A Framework for Choosing Alternative Fueling Solutions

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Abstract

In choosing an alternative fueling solution for the shipping industry there are many things that need to be considered. This paper will try to develop a framework that takes into consideration the different needs of the stakeholders that have interests as to what fueling solution is chosen for ships. This will aim to create a level playing field that will act as a place where the solutions merits and drawbacks can be compared as well as be looked at together with the industry's requirements and desires. It will in its development be based on sustainability theory as well as other applicable theories within the energy industry as well as any other applicable theories. In developing the framework the triple bottom line as well as the Energy Tetralemma developed by Forfas will be used as the basis and other theories will mainly play into how the different technologies are sored as well as how the different categories are weighted in making the final solution. Thus it will provide an answer to what fueling technology is the most applicable as well as looking at the best solution that is not a complete fueling solution but rather an auxiliary one that can be adapted together with the current solutions. It will explore the different advantages and drawbacks of the different solutions and evaluate these up against each other in the developed framework. In developing the framework the Energy Tetralemma and the Industrial Fuel Choice model were used as the two models talk to the same considerations as those faced with choosing a fueling solution, even though they have been gathered from different industries, the considerations raised in the model are similar enough to those faced in this paper for its ideas to be transferrable. In addition to the theories used the paper relies heavily on secondary information gathered from different companies within the shipping industry, as well as

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some industry gotten through communications with maritime consulting firms such as MARCOD and GEMBA Seafood Consulting both to find their recommendations as well as for help in gathering secondary information through them aiding in the search and giving the information that they have available.

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What decision criteria should be used in the choice of alternative fuels?

Introduction

Retrieved from: http://static.worldmaritimenews.com/wp-content/uploads/2012/05/Germany-GL-MAN-Study-on-Costs-and-Benefits-of-LNG-as-Ship-Fuel-for-Container-Vessels.jpg

There are many ship fuels in the market today and these have different advantages and disadvantages, be they economic, environmental or otherwise. The transport sector stands for approximately 15% of the total emissions of greenhouse gasses and in looking only at shipping this stands for a total of 3%

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of the total emissions of greenhouse gasses. Both when it comes to internal competition between shipping firms or competition with other modes of transport, there has been a clear movement in later years that has improved the importance of sustainability in the choice of both mode of transport and company to choose. A company's ecological credentials have become a marketing tool as well as an expectation in many industries with many industries being forced by legislation or outside pressures to lower emissions or face grave economic consequences. Thus there is a need for technologies that can help companies provide their services with lower emissions. As the emissions vary both in size and severity from fuel to fuel there is a need for a way to compare them to each other on a level playing field. Thus there is a need to measure all the positive and negative sides of the different solutions up against each other.

http://ec.europa.eu/clima/policies/transport/shipping/index_en.htm

http://www.tsp-data-portal.org/Breakdown-of-GHG-Emissions-by-Sector-and-Gas#tspQvChart

These propellants have different advantages and disadvantages but majorly new developments are not taken into use if they do not fulfill the need of the shippers or if they are deemed too expensive to be put into fruition by the companies. However, this paper will look at which of these are the most applicable for the future through weighing them against each other in a framework where they can all be weighed up against each other as their benefits may come in different forms. Thus it will provide a level playing-field

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where the different solutions may be measured to gage their current and future potential, splitting the different solutions into two distinct categories; Complete and Auxiliary fueling solutions. They are grouped like this as they either are incremental innovation or radical innovations. Those that are radical would not work with old systems and as such will require a complete switch while the incremental innovations will require little in terms of change of the current paradigms as they are less invasive. This is also looked at in terms of the impact of the solutions, as solutions that have a large enough output to power the ships alone as it is are considered as complete solutions are considered complete solutions whilst those not complete are considered as auxiliary. These will be measured up against each other looking at the economic, social and environmental ramification of any switch from the current fueling solution which is bunker fuel oil. The framework will score the different solutions in categories that are developed through the use for sustainability theories as well as through looking at models and information that is applicable to the decision making process for choosing an alternative fueling solution. In the end this will be used to make an informed decision as to which solution is the most applicable for the industry and thus also the most investable for the companies that aim to invest in using such a solution, such as the ship owners and carriers that need to know this to avoid costs at a later point for retrofitting if they chose the wrong technology for their new builds or to avoid paying several times to retrofit their ships to match the solutions that will be adopted by the industry and thus be a solution that can make money long-term.

As the auxiliary solutions are not mutually exclusive the recommendation for these products will be most based on which provide the greatest benefits as

well as their costs and future potential. As such the choice of solution here will only be for what should be adopted first rather than excluding the other technologies available.

In recent years there has been a large amount of money invested in trying to make more sustainable ship fuels, both more economical and more environmentally sound. But with all the possible fuels shippers and carriers can choose to invest their money in using for their ships there is an importance in finding the right one to invest in as many of these would require substantial investments and if they are not applied to a vast majority of the ships around the world would be difficult to survive. Thus this paper will compare the available fuels for shipping and give recommendations as to witch would be best as well looking at other ideas that may help in fuel-saving for the shipping industry. However, there is not room for one major technology taking over a bit of the market and another one taking another big part of the market.

According to DNV (DNV, 2013) the fuel that will be chosen will be chosen only if it can compete economically with the current fuel, as such the carriers will mainly look at the total cost of building such ships and fuel costs over the lifespan of a ship and any other costs accrued after being built, thus looking at the total costs of a ship on a very long term time frame rather than looking at any one part of it but rather taking a more holistic cost view. The competing fuels will have to outcompete the bunker fuel oil that is being used currently in total costs, however this also includes costs that are related to pollution and taxation costs that are there in using such highly pollutant fuels.

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The Prices of bunker fuel oil have also skyrocketed in later years something that has made such solutions for fueling ships that were less profitable than fuel oil now more or equally profitable, however, many of these fuel solutions will require substantial investments as well as a better infrastructure. Thus there are many costs that are connected with such technologies that may not become apparent if just looking at the cost of building a ship with a technology and seeing its fuel usage. To decide between the available fueling solutions many different decision criteria have been suggested. This paper aims to explore which of these are the most applicable to make the decision through exploring the one that are currently being used to make such decisions as well as looking at other prospective criteria that may aid companies in making such decisions. This will then be used in developing a framework that can be used to determine the most applicable fuel for freight ships. In creating such a framework the paper will gather insights from industry insiders about possible future fueling solutions as well as through gaging the different criteria in choosing an alternative fuels over current fueling solutions.

The framework will also be utilized to look at the current solutions available as additives and supplements and decide which of these are applicable for the industry, This will be done through looking at the solutions that may be retrofitted to the current ships sailing without the costs of a new build or a large remodel of a ship to accommodate a complete fueling solution. Thus there are different time horizons on the different products. The auxiliary solutions are more applicable for the short term as they can more quickly be implemented and the costs are lower than the complete solutions that will have a longer time horizon and thus will need a more long term investment but

may potentially in turn reap even greater rewards. Thus the auxiliary solutions carry less risk.

There are many other ways that ships may improve on their efficiency than through a change in propellants. From the changing trade patterns and move towards a regionalization of shipping with large shipping hubs rather than individual ports or through technological innovations such as using dual propellers or changing the hull shape, but this paper will mainly focus on the key issues pertaining to the choice in propellants, and not to solutions that are not pertaining to these as most of these can be done regardless of the choice of propellant, and their benefits may be reaped regardless of the solution chosen for fueling, they are not considered auxiliary solutions either as they are not directly pertaining to the fueling of the ships, but rather more indirectly affecting it through increased efficiency or other benefits. Thus they will not be encompassed by this thesis.

Problem statement

In the shipping industry there is a lot of investments in researching alternative fuels to power freight ships. There are many different possibilities to choose from, some mutually exclusive to each other and some not. As the different technologies need investment as well as a market, there is a need for companies to know what they should invest in, as if the wrong technology is chosen by a company but not embraced by the market it may not be sustainable to keep it. Thus if the wrong technologies are chosen by companies

there is a clear chance of large investments being made without there being any possibility to recoup them.

There is no clear framework where these solutions can be placed side by side and evaluated against each other for companies to decide what to invest in. As the different technologies have different upsides and downsides there is a need for a tool to measure them up against each other on a level playing-field. This paper aims to develop such a framework as well as develop a recommended solution for investment. The framework will take into consideration the needs of a company choosing such a solution as well as the feasibility of the fuel. It will measure up the requirements of the industries but also consider the other stakeholders as they may be the drivers for the changes both in fueling solutions but also in regulations that will require changes from the industry. This will be done through looking at the information put forth by both the companies developing solutions, the companies that crave such solutions, independent consultants and other stakeholders. As there are many stakeholders that share a large part of the costs and risks of such an investment this thesis will try to unify these views in the framework and take into consideration not only the economic considerations for the stakeholders, but also the environmental and societal implication of it. It will try to make a recommendation based both on the current situation as well as the future outlook as the adaption of alternative fuels will not be instantaneous but rather a lengthy process, as such the measure of a solution will be long-term success and as such the predictions made through looking at insights from the industry leaders in the field, looking at both their experiences and future outlook will strengthen its merits.

Research question

In looking at how you can choose the different solutions for fueling it is very difficult to provide any basis for comparison as the different solutions provide different pros and cons. This being because the aspect of one solution vary greatly from that of another and as such so does the pros and cons of each solution. Those that provide the most benefit for the environment are often not economically viable, and those that are economically viable are often not sustainable for the environment. These considerations are important to weigh up against each other for companies as they may both impact the choices they make and the future of the company financially and otherwise. This wide impact of the decision comes from the changing environment of shipping with regulations becoming more strict and regionalized, even with some ports making their own requirements from shippers, and as such this is leading to a greening of the business with both best practice in the industry as well as regulations impacting the companies in it are requiring them to choose their paths forward and pushing them towards the adaptation of more environmentally friendly solutions. Thu the impact of the decisions are large, and there is a need for a common ground on which the different solutions can be weighed As such the different solutions are difficult to compare as there is currently not a framework that can be used to monetize the positive effects of each solution with a broad focus both on the aspects regarding sustainability, but also other aspects that play into the decision making process, such as the financial viability of the solutions and the other stakeholder interests. What alternative fuel solutions for carrier ships are currently being developed and which one is the most applicable for carriers and where should further investments be made? How can we develop something to measure the

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different considerations up against each other and through this compare the different solutions?

Methodology and Research design

In looking at the problem of choosing an alternative fueling solution there is a need to focus the approach that is used to gather the information, so that not only the optimal solution is found, but that also the correct information is gathered to answer the questions posed in the paper. As such the methodology and design that is chosen will color how the questions are answered and what results this brings. Thus choosing the right design and methodology will impact both the validity and reliability of the paper and thus help determine the strength of the conclusions made on the basis of it. One part of this is choosing a research design. In doing this there is a need to focus on what information is needed to answer the research problem. This would be a mainly qualitative case study as the information about the costs of each individual solution or the investments done by the companies that either support or use the solutions were not able to be found. As a case study it will use the wealth of research that has already been done in the field of alternative fueling technologies for ships and as such the secondary information that is available will both shape the approach to the problem as well as the final solution that is given to the problem through the framework that this paper aims to develop.

