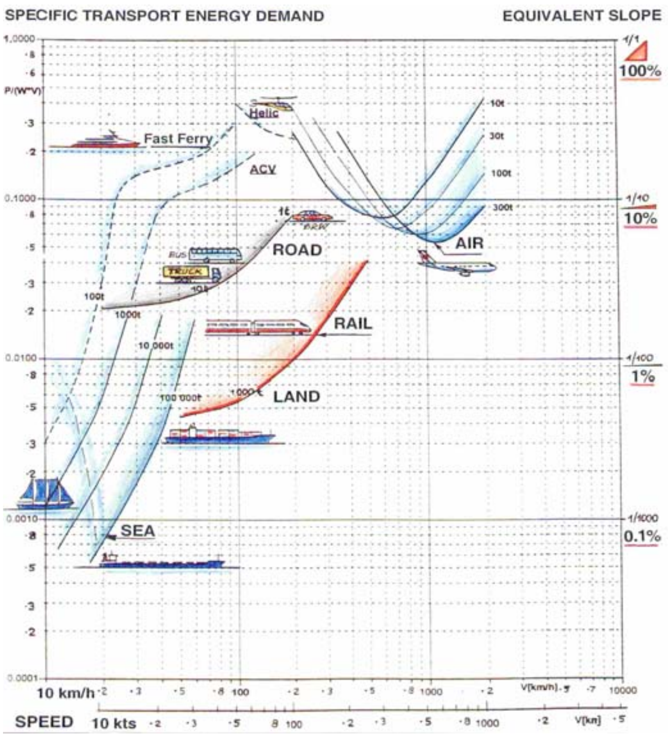

Figure 3. In this Karman-Gabrielli Diagram it is obvious that sea transport is the most energy efficient mode of transport if it is done at reasonable speed and in large units. Fast container- and RoRo-ships at 20 to 30 knots can however easily reach similar levels of energy efficiency as rail and road transport. Fast ferries at 40 to 50 knots can even reach the levels of air transport, but then at only one tenth of air speed.[5]

In conclusion it should be stressed that whatever level of energy efficiency a transport mode represents there are incentives and potentials for fuel saving programmes. The key driver is of course cutting short term costs. Other key strategic reasons are long term expected oil price and market credibility i.e. viability of the company.

The transport sector is on a global basis 96 % dependent on fossil fuels[6]. By burning fossil fuels in a an internal combustion engine in order to carry out transportation there are some significant second order effects occurring as described in the general combustion formula below.

Fuels + Oxygen => Exergy + Anergy + Carbon dioxide + Air pollutants + Water

Activity	Effects
Fossil fuel combustion	Propeller moving vessels (exergy)
	Losses in combustion and water/air resistance (anergy)
	Reduces present finite resources of oil
	Carbon dioxide emissions adding to GHG in the atmosphere[i]
	Emissions such as NOx, HC, PM, SO_2 etc

In summary there is, apart from cost saving gains to reduce fuel also environmental reasons to save fuel.

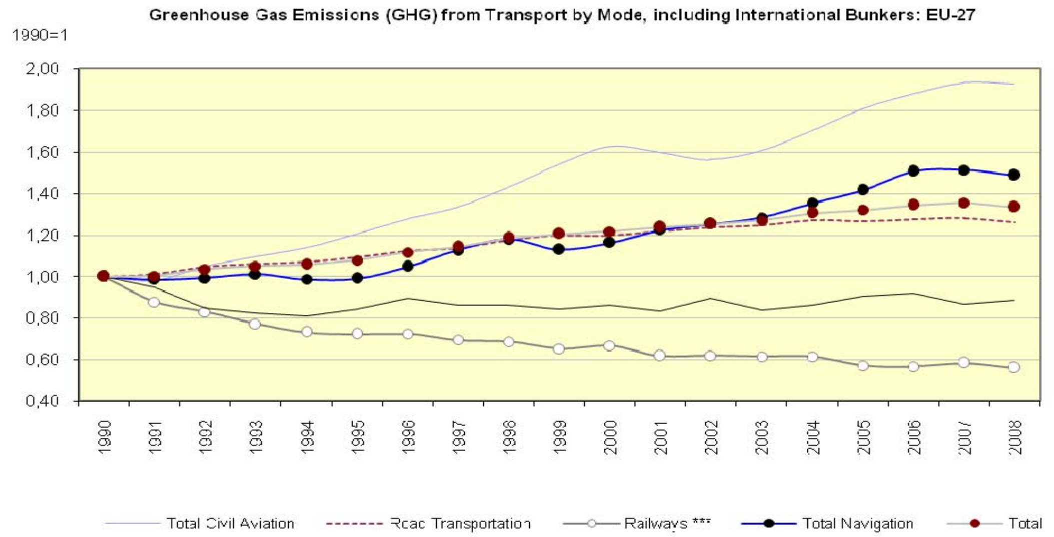

Figure 4. The transport industry development with regard to emissions of green house gases within the EU-27, including international bunker.[7]

[i] Total emission of CO_2 assuming 100% oxidation.CO_2 = carbon content (cc) x (mass weight CO_2)/mass weight C) x TFC (Total Fuel Consumption)

The general trend within the EU is an increase of transport related emissions of green house gases. Maritime transport is not an exception. Based on IEA, below the overall emissions of carbon dioxide emissions is somewhere between 2 and 4% of total global carbon dioxide emissions

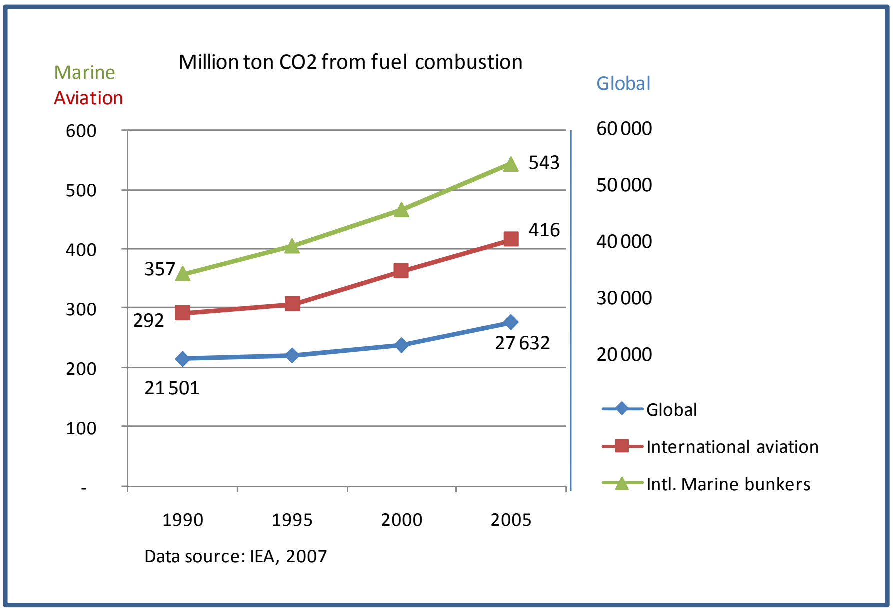

Figure 5. Emissions of carbon dioxide from the sea and air transport industry in comparison of total emissions. Later studies show that sea transport emissions in fact are higher than this graph indicates[8].The most important aspect of this graph is its trend, going in the wrong direction.

A long term strategic aspect of lowering fuel consumption is an improved ability to change towards renewable energy sources. In order to enable introduction of biomass based fuels, total fuel consumption needs to be substantially reduced, both from a cost perspective and from a resource availability point of view. An additional need for this cost cut need is coming bunker legislation aiming at lowering the sulphur content in bunker oils which in effect is predicted to increase bunker costs.

The aim of this report is mainly to introduce the reader to the practical and existing fuel saving programmes within sea transport operation. By adopting long term energy efficiency strategy we strongly believe that sea transport will evolve into an even more competitive mode of transport as well as improving its competitive edge with regard to low emissions and (green) market image.

In general, sea transport conditions seem at present to be the mode of transport with lowest general knowledge among authorities, politicians and traffic specialists. Therefore we hope this study will add to an increasing understanding regarding this mode of transport as one of several viable transport solutions for the future.

The report has been compiled by Andreas Slotte and Magnus Swahn at Conlogic.

2.2 Objectives

The objective of this study is to analyze some shipping companies and study what operational methods they have implemented with regards to their energy efficiency programmes. The results of the implemented methods are also analyzed and general recommendations are assessed when possible.

An assessment of the corporate culture regarding energy efficiency is also made in order to examine what it takes to make shipping company more energy conscious. The hypothesis of the study is that significant savings in fuel consumptions can be made relatively easily but it takes determination and focuses of the company and its employees, both ashore and aboard the vessels i.e. a mentality shift.

The study summarizes various fuel saving measures within sea transport that in effect has the potential to:

- Increase the energy efficiency
- Decrease emissions of green house gases (GHG) adding to global warming
- Decrease emissions of air pollutants with a negative impact on nature and health

2.4. Methodology

This study is based on relevant literature and interviews with leading personnel in the field of operations and the field environment in the shipping companies picked for the study. Furthermore this study is based on a Maritime Management degree thesis at Novia University of Applied Sciences in Åbo. The selection of companies in the study are based on of their size in the sector of shipping that they operate in and because of pre existing notion that they are considered, by active sea-farers, to be pro active in their work to improve energy efficiency.

The outcome of the literature studies and interviews formed a baseline which was compared with practical improvement programmes in order to identify potential discrepancies or supporting evidence with regard to practical and theoretical fuel saving programmes. This baseline of fuel saving effects is based on the estimates made by Wartsila in their Energy Efficiency Catalogue 2011[9]. It is important to point out that the numbers in the catalogue are only estimates made by Wartsila. Since Wartsila has been a well known actor in the world wide maritime cluster for a long time their estimates are however considered as relevant expert opinions. The numbers therefore served as a credible baseline for comparison of the findings of the interviews.

The study was conducted as qualitative research since obtaining large amounts of data about the energy efficiency work of shipping companies was difficult. This information is often regarded as confidential. Interviewing key personnel was therefore considered a sufficient way of discovering the possibilities of what energy efficient operational measures may obtain.

The interviews with the representatives from the shipping companies were carried out in December 2011 as well as in January and March 2012 in person. Follow up questions and/or clarifications were made through telephone conferences or via e-mail.

In chapter 7 the results from the interviews are presented. All statements concerning each company are the opinions the individual interviewee. In general it was fairly easy to assess general relevant information. More specific data and data capturing methodologies were however seen as confidential.