The conceptual framework of the paper will be both descriptive and explanatory as it will mainly be based on secondary research due to the industry's unwillingness to give away information on costs and investments regarding fueling technologies to someone that is not a prospective customer. However these companies and their actions are the subjects of my research, as well as the companies and institutions who research Alternative fueling solutions. When it comes to sampling the different technologies there may prove to be some bias as the solutions that are chosen are the ones most publicized. This does not prove to create too much bias as these are the solutions that have the most market potential and they are the ones getting the publicity needed to be in the evoked set of their customers, and thus be most eligible to be chosen. They thus represent a convenience sample as this was the most applicable method of choice in this situation. The number of technologies chosen have due to time considerations been limited and it has been limited due to the fact that the technologies not taken into considerations either fall partly or entirely into the categories of technologies mentioned in the thesis or that they have not yet reached a point where it can be seen whether they are viable options for the market or not. (Rudestam, 2007)

The aim of the research philosophy is a positivistic one aiming to remove any researcher bias, due to the research being mainly secondary there is a slightly increased bias. The reason for this approach is that the companies selling the solutions may try to pass off intuitive knowledge as facts rather than show empirical data if this can further their cause, as it is a highly competitive field. (Nightingale, 2012) The different technologies are measured on their merits being them current or prospective. Another limitation of the thesis is that of

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time constraint, as the thesis is limited in time there may surface new information that may create new paradigms and change the situation to some extent and thus create a need for further study

As the information they are not willing to divulge is not readily available from other sources this reduces the possibility for primary research, still the paper contains certain learnings from communications with consulting companies that have a maritime focus due to their wealth of secondary information surrounding the subjects as well as their unbiased expertise about the solutions. As the information gathered around the technical specifications and the pros and cons are not information that can be easily duplicated through primary research as they require extensive experiences with the products as well as a technological savvy above what is found in most people not educated in the technologies this does not greatly hurt the validity or reliability of the information. As the research that the thesis is based on is mainly done by third parties and not by the companies producing or using the solutions themselves the bias is greatly reduced thus increasing the validity of the results. (Blumberg et. al., 2011)

The paper will take on a mainly descriptive manner and the research will both be qualitative and quantitative. The quantitative research for this paper will be compiled through both finding accessible financial information compiled by others as well as through interviewing industry professionals. The paper will take on a more qualitative approach in looking at the possible solutions that are available in fueling freight ships. However the framework will also in part use a Benefit-Cost analysis to measure the different solutions up against each

other even though the exact numbers were not available the costs and benefits have been inferred from the information available about the different solutions. To get a complete picture of the costs there would be a need to also quantify the damage done by the emissions, and as the data that focuses around such damage is difficult to quantify as well as difficult to isolate the effect from one industry it cannot be quantified in such an analysis. The damages may be inferred from the fact that ports are aiming to cut emissions at berth more than at sea, and thus it can be seen as more environmentally harmful around populated areas and thus be inferred that the current paradigm of fueling is having adverse effects. In other subjects in the analysis where there is no information on a topic the thesis will induce its answers from the available research.

As there is a great wealth of research surrounding the subjects of the thesis it is possible to do this. And as such take an inductive rather than deductive approach to the problems at hand. It will be a cross sectional design that is based on action research as I will take into consideration the information I get from industry insiders in developing the paper. As these will not be chosen at random this will lessen the possibility of reproducing the study with the same results, but as research points to the fact that industry best practices are dictated by the market in this industry and in looking at nonpartisan consulting companies for help in developing the framework for analysis of the different fuels and that the research into what fuels are the most applicable are largely done by industry leaders who use such nonpartisan consulting companies, this also leads to the study to be more easily be reproduced with similar results. This in all will aid in improving the validity of the study as the cause effect

relationship in the decision making between the different possible fuels is largely the same throughout the organization.

As the interviews that are made are of individuals that work in the organizations there will be placed a high importance on that they convey the views of their organizations and not their individual views. On top of this I will research through secondary research the current industry trends in sustainability. The technical specifications of the different solutions are not applicable to what is to be chosen any difference in this between solutions are not taken into consideration as they fall outside of the scope of the thesis, however the paper acknowledges that such differences may impact the final choice as the cost of implementation and maintenance may also vary on the complexity of the solution, however as this paper does not aim to make claims as to what is more or less complicated and in turn would accrue such costs this is not focused on by the paper. (Trochim, Land, 1982)

The measures of which the technologies are scored against in the developed framework are those best suited to give a complete view of the current and future situation for the solutions as they reflect both the current situation and the future potential of the solutions in question. As the analysis is a qualitative rather than a quantitative one there is a level of subjectivity in the scoring, but as the basis for this scoring is in the research and as such factually based. The choice of a 5 point scale to measure these are for the reader to be able to more clearly identify the strengths and weaknesses of the different solutions and is a way of summarizing the wealth of information surrounding the different

solutions. Due to the framework being based on mainly secondary information it slightly lowers its reliability and validity. However, the answers provided come on a basis of information from reliable sources and the framework is more of a summarization tool as well as a tool to measure the merits of the individual solutions on a level playing field and due to its basis in tried and tested theories and models this makes it so that such a framework can be reproduced with similar results and thus is still relatively high in validity and reliability.

Literature review

In the field of sustainability there are many sides to the same stories. In this thesis the focus is put on the shippers and carriers, and more importantly on the fueling solutions that they can choose to invest in. As such there is a need to look at this from an unbiased view, as the companies that already have an alternative solution in place will be jaded towards that solution whilst those not yet invested in a certain product may have a completely different view. Because of this and the fact that the companies that were contacted were not willing to divulge any information as to their sustainability efforts the information gathered from primary sources comes mainly from MARCOD, The Danish maritime center for operations, and from Gemba Seafood Consulting as these companies are maritime consulting companies that have no bias towards any solution as they are not stakeholders in any of the solutions. Their research into alternative fuels has helped the understanding of the use and need for alternative fuels in the shipping industry as well as for other maritime based

industries such as offshore and ferry traffic. In looking at the research they have accrued and how it has been used in the maritime industries I class these as a very reliable sources. Other sources that have had a large impact on the paper are several consultancy reports in different fields, these provide a stronger bias as they present the information in a way that is set to appeal to a client and their demands, and thus will focus more on that reducing their reliability as other research may produce different results. These are a mix of cross sectional and longitudinal analyses of the subjects they encompass and the longitudinal studies gives a better overview of the time perspectives that the technologies rollout periods will be, while the cross sectional analyses provide a momentary image of the situation.

Industry specific news through newsletters are also used as these provide the paper with examples for the technologies in question and add to their likelihood of coming to fruition if they are seen as successful by the industry and as such help raise the profile of the technology increasing the long term chance of adaption and thus being an important part of the background for the choice of solutions. Other sources used in this respect such as the projects used to substantiate the pressure felt by the industry and the drivers for change are taken from industry sources that may have an agenda in aiming to create greener solutions, but as they are partly funded by the industry as well as other stakeholders this increases their reliability as the results then can be assumed to be less biased as the stakeholders in this situation have a similar aim.

The sources for the theories that provide the backdrop for the paper are from books that range from sustainability to business research methods as well as

environmental economics and come from the course literature from courses that encompass the problems identified in the thesis. There are also taken theories developed more directly created for business and as such are taken from industry sources. Still the theoretical framework is strong as it is based on theories that are widely accepted and used.

For additional information the paper has used sources that either in part or wholly tackle the issues at hand, be it from industry journals or news outlets focusing on maritime news. The information provided within are found to be the most up to date and thus useful in creating a cross sectional analysis such as this one as they paint the picture of the current situation. For these to be useful they need to be relatively new as they are used to paint a picture of the current situation. All the information gathered from industry journals can be sad to have slightly greater reliability than that of news media outlets as the journals are directed towards the industries they are for rather than for the general public. Thus the articles are selected and edited so that they can be of interest to their target audience rather than the general public. These articles also better source their information, further increasing their reliability. The need for information on different technologies or theories that can be used to substantiate the claims made from a background of the produced framework. These sources are looked upon as less reliable as they may take the side of a certain technology and look upon it with rose tinted goggles and not see the problems but rather just the benefits. Those sites used for direct factual information however base themselves on more unbiased research thus increasing their reliability. Some of the information in the thesis is also based on academic papers and dissertations, these are used as a starting point for further research, and are used to provide additional inputs and views to the

paper. There may however be some bias in some of the information, but with a foundation of very reliable sources it does not greatly reduce the validity or reliability of the paper as a whole.

The theories chosen have been chosen as they are the best fit in developing a framework for choice of fuel. The reason for this is that they each represent some of the important facets of the decision making process.

Theoretical Basis for Framework

Sustainability Theories

Retrieved From: http://winnebago.uwex.edu/files/2010/09/Sustainabilityhands.jpg

In developing a framework for choice of alternative fuels certain theories that are already formed can be used to strengthen both the validity and the relevance of the master thesis for the field that it is in. The theories that are closest are those found within the area of sustainability. One such thing is the concept of natural resource economics, this explores the extraction and

utilization of natural resources. In this we can find the concept of energy economics. This concepts talks to the problem at hand for the future as the market is reacting to petroleum resources as a finite amount and thus this talks to the reason for the paper as well as the need for alternative solutions and in this finding those that are not finite and in turn nonrenewable. However it also talks to the subject of energy efficiency as a more effective use of finite resources could extend the time on which we can rely on such solutions. (Field, 2009) In looking at this there is also a need to focus on the assimilative capacity of the environment, or in plainer words the earth's possibility of accepting certain pollutants. This also needs to be taken into consideration when choosing such a solution as the total cost of any solution would also have to consider the emission costs and taxes that are accrued due to emissions. Another consideration that needs to be made is that of the ambient air quality and the environmental quality, this means both the visible as well as invisible signs of pollution. One reason this needs to be considered is that emission regulations are becoming stricter both in general but especially in the ports. This also has aided the adoption of solutions that aim to reduce pollution as well as improve the fuel efficiency, one such example being the demands made by the port of Los Angeles as to emission reductions and their pilot projects for such technologies like cold ironing. (Starcrest consulting group, 2013) These theories speak greatly to the different important considerations that need to be considered in developing the framework. Another theory that affects more the time of adoption than what will be adopted is the socially efficient level of emissions. This can be use and adapted to fit this situation through changing the wording but keeping the main point of the theory through stating that when the costs of paying for your emissions equal those of the costs of changing into something more environmentally friendly to remove these costs,

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this will happen. This is a way of framing the incentives of changing fueling solution, but also shoes how the costs majorly affect the adoption process for the new solution thus highlighting even more the need for the solution to be one that is economically viable. (Field, 2009)

Solow- Natural capital

In looking at the shipping industry you can look at the concept of natural capital. This states that there are some biophysical limits to growth. This is something that will have a profound effect on the regulatory systems that govern the industry, and if the shipping industry could move more away from getting as close to these as possible and rather move towards being the cleanest possible way to transport products the frameworks for regulation of shipping could be moved to aid a larger scale move of transport from other modes of transport to sea freight. This could make sea freight a more attractive mode of transport and thus help create further investments in greening. Thus in looking at greener fuels it is not in an aim to gain competitiveness over other carriers but rather in an attempt to make shipping a better choice than other modes of transport. Thus the thought of an investment analysis will be one that could provide the industry with what they need to know to make a decision as to where the money should be invested.

The Industrial Fuel Choice Model

The industrial fuel choice model is a model developed in 1980 to forecast energy demands on a long term horizon. It is basically a tool that was used to determine the life cycle cost of any one fueling solution, the model tries to

provide a holistic view of the market for alternative fuel, but has a stronger focus on governmental policy than on the individual companies choice, and has a more wide focus on all industries than any one individual on. Thus it takes a more macroeconomic view of society than a more industry or company centric approach. This model is together with the Energy Tetralemma seen as a base for the framework the paper aims to make, as there are certain considerations that this model takes in to consideration that are not fitting for the shipping industry as well as there are some considerations that need to be taken now that were not taken when this model was created. It takes into consideration certain environmental concerns and the long-term costs in looking at alternative solutions but fail to consider the costs that are connected to the building of infrastructure and as it is created earlier than several of the alternative solutions were created it is not completely set to handle all the issues that are connected with this. It does still consider this and due to its longevital outlook it still remains a good resource for those trying to choose a fueling solution. It therefore serves an important purpose as it pinpoints the importance of a longevital outlook of such models and frameworks. (Energy and Environmental Analysis Inc., 1980)

The Energy Tetralemma

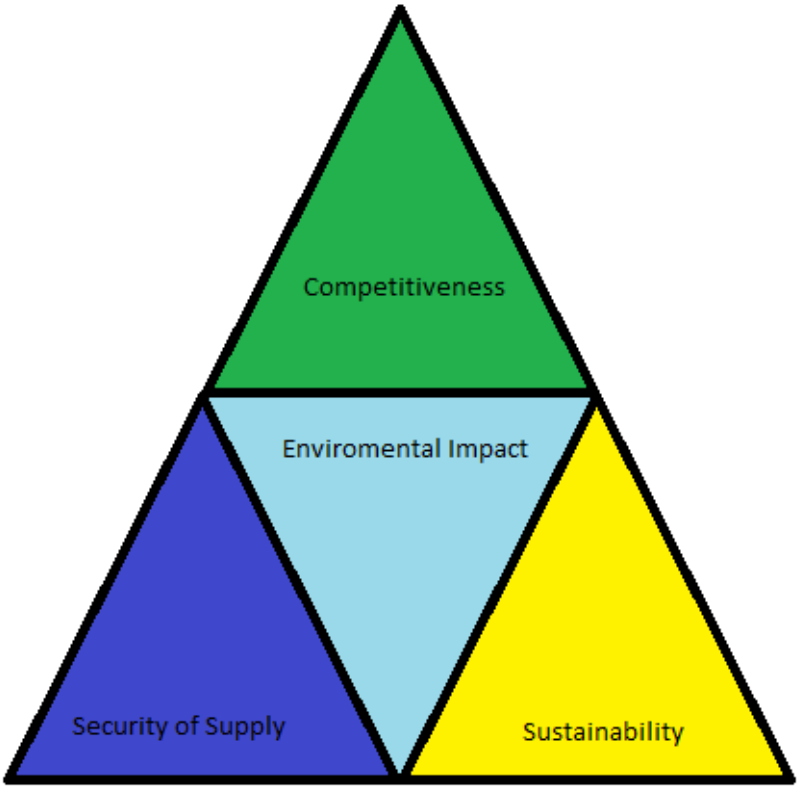
The choice of fuel is an important one with ramifications to not only one company, but rather throughout the supply chain even having an impact on national economies. Thus, there is little help to find from oil producing countries in developing possible products or solutions that may replace the solutions that are already in place for fossil fuels. Thus the focus that will be put on developing solutions for alternative fuels is very complicated as they encompass both countries and companies as well as society and the

environment. Thus there is a need for a framework that can encompass all these things. One such framework is the “Energy Tetralemma” that was developed by Forfas, the Irish policy advisory board for enterprise and science. This framework focuses mainly on the three pillars that are generally internationally seen as the three pillars of

- Competitiveness
- Climate Change
- Security of supply

But they also focus on the concept of sustainability in the model as this has been identified as a very important issue in choosing fuels as any solution chosen needs to be sustainable and possible to use over an extended period of time, and thus needs to be sustainable for all parties involved, thus it incorporates the triple bottom line in this aspect as well as throughout the framework. One issue that this model fails to consider is the future, it has a very limited time span and more than anything provides a picture of the current situation, thus to get a total picture in the framework there is a need to consider the aspect of time and this can be done through seeing the prospective chances an challenges that each solution faces whilst scoring it in the categories provided by the Tetralemma. In adding to this there is also a need to keep in mind other theories within sustainability when considering a solution as from a sustainability point of view there is a need for a holistic view to encompass all the considerations and increase the validity of the framework.

(Forfȧs, 2010)



The split focus in this allows for them to weigh the different possibilities up against each other and thus see what kind of mix is the best possible one. This can also be applied in the industry of shipping as the model was made with fuel choice in mind and not necessarily one industry. In looking at it there are no aspects of this model that is not applicable for shipping. The one addition that can be made is that of adding the concept of infrastructure into the concept of competitiveness as this is an important factor in decision making for choosing an alternative fuel. As this is the most applicable model out there for choosing alternative fuels I will use this as a base for developing the framework for choosing alternative fuels. As such the different reasons for changing to alternative fuels will be grouped into these categories through collecting answers from industry leaders and then weighted from what is deemed most

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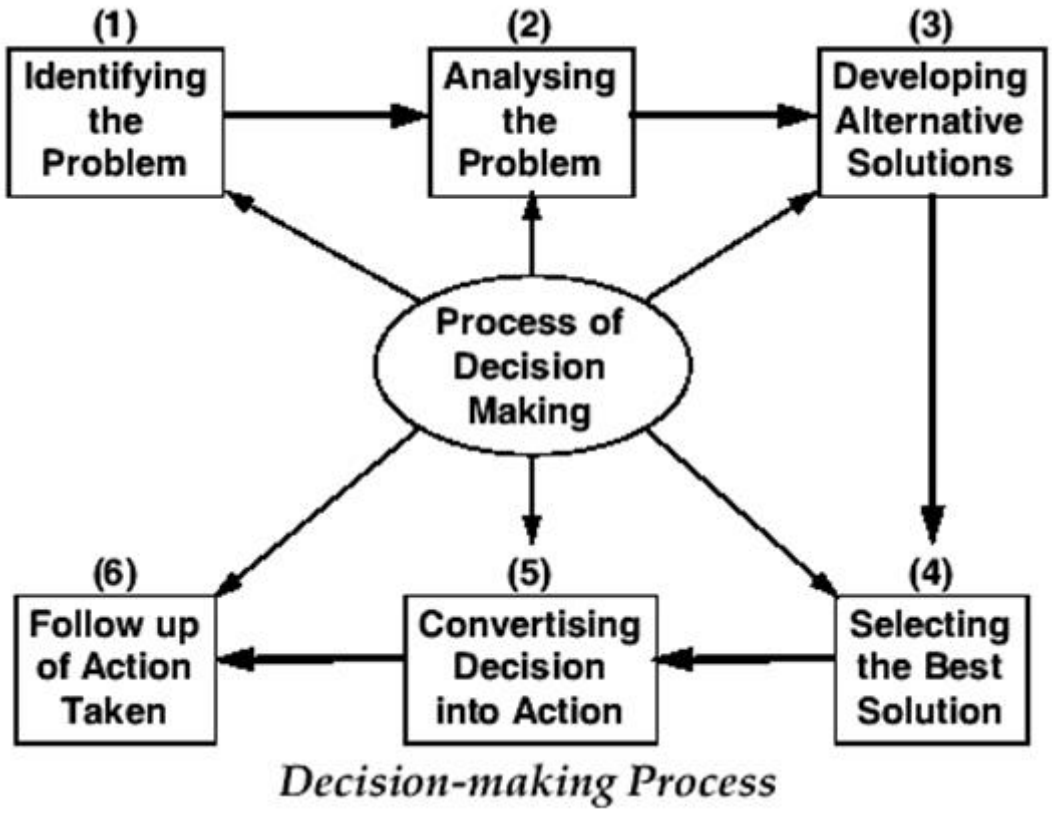
and least important. This will then provide a score in each category as well as a total score. From this there will be made a choice of an additive as well as a complete fueling solution as the best possibility for current and future fueling solutions.

The decision making process for new technologies



Decision-making Process

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As new technologies are adapted over time it is important to look at the decision making process and how this plays into the decision that is finally made. As different decisions take on different processes it would be wise to look at the decision making process of new technology adaptation. Even though this process has at one point been overseen mainly by the management of companies it has in later times become a process where the board will get

more involved as it is a long process where companies will not only affect their own future, but the future of the markets technology wise, it thus becomes important to involve the board as they will look at such a potential change with the eyes of someone that keeps all the potential stakeholders in mind and takes a long term decision for a long term problem. (Kotler, Keller 2009) As this model shows the choice of adoption of a new technology is not only a one off, but rather a choice that will be evaluated as time goes on, and this bodes well for those technologies that have the shortest lead times as they will be able to put these into action quick enough for the choice not to be reevaluated several times before putting the technology into action. It also speaks to one of the costs that would not be considered otherwise, the cost of time, or in this case the cost of time in the matter of reevaluation of the solutions. For unproven solutions that are yet to be put into action this is a significant cost, and for those looking to invest in such a solution this uncertainty will add to the financial viability of a solution. Another cost that can be considered here is the risk of failure of new solutions, be it that they do not reach fruition in their development or that they lack the critical mass for long-term viability, this risk will be inherent with all unproven solutions and is to be considered a cost, however as there is little to say what the uncertainty is in one solution compared to another this is a to be considered a cost that is equal among all unproven solutions, but not with those that are already developed and viable for deployment in the market or those who are already in the marketplace.

http://www.economistinsights.com/sites/default/files/EIU_Technology%20decisions_WEB_FINAL_28-05-%2009.pdf

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Assessing the possibility of different fuels

As the fuels are in part split up into two groups, “Additives and supplementary systems” and “Fully formed fuel solutions” these two will be treated as separate entities. As such the framework that will be used will first treat current possibilities in place in additives and supplementary systems and then look at the fully formed fueling solutions that require significantly higher investments and also will have a potentially longer rollout period and significantly higher cost and risk. In looking at this there are some standout possibilities as to additives and supplements as well as for complete fueling solutions. As additives the ones shown most promising from my research are scrubbers, fuel additives, hybrid power cold ironing and Sky Sails. The clear frontrunner found in my research of fully formed fueling solutions is LNG, however there are plenty of other solutions that are being researched or tested are cold ironing, sail power, DME (a methanol product) and LPG. As a Baseline I am using bunker fuel, or fuel oil as is the solution most used currently by freight ships.

Economic benefit of alternative fuels

As LNG is concerned there is a cost to converting ships into LNG propelled ship, the same is with the use of wind power to aid in reducing fuel usage. As such there is a need for there to be a benefit beyond the environmental for companies to adapt such methods without being forced into it. Part of this can be helped by legislation to incentivize the usage of low emission fuels and reduced costs as the companies will have to pay les as they pollute less.

Another positive aspect cost wise is that of having to constantly have the motor running to avoid it clogging. This will be less necessary for the LNG powered boats as they would allow for engine shutdowns without grave consequences.

The objective of this thesis is to assess how the adaptation of alternative fuels in the shipping industry may aid in making shipping more competitive form of transport through looking at the environmental and economic benefits as well as the possibilities of using these to increase the efficiency of ships

In looking at this the papers aim is to identify the most applicable alternative fuels and look at what benefits that each of these bring. In looking at this the paper will take the approach of using a triple bottom line and thus looking at both economic societal and environmental benefits of each of the new technologies.