2.5 Delimitations

Assessing the environmental impact of a transport services typically includes the resource consumption of inputs, primarily fuel and electricity consumption and corresponding emissions generated by the transport activities. The amount of resource use and emission generating activities is determined by the system boundaries for environmental assessment. According to various studies[10] supportive and indirect activities of transport service can constitute a significant part of overall resource consumption and transport emissions. With a system boundary that includes various indirect activities more environmental factors and resource use are added. This will generally make the estimation more extensive and complex. Below is an overview of the various relevant systems boundaries for the transport system.

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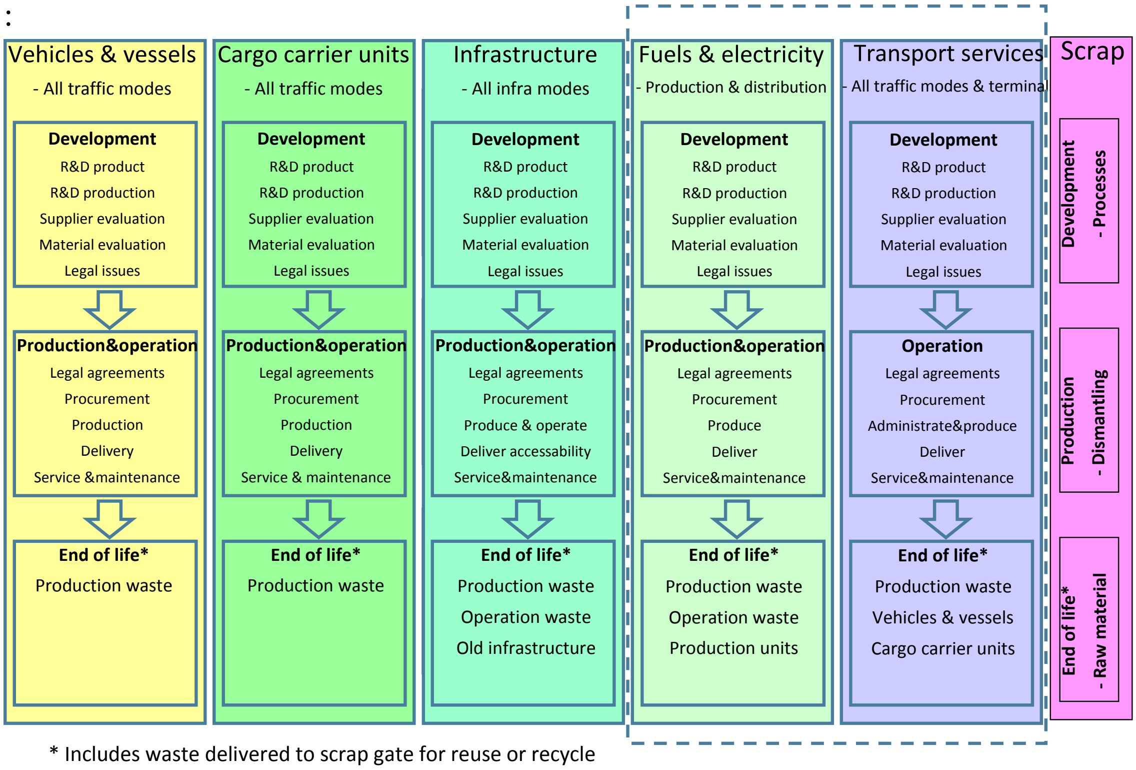

Figure 6. System boundaries for relevant areas in a "cradle to grave" approach.[11]*The dotted area represents the well to wheel system boundary that is the scope of the new CEN-standard for the assessment of transport energy use and emissions of green house gases. The above system boundaries should not be seen as mutually inclusive or exclusive, but rather as modules that can be added or subtracted, depending on the aim of the environmental assessment.*

Transport service, including traffic and transport related activities regarding engine operation for the propulsion and equipment for climate control of goods, and losses in fuel tanks and batteries. This system boundary is often referred to as tank to wheel, ttw.

Fuels & electricity, which includes the supply of energy from energy source to the tank, battery and electric motor (trains). This system boundary is often referred to as well to tank, wtt.

Infrastructure, development operation, maintenance and end of life
Cargo carrier unit, development operation, maintenance and end of life

Vehicle and vessel, development operation, maintenance and end of life

In addition the scrapping processes could be included.

Transport service and fuels & electricity (well to wheel, wtw = wtt + ttw) are the minimum required system boundaries for performance comparisons between different modes of transport. This system boundary is supported by the new CEN standard presently being adopted in the EU.

- This study focus on transport services

- This study investigates potential fuel saving activities being carried out in various operational measures in the Baltic Sea and the North Sea. These measures are all equal or even more relevant in other sea areas. The ship types included are:
  - Passenger ferries
  - RoRo
  - RoPax
  - Container

- Inland water ways was only partly included in the study.

- The study includes only operational activities.

- The study excludes port activities. It is however recognized that port efficiency has a high potential to support fuel saving programmes in sea transport.

- Ports are a crucial interface pre requisite for sea transport in order to link sea based transport systems to land based transport systems. In order to address this important area there are several initiatives going on such as the EU project Mona Lisa, among other tasks aiming at presenting early port availability information to ships in order to adjust speed to an optimum with regard to arrival and fuel consumption.

- This study focus solely on the absolute savings that can be made using the different methods described.

- Other important decisive factors of whether to implement a new fuel saving procedure were not specifically analyzed. Examples of such factors are:
  - Penalty fees for late arrival in a port as a result of slow steaming
  - Revenue loss due to a slower cruising speed that could lead to a fewer trips being possible in a fiscal year.
  - Other direct and indirect costs

The complexity of the shipping industry makes the energy efficiency procedures an interesting object for further studies. The barriers to implement new methods and procedures in a shipping company could therefore be an interesting aspect to investigate further.

3. Overview of sea transport environmental challenges and solutions

This chapter presents a general overview of the environmental challenges facing sea transport operation. In principle these challenges summarizes into:
- Use of finite resources
- Emissions to air (GHG and air pollutants)
- Effluents to water and shore based facilities
- Solid waste to water and shore based facilities

In order to assess the fuel used and related emissions to air one has to understand the complexity of the propulsion system in ships. Below is a simplified figure describing a general configuration for a ship.

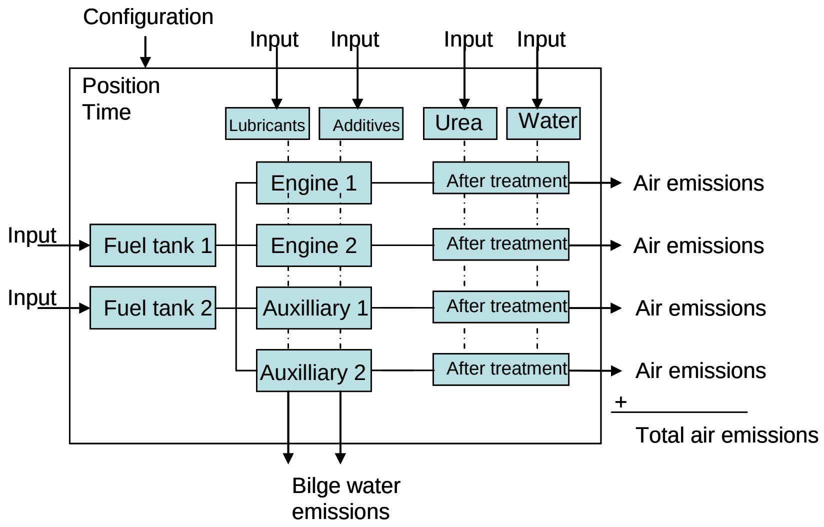

Figure 7. The ship propulsion system often includes several fuel qualities for a number of engines where some may be equipped with fume after treatment devices. The specific use of this system depends on several factors such as position, navigational conditions, weather, legal requirements, commercial aspects etc.[12]

Sea transport generates a number of various negative effects on the environment through its vast number of activities, in ISO 14001 named as environmental aspects. There are as well a number of mitigating measures. This overall picture is described in figure 8.

Environmental effect	Environmental impact	Environmental aspect	Delimitation measures	Efficiency measures	Technology measures
Scarcity of finite resources and damage on nature	Extraction and development of finite resources	Fuels combustion and upstream production, manufacturing and maintenance of vessels.	EC Renewable Energy Directive	Fuel saving activities (see chapter 7)	Cold ironing
Green house effect	Carbon dioxide	Combustion of fuels and their upstream production	EC Renewable Energy Directive	Fuel saving activities (see chapter 7)	LNG propulsion and cold ironing
		Shore land electricity consumption and its upstream generation	"	"	Renewable sources and efficient production
	Methane	Combustion of alternative fuels and their upstream production	"	"	"
	Laughing gas	Combustion of alternative fuels and their upstream production	"	"	"
	Cooling media	Use and release of CFC and HCFC for climate control	UN Montreal protocol	n/a	Soft Freons
Ozone layer depletion	Cooling media	Use and release of CFC and HCFC for climate control	UN Montreal protocol	n/a	Soft Freons
		Use and release of halons from old fire extinguishers	"	n/a	New techniques
Acidification	Nitrogen oxides	Combustion of fuels and their upstream production	EC engine emission standards & market based measures	Fuel saving activities (see chapter 7)	After treatment of fumes
		Shore land electricity consumption and its upstream generation	EC legislation	"	"
	Sulphur oxides	Combustion of fuels and their upstream production	EC Sulphur emission control area	"	Low sulphur fuels and scrubbers
		Shore land electricity consumption and its upstream generation	EC legislation	"	"
Overfertilization	Nitrogen oxides	Combustion of fuels and their upstream production	EC engine emission standards	Fuel saving activities (see chapter 7)	After treatment of fumes
		Shore land electricity consumption and its upstream generation	EC legislation	"	"
Negative impact on nature and health	Toxic emissions and effluents	Undelibetare and deliberate release of oil (bunkering and spills)	EC legislation	n/a	Spill protection decives
		Dangerous goods accidents	"	Precautionary procedures	n/a
		Release of toxic substances from use of various chemicals	"	Precautionary procedures	New techniques
		Toxic coating	"	Fuel saving activities (see chapter 7)	New bio based techniques
	Land erosion	Ship generated waves	Speed restrictions	"	New hull design
	Invasive species	Release of ballast water	EC legislation	Ballast water exchange procedures	After treatment of ballast water
	Solid and fluid waste	Scrapping of old ships and material	"	n/a	n/a
		Maintenance waste (oil, grease, etc.)	"	"	n/a
		Release of bilge, black- and grey water	"	"	After treatment of effluents
		General waste from operation	"	"	n/a
	Noise	Engine noise (main and auxiliary)	n/a	Reducing port hours	Insulation and cold ironing
	Vibrations	Engine vibrations (main and auxiliary)	n/a	"	"
	Particulate matters	Combustion of fuels and their upstream production	EC engine emission standards	Fuel saving activities (see chapter 7)	Fuel quality
		Shore land electricity consumption and its upstream generation	EC legislation	"	Renewable sources and efficient production
	Hydro carbons	Combustion of fuels and their upstream production	EC engine emission standards	"	Fuel quality
		Shore land electricity consumption and its upstream generation	EC legislation	"	Renewable sources and efficient production
Congestion and barrier effects	Sea ways and ports	Sea traffic work	n/a	Spatial planning	Larger vessels i.e. fewer sips needed

Figure 8. An overview of sea transport environmental challenges and a sample of related measures to reduce the negative environmental impact. Apparently, fuel saving activities should play a significant role in the maritime sector´s environmental improvement efforts.