In looking at the current types of alternative fuels being explored for shipping several different ones emerge as possible solutions that may be applicable to use in the future, and that are currently being researched and pursued by companies. Among the most promising are the use of biofuel, the use of LNG (Liquid Natural Gas), the use of Methanol, the use of DME as well as the use of sails in either powering the ships completely or being used in conjunction with current fuels. All these different fuels are currently being developed and tested. Some of the Technologies have even been put into practice as the use of LNG to power ships, as this saw its first application in 2013 on a ship belonging to the shipping company Tote Maritime. Adding to this trend several other carriers have commissioned LNG ships and several have been or are in the process of being built or have already been launched in 2013. The usage of wind power as an addition to regular ships have started to be used. The current

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usage has been successful on certain routes, and has improved effectiveness and fuel efficiency for several cargo ships.

The development of ships running on methanol and DME have been in progress over a long time period and though the technology for propulsion on methanol has been existent for cars but has tried to be adapted for ships over the last few years.

In looking at this it is important to find what types of alternative fuels that are already being utilized in the market. One example of an applicable fuel that is not in use yet and has to large capital requirements is the possibility of nuclear fueled ships. This has been tested for other marine vehicles, i.e. Submarines with varying success, but the implications of a large scale usage of this as ship fuel has further implications than financial. Even though this would to a large degree solve the problem of emissions it has several social quandaries that have to be addressed, one of the major ones is the case of waste disposal. As nuclear waste cannot be disposed of everywhere there is a need for somewhere that ships may dump their nuclear waste where the nuclear half-life will not greatly affect the inhabitants. Another question is that of security. There is a need for very advanced security measures to prevent possible radiation leaks as well as possible meltdowns that may cause problems over large areas. One main point to look at here is the problems there have been with nuclear submarines such as the Kursk, a nuclear submarine that sunk and still poses a threat to the surrounding areas several decades later. Many ports may also be wary of taking in such ships as the potential dangers not only from natural factors, but also from terrorism and the like are also great. One such threat could be pirates, something that has in the past posed a threat to all ships sailing in hostile African waters.

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Sustainable Shipping- How to choose the Right fuel to power boats to see both an economic and environmental benefit

In looking at what is out there as to the different possible fuels that may be used it is important to acknowledge what side you are tackling this problem from, as such this paper will look at the concept of sustainable fuels in shipping from the side of the shippers and carriers rather than taking a more societal perspective and looking at the problem. Therefore the paper will focus on both the financial perspective in looking at the problem at hand. There are several perspectives within this that can be taken, but this paper will mainly focus on what the costs and benefits of using the different alternative fuel solutions, it will also venture into the decision criteria for choosing any of the possible solutions for. Thus the most applicable solutions is doing a cost-benefit analysis from the side of the shippers and carriers and look at what they can do to, however as the industry has been unwilling to part with this information it needs to be found through secondary research and as such will not have the complete picture of the costs as this information is not available.

With an ever increasing price for fuel oil there is created a major impact on the shipping industry. AS it carries most of all the goods transported worldwide such a thing cannot be ignored as it has a huge impact on the profitability and sustainability of shipping as an industry. Thus there is a need for a focus on sustainable fueling solutions and the industry is doing this through investments in development of such solutions. This includes investments in technologies

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that may be retrofit for the existing fleet of ships as well as for new builds. For the companies that are interested in this research there are several organizations, both private, governmental and projects that are a mix of these two that are out there that both provide research, funding for such research and information for those looking for it. There are also grants available for those looking to research such areas to make this an attractive field for companies to be in as many of these solutions currently are not far enough along to be sold in the market.

Background for sustainable development

Sustainability driven thought processes driven by conservation interests often ignore the needs for such things to have a positive influence economically as well as having flexibility in solutions such as in choosing the solution that will be used in the future, in this there can be drawn a parallel to the fight between technologies in other fields such as technology such as the fight between technologies such as the Betamax and the vcr as well as many others. As soon as one technology is seen as that of the future the other will not be future developed and will often prove a bad investment for those who invest in it Those driven by only economic benefit may often ignore the social and environmental effect altogether and thus provide a negative impact for this. That only driven by societal effect of a company's actions may lose their focus on the financial and environmental effects and may in turn not be profitable and maybe not even provide a positive societal effect if its focus does not take into consideration the environmental effects it may have. AS such the need is there for a focus not only one of these but rather on them all as a whole. The

need is there for a holistic view so that none of these considerations go by the wayside.

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Navigating a changing economic context

As for the challenges that make the switch needed the current and future economic climate are among the most important. As has been seen in the financial crisis there was a giant dip in global trade leading to many problems in the shipping industry. One of these issues was the overabundance of ships. This lead to a huge dip in the profitability of the industry with many companies not being able to pay what they owed and going bankrupt. It also lead to a clear shift of power in the shipping industry as the ship owners were left out to dry

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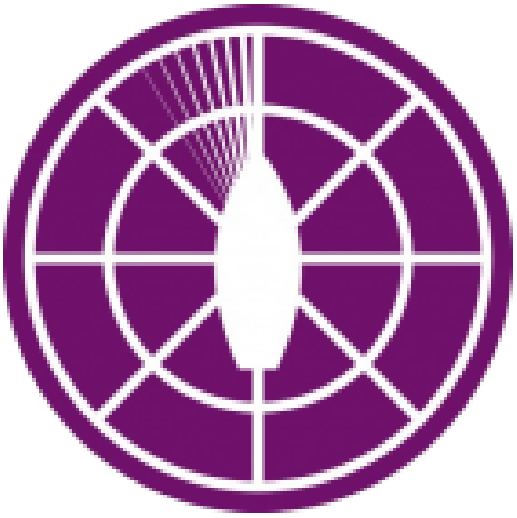
having to compete for business lowering prices to such low levels that everyone struggled to make a profit. This still causes problems as shippers and carriers still have problems agreeing on prices for the services provided by the carriers. There has been a recent effort made to lessen the gap, but problem till arise. The solutions that have been put in place are focused on creating a more dynamic pricing scheme and programs that make anticipatory changes instead of reactive ones. (Nilsen, Dønvik, 2010)

(Bowman, 2011)



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Increased scrutiny and a heightening of expectations

Shipping is facing increased scrutiny both from environmental groups as well as from other groups in society, as seen in many other industries. With increased scrutiny of in port emissions especially as well as a stronger and stronger focus on total emissions as well. Companies with great working conditions, high fuel efficiency, fewer prosecutions for breaking the rules and other such factors are

likely to be favored by customers and suppliers, including ports, financiers and insurers. Thus making it easier to both drum up business and raise the capital they need. This trend towards a more social consciousness in underbuilt by many programs put in place to insure that companies follow the rules as well as investing in solutions that may aid companies in following regulations as they get progressively stricter. (Sustainable Shipping Initiative, n.d.)

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Climate change and the need for new fuel

The volatility of oil prices and their continued increase along with heightened emission regulations put in place to reduce environmental impact has created a system in which it is difficult to make money. Companies can gain competitive advantage by investing in energy efficiency and the transition to new fuels, this is currently a market in which the first mover advantage can be both very profitable and very risky. As the market will embrace that which will cost the least, this is a clear driver to create a low cost solution that can be applied in

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the long term. This pertains to both complete fueling solutions as well as auxiliary ones.

These issues led many to look at both the solutions currently in place as well as the ones that are being researched as alternatives to it. Some look at it from a purely ecological point of view and as such champion the solutions that are being put in place that cause the least harm to the environment, others focus mainly on the cost, be it per gallon of fuel, the cost of retrofits and new builds as well as the decreased emission costs such fuels would entail. Yet the market will not adapt a solution that does not fulfill both these concerns. However the solutions currently being researched are being pushed forward by the current climate of nations wanting to lessen their dependence on foreign oil or oil altogether. Even though many of the solutions that are petroleum based are greatly researched there is a clear need for solutions with an increased focus on the need for a non-petroleum solution I what is chosen is petroleum based. However as this presents itself as a problem that is something that mainly will arise far in the future the paper will mainly focus on which one is currently the best solution.

We lack an integrated theory for developing a foundation for a sustainable future, a theory that recognizes the synergies created between nature, economics, society as a whole, as well as being a theory that can be widely applied. In looking at the Energy tetralemma and further developing this to fit the market in question, in this instance that of shipping fuel it becomes clear that this is an applicable model to be used when measuring the different solutions up against each other, however there is no current system or framework that exists that can do this on a societal scale, as it only applies for individual industries. Another framework that is used is that of the triple

bottom line, as this is more of a framework for decisions for a company or organization it does not fit to create a total societal picture that can assess the problems and find solutions, however it does shine a light on certain parts of the problem, and as such can be deemed as a small part of what in the future may be a more complete framework or theory to look at this from a societal perspective.

Analysis of the possible solutions for fueling freight ships

How Can LNG or wind propulsion systems be effectively integrated into existing and new ships and is this a viable solution for carriers financially who have a too large fleet and can it act as a short or long time competitive advantage for carriers short or long term. Can the combination of new technologies make more environmentally sustainable shipping a reality, or even zero emission shipping. If not how should the rewards and costs be weighted be they economic, environmental or otherwise. How can the regionalization of shipping be fully taken advantage of by specializing fuel solutions for different routes and companies. Can there be an advantage for the entire supply chain in pursuing further regionalization in shipping. How can states and NGO's aid in the implementation and development of such systems that may make financial sense instead of just pursuing research that is done to make environmental sense rather than combining views and create a triple bottom line in the research. How can future legislation aid in developing such technologies into necessary evils in the world of shipping. How the financial benefit of such improvements should be measured and how should the positive and negative results be shared among stakeholders. How can authorities aid in implementation of such efforts. In looking at this we can see that. Could the

adaptation of less emitting technologies be a possible way to reduce emissions in ports and thus reduce the costs of docking in ports? Could the use of LNG allow for simpler refueling? Could the use of LNG allow ships to turn their motors off in ports instead of having to keep them on to make sure that the engine is kept at an acceptable temperature so that it won't clot and create engine problems?

A key issue in looking at the development of new fuels for the market is in if the innovation is market driven or that new regulations force the industry to make changes through legislation. The main market driver for innovation is that of increasing fuel prices. Legislatively one of the main drivers is that of emission regulation.

Ecological economics and the triple bottom line

When looking at ecological economics there is a part of this that has to do with the question of substituting human made capital and ecological capital. However several concepts of ecological economics further help illuminate the problems that you can find across industries, one concept often discussed in ecological economics is the concept of the triple bottom line.

Triple bottom line

The triple bottom line is a framework for companies who want to measure their performance, where performance is not only measured by financial

capital, but also environmental and social capital. This is the best way of measuring a company's successes as well as a way for a company to illustrate the results of investment made and set to be made in the realm of corporate social responsibility and research in alternative solutions for fueling.

Social capital pertains to fair business practices towards employees and the community and the region in which a company conducts business. When pertaining to the triple bottom line the company looks at its stakeholder interests as interdependent and that to score highly on this the company must conduct business in a way not harmful to the community and region it is in. Things that strengthen the company's social capital are things like fair trade agreements or as it is with the shipping industry, projects such as SAYS that equitably shares the profit throughout the supply chain. Other such projects are projects that make sure that there is no use of child labor or other exploitation of labor practices. A company's focus on CSR also plays into their accumulated social capital, i.e. any practice that a company does to aid their community without a profiteering motive can be looked at as going towards heightening the social capital of the company.

Environmental capital refers to the efforts of having sustainable environmental business practices. A company that focuses on this tries to minimize their ecological footprint. Thus in looking at the different fueling solution it will be important to look at how much they pollute compared to other applicable solutions. It also can look at the pollution a company and its efforts in a life cycle perspective, such as with ships, where a ships pollution is based not only on its runtime but also on how it is discarded and if the materials are hazardous

to those who dismantle the ships. Thus any ships that are hazardous to dismantle due to the fact that the technology used aboard consists of hazardous materials that may leak out or that may harm the environment and those around it in the process will be score much worse in this area as the overall environmental impact will be increased by this, however if the technology provides significant cuts in pollution throughout its usage it may ameliorate the impact it has.

Profit pertains to its impact on its stakeholders from a purely financial perspective. As such how a company financially improves the situation of itself and those around it will affect how it scores in this area. As such it is easily confused with the original meaning many give to profit, the financial results of the company. However, in this situation it is rather how a company financially impacts its surroundings as well as their financial results. A company's score here will be measured then on how it both impacts the company as well as the society at large. In looking at the fueling solutions the overall impact will be measured her by the economic benefits it brings all its stakeholders rather than a strict focus on the price of the fuel, however as this is an cost-benefit analysis it will weigh more heavily on the final result.

(Hall, Slaper, n.d.)

(KXC Environmental and Management Consulting, n.d.)

(Field, 2009)

Basis for change- What drives the market forward to new solutions

As the market aims to adopt new technologies it is of paramount importance to understand why it is moving as this allows you to see who the key influencers are as well as gage the market readiness for adopting the proposed changes. As there are many stakeholders in the market as well as in the surrounding societies it also becomes important to investigate who influences the ones who decide on the changes and if these people are motivated purely by what they think is best for the environment or if there are other considerations being made as well.

Where is the Pressure Coming From- the Drivers of Change

In looking at the shift towards cleaner technologies in shipping there is a question in place of who is driving the change, if it is the market that is demanding this change or if it is governmental and local regulation that is doing this. In looking at this there is a clear tendency towards change driven by stricter regulatory systems that have been or are being put in place. One such regulatory system is that of MARPOL-The International Convention for the Prevention of Pollution from Ships. This regulatory system has over the last few years put in place regulation aimed at reducing the pollutants that are allowed from ships both at sea and in port, aiming to create a more green shipping industry through

forcing ship-owners and carriers alike to push for greener technologies for fueling and otherwise. (IMO, 2013)

The solutions that are currently available are not fully formed enough to be viable large scale alternatives, and thus it will take the combined force of the shipping as well as the oil and refinery industries to create lower emission solutions, and as such there is a need created for larger cooperation's and not just the efforts of individual companies that try to put their solutions in place. In sort this will push for a system of coopetition rather than direct competition as the solutions that need to be put in place need help in building the infrastructure needed to create a viable solution for having low emission fuels that match the target levels set by MARPOL.

(International Maritime Organization, 2013)

Another driver is that of cost, through the research out forward in the thesis this is a recurring key factor in the choice of a fueling solution and as such is seen as much as a driver of change as the policies put in place, however this is also aided by the policies put in place by policy changes such as MARPOL as these regulations put heavy financial penalties on the companies that choose not to abide by the regulations, in some cases so strict that there is no other choice making financial sense than lowering emissions to the levels put forward in the regulations.

Another driver of change that becomes quite specific to this market there is that of industry best practice and industry trends. This becomes quite important as very few of the complete fueling solutions have the possibility to coexist in the market as the ship engines generally are built for one or the other

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fuel. This does not play as much into the decision criteria for choosing a supplement or additive, but to an extent the way a product is adopted by the market initially may have great bearing on its long-term success. The current trend towards joint research projects and joint sustainability project such as the SSI (Sustainable shipping initiative) and the SAYS (Save as you sail) project. These projects and projects of the same kind often encompass a large specter of organizations ranging from shippers and carriers to those companies enlisting their services for transporting goods. The SSI is a project that aims to map out where the shipping industry should go over the next 30 years to reach their goals of a more sustainable industry as well as drive the industry towards reaching the goals they set. The SAYS project is one aiming at more equitably sharing the costs and benefits of research towards sustainability in shipping. This project is one that is meant to give an incentive to everyone both the shippers, carriers and the rest of the supply chain in developing better solutions. Thus such projects both act together for the industry at developing solutions as well as in drumming up funds for such projects. Thus this can be viewed as an important driver of change in both instances.

Another factor that may not have a direct impact on the choice of fuel but still may affect it to an extent is the regionalization in shipping and the bunching of routes through key ports, such as Rotterdam for North Europe or as the bunching of routes around Africa creating effective corridors of shipping and reducing the time for a package or good to get from one place to another while also reducing costs. This regionalization allows for short sea shipping with few runs with empty containers instead of having to ship products over long distances in one large leg it can be done cheaper and more efficiently through partitioning the transport legs. Even though this does not in itself affect the

choice of fuel, the concept of short sea shipping allows for solutions for fueling not allowed by long haul shipping, and opens the possibilities as to how the ships can be fueled.

Another driver is one that does not come from the ships, but rather from the ports. As logistical clusters are created, this allows for less costly infrastructure for fueling as ships may not need to enter the same amount of ports as they would do before. This lowers the barriers for alternative fuel solutions as the costs in building infrastructure are lowered.

Environmental Ranking systems as incentives

In looking at ranking systems such as Rightship for ships that measures how much a ship emits it can be seen that their programs of incentivizing more sustainable ship usage through giving reduced port dues to those who produce low emissions. This may help in acting as a catalyst for the changeover to fuel that emits less (Rightship, 2013). In doing this the ports will receive less pollution from visiting ships as well as being able to put a premium on pollution and making it even less desirable for carriers to have fleets of ships that utilize polluting technologies. It may also in turn be used to promote a company's environmental efforts, and also highlight where there is a need for further investments. These ranking systems may also be used in pressuring countries to

take efforts to make their maritime industries more environmentally friendly as it may be used to leverage both reluctant companies as well as countries that are not forthcoming in adhering to international regulations, as it shows how much better or worse individual companies and the industries of countries are in their sustainability efforts. Such Ranking systems coupled with a stricter regulatory system for emissions are clear drivers for positive changes in the maritime industry and are aiding the adaption of new alternative technologies as they give companies a window in which they can showcase their efforts, and in turn strengthen their brands as environmentally friendly.

What are the catalysts for change in the market?

In the market there are several reasons for the change from fuel oil to alternative fuels, there are two major draws, one push and one pull factor. As a push factor is the legislative change that has happened in later years and continues to happen, this is both regarding the emissions as well as the port regulations and other regulatory changes. On the other hand it is that of industry best practices. This pull factor is there as the market will chose whatever option is both the most fiscally viable as well as the option that the market is adapting as single carriers being alone in building infrastructure for the use of new fuels is a cost that is too great for most companies.

Another part of this is the need for the agreement and cooperation of the ports, as these must be a part of this as the ships will need their cooperation for storage and distribution of this fuel. If any fuel is not adapted widely enough the ports will not build the needed infrastructure for them and ships

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will not be able to refuel in some or all of the ports they frequent, something that may prove problematic. Thus the industry best practice and what is adopted by the industry will lead to lesser investment by each party and thus allow for it to be a viable alternative cost wise if it can in price compete with fuel oil. However there are some fuels that may work in tandem such as LPG and LNG where one comes as a by-product in the production of the other. This allows for less costs in both as there is a larger usage of the raw materials. This allows for less costs in production, and even though there is less LPG produced for the ship market it has a better infrastructure than LNG something that allows for it to access the market quicker, and may allow for it to develop some market-share before other alternatives enter the market. Thus it may develop a market share not easily stolen as the choice of retrofitting boats to use LPG creates a certain lock-in effect due to the high price of adapting the ships for a different fuel.

SAYS- Save As you sail

Save as you sail is an initiative that was launched along with the Sustainable Shipping Initiative (SSI). As this project is a joint project between both shippers, carriers, ship-owners, shipbuilders as well as financial institutions and universities. This allows for there to be a wealth of information out there when it comes to what is needed to make the project. The project is an incentive system that is made to create a fairer split of profits from switching to more sustainable fuel solutions. This also helps in mitigating the risk for each individual company. It also allows for companies that probably wouldn't choose to build sustainable ships rather choose this as they are incentivized to do so

through this project. As such, this incentivisation allows companies who would otherwise not invest money in such solutions.

(SSI, n.d.)

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Complete fueling solutions

Certain fueling solutions will not work together with the current solution but rather aim to take over for it by offering a better solution in some way, be it a large cost cut or a more environmentally friendly solution. These solutions have different drawbacks and advantages from each other, but all aim to be a preferred option over the standard fuel oil solution. As such it is important that it is measured up against it as it aims to replace todays bunker fuel oil solution and not only complement it like any auxiliary solution.

Bunker fuel

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Fuel oil is the most widely used propellant for ships, this fuel is a diesel based oil product with a very high viscosity and a constant need of having a high temperature in order to be utilized in ships. This creates the need for the engines of ships run on fuel oil to be constantly on, however, it also helps with the safety compared to less viscos fuels such as the diesel oil used for cars. The fuels high emissions compared to other alternative fuels is in part made up for

by the price compared to many other fuels, as well as the fact that there is no need for retrofitting the engines of the existing ships to match the fuel as well as that there has been continued research on this fuel for a long time. As this is the most used fuel it will be used as a baseline and anything that does not present a significant improvement will not be looked at as a viable option.

LPG

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LPG is another petroleum product that has been greatly researched as fuel both for ships and other vehicles. The usage of LPG as fuel has significant emission cuts as well as fuel cost cuts. Even though this is also a petroleum product it also creates a great need for retrofitting. The production of LPG is set to increase as it can also be produced as a by-product in LNG production. Even though LNG has been greatly pointed out as a fuel for the future of shipping it does not have the same facilities and infrastructure for storage and distribution as LPG. It allows for LPG to reach a greater market more quickly and to cause no need for large investment in developing infrastructure. Through communications with companies through my work at GEMBA Seafood Consulting it was also found that companies had plans to invest in such solutions for their ships that were used for short sea shipping and short haul

freight transport. This increases the feasibility for such a solution, even though this is on a relatively small scale. However it opens for the possibility of a niche market that may be capitalized on and if approached correctly may not be cannibalized greatly even if another complete fueling solution may be adapted by the rest of the market. As there is already infrastructure in place to a certain degree there is less risk for this to be tried out than many of the other solutions.

It can work at lower temperatures than other liquefied gas products and can also work at lower pressures. It also has a large cost benefit to other fuels as it is significantly less expensive than fuel oil, it also burns cleaner in engines lessening the need for repairs and increasing the lifespan of the engine as well as its individual parts. However it requires large investments in safety gear as it is significantly more flammable than fuel oil and requires large costs both in building and in retrofitting ships. This can be seen in the increased standards that are being required for safety on such ships. However in recent time there has been a move towards such retrofits and new builds for smaller ships and as such it shows that there is a potential for ship usage and thus opening the window for further research into the possibilities for such technologies on larger ships. As it is an expanding market for it in the automotive market the technology I still being further developed, and an investment in this could piggyback on those investments of the automotive industry creating less risk for both and progressing faster through a joint research effort. However as such research is being done regardless of the shipping industry's involvement it may be beneficial to them to hold off on large investments in research until the technology is developed to a level where it is applicable as a solution due to a greater fuel economy than the current solutions.

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(Hamble Marine, n.d.)