4. Legal and policy demands

4.1 General EU transport policy

In 2001 the European Union published their first transport policy white paper, Time to decide[13]. This white paper was revised in 2006, as Keep Europe moving - Sustainable mobility for our continent Mid-term review of the European Commission's 2001 Transport White Paper[14].

According to the EU, sustainable mobility means allowing greater mobility while reducing the negative impacts of transport services. Hence, these two policy documents have been developed in order to be the overall framework of the EU´s Sustainable Development[15]. Environmental impact, climate change and energy policies are important aspects of these strategies.

The Commission has over the years put forward several different initiatives to make transport greener and more sustainable[16]. The aim has been to reduce air pollution and climate impact, and introducing the polluter pays principle in practice. In brief the various packages include initiatives such as:
- Internalize all the external costs of transport[17]
- Rail Transport noise reduction from rail freight trains by 50%
- Fuel taxation
- Include aviation in the EU´s Emissions Trading System

The new third European Transport White Book 2011-2020 concludes that transport is fundamental to economy and society. Mobility is considered vital for growth and job creation within the EU. It states that the transport industry directly employs around 10 million people and accounts for about 5% of gross domestic product (GDP).

Effective transport systems are according to the third white paper key to European companies' ability to compete in the world economy. Logistics, such as transport and storage, account for 10–15% of the cost of a finished product for European companies. The quality of transport services has a major impact on people's quality of life. On average 13.2% of every household's budget is spent on transport, goods and services.

As mobility increases the major future transport system faces challenges according to the European commission are:

- Oil will become scarcer in future decades, sourced increasingly from unstable parts of the world. Oil prices are projected to more than double between 2005 levels and 2050 (59 $/barrel in 2005). Current events show the extreme volatility of oil prices.
- Transport has become more energy efficient but still depends on oil for 96% of its energy needs.
- Congestion costs Europe about 1% of gross domestic product (GDP) each year.
- There is the need to drastically reduce world greenhouse gas emissions, with the goal of limiting climate change to 2ºC. Overall, by 2050, the EU needs to reduce emissions by 80–95% below 1990 levels in order to reach this goal.
- Congestion, both on the roads and in the sky, is a major concern. Freight transport activity is projected to increase, with respect to 2005, by around 40% in 2030 and by

little over 80% by 2050. Passenger traffic would grow slightly less than freight transport: 34% by 2030 and 51% by 2050.
- Infrastructure is unequally developed in the eastern and western parts of the EU. In the new Member States there are currently only around 4 800 km of motorways and no purpose-built high-speed rail lines; the conventional railway lines are often in poor condition.
- The EU's transport sector faces growing competition in fast developing world transport markets.

In order to meet these challenges the European Commission outlines strategies in the white paper "Transport 2050 Roadmap to a Single Transport Area that aims to introduce profound structural changes to transform the transport sector." The EU will move forwards in coming years (2011–14) with key measures regarding:

- A major overhaul of the regulatory framework for rail[18]
- Develop a core network of strategic infrastructure in order to create a real Single European Transport Area. The Commission will bring forward new proposals for a core European "multi-modal" network in 2011 with publication of TEN-T (trans-European transport network) guidelines, maps and financing proposals.
- Create a fully functioning multi-modal transport system by removing bottlenecks and barriers in other parts of the air network, inland waterway transport as well as paperless and intelligent shipping in order to create a real "Blue Belt" area, without barriers, for shipping. The Commission will also work to remove restrictions to road cabotage.
- To create a fair financial foundation to transport charges in the direction of an application of the "polluter pays" and "user pays" principle.
- Launch an EU Strategic Transport Technology Plan where the priority will be on producing clean, safe, quiet vehicles for all transport modes. Key areas will include: alternative fuels, new materials, new propulsion systems and the IT and traffic management tools to manage and integrate complex transport systems. The Commission will publish a clean transport systems strategy.
- Develop a strategy for transport in cities.
- For long distance modes, where air travel and maritime transport will remain dominant, the focus will be to increase competitiveness and reduce emissions through:

  - A complete modernisation of Europe's air traffic control system by 2020 (SESAR2).
  - Similar major improvements in traffic management are essential to the overall improvements in efficiency and lower emissions in all modes. That means the deployment of advanced land and waterborne transport management systems (e.g. ERTMS, ITS, RIS, Safeseanet and LRIT3).
- Other key measures for aviation and maritime includes the introduction of cleaner engines, design and shift to sustainable fuels.

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[2] Single European Sky ATM Research, cf http://ec.europa.eu/transport/air/sesar/sesar_en.htm.

[3] European Rail Traffic Management System, Intelligent Transport Systems (for road transport), River Information Services, the EU's maritime information systems SafeSeaNet and Long Range Identification and Tracking of vessels.

- The completion of the European Common Aviation Area of 58 countries and 1 billion inhabitants by 2020; as well as work with international partners and in international organisations such as ICAO (International Civil Aviation Organisation) and IMO (International Maritime Organisation) to promote European competitiveness and climate goals at a global level.
- For maritime, in particular, the target of reducing emissions by at least 40% from bunker fuels can be met by operational measures, technical measures, including new vessel design, and low-carbon fuels. Given the global nature of shipping, these measures need to be worked on in the international context of the IMO to be effective.
- In the short term, there will be a push to move ahead with the necessary EU measures to facilitate multi-modal integrated travel planning, as well as necessary legislative measures to ensure service providers have access to real time travel and traffic information.

The above list (shortened by the authors) aims to highlight some of the key measures which will move forwards in the period 2011–14 to introduce the major structural changes necessary to build an integrated Single European Transport Area.

4.2 Sea transport related environmental legislation

Internationally sea transport is legally controlled by UN,"The United Nations Convention on the Law of the Sea"; UNCLOS including operational aspects as well as emissions to air (part XII, article 212).

In addition the International Maritime Organisation", IMO´s, Convention on the Prevention of Pollution from Ships (Marpol, annex VI) is controlling environmental performance of sea transport.

IMO MARPOL Annex VI aims at reduction of sulphur oxides and nitrogen oxides emissions from ships. This includes the European sea areas determined as Emission Control Areas where there is availability of the adequate fuels and the impacts on short-sea shipping are significant.

The EU Marine Strategy Framework Directive should ensure good environmental status in marine waters covered by their sovereignty or jurisdiction by 2020.

4.2.1 Air pollutants

Non-Road Mobile Machinery, NRMM, Directive 97/68/EC regulate exhaust emissions from different types of engines. The third directive, 2004/26/EC, covers diesel fuelled engines from 19 kW to 560kW for common NRMM and regulates the emission in 3 stages. The directive includes railcars, locomotives and inland waterway vessels. For the two latter categories there are no upper limits concerning engine power.

The different engine stages in the 2004/26/EC directive are:
- Stage III A, 19 to 560 kW including constant speed engines, railcars, locomotives and inland waterway vessels. Effective from 1 January 2006 for certain types of engines.
- Stage III B 37 to 560 kW including, railcars and locomotives. Effective from 1 January 2011
- Stage IV covers engines between 56 and 560 kW. Effective from 1 January 2014.

For regular sea transport engines within the EU, NOx emissions are regulated through three tiers of engines.

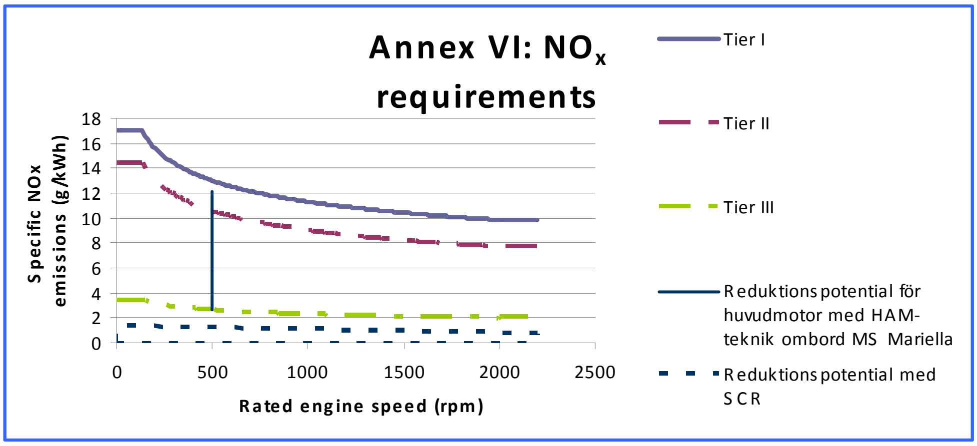


Figure 9. NOx emissions from sea transport engines in the EU are regulated through different engine standards:
Tier 1, until 2010, maximum 9.8 and 17 g/kWh depending on engine speed.
Tier 2, from January 1, 2011 maximum, 7.7 and 14.4 g/kWh depending on engine speed.
Tier 3, from January 1, 2016 maximum2 and 3.4 g/kWh depending on engine speed.

Environmentally adapted fairway and port dues are locally introduced in different geographical places. Since 1993 Sweden has environmentally adapted fairway dues, where costs depending on ship specific NOx emissions. In Norway there is since 2007 environmentally adapted port dues depending on ship specific NOx emissions.

The MARPOL Annex VI19 has in addition a progressive reduction in sulphur oxide (SOx) emissions from ships, with the global sulphur cap reduced initially to 3.50% (from the current 4.50%), effective from 1 January 2012; and then progressively reductions to 0.50 %, effective from 1 January 2020.

The limits applicable in Sulphur Emission Control Areas (SECA´s, as example the Baltic Sea) has been reduced to 1.00% (from the previous 1.50 %); and is being further reduced to 0.10 %, effective from 1 January 2015.