Liquefied Natural Gas (LNG)

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Just as LPG LNG is a liquefied petroleum product Just as LPG LNG is a liquefied petroleum product. It is a liquid that only remains in this form at very low temperatures and therefore has a significant need for cooling technologies to make it an applicable solution. Often hailed as the future of maritime fuel it is a refined product from natural gas. It needs to be hyper cooled for storage to keep it in its liquid form and stable enough for usage in engines. It has both some significant upsides and downsides compared to the solutions it is competing with. It is a petroleum product and thus is a product that cannot replace petroleum products as it is not renewable and will thus run out at some point. However it is a significantly more environmentally friendly petroleum product than fuel oil. However, there is a need for hyper cooling the LNG both

for it to be transported as well as for it to be used in engines. Thus, a lot of energy is needed for the motor to function.

To make it a viable option for ship fuelling for the future the issues regarding this must be addressed. However there are already ships being retrofitted to use LNG as fuel and as such it is the alternative fueling solution that has come the furthest as it is being put into use on a small scale in certain freight ships.

(GCaptain, 2013)

When it comes to cutting emissions LNG comes out as a very strong competitor as an industry wide switch would in turn lower Sulfur Oxide emissions by up to 95% whilst also cutting emissions of Carbon Dioxide by up to 25%, there would also be a drop of Nitrous Oxide by up to 92%.

(Germanischer Lloyd, 2011)

The availability has been increasing over the past few years and solutions have been created to serve ports worldwide and also to facilitate fueling at sea rather than in port. There is also a readiness among suppliers to increase production if the demand were to increase greatly. Increased sales volumes of LNG will also lower the price as the largest costs are fixed rather than dependent on demand. The distribution network will be bettered with increased demand as this is needed to serve the entirety of the prospective market. There are also certain costs that will be lowered through such a switch including maintenance costs as the LNG burns more completely and thus does not leave as much residuals in the engine creating a need for frequent upkeep and cleaning of the engines parts.

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(Rolls Royce, n.d.)

As the fuel is already in use it scores high on certain things, however there is very little infrastructure in place that would allow for a widespread adaptation of this as a fuel, as such the projects that are being done and the ships currently being put in use and built are to be seen more as a test project than a widespread adaptation of the technology. However this is an early stage of this and if the infrastructure can be put in place for a more widespread adoption, their kinks ironed out and the price remain at a lower level than that of fuel it has the potential of once becoming a more fierce competitor to fuel oil and maybe even take large market shares or totally take over the market for ship fuel.

The price of LNG is what more than anything makes it a viable option. The price looking at everything as one is currently fluctuating in a range much lower than fuel oil. This plays in to the equation as the market for natural gas is a lot less volatile than that for natural gas. The volatility of the gas market is created by more localized conditions whereas the fluctuations in the oil market are created through ups and downs in the market as an entirety. The natural gas prices are largely a result of supply and demand, its fluctuations being a result of a disparity in this. Fuel oil prices are however more influenced by political conditions between countries as well as the strength of controlling powers such as OPEC. Thus the price for oil is at an extremely high level whilst natural gas is currently at a lower price than in 1997. Thus there are many positives that play into why the market I hailing LNG powered ships as the way of the future. A large part of this is that the market is less volatile and thus the costs are easier to project. The fact of it being a petroleum product however raises the issue of scarcity in petroleum markets. As the stockpiles are projected to run out at

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some point in the not too distant future the question will be if the market can adapt this technology with enough time for it to be profitable, even though the market has yet to agree on when this will happen. LNG does require either large retrofits or new builds, as such it is required that this can be done in a way that does not pose a significantly higher cost than the current costs of engines. It also has larger special requirements than the current engines taking up place that could otherwise be used for cargo, making it less viable for smaller ships as it takes up a lot of the quite necessary place onboard that is needed for freight forcing it to trade space they could be earning money from with engine space. However there I a possibility of building this at a slightly elevated cost as the day to day costs for fuel will be significantly lower. However in looking at market projections done by Lloyds register there is a clear movement towards more LNG as well as an overall positive tone in the market. This coupled with Germanischer Lloyd's projections of profitability of such systems over those of the current ships and regaining of initial outlay within the first few years speaks well for the solution. (Germanischer Lloyd, 2011) The prices are set to be in a worst case scenario at least comparable with Fuel oil and scrubbers, but will provide benefits not provided by this. The case can also be made for LNG due to its bettering infrastructure with ports around the world building solutions either in port or within close range of the port so that they can meet the market demands. With plenty of ports further developing such infrastructure.

(Hall, 2012)

(Eggert, Gustavo, 2012)

(DNV, n.d.)

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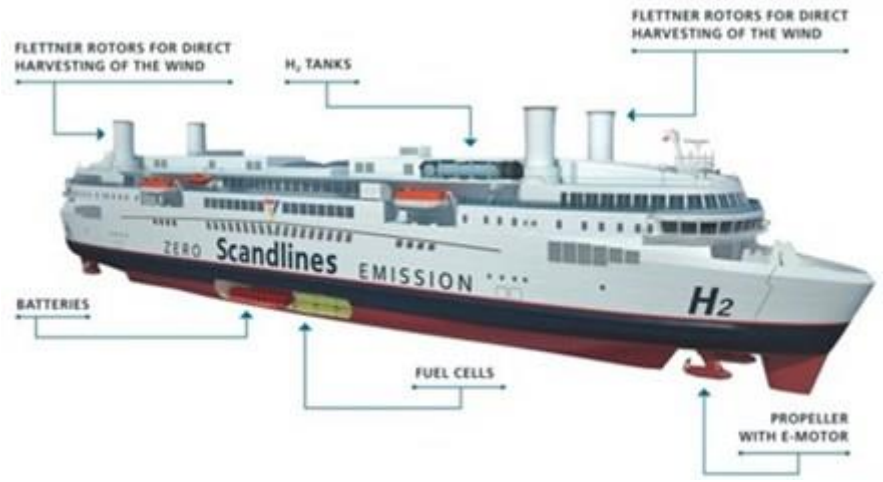
(Lloyds Register, 2012)

Methanol and Biofuels



Retrieved From: http://www.fuelcelltoday.com/media/1747405/gl_440x240.jpg

As a sulfur free, low emissions fuel, with a price point three to four times cheaper than marine distillate fuel, lower in price than LNG, a more beneficial fuel factor for the EEDI than LNG or diesel, it is non-cryogenic and is already in widespread production (~50 million tons per year) for a multitude of uses, including combustion. It has great potential for a much higher production and a distribution infrastructure more easily established than LNG.

The creation of such fuel has been greatly researched and the prospect of using Biomethanol or a biodiesel solution is hailed as a potentially great solution for the environment. As there have been large investments in the production processes they now have the potential to really get a great yield from waste management leading to them being able to extract fuel that can be used for ships from waste and not only from crops as they originally did for biofuel.

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Easy to produce and easy to transport, it has the benefit of being made from the widely available natural gas, biogas, food stocks as well as from waste. Even though it has a plentiful supply and does not have the same problems as similar fueling solutions that are petroleum based as in that they have depleting stocks to take from, it has not yet been widely adapted for use as a marine fuel oil.

Methanol is an alcohol, used mainly for the production of other chemicals or used as a component that is to be blended into gasoline. As a product in itself it is not attractive to the diesel market in that it has a very low quality combustion compared to other heavy duty marine diesels. It's low viscosity, poor lubrication, and corrosive properties and solvency characteristics also play into why it is yet to be considered as a serious contender in the market. It has been left out of the initial choices made by most of the companies that are making investments in alternative fuel for ships, however it may prove to be one of the best contenders for this market as it is easily accessible and has been greatly developed so that it should be made a possible fuel for freight ships and other ships. Methanol can be converted to Dimethylether (DME) by using onboard catalytic converters and thus into a gas. This would be suitable for use in dual fuel type engines. Dual fuel engines are possible solutions for companies that would like to remain using their current fueling solution but also gradually adapt a more environmentally friendly solution.

In looking at Methane and DME as fuelling solutions there are a number of stages that need to happen before it is to become a competitor to fuel oil and

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other petroleum derivatives. There are many things that are specific to marine use that would not be problems for non-sea faring vehicles. The design of the fuelling system is one such thing. Some of the issues that are apparent are: The need for bunkering, storage, handling/preparation, combustion and handling the exhaust emissions.

The best solutions for the current market are those that do not require large retrofitting costs. Biofuels are the only fuel that fall into this category of the fuels on the market today, but these solutions are still in their infancy today. Methanol in itself does pose certain retrofitting costs, but due to it being better developed than many of the current solutions that are on the market it does have certain advantages even over LNG in that it does not require supercoiling solutions to be retrofitted into the ships to use it as it in its natural state is a liquid and is only needed to be transformed into a gas for it to be used in the engines, something that requires significantly less retrofitting. However due to it's more flammable nature with a flash point at 12 Degrees Celsius there are certain handling issues, and thus a need for more security measures than the current fuel oil that has a very low flammability in comparison.

Retrofitting to a methanol/DME fuel supply is feasible but considerations need to be made as the impact to existing fueling systems and how they are arranged need to be taken into fruition if they are to be used for such fuel, including the considerations needed in the fueling process and throughout the other processes it undergoes on the ship, and in general making sure that the process happens safely as the fuel in itself needs to be handled more securely than fuel oil with concerns to safety measures.

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Methanol and DME are fast emerging as a land based transportation fuel around the world due to the many positives of the fuel, and as there is an expected growth in this market and due to its continuous development it is a clear contender in the future in being a replacement for fuel oil along with the other solutions that are more often hailed as the future. Ultimately it comes down to price and risk assessment. If it can provide a cost cut as well as the risk can managed it has a future as a marine fuel.

(Ryan, 2012)

(Alm, 2012)

Additives and auxiliary solutions

As well as there being researched complete solutions there are also being put in place solutions that do not aim to replace the current solutions, but rather to augment them and add to their prowess as a fueling solution or to augment the current solutions. The paper will look at the ones that are to be tested or is already in place in ship today as these are the most applicable products for the market at this point, as those still in development may not come to fruition.