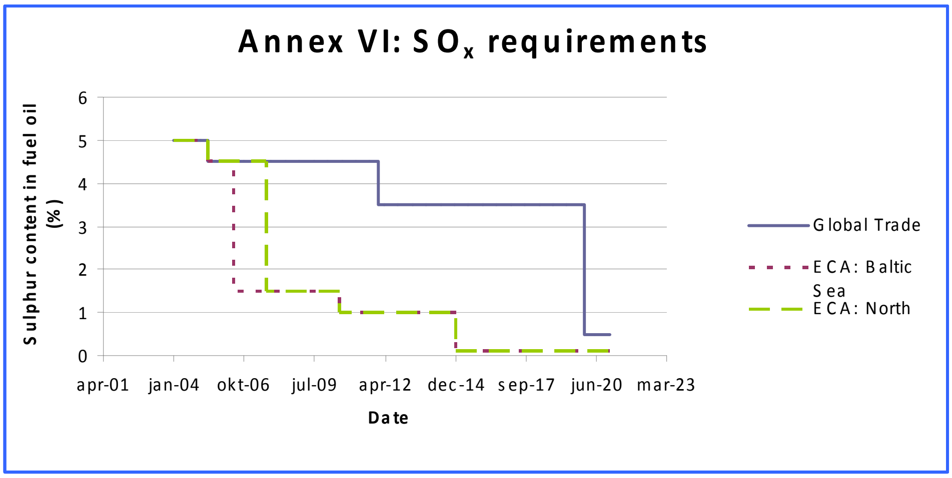


Figure 10. Regulations on sulphur content in bunker oil.

4.2.2 GHG emissions

United Nations Framework Convention on Climate Change (UNFCCC) has the objective to stabilize greenhouse gas concentrations in the atmosphere at a level that will prevent dangerous human interference with the climate system. The United Nations Framework Convention on Climate Change (UNFCCC) was adopted 1992.

The Convention is complemented by the Kyoto Protocol 1997 where 37 industrialized countries and the European Community have committed to reducing their emissions by an average of 5 percent by 2012 against 1990 levels. The Conference of the Parties (COP) is the "supreme body" of the Convention, that is, its highest decision-making authority. It is an association of all the countries that are Parties to the Convention. The COP meets every year, unless the Parties decide otherwise.

Abbreviation	**Explanation**	**Comments**
BFO	Bunker Fuel Oil	Also named MFO, HFO, IFO
HFO	Heavy Fuel Oil	Also named MFO, BFO, IFO
IFO 180	Intermediate Fuel Oil	IFO 180 means a viscosity of 180 cSt at 50°C.
IFO 380	Intermediate Fuel Oil	Sometimes mentioned as bunker. C. IFO 380 means a viscosity of 380 cSt at 50°C.
MDF	Marine Diesel Fuel	A distilled fuel that may contain small fractions of RO. Also named MDO.
MDO	Marine Diesel Oil	See MDF
MFO	Marine Fuel Oil	Also named BFO, HFO, IFO
MGO	Marine Gas Oil	A lighter and better quality fraction than marine diesel oil adapted to high speed engines. The fuel does not include any fraction of RO.
DMA	Standard for MGO	Maximum sulphur content of 1.5 percentage
DMX	Standard for MGO	Maximum sulphur content of 1.0 percentage
LS	Low Sulphur	Sulphur adapted to SECA[4]
RO	Residual Oil	After refinery of crude oil the remaining fraction is RO. Also named MFO, HFO, IFO or BFO.

Figure 11. Fuel qualities in sea transport.[20]

Directive on CO_2 emission trading (2003/87/EC, amendment 2009/29/EC). From transport sector, international maritime shipping and aviation are included in the directive. Electrified rail transport is already indirectly included in the emission trading, due to the inclusion of energy sector. In practice emission trade presently only includes air transport.

The EU Directive on Taxation of Energy Products and Electricity (2003/96/EC) sets the minimum tax levels on fossil fuels.

The directive on the promotion of the use of bio fuels or other renewable fuels for transport (2003/30/EC). Aims at 5.75 % for use of bio fuels calculated on the basis of energy content of all petrol and diesel for transport presented by 31 December 2010. Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing.

[4] Sulphur oxide Emission Control Area

Directives 2001/77/EC and 2003/30/EC sets the minimum target for transport purposes to10% in every Member State in 2020. The Commission policy is to increase the proportion of bio fuels up to 20 %, decrease the energy consumption by 20 % and decrease the CO_2 emissions by 20 % in 2020.

Based on the 1990 levels the Swedish environmental aims for 2020 are:

- 40 % reduction of GHG emissions for the non trading sector
- 50 % renewable energy
- 10 % renewable energy in the transport sector

For 2030, Sweden aims for a fleet of vehicles entirely independent of fossil fuels.

In summary it is obvious that the EU aims at developing the transport sector commercially meanwhile its negative impact will be reduced. These two objectives have several built in contradictions and challenges. The area of operational fuel efficiency improvements however has few drawbacks with regard to the overall policies proposed by EU and internationally.

5. General fuel efficiency

Saving fuel is not just a matter of protecting the environment; it is also a question of financial benefits. With every less tonne fuel consumed in propelling a ship forward, there is the monetary value of that tonne saved. In a case where fuel can be saved with little or small cost for the ship operator, the benefits are both environmental and economical. There are often no, or at least relatively small costs involved when operational saving measures are implemented. Therefore, operational measures are often the easiest bunker-saving activities to implement.

Oil and fuel prices are currently at a high level and there is no reason to believe that prices will drop in the future. Higher price on fuel will further increase the incentives to reduce bunker consumption. Every shipping company should realize that a tonne of saved fuel today will be worth even more in the future.

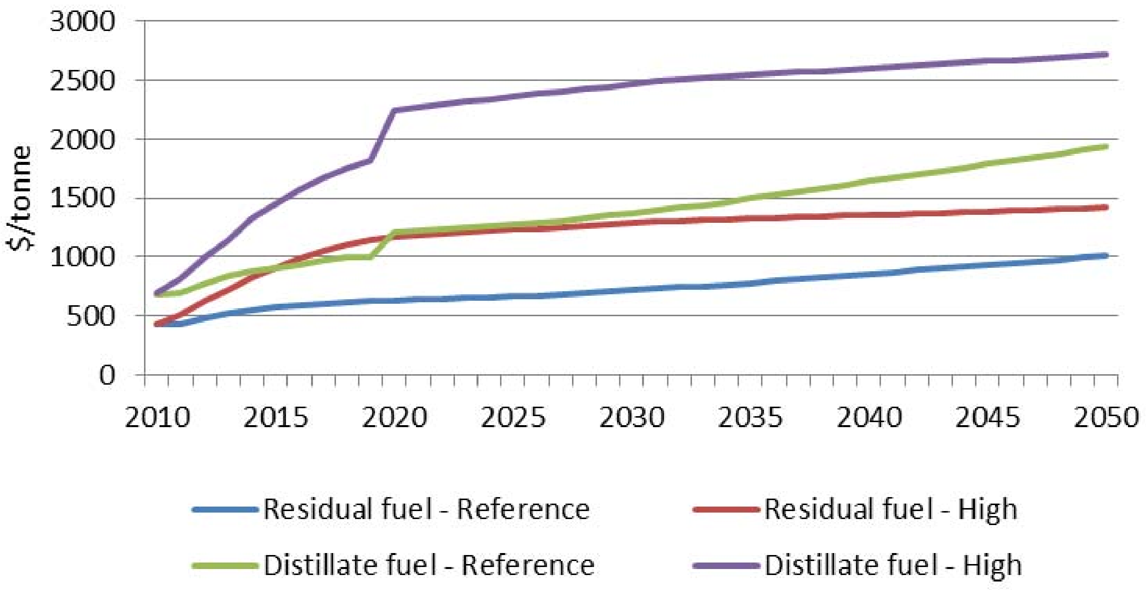


Figure 12. Predicted fuel prices 2010 – 2050[21]

In figure 12 above the IMO´s projection of potential fuel prices from 2009 until 2050 is presented. The reference price starts at 371/594 $/tonne for residual/distillate and peaks at 1008/1935 $/tonne in 2050. The high estimate starts at 371/594 $/tonne and peaks at 1416/2719 $/tonne in 2050. In the reference scenario the price almost triples for residual fuels and a little more than triples for distillates. The high estimate shows price increases that are almost four times as high for residual fuels and about four and a half times for distillates[22].

Commercial ships usually run on Heavy Fuel Oil (HFO) that is a residual fuel and/or Marine Diesel Oil (MDO) that is a residual diluted with distillate fuel. The bunker cost for an average vessel will therefore be the combined HFO and MDO bunker consumption times a weighted average that lies somewhere between the prices of the residual- and distillate fuels. This illustrates well that a tonne saved today will increase its cost cut over time and end up saving anywhere between about three and four times its present market value by 2050.

5.1 Possible saving due to operational measures

There are a number of operational measures that can be implemented onboard a ship with little or no investment cost. The actual savings in bunker consumption naturally depends on the actual measure implemented. Some studies also assess the possible monetary gaining in lowering carbon dioxide emissions at sea.

According to the new CEN-standard, the emission of CO_2e (ttw) is 3.15 kg/kg HFO and according to agreements within the IMO when developing the EEDI[5] the CO_2 emissions from one kg of HFO was set at 3.1144 kg/kg. Analyzing the emissions of CO_2 only we therefore use the number of 3.1144 kg/kg as it is also in line with the CEN data on CO_2e (including also methane and laughing gas)

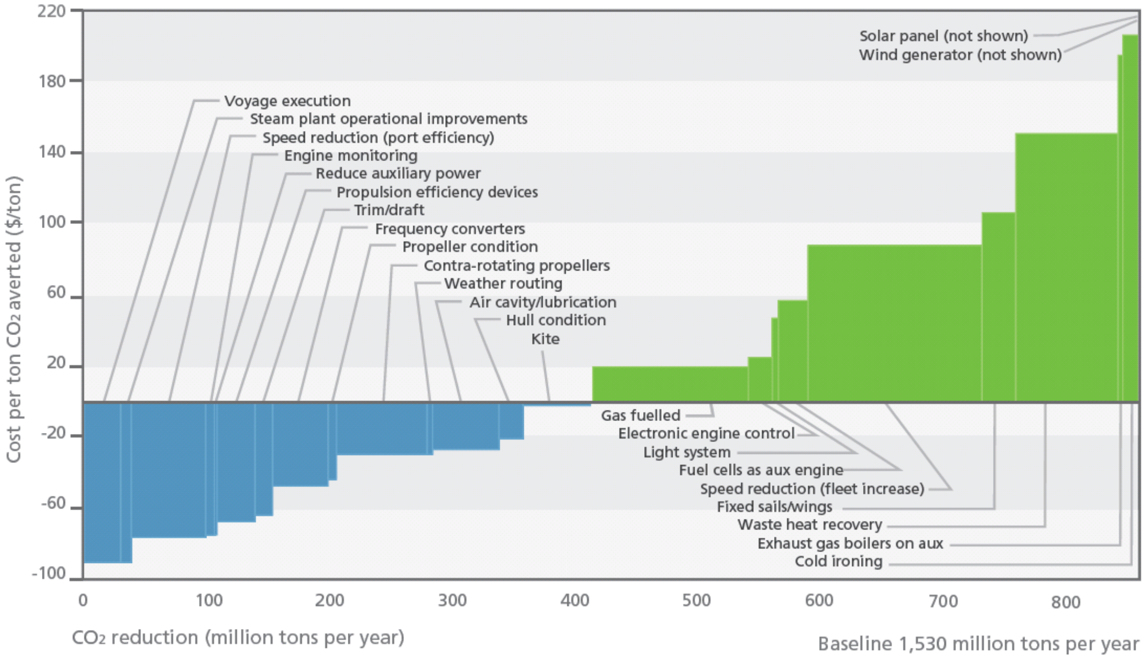


Figure 13. The marginal cost of carbon dioxide reduction by different measures.[23]

In figure 13 the marginal cost of different CO_2 reduction alternatives in the world fleet are shown. All the measures that show a negative marginal cost (blue bars in the figure) are measures that will save money from the moment of implementation. The opposite is also true; the green bars tell us that implementing that particular measure will generate a cost for each additional tonne of CO_2 not emitted. Given the assumption that one tonne of HFO emits approximately 3.1 tonnes of CO_2, the marginal cost of reducing one tonne of CO_2 can be divided by 3.1 to get the monetary value of reducing the bunker consumption by one tonne. The blue bars will show the profit made and the green bars the loss accumulated. If we also assume the price development of residual- and distillate fuels that IMO predicts, that monetary value can be multiplied by the price hike to estimate future savings or losses.

It is easy to see from Figure 13 that many of the measures with a negative marginal cost are operational. On the other hand all of the measures with a positive marginal cost are technical and/or possible only in new built ships. Because of this correlation it seems as though the easiest and most profitable way to start reducing the bunker consumption in any company would be to go at it from an operational point of view.

[5] Energy Efficiency Design Index

The exponentially decreasing environmental performance curve shows us the same fact in a different context: when implementing measures that are aimed at preserving the environment, the investment cost buys a lot of result early on. The more work done, the harder it gets to continue showing positive results and the marginal cost for continued improvement increases exponentially.

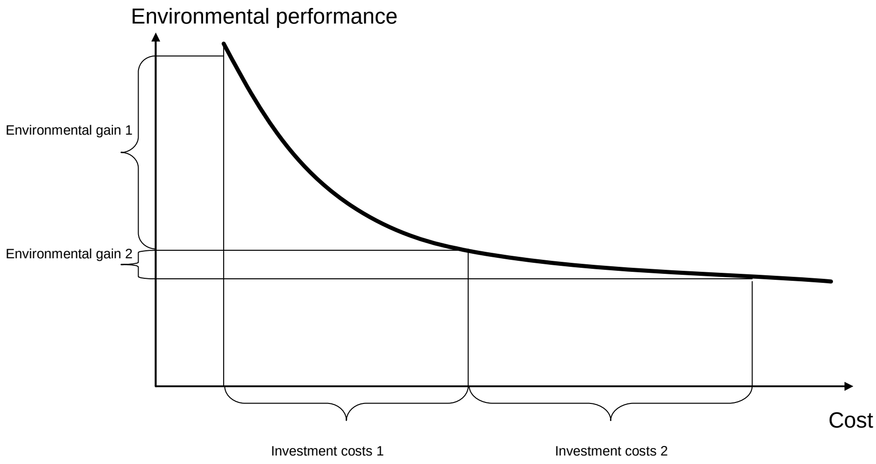


Figure 14. The exponentially increasing cost of environmental gain.[24]

In figure 14 the exponentially increasing marginal cost of environmental gain is evident. The first investment buys a significant amount of environmental gain. The second investment is larger than the first, but still only buys a fragment of the gain. The environmental performance curve fits perfectly into the theory that operational measures will buy a lot of bunker consumption reduction for a relatively small cost.

5.2 Why saving money on bunker consumption should be important to a company.

The basic concept of company operations tells us that a company needs to make a profit to survive long term. By saving money on operations the profit margins will increase which in turn will increase the shareholders return on investment. From a strictly financial point of view the environmental factors are just an added bonus (assuming no internalisation of external costs) even though the environmental savings probably are usable in the company's PR department, since ecological care currently is a hot and media sexy topic. There is however also a long term survivability issue that the company will benefit from.

Company's profitability is the difference between the amount of capital used on running the business and the revenues received from the customer. The customer pays a price for the company's product that is defined in theory by the law of supply and demand and it is reached in the equilibrium between the two.

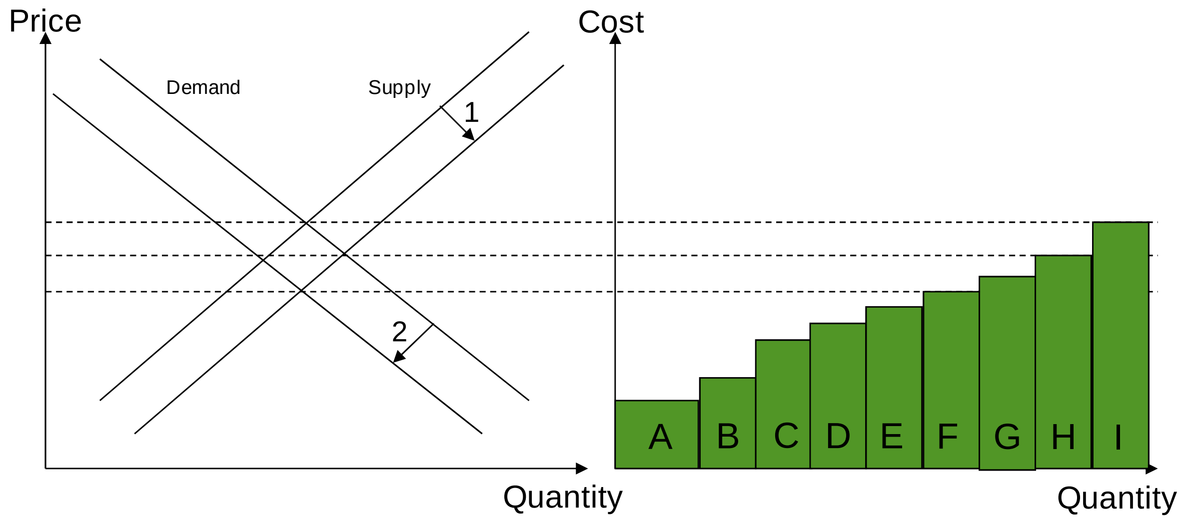


Figure 15. The Salter diagram describes the commercial effects of changing market supply and demand on company profitability.[25]

In figure 15 different supply and demand curves are shown in the left hand diagram and the effects of these on companies A-I on the right hand side. The green bars in the right hand diagram are the total operational costs of the companies and it is obvious that company A has the lowest and company I the highest total operational costs. The empty space between the top of each green bar and the equilibrium, represented by horizontal lines, represents the difference between revenue and cost, i.e. the operational profit. In the staring scenario companies A-H are profitable and company I just breaks even. In scenario 1) the supply grows (e.g. new companies enter the market that offers the same services as A-I) and therefore the market price equilibrium moves down and to the right (1). In this new scenario companies A-G are profitable, company H breaks even and company I loses money. In the third scenario 2) the demand decreases (e.g. as during a financial crises) and the market equilibrium price continues down but to the left (2). Now only companies A-E are profitable, company F breaks even and companies G-I are all losing money.

The above mentioned scenarios are simplified but still present the correlation between costs and profitability during the wide normal market changes that are out of control of the individual company. The company that has put the most effort into reducing costs will make the most profit and have the highest chances of long-term survival.

In above mentioned scenarios this company is company A. In the shipping business a company that purposefully works towards reducing its fuel consumption, and therefore its costs, could have significant advantages over its competitors if the market changes for the worse.

Figure 16. A modern crude oil vessel designed for the Baltic Sea with a maximum size and highest safety and ice standards. Length 182.9 m. Beam 40 m. 65 200 DWT. This concept illuminates one major measure to increase cost and fuel efficiency by maximizing the size of vessel.

5.3 Why more is not done already

Since many, if not all, of the operational measures described in this paper have been known for a significant period of time, the question of why they have not been more widely adapted rises. Adding that many of these measures are possible to implement at a small, or no cost to the ship operator, the answer is even more allusive. In theory this probably relates to the concept of the energy-efficiency gap[26], described through below sea transport examples.

A significant reason for not improving energy effectiveness in the shipping industry might be that a large share of the fuel expenses is passed on to the customer. As much as 70% -90% of the bunker costs might not actually be paid by the shipping company but by the end customer, e.g. bunker surcharges that passenger cruise companies sometimes levy[27].

Another major reason for the non actions taken can probably be found in the parts of the shipping industry that involve a lot of bare boat and time charter contracts. Since the ship owner is the one responsible for improvements on the ship, but the charterer is the one paying for the fuel there is no incentive for the owner to invest in improvements (e.g. measuring equipment) onboard the vessel[28].

A third issue is that second hand prices of vessels do not correlate with the investments made to increase their fuel efficiency. The ship owner who has invested money in bunker saving equipment will not see an increase in the price he gets once he sells the vessel[29].

Shipyards are also not prone to change their ship designs at a reasonable cost or they simply do not have the capacity to do so[30]. Therefore especially a smaller shipping company has little or no possibilities to affect the design of a “standard” ship.

Finally, the initial cost in developing a new energy saving method might discourage a ship owner from making the investment[31]. Even though the investment is sure to pay itself off in the long run, the owner might not be in the position, real or imagined, to make the investment.

During January, February and March 2012 we conducted a series of interviews with experts on energy efficiency. The experts were all employed by shipping companies that by seafarers are considered leaders in the field of energy saving. The aim of the interviews was to study the general process in the shipping company when working with energy conservation measures and to examine which of the more common operational measures were implemented and how.

We noticed that a common denominator among the experts was that they all seemed very proud of the amount of work their companies were putting into solving and developing energy related questions. The experts´ willingness and openness in sharing information about their companies and the work they are doing was also surprising.

As the individual interviews progressed it became apparent in each interview individually, that a whole-hearted commitment to energy efficiency and ecological thinking is of utmost importance if you truly want to make a change in the way the shipping industry is run. Mr Jivén of Maersk Line noted that being a leader in the field of energy efficiency, the path starts with top management saying so openly and officially. The questions that arise when trying to implement new measures are complicated and affect a lot of people; therefore effective communication within the company is crucial for success, said Mr Tunell of Wallenius Marine.

Figure 17. More spectacular ideas on fuel savings are continuously presented. This is a kite from the German company Beluga that will save fuels by 10-15 % in a first phase but later up to 30 – 35 %[32].