Fuel additives

Retrieved from: http://www.bellperformance.com/Portals/68152/images/ocean-air-freight.jpg

Fuel additives such as asphaltenes are an existing available source for cost cutting for petroleum. These can either help in cutting emissions, cutting upkeep costs or cutting the fuel usage in itself. Such additives are often put in use in trying to cut the fuel usage, but usually only provide minor cuts in costs of ca. 3-6%. However, such additives can have major effects other than merely cutting in the fuel usage itself. It can also help in cutting emission costs, having a two pronged approach to cost cutting. The additives try to create optimal combustion in the engines and prevent build ups of unburnt fuel throughout engines. There has been a lot of unscrupulous providers in the market that has made the market for additives more unstable and the growth in usage of additives flail, but there have been a lot of improvement in the technologies utilized in these additives and this has led to great possible savings available to those that use the most efficient combination of additives. As such technologies are already in use even if only to a limited extent there is a high

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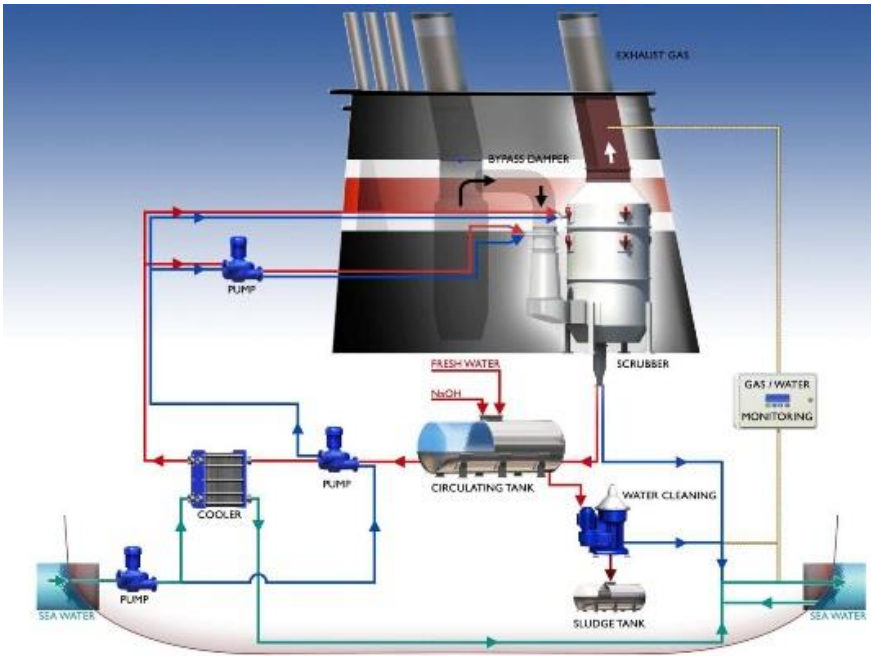
feasibility for these technologies, however, due to previous products being proven as ineffective there is a need for further research into additives that provide concrete proof that such products are effective. This would increase the feasibility of fuel additives as a potential solution to reduce emissions and to improve effectiveness for freight ships

http://www.thestrategyworks.com/articles/sept.pdf

(The Motorship, 2011)

Scrubbers



Retrieved From: http://officerofthewatch.files.wordpress.com/2012/06/2012-06-20-figure-2-eca-retrofit-study.jpg

The concept of scrubbers is that of taking the current emissions that come from shipping fuel and cutting this through treating the exhaust gasses with solutions that can bind the sulfur that is a harmful airborne emission and rather binding it with chemicals that will make it safe to be released into the sea which already

has a large concentration of sulfur and such emissions would not make a major impact to the ecosystems of the sea.

Such technologies have been adapted by some ships that have seen great environmental gains from this and thus this technology may be something that will make the transition to other less environmentally harmful fuels like LNG or otherwise more difficult as these systems may more easily be retrofitted on existing vessels. However, as this is a possible technology that might be utilized to secure a more environmentally sound way of doing sea freight it needs to be considered as one of the possible alternatives in making ship fuel more environmentally sound even though it does not entail switching from bunker fuel. The systems needed to be put in place are made to remove the gasses emitted through exhaust by sea water filtration, a process that dilutes the harmful gasses from the exhaust into the sea water. There is little danger in this as the sea water helps bind the gasses into less harmful sulfites. There is little worry in doing this as sea water already contain a rather large amount of sulfites. If higher efficiency is needed the addition of caustic soda can be added to improve on the efficiency. The technology is currently being tried out worldwide and is being adapted by several freight ships as a technology to aid in reducing pollution. As such it is seen as a high potential solution when it comes to competitiveness as it is currently in use. It is a product that is has very little need for any scarce natural resources and as such it scores high in the category of security of supply. As it greatly reduces the harm of the current fueling solution it can be seen as a sustainable solution until the point where the fuel type changes as this could entail a large switch in methods. Thus it is deemed as a very strong solution

(Clean North Sea shipping, 2012)

(Pojahnpalo, 2012)

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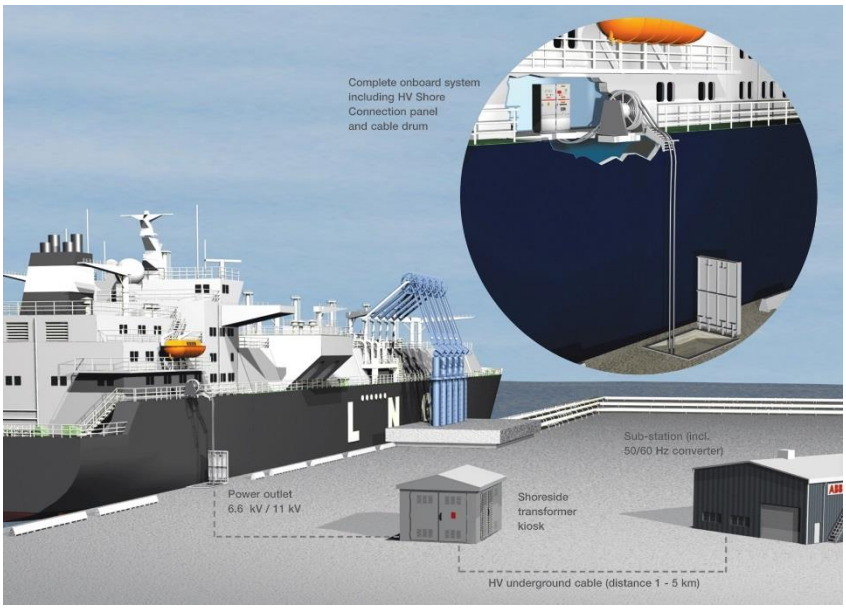
Cold Ironing



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Cold Ironing is an alternative technology that has been developed in later years to allow for ships to stay in ports without having their engines on. This technology could potentially cut down emissions greatly as well as the costs that surround this. The concept is basically electrically powering the systems aboard a ship while in a port through using a power source located on the shore. This would allow for a reduced fuel usage as well as aid shippers and carriers when it comes to costs that are related to emissions. With emission standards and regulations being sharpened greatly this is an area of fueling where there are significant potential cuts to be made. However, there is a large need for investments both by ports and by carriers in developing this further, and even though it has been successful in being implicated in several ports worldwide, the investments needed have not been made by a lot of ports and carriers as they are dependent on the other party using the technology for it to be applicable for them to use. However there has been done studies on the

pollution benefits as well as the health benefits of cold ironing. These studies proved significant improvements in both pollution and showed significant health benefits. There has been some success in pilot projects for this for ferries as well as some larger ships, but for now it has seen the largest gains in ferry traffic where it has been developed to a point where it can either partly or fully serve the energy needs of the ferries and also fuel them for their trips.

As more and more ports start using the technologies that are required for cold ironing the feasibility of a large scale switch among carriers to technologies that allow for this shore power when in ports. There have been studies that have been done on this subject and one of the main problems is the differing power needed for different boats as well as the differing needs of power throughout the year. Thus there has been developed converters that allow for ships to use a different voltage than they normally would when arriving at a port. It has been researched and found successful for ferries who use shore power as their only propellant (communications with MARCOD) It has also been researched for short sea shipping as well as for powering electricity in port and all the research has given positive results, something that adds to the feasibility of this technology. As a pilot project it has also been adopted by the Port of Los Angeles that use this to aid them in reaching their targets of emission reduction for all activities in the port. They do not require the ships to use their solutions but require that the end product is the same as if they use shore power while at berth. But with requirements quite stringent they are pushing the ships that dock there towards using their solution and rely on shore power for some or all of their onboard energy needs whilst at berth. (Port of Los Angeles, 2013) There are also several companies that have experimented with creating hybrid

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ships partly powered by shore power. The main obstacles are the retrofitting costs for the ships as well as the large costs for ports in having the electricity available at all time as well as building costs for ports to allow for shore power. However, if it is widely accepted and adopted it may be beneficial for ports to adopt such a solution. If many ships have the technology needed in place it may at least be a viable solution for powering all ships whilst in port and as such allow them to pollute as little as possible around those places where their emission requirements are among the strictest. As such it is placed among the partial fueling solutions for now as it does not have the potential currently to power ships throughout their journeys for freight shipping, however it may do so in the future.

Wind power

Retrieved From: http://www.earthtechling.com/wp-content/uploads/2011/03/Kite-Ship.jpg

Wind power would come in a similar category as Cold Ironing as it is not currently being researched as a sole way of powering cargo ships. However it

has seen a large amount of usage and the potential fuel savings that are available from the usage of the technology have been proven on several freight routes. The technology currently available and in use is a computerized kite system that allows for ships to potentially cut their fuel usage by between 10 and 35 percent (http://www.engineerlive.com/content/20117).Therer are a few other types of wind propulsion systems that are in development, but for now this system is the only one in use on anything more than testing. The technology for it can be applied to boats without a need for a very large retrofit, something that the alternative fuel systems all have a larger need for. Thus it is a system that may work both as a fuel saver on its own or in tandem with another alternative propulsion technology. However in recent times there has been a resurgence in research on sail ships, not only to power ships in part, but entirely power freight ships. This research has shown results that there will be great retrofitting costs as well as still a need for traditional engines to supplement as there is a need for alternate propulsion when there is no wind. Through this it is not considered a feasible solution for freight ship propulsion on its own thus far, but may be so in the future, and is currently being developed for freight ships as a more complete fueling solution. As such it will be looked at as an auxiliary system for now but in the future may be looked at as a more complete fueling solution. (sustainablebusiness.com, 2012)

In looking at it's potential as well as it's sustainability it is one of the most sustainable solutions as there is no scarcity of wind, however it does only have a large effect on certain routes as the wind conditions are better for such propulsion on certain routes. As such it has great potential, but not on an entire fleet. However it has a potential of being an auxiliary solution that may be adopted by any or all ships traveling routes that have the potential for fuel

savings from wind power. As it does not require massive retrofits, but can however provide large fuel savings it is a very cost effective solution for those who use it to cut both their fuelling costs as well as their emissions. As it can be used along with any other technology and does not require any special consideration other than to be used on route that are windy it is deemed to be very competitive. However, if it is one day to be deemed a complete fuelling solution it will require something that can propel it when there is no or too little wind to propel it forward. As such it remains an auxiliary solution with the potential of in the future becoming a more complete solution if the technology is developed so that it allows for it to be so.

Results of Analysis

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Through looking at the theories that apply to the decision as well as those used by similar industries it shows both what the different solutions are to be measured upon as well as how thee should be weighted. As the financial cost of the solutions remain as that of highest importance it is weighted as such, and even though other categories that will be used within the framework will contain costs as well, these fall under their own categories along with other considerations that fall into these categories. The different solutions all come with different drawbacks and advantages that are not easily translated directly into costs for those that invest in them and as such the framework serves a purpose for those in the decision making process. The considerations faced in similar industries as pointed out by the Energy Tetralemma and The Industrial Fuel Choice Model will be instrumental in deciding the different categories they different solutions will be scored on. These categories will together form a picture of which solutions are the best and should be invested in. The basis for the numerical values given to each solution in each category is on the basis of the information gathered in the analysis section of the paper.

Framework for comparison

In developing a framework for comparing the different solutions it becomes apparent that the considerations are not the same in choosing an entire fueling solution as it is in developing an auxiliary solution or an additive. However, the two represent two different routes that companies can go down in choosing what to invest in to improve their fueling solution. As such the framework will

see the two separately and as such look at them side by side in the framework. As the framework is built on the basis of the Energy Tetralemma as well as other sustainability research theories the different fueling solutions will be measured in the categories provided by the Energy Tetralemma model in conjunction with the triple bottom line, but scored with all the sustainability theories used in mind. Through looking at the amassed research the solutions will receive a score in the different categories from 1 to 5. As the categories in the model are given equal importance and thus seen as equally important the categories will receive equal weighting due to equal importance being placed on them the categories will be weighed for importance and the one with the most points all together will be the most applicable fueling solution. The different thing it will be measured on will be Competitiveness, Security of Supply, Environmental Impact and Sustainability.

Competitiveness

The competitiveness will largely be measured on how the fueling solution is being adapted by the market. Solutions that have yet to be used therefore will score lower here, but industry forecasts about their future will also be taken into consideration.