6. The measuring problem

Another common denominator in the interviews was that the respondents immediately turned to the problem of measuring. The effect of an implemented energy efficiency technique can only be assessed if you can accurately measure the effect of said technique. As it turns out, the most problematic aspect of the measuring difficulties is the measuring of the vessel's speed through water (STW), all of the shipping's company interviewees thought. Speed over ground (SOG) is fairly accurately measured today with the help of satellite navigation, but to find out whether or not you are saving bunker STW is crucial. If the vessel encounters strong currents the SOG might differ greatly depending on the direction of the current contra the heading of the vessel. The engine however is turning the propeller at constant speed with constant fuel consumption, regardless of the difference in SOG.

Since the ocean is never completely still the measurement must be made in STW. Because many of the techniques are only expected to save a fraction of a percent of bunker, the measuring of the ships STW should be made with an accuracy that is not attainable today. To measure hull and propeller performance Wallenius Marine have made several sea trials but still the results are conflicting.

To get as accurate data as possible Maersk Line retrofitted 8000 measuring points on its PS-class vessels. All the information gathered is followed in real time and the ships are benchmarked against each other. The information gathered is also of utmost importance when designing the next generation, Triple E, container vessels.

Stena Line has invested a lot of time and money in upgrading their measurement equipment with, amongst others, portable measuring equipment that easily can be moved to measure the quantity of current interest. The measuring results also made the switch to new frequency-controlled pumps an easy choice since it was noted that almost all pumps were operating with unnecessary high effect and the pay-off time of new control systems for the pumps would be short.

With eleven vessels with one hertz measuring techniques Per Tunell of Wallenius Marine still noted that frustration sometimes arises in the company when measuring data is not consistent. Performance can vary over time without apparent reasons by as much as tens of percentages. As of today Wallenius Marine are still trying to find the underlying explanations.

7. Operational and maintenance fuel saving potentials

In order to evaluate practical improvement programmes we used a summary made by Wartsila in their Energy Efficiency Catalogue 2011. This was done to benchmark practical and theoretical fuel saving programmes. It is important to point out that the numbers in the catalogue are estimates made by Wartsila. Since Wartsila has been a well known actor in the world wide maritime cluster for a long time their estimates are however considered as relevant expert opinions. The expected effects therefore served as a credible baseline for comparison of the findings of the interviews.

Action	**General saving potential**
Turnaround time in port	< 10%
Propeller surface finish/polishing	< 10%
Hull surface – Hull coating	< 5%
Part load operation optimisation	< 4%
Voyage planning – weather routing	< 10%
Ship speed reduction	< 23%
Vessel trim	< 5%
Autopilot adjustments	< 10%
Energy saving operation awareness	< 4%
Condition Based Maintenance (CBM)	< 5%
Hull cleaning	< 3%

Figure 18. Potential fuels saving activities according to Wärtsila [33]It should be noted that these rough numbers may be relevant for specific operators, ships, trade lanes but for others irrelevant as their operational conditions may be very different.

8. Practical fuel saving activities

Methods that are possible to implement onboard a vessel with little or no investment costs are deemed operational in this chapter. The included examples are a few elected examples of what the companies has implemented. In sub chapter 8.1 the term "Eco driving" also includes a measure of human attitudes towards environmental issues that strictly cannot be called operational but that are included anyway. The attitude towards change is of utmost importance when trying to establish whether a new measure has a chance of being successful or not.

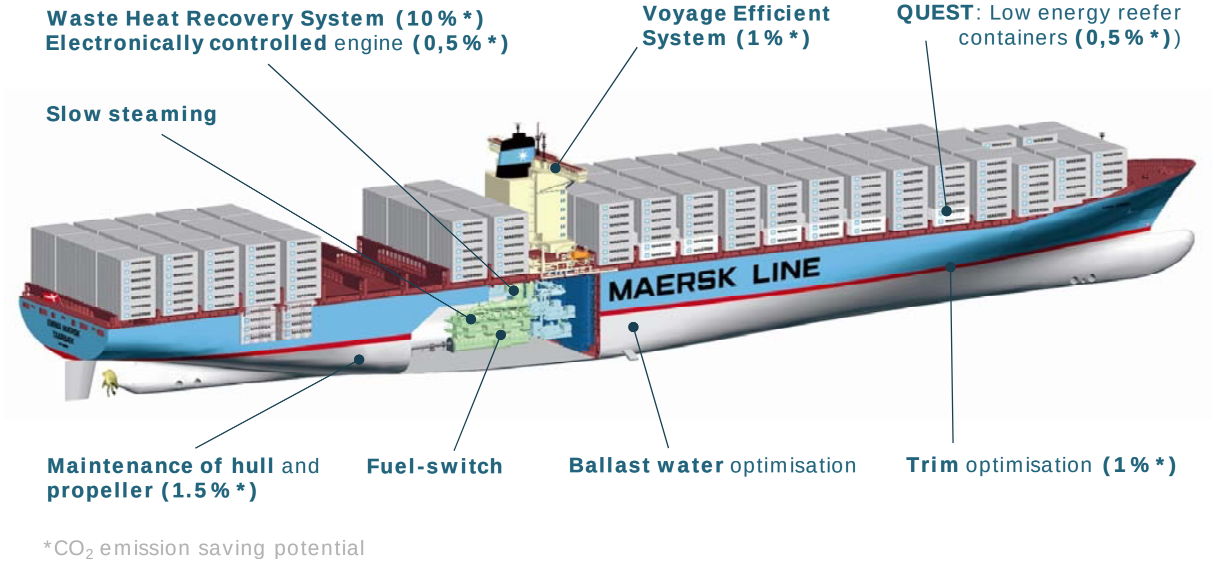


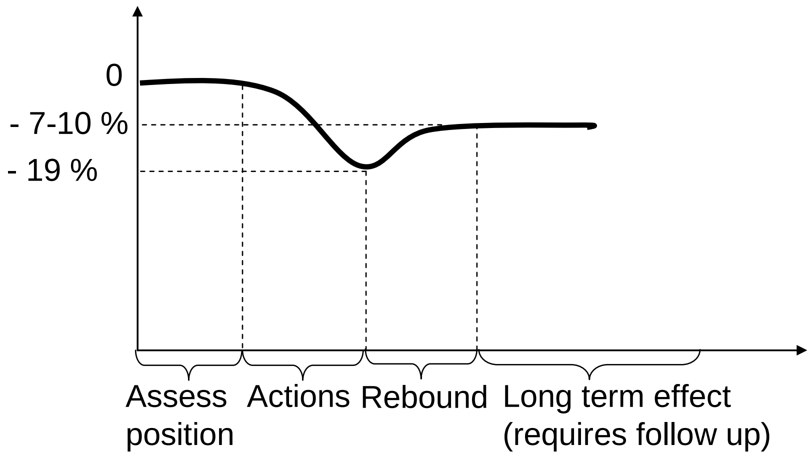
Figure 19. Maersk line and their PS type vessels[34].

8.1 Eco driving

The term "Eco driving" can mean a number of things. Usually in the maritime industry the term is used to describe the operational use of the main propulsion during a sea voyage. We have chosen to include the mindset of the individual person in which this person regards changes in operational routines and how the person is motivated to perform more fuel efficiently.

The way in which any given ship is to be operated for maximum energy efficiency is always individual, due to the unique layout concerning main- and auxiliary engines, hull form, route, autopilot settings and multiple other variables of each ship. Some general guidelines can however hopefully be drawn up for use onboard various types of vessels.

Figure 20. Viking Energy, a Norwegian gas fuelled supply vessel. In its operation significant differences in fuel consumption in comparison to its sister ship has been identified[35].



F*igure 21. Rebound effects on eco driving are a well known fact. This graph comes from lessons learnt in road transport[36]. The key challenge in sea transport is to assess a credible baseline where external factors affecting the result are eliminated.*

8.1.1 Expected gains

According to Wartsila Marines Energy Efficiency Catalogue a culture and mind set among the crew onboard could alone generate as much as a 10% reduction in fuel consumption. Adding a slower cruise speed, autopilot adjustments and other operational factors the fuel consumption savings can be even greater.

8.1.2 Measures carried out

Maersk Line
According to Maersk Line, shipping crew knowledge about fuel consumption reduction is crucial for any gains to be made. Their crews are continuously educated, mainly through the masters and chief engineers of the vessels, to improve performance. All sister ships fuel efficiency performance is continuously benchmarked against each other for ease of comparison between ships. The masters and chief engineers receive an annual appraisal in which fuel consumption plays a major part. Other parts of the appraisal include safety onboard and crew well being.

Stena Line
Stena Line educates their officers once a year ashore and once a year with a visit from technical shore personnel onboard all the vessels. A concern within Stena Line is the reluctance of some officers to change the way they operate their ship and to implement new routines. This problem can to some extent be conquered by training and education but accuracy in recruiting and incentives for current crews are also important in continuously improving performance.

Stena Line has implemented a program called Stena Innovations that includes monetary bonuses to every employee that comes up with an energy- and/or cost saving idea that is implemented. A price for "best vessel" is also presented every year as a way of promoting the energy saving way of thinking.

Crew members that show interest in developing the company's energy saving plans are selected to help with or run new projects outside the boundaries of their usual jobs. This provides an incentive for the individual as well as promotes energy efficiency thinking.

Stena Line has completed approximately 100 fuel efficiency projects since 2005 and estimates the total saved fuel since then at a quantity of 16.000 tonnes. Mr. Hellring also noted that Stena Line without delay implements all bunker saving ideas that can be shown to have a pay off time of 2 years or less.

Figure 22. Windmills onboard Stena Jutlandica. The interesting effect of this solution is that it delivers electricity meanwhile it reduces the wind drag from the ship building[37].

Wallenius Marine
Wallenius Marine focuses on training their vessel crews with officers' conferences twice a year as well as computer-based environmental training aboard the ships. There is high focus on training existing crews to be more energy efficient but the interest in environmental questions is already screened during the recruitment of officers.

Wallenius has a "Proposal committee" to which all improvement initiatives can be sent. Implemented initiatives are rewarded. In addition an Energy Efficiency competition was held 2011 within the fleet with a high rate of participation.

Neste Oil
Neste Oil has produced an operational manual for their energy efficiency techniques. The manual is soon to be updated as the work towards ever more efficient energy use continues. An incentive program that, amongst other factors, measures the vessels energy efficiency is also in use and it rewards captains and chief engineers. Improvements and new operational measures are usually implemented when freight rates are low so as not to lose business opportunities.

8.2 Weather routing

Weather routing or route optimizing are terms used for route planning that includes other factors than the traditional route plan, i.e. the shortest, safe route between two given points. In optimal conditions the least amount of fuel consumed by a ship would be by travelling the shortest possible distance between two points. In theory this always means using a great circle but a rhumb line is often used on many shorter distances since the difference is negligible. It is considered good seamanship to take weather forecasts into account for reasons of safety, but to do it for the sake of bunker economy is not as widespread.

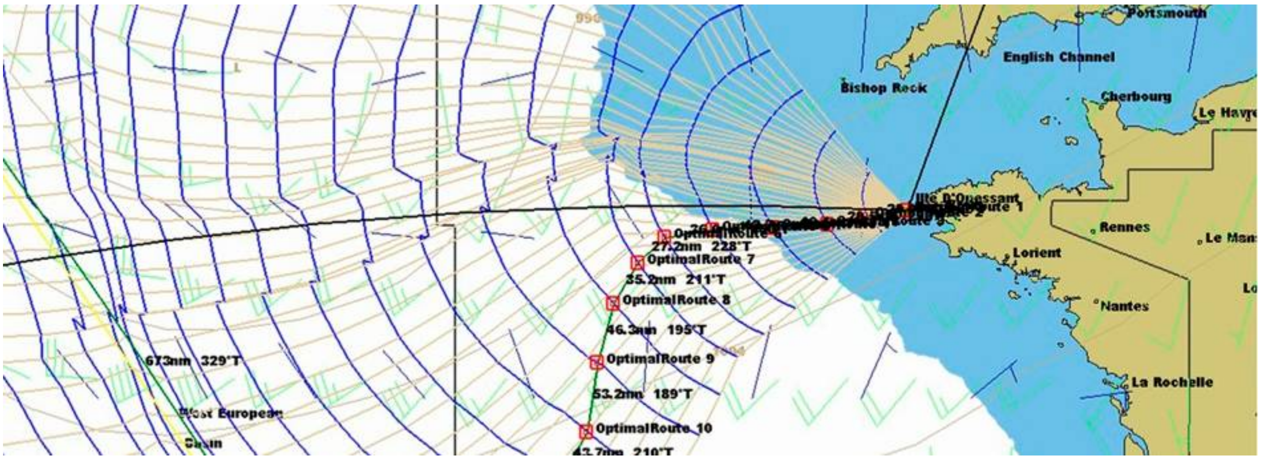


Figure 23. Optimising the route with help from various advanced forecasts on wind and current development[38].

Since weather and currents greatly can affect the speed over ground (SOG), or the speed at which the vessel is actually approaching its goal, there can be an advantage in choosing a route that uses the weather conditions to improve the SOG or at least minimizes the loss in SOG in unfavourable conditions. A route optimizing service will expectedly be more effective the longer the route is. Crossing an ocean can be done in a multitude of ways whilst crossing a bay or navigating in archipelago conditions might only have a few viable route options.

Many different types of weather routing services are available, ranging from the deck officers making their own judgement based on weather maps to complex systems where expert meteorologists give recommendations based on sophisticated data from a number of weather services. A company's vessels´ automated communication between each other, sharing information about current and wind, speed and direction is a modern weather routing service.

8.2.1 Expected Gains

The gains expected by using weather routing are higher the longer the journey is. This is because the ship is exposed to the weather for a longer time and the possibilities for different route choices are greater. The expected gain can be up to a 10% reduction in fuel consumption given a scenario with a long journey, for example an ocean crossing in foul weather (Wartsila, 2011). It is, however, noteworthy that also on short routes there are consumption savings to be made, especially if the conditions are such that strong currents and/or heavy winds are often encountered.

8.2.2 Measures carried out

Maersk Line
Weather routing has been a tool for Maersk Line in reducing bunker consumption for a long time. The newest system in use uses a wide variety of factors when determining the most effective route between two points. The vessels in the fleet automatically communicate the weather and current information they currently are experiencing to all the other vessels and therefore a database of weather information from around the globe is created and continuously updated. The system is also implemented on all vessels that are chartered by Maersk. The effects on bunker consumption are considered substantial.

Neste Oil
For 6-8 years Neste Oil used weather routing services sporadically. Weather routing services were bought on a trip-by-trip basis only when the vessel had an ocean crossing or other longer trip ahead. The positive effects on bunker consumption did, however, inspire the implementation of a fleet-wide weather routing system. Since the autumn 2011 a weather routing service is permanently available to all the vessels in the fleet. Factors taken into account in the system are currents, wind and wave height prognosis. The information is then analyzed by a team of experts at a meteorological institute and a route recommendation is constructed. Neste Oil estimates the bunker savings to be in the range of Wartsila´s Energy Efficiency catalogue.

Stena Line
Since Stena Line operates on shorter routes than the other companies interviewed in this report, the expected gains from weather routing are naturally smaller. However, I found it very interesting that Stena Line uses weather routing on the route between Oslo and Frederikshavn (a distance of just under 160 nautical miles). The bunker saved with the implemented weather routing is estimated at 1 – 1.5 %.

8.3 Slow steaming

Slow steaming is a bus word that aims at describing the operational measure of reducing the vessel speed in order to save fuel. It is however difficult to define slow steaming. In general it can be said that a reduction of speed reduces bunker consumption per nautical mile. There are, however, nuances, mainly because of different engine room layouts, that need to be accounted for. When s vessel designed for 20 knots operates in 13 is either poorly designed or it is used to buffer market fluctuations. The general note that a reduction of speed reduces bunker consumption per nautical mile is true down to a certain speed where the consumption for electricity will make the curve turn up again. Hence slow steaming will generally improve fuel efficiency to a certain degree and the way it should be done depends on the technical characteristics of the actual vessel.

8.3.1 Expected gains

The bunker saving can be significant if the speed is reduced drastically, but already a modest decrease in speed of 1 knot can reduce bunker consumption by 11%. (Wartsila, 2011)

The layout of a given vessel’s engine room greatly affects the actual bunker reduction for a number of reasons:

- A vessel with only one main engine will probably gain the most from a speed reduction if the engines load program is also modified for the new speed, even if just a speed reduction in itself also will reduce bunker consumption. (Wartsila, 2011)
- A vessel with more than one main engine can probably use a lesser number of main engines if travelling at a smaller speed than if travelling at full speed. A smaller number of engines in use also means less bunker consumed.
- If the operating speed of a ship is reduced, other fuel savings might also be possible, for example changing the propeller to better suit the new speed range might give additional savings.

One shipper remarked on this topic that fuel savings were not so big as expected due to present ships were designed for another speed.

8.3.2 Measures carried out

Tallink Silja

In 2012 Tallink Silja decided to increase the travel time for its ferries travelling between Stockholm and Helsinki via Mariehamn on their eastbound leg during the months when ice conditions were expected. The arrival time in Helsinki was moved 35 minutes forward but the departure time from Stockholm and the arrival- and departure times in Mariehamn were unchanged. This effectively increased the travel time on the leg from Mariehamn to Helsinki by 35 minutes whilst the distance obviously was unchanged. The first numbers gathered by M/S Silja Serenade showed that a saving of approximately 6 tons of fuel oil was made every trip from Mariehamn to Helsinki. The savings for one vessel during one month amounted to about 80 tons. The direct reason for the savings in fuel consumption was that one main engine less was used for a period of about 5 hours on each trip.

The CO_2 not emitted by this change in schedule can, according to section 5.2 in this report, be estimated to approximately 232 tonnes per vessel per month. The money saved on bunker can equally be estimated to approximately 56.000 Euros, given a current bunker price of about

700 Euros per tonne. For the two ships operating on the Helsinki – Mariehamn – Stockholm line the total savings where, therefore, just under 500 tonnes of CO_2 not emitted at the "cost" of saving the company over 100.000 Euros every month.

Stena Line

One ship was moved to a new route with a new timetable that only required a cruising speed of 18 knots instead of the 26 knots that is the ship's maximum speed. A change of propeller to a design more suitable for the new speed resulted in a fuel saving of approximately 16 %. The old propeller is kept in store, awaiting possible future use and the cost of the new propeller was quickly paid off by the bunker savings.

Maersk Line

Maersk Line has been trying different ways of slow steaming and the results have been a distinguishable reduction in bunker consumption. In the beginning, engine manufacturers objected to the idea due to imagined risks of the engines taking damage, but a test program was carried out on 120 vessels. That test showed no negative effects. The Maersk Line vessels slow steam as low as 5 knots but the normal cruising speed within the new speed scheme is usually around 15-17 knots. The total bunker consumption reduction because of slow steaming in the Maersk fleet is approximately 7%. A concept of so-called super slow steaming is also being planned; the concept will lower the cruising speed to 12-14 knots, saving even more bunker.

Slow steaming had some operational problems that had to be addressed by the company. A decision was made that the Maersk Line ships will continue to slow steam even if a shortage of capacity is noticed. A concentration of ports in which cargo was loaded and unloaded was also implemented to shorten the total time needed for a voyage with increased travelling time at sea with the slower speed.

Lessons learned from the implementation of slow steaming also affected the design of the new Triple E container ship series. A reduction in the maximum speed of the Triple E series to 23 knots from the previous standard of 25 knots in the PS-series, the Triple E hull is now being built in a more box like shape than its predecessors. A more boxed hull equals more boxed like cargo compartments and therefore a higher number of containers that can be loaded, which in turn means lower relative fuel consumption per cargo unit.

Because of the reduction in top speed, the Triple E series is also fitted with 19% smaller main engines than the PS series whilst loading 16% more containers. The combined advantages of the design features will give the ships of the Triple E series a 20% better fuel consumption than the one generation older PS series.

Neste Oil

During the low freight rates of the summer and autumn 2008, Neste Oil decided that all the vessels of the fleet where to cruise at 80% of the engine capacity. The bunker savings were in line with what Wartsila´s Energy Efficiency Catalogue 2011 predicts.

8.4 Trim

The trim of a ship is the difference between the draft at the forward- and aft perpendiculars (PP). If the drafts at both perpendiculars are equal, the ship is considered to be on even keel. If the draft at the forward PP is greater than at the aft the ship has a negative trim and if the forward draft is lesser than the draft at the aft PP the ship has positive trim.

At what trim a vessel is most energy efficient is individual to the vessel type and sometimes even sister ships might have different optimums. The common conception amongst seafarers is that a ship should always be floating on even keel or with a slight negative trim to be most efficient. The most efficient trim should, however, always be measured on the ship to avoid speculation and possible negative fuel consumption consequences.

Factors like the shape of the hull i.e. draft and cruising speed all affect the optimum trim and therefore it is impossible to give a general answer as to what the optimum trim for a vessel is[39]. Wartsila´s Energy Efficiency Guide, however, speculates that the difference between the least effective and most effective trim with a given hull shape with a given draft and speed might be as high as 20%.

8.4.1 Expected gain

Because of the reasons mentioned in the trim explanation an estimate of fuel savings is difficult to give. The gain could however be as big as 5% (Wartsila, 2011) but it is more likely that, at least on a ship with an experienced crew that already trim their vessel according to acquired experience, the gain would be smaller.