The price of the solutions both of the fuel and retrofitting cost as well as if it must be done on new-builds or can be retrofitted to existing ships will be taken into consideration. The risk of failure of the solutions shall also be considered here as it is a possible cost for those solutions that are unproven or have yet to reach the marketplace. The time horizon will also be part of the consideration

as the solutions that require the most time to market and those with the least difference between costs and benefits are seen as the least competitive. This includes the costs of reevaluation. As the economical aspect of the solution is seen as the most important, as the industry sees this as the most important issue in choosing a solution this will be weighted with double the importance of the other categories. This will aid in giving a real life insight into the decision making process as this is viewed by the companies that actually make the choice as the most important aspect.

Security of supply

In looking at the security of supply the main focus will be the accessibility as well as if it is renewable or if it has large or small amounts available for future consumption. As such fuels that are renewable or have large reservoirs available will score higher than those with diminishing supplies. As fuel oil I the baseline it will be scored as a 3 here and anything with a higher score will have a larger reservoir to take from than fuel oil or be sustainable whilst those with 3 or lower will be deemed as worse. Security of supply is also based on the source of supply, this is also affected by things like political unrest in regions that may affect the future supply or other outside influences that may halt the production or create stoppages in the supply, thus the infrastructure also plays into this, as the solutions that have little or no infrastructure may have problems reaching their customers efficiently.

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Environmental Impact

In looking at the environmental impact the main focus will be on if it is a significant improvement from the baseline of fuel oil. As fuel oil is deemed the least environmentally friendly as the different fuelling and auxiliary solutions are there to improve on this to meet stricter environmental regulations. As such the baseline score here will be at 1 as fuel oil will be deemed as the worst for the environment of the fueling solutions. The solutions that provide the biggest effects in a positive way towards the environment score highest, thus the products that cut emissions the most or improve efficiency the most will score highest.

Sustainability

When it comes to sustainability there is a three pronged way of scoring it as it needs to fulfill all three categories stipulated in the triple bottom line. The three Ps are what is then looked at for this: People, Profit and Planet. In the realm of people it needs to not have an adverse effect on the people who use it or on society in general, for this this both entails pollution that effects people, jobs created or lost and the overall societal impact of the solution. For Profit the main focus will be on the cost of the solution, both with regards to initial outlay as well as the running costs of the fueling solution. Thus the different solutions will score based on their long-term effect in all these categories. For the planet portion they will be scored on how they improve on the current emissions as well as any other environmentally positive effects they may have.

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For the people it will be considered the impact that such a switch would have on stakeholders and the market. Thus as a whole it will be scored as a sum of how it scores on all these three categories

(The economist, 2009)

The Framework

	Competitiveness (weighted double)	Security of supply	Environmental Impact	Sustainability
Fuel Oil	8	3	1	1
LPG	4	4	4	3
LNG	8	4	4	4
Methane	6	5	4	4
Wind Power	4	5	5	5
Fuel Additives	10	4	3	4
Cold Ironing	8	5	3	5
Scrubbers	10	5	4	5

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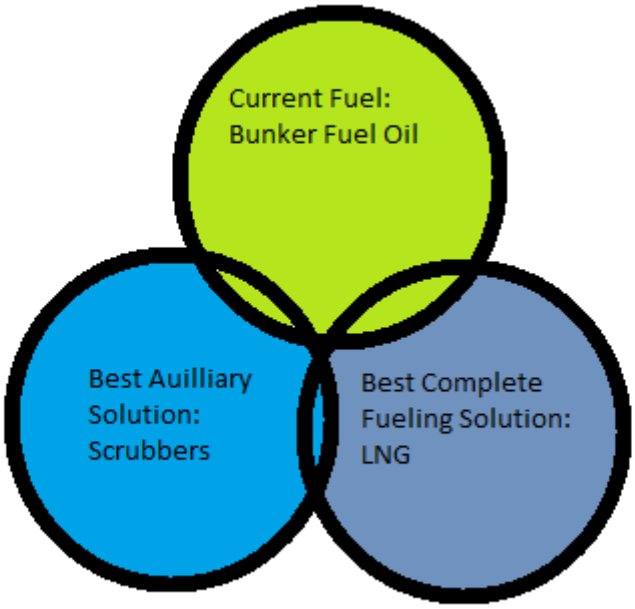
Conclusion



Through talks with people within Maersk at a recruitment event at Copenhagen Business School it became apparent that there is no current plans to make a change in the fueling solution for their ships, however there are being done major investments in both research on the solutions to reducing emissions as well as projects such as the sustainable shipping initiative, that both aim to aid the transition to an industry with lesser emissions as well as bringing the companies throughout the supply chain together to aid this. They also mentioned that for any solution to be adopted by the market in its entirety it needed to provide financial benefits in comparison to the current fueling solution. As such the economic aspect of the choice reigns supreme. Thus this

is weighted more than the other categories. When weighing the different considerations that are there for a solution it needs to be stated that even though these solutions are at different stages in their development this is not a main focus in the decision making process. The framework that has been developed tries to take a holistic view of the current situation as well as take an aim to what the future holds for the different fuels whilst looking at what is currently in place as to infrastructure as well as if the resources required are finite or not, it also shines a light on the subject of sustainability of a solution not only environmental sustainability but also if its usage can be sustained over time without depleting supplies. There has also been a focus on the economic side of the equation with both a focus on the cost of the individual solution as well as at the costs both in developing infrastructure as well as in further technological development for the products where this is needed. In the end the solution that will be applied will depend on when the costs of keeping the current solution outweigh those of the new solutions or if the customers of the carriers has an increased willingness to pay for more environmentally friendly solutions to a point where such extra income outweighs the costs of the new solution.

In looking at the possible solutions for fueling there are a few that have different good sides and downsides. As such the ones that are most applicable are those with the fewest downsides. However, as some of the solutions have been adopted by the market and are currently in growth, they may become the solution that the market adapts. However the framework will provide an answer to what has the most potential as a fueling solution. As the complete fueling solutions and the auxiliary solutions are not mutually exclusive and the

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auxiliary solutions have more potential to be adapted on the current fleet of boats and not only on new-builds or boats that would require major retrofits, they will be seen as the solutions for today whilst the complete fueling solutions will be seen as the potential solutions for tomorrow and the future. However if there are certain points that differentiate the different solutions even though they score similarly overall they have a similar potential going forward and it will be up to the market to decide what it finds the most important.

As the risk is different for a complete solution and an auxiliary solution these two may both be done over time but as a long term goal a complete fueling solution change, however to meet the current regulatory changes more quickly the auxiliary solutions should be put in place so that the companies that aim for more sustainable solutions can reap the benefits, including costs for emissions.

In Looking at the complete fueling solutions to clear frontrunners come forward at the same high score, those are LNG and Methane Biofuels. As these two have an equally high score found through research they will most likely be the solutions. However, the fact of LNG being further developed as well as better financed for research and trial it comes out as a victor by just a small bit. As there are significant orders both for now and in the future for LNG powered ships they are in the end of the development whilst the methane is not there yet. Methanol however may at a point in the future take this place as much of the research done on the subject hails it as a better and more renewable source of power, thus if further developed and it betters the fuel usage needed to power a boat on methanol it may be a very applicable solution. It may also become an applicable solution for those ships only doing short sea shipping as well as those dually fuelled. In essence we will have to wait and see which fuel

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will survive the tests of time but at this point the first mover advantage into the new market for sustainable fueling solutions must be given to LNG. Due to its widespread praise in the industry it inches out methanol as the best solution. It may still not be able to take the entire market for ship fuel in the close future, but with many successful trials around the world it does have the promise of becoming one of the most or maybe even at one point the preferred solution for fuel for the market as a whole.

When it comes to auxiliary solutions there is a very clear frontrunner, Scrubbers. Scrubbers provide a high score in all categories as it delivers great promise due to its current widespread usage and lack of criticisms. The other auxiliary solutions are either underdeveloped or not providing a good enough solution that can be applied with relative ease to ships worldwide. As scrubbers are providing a solution that could lessen the environmental impact of shipping through lessening harmful emissions it comes across as a clear winner. However they do not give a significant fuel cut but rather helps cost cutting in other ways such as helping reach the goals of lowering emissions and thus avoiding the costs that companies have to pay for such emissions. As far as the other solutions go there is merit to many of them, but one that widely receives praise is that of cold ironing. It may prove a solution that may nearly wipe out emissions in port, something that is an increasing concern with the centralization of ports into shipping hubs both on a national and international basis. However there is a lot of promise for the other solutions as well, each reaching out and taking some of the prospective market for auxiliary solutions, all being developed further and researched, so the position that scrubbers have today may not be the same tomorrow, however none of these solutions are

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mutually exclusive so they could potentially live in harmony without taking too much of each other's markets.

In the current market there is a clear push towards more sustainable solutions, and due to their current cost benefits to bunker fuel oil, LNG has a chance of becoming the preferred fueling solution for new-builds. Scrubbers are currently being used with great results in many ships and allow for companies to better meet stricter fueling solutions, however other auxiliary solutions such as cold ironing or fuel additives may also be used as these are not mutually exclusive. There is a near constant stream of research in this field and the solutions that we see today may not necessarily be those chosen tomorrow, but as it stands the solutions that are the most easily investable due to showing great promise are LNG and Scrubbers, these are he solutions that provide the largest benefits currently and have the most promise for the future. But if the market embraces LNG there may be a need to research new auxiliary solutions that work with LNG powered engines, thus it is a process and even though these technologies are the best today other technologies may take their place in the future.

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Implications

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Through the thesis and development of the framework for choice of fueling solution it has become apparent that there are a host of different reasons for choices of fueling solutions. It has also become apparent that the question of choice of fueling solutions is something that may not have an immediate impact as the solution that the market chooses is the one that is the most financially viable as in the end this bears great importance. Thus, there will not be an industry wide change until the alternative fueling solutions reach a similar price point to fuel oil. However the implications of the framework and through this the choice of LNG and Scrubbers are that they are the solutions that are most likely to achieve success, and through the recent adoption of these solutions by several companies this helps further build its chances of success. It also has implications for the choice of solutions for the future as it

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allows for companies to compare solutions on a level playing field, through looking at how this has been done in other industries as well as look at how the shipping industry makes these decisions the framework can be used as a tool to put forth the different advantages and disadvantages of the different solutions. Thus the framework will also allow for future solutions to be measured up against the solutions already being considered. As the paper has recognized that the process will take several decision making and control processes it allows for a way to provide an overview of the current solutions and compare them in a way that answers if the solution most favored by the market currently is still the best possible fit or if there might be a better fit out there.

Research Implications

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As the thesis takes a qualitative approach in evaluating the different fueling solutions there is a need for further study into the economic benefits of the different solutions. Such a paper should take a similar aim to what this paper

has done in creating a level playing field on which the different solutions could be measured as this is needed due to the difference in the way of costing the different solutions as well as the different benefits of the solutions that can provide different economic as well as other benefits.

Another idea for further study is to delve deeper into the most applicable solutions and look more at their prospective times to market as well as looking at their current market shares.

Studying other solutions than those directly connected with fuel should also be considered as research shows significant improvements in things such as fuel economy from other solutions such as different ship designs. This should be done with both an engineering and economics perspective as it is important that the proposed design changes and otherwise are feasible for ships and not just something that would only provide theoretical gains. The full picture of the process and the players involved in the decision making process would add value for those looking to find investors and the people that need to be influenced to

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