8.4.2 Measures carried out

Maersk Line
Measurements onboard the PS class vessels have concluded that optimal trim saves Maersk approximately 1% in bunker consumption. The difficulty in trimming the ship to the optimal, without using ballast water with its added weight, used to be that the cargo weight of the containers loaded was not exactly known. The vessel had to rely on the weight information provided by the freight consignor. That piece of data was outside the control of the company and many times turned out to be wrong. The aggregated errors could therefore be substantial on a vessel with a 15.000 TEU capacity. Maersk Line now demands that all containers are weighed before loading and that data is then processed in a load computer program to achieve optimal loading for an optimal trim.

Wallenius Marine
The results of measuring fuel consumption in different ballast conditions concluded that an optimally ballasted vessel would use approximately 3% less fuel than on a benchmark voyage. An add-on to the loading computer now optimizes the ballast distribution, within set conditions, to achieve higher energy efficiency.

Thun tank
At present Thun tank is in the process of assessing a relevant fuel consumption baseline that will be their benchmark for evaluation of trim improvement measures. The expected gains are 2% savings on the fuel consumption.

9. Conclusions

The interviews carried out as a part of the research for this report were done with experts in the field of energy efficiency. A greater number of interviews would probably have lead to even more ideas on how to preserve energy and to more solid data regarding the methods described in this report. Even so, the expert opinion of the interviewees paints an adequate picture of what is at least possible, given time and resources, in terms of making energy use more efficient.

The fossil fuels used to propel the ships of today across vast oceans are a finite resource. In addition, the combustion of carbon based energy forms emits greenhouse gases and other air pollutants that are destructive to the ecological environment.

Shipping in general is an energy efficient way of transporting goods, even though it emits substantial amount of greenhouse gases in absolute terms. The sea trade is crucial to an ever growing global economy and will grow at the same rate. Measures to reduce the shipping industry’s ecological footprint should be a priority for everyone involved. It is not just a question about the environment; it is a question of economic survival.

In this study, theoretical and suggested saving potentials were confirmed in the carried out interviews. It seems there are a number of relatively easy ways to reduce bunker consumption in sea transports. A lot of research has already been done and is only awaiting implementation. The possibilities seem so vast that it is amazing that more is not done in the field internationally.

Overall business logic, aiming at increasing profit margins where significant cost cut at short pay back time should rank high on the management agenda. In addition to increasing the profit margins, the emissions of green house gases would decrease by fuel saving programmes. This should be sufficient drivers to implement thorough fuel saving programmes for every ship owner. Still we see several saving activities not being carried out by the shipping industry in general. The activities themselves seem easy enough to carry out, but there are some severe hurdles that need to be addressed.

The most severe hurdle to overcome links to our observation throughout this study that there is a need for a strong and solid company culture that continuously strives for improvements with regard to energy efficiency. This culture must be based on solid and continuous measurements in order to assess a credible assessment of actual fuel consumption. As new trials of fuel saving activities are carried out they must be evaluated and verified before implemented on other ships.

The main problems really seem to be the measuring and the consequent uncertainty in what the real results are. Another issue is the human weakness of accepting change related to fuel saving measures. Regarding the measuring problem it is evident that some investments are needed if the actual results are to be accurately measured. There is, however, the possibility to simply take advantage of research and measurements already made by others and trust that their energy conserving effects will bring monetary advantages in the long run. The instant effect of a certain implemented method is only relevant if the aim is to continuously improve operations. If the ambition level is lower, smaller investments are needed. Substantial savings in fuel consumption can still be made even though the measuring is not state of the art.

Another reason why more is not done seem partly to be the result of the energy gap described by below examples:

- A significant reason for not improving energy effectiveness in the shipping industry might be that a large share of the fuel expenses is passed on to the customer. As much as 70% -90% of the bunker costs might not actually be paid by the shipping company but by the end customer, e.g. bunker surcharges that passenger cruise companies sometimes levy.
- Another major reason for the non actions taken can probably be found in the parts of the shipping industry that involve a lot of bare boat and time charter contracts. Since the ship owner is the one responsible for improvements on the ship, but the charterer is the one paying for the fuel there is no incentive for the owner to invest in improvements (e.g. measuring equipment) onboard the vessel.
- A third issue is that second hand prices of vessels do not correlate with the investments made to increase their fuel efficiency. The ship owner who has invested money in bunker saving equipment will not see an increase in the price he gets once he sells the vessel.
- Shipyards are also not prone to change their ship designs at a reasonable cost or they simply do not have the capacity to do so. Therefore especially a smaller shipping company has little or no possibilities to affect the design of a “standard” ship.
- Finally, the initial cost in developing a new energy saving method might discourage a ship owner from making the investment. Even though the investment is sure to pay itself off in the long run, the owner might not be in the position, real or imagined, to make the investment.

If the energy gap remains there may be a need to provide a framework for modern energy efficient operations that should be aimed at by all shipping companies.

During the interviews it really became apparent that what is needed above all is the will to change the way we consider fuel efficiency. The unwillingness of humans to change established patterns of operations is a significant hurdle. Resolving this challenge will need forming and developing the minds of the managers of the company. From there it should be communicated down through the ranks so that it finally is intrinsic within the whole company culture. Incentive programmes for crews also seems like a well working concept for coming up with new, energy saving, ideas. It is obvious that the people who operate a vessel have a great knowledge of how to maximize the output of the resources available. Their knowledge, experience and ingenuity are immaterial commodities that the company can take advantage of at no extra cost. The company just has to elicit the new ideas by proper motivation.

There are numerous saving regarding fuel consumption to be made by operational measures alone. The fuel wasted in today´s shipping industry represents money that could be better spent elsewhere; it should therefore be in every ship owner’s interest to use that money more efficiently. The road to better fuel economy aboard is long and winding, so the sooner improvements are begun, the better.

10. Abbreviations and nomenclature

Abbreviation	Explanation
Bare boat	An arrangement of hiring a ship whereby no crew or provisions are included as part of the agreement
Bilge water	Bilge is the lowest compartment on a ship where water and other spills are gathered. This fluid often contains various toxic substances.
Black water	Toilette sewage
CCU	Cargo Carrier Unit
CH_4	Methane
CO	Carbon oxide
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CFC	Chlorine Fluor carbon
CDM	Clean Development Mechanism (Kyoto agreement)
CRT	Continuous Regenerating Trap
CH_4	Methane as biogas or natural gas
Cold ironing	Land shore electricity
Diesel	Fuel and engine principle (Rudolf Diesel)
DME	Dimetylether
Displacement	The actual total weight of the vessel
DWT	Dead weight tonne is the displacement at any loaded condition minus the lightship weight. It includes the crew, passengers, cargo, fuel, water, and stores
EEA	European Environmental Agency
EMAS	Eco Management and Audit Scheme
EPA	Environmental Protection Agency (e.g. US EPA)
EPD	Environmental Product Declaration
EGR	Exhaust Gas Recirculation
Emission allowances	One of the flexible mechanism suggested by the Kyoto agreement
Euro class	EU heavy vehicle emission standards
ETA	Estimated time of arrival
F-T diesel	Fischer Tropsch (Diesel) i.e. synthetic diesel
GWP	Global Warming Potential
GHG	Green House Gas
GT	Gross tonne, a function of the volume of all ship's enclosed spaces
Grey water	All sewage apart from toilette sewage
HAM	Humid Air Motors (also SAM and Wetpac)
HSD	High speed diesel engine
Hybrid	A mix of two techniques e.g. electric/diesel engine
HFC	Hydro Fluor carbon
HC	Hydrocarbons
H_2	Hydrogen
NH_3	Ammoniac
NMHC	Non-methane Hydro Carbons

Abbreviation (cont.)	**Explanation**
ICE Classification	Ships with an Ice Class have a strengthened hull and additional engine power to enable them to navigate through sea ice
ISO	International Organisation for Standardization
ISO 14 001	Environmental management system
ISO 9001	Quality management system
ISO 50 001	Energy management standard
JI	Joint Implementation, One of the flexible mechanism suggested by the Kyoto agreement
IMO	International Maritime Organisation
LNG	liquefied natural gas
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
Abbreviation (cont)	Explanation
LCI	Life Cycle Inventory
Lm	Lane meters (ferry cargo capacity)
NO_2	Nitrogen dioxide
N_2O	Laughing gas
NOx	Nitrogen oxides
N	Nitrogen
NTM	Network for transport and environment
MAUT	German road toll system
MSD	Medium speed diesel engine
Motor alcohols	Ethanol and methanol
Market based measures	Economical incentives in order to favour a specific behaviour
Otto	Petrol engine principle
ODP	Ozone Depletion Potential
O_2	Oxygen
O_3	Ozone
PM	Particulate matters
PCR	Product Category Rules
PSSA	Particularly Sensitive Sea Areas
Renewable fuels	Fuel based on renewable primary biomass
RME	Rape seed oil
Regulated emissions	Emissions to air being regulated by engine standards
RoRo	Roll on/roll off (cargo)
RoPax	Roll on/roll off (cargo and passenger)
Rhumb line	
SO_2	Sulphur oxides
SQAS	Safety & Quality System Assessment within the chemistry industry
SCR	Selective Catalytic Reduction
ST	Steam turbine engine
SSD	Slow speed diesel engine
Slow steaming	
SOG	Speed Over the Ground is the speed of the vessel relative to the surface of the earth
STW	Speed Through Water (STW) is the speed of the vessel relative to the water.

Abbreviation (cont.)	**Explanation**
Stuffing & stripping	The packing and unpacking of containers or other cargo carrier units
TEU	Twenty Foot Equal Unit (container)
THC	Total hydro carbons
ttw	Tank to Wheel
TEN	Trans European Network
Time charter	The vessel is hired for a specific amount of time. The owner still manages the vessel but the charterer gives orders for the employment of the ship.
Vetting system	A process of examination and evaluation of performance
VOC	Volatile organic compounds
VLCC	Very large crude carrier
wtw	Well to Wheel
wtt	Well to Tank
UREA	Ammoniac based reduction liquid

11. Interviewees

Mr. Karl Jivén
Sustainability Manager, Maersk Line
Located in Gothenburg

Mr. Lars-Erik Hellring
Superintendent, Project Manager, Energy Saving Programme, Stena Line
Located in Gothenburg

Mr. Hannes Johnson
Doctoral student, Chalmers Maritime Environment
Located in Gothenburg

Mr. Per Tunell
Head of Environmental Management, Wallenius Marine
Located in Stockholm

Mr. Sami Niemelä
Technical Manager, Neste Oil
Located in Helsinki

Mr. Ola Bengtsson
Senior Captain, M/S Silja Symphony
Located in Stockholm

Mr. Henrik Källsson
Technical department, Thun Ship Management AB
Located in Lidköping

Mr Fredrik Backman
Vettting coordinator, Preem AB
Located in Stockholm

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